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ABSTRACT

This thesis investigated the effects of certain personal and situational variables on the acquisition sequence of graphical interpretational skills. A comprehensive learning hierarchy of basic graphical interpretational skills was prepared according to the method of task analysis proposed by Gagne, and was subjected to a series of empirical validation studies. These studies involved the preparation of a comprehensive instructional programme, with appropriate questions inserted after each interpretative skill; the same hierarchical network of graphical interpretation skills was substantiated in each of the validation studies. Subsequent studies with interstate and overseas students were used to test the possible effects of differences in curricular and cultural background, age and nominal academic level. Each of these studies produced similar validation results. The author concludes that the acquisition sequence of graphical interpretational skills may be largely independent of the specified personal and situational characteristics examined in this research. An extensive analysis was also made of possible subdivisional skills within each of the basic intellectual abilities. In addition, this analysis involved the development of a new statistical test for the difference between two dichotomous skills. (Author/MLH)

THE EFFECTS OF CERTAIN PERSONAL AND SITUATIONAL VARIABLES ON THE ACQUISITION SEQUENCE OF GRAPHICAL INTERPRETATION SKILLS

VOLUME I

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(VOLUME I)

ABSTRACT

This thesis is concerned with the effects of certain personal and situational variables on the acquisition sequence of graphical interpretation skills. A comprehensive learning hierarchy of basic graphical interpretation skills was prepared according to the method of task analysis initially proposed by Gagné. An extensive analysis was then made of possible subdivisional skills within each of the basic intellectual abilities. The reasons for this analysis were -

(1) to determine more precisely the limits of lateral transfer associated with each of these basic skills, and thus -

(2) to avoid invalidating likely connections through comparison of different subdivisional skills at successive levels of the learning hierarchy.

This analysis also involved the development of a new statistical test for the difference between two dichotomous skills. This test, which accounts for errors of measurement, was based on a model developed earlier by White and Clark for a test of hierarchical dependence.

Following the analysis of subdivisional skills, the postulated learning hierarchy was subjected to a series of empirical validation studies. These studies involved the preparation of a comprehensive instructional programme, with appropriate questions inserted after each interpretative skill. The validation programme was initially tested in three separate parallel forms, in order to determine the effects of a different informational model and extended numerical

range on the acquisition sequence of skills. Apart from occasional inconsistencies, apparently produced through the repetition of instructions in one section of the validation programme, the same hierarchical network of graphical interpretation skills was substantiated in each of these validation studies.

Subsequent studies with interstate and overseas students were used to test the possible effects of differences in curricular and cultural background, age and nominal academic level. Each of these studies produced similar validation results, though again with minor inconsistencies. Thus it seems that the acquisition sequence of graphical interpretation skills may be largely independent of the specified personal and situational characteristics examined in this research.

This conclusion is qualified by two important observations derived from the analysis of subdivisional skills and the series of parallel validation studies.

(1) The potential generalisation of any basic intellectual skill is restricted to the scope of subdivisional conditions within which it is initially taught.

(2) The mastery of intellectual skills in one informational context does not imply the capacity to translate these skills to a different informational context without provision of the relevant terminology or instructional cues.

Apart from providing evidence to substantiate the basic principle of hierarchical learning, these studies present a number of important implications for research and curriculum development.

This thesis contains no material previously submitted or accepted for the award of any other degree or diploma, and to the best of my knowledge and belief contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

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INTRODUCTION

The principle of hierarchical learning, which involves the sequential acquisition of logically related and progressively complex behavioural capabilities, has long been a dominant influence on curriculum planning and development, more particularly in the scientific disciplines. This influence is probably related to the well-established hierarchical organisation, or substantive structure of scientific knowledge (see Ausubel & Robinson 1969/p142; Bruner 1960; Dressel et al 1960; Schwab 1964), and has tended to result in a rigid sequential approach to the teaching of scientific skills. Although this general approach has been relatively consistent, the presentation sequence of particular skills defined within specific topics has often varied from one course to another, since these patterns of sequential learning have generally been based on the intuitive reasoning of individual curriculum writers or teachers, rather than on objective or empirical research. Thus many important topics have been presented in different curriculum programmes through logically incompatible learning sequences (one example is presented in Chapter II), and these programmes have often been widely used without consideration for the possible effects of certain recognised learning variables, such as age and academic level, curricular and cultural background, on the acquisition sequence or pattern of relevant skills.

The object of this research is to construct, and validate by empirical means, a hierarchical network of graphical interpretation skills, and to examine the effects of certain personal and situational variables on the acquisition sequence of these interpretative skills.

The theoretical basis for this research, which involves the nature and conditions of hierarchical or sequential learning, is examined in Chapter I, and this is followed by an outline of previous investigations on the construction and validation of learning hierarchies. Chapter II then examines the field of graphical interpretation skills, with particular reference to the differences in teaching approach and presentation sequence of these skills. This chapter concludes with the case for more definitive research.

Chapter III describes the postulation and preliminary validation of a comprehensive learning hierarchy of basic graphical interpretation skills. The classification and analysis of subdivisional skills within each of these basic interpretative abilities is outlined in Chapter IV. This analysis is then used as a basis for specifying certain modifications and restrictions to the postulated learning hierarchy prior to the validation trial (Chapter V).

The first major empirical validation of the postulated learning hierarchy is described in Chapter VI, and this is followed by two parallel validation studies, using modified instructional and testing programmes, which examine the effects of a different informational model (Chapter VII) and extended numerical range (Chapter VIII) on the acquisition sequence of graphical interpretation skills. Subsequent validation studies with interstate and overseas students are used to test the possible effects of other important variables, including curricular and cultural background (Chapters IX and X respectively), on the postulated learning hierarchy, while the interactive influence of a different cultural background and specific informational model is examined in Chapter XI. Chapter XII presents a summary of the major conclusions arising from these validation studies, and examines the resultant implications for research and curriculum development.

CHAPTER I

AN OUTLINE OF THEORY AND RESEARCH RELATED TO HIERARCHICAL LEARNING

1. The Theoretical Basis of Hierarchical Learning

The principle of hierarchical learning depends on the recognition of different levels of cognitive capability, associated in some form of hierarchical organisation through the postulation of learning transfer, and is compatible in terms of these essential characteristics with many recent models of learning and instruction. The basic element of hierarchical interrelationship between different levels of learning behaviour is emphasised in the following outlines for several of these theoretical models.

The most explicit, and perhaps the most prominent model of hierarchical learning is that proposed by Gagné (1965). This model defines eight different types of progressively complex learning behaviour - signal-learning, stimulus-response learning, chaining, verbal association, multiple discrimination, concept learning, principle learning and problem solving. The lower levels, or simpler forms of learning are relatively limited in scope, while the higher or more complex levels may also involve some degree of internal differentiation. Each of these learning processes is characterised by its own set of necessary or facilitating conditions, and is hierarchically related to the others in terms of its essential prerequisite capabilities.

A number of other prominent models, although different from that of Gagné in terms of basic definition, also recognise some form of hierarchical organisation with respect to learning behaviour. Ausubel (1961) for example, initially defines three principal kinds of learning (rote and meaningful learning, concept formation, and verbal and non-verbal problem solving), but later modifies this model (Ausubel & Robinson 1969/p59) to a hierarchically organised set of five learning processes, beginning at the lowest level with representational learning (or naming), and progressing through concept learning, proposition learning and problem solving, to creativity at the highest level. Both of these models include a number of intermediate divisions (representational learning, for example, is the last of eight sequential stages in concept acquisition - Ausubel 1968/p517), and are further complicated by two additional independent dimensions (rote/meaningful and reception/discovery) which cut across each of these categories.

Bloom's Taxonomy of Educational Objectives (Bloom 1956) defines, in the cognitive domain, six progressively complex classes of learning or educational behaviour - knowledge, comprehension, application, analysis, synthesis and evaluation - and incorporates a system of hierarchically organised subdivisions within each level or class (Bloom 1956/p30; see also Dressel <u>et al</u> 1960). This model is generally compatible with those of both Gagné (1965/p261) and Ausubel (Ausubel & Robinson 1969/p27), although in the latter case at least there are a number of important process distinctions (Ausubel & Robinson 1969/p74).

Tennyson and Merrill (1971) also recognise certain common organisational characteristics in the hier rchical schemes of Gagné (1965) and Bloom (1956), and compare these with Merrill's own learning and instructional paradigm (Merrill 1971). With respect to the aspect of learning, however, this model is little more than a reclassification of Gagné's original scheme, although it does involve an additional dimension of emotional behaviour, and distinguishes a further class of learning at both the psychomotor and lower cognitive levels.

Bruner's general models of learning (1960) and instruction (1966), while still in a sense hierarchical, are based predominantly on the developmental approach initiated by Piaget (1950), and are concerned in this respect with the gradual transition through three sequential stages of information processing - enactive, iconic and symbolic representation (Bruner 1964). These models are not explicitly compatible with those outlined above, at least in terms of general organisational structure, but still incorporate certain conditions of prerequisite learning and transferability which are consistent with the basic principle of hierarchical learning.

In addition to the common characteristic of hierarchical organisation, each of the models outlined above involves the postulation of learning transfer, which may be defined in general terms as the influence of learning in one situation upon subsequent learning in another. Transfer, in fact, is an essential condition for any model of hierarchical learning, since the sequential acquisition of progressively complex skills depends on the recollection and application of previously learned abilities. Although applicable by definition at any behavioural level, this type of learning transfer assumes particular importance with the higher cognitive skills, which involve more extensive and more complex prerequisite abilities than those at lower levels.

The lower categories or levels of learning - classified "knowledge" in Bloom's Taxonomy (1956), and probably analogous to "rote learning" (Ausubel & Robinson 1969), "memorisation" (Merrill 1971), "verbal association" and "multiple discrimination" (Gagné 1965; see also Tennyson & Merrill 1971) - require only that certain specific information be recalled in the same situation, or another very similar to that in which the learning first took place. These skills obviously involve only limited application of specific learning transfer. The higher forms, however, involve additional characteristics of abstraction and generalisation, which may also require a different type of learning or behavioural transfer to that involved in the process of hierarchical acquisition. It may be useful, therefore, to examine more closely the whole concept of learning transfer, and thus to clarify its role in the acquisition and application of higher cognitive skills.

Gagné (1965) distinguishes two different types of behavioural transfer - generalisation or "lateral transfer", which involves the ability to recognise and apply the appropriate concepts or principles in relatively unfamiliar situations, and facilitation or "vertical transfer", in which the acquisition of more complex skills (though not necessarily different in the taxonomic sense) is facilitated by incorporation with an existing cognitive structure of related subordinate capabilities. Ausubel differentiates the latter into more specific categories - "sequential transfer", in which both of the relevant skills are at the same behavioural level, and "vertical transfer", which defines a somewhat different, but probably overlapping situation where learning at one behavioural level facilitates subsequent learning at a higher level (Ausubel & Robinson 1969/p138). Sequential transfer seems in this sense to refer more particularly to the higher cognitive skills such as concept and principle learning, where many different levels of complexity may be defined within the same basic category of cognitive ability. Nevertheless Ausubel's distinction between vertical and sequential transfer is probably unnecessary on theoretical grounds, since both by definition mediate the acquisition of more complex capabilities.

The most important conditions of lateral transfer are suggested by Gagné (1956/p232) to be those of a personal or internal nature, and probably include both innate and acquired capabilities. It is suggested, moreover, with respect to acquisition, that this form of transferability is in part a function of the breadth or variety of one's experience, and may be improved to this extent by appropriate teaching techniques. Both Ausubel (1969/p154) and Bruner (1960/p25) advocate, as an extension or alternative to this, the teaching of general principles rather than specific solutions or skills, and Bloom (1956/p38) also emphasises the acquisition of "generalised techniques" as an essential component of higher ("intellectual") learning skills.

The conditions of vertical and sequential transfer are generally similar, and include a number of both internal (personal) and external (situational) characteristics. The latter are common to many of the higher-order capabilities, and include the nature of material to be learned (Ausubel 1969/p142) and the sequence in which it is presented (Ausubel 1969/p143; Bruner 1960/p13; Gagné 1965/p149), the quality of instruction (Gagné 1965/p146; Carroll 1963), and the opportunity or time allowed for learning (Carroll 1963). With respect to internal conditions, Gagné asserts(1962) and later reiterates that the most important of these is the "prior learning of pre-requisite capabilities" (1970), while Ausubel similarly maintains that vertical or sequential transfer is "largely a function of the relevance, meaningfulness, clarity, stability, integrativeness and explanatory power of the originally learned subsumers" (Ausubel 1968/p161). These characteristics of "cognitive structure" (Ausubel & Robinson 1969/p158) are related in turn to both the nature, or more particularly the "sequential dependence" (Ausubel & Robinson 1969/p142) of the subject material, and to the acquisition sequence of relevant cognitive skills.

It is important at this stage to emphasise the distinction between intellectual skills and verbalised knowledge. The former, alternatively called "generalised skills" (White 1971) or "cognitive strategies" (Gagné 1968), each represent a general class of individual learning tasks, while elements of verbalised knowledge define single or specific abilities at a lower cognitive level, with no comparable potential for generalisation. These two types of learning may be illustrated with examples from a hierarchy of graphical interpretation skills previously examined by White (1971). Thus the ability to rule a tangent to a curve at any specified point (p43) represents a relatively complex intellectual skill, and describes an almost infinite range of individual examples, each involving a different type of curve or point of contact. On the other hand, however, the recognition of "second" as a unit of time (p42), which represents an element of verbalised knowledge, involves only a single and quite specific task.

In establishing the theoretical distinction between verbalised knowledge and intellectual skills, Gagné (1968) suggests that while elements of verbalised knowledge may be subordinate to related intellectual skills, they do not share with each other the same relationship of positive (vertical) transfer. This assertion is empirically substantiated by White (1971/p329), who concludes from his own results that although elements of verbalised knowledge may be learned apparently without prerequisites, they are often themselves prerequisites for the learning of generalised or intellectual skills.

It follows from the whole discussion above that the principle of hierarchical learning and associated general conditions of transfer are consistent with a number of recent learning and instructional models. The most explicit of these models, however, is that proposed by Gagné (1965), since this model expresses more precisely than the others the interrelationship between complex abilities and subordinate or prerequisite skills, although the degree of inter-dependence, initially proposed in absolute terms (Gagné 1962/p362), would appear to be a matter of individual interpretation (see White

1971/p327). The relative precision or simplicity of Gagné's model is an obvious advantage in any attempt at empirical validation, and thus most, if not all of the recent research on aspects of hierarchical learning has been related to this framework. It seems appropriate, therefore, to use this model as a basis for the present research in constructing and validating a hierarchical network of graphical interpretation skills, and examining some of the conditions which may affect the acquisition sequence of these skills. Thus the following section is concerned with the application of Gagné's model to the problem of hierarchical construction, and Section 3 presents a summary of relevant research on empirical validation, together with other associated aspects of hierarchical learning.

2. The Application of Gagné's Model to the Construction of Learning Hierarchies

It follows in Gagné's model of learning from the nature and conditions of vertical transfer that any group of logically related skills can be arranged in a hierarchical sequence or structure, such that each of these capabilities is intrinsically dependent on the mastery of its subordinate skills. Thus any complex skill may be gradually resolved by logical task analysis to produce a series of progressively simpler subordinate skills, which in theory should generate "a substantial amount of positive transfer" (Gagné 1968) to the learning of subsequent capabilities. This system must inevitably involve several different levels of learning behaviour if the terminal skill is extended to its simplest possible subordinates, although many experimental hierarchies have been restricted to the levels of concept and principle learning (involving only intellectual skills), which may in themselves incorporate multiple levels of complexity.

Perhaps the most important implication of this model is that the resultant theoretical learning hierarchies are readily subjected to empirical validation, thus emphasising the relative applicability of Gagné's (1965) model, at least in the experimental sense, over those of Ausubel (1968) and Bruner (1960; 1966). Empirical research on the construction and validation of learning hierarchies, initiated in recent years by Gagné and his associates (Gagné & Paradise 1961; Gagné 1962; Gagné et al 1962; Gagné & Bassler 1963), has already revealed considerable information on the acquisition pathways of certain scientific and mathematical skills, and has also produced a number of important methodological developments. The outline presented below examines several different areas of emphasis in this research, in order to show the diversity of approach and to illustrate a few of the more important methodological problems.

3. Experimental Research on Learning Hierarchies

The predominant areas of interest in research on learning hierarchies have probably been those of construction and empirical validation, and this emphasis is reflected in a number of recent reviews (Capie & Jones 1971; Resnick & Wang 1969; White 1971; Walbesser & Eisenberg 1972) Associated aspects of this research, to be elaborated at a later stage, include various teaching and testing techniques, a relatively limited range of scientific and mathematical topics, and a somewhat broader spectrum of student age and academic level. In terms of methodological interest, however, the problems of construction and validation would seem most relevant to this study, and hence these aspects of research are examined more extensively below.

(A) Construction of Learning Hierarchies

The initial definition or construction of learning hierarchies may be achieved by a number of different methods, the most popular of which is probably Gagné's task analysis model (see Gagné & Paradise 1961). This involves firstly defining the terminal skill, then asking the question "'What would the individual have to know how to do in order to be able to achieve this (new) task, when given only instructions?'". By successive applications of this technique, any complex intellectual skill may be gradually broken down to produce a hierarchical network of simpler subordinate skills. Merrill (1971) outlines an alternative approach to the construction of learning hierarchies, based on an information processing model. He claims, however, that neither this nor Gagné's task analysis procedure are individually sufficient for every type of intellectual task.

An experimental method of construction reported by Smith (1970) involves the hierarchical rating by difficulty level of supposedly related items from a general question pool, and defining on the basis of this analysis the appropriate intellectual skills associated with each resultant question group. This method falsely presupposes, however, that a difference in item difficulty level reflects a positive hierarchical relationship between respective skills, and thus the model is logically unsound. White (1971/p126), for example, establishes a hierarchical connection between two related skills of graphical interpretation in which, contrary to general expectations, the higher skill is apparently easier than the specified prerequisite.

Alternative experimental procedures (see Walbesser & Eisenberg 1972) include both student-generated and instructor-generated systems, and an additional combination of both. It seems, however, that "expert"-generated hierarchies (see Gagné & Paradise 1961) are not necessarily equivalent to those produced by students for the same terminal skill (Walbesser & Eisenberg 1972), though as yet there has been no systematic research on the relative rates and patterns of acquisition. This information is consistent with Gagné's (1968) assertion that a logically constructed learning hierarchy does not necessarily represent the most appropriate acquisition sequence, and may also substantiate Ausubel's (1968/p45) distinction between the logical (or substantive) and psychological (or meaningful) structure of knowledge (see also Ausubel & Robinson 1969/p53).

Of the various methods outlined above for the construction of learning hierarchies, Gagné's task analysis model is probably the simplest and most practical technique. As yet there is no conclusive evidence from comparative studies to suggest that the more complex or sophisticated methods are in any way superior, or that the task analysis model is in itself inadequate. This evidence, however, could not be obtained without a sound validation technique, and as explained in the following section, none of the validation techniques yet produced could be accepted without some critical or cautionary comment.

(B) Validation of Learning Hierarchies

Approaches to the validation of learning hierarchies have in general followed one of three basic patterns. The first of these, used by Gagné and his associates in their early experiments (Gagné & Paradise 1961; Gagné et al 1962; Gagné & Bassler 1963), and later by Capie & Jones (1970), Gray (1969), and Wiegand (1970), examines the relationship of positive transfer to a single terminal skill from a comprehensive group or system of subordinate skills. An alternative method (see Resnick & Wang 1969; Wang, Resnick & Boozer 1970) involves the analysis of integral learning sequences, while the third examines independently each postulated step between two hierarchically related capabilities. The latter procedure is used by Olsen (1968), Raven (1967/8), Smith (1970) and White (1971). Each of these approaches demands a different type of statistical validation technique, and although a variety of techniques have been suggested, most are either inadequate or inappropriate for this purpose.

Perhaps the simplest of statistical validation techniques is that adopted by Olsen (1968) and Raven (1967/8), which involves a comparison of item difficulties between pairs of supposedly related individual skills. This method is based on the same false rationale as that proposed by Smith (1970) for the construction of learning hierarchies, and is also rejected on logical grounds by White (1971), since a difference in item difficulty levels need not necessarily reflect a positive hierarchical relationship between respective capabilities.

The measure of "proportion positive transfer" introduced by Gagné and Paradise (1961) is based on the four-fold correlation matrix shown in Table 1/1. This is examined in detail by White (1971) and subsequently rejected as an impractical and misleading index, since at best it merely reflects a positive correlation between the relevant skills, and the values which might be expected for independent skills are often relatively high. A modification of this technique by the Commission on Science Education for the American Association for Advancement of Science (see Walbesser & Eisenberg 1972) involves the calculation of three complementary indices from the same basic correlation table. Subsequent variations on this technique are provided by Capie & Jones (1970) with the addition of a "necessity ratio", and independently by Walbesser and Eisenberg (1972) with two further complementary indices. The Phi and Phimax coefficients attributed to Carroll (see Resnick & Wang 1969) are also based on a similar matrix model. Each of the indices mentioned above is defined in Table 1/1. Although commonly used in other recent studies (Kane,McDaniel & Phillips 1971, Gray 1969) these methods all suffer from certain basic deficiencies - none, for example, can account for errors of measurement, or indicate levels of significance for observed deviations from ideal or expected behaviour.

TABLE 1/1

Correlation Matrix Indices for the Validation of Learning Hierarchies

		Superordinate Skill −	Superordinate Skill +
Subordinate Skill (or set of skills)	+	C	A
	−	D	B

A = (+,+)
B = (+,−)
C = (−,+)
D = (−,−)

SOURCE	INDEX Title	INDEX Measure
Gagné & Paradise (1961)	Proportion Positive Transfer	$\frac{A+D}{A+B+D}$
A.A.A.S. Commission on Science Education (from Walbesser & Eisenberg 1972)	Consistency Ratio	$\frac{A}{A+B}$
	Adequacy Ratio	$\frac{A}{A+C}$
	Completeness Ratio	$\frac{A}{A+D}$
Capie & Jones (1970)	Necessity Ratio	$\frac{D}{B+D}$
Walbesser & Eisenberg (1972)	Inverse Consistency Ratio	$\frac{D}{C+D}$
	Inverse Adequacy Ratio	$\frac{D}{B+D}$
Carroll (See Resnick & Wang 1969)	Phi/phimax coefficients	$\frac{AD-BC}{(A+C)(B+D)(C+D)(A+B)}$
Smith (1970)	Decision Rule	$B < \frac{1}{4} C$

A variation reported by Smith (1970) on the single index validation method involves the use of five questions to test each skill, with an arbitrary criterion for mastery set at four correct responses. The subsequent analysis is based on the same informational table as that discussed above (see Gagne & Paradise 1961), but in this case is applied to various combinations of individual skills. The critical proportion of observed exceptions to any postulated hierarchical sequence is set, as in all of the methods outlined above, by intuitive or arbitrary definition. Thus, although this system may account to some extent for potential errors of measurement, it still provides no measure of significance by which to accept or reject any postulated hierarchical relationship.

The Guttman model of Scalogram Analysis (Guttman 1944) is discussed, together with various modifications, in a number of recent reviews (Resnick & Wang 1969; Wang, Resnick & Boozer 1970; Walbesser & Eisenberg 1972). These methods, however, are not extensively used for hierarchical validation, since they can only be applied to linear sequences of skills (which are seldom achieved in practical situations), and provide no means to distinguish between subordinate and co-ordinate relationships (Walbesser & Eisenberg 1972). The Walbesser-Eisenberg (1971) technique and associated variations are also prone to the latter limitation (Capie & Jones 1971), more particularly if they are used with pairs of single skills, rather than applied to composite groups.

The test of hierarchical dependence developed by White and Clark (White 1971, White & Clark 1973), which accounts for errors of measurement in determining the probabilities associated with acceptance or rejection of postulated learning sequences, is probably the most useful technique in this field. This method is free from most of the limitations inherent in the earlier models, and with certain reasonable approximations is reduced to a relatively simple computational procedure. The same model is used (with minor modifications) as the basis for several validation experiments incorporated in this project, and will therefore be discussed more extensively in a later section.

(C) Teaching and Testing Techniques

The teaching and testing techniques associated with hierarchy validation experiments, which are to some extent determined by the selection of statistical procedures, have also shown some interesting developmental differences. Written instructions are probably the rule, though not without exception (see Smith 1970, Capie & Jones 1970, Olsen 1968, Resnick & Wang 1969), and these are often presented in some form of individual learning programme (for example see Gagné & Paradise 1961, Gagné & Bassler 1963, Kolb 1967/8, Gray 1969, White 1971). The testing materials are generally concentrated at the end of the learning sequence (Gagné & Paradise 1961, Gagné et al 1962, Kolb 1967/8) and may even be delayed some time beyond this stage (Okey 1968), but evidence of random forgetting with respect to lower elements (Gagné & Bassler 1963) substantiates the approach adopted more recently by White (1971) in which appropriate questions are incorporated within the learning programme.

(D) Subject Areas, Age and Academic Level

The range of subject areas in experiments on learning hierarchies has so far been restricted to a relatively small selection of mathematical topics (Gagné & Paradise 1961; Gagné et al 1962; Gagné & Bassler 1963; Kane, McDaniel & Phillips 1971; Resnick, Wang & Kaplan 1970; Wang, Resnick & Boozer 1970), and associated areas of physical science (Gray 1969; White 1971; Wiegand 1970; Capie & Jones 1970). These two subject areas both possess a strong substantive or logical structure, and therefore seem more likely to be consistent with this type of learning model. On the other hand, however, the same validation studies have included a much more representative range of student age and academic level, with a number of pre-school studies (for example see Resnick 1967; Wang, Resnick & Boozer 1970) augmenting those at higher levels (Gagné & Paradise 1961; Gagné & Bassler 1963; Gray 1969; White 1971; Wiegand 1970; Capie & Jones 1970).

In spite of certain methodological weaknesses, most of these studies on hierarchical learning have produced results consistent with Gagné's theoretical model. Moreover, the evidence against this model is either openly inconsistent (see Merrill 1965; Merrill, Barton & Wood 1970) or rendered inconclusive through basic methodological flaws (White 1971/p23-25). It seems, therefore, that the model is basically sound, but the limitations in scope and methodological deficiencies in most of the previous studies suggest a need for more extensive research on the nature and conditions of hierarchical learning.

Apart from this general objective, the present research is also concerned with the practical implications of specific curriculum studies in science and mathematics - more particularly with basic skills of graphical interpretation, a topic which is relevant to both of these subject areas. Graphical interpretation skills have a position of recognised importance in both local and international curriculum studies, and this position ensures, at least to some extent, the practical significance of any relevant research. In addition these skills are often presented in hierarchial or sequential form, an approach consistent with the model adopted above, yet the logical inconsistency of presentation sequence in different curriculum programmes implies a need for empirical validation of a comprehensive learning hierarchy to substantiate or replace the current courses. This theme is expanded in Chapter II, which establishes in detail the practical importance of graphical interpretation skills, then examines the variation in sequence and approach to the teaching of these skills, and finally presents an outline of relevant research as a basis for the subsequent development of a comprehensive learning hierarchy.

CHAPTER II

AN ANALYSIS OF GRAPHICAL INTERPRETATION SKILLS — RECOGNITION, APPLICATION AND RESEARCH

1. The Practical Importance of Graphical Interpretation Skills

The ever-increasing use of graphical techniques for both scientific and statistical communication has established the status of associated interpretative skills as a fundamental aspect of general curriculum studies. Riggs (1966) cites a number of national (American) curriculum experts to substantiate this position, and similar views have often been expressed by both local (Blachford 1971, 1972; Cleaves 1972) and international authorities (Butler, Wren & Banks 1970/p217; Grobman 1969). The importance of graphical interpretation skills is now recognised in a practical sense by educational organisations and authorities throughout the world, and this is shown in many curriculum programmes and associated examinations. Nevertheless there is an increasing amount of evidence from recent testing programmes that these techniques are often poorly understood, and thus by implication poorly taught. Common learning difficulties with respect to these abilities are reflected in a number of local high school curriculum examination results, and on a broader scale in both national and international subject achievement tests.

An analysis of V.U.S.E.B. (Victorian Universities and Schools Examinations Board) Leaving and Higher School Certificate (Matriculation) examinations (see Table 2/1 below) in Physics, Chemistry and Biology, which constitute the major scientific disciplines studied at this level, indicates the relative importance of graphical interpretation skills throughout the past five years. Both Physics and Biology examinations have maintained a considerable proportion

TABLE 2/1

Questions on Graphical Interpretation in V.U.S.E.B. Leaving and H.S.C. (Matriculation) Examination Papers (1968-1972)

SUBJECT	YEAR	LEVEL: LEAVING — Number of Questions: Graphical	LEAVING — Number of Questions: Total	H.S.C. — Number of Questions: Graphical	H.S.C. — Number of Questions: Total
Physics	1968	7	21	23	113
	1969	4	23	27	110
	1970	7	24	28	108
	1971	9	25	39	109
	1972	7	27	31	107
Chemistry	1968	1	16	1	49
	1969	2	14	0	50
	1970	1	13	0	49
	1971	1	13	0	48
	1972	2	10	0	39
Biology	1968	8	42	4	37
	1969	4	42	4	36
	1970	8	45	2	35
	1971	10	47	4	48
	1972	12	47	7	48

of questions related to graphical skills, while in Chemistry the number of graphical questions has been relatively small.

Item analysis information based on the results of these examinations (see Mackay 1969(a), 1970(a), 1971, White 1972(a) for Leaving Physics; Mackay 1969(b), 1971, White 1972(a) for H.S.C. Physics; Batten & Mackay 1969, 1970, 1971, White 1972(b) for Leaving Biology) reveals that questions of graphical interpretation are often among the most difficult in their respective papers, and this is reiterated in examiners' reports (V.U.S.E.B. Reports of Examiners for Leaving and H.S.C. examinations 1968-1972). This does not necessarily reflect a corresponding level of difficulty for specific graphical interpretation skills, since many of these questions are of a composite nature, but the weight of correlative evidence certainly indicates some difficulty with the relevant interpretative skills.

The ability to understand and to "translate between verbal, symbolic, tabular, graphical, diagrammatic and pictorial material" is an important and explicit objective for the Commonwealth Secondary Scholarship Examinations (Australian Council for Educational Research 1967) in both Quantitative Thinking, and Comprehension and Interpretation in the Sciences. A review of relevant C.S.S.E. papers (see Table 2/2 below), which are presented in every state at the intermediate high school year, indicates again the importance attributed to graphical interpretation skills. Item analysis results from these examinations (A.C.E.R. - unpublished confidential information) show general fluctuations in difficulty levels for particular questions from state to state, but at the same time emphasise a predominantly poor

TABLE 2/2

Questions on Graphical Interpretation in Commonwealth Secondary Scholarship Examination Papers

(A.C.E.R. 1964-1972)

YEAR	COMPREHENSION AND INTERPRETATION (SCIENCE)		QUANTITATIVE THINKING	
	Number of Questions		Number of Questions	
	Graphical	Total	Graphical	Total
1964	8	74	3	64
1965	0	71	7	60
1966	9	70	10	61
1967	19	64	7	60
1968	11	65	10	61
1969	18	62	4	61
1970	15	60	4	61
1971	14	66	2	62
1972	13	63	5	62

performance in both subjects on questions of graphical interpretation.

The I.E.A. (International Association for the Evaluation of Educational Achievement) cognitive achievement tests in science (A.C.E.R. 1970) and mathematics (A.C.E.R. 1964), which have been conducted at various equivalent levels in twelve countries throughout the world, incorporate somewhat fewer questions on graphical interpretation (Table 2/3) than most of the tests discussed above, although many of the relevant skills are rated as important specific objectives in mathematics (Keeves 1966) for both the thirteen-year old (Tests A-C) and pre-university (Tests 5-9) student populations. Evaluative information for the science testing programme has not yet been released, but the results for mathematics indicate that levels of achievement in Australia (Keeves 1966) for particular questions involving graphical interpretation skills are in general substantially lower than the corresponding international average (Husén 1967), although Keeves and Radford (1969) suggest that by international standards the overall results for Australian students are also relatively low. The tests in mathematics were conducted several years ago, but substantiating evidence above from both local and national examinations suggests that the general understanding of graphical interpretation skills has probably not improved in recent years. Thus accepting the practical importance of this area, we must now examine more closely the methods of approach by which these skills are taught.

2. The Teaching of Graphical Interpretation Skills

The teaching of graphical interpretation skills is by no means

TABLE 2/3

Questions on Graphical Interpretation
in I.E.A. Cognitive Achievement Tests
(A.C.E.R. 1964, 1970)

MATHEMATICS (1964)			SCIENCE (1970)		
	Number of Questions			Number of Questions	
TOPIC	Graphical	Total	TOPIC	Graphical	Total
Test A	1	23	General		
B	3	24	Science II A	2	40
C	1	23	B	0	40
5	3	21	General		
6	0	17	Science IV A	4	36
7	1	17	B	1	30
8	0	16			
9	2	15	Physics	0	40
			Chemistry	4	40
			Biology	5	40

confined, in spite of certain common objectives, to a single or uniform approach, and the actual diversity of approach is probably best reflected in a systematic analysis of current local and overseas curriculum programmes. These courses of instruction may be conveniently classified into two basic categories - (a) General courses, usually incorporated in the mathematics curriculum and introduced at the primary or elementary stage, and (b) Service courses, which are typically associated with one of the scientific studies, and presented at a somewhat later stage of intermediate (junior high school) or secondary education. General courses on graphical interpretation are included in all Australian state primary mathematics curricula (for example see Education Department/ Victoria (1965-1969), Queensland (1966-1968), South Australia (1969-1971) for curriculum outlines), the S.M.S.G. Elementary Mathematics Program (School Mathematics Study Group 1962) and in the Nuffield Mathematics Project (1969). Service courses are produced by the Intermediate Science Curriculum Study (1970), Biological Science Curriculum Study (1970) and Australian Science Education Project (1972) to complement their respective scientific programmes. An analysis of these courses is outlined in Table 2/4.

A comparative review of these instructional courses or programmes reveals a number of interesting and important differences. Despite the claim by Smith (1970) that "the treatment of graphs in the primary mathematics program often lays the main stress on construction work", several of these programmes (Ed. Dept./Qld., Nuffield (2),

TABLE 2/4

Courses of Instruction on Graphical Interpretation

Programme/Course	Stage of Introduction	Predominant Approach	Graphical Forms
Education Dept. (Victoria)	early primary grades (1-3)	Developmental	Bar, Line, Circle, Picture graph
Education Dept. (Queensland)	early primary grades (1-3)	Hierarchical	Bar, Line, Circle, Picture graph
Education Dept. (Sth. Aust.)	grade 3	Hierarchical	Bar, Line, Circle, Picture graph
Nuffield (1)	early primary grades (1-3)	Develpmental	Bar, Line, Circle, Picture graph
Nuffield (2)	middle primary grades (3-5)	Hierarchical	Line graph only
S.M.S.G.	grade 6	Hierarchical	Bar, Line, Circle, Picture graph
I.S.C.S.	early High School grades (7-9)	Hierarchical	Line graph only
B.S.C.S.	middle High School grades (9-11)	Hierarchical	Line graph only
A.S.E.P. (National Trial Unit)	early High School grades (7-9)	Hierarchical	Line graph only

S.M.S.G.) deal only with interpretative skills, and the other General courses also emphasise this area. In contrast with this, however, the Service courses (I.S.C.S., B.S.C.S., A.S.E.P.) are directed more toward constructional techniques, which are generally thought to involve a different, though probably overlapping set of skills.

The numerical range used in graphical exercises throughout the General courses often lags well behind the introduction of more complex and extensive number systems in other sections of the primary curriculum, and even the high school Service courses are restricted to relatively simple number systems. There are, however, certain differences with respect to numerical range, which may involve either integral or rational numbers of different degrees in magnitude, depending on the course and level. Although negative numbers occur in the S.M.S.G. programme, these are rarely used in introductory graphical exercises.

The introductory vocabulary of specific graphical terms (such as "horizontal", "vertical","co-ordinate" and "axis") is generally fairly limited in the primary or General programmes, particularly at the lower grades, but seems to be more extensive in the high school Service courses, which often cover more sophisticated skills. In contrast with this, however, the range of informational models or examples is usually more extensive in the General courses listed above. The range of graphical forms is also wider in these programmes (see Table 2/4), which in general cover all four basic models recommended by Dutton & Riggs (1969), while the Service courses are concerned only with the two-dimensional line segment graph. This, according to Weintraub (1967), is "one of the most difficult of all graphic forms to interpret", though it is also by far the most common and versatile form.

The programmes or courses outlined above involve two different types of approach to the teaching of graphical interpretation skills. The Developmental approach, which is used in the Victorian state curriculum and one of the Nuffield programmes (see Table 2/4), is based on Piaget's (1950) theoretical model of developmental psychology, and emphasises the gradual transition from simple operations with concrete objects to the abstract representation of more complex statistical data. Thus the section on "Statistics and Graphs" in the Victorian state curriculum begins with relationships between real or tangible objects, and proceeds through various stages of symbolic representation, initially with the same set of three-dimensional objects (such as beads), and subsequently with two-dimensional symbols (bars or strips of paper), to a later series of exercises in more abstract pictorial representation (Applied Number/ Sections A-C 1969, D-F 1969; Mathematics/Sections G 1968, H & I 1969).

The Hierarchical approach, which is adopted in the other General courses and all the high school Service programmes (see Table 2/4), follows Gagné's type of learning model, and concentrates on a logically defined sequence of more specific and progressively complex graphical skills, all of which typically involve some form of abstract representation. The S.M.S.G. programme (Grade 6 (part 2) / Section 5, 1962), which follows this approach, begins with number-line examples, and progresses through plane rectangular co-ordinates to displacement calculations, and subsequently to geometric translations and reflections.

These two approaches are not completely incompatible, but rather reflect a differential emphasis, which may in part be a feature of the age or academic level at which the respective types of programme are introduced. If the Hierarchical model, for example, is extended to its simplest subordinate levels of representational ability, the lowest skills may well resemble the introductory activities proposed in the Developmental programmes. Most of the Hierarchical courses, however, are limited to more sophisticated levels of abstract representation, in which there is a greater capacity for generalisation, and hence a greater opportunity for practical application of the relevant interpretative skills. It seems appropriate, for similar reasons, that the present research is also concerned with more versatile intellectual skills, and thus remains consistent with the principle of hierarchical learning on which most of these courses are based.

One of the most important features of the hierarchically based programmes, however, is that each of those outlined in this analysis presents a different "logical" sequence of graphical interpretation skills, and these sequences are often incompatible. The I.S.C.S. and A.S.E.P (first trial) courses, for example, both incorporate the reading of linear scales after the introduction to co-ordinate location, while other courses with the same hierarchical approach present these skills in the opposite order. This discrepancy in presentation is apparently produced by the use of intuitively defined, rather than experimentally validated learning sequences, although formative evaluation (and subsequent modification) of the A.S.E.P. Service programme (A.S.E.P. 1973) suggests at least some recognition of the necessity for empirical observations. The background of experimental research in this area is rather limited, and generally inconclusive, but a few of the relevant studies are examined in the following section as a basis for the subsequent selection and hierarchical organisation of appropriate abilities.

3. Experimental Research on Graphical Interpretation

Much of the research on graphical interpretation is concerned with the applicability of different graphical forms rather than specific learning skills, but may be useful in the selection of a suitable subject field. An early analysis by Washburne (1927) examines, by means of a common instructional programme, the relative effectiveness of textual, tabular, and various graphical forms for the presentation of certain quantitative material. Washburne concludes that the type of presentation model has a substantial effect on resultant learning levels, but that differences in the quantity of data have relatively little influence on comparative effectiveness. A number of other research studies in which interpretative difficulties are compared for different graphical forms have recently been reviewed by Riggs (1966). Several of these studies, however, make no attempt to teach the relevant skills, and those which do involve an instructional course often produce conflicting results.

Riggs (1966) includes four basic types of graphical model in the development of a programmed text for fifth grade students, but makes no attempt at sequence validation (see also Dutton & Riggs 1969). Most interpretative skills contained within this programme are concerned only with the recognition of specific graphical terms, and in fact half of the explicit behavioural objectives involve aspects of verbalised knowledge. The intellectual skills include calculations of amount (or co-ordinate position) and comparative values (difference or displacement), together with rank and average estimations. Riggs adopts a pretest/programme/post-test design with a single test of 70 multiple-choice items. This includes a preliminary section on prerequisite skills, involving basic computational processes not included in the programme, and the remaining items serve as a comprehension criterion test. The most obvious and important weakness with this study is the failure to recognise the need for empirical sequence validation, which seems to be inconsistent with the fundamental assumptions of programmatic learning and instruction.

The investigation by Kolb (1967/8) of a hierarchical learning sequence, which is concerned with various interpretative skills related to line-segment graphs, follows closely the methodological approach outlined by Gagné and Paradise (1961). This design involves a single question for each element or ability, included at the end of a comprehensive learning programme, and is criticised by White

(1971) on both practical and statistical grounds. Kolb (1967/8) reports a number of exceptions to the postulated learning sequence, though White (1971) attributes many of these to the elements of verbalised knowledge and possible errors of measurement.

The A.C.E.R. research and development project reported by Smith (1970) involves the validation of an extensive learning sequence of graphical interpretation skills (including the four basic models recommended by Dutton & Riggs (1969)), which is directed at the upper primary grades. The method of hierarchical construction, which is based on item difficulties for a general pool of relevant questions, has already been discussed in Chapter I, together with the associated statistical validation technique. In spite of various methodological deficiencies, this is probably one of the more useful and comprehensive studies in the field of graphical interpretation, though it can not claim to provide an essential learning sequence of interpretative skills.

The most reliable attempt at hierarchical validation with respect to graphical skills is that reported by White (1971), although this study was restricted to a relatively limited range of interpretative skills leading to the calculation of velocity from a distance/time (two-dimensional line segment) graph. Perhaps the most important methodological features of this study involved the placement of appropriate evaluation questions throughout the learning programme, the determination of subdivisions within each element or skill, and the development of a statistical test to account for errors of measurement (see also White & Clark 1973). As suggested in Chapter I, the elements of verbalised knowledge incorporated in this model did not generally conform to the expected hierarchical relationships, at least with respect to their postulated subordinate skills, but apart from these exceptions the model was generally valid. Despite the significant methodological features of this study, the relatively limited scope of postulated skills restricts its potential application as a basis for general teaching or diagnostic programmes.

The necessity for, and practical value of an empirically validated sequence of graphical interpretation skills is emphasised by - (a) the recognised importance of these abilities, as shown in both local and international subject examinations and in various instructional programmes, (b) the lack of general understanding indicated by relevant examination results, and (c) the incompatibility of presentation sequence in different curriculum programmes. Moreover, the limitations in methodology and scope of existing research studies reinforce the need for more extensive investigations. The first aspect of this project therefore involves the construction and empirical validation of a comprehensive learning sequence of graphical interpretation skills, and this is introduced in Chapter III.

CHAPTER III

THE CONSTRUCTION AND PRELIMINARY VALIDATION OF A HIERARCHICAL LEARNING SEQUENCE OF BASIC GRAPHICAL INTERPRETATION SKILLS

1. Construction of the Learning Hierarchy

The construction and validation of a comprehensive learning hierarchy concerned with basic skills of graphical interpretation requires a number of important practical considerations. In the first place there are four basic categories of representational model - bar graphs (or histograms), line-segment graphs, circle graphs (or pie charts) and pictographs - recommended for general instruction by various curriculum authorities (see Dutton and Riggs 1969). Each of these categories or graphical forms is commonly used in a wide range of educational programmes and popular publications, and each involves a different, though probably overlapping set of skills. There are, in addition to this, at least six different areas of graphical interpretation. These are represented by (1) position or co-ordinate location, including, in the case of histograms or line-segment graphs, (2) interpolation and extrapolation (the determination of general trends), and (3) turning points (maximum and minimum values), together with (4) displacement, (5) slope (or gradient), and (6) area.

Not all of these interpretative areas are appropriate to every graphical form, but in spite of this it would clearly be impossible to provide for every relevant combination of form and associated skills in the preparation of a limited practical research design. Thus in respect to these obvious experimental constraints, it was decided to restrict the scope of the present study to a single graphical or representational form, but in partial compensation to select one involving every type of interpretative skill. The only form meeting this condition is the two-dimensional line-segment graph, which because of its versatility is probably the most popular representational form. Weintraub (1967) suggests that this is also "one of the most difficult of all graphic forms to interpret", although results from a number of studies reported by Riggs (1966) are in conflict with this assertion.

The necessity for uniform terminology to define each interpretative result (such asposition, displacement or gradient), and for versatility in relation to areas of meaningful interpretation, obviously tends to limit the range of specific informational relationships appropriate for a comprehensive learning programme. The most general type of informational model, and one which meets the necessary conditions of uniformity and versatility, is the abstract or symbolic relational model involving the variables X and Y. This was consequently selected as the most appropriate model for the present research. It is also, perhaps, the least likely to involve conceptual difficulties with more complex interpretative skills, and this project later examines the extent of these conceptual difficulties through analogous investigations with a ditterent informational model. These investigations are discussed in Chapters VII and XI.

Each of the six different areas of graphical interpretation outlined above requires, by logical definition, a different terminal skill or set of skills. Thus the initial construction of the learning hierarchy, which followed Gagné's task analysis method (Gagné and Paradise 1961), was undertaken in six different sections, corresponding to these interpretative areas. Each of the associated terminal skills was then subjected independently to hierarchical task analysis, so that a comprehensive system of appropriate subordinate skills could be defined. Although independent with respect to terminal skills, each of the six interpretative areas was found, as expected, to be logically related through a complex system of subordinate associations. An outline of the postulated hierarchy is presented in Table 3/7, and a more detailed description of particular interpretative skills in Tables 3/1-3/6. In some cases alternative constructional skills, which appear to be closely related to certain interpretative abilities, have also been outlined (see Tables3/1 and 3/4).

2. Preliminary Validation of the Learning Hierarchy

The need for preliminary validation of theoretical learning hierarchies is emphasised by White (1971) on the grounds that the presentation sequence of questions and instructions within the learning programme, which is determined by the hierarchical order of appropriate skills, limits in turn the extent of subsequent statistical analysis. Thus empirical validation procedures can only be applied to a specified pattern or system of skills, and can not be used to generate new relationships. In accordance with this argument, the postulated learning hierarchy of graphical interpretation skills was subjected to various methods of subjective validation to ensure the most appropriate presentation sequence.

The procedure for preliminary or subjective validation involved consultation with several experienced teachers and curriculum experts, as suggested by White (1971), comparison with appropriate textbooks and current learning programmes, and consideration of both the results and recommendations of other relevant research. In general the consultants agreed that the postulated system of skills was logically sound, but information from research reports and other literary sources was often contradictory and generally incomplete. The diversity of sequential presentation in current learning programmes has already been discussed in Chapter II, and most of the previous attempts at empirical validation have proved equally inconsistent through various methodological deficiencies and consequently inconclusive results. The validation study by White (1971), however, proved a much more reliable comparative guide for sections involving the same or closely analogous skills, and the postulated hierarchy outlined above proved consistent in these areas of common application.

Following the preliminary validation of basic intellectual skills, it was necessary to define more precisely the possible subdivisional abilities incorporated within each basic skill. This procedure was recommended by White (1971), in order to avoid subsequent confusion between parallel hierarchical relationships involving independent subdivisional skills, which might cause the unwarranted rejection of a valid learning sequence. The definition and analysis of subdivisional skills is examined in Chapter IV.

TABLES 3/1-3/7

Postulated Learning Hierachy of Basic

Graphical Interpretation Skills (Initial Version)

CLASSIFICATION CODE

INTERPRETATIVE AREA

1. Calculation of Position (a) - Co-ordinate location.
2. Calculation of Position (b) - Interpolation and Extrapolation.
3. Calculation of Position (c) - Maximum and Minimum values.
4. Calculation of Displacement.
5. Calculation of Slope or Gradient.
6. Calculation of Area.

EXPLANATORY NOTES

Each of the following skills is specifically classified according to a complex numerical and alphabetical code. The first number of this code represents the interpretative area as shown in the table above. The second number indicates the level of a particular ability within this area, rated downward from the appropriate terminal skill. Where letters are also used, these represent secondary sequences or streams, and indicate branching in the hierarchical network. Skills which occur in more than one interpretative area are classified according to that in which they are first defined.

TABLE 3/1

Skills for Calculation of Position (A)

1/1 Calculate the Horizontal or Vertical position of a given point on a two-dimensional grid or line-segment graph. (Alternatively mark the position of a point, specified by two given co-ordinates.)

↑

1/2 Calculate the position of a given point on a single Horizontal or Vertical number line. (Alternatively mark the position of a point, specified by a given value.)

TABLE 3/2

Skills for Calculation of Position (B)

2/1(A) Calculate the Horizontal or Vertical position of a point, specified by one co-ordinate, interpolated between a given row of points on a two-dimensional grid.

2/1(B) Calculate the Horizontal or Vertical position of a point, specified by one co-ordinate, extrapolated beyond a given line segment (or row of points) on a two-dimensional grid.

1/1

TABLE 3/3

Skills for Calculation of Position (C)

3/1 Calculate the Maximum or Minimum value of a curve (giving Horizontal or Vertical position) drawn on a two-dimensional grid.

1/1

3/2 Identify from a mixed sample of convex, concave and inflexional curves, those with a Maximum or Minimum Turning Point.

TABLE 3/4

Skills for Calculation of Displacement

4/1 Calculate the Horizontal or Vertical displacement between two given points on a two-dimensional grid or line-segment graph. (Alternatively mark the location of a point, given its displacement from a specified position.)

1/1

4/2 Calculate the displacement between two given points on a single Horizontal or Vertical number line. (Alternatively mark the location of a point, given its displacement from a specified position.)

1/2

4/3 Complete the calculation A-B=C, given any meaningful combination of two specific values.

TABLE 3/5

Skills for Calculation of Gradient

5/1 Calculate the gradient of a curve on a two-dimensional grid at a fixed point specified by one (Horizontal or Vertical) co-ordinate.

5/2(A) Calculate the gradient of a straight line segment drawn on a two-dimensional grid.

5/2(B) Draw the Tangent to a curve on a two-dimensional grid at a fixed point specified by one (Horizontal or Vertical) co-ordinate.

4/1

1/1

5/3(A) Calculate the gradient of a straight line segment, given both the Horizontal and Vertical displacement values.

5/3(B) Draw the Tangent to a curve at a given point of contact.

5/4(A) Complete the calculation A/B = C, given any meaningful combination of two specific values.

TABLE 3/6

Skills for Calculation of Area

6/1 Calculate the approximate area (by the method of counting squares) enclosed between two points of a given line segment, each specified by one co-ordinate, and the Horizontal axis of a two-dimensional grid.

1/1

6/2 Calculate the approximate area (by the method of counting squares) enclosed between two marked points on a given line segment and the Horizontal axis of a two-dimensional grid.

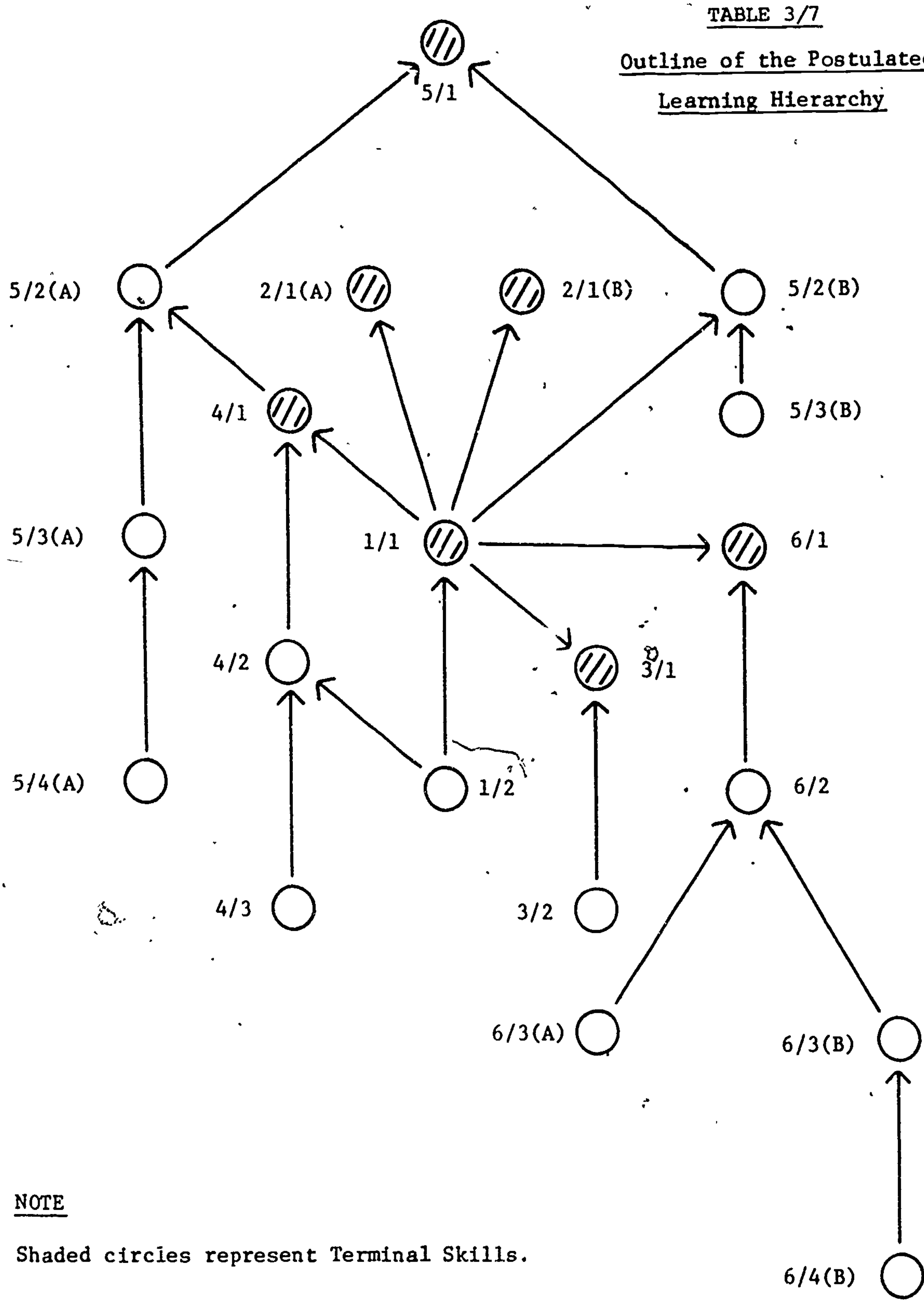
6/3(A) Classify a particular segment of a divided rectangular block as less than, or not less than half of the total area.

6/3(B) Calculate the area of a rectangular block, given the values for length and height.

6/4(B) Complete the calculation AxB = C, given any meaningful combination of two specific values.

TABLE 3/7

Outline of the Postulated Learning Hierarchy



NOTE

Shaded circles represent Terminal Skills.

CHAPTER IV

THE DEFINITION AND ANALYSIS OF SUBDIVISIONAL SKILLS

1. The Definition of Subdivisional Skills

Each of the intellectual skills outlined in Chapter III represents a composite group or class of more specific tasks with certain common operational or behavioural characteristics. Each class may also contain a number of smaller groups or subdivisions, which are more precisely defined in terms of common characteristics, and which represent logically distinct, but related aspects of the same general type of intellectual skill. Thus the ability to read the position of a given point on a graduated number line (element 1/2) may contain, as independent subdivisional skills, the ability to read both integral and decimal numbers, which may in turn have either positive or negative sign, and the ability to interpret both Horizontal and Vertical number lines (see Table 4/2). The meaning of independence in this context is that the learning of one of these subdivisional skills does not imply immediate acquisition of others in the same larger group defined by the basic element or intellectual skill.

The operational characteristics which serve to differentiate subdivisional skills, such as axis orientation and computational procedure, are initially defined by logical analysis, and do not necessarily represent independent abilities. A subsequent empirical analysis must therefore be made in order to determine which of the postulated subdivisions in effect involve different capabilities. This amounts to the determination of practical limits associated with lateral transfer, and suggests an alternative definition of subdivisional skills as those within which the learning of a single specific example provides immediate lateral transfer to others defined in the same classification group. This definition of subdivisional skills in terms of learning transfer indicates again the need for empirical, rather than logical delineation.

The necessity for empirical analysis of subdivisional skills is emphasised by White (1971) for two important practical reasons. In the first place hierarchical validation involves the testing of each intellectual skill with at least two representative questions (to account for errors of measurement), but if these involve different subdivisional skills then the errors of measurement will be considerably increased, and the power of the statistical validation technique will therefore be reduced. An alternative, and probably more serious problem arises when the questions proposed for testing hierarchically related skills do not represent analgogous subdivisional areas. In this case the postulated hierarchical relationship of vertical or sequential transfer may be invalidated through cross-analysis with independent subdivisional skills at different levels, and thus an important instructional step may be falsely omitted or abandoned.

The definition and empirical analysis of subdivisional skills is a fundamental feature of the procedure outlined by White (1971) for the validation of learning hierarchies, but is not a characteristic, at least in the same systematic sense, of any previous research in this field. Smith (1970) identifies a number of common "variations" on basic postulated principles of graphical interpretation, and defines the questions and instructional materials for each principle in the validation programme according to the simplest of these apparent variations. Although this study involves no systematic analysis of the postulated variations or subdivisional skills, it does at least recognise their existence, and in terms of the resultant experimental constraints probably takes a conservative approach. The subdivisional analysis by White (1971), however, is much more systematic in nature and comprehensive in scope than any previous experimental studies, and therefore serves as a useful model for the present research project.

In delineating subdivisional skills, a balance must be made between the necessity for comprehensive identification and the practical constraints associated with empirical analysis. Thus White (1971) suggests the limited use of implication or extrapolation, to infer from empirically established subdivisional skills at one level of the learning hierarchy the existence of analogous subdivisions at subsequent levels. This process limits the necessity for empirical analysis, which might otherwise become impracticable in scope and disproportionate in overall significance, because of the statistical requirement for duplicate questions to account for errors of measurement in the testing of each subdivisional skill.

With regard to these considerations of comprehensive identification and practical constraint, a number of logically independent subdivisions was defined for each of the intellectual skills outlined in Chapter III. There were, however, two exceptions (elements 5/I and 6/I), which probably represent the most complex of these abilities, and would therefore involve the largest number of potential subdivisions. Since both of these exceptions are terminal skills, their likely subdivisional elements may be specified by implication from analogous subdivisions in constituent or subordinate skills. An outline of all the specified subdivisional skills, together with explanatory notes and appropriate testing groups, is presented in Tables 4/1-4/18. Each of these subdivisional groups is represented by duplicate questions in a comprehensive analytical test presented in Volume II. This test contains a total of 240 questions, representing 120 subdivisional groups from 18 basic skills of graphical interpretation.

TABLES 4/1-4/18

Comprehensive Outline of Subdivisional Skills

ABREVIATION CODE

(1) Axis Direction or Orientation

- H Horizontal
- V Vertical

(2) Numerical Value

- I Integral number
- D Decimal

(3) Numerical Sign

- \+ Positive
- \- Negative

(4) Constructional Skills (c)

EXPLANATORY NOTES

(1) Each question group incorporates two different questions, marked (a) and (b) (see Volume II), corresponding to the same subdivisional classification.

(2) Complex classifications (e.g. V/I/+) represent simultaneous, not alternative conditions.

(3) The numbers shown for "Tests" indicate question group comparisons, which reflect specified subdivisional differences in respectively defined abilities.

TABLE 4/1

Subdivisional Skills for Element 1/1

QUESTION GROUP	SUBDIVISIONS (Required Co-ordinate) Direction	Number	Sign	Alternative Co-ordinate
1	H	I	+	V/I/+
2(C)	H	I	+	V/I/+
3	H	I	-	V/I/+
4	H	I	0	V/I/+
5	H	D	+	V/I/+
6	V	I	+	H/I/+

NOTES

1. Question group 2 represents an analogous constructional skill, and has the same subdivisional conditions as those for the interpretative ability represented by question group 1.

2. The numerical values of alternative co-ordinates are not necessarily the same, although all involve integral numbers.

TESTS

(1) Co-ordinate Divisions

Horizontal/Vertical (Direction) = 1/6

Integral/Decimal (Number) = 1/5

Positive/Negative (Sign) = 1/3

Positive/Zero (Sign) = 1/4

(2) Interpretation/Construction = 1/2

TABLE 4/2

Subdivisional Skills for Element 1/2

QUESTION GROUP	SUBDIVISIONS (Position) Direction	Number	Sign
1	H	I	+
2(C)	H	I	+
3	H	I	−
4	H	I	0
5	H	D	+
6	V	I	+

NOTES

1. Question group 2 represents an analogous constructional skill, and has the same subdivisional conditions as those for the interpretative ability represented by question group 1.

TESTS

(1) Positional Divisions

Horizontal/Vertical (Direction) = 1/6

Integral/Decimal (Number) = 1/5

Positive/Negative (Sign) = 1/3

Positive/Zero (Sign) = 1/4

(2) Interpretation/Construction = 1/2

TABLE 4/3

Subdivisional Skills for Element 2/1(A)

QUESTION GROUP	SUBDIVISIONS Required Co-ordinate	Alternative Co-ordinate	Slope	Interpolation Distance
1	V/I/+	H/I/+	+1	2
2	H/I/+	V/I/+	+1	2
3	V/I/+	H/I/+	-1	2
4	V/I/+	H/I/+	0	2
5	H/I/+	V/I/+	1/0	2
6	V/D/+	H/I/+	+1	2
7	V/I/-	H/I/+	+1	2
8	V/I/0	H/I/+	+1	2
9	V/I/+	H/I/+	+1	4

NOTES

1. The conditions for direction, number and sign are listed respectively for both required and alternative co-ordinates.

2. The given points for every question group were equally spaced at intervals of 2.0 (Horizontal) units.

3. The values listed above for Interpolation Distance refer to the relevant number of Horizontal units.

TESTS

(1) Co-ordinate Divisions

Horizontal/Vertical (Direction) = 1/2

Integral/Decimal (Number) = 1/6

Positive/Negative (Sign) = 1/7

Positive/Zero (Sign) = 1/8

(2) Slope

Positive/Negative = 1/3

Positive/0 (Horizontal) = 1/4

Positive/∞ (Vertical) = 5/2*

(3) Interpolation Distance

Short (2 units)/Long (4 units) = 1/9.

* This comparison is analogous to 1/4 with the Horizontal and Vertical axes reversed.

TABLE 4/4

Subdivisional Skills for Element 2/1(B)

QUESTION GROUP	SUBDIVISIONS Required Co-ordinate	Alternative Co-ordinate	Slope	Extrapolation Distance
1	V/I/+	H/I/+	+1	2
2	H/I/+	V/I/+	+1	2
3	V/I/+	H/I/+	-1	2
4	V/I/+	H/I/+	0	2
5	H/I/+	V/I/+	1/0	2
6	V/I/+	H/I/+	+1	2
7	V/D/+	H/I/+	+1	2
8	V/I/-	H/I/+	+1	2
9	V/I/0	H/I/+	+1	2
10	V/I/+	H/I/+	+1	2
11	V/I/+	H/I/+	+1	6

NOTES

1. The conditions for direction, number and sign are listed respectively for both required and alternative co-ordinates.

2. The direction of extrapolation is negative (Right to Left) for question group 6, but positive in all other cases.

3. Question group 10 involves extrapolation beyond a row of points (equally spaced at intervals of 2.0 Horizontal units), while the other groups all involve line segments.

4. The values listed above for Extrapolation Distance refer to the relevant number of Horizontal units.

TESTS

(1) Co-ordinate Divisions

Horizontal/Vertical (Direction)	=	1/2
Integral/Decimal (Number)	=	1/7
Positive/Negative (Sign)	=	1/8
Positive/Zero (Sign)	=	1/9

(2) Slope

Positive/Negative	=	1/3
Positive/0 (Horizontal)	=	1/4
Positive/∞ (Vertical)	=	2/5*

(3) Extrapolation Distance

Short (2 units)/Long (6 units)	=	1/11

(4) Direction of Extrapolation

Positive/Negative	=	1/6

(5) Line Segment/Points = 1/10

* This comparison is analogous to 1/4 with the Horizontal and Vertical axes reversed.

TABLE 4/5

Subdivisional Skills for Element 3/1

QUESTION GROUP	SUBDIVISIONS Required Co-ordinate	Alternative Co-ordinate	Turning Point
1	V/I/+	H/I/+	Maximum
2	V/I/+	H/I/+	Minimum
3	H/I/+	V/I/+	Maximum
4	H/I/+	V/I/+	Maximum
5	V/D/+	H/I/+	Maximum
6	V/I/-	H/I/+	Maximum
7	V/I/O	H/I/+	Maximum

NOTES

1. Question group 4 requires the calculation of Horizontal position corresponding to a maximum Vertical value, while question group 3 involves the calculation of a maximum Horizontal value.
2. Although the alternative co-ordinates are all positive integers, the actual numerical values are not the same.

TESTS

(1) Co-ordinate Divisions

Horizontal/Vertical (Direction) = 1/3
Integral/Decimal (Number) = 1/5
Positive/Negative (Sign) = 1/6
Positive/Zero (Sign) = 1/7

(2) Turning Point

Maximum/Minimum = 1/2

(3) Required Position

Turning Point/Alternative Co-ordinate = 1/4

TABLE 4/6

Subdivisional Skills for Element 3/2

QUESTION GROUP	Turning Point
1	Maximum
2	Minimum

NOTES

1. Each question involved selection from seven examples in order to reduce the guessing error to less than one per cent. (The probability of guessing the correct result is 1/2 for each given curve, and therefore $(\frac{1}{2})^7$ overall).
2. Inflexional curves (having no maximum or minimum turning point) were also used in these examples.

TEST

Turning Point

Maximum/Minimum = 1/2

TABLE 4/7

Subdivisional Skills for Element 4/1

QUESTION	SUBDIVISIONS (Required Co-ordinates)				Alternative
GROUP	Direction	Number	Sign	Displacement	Co-ordinates
1	H	I	+	I/+	V/I/+
2(C)	H	I	+	I/+	V/I/+
3(C)	H	I	+	I/+	V/I/+
4	V	I	+	I/+	H/I/+
5	H	D	+	D/+	V/I/+
6	H	I	-	I/-	V/I/+
7	H	I	+	I/-	V/I/+
8	H	I	0/+	I/+	V/I/+

NOTES

1. Question groups 2 and 3 represent analogous constructional skills, with the smaller and larger values respectively provided, and have the same subdivisional conditions as those for the interpretative ability represented by question group 1.

2. If Horizontal and Vertical directions represent independent subdivisions, and if constructional skills are different from those of interpretation, then a difference between question groups 2 and 3 might only reflect the independence of Horizontal and Vertical displacement calculations, rather than the postulated constructional subdivisions. Thus both co-ordinate points are given the same vertical position in each of these question groups.

3. The values given in question group 5 were selected to avoid complex "carryover" calculations, since this subdivisional skill is concerned with direct interpretative, rather than computational ability.

4. The fractional difference between points in question group 5 was always set greater than 0.2, since this value corresponded to the total limit of tolerance in associated reading errors.

5. The calculation of a zero displacement value was considered a trivial case, and therefore not included in this analysis.

TESTS

(1) Co-ordinate Divisions

Horizontal/Vertical (Direction)	=	1/4
Integral/Decimal (Number)	=	1/5
Positive/Negative (Sign)	=	1/6
Positive/Zero (Sign)	=	1/8

(2) Displacement

Positive/Negative	=	1/7

(3) Interpretation/Construction = 1/2

1/3

(4) Constructional Subdivisions = 2/3

TABLE 4/8

Subdivisional Skills for Element 4/2

QUESTION GROUP	SUBDIVISIONS (Positon and Displacement) Direction	Number	Sign	Displacement
1	H	I	+	I/+
2 (C)	H	I	+	I/+
3 (C)	H	I	+	I/+
4	V	I	+	I/+
5	H	D	+	D/+
6	H	I	-	I/+
7	H	I	+	I/-
8	H	I	0/+	I/+

NOTES

See Notes 1, 3, 4 and 5 for Element 4/1.

TESTS

(1) Positional Divisions

Horizontal/Vertical (Direction) = 1/4
Integral/Decimal (Number) = 1/5
Positive/Negative (Sign) = 1/6
Positive/Zero (Sign) = 1/8

(2) Displacement

Positive/Negative = 1/7

(3) Interpretation/Construction = 1/2

1/3

(4) Constructional Subdivisions = 2/3

TABLE 4/9

Subdivisional Skills for Element 4/3

QUESTION GROUP	SUBDIVISIONS Number	Sign	Result
1	I	+	I/+
2	I	+	I/+
3	I	+	I/+
4	D	+	D/+
5	I	-	I/+
6	I	+	I/-
7	I	0/+	I/+

NOTES

1. Question groups 1 and 5 reflect a difference in operational variables with the same internal relationship (B<A, so that A ∸ B = I/+).

2. Question groups 1 and 6 reflect a difference in relationship (A - B = I/-) between similar operational variables (A and B both I/+).

3. Question groups 1, 2 and 3 represent differences in presentation format of subtraction calculations, corresponding to the type of interpretative or constructional skill represented by analogous question groups in elements 4/1 and 4/2.

TESTS

(1) Given Values

Integral/Decimal (Number)	=	1/4
Positive/Negative (Sign)	=	1/5
Positive/Zero (Sign)	=	1/7

TABLE 4/10

Subdivisional Skills for Element 5/2(A)

QUESTION GROUP	SUBDIVISIONS		
	Horizontal Displacement	Vertical Displacement	Gradient
1	I/+	I/+	I/+(>1)
2	I/+	I/+	D/+(>1)
3	D/+	D/+	D/+(>1)
4	I/+	I/+	D/+(<1)
5	I/-	I/-	I/+(>1)
6	I/+	I/-	I/-(<1)
7	I/+	0	0
8	0	I/+	∞

NOTES

1. All line segments were drawn in the first quadrant, with both end points positive, but the displacment calculations could be either positive or negative as shown above.
2. The conditions for number and sign are presented respectively for both Horizontal and Vertical displacement subdivisions.
3. Question group comparisons 1/2 and 1/4 represent different relationships between similar operational variables, while comparisons 1/5 and 2/3 represent similar relationships between different operational variables.

TESTS

(1) Displacement Divisions (Same category for Gradient)

Integral/Decimal (Number)	=	2/3
Positive/Negative (Sign)	=	1/5

(2) Gradient

Integral/Decimal (Number)	=	1/2, 1/3, 1/4
Positive/Negative (Sign)	=	1/6
Positive/Zero	=	1/7*
Positive/Infinite	=	1/8*
Zero/Infinite	=	7/8*

* These tests are included as special cases.

TABLE 4/11

Subdivisional Skills for Element 5/3(A)

QUESTION GROUP	SUBDIVISIONS		
	Horizontal Displacement	Vertical Displacement	Gradient
1	I/+	I/+	I/+(>1)
2	I/+	I/+	D/+(>1)
3	D/+	D/+	D/+(>1)
4	I/+	I/+	D/+(<1)
5	I/-	I/-	I/+(>1)
6	I/+	I/-	I/-(<1)
7	I/+	0	0
8	0	I/+	∞

NOTES

1. See Notes 2 and 3 for Element 5/2(A).
2. The line for each of the questions above was drawn in the first (upper Right Hand Side) quadrant on unmarked orthogonal axes.

TESTS

(1) Displacement Divisions (Same category for Gradient)

Integral/Decimal (Number) = 2/3

Positive/Negative (Sign) = 1/5

(2) Gradient

Integral/Decimal (Number)	=	1/2, 1/3, 1/4
Positive/Negative (Sign)	=	1/6
Positive/Zero	=	1/7*
Positive/Infinite	=	1/8*
Zero/Infinite	=	7/8*

* These tests are included as special cases.

TABLE 4/12

Subdivisional Skills for Element 5/4(A)

QUESTION GROUP	SUBDIVISIONS Denominator	Numerator	Quotient
1	I/+	I/+	I/+(>1)
2	I/+	I/+	D/+(>1)
3	D/+	D/+	D/+(>1)
4	I/+	I/+	D/+(<1)
5	I/-	I/-	I/+(>1)
6	I/+	I/-	I/-(<1)
7	I/+	0	0
8	0	I/+	∞

NOTES

1. The conditions for number and sign are presented respectively for both Numerator and Denominator.
2. See Note 3 for Element 5/2(A).

TESTS

(1) Divisions of Variables (Same category for Quotient)

Integral/Decimal (Number) = 2/3

Positive/Negative (Sign) = 1/5

(2) Quotient

Integral/Decimal (Number	=	1/2, 1/3, 1/4
Positive/Negative (Sign)	=	1/6
Positive/Zero	=	1/7*
Positive/Infinite	=	1/8*
Zero/Infinite	=	7/8*

* These tests are included as special cases.

TABLE 4/13

Subdivisional Skills for Element 5/2(B)

QUESTION GROUP	SUBDIVISIONS Specified Co-ordinate	Alternative Co-ordinate	Slope of Tangent
1	H/I/+	V/I/+	+
2	H/I/-	V/I/+	+
3	H/I/0	V/I/+	+
4	H/D/+	V/I/+	+
5	V/I/+	H/I/+	+
6	H/I/+	V/I/+	-
7	H/I/+	V/I/+	0
8	H/I/+	V/I/+	∞
9	H/I/+	V/I/+	+

NOTES

1. The conditions for direction, number and sign are presented respectively for both specified and alternative co-ordinates.
2. The specified (Horizontal) co-ordinates for question groups 6-9 are the same as those for respective questions (a) and (b) in group 1.
3. Question group 9 refers to a concave curve (bending upward at the ends away from the Horizontal axis), while those for the other question groups are all convex.
4. The co-ordinate subdivisions outlined above are analogous to those for Element 1/1.

TESTS

(1) Co-ordinate Divisions

Horizontal/Vertical (Direction)	=	1/5
Integral/Decimal (Number)	=	1/4
Positive/Negative (Sign)	=	1/2
Positive/Zero	=	1/3

(2) Slope of Tangent

Positive/Negative	=	1/6
Positive/0 (Horizontal)	=	1/7
Positive/∞ (Vertical)	=	1/8

(3) Type of Curve

Convex/Concave	=	1/9

TABLE 4/14

Subdivisional Skills for Element 5/3(B)

QUESTION GROUP	SUBDIVISIONS Slope of Tangent	Type of Curve
1	+	Convex
2	-	Convex
3	0	Convex
4	∞	Convex
5	+	Concave

NOTES

1. The curve for each of the questions above was drawn in the first (Upper Right Hand Side) quadrant on unmarked orthogonal axes.
2. Question group 4 involves a Right Hand Turning Point and Vertical Tangent.

TESTS

(1) Slope of Tangent

Positive/Negative	=	1/2
Positive/0 (Horizontal)	=	1/3
Positive/∞ (Vertical)	=	1/4

(2) Type of Curve

Convex/Concave	=	1/5

TABLE 4/15

Subdivisional Skills for Element 6/2

QUESTION GROUP	Horizontal Co-ordinates	SUBDIVISIONS Horizontal Scale Units	Vertical Scale Units
1	I/+	I/+	I/+(>1)
2	I/+	I/+	I/+(>1)
3	D/+	I/+	I/+(>1)
4	I/+,-	I/+	I/+(>1)
5	0,I/+	I/+	I/+(>1)
6	I/+	D/+(>1)	D/+(>1)
7	I/+	I/+=1.0	I/+(>1)
8	I/+	D/+(<1)	I/+(>1)

NOTES

1. The conditions for number and sign are presented respectively for both co-ordinates and scale units.

2. All line segments (except for question groups 4 and 5) were drawn in the first quadrant, with both end-points positive.

3. Both Horizontal end-point co-ordinates are defined in the same category within a particular question group, except for groups 4 and 5. The Vertical end-point co-ordinates are defined in the same category for every question group.

4. The Horizontal and Vertical scale units, although generally defined in the same category, do not have equal numerical values.

5. Question group 2 involves the calculation of area beneath a curve, while the others all refer to straight line segments.

6. Question group 3 involves compound skills of decimal multiplication (c/f question groups 2 and 4 in Element 6/3(B)) in order to account for fractional areas at each end of the given line segment.

7. Question group 4 is likely to be more difficult than others because of the complex calculation involving both positive and negative areas.

TESTS

(1) Co-ordinate Divisions (Horizontal end-points)

Integral/Decimal (Number)	=	1/3
Positive/Negative (Sign)	=	1/4
Positive/Zero	=	1/5

(2) Scale Unit Divisions

Integral/Decimal	=	1/6
Integral (H and V)/H=1	=	1/7*
Integral (H and V)/H<1	=	1/8*

(3) Type of Line Segment

Straight Line/Curve	=	1/2

* These tests are included as special cases. The Vertical scale units are in each case positive integral numbers.

TABLE 4/16

Subdivisional Skills for Element 6/3(A)

QUESTION GROUP	Division Line
1	Straight
2	Curved

NOTES

1. Seven examples were presented for each question, so that the resultant guessing error was less than one per cent (see Note 1 for Element 3/2).
2. A square format was used in each case, corresponding to (but larger than) the basic unit shown in the standard two-dimensional grid.

TEST

Division Line

Straight/Curved = 1/2.

TABLE 4/17

Subdivisional Skills for Element 6/3(B)

QUESTION GROUP	SUBDIVISIONS Length	Height
1	I/+(>1)	I/+(>1)
2	D/+(>1)	D/+(>1)
3	I/+=1.0	I/+(>1)
4	D/+(<1)	I/+(>1)

NOTES

1. The conditions for Number and Sign are presented respectively for both length and height.
2. Although sometimes defined in the same category, the dimensions of length and height for a particular calculation do not have the same numerical value.
3. Negative number calculations are not included as potential subdivisions of this element, although one is involved as a co-ordinate subdivision in Element 6/2 (Question group 4).

TESTS

Dimensional Divisions

Integral/Decimal	=	1/2
Integral (L and H)/H=1	=	1/3*
Integral (L and H)/H<1	=	1/4*

* These tests are included as special cases. The values for Length are in each case positive integral numbers.

TABLE 4/18

Subdivisional Skills for Element 6/4(B)

QUESTION GROUP	SUBDIVISIONS First Number (A)	Second Number (B)
1	I/+(>1)	I/+(>1)
2	D/+(>1)	D/+(>1)
3	I/+=1.0	I/+(>1)
4	D/+(<1)	I/+(>1)

NOTES

1. The conditions for number and sign are presented respectively for both numerical variables.
2. Negative number calculations are not included as potential subdivisions of this element.
3. Although sometimes defined in the same category, the first and second numbers for a particular calculation do not have the same value.

TESTS

Numerical Divisions

Integral/Decimal = 1/2

Integral (A and B)/A=1 = 1/3*

Integral (A and B)/A<1 = 1/4*

* These tests are included as special cases. See also the corresponding Dimensional divisions for Element 6/3(B) and Scale Unit divisions for Element 6/2.

2. The Analysis of Subdivisional Skills

(A) General Considerations

Ideally the analysis of subdivisional skills should involve the same type of integrated instructional and testing programme as that recommended by various authorities (Gagné & Paradise 1961, Gagné & Bassler 1963, White 1971) for the validation of learning hierarchies. Such a procedure would probably involve the teaching of a particular skill within the constraints of a single subdivisional area, followed by testing in each of the postulated subdivisional areas in order to determine the actual limits of immediate lateral transfer. In practice, however, this method may require extensive preparations and preliminary trials to develop and evaluate the appropriate instructional materials, and hence may prove, in terms of overall significance, an unrealistic proposition. More practical, if somewhat weaker alternative procedures must therefore be considered.

The method used by White (1971) for the analysis of subdivisional skills involves no teaching or instructional programme, and depends instead on more or less long-term recall from previous curricular experience. The lack of a suitable instructional programme introduces an obvious methodological weakness, but probably not as critical in this case as in the validation of hierarchical learning sequences, since the analysis of subdivisional skills is concerned with lateral, rather than vertical or sequential transfer, and thus does not involve the simultaneous recall of recently acquired prerequisite or subordinate skills. It follows, then, that if the subsequent statistical analysis provides a reliable indication of subdivisional difference, the simplified method proposed by White (1971) affords a logically valid and more practical alternative than the tedious instructional procedure outlined above. Because of the large number of postulated subdivisional skills outlined in the previous section, the simplified analytical technique, which obviates the necessity for the development of instructional programmes, was selected as the most appropriate model for this research.

(B) The Preliminary Test

It is impossible, for obvious logical reasons, to determine subdivisional differences if every subject fails, or if everyone passes the relevant criterion test, and in fact it is suggested by White (1971/p.37) that the level of item difficulty should be maintained within the limits of 0.2 and 0.8 for effective discrimination. Thus in order to determine the most appropriate level for testing each basic intellectual ability and relevant set of subdivisional skills, a preliminary test was prepared comprising a single question (or two in the case of alternative constructional skills) from each of the basic graphical interpretation skills. This test was then administered to one class at each of three alternate academic levels in a single Melbourne metropolitan high school.[a] The questions selected for this preliminary test were considered to represent an intermediate level of difficulty between the simplest and most complex or difficult of the various subdivisional areas for each of the fundamental skills. The description and results of this preliminary test, together with explanatory notes, are presented in Table 4/19.

(C) Administration of the Major Subdivisional Analysis

On the basis of results from the preliminary test, suitable levels were selected for the subdivisional analysis of each fundamental interpretative skill. Thus the eighteen groups of subdivisional skills included in this analysis were distributed over four different high school grades or academic levels. A list of the relevant subdivisional groups presented at each level is shown in Table 4/20.

The testing population selected for the analysis of subdivisional skills involved a random choice of four metropolitan co-educational high schools in Melbourne. A single class at each of the four testing levels was selected from every participating school, so that the total testing population at each level involved at least one hundred students. This number corresponds to the minimal requirement recommended for the test of hierarchical dependence developed by White and Clark (1973), and since the test for subdivisional difference (outlined in Appendix I) was developed from the same basic type of statistical model, an equivalent sample size was considered appropriate for this aspect of the present research.

The practical procedure for subdivisional analysis involved the preparation of a separate book of questions to test each basic skill, in order to allow some flexibility in timing and arrangement for classes with the longer or larger numbers of tests. No particular

TABLE 4/19

Results of the Preliminary Test for Subdivisional Analysis

(Westall High School)

QUESTION NUMBER	DIFFICULTY LEVEL Form I	Form III	Form V
1/1 - 5(a)	0.94	0.38	0.23
1/1 - 5(b)*	0.97	0.48	0.14
1/2 - 5(a)*	0.83	0.08	0.00
1/2 - 5(b)*	0.73	0.03	0.00
2/1(B) - 7(a)	1.00	0.78	0.59
3/1 - 5(a)	1.00	0.50	0.09
3/2 - 1(a)	0.94	1.00	0.27
4/1 - 4(a)	0.97	0.48	0.36
4/2 - 4(a)	0.92	0.28	0.23
4/3 - 2(a)	0.11	0.08	0.05
5/2(A) - 3(a)	1.00	0.98	0.45
5/3(A) - 3(a)	1.00	0.98	0.68
5/4(A) - 3(a)	0.97	0.35	0.50
5/2(B) - 4(a)	1.00	0.90	0.36
5/3(B) - 1(a)	1.00	0.93	0.32
6/2 - 3(a)	1.00	0.88	0.77
6/3(A) - 1(a)	0.66	0.43	0.18
6/3(B) - 2(a)	0.86	0.25	0.45
6/4(B) - 2(a)	0.86	0.20	0.41
Number of Students	35	40	22

NOTES (Table 4/19)

(1) The questions listed above are classified by the same numerical and alphabetical code as that used previously for the definition of basic skills and subdivisional groups. Each of these questions is presented with its appropriate group in Volume II.

(2) The form I class in this preliminary test was an ungraded group of students. The form III group was graded by the school administration as average or slightly above on general academic ability, and the form V class (Biology group) was selected on the basis of subject preference. All groups contained both male and female students.

(3) Ample time was given (30-40 minutes) for every student to complete the test.

(4) Questions marked with an asterisk (*) were presented as constructional, rather than interpretative tasks.

TABLE 4/20

Distribution of Subdivisional Testing Groups

LEVEL (Form)	INTERPRETATIVE AREA 1	2	3	4	5	6
1	1/2			4/3		6/3(A)
2	1/1			4/2	5/4(A)	6/4(B)
						6/3(B)
3		2/1(A)	3/2	4/1	5/3(B)	
		2/1(B)	3/1		5/2(B)	
4					5/3(A)	6/2
					5/2(A)	

limit was set for the total testing time, and in practice it was found that almost every student finished comfortably within a calculated rate of one question per minute. In addition, no class was involved in testing for more than one full period (40-50 minutes) at a time, and alternative periods were used when the total requirement exceeded this limit.

The questions within each book were arranged in a different random sequence for every individual, in order to determine the effect, if any, of initial testing practice on subsequent performance. A similar study was made by White (1971), who found no significant practice effect, but it was nevertheless thought desirable to substantiate this result within the somewhat different context of the present research project. The results of this analysis are presented in Section 3.

Perhaps the most important aspect of subdivisional analysis concerns the choice of an appropriate statistical technique. The only precedent, used by White (1971), involves a fundamentally intuitive decision, substantiated with a complex statistical test (Lord 1957). This test, however, is inappropriate for dichotomous data (White 1971/p.46, also F.M. Lord - personal communication 1971), and therefore strictly inapplicable to this method of subdivisional analysis.

An alternative test, which accounts for errors of measurement and is therefore appropriate for dichotomous data, was developed for this project in association with Dr. R.T. White (Faculty of Education, Monash University), and was based on the model developed earlier by White and Clark (1973, see also White 1971) for the analysis of hierarchical dependence. This test of subdivisional difference, outlined in Appendix I (Volume I), involves the calculation of probability associated with the occurrence by chance, or through errors of measurement, of an observed or specified number of exceptions to any pair of supposedly similar subdivisional skills. If this probability is less than a certain (arbitrary) critical level, then the question groups being compared are considered to represent different subdivisional skills. The critical level selected for the overall analysis was 0.10, so that the chance of a type I error (false declaration of independent subdivisional skills) in any particular comparison or test is given by $\alpha = 1 - \sqrt[N]{0.90}$ where N is the total number of independent tests. Thus for the 112 subdivisional tests involved in this analysis, the critical level for each is given by $\alpha = 0.0010$.

(D) Results of Subdivisional Analysis

A comprehensive list of results for the analysis of subdivisional skills is presented in Tables 4/21-4/48. This list contains a descriptive classification of each question group comparison, together with the relevant probability level and appropriate conclusion. Because of occasional student errors of omission in the testing books, some of these had to be discarded, so that the total number of students represented in the analysis was not constant over any particular sampling level, but was the same for each postulated subdivision within a particular basic skill.

(E) Discussion of Results and General Observations.

Several of the postulated subdivisional classification groups are relevant to a more or less general range of graphical interpretation areas, and are therefore represented by analogous question groups in many of the basic interpretative skills. The empirical results derived from these analogous question groups are in most cases quite consistent, and generally substantiate the independence of the postulated subdivisional skills. These results, which are discussed in further detail below, suggest that the initially postulated network of basic intellectual skills may in fact represent a considerably more complex pattern of parallel hierarchical relationships between analogous but independent subdivisions of the relevant basic skills.

The independence of interpretative and constructional subdivisions is obvious from the relevant results for Elements 1/2 (Table 4/22(B)) and 1/1 (Table 4/21(A)), which are concerned respectively with positional and co-ordinate location, but the difference is less clearly defined in the case of linear and co-ordinate displacement calculations, represented respectively by Elements 4/2 and 4/1. In this case it seems that the difference between interpretative and constructional skills, indicated in Tables 4/29(D) and 4/30(A) for Element 4/1, and in Tables 4/31(D) and 4/32(A) for

Element 4/2, may depend on the type of informational or presentation format associated with the constructional skill, although comparative information from certain constructional subdivisions (see Table 4/32(B) for Element 4/2 and Table 4/30(B) for Element 4/1) strongly suggests that in these cases the presentation format is irrelevant. A conservative decision based on these results would be that interpretative and constructional aspects of graphical interpretation are represented by independent subdivisional skills, at least within the areas examined above, and should therefore be separately defined for the purpose of hierarchical validation.

The respective levels of difficulty for interpretative and constructional skills do not reflect the differences suggested by the subdivisional analysis, and in fact appear to involve no consistent relationship at all. Many students who were able to plot correct co-ordinate positions in Element 1/1 were unable to read the required values for analogous given points, although the same effect was not evident for linear point location (Element 1/2), and if anything the opposite was true in the case of displacement calculation skills (Elements 4/1 and 4/2). This emphasises the practical risk involved in using an index of difficulty as a measure of subdivisional difference.

The interpretative difference between Horizontal and Vertical direction (or axis orientation) is substantiated in a range of subdivisional comparisons associated with various skills involving both linear position (Elements 1/2 and 4/2) and two-dimensional co-ordinate location (Elements 1/1, 2/1(A), 2/1(B), 3/1, 4/1 and 5/2(B)).

An examination of predominant errors suggests that this difference is not a reflection of any common systematic misunderstanding or misinterpretation of instructions, since the most prevalent sources of error, which include both random interchange and consistent confusion of Horizontal with Vertical directions, and the provision of compound answers involving both co-ordinates, should not contribute to the number of exceptions observed in the 0/2 and 2/0 cells of the relevant correlation tables. Thus interpretative questions involving Horizontal and Vertical position can safely be considered to involve independent subdivisional skills.

The comparison of subdivisional skills involving integral and decimal numbers also reveals a relatively consistent pattern of independence with respect to both linear position (Elements 1/2 and 4/2) and two-dimensional co-ordinate location (Elements 2/1(A), 2/1(B), 3/1 and 5/2(B)), although in two cases (Elements 1/1 and 4/1) the difference is doubtful. This result could well be due to the popular practice of 'rounding off' fractional positions to the nearest integral number. Although not always done consistently (for example see results for subdivisional group 7 in Element 2/1(B)), this was perhaps the most common source of systematic error. Irrespective of the likely cause, however, the interpretative skills concerned with integral and fractional positions do not involve immediate mutual transfer, and must therefore be assumed to involve independent subdivisional abilities.

The independence of integral and decimal subdivisions is also shown in the analytical results for almost every computational skill. With respect to operational variables, the difference between integral and decimal calculations is firmly established for subtraction (Element 4/3), division (Element 5/4(A))and multiplication (Element 6/4(B)). For alternative subdivisions efined in terms of computational result, the integral/decimal difference is also generally substantiated for calculations of quotient (Element 5/4(A)), difference (Element 4/3) and area (Elements 6/2 and 6/3(B)), although the results for gradient (Elements 5/2(A) and 5/3(A)) are inconsistent, and those for displacement (Elements 4/1 and 4/2) inconclusive.

Calculations of positive and negative values associated with linear position (Elements 1/2 and 4/2) are considered, on the basis of this analysis, to involve different subdivisional skills, and with a single possible exception (Element 5/2(B)), the same conclusion is indicated for analogous subdivisional skills of plane co-ordinate location (Elements 1/1, 2/1/(A), 2/1(B), 3/1, 4/1 and 6/2). Moreover the interpretation of a zero position, included as a special case, appears in many instances to involve an additional independent subdivision, although for some Elements (2/1(B), 4/1, 4/2 and 6/2) this conclusion is doubtful.

Computational questions concerned with positive and negative numbers are also shown in this analysis to involve independent subdivisional skills for both subtraction (Element 4/3) and division (Element 5/4(A)). Alternative skills defined in terms of computational result are similarly substantiated as independent subdivisions for each of the basic skills involving gradient (Elements 5/2(A) and 5/3(A)) and quotient (Element 5/4(A)), difference (Element 4/3) and displacement (Elements 4/1 and 4/2). Again the special cases involving results of zero, and for quotient and gradient infinity, must all be considered to involve independent subdivisional skills. Subdivisions involving zero or negative numbers were not defined for skills concerned with multiplication or the calculation of area, since these have no general practical value in graphical interpretation. Likewise a zero result for difference or displacement was considered a trivial case, and therefore not included in this analysis.

In addition to the general characteristics examined above, most of the basic interpretative skills incorporate a number of more specific postulated subdivisions. Although separately defined for individual skills, these specific subdivisional characteristics may also refer in a broader sense to other basic skills associated with the same area of graphical interpretation, and are therefore discussed below within the appropriate context of interpretative area.

According to the results of this analysis, differences in distance of interpolation (Element 2/1(A)) or extrapolation (Element 2/1(B)) do not involve corresponding differences in the relevant subdivisional skills. Changes in direction of extrapolation are also covered by the same subdivisional skill (Table 4/26(C)), and the nature of given information, whether line segment or row of points, similarly appears to be irrelevant as a practical subdivisional criterion for extrapolation skills (Table 4/27(C)). In contrast with these results, however, differences in slope of the given line segment (Element 2/1(B)) or row of points (Element 2/1(A)) appear to involve different subdivisional skills of extrapolation and interpolation respectively for both positive and negative categories, in addition to the special cases of zero and infinite (vertical) gradient.

The difference between interpolation and extrapolation skills, represented respectively by Elements 2/1(A) and 2/1(B) in the postulated learning hierarchy, was confirmed by empirical analysis (Table 4/48(D)) under similar subdivisional conditions for both of these basic skills. The testing population (form 3) was also the same for both abilities, although the relevant groups of questions were presented at different times.

The importance of the nature of turning point as a criterion for subdivisional classification is not clear from this analysis. The postulated subdivisional skills concerned with the calculation of maximum and minimum values (Element 3/1) are clearly independent (Table 4/28(A)), but the analogous question groups involving the recognition of appropriate turning points (Element 3/2) apparently represent the same subdivisional skill (Table 4/29(C)). It seems, however, from an examination of predominant errors, that the instructions to these questions were often poorly understood, and the resultant difficulty levels are probably too high for effective discrimination between the postulated subdivisional skills.

The calculation of gradient at any point on a curve involves the construction of a tangent to the curve at the specified point of contact. The construction of tangents with positive and negative slope both appear to involve the same subdivisional skill (Elements 5/2(B) and 5/3(B)), although the special cases of zero and infinite (vertical) slope may well be independent of the positive/negative subdivision. The nature of the curve (convex or concave) may also be an important subdivisional criterion, although results for the relevant test in Element 5/2(B) are inconsistent with those for the postulated subordinate skill (Element 5/3(B)).

The postulated subdivisional skills involving the estimation (Element 6/3(A)) and calculation of area (Element 6/2) are probably the same for both straight line segments and curves. Since no instructions were given for calculating area, a number of different methods were used, many of them inappropriate, and often inconsistently applied. Predominant errors in the calculation of simple rectangular area (Element 6/3(B)) involved various multiples of the perimeter and combinations of squared dimensions, while those for the graphical model (Element 6/2) included the gradient (for straight line segments) and various combinations of end-point co-ordinate dimensions. The specified scale units were also frequently ignored.

The analysis outlined above, and resultant confirmation of a range of independent subdivisions within each of the basic graphical interpretation skills, has important implications for the subsequent validation of postulated hierarchical relationships. Apart from necessitating separate instructions for directional subdivisions, and the reorganisation of certain interpretative and constructional skills, further constraints must also be applied on the use of numerical range and sign, with respect to both variables (or co-ordinates) and specific computational results, in order to maintain the validation study within realistic limits. These modifications and constraints are discussed in Chapter V.

TABLES 4/21-4/48

Results of Subdivisional Analysis

PRELIMINARY NOTES

(1) The following results are presented in correlation matrix form, with the number of questions correct for each specified subdivisional group listed on the top and left hand side of the relevant table. The numbers of students corresponding to the various correlational groups are presented within the table, and the appropriate marginal totals at the outer edge (listed T). The number in the lower right hand corner of each table represents the total population sample for the particular test.

(2) The Element number code and classification for comparative tests have already been outlined in Tables 4/1-4/18.

(3) P indicates the combined probability that the observed number of students in the 0/2 and 2/0 cells in each table could have occurred through errors of measurement, assuming (under the null hypothesis) that both question groups represent the same subdivisional skill. Where no students are recorded in the 0/2 or 2/0 cell, the relevant individual probability of occurrence is equal to 1.0, although in some cases the number in the opposite exceptional cell is alone sufficiently high to reduce the combined probability below the critical level or specified point of significance.

(A)

GROUP 1 \ GROUP 2	0	1	2	T
2	4	1	47	52
1	4	1	8	13
0	15	7	18	40
T	23	9	73	105

ELEMENT 1/1

TEST Interpretation/Construction

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(B)

GROUP 1 \ GROUP 3	0	1	2	T
2	2	1	49	52
1	7	4	2	13
0	34	3	3	40
T	43	8	54	105

ELEMENT 1/1

TEST +/- (Co-ordinates)

P = 0.0001

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 4	0	1	2	T
2	5	7	41	52
1	7	1	4	13
0	38	1	1	40
T	50	9	46	105

ELEMENT 1/1

TEST +/0 (Co-ordinates)

P = 0.0006

CONCLUSION Question groups 1 and 4 represent different subdivisional skills.

(D)

GROUP 1 \ GROUP 5	0	1	2	T
2	8	14	30	52
1	6	3	4	13
0	35	4	1	40
T	49	21	35	105

ELEMENT 1/1

TEST I/D (Co-ordinates)

P = 0.0013

CONCLUSION Question groups 1 and 5 may represent the same subdivisional skill.

TABLE 4/22

(A)

GROUP 1 \ GROUP 6	0	1	2	T
2	6	6	40	52
1	7	4	2	13
0	22	7	11	40
T	35	17	53	105

ELEMENT 1/1

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 6 represent different subdivisional skills.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	6	3	74	83
1	2	0	7	9
0	7	2	5	14
T	15	5	86	106

ELEMENT 1/2

TEST Interpretation/Construction

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 3	0	1	2	T
2	13	12	58	83
1	4	3	2	9
0	10	2	2	14
T	27	17	62	106

ELEMENT 1/2

TEST +/- (Position)

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

(D)

GROUP 1 \ GROUP 4	0	1	2	T
2	3	2	78	83
1	1	0	8	9
0	6	1	7	14
T	10	3	93	106

ELEMENT 1/2

TEST +/0 (Position)

P = 0.0000

CONCLUSION Question groups 1 and 4 represent different subdivisional skills.

TABLE 4/23

(A) GROUP 5 × GROUP 1

GROUP 1	0	1	2	T
2	26	10	47	83
1	5	1	3	9
0	13	1	0	14
T	44	12	50	106

ELEMENT 1/2

TEST I/D (Position)

P = 0.0000

CONCLUSION Question groups 1 and 5 represent different subdivisional skills.

(B) GROUP 6 × GROUP 1

GROUP 1	0	1	2	T
2	2	5	76	83
1	2	3	4	9
0	5	4	5	14
T	9	12	85	106

ELEMENT 1/2

TEST H/V (Position)

P = 0.0000

CONCLUSION Question groups 1 and 6 represent different subdivisional skills.

(C) GROUP 2 × GROUP 1

GROUP 1	0	1	2	T
2	3	7	59	69
1	3	3	2	8
0	26	2	2	30
T	32	12	63	107

ELEMENT 2/1(A)

TEST H/V (Co-ordinates)

P = 0.0001

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(D) GROUP 3 × GROUP 1

GROUP 1	0	1	2	T
2	0	2	67	69
1	0	3	5	8
0	25	2	3	30
T	25	7	75	107

ELEMENT 2/1(A)

TEST +/- (Slope)

P = 0.0007

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

TABLE 4/24

(A)

GROUP 1 \ GROUP 4	0	1	2	T
2	2	4	63	69
1	1	2	5	8
0	17	6	7	30
T	20	12	75	107

ELEMENT 2/1(A)

TEST +/0 (Slope)

P = 0.0000

CONCLUSION Question groups 1 and 4 represent different subdivisional skills.

(B)

GROUP 2 \ GROUP 5	0	1	2	T
2	0	2	61	63
1	0	2	10	12
0	23	3	6	32
T	23	7	77	107

ELEMENT 2/1(A)

TEST +/∞ (Slope)

P = 0.0051

CONCLUSION Question groups 2 and 5 may represent the same subdivisional skill.

(C)

GROUP 1 \ GROUP 6	0	1	2	T
2	38	13	18	69
1	8	0	0	8
0	29	1	0	30
T	75	14	18	107

ELEMENT 2/1(A)

TEST I/D (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 6 represent different subdivisional skills.

(D)

GROUP 1 \ GROUP 7	0	1	2	T
2	7	5	57	69
1	3	2	3	8
0	26	2	2	30
T	36	9	62	107

ELEMENT 2/1(A)

TEST +/- (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 7 represent different subdivisional skills.

TABLE 4/25

(A)

GROUP 8

GROUP 1	0	1	2	T
2	3	8	58	69
1	5	0	3	8
0	26	2	2	30
T	34	10	63	107

ELEMENT 2/1(A)

TEST +/0 (Co-ordinates)

P = 0.0001

CONCLUSION Question groups 1 and 8 represent different subdivisional skills.

(B)

GROUP 9

GROUP 1	0	1	2	T
2	1	5	63	69
1	2	0	6	8
0	25	4	1	30
T	28	9	70	107

ELEMENT 2/1(A)

TEST Interpolation Distance

P = 0.0251

CONCLUSION Question groups 1 and 9 represent the same subdivisional skill.

(C)

GROUP 2

GROUP 1	0	1	2	T
2	4	7	47	58
1	4	2	4	10
0	36	1	0	37
T	44	10	51	105

ELEMENT 2/1(B)

TEST H/V (Co-ordinates)

P = 0.0083

CONCLUSION Question groups 1 and 2 may represent the same subdivisional skill.

(D)

GROUP 3

GROUP 1	0	1	2	T
2	1	7	50	58
1	2	5	3	10
0	30	4	3	37
T	33	16	56	105

ELEMENT 2/1(B)

TEST +/- (Slope)

P = 0.0056

CONCLUSION Question groups 1 and 3 probably represent the same subdivisional skill.

TABLE 4/26

(A)

GROUP 1 \ GROUP 4	0	1	2	T
2	5	1	52	58
1	3	0	7	10
0	30	4	3	37
T	38	5	62	105

ELEMENT 2/1(B)

TEST +/0 (Slope)

P = 0.0000

CONCLUSION Question groups 1 and 4 represent different subdivisional skills.

(B)

GROUP 2 \ GROUP 5	0	1	2	T
2	6	3	42	51
1	1	1	8	10
0	31	7	6	44
T	38	11	56	105

ELEMENT 2/1(B)

TEST +/∞ (Slope)

P = 0.0000

CONCLUSION Question groups 2 and 5 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 6	0	1	2	T
2	0	9	49	58
1	2	2	6	10
0	33	4	0	37
T	35	15	55	105

ELEMENT 2/1(B)

TEST +/- (Direction)

P = 1.0000

CONCLUSION Question groups 1 and 6 represent the same subdivisional skills.

(D)

GROUP 1 \ GROUP 7	0	1	2	T
2	28	21	9	58
1	8	2	0	10
0	37	0	0	37
T	73	23	9	105

ELEMENT 2/1(B)

TEST I/D (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 7 represent different subdivisional skills.

TABLE 4/27

(A) GROUP 8 / GROUP 1

	0	1	2	T
2	5	6	47	58
1	4	0	6	10
0	33	3	1	37
T	42	9	54	105

ELEMENT 2/1(B)

TEST +/- (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 8 represent different subdivisional skills.

(B) GROUP 9 / GROUP 1

	0	1	2	T
2	3	6	49	58
1	5	2	3	10
0	37	0	0	37
T	45	8	52	105

ELEMENT 2/1(B)

TEST +/0 (Co-ordinates)

P = 0.0323

CONCLUSION Question groups 1 and 9 probably represent the same subdivisional skill.

(C) GROUP 10 / GROUP 1

	0	1	2	T
2	0	5	53	58
1	4	4	2	10
0	37	0	0	37
T	41	9	55	105

ELEMENT 2/1(B)

TEST Line/Points

P = 1.0000

CONCLUSION Question groups 1 and 10 represent the same subdivisional skill.

(D) GROUP 11 / GROUP 1

	0	1	2	T
2	4	8	46	58
1	3	5	2	10
0	32	5	0	37
T	39	18	48	105

ELEMENT 2/1(B)

TEST Extrapolation Distance

P = 0.0297

CONCLUSION Question groups 1 and 11 probably represent the same subdivisional skill.

TABLE 4/28

(A)

		GROUP 2			
		0	1	2	T
GROUP 1	2	8	11	64	83
	1	3	3	5	11
	0	16	0	2	18
	T	27	14	71	112

ELEMENT 3/1

TEST T.P. (Maximum/Minimum)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(B)

		GROUP 3			
		0	1	2	T
GROUP 1	2	4	10	69	83
	1	4	2	5	11
	0	15	0	3	18
	T	23	12	77	112

ELEMENT 3/1

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

(C)

		GROUP 4			
		0	1	2	T
GROUP 1	2	14	16	53	83
	1	3	2	6	11
	0	15	0	3	18
	T	32	18	62	112

ELEMENT 3/1

TEST T.P./Alternative

P = 0.0000

CONCLUSION Question groups 1 and 4 represent different subdivisional skills.

(D)

		GROUP 5			
		0	1	2	T
GROUP 1	2	14	18	51	83
	1	4	5	2	11
	0	12	4	2	18
	T	30	27	55	112

ELEMENT 3/1

TEST I/D (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 5 represent different subdivisional skills.

TABLE 4/29

(A)

		GROUP 6			
		0	1	2	T
GROUP 1	2	6	4	73	83
	1	2	3	6	11
	0	14	3	1	18
	T	22	10	80	112

ELEMENT 3/1

TEST +/- (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 6 represent different subdivisional skills.

(B)

		GROUP 7			
		0	1	2	T
GROUP 1	2	8	18	57	83
	1	7	1	3	11
	0	14	1	3	18
	T	29	20	63	112

ELEMENT 3/1

TEST +/0 (Co-ordinates)

P = 0.0001

CONCLUSION Question groups 1 and 7 represent different subdivisional skills.

(C)

		GROUP 2			
		0	1	2	T
GROUP 1	2	1	1	12	14
	1	4	1	6	11
	0	81	2	0	83
	T	86	4	18	108

ELEMENT 3/2

TEST T.P. (Max./Min.)

P = 0.3278

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(D)

		GROUP 2			
		0	1	2	T
GROUP 1	2	12	12	26	50
	1	12	4	7	23
	0	25	5	0	30
	T	49	21	33	103

ELEMENT 4/1

TEST Interpretation /Construction

P = 0.0030

CONCLUSION Question groups 1 and 2 may represent the same subdivisional skill.

TABLE 4/30

(A)

GROUP 1 \ GROUP 3	0	1	2	T
2	9	3	38	50
1	10	5	8	23
0	23	5	2	30
T	42	13	48	103

ELEMENT 4/1

TEST Interpretation/Construction

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

(B)

GROUP 2 \ GROUP 3	0	1	2	T
2	0	4	29	33
1	3	4	14	21
0	39	5	5	49
T	42	13	48	103

ELEMENT 4/1

TEST Constructional Divisions

P = 0.0373

CONCLUSION Question groups 2 and 3 probably represent the same subdivisional skill.

(C)

GROUP 1 \ GROUP 4	0	1	2	T
2	9	10	31	50
1	8	11	4	23
0	20	3	7	30
T	37	24	42	103

ELEMENT 4/1

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 4 represent different subdivisional skills.

(D)

GROUP 1 \ GROUP 5	0	1	2	T
2	12	20	18	50
1	12	9	2	23
0	23	6	1	30
T	47	35	21	103

ELEMENT 4/1

TEST I/D (Co-ordinates)

P = 0.0845

CONCLUSION Question groups 1 and 5 represent the same subdivisional skill.

TABLE 4/31

(A)

GROUP 1 \ GROUP 6	0	1	2	T
2	27	5	18	50
1	14	7	2	23
0	27	3	0	30
T	68	15	20	103

ELEMENT 4/1

TEST +/- (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 6 represent different subdivisional skills.

(B)

GROUP 1 \ GROUP 7	0	1	2	T
2	34	6	10	50
1	20	0	3	23
0	27	2	1	30
T	81	8	14	103

ELEMENT 4/1

TEST +/- (Displacement)

P = 0.0000

CONCLUSION Question groups 1 and 7 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 8	0	1	2	T
2	1	3	46	50
1	5	7	11	23
0	18	11	1	30
T	24	21	58	103

ELEMENT 4/1

TEST +/0 (Co-ordinates)

P = 0.4267

CONCLUSION Question groups 1 and 8 represent the same subdivisional skill.

(D)

GROUP 1 \ GROUP 2	0	1	2	T
2	12	7	71	90
1	2	0	2	4
0	12	1	1	14
T	26	8	74	108

ELEMENT 4/2

TEST Interpretation/Construction

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

TABLE 4/32

(A)

GROUP 1 \ GROUP 3	0	1	2	T
2	5	23	62	90
1	3	1	0	4
0	11	3	0	14
T	19	27	62	108

ELEMENT 4/2

TEST Interpretation/Construction

P = 0.2016

CONCLUSION Question groups 1 and 3 represent the same subdivisional skill.

(B)

GROUP 2 \ GROUP 3	0	1	2	T
2	1	19	54	74
1	0	4	4	8
0	18	4	4	26
T	19	27	62	108

ELEMENT 4/2

TEST Constructional Divisions

P = 0.0226

CONCLUSION Question groups 2 and 3 probably represent the same subdivisional skill.

(C)

GROUP 1 \ GROUP 4	0	1	2	T
2	3	10	77	90
1	1	1	2	4
0	13	0	1	14
T	17	11	80	108

ELEMENT 4/2

TEST H/V (Position)

P = 0.0013

CONCLUSION Question groups 1 and 4 may represent the same subdivisional skill.

(D)

GROUP 1 \ GROUP 5	0	1	2	T
2	25	22	43	90
1	4	0	0	4
0	12	1	1	14
T	41	23	44	108

ELEMENT 4/2

TEST I/D (Position)

P = 0.0000

CONCLUSION Question groups 1 and 5 represent different subdivisional skills.

TABLE 4/33

(A)

		GROUP 6			
		0	1	2	T
GROUP 1	2	61	10	19	90
	1	4	0	0	4
	0	14	0	0	14
	T	79	10	19	108

ELEMENT 4/2

TEST +/- (Position)

P = 0.0000

CONCLUSION Question groups 1 and 6 represent different subdivisional skills.

(B)

		GROUP 7			
		0	1	2	T
GROUP 1	2	48	22	20	90
	1	4	0	0	4
	0	14	0	0	14
	T	66	22	20	108

ELEMENT 4/2

TEST +/- (Displacement)

P = 0.0000

CONCLUSION Question groups 1 and 7 represent different subdivisional skills.

(C)

		GROUP 8			
		0	1	2	T
GROUP 1	2	0	5	85	90
	1	1	1	2	4
	0	7	2	5	14
	T	8	8	92	108

ELEMENT 4/2

TEST +/0 (Position)

P = 0.0030

CONCLUSION Question groups 1 and 8 may represent the same subdivisional skill.

(D)

		GROUP 2			
		0	1	2	T
GROUP 1	2	4	13	82	99
	1	1	1	3	5
	0	2	1	1	4
	T	7	15	86	108

ELEMENT 4/3

TEST Presentation Format

P = 0.0020

CONCLUSION Question groups 1 and 2 may represent the same subdivisional skill.

TABLE 4/34

(A)

		GROUP 3			
		0	1	2	T
GROUP 1	2	2	5	92	99
	1	0	0	5	5
	0	3	0	1	4
	T	5	5	98	108

ELEMENT 4/3

TEST Presentation Format

P = 0.0003

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

(B)

		GROUP 3			
		0	1	2	T
GROUP 2	2	0	5	81	86
	1	1	0	14	15
	0	4	0	3	7
	T	5	5	98	108

ELEMENT 4/3

TEST Presentation Format

P = 0.0458

CONCLUSION Question groups 2 and 3 probably represent the same subdivisional skill.

(C)

		GROUP 4			
		0	1	2	T
GROUP 1	2	8	10	81	99
	1	1	0	4	5
	0	0	0	4	4
	T	9	10	89	108

ELEMENT 4/3

TEST I/D (Numbers)

P = 0.0000

CONCLUSION Question groups 1 and 4 represent different subdivisional skills.

(D)

		GROUP 5			
		0	1	2	T
GROUP 1	2	81	7	11	99
	1	3	1	1	5
	0	4	0	0	4
	T	88	8	12	108

ELEMENT 4/3

TEST +/- (Numbers)

P = 0.0000

CONCLUSION Question groups 1 and 5 represent different subdivisional skills.

TABLE 4/35

(A)

GROUP 1 \ GROUP 6	0	1	2	T
2	34	17	48	99
1	3	1	1	5
0	4	0	0	4
T	41	18	49	108

ELEMENT 4/3

TEST +/- (Result)

P = 0.0000

CONCLUSION Question groups 1 and 6 represent different subdivisional skills.

(B)

GROUP 1 \ GROUP 7	0	1	2	T.
2	5	4	90	99
1	0	1	4	5
0	2	1	1	4
T	7	6	95	108

ELEMENT 4/3

TEST +/0 (Numbers)

P = 0.0000

CONCLUSION Question groups 1 and 7 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	5	11	35	51
1	4	2	2	8
0	39	3	3	45
T	48	16	40	104

ELEMENT 5/2(A)

TEST I/D (Gradient)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(D)

GROUP 1 \ GROUP 3	0	1	2	T
2	17	15	19	51
1	5	3	0	8
0	40	5	0	45
T	62	23	19	104

ELEMENT 5/2(A)

TEST I/D (Gradient)

P = 0.0065

CONCLUSION Question groups 1 and 3 may represent the same subdivisional skill.

TABLE 4/36

(A)

GROUP 2 \ GROUP 3	0	1	2	T
2	11	13	16	40
1	9	5	2	16
0	42	5	1	48
T	62	23	19	104

ELEMENT 5/2(A)

TEST I/D (Displacement)

P = 0.0012

CONCLUSION Question groups 2 and 3 may represent the same subdivisional skill.

(B)

GROUP 1 \ GROUP 4	0	1	2	T
2	6	5	40	51
1	4	3	1	8
0	42	1	2	45
T	52	9	43	104

ELEMENT 5/2(A)

TEST I/D (Gradient)

P = 0.0000

CONCLUSION Question groups 1 and 4 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 5	0	1	2	T
2	1	5	45	51
1	2	3	3	8
0	40	3	2	45
T	43	11	50	104

ELEMENT 5/2(A)

TEST +/- (Displacement)

P = 0.0230

CONCLUSION Question groups 1 and 5 probably represent the same subdivisional skill.

(D)

GROUP 1 \ GROUP 6	0	1	2	T
2	25	3	23	51
1	5	0	3	8
0	43	2	0	45
T	73	5	26	104

ELEMENT 5/2(A)

TEST +/- (Gradient)

P = 0.0000

CONCLUSION Question groups 1 and 6 represent different subdivisional skills.

(A)

GROUP 7

GROUP 1	0	1	2	T
2	18	3	30	51
1	4	1	3	8
0	33	1	11	45
T	55	5	44	104

ELEMENT 5/2(A)

TEST +/0 (Gradient)

P = 0.0000

CONCLUSION Question groups 1 and 7 represent different subdivisional skills.

(B)

GROUP 8

GROUP 1	0	1	2	T
2	48	1	2	51
1	8	0	0	8
0	45	0	0	45
T	101	1	2	104

ELEMENT 5/2(A)

TEST +/∞ (Gradient)

P = 0.0000

CONCLUSION Question groups 1 and 8 represent different subdivisional skills.

(C)

GROUP 8

GROUP 7	0	1	2	T
2	41	1	2	44
1	5	0	0	5
0	55	0	0	55
T	101	1	2	104

ELEMENT 5/2(A)

TEST 0/∞ (Gradient)

P = 0.0000

CONCLUSION Question groups 7 and 8 represent different subdivisional skills.

(D)

GROUP 2

GROUP 1	0	1	2	T
2	7	13	40	60
1	6	2	0	8
0	36	0	1	37
T	49	15	41	105

ELEMENT 5/3(A)

TEST I/D (Gradient)

P = 0.0040

CONCLUSION Question groups 1 and 2 may represent the same subdivisional skill.

(A)

GROUP 1 \ GROUP 3	0	1	2	T
2	29	11	20	60
1	8	0	0	8
0	36	0	1	37
T	73	11	21	105

ELEMENT 5/3(A)

TEST I/D (Gradient)

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

(B)

GROUP 2 \ GROUP 3	0	1	2	T
2	18	6	17	41
1	7	4	4	15
0	48	1	0	49
T	73	11	21	105

ELEMENT 5/3(A)

TEST I/D (Displacement)

P = 0.0000

CONCLUSION Question groups 2 and 3 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 4	0	1	2	T
2	5	13	42	60
1	6	1	1	8
0	35	2	0	37
T	46	16	43	105

ELEMENT 5/3(A)

TEST I/D (Gradient)

P = 0.0663

CONCLUSION Question groups 1 and 4 probably represent the same subdivisional skill.

(D)

GROUP 1 \ GROUP 5	0	1	2	T
2	9	12	39	60
1	6	1	1	8
0	37	0	0	37
T	52	13	40	105

ELEMENT 5/3(A)

TEST +/- (Displacement)

P = 0.0030

CONCLUSION Question groups 1 and 5 may represent the same subdivisional skill.

TABLE 4/39

(A)

GROUP 1 \ GROUP 6	0	1	2	T
2	4	4	52	60
1	4	2	2	8
0	35	1	1	37
T	43	7	55	105

ELEMENT 5/3(A)

TEST +/- (Gradient)

P = 0.0001

CONCLUSION Question groups 1 and 6 represent different subdivisional skills.

(B)

GROUP 1 \ GROUP 7	0	1	2	T
2	22	5	33	60
1	6	1	1	8
0	28	2	7	37
T	56	8	41	105

ELEMENT 5/3(A)

TEST +/0 (Gradient)

P = 0.0000

CONCLUSION Question groups 1 and 7 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 8	0	1	2	T
2	54	0	6	60
1	8	0	0	8
0	36	0	1	37
T	98	0	7	105

ELEMENT 5/3(A)

TEST +/∞ (Gradient)

P = 0.0000

CONCLUSION Question groups 1 and 8 represent different subdivisional skills.

(D)

GROUP 7 \ GROUP 8	0	1	2	T
2	36	0	5	41
1	6	0	2	8
0	56	0	0	56
T	98	0	7	105

ELEMENT 5/3(A)

TEST 0/∞ (Gradient)

P = 0.0000

CONCLUSION Question groups 7 and 8 represent different subdivisional skills.

(A)

		GROUP 2			
		0	1	2	T
GROUP 1	2	39	16	54	109
	1	1	0	0	1
	0	1	0	0	1
	T	41	16	54	111

ELEMENT 5/4(A)

TEST I/D (Quotient)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(B)

		GROUP 3			
		0	1	2	T
GROUP 1	2	67	20	22	109
	1	1	0	0	1
	0	1	0	0	1
	T	69	20	22	111

ELEMENT 5/4(A)

TEST I/D (Quotient)

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

(C)

		GROUP 3			
		0	1	2	T
GROUP 2	2	24	12	18	54
	1	9	4	3	16
	0	36	4	1	41
	T	69	20	22	111

ELEMENT 5/4(A)

TEST I/D (Variables)

P = 0.0000

CONCLUSION Question groups 2 and 3 represent different subdivisional skills.

(D)

		GROUP 4			
		0	1	2	T
GROUP 1	2	57	14	38	109
	1	1	0	0	1
	0	1	0	0	1
	T	59	14	38	111

ELEMENT 5/4(A)

TEST I/D (Quotient)

P = 0.0000

CONCLUSION Question groups 1 and 4 represent different subdivisional skills.

TABLE 4/41

(A)

GROUP 5 (columns) × GROUP 1 (rows)

GROUP 1	0	1	2	T
2	39	10	60	109
1	0	1	0	1
0	1	0	0	1
T	40	11	60	111

ELEMENT 5/4(A)

TEST +/- (Variables)

P = 0.0000

CONCLUSION Question groups 1 and 5 represent different subdivisional skills.

(B)

GROUP 6 (columns) × GROUP 1 (rows)

GROUP 1	0	1	2	T
2	13	23	73	109
1	0	0	1	1
0	1	0	0	1
T	14	23	74	111

ELEMENT 5/4(A)

TEST +/- (Quotient)

P = 0.0006

CONCLUSION Question groups 1 and 6 represent different subdivisional skills.

(C)

GROUP 7 (columns) × GROUP 1 (rows)

GROUP 1	0	1	2	T
2	13	7	89	109
1	0	0	1	1
0	0	0	1	1
T	13	7	91	111

ELEMENT 5/4(A)

TEST +/0 (Quotient)

P = 0.0000

CONCLUSION Question groups 1 and 7 represent different subdivisional skills.

(D)

GROUP 8 (columns) × GROUP 1 (rows)

GROUP 1	0	1	2	T
2	106	0	3	109
1	1	0	0	1
0	1	0	0	1
T	108	0	3	111

ELEMENT 5/4(A)

TEST +/∞ (Quotient)

P = 0.0000

CONCLUSION Question groups 1 and 8 represent different subdivisional skills.

(A)

		GROUP 8: 0	1	2	T
GROUP 7	2	88	0	3	91
	1	7	0	0	7
	0	13	0	0	13
	T	108	0	3	111

ELEMENT 5/4(A)

TEST 0/∞ (Quotient)

P = 0.0000

CONCLUSION Question groups 7 and 8 represent different subdivisional skills.

(B)

		GROUP 2: 0	1	2	T
GROUP 1	2	4	14	37	55
	1	2	3	0	5
	0	42	2	0	44
	T	48	19	37	104

ELEMENT 5/2(B)

TEST +/- (Co-ordinates)

P = 0.1921

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(C)

		GROUP 3: 0	1	2	T
GROUP 1	2	6	9	40	55
	1	2	3	0	5
	0	42	1	1	44
	T	50	13	41	104

ELEMENT 5/2(B)

TEST +/0 (Co-ordinates)

P = 0.0001

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

(D)

		GROUP 4: 0	1	2	T
GROUP 1	2	3	2	50	55
	1	2	2	1	5
	0	44	0	0	44
	T	49	4	51	104

ELEMENT 5/2(B)

TEST I/D (Co-ordinates)

P = 0.0017

CONCLUSION Question groups 1 and 4 may represent the same subdivisional skills.

(A)

GROUP 5

GROUP 1	0	1	2	T
2	9	5	41	55
1	4	1	0	5
0	42	2	0	44
T	55	8	41	104

ELEMENT 5/2(B)

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 5 represent different subdivisional skills.

(B)

GROUP 6

GROUP 1	0	1	2	T
2	1	2	52	55
1	2	1	2	5
0	43	1	0	44
T	46	4	54	104

ELEMENT 5/2(B)

TEST +/- (Slope)

P = 0.0848

CONCLUSION Question groups 1 and 6 represent the same subdivisional skill.

(C)

GROUP 7

GROUP 1	0	1	2	T
2	0	2	53	55
1	0	2	3	5
0	43	1	0	44
T	43	5	56	104

ELEMENT 5/2(B)

TEST +/0 (Slope)

P = 1.0000

CONCLUSION Question groups 1 and 7 represent the same subdivisional skill.

(D)

GROUP 8

GROUP 1	0	1	2	T
2	0	4	51	55
1	0	2	3	5
0	28	3	13	44
T	28	9	67	104

ELEMENT 5/2(B)

TEST +/∞ (Slope)

P = 0.0000

CONCLUSION Question groups 1 and 8 represent different subdivisional skills.

TABLE 4/44

(A)

GROUP 9 (columns) × GROUP 1 (rows)

	0	1	2	T
2	1	8	46	55
1	3	2	0	5
0	40	2	2	44
T	44	12	48	104

ELEMENT 5/2(B)

TEST Convex/Concave

P = 0.0008

CONCLUSION Question groups 1 and 9 represent different subdivisional groups.

(B)

GROUP 2 (columns) × GROUP 1 (rows)

	0	1	2	T
2	0	2	53	55
1	2	2	1	5
0	43	0	1	44
T	45	4	55	104

ELEMENT 5/3(B)

TEST +/- (Slope)

P = 0.0402

CONCLUSION Question groups 1 and 2 probably represent the same subdivisional skill.

(C)

GROUP 3 (columns) × GROUP 1 (rows)

	0	1	2	T
2	0	4	51	55
1	0	0	5	5
0	39	0	5	44
T	39	4	61	104

ELEMENT 5/3(B)

TEST +/0 (Slope)

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

(D)

GROUP 4 (columns) × GROUP 1 (rows)

	0	1	2	T
2	0	5	50	55
1	1	2	2	5
0	38	2	4	44
T	39	9	56	104

ELEMENT 5/3(B)

TEST +/∞ (Slope)

P = 0.0004

CONCLUSION Question groups 1 and 4 represent different subdivisional skills.

TABLE 4/45

(A)

GROUP 5 (columns) × GROUP 1 (rows)

GROUP 1	0	1	2	T
2	1	1	53	55
1	1	3	1	5
0	42	2	0	44
T	44	6	54	104

ELEMENT 5/3(B)

TEST Convex/Concave

P = 0.0845

CONCLUSION Question groups 1 and 5 represent the same subdivisional skill.

(B)

GROUP 2 (columns) × GROUP 1 (rows)

GROUP 1	0	1	2	T
2	8	6	1	15
1	6	3	2	11
0	75	3	0	78
T	89	12	3	104

ELEMENT 6/2

TEST Straight line/Curve

P = 0.1370

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(C)

GROUP 3 (columns) × GROUP 1 (rows)

GROUP 1	0	1	2	T
2	1	5	9	15
1	3	7	1	11
0	70	6	2	78
T	74	18	12	104

ELEMENT 6/2

TEST I/D (Co-ordinates)

P = 0.0545

CONCLUSION Question groups 1 and 3 represent the same subdivisional skill.

(D)

GROUP 4 (columns) × GROUP 1 (rows)

GROUP 1	0	1	2	T
2	6	4	5	15
1	5	4	2	11
0	73	3	2	78
T	84	11	9	104

ELEMENT 6/2

TEST +/- (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 4 represent different subdivisional skills.

TABLE 4/46

(A)

GROUP 1 \ GROUP 5	0	1	2	T
2	0	4	11	15
1	2	6	3	11
0	73	2	3	78
T	75	12	17	104

ELEMENT 6/2

TEST +/0 (Co-ordinates)

P = 0.0132

CONCLUSION Question groups 1 and 5 probably represent the same subdivisional skill.

(B)

GROUP 1 \ GROUP 6	0	1	2	T
2	6	4	5	15
1	5	3	3	11
0	73	4	1	78
T	84	11	9	104

ELEMENT 6/2

TEST I/D (Scale)

P = 0.0001

CONCLUSION Question groups 1 and 6 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 7	0	1	2	T
2	5	3	7	15
1	2	4	5	11
0	70	6	2	78
T	77	13	14	104

ELEMENT 6/2

TEST H = I/1 (Scale)

P = 0.0000

CONCLUSION Question groups 1 and 7 represent different subdivisional skills.

(D)

GROUP 1 \ GROUP 8	0	1	2	T
2	3	5	7	15
1	5	1	5	11
0	72	3	3	78
T	80	9	15	104

ELEMENT 6/2

TEST H = I/D (Scale)

P = 0.0000

CONCLUSION Question groups 1 and 8 represent different subdivisional skills.

TABLE 4/47

(A)

		GROUP 2: 0	1	2	T
GROUP 1	2	5	9	15	29
	1	6	3	11	20
	0	53	4	1	58
	T	64	16	27	107

ELEMENT 6/3(A)

TEST Straight Line/Curve

P = 0.0023

CONCLUSION Question groups 1 and 2 may represent the same subdivisional skill.

(B)

		GROUP 2: 0	1	2	T
GROUP 1	2	26	19	48	93
	1	5	0	0	5
	0	10	0	0	10
	T	41	19	48	108

ELEMENT 6/3(B)

TEST I/D (Dimensions)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

		GROUP 3: 0	1	2	T
GROUP 1	2	0	0	93	93
	1	1	0	4	5
	0	10	0	0	10
	T	11	0	97	108

ELEMENT 6/3(B)

TEST H = I/1 (Dimensions)

P = 1.0000

CONCLUSION Question groups 1 and 3 represent the same subdivisional skill.

(D)

		GROUP 4: 0	1	2	T
GROUP 1	2	12	8	73	93
	1	2	0	3	5
	0	10	0	0	10
	T	24	8	76	108

ELEMENT 6/3(B)

TEST H = I/D (< 1)

P = 0.0000

CONCLUSION Question groups 1 and 4 represent different subdivisional skills.

TABLE 4/48

(A)

GROUP 1 \ GROUP 2	0	1	2	T
2	34	19	41	94
1	4	4	5	13
0	2	0	3	5
T	40	23	49	112

ELEMENT 6/4(B)

TEST I/D (Numbers)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(B)

GROUP 1 \ GROUP 3	0	1	2	T
2	0	0	94	94
1	0	1	12	13
0	3	0	2	5
T	3	1	108	112

ELEMENT 6/4(B)

TEST A = I/1 (Numbers)

P = 0.1502

CONCLUSION Question groups 1 and 3 represent the same subdivisional skill.

(C)

GROUP 1 \ GROUP 4	0	1	2	T
2	14	14	66	94
1	3	0	10	13
0	2	0	3	5
T	19	14	79	112

ELEMENT 6/4(B)

TEST A = I/D (<1)

P = 0.0000

CONCLUSION Question groups 1 and 4 represent different subdivisional skills.

(D)

GROUP 2/1(A)-1 \ GROUP 2/1(B)-10	0	1	2	T
2	10	7	49	66
1	5	0	3	8
0	25	0	2	27
T	40	7	54	101

ELEMENT 2/1(A) - 2/1(B)

TEST Interpolation/Extrapolation

P = 0.0000

CONCLUSION Interpolation and Extrapolation involve independent skills.

3. The Effect of Initial Testing Practice on Subsequent Performance

In order to determine the effect of initial testing practice on subsequent performance, the questions within each book, incorporating all subdivisional groups for a particular intellectual skill, were arranged in a different random sequence for every student. If the practice effect were insignificant, that is, if attempting earlier questions had no noticeable effect on later performance, it could be expected that the number of correct responses for any question would be independent of the order of presentation within the appropriate book. Since this result could be affected by errors of measurement, the correlated observations of question performance and position were tested, by the calculation of Cochran's Q (Cochran 1950), to determine whether or not they could be accounted for by chance occurrence under the null hypothesis of no practice effect.

The probability associated with the occurrence of observed results under the null hypothesis is presented for each set of questions in Table 4/49. Only two of these probabilities, namely those for Elements 3/2 and 5/3(B), are less than 0.05, and if the observed distribution of all eighteen probabilities is compared with their expected distribution under the hypothesis of no change in testing performance for any element (see Table 4/50), it can be shown that both of these distributions are effectively the same. This comparison involves the Kolmogorov-Smirnov test (see Bradley 1968) for goodness of fit.

It can safely be assumed from the results of this analysis that the use of multiple questions to test each basic skill will not involve a significant practice effect, that is, the initial attempt at questions for any particular skill will have little influence on subsequent performance in tasks of a similar nature. This assumption, which was similarly confirmed by White (1971), has important implications for the statistical analysis of hierarchical relationships, since it obviates the necessity to consider any complicating practice effect, while allowing the use of multiple questions to account for errors of measurement. Thus duplicate questions are used in this research to test each basic and subdivisional skill in the hierarchy validation programme. The development and trial of this validation programme are described in Chapter V.

TABLE 4/49

The Effect of Testing Practice on Subsequent Performance

Element Number	Number of Students	Number of Questions	Q	P
1/1	105	12	16.0	0.15
1/2	106	12	5.2	0.92
2/1(A)	107	18	22.9	0.16
2/1(B)	105	22	16.8	0.73
3/1	112	14	14.1	0.37
3/2	108	4	9.4	0.023
4/1	103	16	11.3	0.73
4/2	108	16	14.8	0.47
4/3	108	14	10.9	0.61
5/2(A)	104	16	14.2	0.51
5/3(A)	105	16	8.0	0.92
5/4(A)	111	16	24.8	0.05
5/2(B)	104	18	18.8	0.34
5/3(B)	104	10	17.2	0.047
6/2	104	16	12.8	0.61
6/3(A)	107	4	0.76	0.86
6/3(B)	108	8	5.2	0.64
6/4(B)	112	8	1.7	0.97

NOTES

(1) $$Q = \frac{J(J-1)\ \Sigma Y_j^{\ 2} - (J-1)(\Sigma Y_k)^2}{J\Sigma Y_k - \Sigma Y_k^{\ 2}}$$

$\underline{J}$ is the number of questions used to test a particular element, and $\underline{Y}_j$ is the total score for all students on a specified question (j). $\underline{Y}_k$ is the number of questions correct for any given student (k).

(2) $\underline{Q}$ is distributed as χ^2 on (J-1) degrees of freedom under the hypothesis of no change in performance throughout the appropriate test. $\underline{P}$ is the probability associated with the observed value of Q occurring under the same hypothesis.

TABLE 4/50

Observed and Expected Distributions of P (from Table 4/49)

X	$S_n(X)$	$F_o(X)$	$\lvert S_n(X)-F_o(X) \rvert$
9.4	0.06	0.023	0.04
17.2	0.11	0.047	0.06
24.8	0.17	0.05	0.12*
16.0	0.22	0.15	0.07
22.9	0.28	0.16	0.12*
18.8	0.33	0.34	0.01
14.1	0.39	0.37	0.02
14.8	0.44	0.47	0.03
14.2	0.50	0.51	0.01
10.9	0.56	0.61	0.05
12.8	0.61	0.61	0.00
5.2	0.67	0.64	0.03
11.3	0.72	0.73	0.01
16.8	0.78	0.73	0.05
0.76	0.83	0.86	0.03
5.2	0.89	0.92	0.03
8.0	0.94	0.92	0.02
1.7	1.00	0.97	0.03

NOTES

(1) X is the observed value of Q, and $F_o(X)$ the corresponding value of P (both derived from Table 4/49), under the hypothesis of no change in testing performance for any element. $S_n(X)$ is the expected cumulative frequency for the observed values of Q.

(2) The maximum value of $|Sn(X)-F_o(X)|$ is 0.12 (*). This value is not significant at the 0.05, or even at the 0.20 level, which requires a maximum deviation of 0.24 for significance. The hypothesis of no change in testing performance for any element is therefore accepted as valid.

CHAPTER V

THE MODIFICATION AND TRIAL VALIDATION OF THE POSTULATED LEARNING HIERARCHY

1. Introduction

Following the subdivisional analysis outlined in Chapter IV, several important modifications were made to the definition of certain basic skills, and to the nature of associated interrelationships in the postulated learning hierarchy. In addition to these modifications, a number of general restrictions were imposed so that the range of independent subdivisional skills within each of the basic abilities could be minimised, thus reducing the danger of falsely rejecting any valid hierarchical relationship. An outline of these modifications and restrictions is presented below in section 2, explained within the context of relevant interpretative areas, and incorporating the appropriate rationale.

2. Modifications and General Restrictions to the Postulated Learning Hierarchy

The analysis of subdivisional skills for calculating the position of a point on a two-dimensional grid did not include the case of a specified position on a continuous line-segment graph, because this was considered, on closer inspection, to involve a different type of skill, though probably related to the former at a higher level of complexity. Thus the calculation of position on a continuous line-segment graph was subsequently defined as a new terminal skill for area 1, dependent upon calculating the position of an isolated point, and involving its own analogous set of subdivisional skills. The actual location of a specified point on a continuous line-segment graph, which is the parallel constructional skill to the interpretative calculation of position, does not appear to involve the same procedural steps, and was therefore defined as an independent terminal skill for area 1. The addition of these interpretative and constructional skills, designated elements 1/1(A) and 1/1(B) respectively (see Table 5/4), also necessitated a redefinition of relevant interrelationships with other areas of the postulated learning hierarchy, and these changes are outlined at appropriate points below.

In addition to the basic structural changes associated with area 1, a number of more general modifications and restrictions were imposed on each of these positional abilities with respect to the relevant subdivisional skills outlined and empirically established in Chapter IV. It was decided, for example, to restrict the use of numerical positions to a limited range of positive integers (1-10), in order to avoid confusion with the independent skills involving negative and decimal numbers, and the special case of zero. It was recognised, in addition, that the different subdivisional skills for calculating Horizontal and Vertical position would have to be independently taught and tested, since both would be necessary in the subsequent calculation of gradient (area 5). The limitations outlined above on positional number and sign were also applied to other basic skills interrelated with those of area 1.

The basic intellectual skills of interpolation (element 2/1(A)) and extrapolation (element 2/1(B)) were considered, when defined in terms of operational instructions, to be hierarchically related to the newly defined terminal skill concerned with positional calculation from a line-segment graph (element (1/1(A)), rather than that involving a single or isolated point. Apart from this modification to the postulated interrelationship, the same subdivisional restrictions of positional number and sign, previously determined for area 1, were applied to both interpolation and extrapolation skills. An additional restriction to positive linear slope was also imposed for area 2 on the basis of the former subdivisional analysis, and it was decided to adopt a uniform level of interpolation and extrapolation distance, although this was a matter of subjective choice rather empirical necessity.

From the relative difficulty levels of elements 3/1 and 3/2, which were tested for subdivisional analysis on the same sample of students, it was decided to reverse the initially postulated relationship. Although the two basic skills were considered to be logically related, it was evident from the results outlined in Chapter IV that, despite the misinterpretation of instructions associated with element 3/2, the postulated sequence was most unlikely to be substantiated by empirical validation. Thus the calculation of maximum and minimum values was redefined as a subordinate skill to the general recognition of particular turning points. The interrelationship between positional calculation and that concerned with maximum/minimum values was also redefined (see Table 5/6), and the same limitations on number and sign were applied to both of the relevant (interrelated) skills.

In accordance with imposed restrictions on positional calculation, the values for determining difference and displacement (area 4) were also confined to a limited range of positive integral numbers (1-10), and the results for each appropriate question and example were similarly contrived to avoid complex calculations involving different subdivisional skills. The separate subdivisional skills for calculating Horizontal and Vertical displacement were independently taught and tested, since both were later required for the determination of gradient (area 5). The interrelationship between positional and displacement skills (areas 1 and 4 respectively) remained unchanged by basic definition (see Tables 5/4 and 5/7), but the reorganisation of area 1 necessitated certain changes in numerical classification.

Restrictions on numerical range and sign for the calculation of quotient and gradient (area 5) were analogous to those imposed in areas 1 and 4, with respect to both co-ordinate variables and result. One structural change was made, however, to the postulated interrelationship between areas 1 and 5, since element 5/2(B), which involves the construction of a tangent to a curve at a specified point of contact, was considered more appropriately related to the newly defined constructional skill 1/1(B), which involves positional location on a line-segment graph, than to the formerly related skill concerned with isolated points.

A similar change was made to the postulated relationship between element 6/1, which involves the calculation of area between specified points on a line-segment graph, and the subordinate skill of co-ordinate location (area 1), with element 1/1 (B) replacing the formerly related skill concerned with isolated points. A number of other changes were also made to area 6, including the use of a more appropriate format (two dimensional grid) for the classification of divided rectangular segments (element 6/3(A)), and the definition of an additional basic skill (designated 6/3(B) in Table 5/9) concerned with calculating the area of rectangular blocks from Horizontal and Vertical scales on a two-dimensional grid. Restrictions on number and sign for skills involving the calculation of graphical area generally followed those outlined above for other basic skills, although in this case the numerical range was extended beyond the former limit of 10. Where larger numbers were involved, however, analogous questions were used at lower levels to test for similar subdivisional skills. The ability to count was also considered a prerequisite for certain skills in area 6, but was assumed to be commonly mastered at the prospective testing level, and therefore too elementary for effective hierarchical discrimination.

With the various structural modifications and practical testing restrictions outlined above, the postulated learning hierarchy was considered to be in a suitable form for trial validation. A comprehensive instructional programme was therefore prepared, incorporating duplicate questions at appropriate intervals to test each basic skill. The reasons for this trial validation experiment were to evaluate the applicability and effectiveness of the teaching materials, to eliminate instructional errors from the various examples and testing questions, to detect any gross inconsistencies in the postulated learning hierarchy, and to determine both the amount of time required and the most appropriate application level for the final validation programme. The preparation and administration of the validation trial are outlined below in section 3, while the results and implications are subsequently discussed in section 4.

3. Preparation and Administration of the Validation Trial

The organisation of instructional and testing materials for the validation trial was basically the same as that proposed by White (1971 /pp31-33) for the validation of learning hierarchies. This involved teaching and immediately testing each skill in turn, progressing along linear hierarchical sequences and beginning at the lowest level in each, with special provision for retesting at appropriate branching points. There was, however, one important difference from the model proposed by White, in that this research involved no regular retesting pattern for skills in each linear sequence. The regular retesting procedure was adopted by White (1971) as a check on whether postulated subordinate skills were learned in the process of attempting subsequent higher-order elements, but it was considered in this case that the occurrence of such behaviour should invalidate the postulated relationship of hierarchical dependence, and that any subjects included in this category should be classified as 'legitimate' exceptions to the postulated sequence, rather than omitted from the validation test (see White 1971/p32).

The instructions and examples provided for each of the basic and subdivisional skills were explained as clearly and as simply as possible, with all specific graphical terms, such as 'horizontal', 'vertical', 'axis', and 'tangent', explicitly defined in more common terms and illustrated on first occurrence. An indication of the level of understanding among Victorian high school students of certain relevant scientific terms was provided in the results of an extensive local study by Gardner (1972), and the assumptions of expected common vocabulary were generally based on these results. Symbolic notation (e.g. X(A) = Horizontal position of point A) was extensively used throughout the trial programme, but was also explained and illustrated on first occurrence.

The trial validation programme was divided into three sections of approximately equal length, each intended to be comfortably completed in a single testing period of 40-50 minutes. Each section was concerned with different areas of graphical interpretation, although certain of the skills included in section 1 were also postulated prerequisites for sections 2 and 3, so that the sections were administered in proper numerical order. An outline of the presentation sequence of basic and subdivisional skills within each section of the programme is shown in Table 5/1.

Administration of the trial validation programme involved a single class of students at each of three consecutive levels from grade 6 (primary) to form 2 (secondary). For the primary class (grade 6) the programme was presented in three alternate 40-minute periods with one section covered in each, while for both of the secondary forms, it was presented, as a matter of administrative convenience, in consecutive testing periods. The completion time for each class and programme is shown in Table 5/2.

TABLE 5/1(A)

The Sequence of Basic and Subdivisional Skills in the Trial Validation Programme

Section 1

Page	Element Number or Basic Skill	Subdivisional Conditions
1	1/3	Position H/I/+
2		V/I/+
3	1/2	Required Co-ordinate H/I/+
4		V/I/+
5	1/1(A)	Required Co-ordinate H/I/+
6	2/1(A)	Required Co-ordinate H/I/+
7	2/1(B)	Required Co-ordinate H/I/+
8	3/2	Maximum Value V/I/+
9		Minimum Value V/I/+
10	3/1	Maximum Turning Point

TABLE 5/1(B)

The Sequence of Basic and Subdivisional Skills in the Trial Validation Programme

Section 2

Page	Element Number or Basic Skill	Subdivisional Conditions
1	1/3	Retest (H/I/+ and V/I/+)
	4/3	Numbers and Result I/+
2	4/2	Position and Displacement H/I/+
3		V/I/+
4	4/1	Co-ordinates and Displacement H/I/+
5		V/I/+
6	5/4(A)	Numbers and Quotient I/+
	5/3(A)	Gradient and Displacement I/+
7	4/1	Retest (H/I/+ and V/I/+)
8	5/2(A)	Co-ordinates, Displacement and Gradient I/+
9	5/3(B)	Tangent slope positive
10	5/2(B)	Contact position H/I/+, Tangent slope positive
11	5/1	As for 5/2(B) with Gradient I/+

TABLE 5/1(C)

The Sequence of Basic and Subdivisional Skills in the Trial Validation Programme

Section 3

Page	Element Number or Basic Skill	Subdivisional Conditions
1	6/5(B)	Numbers and Result I/+
	6/4(B)	Dimensions I/+
2	6/3(B)	Scale Units I/+
3	6/3(A)	Straight line
5		Curve
6	6/2	Straight line, end-points I/+
7		Curve, end-points I/+
8	1/1(B)	Required co-ordinate H/I/+
9	6/1	Straight line, end-points H/I/+
10		Curve, end-points H/I/+

NOTES

(1) The abbreviations used above for subdivisional conditions are the same as those defined in Chapter 4. (see preliminary notes for Tables 4/1-4/18).

(2) Except for retest segments, the presentation of each specified skill involved a short explanatory or instructional sequence, generally containing a fully worked example, followed by two appropriate testing questions.

(3) Section 1 contained a total of 24 questions (excluding those in worked examples), and sections 2 and 3 contained respectively 29 and 20 questions.

TABLE 5/2

Completion Times for the Trial Validation Programme

Section	Completion Time (in minutes) Grade 6	Form 1	Form 2
1	40	30	30
2	25	35	25
3	25	25	20
TOTAL	90	90	75

NOTES

(1) Section 1 contained a total of 10 pages, and sections 2 and 3 contained respectively 12 and 10.

(2) The sections were presented to each class in proper numerical order, but in alternate periods for grade 6, and consecutively to forms 1 and 2.

(3) Results for grade 6 were taken at Oakleigh State (Primary) School, and those for forms 1 and 2 at Oakleigh High School.

4. Results and Implications of the Validation Trial

With respect to the general applicability of the teaching and testing materials, there were no reported difficulties with any specific words or explanations of symbolic notation, but the instructions for element 3/1 were apparently poorly understood at all three testing levels, and these were therefore modified for the final validation programme. A further basic skill (designated 3/2(B) in Table 5/6) concerned with the location of turning points, was subsequently included as a postulated prerequisite for element 3/1, since the concept of turning points had not been previously covered, and the omission of this explanation might in part have been responsible for the misinterpretation of instructions mentioned above.

The amount of information provided for teaching the various basic and subdivisional skills was in most cases evidently adequate, given that some students must fail each skill for effective hierarchical discrimination, and in fact it may be seen from the list of difficulty levels (Table 5/3) that most skills were below 0.5, even for the primary (grade 6) class. In contrast with this, however, elements 5/2(A), 5/1, 6/2 and 6/1 all proved exceptionally difficult, although no problems were reported with reading or understanding of the relevant instructions, and so additional examples or explanatory notes were provided for these skills in the final validation programme.

Other structural changes to the trial validation programme included the addition of retesting segments at various branching points in the postulated learning hierarchy, and the translocation

TABLE 5/3

Difficulty Levels for Basic Intellectual Skills in the Trial Validation Programme

Element Number*	DIFFICULTY LEVEL Grade 6	Form 1	Form 2
1/3	0.06	0.00	0.00
1/2	0.48	0.47	0.21
1/1 (A)	0.81	0.72	0.50
1/1 (B)	0.16	0.09	0.05
2/1 (A)	0.61	0.56	0.42
2/1 (B)	0.81	0.69	0.60
3/2	0.30	0.16	0.18
3/1	0.52	0.53	0.50
4/3	0.03	0.03	0.03
4/2	0.23	0.12	0.05
4/1	0.58	0.31	0.26
5/4 (A)	0.26	0.12	0.13
5/3 (A)	0.58	0.28	0.29
5/2 (A)	0.90	0.87	0.74
5/3 (B)	0.13	0.22	0.10
5/2 (B)	0.55	0.47	0.26
5/1	1.00	0.97	0.68
6/5 (B)	0.03	0.00	0.03
6/4 (B)	0.19	0.12	0.08
6/3 (B)	0.58	0.34	0.21
6/3 (A)	0.39	0.28	0.31
6/2	0.90	0.72	0.50
6/1	0.87	0.81	0.53

NOTES (Table 5/3)

*(1) The element numbers listed above refer to basic intellectual skills outlined in the modified and final testing version of the postulated learning hierarchy (Tables 5/4-5/10).

(2) Where several subdivisional skills were tested for a particular element, the first of these only is presented in the table above.

(3) The difficulty levels listed above are calculated as the proportion of students who failed at least one of the two questions used to test each skill.

(4) Difficulty levels for retest segments are not included in the table above, but were generally lower than those for initial presentation, suggesting some degree of learning during practice at more complex skills. This might also explain the exceptionally low difficulty level for element 1/1(B), which was presented only in section 3.

(5) Results for grade 6 were taken at Oakleigh State School, and those for forms 1 and 2 at Oakleigh High School.

of element 1/1(B) (previously placed in section 3) to precede element 1/1(A) in section 1, since it was decided to test for a possible hierarchical relationship between these two basic skills.

There were no serious instructional or computational errors discovered in the testing questions, although in one case the answer to a question involving the calculation of gradient was the same as that for a previous example, and this increased the level of apparent guessing error. Coincidental results of this type were therefore avoided in subsequent modifications, as were complex calculations with a numerical result of one, since this appeared to be the most popular guess for students lacking the relevant capabilities.

From an analysis of difficulty levels associated with each of the basic and subdivisional skills (Table 5/3), and a review of comparative results for supposedly related elements, there appeared to be no gross inconsistencies in the postulated learning hierarchy. Thus apart from the various additions and modifications mentioned above, no major structural changes were made to the sequence of postulated skills in preparing the final validation programme. An outline of the modified and final testing version of the postulated learning hierarchy is presented in Tables 5/4-5/10. The major validation programme designed to test this learning hierarchy is included in Volume III (Progamme I).

It was determined from the list of difficulty levels for each element in the trial programme (Table 5/3) that form 1 would be the most appropriate academic level for administration of the final validation programme. The total proportion of skills within the ideal difficulty range of 0.2 to 0.8, which should produce the most effective discrimination, showed little difference across any of the trial testing levels, but it seemed from an analysis of more specific trends that the form 1 level would probably produce the most acceptable overall range of specific item difficulty, without the general problems of concentration or reading ability more evident in lower grades, or of interference at higher levels from previous curricular experience in related subject areas.

The anticipated amount of time required to complete each section of the major validation programme was derived from the trial form 1 completion times outlined in Table 5/2. It was considered, on the basis of these results, that an allowance of 2-3 minutes/page should be adequate for almost every student at this level, although it was intended, if possible, to maintain sufficient administrative flexibility to avoid the imposition of any absolute limits on completion time.

Having determined the necessary modifications to both the postulated learning hierarchy and the trial validation programme, and having established the most appropriate application level and anticipated completion time for the modified learning programme, more specific preparations could then be made for the major validation experiment. The preparation and administration of the final validation programme, together with results and appropriate conclusions, are presented in Chapter VI.

TABLES 5/4 - 5/10

Basic Skills of Graphical Interpretation

Postulated Learning Hierarchy

(Modified and Final Testing Version)

INTERPRETATIVE AREA

1. Position (Co-ordinate location)
2. Position (Interpolation and Extrapolation)
3. Position (Turning Points)
4. Displacement
5. Gradient (Slope)
6. Area

CLASSIFICATION CODE

The first number for each element represents the appropriate interpretative area, and the second number indicates the hierarchical level within that area, rated downward from the relevant terminal skill. Where letters are also used, these indicate secondary sequences within the same interpretative area.

TABLE 5/4

Position (A)

1/1(A) Calculate the Horizontal or Vertical position of a given point, specified by one co-ordinate, on a two-dimensional line-segment graph.

1/1(B) Mark the position of a point, specified by one co-ordinate (Horizontal or Vertical) on a two-dimensional line-segment graph.

1/2 Calculate the Horizontal or Vertical position of a given point on a two-dimensional grid.

1/3 Calculate the position of a given point on a single Horizontal or Vertical number line.

TABLE 5/5

Position (B)

2/1(A) Calculate the Horizontal or Vertical position of a point, specified by one co-ordinate, interpolated between a given row of points on a two-dimensional grid.

2/1(B) Calculate the Horizontal or Vertical position of a point, specified by one co-ordinate, extrapolated beyond a given line segment (or row of points) on a two-dimensional grid.

1/1(A)

TABLE 5/6

Position (C)

3/1 Identify from a mixed sample of convex and concave curves, those with a Maximum or Minimum Turning Point.

3/2(A) Calculate the Maximum or Minimum value of a curve drawn on a two-dimensional grid

3/2(B) Identify and mark the Turning Point on a given curve.

1/1(A)

TABLE 5/7

Displacement

4/1 Calculate the Horizontal or Vertical displacement between two given points on a two-dimensional grid or line-segment graph.

↑ 1/2

↑

4/2 Calculate the displacment between two given points on a single Horizontal or Vertical number line.

↑ 1/3

↑

4/3 Calculate the difference between two given numbers. (Both numbers and result restricted to positive integers).

TABLE 5/8

Gradient

5/1 Calculate the gradient of a curve on a two-dimensional grid at a fixed point of contact specified by one (Horizontal or Vertical) co-ordinate.

5/2(A) Calculate the gradient of a straight line segment drawn on a two-dimensional grid.

4/1

5/2(B) Draw the Tangent to a curve on a two-dimensional grid at a fixed point of contact specified by one (Horizontal or Vertical) co-ordinate.

1/1(B)

5/3(A) Calculate the gradient of a straight line segment, given both the Horizontal and Vertical displacement values.

5/3(B) Draw the Tangent to a curve at a given point of contact.

5/4(A) Calculate the quotient of two given numbers. (Both numbers and result restricted to positive integers).

TABLE 5/9

Area

6/1 Calculate the approximate area (by the method of counting squares) enclosed between two points of a given line segment, each specified by one co-ordinate, and the Horizontal axis of a two-dimensional grid.

1/1(B)

6/2 Calculate the approximate area (by the method of counting squares) enclosed between two marked points on a given line segment and the Horizontal axis of a two-dimensional grid.

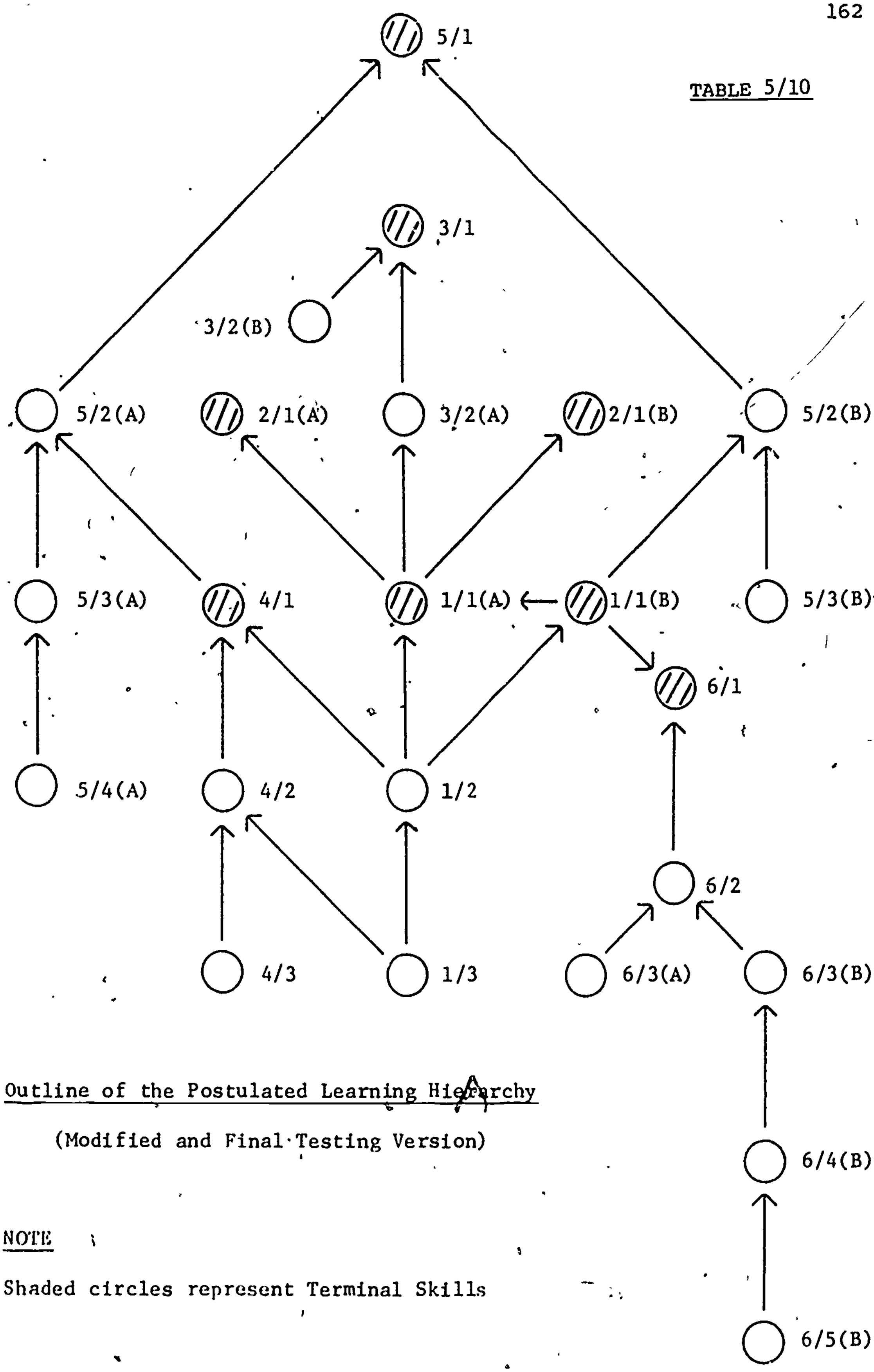
6/3(A) Classify the blocks to be counted in order to calculate the area of a specified section on a two-dimensional line-segment graph, where some of the blocks are cut by the given line.

6/3(B) Calculate the area of a single block on a two-dimensional grid from the Horizontal and Vertical scale calibration.

6/4(B) Calculate the area of a rectangular block, given the values for length and height.

6/5(B) Calculate the product of two numbers. (Both numbers and result restricted to positive integers).

TABLE 5/10



Outline of the Postulated Learning Hierarchy

(Modified and Final Testing Version)

NOTE

Shaded circles represent Terminal Skills

CHAPTER VI

FINAL VALIDATION OF THE POSTULATED LEARNING HIERARCHY

(PROGRAMME I/VICTORIA)

1. Preparation and Administration of the Final Validation Programme

The organisational structure of the final validation programme was the same as that outlined for the trial in Chapter V, with each of the basic and subdivisional skills presented in turn by means of instructional notes, examples, and immediate testing questions. The programme was again divided into three sections analogous to those in the validation trial, with each section involving different areas of graphical interpretation. This programme was longer than that for the validation trial, since it was based on the modified version of the postulated learning hierarchy (Tables 5/4-5/10), which incorporated certain additional skills and more complex interrelationships between interpretative areas, necessitating additional retesting questions at the various branching points. An outline of these modifications, together with appropriate changes to instructional notes, examples and testing questions, has already been presented in Chapter V. The presentation sequence of skills for each section of the final validation programme is shown in Table 6/1, and a copy of the programme itself is included in Volume III (Programme I). An outline of the relevant subdivisional skills included in the final validation programme, listing appropriate question groups for subsequent analysis, is presented in Table 6/2.

Administration of the final validation programme involved a total of 192 form 1 students from eleven randomly selected metropolitan co-educational high schools in Melbourne. This sample contained approximately equal numbers of male and female students, ranging in age from 11 to 14 years (taken to the nearest year) with a mean of 12.5. The number of students involved from each participating school is shown in Table 6/3. For most of these schools only half a class of students was involved, with the rest of the class engaged in one of the parallel validation programmes (see Volume III, Programmes II and III) prepared to examine the effects of certain situational variables on hierarchical learning. These alternative validation programmes are discussed in Chapters VII and VIII. The reasons for using two programmes with each class of students were to reduce the extent of copying from neighbouring students in the class, since this is probably the most serious risk involved in the validation of learning hierarchies, and to spread the required testing sample for each of the validation programmes over a wider range of schools. None of the classes in participating schools were streamed at the form 1 level, so that each of the student testing groups could be assumed to represent a reasonable spectrum of academic ability.

The three instructional and testing sections of the final validation programme were presented consecutively and in proper numerical order to each participating class. Since the total time involved was generally more than 100 minutes, short breaks of about five minutes were given for relief at regular 30-minute intervals. Consecutive presentation of the three programme sections also meant that a considerable waiting time was involved between the first and the last students to finish within each class. Thus in order to minimise the inevitable interference with those still working on the programme, students who finished were either promptly removed from the classroom or given some alternative form of individual activity. A list of both the shortest and longest completion times for each class is presented in Table 6/3.

In order to determine more accurately the rate at which students progressed through various stages of the validation programme, a single class was used to provide information on the number of pages completed at specified five or ten minute intervals. This information was intended to determine whether common fluctuations in working rate might occur at particular times or in certain segments of the programme, or more particularly to reveal the existence of any familiarisation lag at the beginning of the programme, or gradual decline in rate toward the end. The results of this analysis, shown in figure 6.1, indicate a generally constant working rate, and are consistent with the observations reported by White (1971/pp 114-116), based on a different informational technique, for a similar type of validation programme.

TABLE 6/1(A)

Sequence of Basic and Subdivisional Skills in the Final Validation Programme

Section 1

Page	Element Number (Basic Skill)	Relevant Subdivisional Conditions
1	1/3	Position H/I/+
2		V/I/+
3	1/2	Required Co-ordinate H/I/+
		V/I/+
5	1/1(B)	Given co-ordinates V/I/+ and H/I/+ also Straight line/curve
	1/1(A)	Required Co-ordinates H/I/+ and V/I/+ also Straight line/curve
8	2/1(A)	Required Co-ordinate H/I/+
10	2/1(B)	Required Co-ordinate H/I/+ from Line or row of points
12	1/2	Co-ordinates H/I/+ and V/I/+ (Retest)
13	3/2(A)	Maximum Value V/I/+
		Minimum Value V/I/+
16	3/2(B)	Maximum/Minimum Turning Points
17	3/1	Maximum Turning Point.

TABLE 6/1(B)

Sequence of Basic and Subdivisional Skills in the Final Validation Programme

Section 2

Page	Element Number (Basic Skill)	Relevant Subdivisional Conditions
1	1/3	Position H/I/+ and V/I/+ (Retest)
	4/3	Numbers and Result I/+
2	4/2	Position and Displacement H/I/+
3		V/I/+
4	1/2	Co-ordinates H/I/+ and V/I/+ (Retest)
5	4/1	Co-ordinates and Displacement H/I/+ V/I/+
7	5/4(A)	Numbers and Quotient I/+
	5/3(A)	Gradient and Displacement I/+
9	4/1	Co-ordinates and Displacement H/I/+ and V/I/+ (Retest)
10	5/2(A)	Co-ordinates, Displacement and Gradient all I/+
12	5/3(B)	Tangent Slope Negative Curves Convex and Concave
13	1/1(B)	Co-ordinates H/I/+, Curve (Retest)
14	5/2(B)	Contact point H/I/+, Tangent Slope Negative and Positive
15	5/2(A)	Retest (conditions as before)
16	5/1	Contact point H/I/+, Gradient I/+, Convex and Concave Curves

TABLE 6/1(C)

Sequence of Basic and Subdivisional Skills in the Final Validation Programme

Section 3

Page	Element Number (Basic Skill)	Relevant Subdivisional Conditions
1	6/5(B)	Numbers and Result I/+ Range <10 and >10
	6/4(B)	Dimensions and Result I/+
2	6/3(B)	Scale Units I/+ (<10)
4	6/3(A)	Straight line segment and Curve, End-points I/+
	6/3(B)	Scale Units I/+ (Retest)
	6/3(C)	Range >10
	6/2	Straight line segment and Curve, End-points I/+
10	1/1(B)	Co-ordinates H/I/+ with Straight line segment and Curve (Retest)
12	6/1	Straight line segment and Curve, End-points I/+, Scale Units I/+ (<10)

NOTES

1. The abbreviations used above for subdivisional conditions are the same as those defined in Chapter IV (see preliminary notes for Tables 4/1-4/18).

2. Except for retest segments, the presentation of each specified skill involved a short explanatory or instructional sequence, generally containing a fully worked example, followed by two appropriate testing questions.

NOTES (Table 9/1)

3. Section 1 contained a total of 42 questions (excluding those in worked examples) and sections 2 and 3 contained respectively 38 and 32 questions.

TABLE 6/2

The Classification of Subdivisional Skills Included in the Final Validation Programme

Element Number	Question Group	Relevant Subdivisional Conditions
1/3	1	Position H/I/+
	2	V/I/+
1/2	1	Required co-ordinate H/I/+
	2	V/I/+
1/1(B)	1	Straight line, Given co-ordinate H/I/+
	2	V/I/+
	3	Curve, Given co-ordinate H/I/+
	4	V/I/+
1/1(A)	1	Straight line, Required co-ordinate H/I/+
	2	V/I/+
	3	Curve, Required co-ordinate H/I/+
	4	V/I/+
2/1(A)	1	Required co-ordinate H/I/+
2/1(B)	1	Straight line, Required co-ordinate H/I/+
	2	Row of Points, Co-ordinate H/I/
3/2(A)	1	Maximum Value V/I/+
	2	Minimum Value V/I/+
4/2	1	Displacement H/I/+
	2	V/I/+
4/1	1	Displacement H/I/+
	2	V/I/+
6/5(B)	1	Numerical Variables <10
	2	>10
6/3(A)	1	Straight line segment
	2	Curve
6/2	1	Straight line segment
	2	Curve
6/1	1	Straight line segment
	2	Curve

NOTES (Table 6/2)

1. The table above outlines the variable conditions for each of the basic skills in which different subdivisional groups were used for the final validation programme. Other conditions or restrictions not listed above are assumed to be constant for each of the relevant subdivisional skills.

2. Elements not listed above were restricted to a single pair of questions representing only one of the subdivisional classification groups outlined in Chapter IV. The relevant conditions are also discussed for each of these basic skills in Chapter V (sections 2 and 4).

3. The classification symbols used above are the same as those defined in Chapter IV (see preliminary notes for Tables 4/1-4/18).

TABLE 6/3

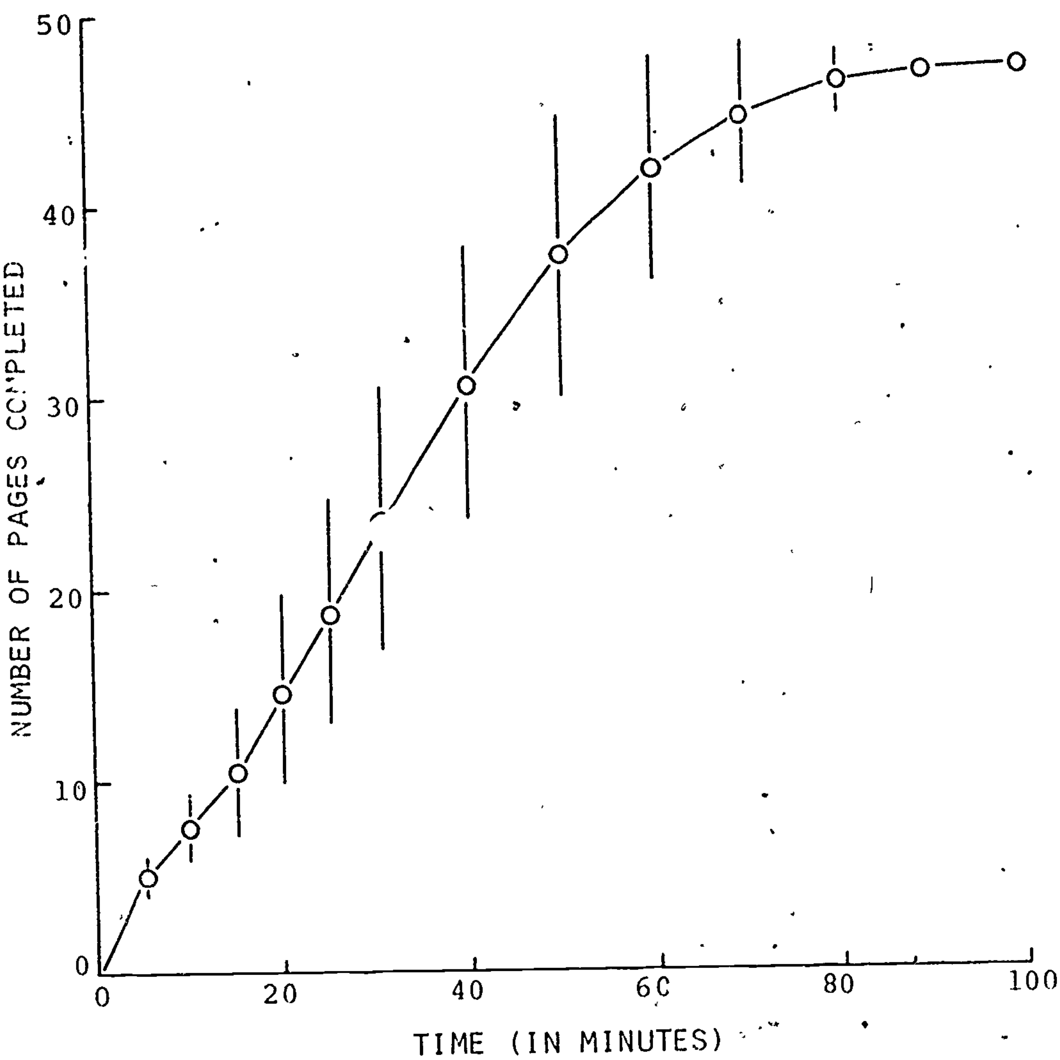
Sample Numbers and Completion Times for the Final Validation Programme

HIGH SCHOOL	Number of Students in Sample	Shortest Completion Time (mins.)	Longest Completion Time (mins.)
Blackburn	21	57	116
Brighton	14	52	120
Caulfield	18	48	105
Dandenong	17	63	110
Essendon	14	60	94
Frankston	15	65	122
Heidelberg	14	58	145
Kew	12	37	116
Lakeside	16	67	107
Monash	19	52	93
Norwood	32	40	92
Mean Completion Time		54.4	110.9
Standard Deviation		9.8	15.6

FIGURE 6.1

Progression Rate for Programme I

(Norwood High School)



NOTES

1. Circles indicate the mean number of pages completed at specified times.
2. Vertical lines represent the appropriate Standard Deviation.
3. Number of students involved = 32.

2. Results and Implications of the Final Validation Programme

The analysis of postulated hierarchical relationships followed in general the method proposed by White (1971), although some important modifications were made to the statistical validation technique (see also White and Clark 1973). The null hypothesis used by White was that no exceptions, other than those arising through errors of measurement, should occur to any postulated hierarchical sequence. It was considered in this case, however, that such a rigid hypothesis was probably unrealistic, since it ignores the possibility of exceptions arising through the use of unidentified prerequisite skills or alternative learning pathways. The calculation of displacement, for example, is postulated in the present hierarchy to be dependent on the skills of subtraction and individual point location, but might also be achieved by counting the number of marked divisions from one point to the other. This method, which bypasses the postulated prerequisite skills, is relatively inefficient, and therefore rarely used, but its very existence would probably invalidate the postulated sequence of skills under the conditions of absolute dependence imposed by White (1971). Less obvious alternative procedures might also be used for calculating linear displacement, and it seems unlikely that every conceivable prerequisite skill could be accommodated in a limited research design.

In accordance with this argument, it was decided that some degree of flexibility should be incorporated in the statistical validation technique. Thus in order to account for a range of possible exceptions(other than those arising through errors of measurement) to any particular hierarchical sequence, the null hypothesis was proposed and tested at three different levels of stringency. The most critical case, which was the same as that used earlier by White (1971), involved an absolute assumption of no exceptions, while the two "weaker" null hypotheses both allowed some small proportion of unqualified exceptions. The latter conditions are probably consistent with Gagné's (1968,1970) more recent orientation toward substantial, rather than absolute hierarchical dependence with respect to specified sequences of related intellectual skills.

An additional modification to White's (1971) design was that the specified proportion of exceptions for both of the weaker null hypotheses was tied, for each comparative test, to the number of students who succeeded at the higher skill. This adaptation was made to cover the extreme situations where very few students succeeded at the higher skill, since it would be pointless in such cases to expect the same fixed proportion of the total sample to achieve the higher skill without having the postulated prerequisite, that is, to expect the same overall proportion of exceptions to the postulated hierarchical relationship. The alternative hypothesis proposed by White (1971) involved a specified proportion of exceptions based only on the total sample, and was therefore considered to be inadequate for the type of situation outlined above. The alternative hypothesis proposed for the calculation of power in this research was similar in form to the weaker null hypotheses, but involved a considerably higher proportion (0.10) of anticipated exceptions. A more detailed statement of the null and alternative hypotheses is presented in the preliminary notes for Tables 6/4-6/25.

The overall level of significance (or probability of false rejection) for analysis of the 61 postulated hierarchical connections involved in the final validation was selected as 0.05, so that the individual probability of a Type 1 error for any single step was determined by the expression $\alpha = 1 - \sqrt[N]{(1-0.05)} = 1 - \sqrt[61]{0.95} = 0.00087$ (or approximately 0.001). The power was determined for each of the null hypotheses against the same alternative, and was used as an indication of confidence in each specific conclusion. The decision on acceptance or rejection of each postulated connection was based on the calculation of a critical number of exceptions permitted under the appropriate null hypothesis. The empirical validation results for the 61 connections of the postulated learning hierarchy (final testing version) are presented in Tables 6/4-6/25. Test/retest correlation results for certain basic skills are also included in this analysis.

The analysis of relevant subdivisional skills included in the validation programme was similar to that described in Chapter IV. The overall level of significance for this analysis was also chosen as 0.05, so that the individual probability of a type I error in any of the 20 comparative tests was given by the expression $\alpha = 1 - \sqrt[20]{0.95} = 0.0026$. The results of this analysis are presented in Tables 6/26-6/30, and the classification of relevant subdivisional conditions and appropriate question groups has already been outlined in Table 6/2.

A review of the validation and subdivisional analysis results for

Programme I suggests that the modified version of the postulated learning hierarchy was generally well substantiated, in spite of a few anomalous and occasionally contradictory results. A more detailed explanation of these results is presented below in relation to appropriate areas of graphical interpretation.

With respect to positional skills (areas 1-3), the empirical validation results were often inconsistent, although the general pattern of hierarchical relationships is relatively clear. The postulated relationship between elements 1/2 and 1/1(A), which was derived from a close inspection of the relevant operational instructions for each of these basic skills, was that the "Horizontal" and "Vertical" subdivisional groups of element 1/1(A) were individually dependent on both analogous groups from element 1/2. This relationship was tested in four supposedly parallel situations under different subdivisional conditions, and was accepted as valid at the absolute level in one of these, and at a weaker level in two others, but was rejected in the fourth case at all three null hypothesis levels (see Figure 6.2). As a tentative general conclusion the postulated relationship would probably be accepted, but the inconsistency in these results would suggest some reservations in this judgment.

In contrast with the inconsistencies above, the postulated hierarchical connections between elements 1/2 and 1/1(B), and between 1/1(B) and 1/1(A), each tested in four parallel subdivisional groups, were both unequivocally resolved, but with opposite conclusions. Element 1/2 was rejected at all three Ho levels as a prerequisite for the constructional skill 1/1(B), although the latter was accepted at the absolute level as a subordinate skill to element 1/1(A). The postulated parallel connections between analogous subdivisional groups for elements 1/2 and 1/3 were also both accepted, but at a weaker level. The independence of specified subdivisional groups within each of these basic skills is substantiated by the relevant analytical results outlined in Tables 6/26 and 6/27, and these results in turn establish the independence between parallel hierarchical relationships involving different subdivisional skills.

The postulated interrelationships between element 2/1(B) and both of the terminal skills for area 1 were accepted at different Ho levels for each subdivision of the higher skill, although analogous connections for element 2/1(A) were rejected even at the weakest Ho level (Figure 6.3). In all of these tests, however, the power was exceptionally low, and reflected gross inconsistencies in response for apparently similar questions. The same inconsistent trends in response were apparent in area 3 (see Figure 6.4), where element 1/2 was rejected, and 1/1(A) accepted, as a prerequisite skill for both subdivisional groups of element 3/2(A). It is also interesting to note that element 1/2 was previously rejected as a prerequisite for 1/1(A) under the same subdivisional conditions, although parallel connections were accepted for different subdivisional groups. The other hierarchical connections involved in area 3 were all accepted at the absolute Ho level, although again the power was exceptionally low.

The difference between interpolation and extrapolation skills (area 2), and between the two subdivisional groups of element 2/1(B) (extrapolation), is shown by the results in Table 6/28. In contrast with this, however, the postulated subdivisional groups for elements 3/2(A), 1/2 and 1/3 appear in each respective case to represent the same ability, although for element 1/3 (Retest) the difficulty level is obviously too low for reliable discrimination.

Test/retest correlation results for elements 1/2 and 1/1(A) (see Table 6/31) suggest that many students were able to learn these two subordinate skills in the process of attempting more complex capabilities. Although it was argued in Chapter V that these students should be classified as "legitimate" exceptions to the postulated hierarchical sequence, the repetition of similar instructional procedures in progressively complex examples may effectively involve reteaching the simpler or subordinate skills, and thus invalidate this assumption. It would seem, therefore, that in cases where a number of similar skills are involved, the regular retesting method adopted by White (1971) may be essential for effective hierarchical discrimination.

Although all of the postulated hierarchical connections involved in areas 4-6 were accepted at the absolute null hypothesis level (see Figures 6.5-6.7), the power was often extremely low, reflecting again, at least to some extent, the inconsistency in response for supposedly similar questions. This was not a result of testing fatigue, since it was evident in all three sections of the validation programme, nor was it caused through any obvious systematic errors, or lack of understanding with respect to either questions or instructions. Moreover since the questions used for each of the basic skills were representative of the same established subdivisional group, it seems unlikely that these were too loosely defined to expect a more consistent response. Thus it seems that the observed inconsistency may simply be a feature of the age or academic testing level, which was considerably lower than that for the earlier validation study by White (1971), and may therefore be particularly difficult to overcome. Some improvement could possibly be achieved by the use of additional testing questions for each of the basic skills, although this would substantially increase the length of the validation programme, and hence also the administrative inconvenience.

An alternative reason to explain in part the exceptional lack of power, particularly for more complex capabilities, is that the proportion of exceptions (in relation to the total sample) permitted under the alternative hypothesis was defined as a function of the difficulty level for the superordinate skill. Thus if the number of students possessing the higher skill is very small, then the conditions of the null and alternative hypotheses are similar, and the power is accordingly low. It should be emphasised, perhaps, that this explanation does not provide a total substitute for the effects of inconsistency outlined above.

Another problem of statistical power, also influenced to some extent by the general response inconsistency, occurred in a number of cases where very few students lacked the relevant subordinate skill. In extreme situations of this type, the expected number of exceptions under the absolute null hypothesis was higher than the total number of students who failed the subordinate skill, so that the postulated hierarchical connection could not possibly be rejected (see Tables

6/4(B), 6/15(B), 6/16(A) and 6/21(B)). We might expect in such circumstances that the power should be particularly low, but since the alternative hypothesis did not take account of the subordinate skill difficulty level, the power for these tests was often unrealistically high. It seems, therefore, that an additional modification to the alternative hypothesis may be required to take account of possible extremes in the subordinate skill difficulty level.

The subdivisional analysis results for elements 6/1 and 6/2 (Table 6/30) suggest that the calculation of area under straight line segments and curves involves respectively different subdivisional skills, although for element 6/3(A) the analogous classification groups are represented by the same ability. The result above for element 6/2 is in conflict with that reported in Chapter V, although the earlier analysis was based only on recollection from past curricular experience, rather than immediate recall from a more specific instructional programme, and would therefore be less reliable.

Apart from the outright rejection of a few of the postulated hierarchical connections in areas 1-3, and occasional inconsistencies observed for parallel subdivisional relationships in the same interpretative areas, the postulated learning hierarchy (final testing version) was accepted as valid within the specified range of null hypothesis levels. Most of the connections (including all in areas 4-6) were accepted at the absolute Ho level, and others under somewhat less stringent, but nevertheless realistic conditions. Certain reservations must be made, however, for the common inconsistencies in question response and the consequent loss of power, although the complicating effect of element difficulty on this index has already been explained.

Although the validation study outlined above was concerned with general intellectual skills of graphical interpretation, the extrapolation of results is limited by the previously imposed restriction to a single abstract informational model with variables X and Y. It was considered important, therefore, to determine whether the same specific pattern of hierarchical relationships, or of vertical or sequential transfer, would operate in a somewhat different informational situation. Thus an analogous study was conducted with a parallel validation programme, which involved the same intellectual skills applied to a more concrete or potentially meaningful informational model. The preparation and administration of this programme, together with results and implications of the subsequent validation study, are presented in Chapter VII.

TABLES 6/4-6/25

Validation Results for the Postulated Learning Hierarchy

(Final Testing Version)

PRELIMINARY NOTES

1. The following tables present the results for each of the postulated hierarchical connections between basic and subdivisional skills incorporated in the final validation programme. These results are presented in correlation matrix form, listing the number of questions correct for each element, and the appropriate marginal totals.

2. Where elements are presented under several different subdivisional conditions (see Table 6/2), the particular classification for these conditions is given after the element or basic skill code. The classification and definition for each element is outlined in Tables 5/4-5/10 (Chapter V), and the abbreviations used for the various subdivisional conditions are listed below.

SUBDIVISIONAL CLASSIFICATION CODE

i. Axis Orientation

H Horizontal

V Vertical

ii. Nature of graphical information

S Straight line segment

C Curve

P Row of points

Other relevant conditions are outlined in Table 6/2.

3. The null hypothesis is defined at each of the following levels.

    (a) Ho (0.00) - The proportion of those students possessing the higher skill who do not have the postulated prerequisite = 0.00.

    (b) Ho (0.01) - The proportion of those students possessing the higher skill who do not have the postulated prerequisite = 0.01 (or less).

    (c) Ho (0.02) - The proportion of those students possessing the higher skill who do not have the postulated prerequisite = 0.02 (or less)

The alternative hypothesis (Ha) stipulates that the proportion of those students possessing the higher skill who do not have the postulated prerequisite = 0.10 (or less).

4. The critical number of exceptions (C) permitted in the 0/2 cell of the relevant correlation table is listed for each level of the null hypothesis, together with the power calculated for each of these Ho levels against the same alternative hypothesis (defined above).

5. Element 6/3(C) (not previously defined in Chapter V) involves the skill of counting squares on a two-dimensional grid.

TABLE 6/4

(A) ELEMENT 1/2-H

ELEMENT 1/3-H	0	1	2	T
2	51	10	119	180
1	1	0	2	3
0	2	3	4	9
T	54	13	125	192

Ho	C	POWER
0.00	2	0.9997
0.01	6	0.9675
0.02	9	0.7989

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level.

(B) ELEMENT 1/2-V

ELEMENT 1/3-V	0	1	2	T
2	49	8	126	183
1	3	0	0	3
0	3	1	2	6
T	55	9	128	192

Ho	C	POWER
0.00	1	1.0000
0.01	6	0.9736
0.02	9	0.8249

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is unrealistically high.

(C) ELEMENT 1/1(B)-V/S

ELEMENT 1/2-V	0	1	2	T
2	34	12	82	128
1	7	1	1	9
0	32	8	15	55
T	73	21	98	192

Ho	C	POWER
0.00	5	0.9530
0.01	7	0.8263
0.02	9	0.6036

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

TABLE 6/5

(A) ELEMENT 1/1(A)-H/S

ELEMENT 1/1(B)-V/S

	0	1	2	T
2	15	5	78	98
1	6	15	0	21
0	67	6	0	73
T	88	26	78	192

Ho	C	POWER
0.00	7	0.7187
0.01	9	0.4560
0.02	10	0.3307

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(B) ELEMENT 1/1(A)-H/S

ELEMENT 1/2-V

	0	1	2	T
2	37	18	73	128
1	8	1	0	9
0	43	7	5	55
T	88	26	78	192

Ho	C	POWER
0.00	5	0.8541
0.01	7	0.6149
0.02	9	0.3416

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(C) ELEMENT 1/1(A)-H/S

ELEMENT 1/2-H

	0	1	2	T
2	32	19	74	125
1	13	0	0	13
0	43	7	4	54
T	88	26	78	192

Ho	C	POWER
0.00	5	0.8594
0.01	7	0.6242
0.02	9	0.3510

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

TABLE 6/6

(A) ELEMENT 1/1(B)-H/S

ELEMENT 1/2-H	0	1	2	T
2	21	15	89	125
1	9	1	3	13
0	29	10	15	54
T	59	26	107	192

Ho	C	POWER
0.00	8	0.8570
0.01	10	0.6656
0.02	12	0.4306

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(B) ELEMENT 1/1(A)-V/S

ELEMENT 1/1(B)-H/S	0	1	2	T
2	15	4	88	107
1	13	12	1	26
0	54	5	0	59
T	82	21	89	192

Ho	C	POWER
0.00	7	0.8152
0.01	9	0.5867
0.02	11	0.3387

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(C) ELEMENT 1/1(A)-V/S

ELEMENT 1/2-H	0	1	2	T
2	31	15	79	125
1	11	1	1	13
0	40	5	9	54
T	82	21	89	192

Ho	C	POWER
0.00	5	0.9187
0.01	7	0.7420
0.02	9	0.4850

CONCLUSION The postulated connection is accepted as valid at the third (0.02) Ho level, although the power at this level is particularly low.

TABLE 6/7

(A) ELEMENT 1/1(A)-V,S

ELEMENT 1/2-V	0	1	2	T
2	35	14	79	128
1	5	3	1	9
0	42	4	9	55
T	82	21	89	192

Ho	C	POWER
0.00	5	0.9145
0.01	7	0.7327
0.02	9	0.4733

CONCLUSION The postulated connection is accepted as valid at the third (0.02) Ho level, although the power at this level is particularly low.

(B) ELEMENT 1/1(B)-V/C

ELEMENT 1/2-V	0	1	2	T
2	22	15	91	128
1	2	3	4	9
0	25	6	24	55
T	49	24	119	192

Ho	C	POWER
0.00	8	0.9247
0.01	10	0.7907
0.02	12	0.5857

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(C) ELEMENT 1/1(A)-H/C

ELEMENT 1/1(B)-V/C	0	1	2	T
2	26	3	90	119
1	9	15	0	24
0	44	5	0	49
T	79	23	90	192

Ho	C	POWER
0.00	7	0.7992
0.01	8	0.6888
0.02	10	0.4346

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

TABLE 6/8

(A) ELEMENT 1/1(A)-H/C

ELEMENT 1/2-V		0	1	2	T
	2	32	14	82	128
	1	7	2	0	9
	0	40	7	8	55
	T	79	23	90	192

Ho	C	POWER
0.00	5	0.9245
0.01	7	0.7552
0.02	9	0.5022

CONCLUSION The postulated connection is accepted as valid at the third (0.02) Ho level, although the power at this level is particularly low.

(B) ELEMENT 1/1(A)-H/C

ELEMENT 1/2-H		0	1	2	T
	2	30	13	82	125
	1	11	2	0	13
	0	38	8	8	54
	T	79	23	90	192

Ho	C	POWER
0.00	6	0.8602
0.01	8	0.6441
0.02	9	0.5133

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is relatively low.

(C) ELEMENT 1/1(B)-H/C

ELEMENT 1/2-H		0	1	2	T
	2	35	4	86	125
	1	10	1	2	13
	0	33	3	18	54
	T	78	8	106	192

Ho	C	POWER
0.00	3	0.9956
0.01	6	. 9238
0.02	9	0.6564

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

TABLE 6/9

(A). ELEMENT 1/1(A)-V/C

ELEMENT 1/1(B)-H/G

	0	1	2	T
2	16	3	87	106
1	4	4	0	8
0	60	18	0	78
T	80	25	87	192

Ho	C	POWER
0.00	7	0.7752
0.01	8	0.6584
0.02	10	0.5006

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(B) ELEMENT 1/1(A)-V/C

ELEMENT 1/2-H

	0	1	2	T
2	36	13	76	125
1	11	1	1	13
0	33	11	10	54
T	80	25	87	192

Ho	C	POWER
0.00	6	0.8432
0.01	8	0.6153
0.02	9	0.4824

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(C) ELEMENT 1/1(A)-V/C

ELEMENT 1/2-V

	0	1	2	T
2	38	15	75	128
1	7	1	1	9
0	35	9	11	55
T	80	25	87	192

Ho	C	POWER
0.00	6	0.8372
0.01	8	0.6053
0.02	9	0.4719

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

TABLE 6/10

(A) ELEMENT 2/1(A)-H/P

ELEMENT 1/1(A)-H/S	0	1	2	T
2	15	8	55	78
1	18	1	7	26
0	60	14	14	88
T	93	23	76	192

Ho	C	POWER
0.00	9	0.5177
0.01	10	0.3895
0.02	12	0.1833

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(B) ELEMENT 2/1(A)-H/P

ELEMENT 1/1(B)-V/S	0	1	2	T
2	32	9	57	98
1	13	2	6	21
0	48	12	13	73
T	93	23	76	192

Ho	C	POWER
0.00	7	0.6663
0.01	8	0.5302
0.02	10	0.2758

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(C) ELEMENT 2/1(B)-H/S

ELEMENT 1/1(A)-H/S	0	1	2	T
2	18	8	52	78
1	18	2	6	26
0	65	12	11	88
T	101	22	69	192

Ho	C	POWER
0.00	8	0.5198
0.01	9	0.3852
0.02	11	0.1729

CONCLUSION The postulated connection is accepted as valid at the third (0.02) Ho level, although the power at this level is extremely low.

TABLE 6/11

(A) ELEMENT 2/1(B)-H/S

ELEMENT 1/1(B)-V/S	0	1	2	T
2	34	11	53	98
1	13	0	8	21
0	54	11	8	73
T	101	22	69	192

Ho	C	POWER
0.00	6	0.6900
0.01	8	0.4053
0.02	9	0.2788

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is particularly low.

(B) ELEMENT 2/1(B)-H/P

ELEMENT 1/1(A)-H/S	0	1	2	T
2	22	7	49	78
1	19	3	4	26
0	64	16	8	88
T	105	26	61	192

Ho	C	POWER
0.00	8	0.4092
0.01	9	0.2823
0.02	10	0.1811

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C) ELEMENT 2/1(B)-H/P

ELEMENT 1/1(B)-V/S	0	1	2	T
2	39	10	49	98
1	12	5	4	21
0	54	11	8	73
T	105	26	61	192

Ho	C	POWER
0.00	6	0.5899
0.01	8	0.3017
0.02	9	0.1918

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is particularly low.

TABLE 6/12

(A) ELEMENT 3/2(A)-Max.

ELEMENT 1/2-V	0	1	2	T
2	23	22	71	116
1	9	5	3	17
0	31	7	21	59
T	63	34	95	192

Ho	C	POWER
0.00	10	0.6219
0.01	12	0.3839
0.02	13	0.2787

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(B) ELEMENT 3/2(A)-Max.

ELEMENT 1/1(A)-V/C	0	1	2	T
2	24	25	76	125
1	12	6	6	24
0	27	3	13	43
T	63	34	95	192

Ho	C	POWER
0.00	9	0.6846
0.01	11	0.4417
0.02	12	0.3273

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(C) ELEMENT 3/2(A)-Min.

ELEMENT 1/2-V	0	1	2	T
2	20	29	67	116
1	7	6	4	17
0	24	10	25	59
T	51	45	96	192

Ho	C	POWER
0.00	15	0.2923
0.01	16	0.2079
0.02	17	0.1411

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

TABLE 6/13

(A) ELEMENT 3/2(A)-Min.

ELEMENT 1/1(A)-V/C	0	1	2	T
2	19	27	79	125
1	11	7	6	24
0	21	11	11	43
T	51	45	96	192

Ho	C	POWER
0.00	13	0.3556
0.01	14	0.2570
0.02	15	0.1765

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B) ELEMENT 3/1

ELEMENT 3/2(B)	0	1	2	T
2	58	62	44	164
1	4	2	1	7
0	17	2	2	21
T	79	66	47	192

Ho	C	POWER
0.00	7	0.1173
0.01	8	0.0574
0.02	9	0.0256

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 3/1

ELEMENT 3/2(A)-Max.	0	1	2	T
2	22	33	40	95
1	16	15	3	34
0	41	18	4	63
T	79	66	47	192

Ho	C	POWER
0.00	15	0.0218
0.01	16	0.0107
0.02	16	0.0107

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 6/14

(A) ELEMENT 3/1

ELEMENT 3/2(A)-Min.	0	1	2	T
2	24	35	37	96
1	21	16	8	45
0	34	15	2	51
T	79	66	47	192

Ho	C	POWER
0.00	14	0.0233
0.01	15	0.0113
0.02	15	0.0113

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 1/2-V (Retest)

ELEMENT 1/2-V	0	1	2	T
2	23	7	98	128
1	6	2	1	9
0	30	8	17	55
T	59	17	116	192

Ho	C	POWER
0.00	5	0.9854
0.01	8	0.8711
0.02	10	0.6895

CONCLUSION This skill was acquired by a significant proportion of students in the process of attempting more complex capabilities.

(C) ELEMENT 1/1(A)-V (Retest)

ELEMENT 1/1(A)-V	0	1	2	T
2	1	5	81	87
1	4	5	16	25
0	38	14	28	80
T	43	24	125	192

Ho	C	POWER
0.00	14	0.7336
0.01	16	0.5408
0.02	18	0.3445

CONCLUSION This skill was acquired by a signi cant proportion of students in the process of attempting more complex capabilities.

TABLE 6/15

(A) ELEMENT 4/2-H

ELEMENT 4/3

	0	1	2	T
2	32	8	145	185
1	3	0	1	4
0	3	0	0	3
T	38	8	146	192

Ho	C	POWER
0.00	2	1.0000
0.01	7	0.9794
0.02	10	0.8633

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 4/2-V

ELEMENT 4/3

	0	1	2	T
2	34	50	101	185
1	1	2	1	4
0	3	0	0	3
T	38	52	102	192

Ho	C	POWER
0.00	4	0.8754
0.01	6	0.6306
0.02	8	0.3413

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(C) ELEMENT 4/2-H

ELEMENT 1/3-H

	0	1	2	T
2	36	7	146	189
1	0	0	0	0
0	2	1	0	3
T	38	8	146	192

Ho	C	POWER
0.00	1	1.0000
0.01	7	0.9792
0.02	10	0.8624

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 6/16

(A) ELEMENT 4/2-V

ELEMENT 1/3-V	0	1	2	T
2	34	51	101	186
1	1	0	1	2
0	3	1	0	4
T	38	52	102	192

Ho	C	POWER
0.00	4	0.8864
0.01	6	0.6523
0.02	8	0.3638

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(B) ELEMENT 4/1-H

ELEMENT 4/2-H	0	1	2	T
2	24	21	101	146
1	2	1	5	8
0	37	0	1	38
T	63	22	107	192

Ho	C	POWER
0.00	5	0.9700
0.01	8	0.7917
0.02	10	0.5657

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 4/1-V

ELEMENT 4/2-V	0	1	2	T
2	16	14	72	102
1	9	2	41	52
0	35	2	1	38
T	60	18	114	192

Ho	C	POWER
0.00	14	0.6242
0.01	15	0.5201
0.02	17	0.3202

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLE 6/17

(A) ELEMENT 4/1-H

ELEMENT 1/2-H		0	1	2	T
	2	20	14	99	133
	1	6	4	8	18
	0	37	4	0	41
	T	63	22	107	192

Ho	C	POWER
0.00	6	0.9467
0.01	8	0.8218
0.02	10	0.6097

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 4/1-V

ELEMENT 1/2-V		0	1	2	T
	2	19	8	98	125
	1	7	1	13	21
	0	34	9	3	46
	T	60	18	114	192

Ho	C	POWER
0.00	6	0.9687
0.01	9	0.8040
0.02	11	0.5946

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 5/3(A)

ELEMENT 5/4(A)		0	1	2	T
	2	41	6	108	155
	1	8	1	0	9
	0	24	2	2	28
	T	73	9	110	192

Ho	C	POWER
0.00	3	0.9962
0.01	6	0.9315
0.02	8	0.7854

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 6/18

(A) ELEMENT 5/2(A) × ELEMENT 5/3(A)

ELEMENT 5/3(A)	0	1	2	T
2	63	12	35	110
1	9	0	0	9
0	64	6	3	73
T	136	18	38	192

Ho	C	POWER
0.00	3	0.5802
0.01	5	0.2226
0.02	6	0.1147

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B) ELEMENT 5/2(A) × ELEMENT 4/1-H

ELEMENT 4/1-H	0	1	2	T
2	58	10	36	104
1	9	1	1	11
0	69	7	1	77
T	136	18	38	192

Ho	C	POWER
0.00	3	0.5895
0.01	5	0.2303
0.02	6	0.1199

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C) ELEMENT 5/2(A) × ELEMENT 4/1-V

ELEMENT 4/1-V	0	1	2	T
2	57	10	33	100
1	13	1	4	18
0	66	7	1	74
T	136	18	38	192

Ho	C	POWER
0.00	4	0.4184
0.01	5	0.2520
0.02	6	0.1348

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLE 6/19

(A)

ELEMENT 5/3(B) (rows) × ELEMENT 5/2(B) (columns)

	0	1	2	T
2	15	7	68	90
1	7	5	6	18
0	78	6	0	84
T	100	18	74	192

Ho	C	POWER
0.00	6	0.7369
0.01	7	0.6031
0.02	9	0.3300

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(B)

ELEMENT 1/1(B)-H/C (rows) × ELEMENT 5/2(B) (columns)

	0	1	2	T
2	37	14	70	121
1	11	2	2	15
0	52	2	2	56
T	100	18	74	192

Ho	C	POWER
0.00	4	0.8978
0.01	6	0.6759
0.02	8	0.3894

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(C)

ELEMENT 5/2(B) (rows) × ELEMENT 5/1 (columns)

	0	1	2	T
2	41	19	14	74
1	13	4	1	18
0	90	10	0	100
T	144	33	15	192

Ho	C	POWER
0.00	6	0.0133
0.01	6	0.0133
0.02	7	0.0039

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 6/20

(A) ELEMENT 5/1

ELEMENT 5/2(A)

	0	1	2	T
2	15	15	15	45
1	18	7	0	25
0	111	11	0	122
T	144	33	15	192

Ho	C	POWER
0.00	7	0.0144
0.01	8	0.0047
0.02	8	0.0047

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 4/1-H (Retest)

ELEMENT 4/1-H

	0	1	2	T
2	14	7	86	107
1	7	2	13	22
0	56	2	5	63
T	77	11	104	192

Ho	C	POWER
0.00	6	0.9419
0.01	8	0.8099
0.02	10	0.5920

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

(C) ELEMENT 4/1-V (Retest)

ELEMENT 4/1-V

	0	1	2	T
2	16	12	86	114
1	5	3	10	18
0	53	3	4	60
T	74	18	100	192

Ho	C	POWER
0.00	6	0.9253
0.01	8	0.7714
0.02	10	0.5376

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

TABLE 6/21

(A) ELEMENT 5/2(A) (Retest)

ELEMENT 5/2(A)	0	1	2	T
2	1	3	34	38
1	10	1	7	18
0	111	21	4	136
T	122	25	45	192

Ho	C	POWER
0.00	9	0.1596
0.01	10	0.0904
0.02	11	0.0474

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

(B) ELEMENT 6/4(B)

ELEMENT 6/5(B)	0	1	2	T
2	26	15	143	184
1	3	0	4	7
0	1	0	0	1
T	30	15	147	192

Ho	C	POWER
0.00	2	0.9999
0.01	7	0.9730
0.02	9	0.9001

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(C) ELEMENT 6/3(B)

ELEMENT 6/4(B)	0	1	2	T
2	43	10	94	147
1	8	0	7	15
0	24	2	4	30
T	75	12	105	192

Ho	C	POWER
0.00	4	0.9847
0.01	6	0.9180
0.02	9	0.6409

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 6/22

(A) ELEMENT 6/2-S

ELEMENT 6/3 (B)	0	1	2	T
2	29	14	43	86
1	17	3	2	22
0	84	0	0	84
T	130	17	45	192

Ho	C	POWER
0.00	5	0.4296
0.01	6	0.2746
0.02	7	0.1587

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B) ELEMENT 6/2-S

ELEMENT 6/3 (A)-S	0	1	2	T
2	20	9	45	74
1	29	7	0	36
0	81	1	0	82
T	130	17	45	192

Ho	C	POWER
0.00	7	0.2910
0.01	9	0.0996
0.02	9	0.0996

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 6/2-S

ELEMENT 6/5 (B)	0	1	2	T
2	88	14	41	143
1	31	3	3	37
0	11	0	1	12
T	130	17	45	192

Ho	C	POWER
0.00	4	0.5611
0.01	6	0.2352
0.02	7	0.1302

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLE 6/23

(A)

ELEMENT 6/2-C (columns); ELEMENT 6/3(B) (rows)

	0	1	2	T
2	32	9	50	91
1	10	4	0	14
0	87	0	0	87
T	129	13	50	192

Ho	C	POWER
0.00	4	0.6272
0.01	5	0.4520
0.02	6	0.2944

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B)

ELEMENT 6/2-C (columns); ELEMENT 6/3(A)-C (rows)

	0	1	2	T
2	30	9	50	89
1	12	4	0	16
0	87	0	0	87
T	129	13	50	192

Ho	C	POWER
0.00	4	0.6394
0.01	5	0.4652
0.02	7	0.1828

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C)

ELEMENT 6/2-C (columns); ELEMENT 6/5(B) (rows)

	0	1	2	T
2	87	10	46	143
1	30	3	4	37
0	12	0	0	12
T	129	13	50	192

Ho	C	POWER
0.00	4	0.6566
0.01	6	0.3238
0.02	7	0.1964

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLE 6/24

(A) ELEMENT 6/1-H/S

ELEMENT 6/2-S

	0	1	2	T
2	8	14	23	45
1	7	3	7	17
0	125	3	2	130
T	140	20	32	192

Ho	C	POWER
0.00	6	0.1541
0.01	7	0.0[illegible]62
0.02	8	0.0340

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 6/1-H/C

ELEMENT 6/2-C

	0	1	2	T
2	10	9	31	50
1	3	3	7	13
0	121	6	2	129
T	134	18	40	192

Ho	C	POWER
0.00	5	0.3667
0.01	6	0.2216
0.02	7	0.1206

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C) ELEMENT 6/1-H/S

ELEMENT 1/1(B)-H/S

	0	1	2	T
2	102	19	32	153
1	9	1	0	10
0	29	0	0	29
T	140	20	32	192

Ho	C	POWER
0.00	2	0.6371
0.01	4	0.2311
0.02	5	0.1120

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLE 6/25

(A) ELEMENT 6/1-H/C

ELEMENT 1/1(B)-H/C	0	1	2	T
2	95	17	39	151
1	12	1	1	14
0	27	0	0	27
T	134	18	40	192

Ho	C	POWER
0.00	3	0.5881
0.01	4	0.3909
0.02	5	0.2292

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B) ELEMENT 6/2-S

ELEMENT 6/3(C)	0	1	2	T
2	19	8	45	72
1	29	9	0	38
0	82	0	0	82
T	130	17	45	192

Ho	C	POWER
0.00	8	0.2022
0.01	9	0.1167
0.02	10	0.0621

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 6/2-C

ELEMENT 6/3(C)	0	1	2	T
2	26	9	50	85
1	15	4	0	19
0	88	0	0	88
T	129	13	50	192

Ho	C	POWER
0.00	5	0.4912
0.01	6	0.3302
0.02	7	0.2015

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLES 6/26-6/30

Subdivisional Analysis Results for the Postulated Learning

Hierarchy (Final Testing Version)

PRELIMINARY NOTES

1. The following tables contain the subdivisional analysis results for certain basic skills incorporated in the final validation programme. These results are presented in correlation matrix form, listing the number of questions correct for each element, and the appropriate marginal totals.

2. The classification and definition for each element or basic skill is outlined in Tables 5/4-5/10 (Chapter V), and a list of the relevant subdivisional question groups is presented in Table 6/2.

3. P represents the combined probability that the observed number of students in the 0/2 and 2/0 cells could have occurred through chance (or errors of measurement) under the null hypothesis that no-one can possess only one of the relevant subdivisional skills without also having the other.

TABLE 6/26

(A)

GROUP 1 \ GROUP 2	0	1	2	T
2	2	0	178	180
1	0	1	2	3
0	4	2	3	9
T	6	3	183	192

ELEMENT 1/3

TEST H/V (Position)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	3	2	120	125
1	6	4	3	13
0	46	3	5	54
T	55	9	128	192

ELEMENT 1/2

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	13	13	81	107
1	11	3	12	26
0	49	5	5	59
T	73	21	98	192

ELEMENT 1/1(B)

TEST H/V (C-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(D)

GROUP 1 \ GROUP 3	0	1	2	T
2	10	3	94	107
1	15	2	9	26
0	53	3	3	59
T	78	8	106	192

ELEMENT 1/1(B)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

TABLE 6/27

(A)

GROUP 2 \ GROUP 4	0	1	2	T
2	3	3	92	98
1	3	7	11	21
0	43	14	16	73
T	49	24	119	192

ELEMENT 1/1(B)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 2 and 4 represent different subdivisional skills.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	2	6	70	78
1	13	6	7	26
0	67	9	12	88
T	82	21	89	192

ELEMENT 1/1(A)

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 3	0	1	2	T
2	5	4	69	78
1	9	5	12	26
0	65	14	9	88
T	79	23	90	192

ELEMENT 1/1(A)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

(D)

GROUP 2 \ GROUP 4	0	1	2	T
2	9	7	73	89
1	13	3	5	21
0	58	15	9	82
T	80	25	87	192

ELEMENT 1/1(A)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 2 and 4 represent different subdivisional skills.

TABLE 6/28

(A)

		GROUP 2/1(B)-2			
		0	1	2	T
GROUP 2/1(A)-1	2	14	9	53	76
	1	15	6	2	23
	0	76	11	6	93
	T	105	26	61	192

ELEMENT 2/1(A)-2/1(B)

TEST Interpolation/Extrapolation

P = 0.0000

CONCLUSION Elements 2/1(A) and 2/1(B) represent different basic skills.

(B)

		GROUP 2			
		0	1	2	T
GROUP 1	2	5	15	49	69
	1	11	3	8	22
	0	89	8	4	101
	T	105	26	61	192

ELEMENT 2/1(B)

TEST Line/Points

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

		GROUP 2			
		0	1	2	T
GROUP 1	2	3	12	80	95
	1	8	16	10	34
	0	40	17	6	63
	T	51	45	96	192

ELEMENT 3/2(A)

TEST Max./Min. Values

P = 0.0207

CONCLUSION Question groups 1 and 2 probably represent the same subdivisional skill.

(D)

		GROUP 2			
		0	1	2	T
GROUP 1	2	1	2	186	189
	1	0	0	0	0
	0	3	0	0	3
	T	4	2	186	192

ELEMENT 1/3 (Retest)

TEST H/V (Position)

P = 0.0125

CONCLUSION Question groups 1 and 2 probably represent the same subdivisional skill.

TABLE 6/29

(A)

GROUP 1 \ GROUP 2	0	1	2	T
2	2	9	122	133
1	7	8	3	18
0	37	4	0	41
T	46	21	125	192

ELEMENT 1/2 (Retest)

TEST H/V (Co-ordinates)

P = 0.2324

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	3	48	95	146
1	0	3	5	8
0	35	1	2	38
T	38	52	102	192

ELEMENT 4/2

TEST H/V (Displacement)

P = 0.0414

CONCLUSION Question groups 1 and 2 probably represent the same subdivisional skill.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	2	2	103	107
1	3	12	7	22
0	55	4	4	63
T	60	18	114	192

ELEMENT 4/1

TEST H/V (Displacement)

P = 0.0005

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(D)

GROUP 1 \ GROUP 3	0	1	2	T
2	2	7	144	153
1	0	5	5	10
0	25	2	2	29
T	27	14	151	192

ELEMENT 1/1(B) (Retest)

TEST Straight Line/Curve

P = 0.0003

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

TABLE 6/30

(A)

GROUP 1 \ GROUP 2	0	1	2	T
2	10	35	139	184
1	1	2	4	7
0	1	0	0	1
T	12	37	143	192

ELEMENT 6/5(B)

TEST Numerical Range

P = 0.0060

CONCLUSION Question groups 1 and 2 may represent the same subdivisional skill.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	3	5	66	74
1	9	7	20	36
0	75	4	3	82
T	87	16	89	192

ELEMENT 6/3(A)

TEST Straight Line/Curve

P = 0.0147

CONCLUSION Question groups 1 and 2 probably represent the same subdivisional skill.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	2	7	36	45
1	1	4	12	17
0	126	2	2	130
T	129	13	50	192

ELEMENT 6/2

TEST Straight Line/Curve

P = 0.0026

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(D)

GROUP 1 \ GROUP 2	0	1	2	T
2	2	6	24	32
1	0	8	12	20
0	132	4	4	140
T	134	18	40	192

ELEMENT 6/1

TEST Straight Line/Curve

P = 0.0017

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

FIGURES 6.2-6.7

Outline of the Validated Learning Hierarchy

PRELIMINARY NOTES

1. The following figures present an outline of each validated (and rejected) connection for the final testing version of the postulated learning hierarchy. The classification and definition for each element or basic skill is outlined in Tables 5/4-5/10 (Chapter V), and abbreviations used for the relevant subdivisional conditions are listed in the preliminary notes for Tables 6/4-6/25.

2. Lines representing hierarchical connections are classified according to the following key.

   Connection accepted as valid at the absolute H_o level.

   Connection accepted as valid at "weaker" (0.01 and 0.02) Ho levels.

   Connection rejected as invalid at all three specified Ho levels.

3. The reversal of Horizontal and Vertical subdivisional classification groups for Element 1/1(B) reflects the reference in this case to given, rather than required co-ordinates.

FIGURE 6.2

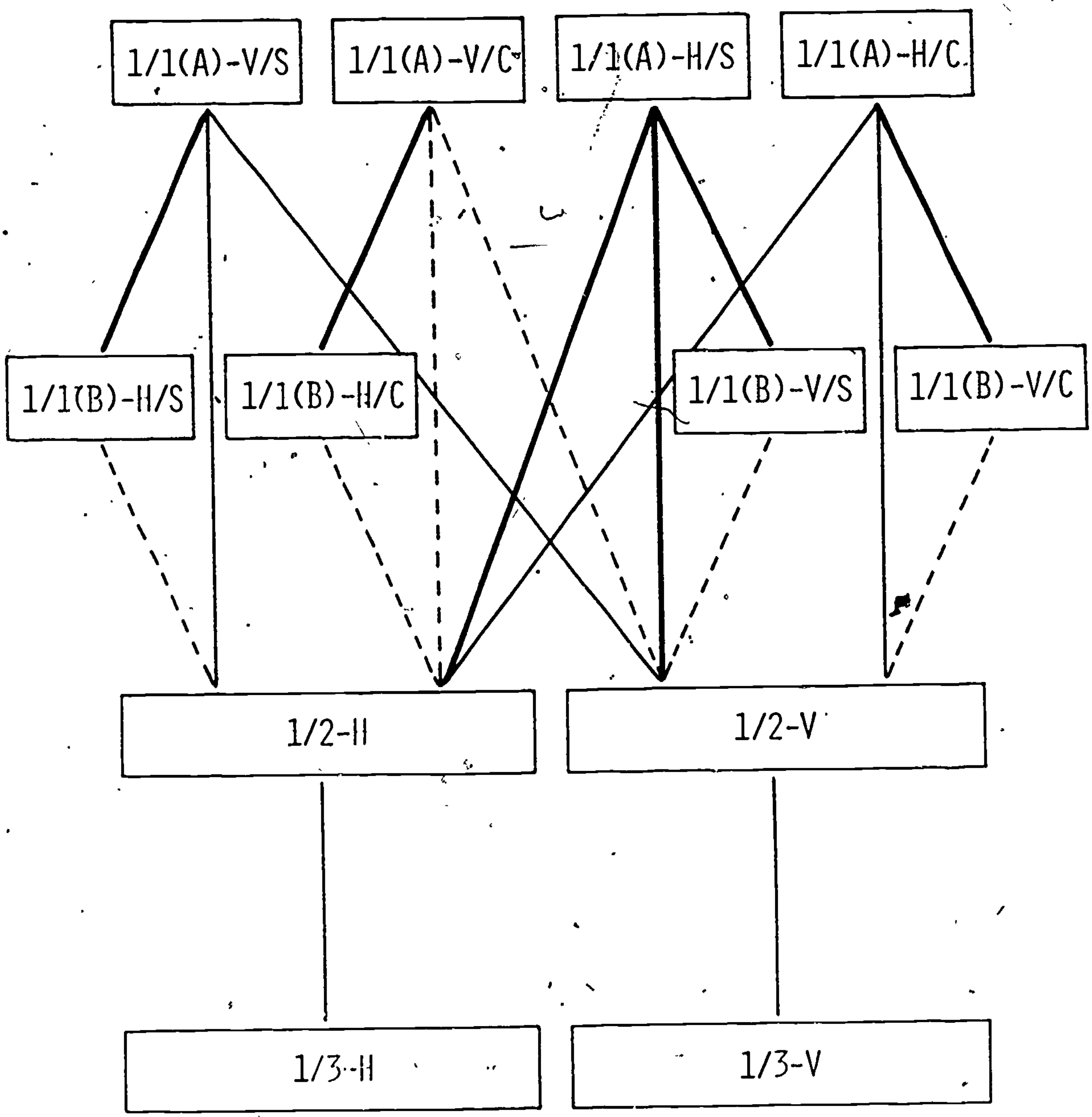

1/1(A)-V/S
1/1(A)-V/C
1/1(A)-H/S
1/1(A)-H/C
1/1(B)-H/S
1/1(B)-H/C
1/1(B)-V/S
1/1(B)-V/C
1/2-H
1/2-V
1/3-H
1/3-V

FIGURE 6.3

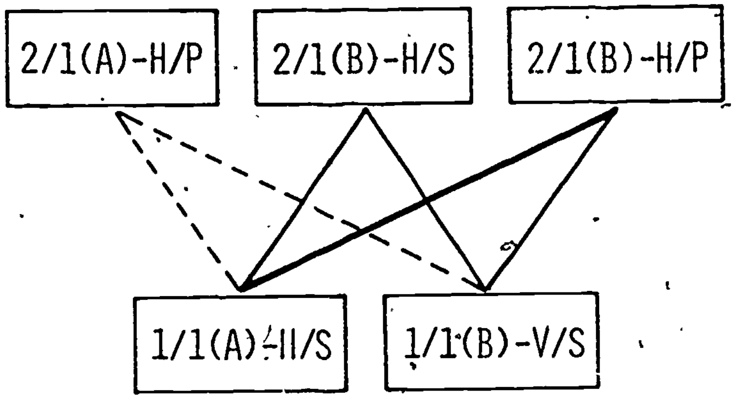


FIGURE 6.4

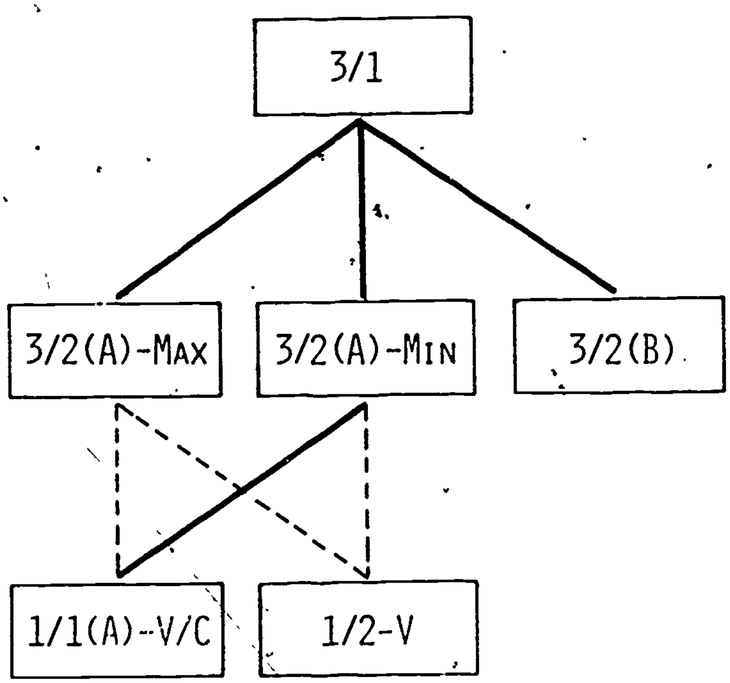


FIGURE 6.5

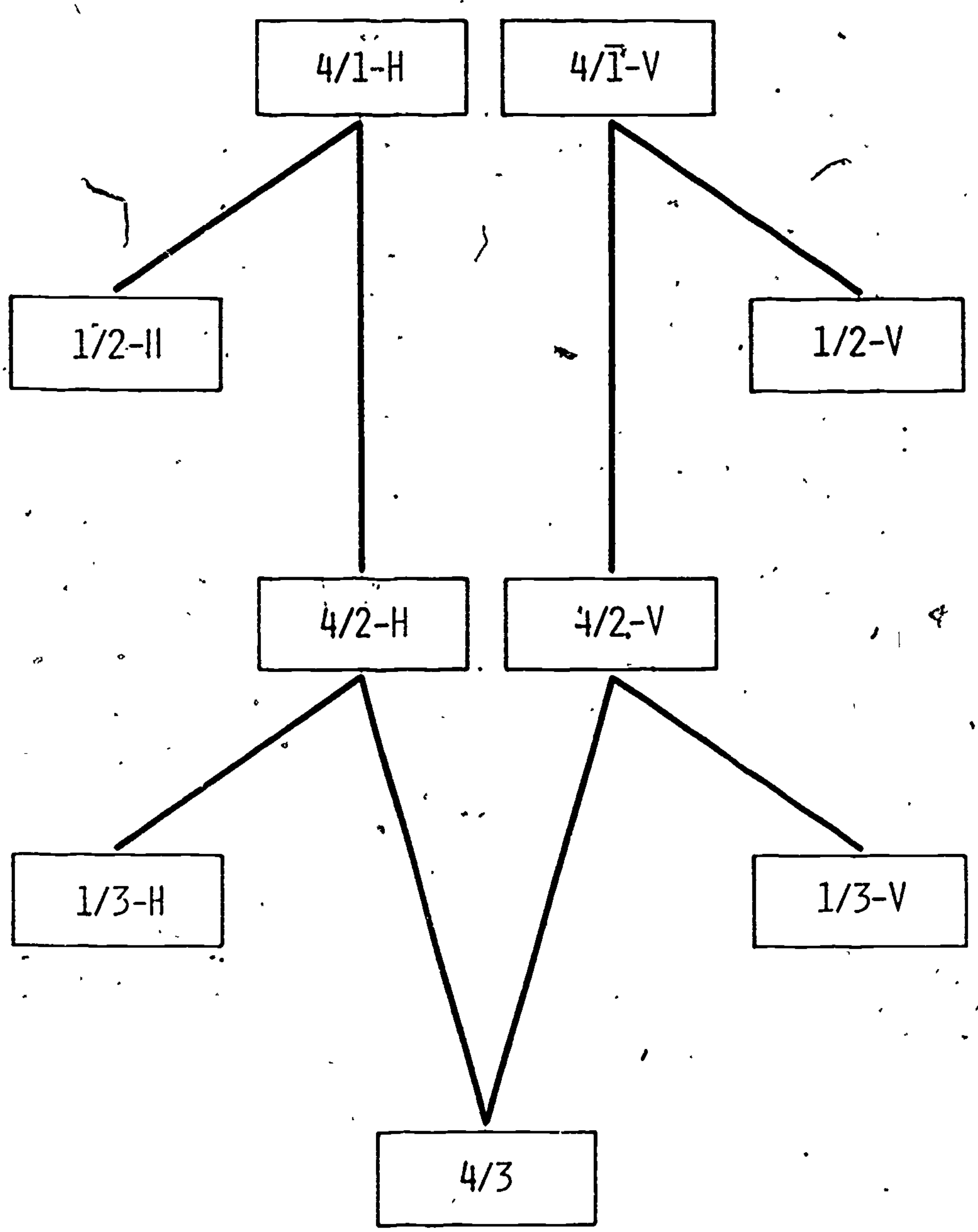


FIGURE 6.6

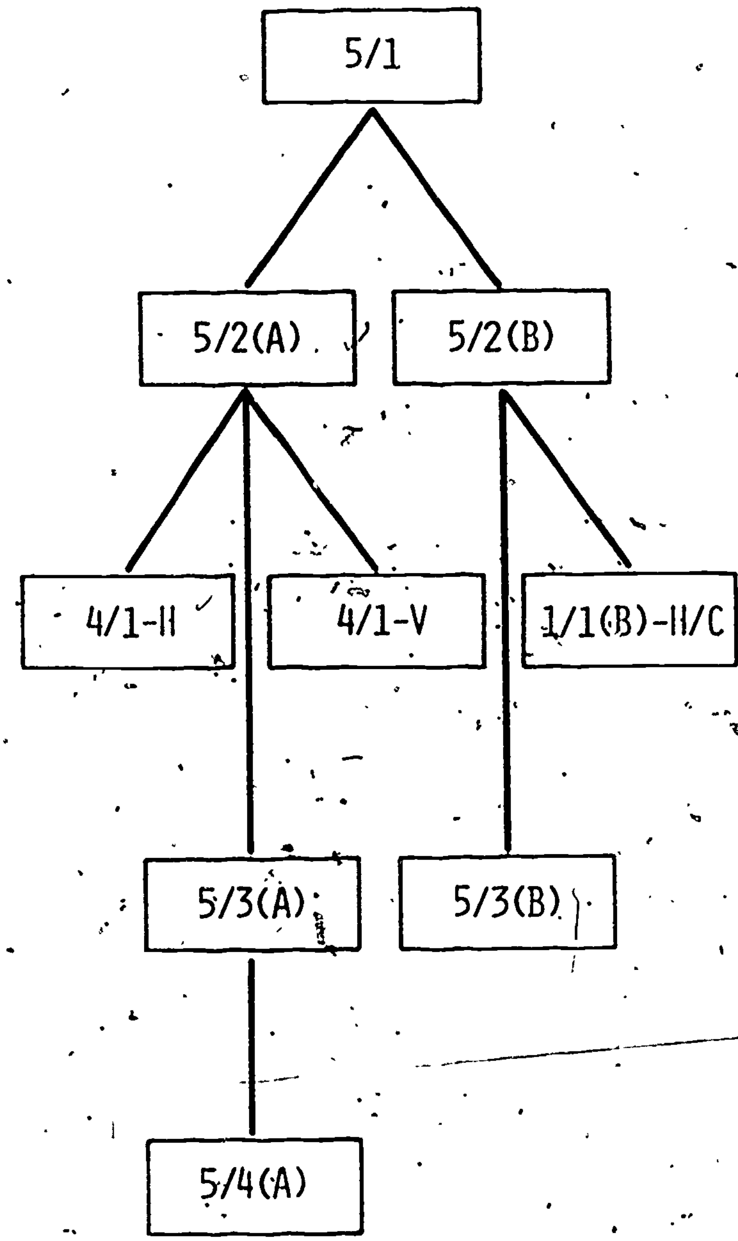
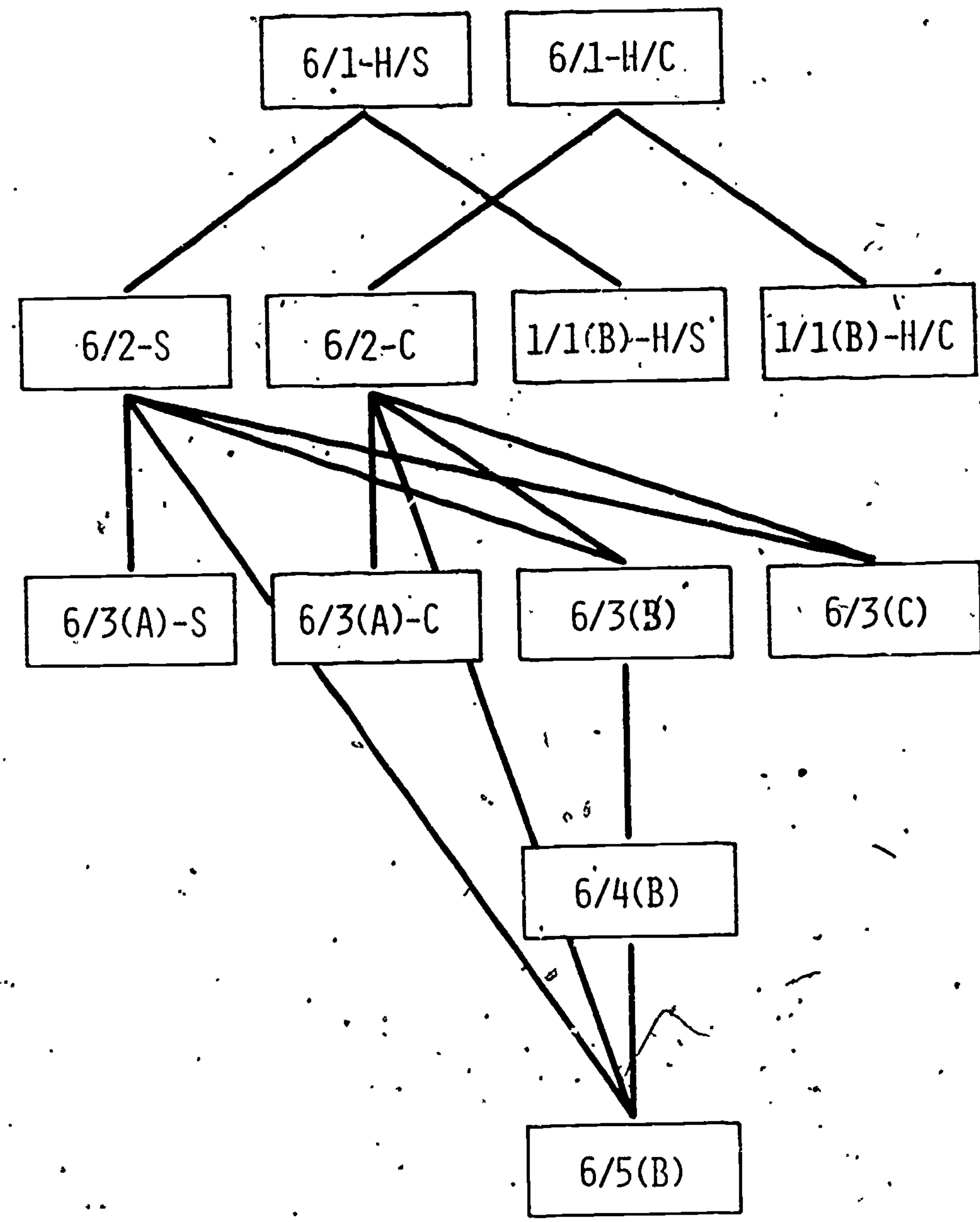


FIGURE 6.7



CHAPTER VII

THE EFFECTS OF A DIFFERENT INFORMATIONAL MODEL ON THE POSTULATED LEARNING HIERARCHY

1. Introduction

The application of graphical interpretation skills to different informational models involves, apart from the use of basic measurement and computational procedures as defined in Chapter V, the recognition or selection of appropriate interpretative skills. This in turn requires some meaningful translation or understanding of specific terms (such as length, height, time or rate of change) associated with each type of informational model. In other words, the generalisation of graphical interpretation skills requires mastery of both the basic intellectual abilities and more specific elements of terminology or verbalised knowledge. The obvious question arising from this assertion is that, given the appropriate elements of verbalised knowledge for a particular informational model, is the learning sequence of basic intellectual skills, directed toward analogous terminal abilities, the same as that for the corresponding symbolic or general abstract model (outlined and examined respectively in Chapters V and VI)?

The question of analogous learning hierarchies for different informational models has never been rigorously examined, and in fact it seems to be assumed in a number of research reports and current curriculum programmes (reviewed in Chapter II) that the same hierarchical sequence is appropriate for any type of informational model. The experimental Graph Skills Program reported by Smith (1970) uses a variety of models to teach and test each fundamental skill in the development and attempted validation of a comprehensive learning sequence. However these informational models are collectively, rather than individually examined in the analysis of hierarchical relationships, and are not consistently grouped in the same systematic pattern or set for each of the basic skills. Thus the validation programme involves a relatively complex mixture of informational models, and each hierarchical connection may involve a different set.

The General courses of instruction on graphical interpretation skills outlined in Chapter II (see courses 1-6 in Table 2/4) also involve an extensive range of informational models, and although specific variables and units may be different for each of these models, the basic intellectual or interpretative skills are assumed to be the same. The Service courses (I.S.C.S., B.S.C.S., A.S.E.P.) are by contrast more limited in scope, and give particular emphasis to a few specific informational models, but again the instructional sequence of basic intellectual skills is assumed to be independent of the more specific informational context.

The evidence given by White (1971), relating to the restricted subordinate role of verbalised knowledge elements with respect to general intellectual skills, is consistent with the assumption outlined above of a common hierarchical sequence of basic intellectual skills for a range of different informational models. Since it is shown by White that elements of specific terminology (verbalised knowledge) can only take a limited subordinate role in complex learning hierarchies, it would seem that they are essentially independent of the system of intellectual skills, and could therefore be adapted, without affecting the basic hierarchical structure, to any specific informational model. The relevant limitation of White's study, however, is that only one such model is examined.

In accordance with the research implications and assumptions outlined above, it was decided to examine, by means of a parallel validation study, the effect of a different informational model on the sequence of basic graphical interpretation skills defined in Chapter V. The selection of a suitable model, and the preparation and administration of the appropriate validation programme, are discussed below in section 2.

2. The Preparation and Administration of Validation Programme II

The selection of a suitable alternative informational model for the analysis of basic graphical interpretation skills involved a number of important considerations. It was essential, for example, that the model should be realistic in both general concept and numerical detail, and interpretable in a meaningful sense at the form 1 testing level. Moreover it was necessary that this condition of meaningful interpretation should apply to each of the previously defined interpretative areas. It was decided, therefore, to use some form of rate/time graphical model, for which the area could be meaningfully interpreted as total amount/given time, although the gradient (rate of change in given rate) might be relatively difficult to explain. This model was based on a population concept, initiated by the recent international interest in Environmental Education, and involved the major variables of Time (Horizontal Axis) and Annual

Birth Rate (Vertical Axis).

Apart from the obvious differences with respect to specific terminology, which was always explained on first occurrence and illustrated by example, the validation programme constructed for this model (see Programme II in Volume III) was identical to that for the abstract model examined in Chapter VI. Certain differences in symbolic notation were also required for Programme II, and these symbols were used extensively throughout the validation programme, but again they were explained and illustrated on first occurrence. The sequence of basic and subdivisional skills, which was identical to that for Programme I, has already been outlined in Table 6/1, and the classification of relevant subdivisional skills in Table 6/2 (Chapter VI).

The administration of Programme II involved a total of 211 form 1 students from twelve randomly selected co-educational high schools in Melbourne. The total testing sample involved approximately equal numbers of male and female students, ranging in age from 11 to 14 years (taken to the nearest year) with a mean of 12.6. The number of students involved from each participating school is shown in Table 7/1. For most of these schools only half a class of students was involved, while as explained for Programme I in Chapter VI, the rest of the class were simultaneously engaged in one of the alternative validation programmes.

TABLE 7/1

Sample Numbers and Completion Times for Validation

Programme II

HIGH SCHOOL	Number of Students in Sample	Shortest Completion Time (minutes)	Longest Completion Time (minutes)
Altona North	20	61	114
Blackburn	21	55	108
Brighton	14	53	114
Caulfield	16	49	102
Collingwood	11	42	107
Dandenong	15	58	106
Donvale	15	45	86
Frankston	18	62	113
Moorabbin	31	37	84
Moorleigh	20	52	110
Vermont	14	54	108
Waverley	16	49	135
Mean Completion Time		51.4	107.3
Standard Deviation		7.5	13.2

The conditions of administration for the second validation programme were, along with the characteristics of the sampling population mentioned above, analogous to those for Programme I, and involved consecutive presentation of the three constituent sections with periodic breaks for concentration relief. A list of the shortest and longest completion times for each participating class is presented in Table 7/1. These times show marginally smaller variations than those for Programme I (Table 6/3), but the mean values are not significantly different at the 0.05 level (t-test for difference of sample means - see Glass and Stanley 1970). The progress curve for Programme II (Figure 7.1) is also similar to that for the first validation programme (Figure 6.1), although in this case the rate appears to increase beyond the 25-minute mark, rather than continue in the same expected linear trend.

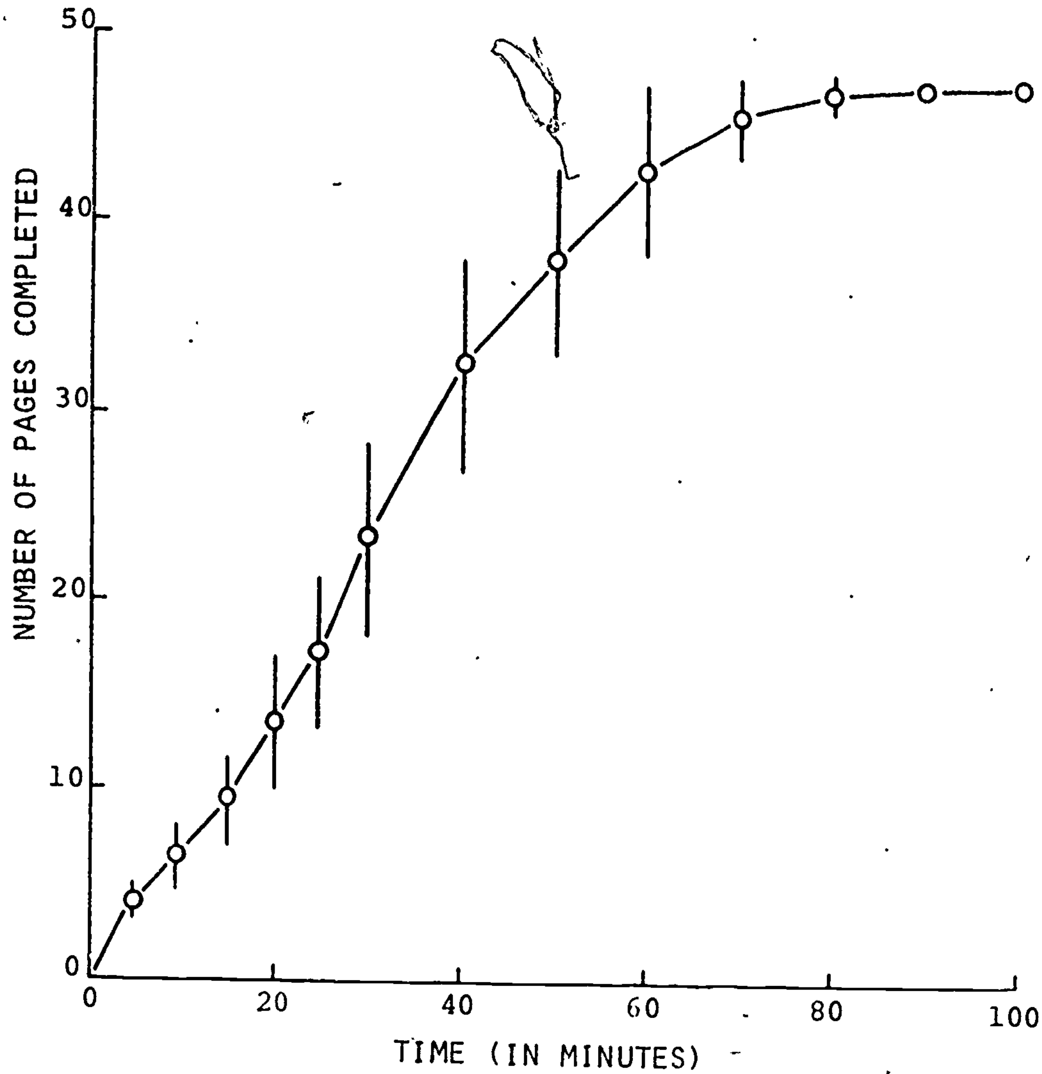
3. <u>Results and Implications of Validation Programme II</u>

The results for the second validation programme were subjected to the same statistical analysis as those for Programme I (Chapter 6). Thus each of the postulated hierarchical connections was tested at three different null hypothesis levels, with the individual probability of a Type I error given by $\alpha = 0.00087$. The results of this analysis are presented in Tables 7/2-7/23, and those for the subsequent analysis of relevant subdivisional skills are outlined in Tables 7/24-7/28. In the latter case $\alpha = 0.0026$ for each of the 20 comparative tests.

FIGURE 7.1

Progression Rate for Programme II

(Moorabbin High School)



NOTES

1. Circles represent the mean number of pages completed at specified times.
2. Vertical lines represent the appropriate Standard Deviation.
3. Number of students involved = 31.

In general the number of exceptions observed for each of the postulated hierarchical connections was lower for this validation study than in the previous case (Programme I). Thus most of the postulated connections were accepted as valid at the absolute Ho level, since the levels of response inconsistency, and hence the calculated critical numbers in the 0/2 cells of the relevant correlation tables, were in most cases similar for both validation programmes. From a review of predominant errors, it seems that the drop in exceptions for Programme II was probably attributable to less confusion between Horizontal and Vertical co-ordinates, with the differential axis labels of Time and Annual Birth Rate apparently producing more effective discrimination, at least with respect to positional skills (areas 1-3). As a corollary of the generally fewer exceptions to the postulated learning hierarchy, only one of the test/retest correlation tables (representing element 1/1(A) in Table 7/12(C)) indicated a significant level of learning during practice at subsequent higher-order skills.

Perhaps the most prominent difference in results between Programmes I and II was that concerning the postulated connection between elements 1/2 and 1/1(B). This relationship was tested (in both validation programmes) in four parallel situations under different subdivisional conditions, and was rejected under all conditions in Programme I, but accepted for each case in Programme II (Figure 7.2). Similar discrepancies were observed for the connections between element 2/1(A) and its postulated subordinate skills (Figure 7.3), and for the various interrelationships between elements 1/2, 1/1(A) and 3/2(A) (Figure 7.4). Each of these postulated relationships was rejected as invalid under one or more of the tested subdivisional conditions in Programme I, but all were accepted in Programme II at one of the various null hypothesis levels, although in some cases the power was relatively low.

Similar results were obtained in both validation programmes for all of the postulated connections in areas 4-6 (Figures 7.5-7.7). For a few of the more difficult skills, however, the calculated power was extremely low, reflecting in part the response inconsistencies for both validation programmes, but more significantly the difficulty levels of the higher or more complex skills. With respect to element 5/1, for example, only three students answered both questions correctly in Programme II (Table 7/17(C)), so that in this case the null and alternative hypotheses were effectively the same, and thus the statistical test was rendered ineffective by the total loss of power. In cases such as this, the final judgement of validity can only be subjective.

The results of the subdivisional analysis for the second validation programme are generally similar to those for Programme I, and thus consistent with the earlier analysis outlined in Chapter IV. In contrast with the Programme I results, however, the difference in Programme II between Horizontal and Vertical co-ordinate subdivisions in elements 1/2 and 1/3 is maintained in both retesting situations. The results for elements 6/2 and 6/3(A) are also different for each programme, but since the general analytical pattern for area 6 is internally inconsistent for both validation programmes, these discrepancies are probably not important.

The difficulty levels for each of the corresponding elements show considerable variations between Programmes I and II. In most cases the difficulty levels are substantially lower for Programme II, but for elements 3/1 and 5/2(A) they are approximately the same, and for elements 5/1, 6/3(B), 6/2 and 6/1 they are higher than the relevant levels for Programme I. It seems, from a review of predominant errors, that although the specific axis labels used in Programme II are generally an advantage for positional and displacement skills, the derivative terms for gradient (rate of change in Annual Birth Rate) and area (total number of births/100 people) are apparently more confusing than the corresponding general or symbolic terms.

The results of this analysis, together with that discussed in Chapter VI, clearly show that the hierarchical network of basic graphical interpretation skills is substantially the same for both general and specific informational models. Thus in spite of certain discrepancies with respect to positional skills (areas 1-3), which may simply be a product of more general inconsistencies observed in the relevant section of Programme I, the overall pattern of basic intellectual skills is independent of the more specific terminology and symbolic notation associated with individual elements, although this may affect the relevant difficulty levels. This result is consistent with the implications of previous research by White (1971), and with the assumptions (outlined in section 1) of current curriculum programmes on graphical interpretation.

The research outlined above has important implications with respect to graphical interpretation skills for both curriculum development and associated classroom practice, since it establishes an empirical basis for the use of a common instructional sequence of general interpretative skills, which may be related at each level to a range of more specific informational models, or more meaningful situations. Thus the same hierarchical structure of intellectual skills may be used to cover an almost infinite range of specific interpretative tasks, provided that the relevant notation or terminology is understood.

In spite of this potential generalisation, however, the determination of independent subdivisional skills within each of the basic intellectual abilities remains an important limiting factor, and restricts the use of any basic skill, in both general and specific informational context, to the relevant subdivisional or instructional conditions. One of the most important subdivisional conditions within the postulated learning hierarchy is that of numerical range (outlined and established for various elements in Chapter IV), which applies to, and thus restricts the use of almost every basic skill. The extension of this range from integral to decimal numbers should therefore expand the generalisation potential of each relevant ability, but may also increase the resultant computational complexity. The specific effects of this change on the postulated learning hierarchy are examined in Chapter VIII by means of an additional complementary validation study.

TABLES 7/2-7/23

Validation Results for Programme II

(Victoria)

PRELIMINARY NOTES

1. The following tables present the results for each of the postulated hierarchical connections between basic and subdivisional skills incoporated in Programme II. These results are presented in correlation matrix form, listing the number of questions correct for each element, and the appropriate marginal totals.

2. The critical number of exceptions (C) permitted in the 0/2 cell of the relevant correlation table is listed, together with the appropriate statistical power, for each of the null hypothesis levels defined in Chapter VI (see preliminary notes for Tables 6/4-6/25).

3. The classification code for each element is outlined in Tables 5/4-5/10, and the relevant subdivisional conditions are presented in Tables 6/4-6/25 (preliminary notes).

4. Element 6/3(C) (not previously defined in Chapter V) involves the skill of counting sqaures on a two-dimensional grid.

TABLE 7/2

(A) ELEMENT 1/2-H

ELEMENT 1/3-H	0	1	2	T
2	21	14	159	194
1	3	0	8	11
0	3	3	0	6
T	27	17	167	211

Ho	C	POWER
0.00	4	0.9997
0.01	8	0.9809
0.02	11	0.8797

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 1/2-V

ELEMENT 1/3-V	0	1	2	T
2	16	22	164	202
1	2	0	2	4
0	2	2	1	5
T	20	24	167	211

Ho	C	POWER
0.00	4	0.9990
0.01	8	0.9558
0.02	10	0.8612

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 1/1(B)-V/S

ELEMENT 1/2-V	0	1	2	T
2	26	15	126	167
1	9	2	13	24
0	11	3	6	20
T	46	20	145	211

Ho	C	POWER
0.00	6	0.9939
0.01	9	0.9379
0.02	11	0.8266

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 7/3

(A) ELEMENT 1/1(A)-H/S

ELEMENT 1/1(B)-V/S		0	1	2	T
	2	16	2	127	145
	1	8	12	0	20
	0	42	4	0	46
	T	66	18	127	211

Ho	C	POWER
0.00	6	0.9837
0.01	8	0.9285
0.02	11	0.7055

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 1/1(A)-H/S

ELEMENT 1/2-V		0	1	2	T
	2	41	15	111	167
	1	11	1	12	24
	0	14	2	4	20
	T	66	18	127	211

Ho	C	POWER
0.00	5	0.9920
0.01	8	0.9154
0.02	10	0.7724

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 1/1(A)-H/S

ELEMENT 1/2-H		0	1	2	T
	2	36	13	118	167
	1	10	0	7	17
	0	20	5	2	27
	T	66	18	127	211

Ho	C	POWER
0.00	4	0.9971
0.01	7	0.9524
0.02	10	0.7605

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 7/4

(A)

ELEMENT 1/1(B)-H/S (columns); ELEMENT 1/2-H (rows)

	0	1	2	T
2	7	12	148	167
1	7	2	8	17
0	12	10	5	27
T	26	24	161	211

Ho	C	POWER
0.00	10	0.9570
0.01	12	0.8746
0.02	14	0.7280

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B)

ELEMENT 1/1(A)-V/S (columns); ELEMENT 1/1(B)-H/S (rows)

	0	1	2	T
2	4	6	151	161
1	8	16	0	24
0	21	5	0	26
T	33	27	151	211

Ho	C	POWER
0.00	9	0.9641
0.01	12	0.8232
0.02	14	0.6485

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C)

ELEMENT 1/1(A)-V/S (columns); ELEMENT 1/2-H (rows)

	0	1	2	T
2	12	13	142	167
1	7	4	6	17
0	14	10	3	27
T	33	27	151	211

Ho	C	POWER
0.00	9	0.9598
0.01	11	0.8766
0.02	14	0.6281

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 7/5

(A) ELEMENT 1/1(A)-V/S

ELEMENT 1/2-V		0	1	2	T
	2	17	16	134	167
	1	8	4	12	24
	0	8	7	5	20
	T	33	27	151	211

Ho	C	POWER
0.00	8	0.9760
0.01	11	0.8587
0.02	13	0.6956

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 1/1(B)-V/C

ELEMENT 1/2-V		0	1	2	T
	2	18	3	146	167
	1	7	2	15	24
	0	12	3	5	20
	T	37	8	166	211

Ho	C	POWER
0.00	5	0.9996
0.01	9	0.9810
0.02	12	0.8875

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 1/1(A)-H/C

ELEMENT 1/1(B)-V/C		0	1	2	T
	2	16	7	143	166
	1	4	4	0	8
	0	33	4	0	37
	T	53	15	143	211

Ho	C	POWER
0.00	4	0.9991
0.01	8	0.9596
0.02	10	0.8705

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 7/6

(A) ELEMENT 1/1(A)-H/C

ELEMENT 1/2-V	0	1	2	T
2	29	12	126	167
1	9	2	13	24
0	15	1	4	20
T	53	15	143	211

Ho	C	Power
0.00	5	0.9976
0.01	8	0.9645
0.02	11	0.8146

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 1/1(A)-H/C

ELEMENT 1/2-H	0	1	2	T
2	22	13	132	167
1	10	1	6	17
0	21	1	5	27
T	53	15	143	211

Ho	C	Power
0.00	5	0.9973
0.01	8	0.9612
0.02	11	0.8031

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 1/1(B)-H/C

ELEMENT 1/2-H	0	1	2	T
2	12	4	151	167
1	8	1	8	17
0	21	1	5	27
T	41	6	164	211

Ho	C	Power
0.00	4	0.9999
0.01	8	0.9884
0.02	11	0.9169

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level.

TABLE 7/7

(A)

ELEMENT 1/1(A)-V/C (columns); ELEMENT 1/1(B)-H/C (rows)

	0	1	2	T
2	8	1	155	164
1	2	4	0	6
0	38	3	0	41
T	48	8	155	211

Ho	C	POWER
0.00	3	0.9999
0.01	7	0.9900
0.02	10	0.9186

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B)

ELEMENT 1/1(A)-V/C (columns); ELEMENT 1/2-H (rows)

	0	1	2	T
2	19	4	144	167
1	6	3	8	17
0	23	1	3	27
T	48	8	155	211

Ho	C	POWER
0.00	4	0.9997
0.01	8	0.9800
0.02	11	0.8756

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C)

ELEMENT 1/1(A)-V/C (columns); ELEMENT 1/2-V (rows)

	0	1	2	T
2	26	3	138	167
1	10	1	13	24
0	12	4	4	20
T	48	8	155	211

Ho	C	POWER
0.00	5	0.9991
0.01	8	0.9828
0.02	11	0.8882

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 7/8

(A) ELEMENT 2/1(A)-H/P

ELEMENT 1/1(A)-H/S	0	1	2	T
2	25	7	95	127
1	11	2	5	18
0	42	13	11	66
T	78	22	111	211

Ho	C	POWER
0.00	6	0.9634
0.01	9	0.7834
0.02	11	0.5663

CONCLUSION The postulated connection is accepted as valid at the third (0.02) Ho level, although the power at this level is particularly low.

(B) ELEMENT 2/1(A)-H/P

ELEMENT 1/1(B)-V/S	0	1	2	T
2	31	10	104	145
1	13	2	5	20
0	34	10	2	46
T	78	22	111	211

Ho	C	POWER
0.00	6	0.9556
0.01	8	0.8448
0.02	10	0.6464

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 2/1(B)-H/S

ELEMENT 1/1(A)-H/S	0	1	2	T
2	33	24	70	127
1	12	4	2	18
0	49	11	6	66
T	94	39	78	211

Ho	C	POWER
0.00	8	0.6008
0.01	10	0.3417
0.02	11	0.2344

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLE 7/9

(A) ELEMENT 2/1(B)-H/S

ELEMENT 1/1(B)-V/S		0	1	2	T
	2	46	26	73	145
	1	12	8	0	20
	0	36	5	5	46
	T	94	39	78	211

Ho	C	POWER
0.00	7	0.6573
0.01	8	0.5205
0.02	10	0.2680

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B) ELEMENT 2/1(B)-H/P

ELEMENT 1/1(A)-H/S		0	1	2	T
	2	43	21	63	127
	1	14	0	4	18
	0	53	6	7	66
	T	110	27	74	211

Ho	C	POWER
0.00	6	0.7176
0.01	7	0.5804
0.02	9	0.3088

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is particularly low.

(C) ELEMENT 2/1(B)-H/P

ELEMENT 1/1(B)-V/S		0	1	2	T
	2	56	22	67	145
	1	16	2	2	20
	0	38	3	5	46
	T	110	27	74	211

Ho	C	POWER
0.00	5	0.8108
0.01	7	0.5448
0.02	8	0.4025

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

TABLE 7/10

(A)

ELEMENT 3/2(A)-Max.

ELEMENT 1/2-V	0	1	2	T
2	37	44	93	174
1	5	5	8	18
0	9	6	4	19
T	51	55	105	211

Ho	C	POWER
0.00	9	0.5970
0.01	10	0.4700
0.02	12	0.2451

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B)

ELEMENT 3/2(A)-Max.

ELEMENT 1/1(A)-V/C	0	1	2	T
2	29	39	94	162
1	8	4	3	15
0	14	12	8	34
T	51	55	105	211

Ho	C	POWER
0.00	12	0.4502
0.01	13	0.3396
0.02	15	0.1657

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C)

ELEMENT 3/2(A)-Min.

ELEMENT 1/2-V	0	1	2	T
2	40	37	97	174
1	6	5	7	18
0	10	8	1	19
T	56	50	105	211

Ho	C	POWER
0.00	8	0.7255
0.01	9	0.6056
0.02	11	0.3579

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

TABLE 7/11

(A) ELEMENT 3/2(A)-Max.

ELEMENT 1/1(A)-V/C	0	1	2	T
2	30	35	97	162
1	7	5	3	15
0	19	10	5	34
T	56	50	105	211

Ho	C	POWER
0.00	10	0.6457
0.01	12	0.4097
0.02	13	0.3022

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B) ELEMENT 3/1

ELEMENT 3/2(B)	0	1	2	T
2	53	78	43	174
1	8	3	0	11
0	18	8	0	26
T	79	89	43	211

Ho	C	POWER
0.00	10	0.0118
0.01	11	0.0045
0.02	11	0.0045

CONCLUSION. The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 3/1

ELEMENT 3/2(A)-Max.	0	1	2	T
2	22	50	33	105
1	27	22	6	55
0	30	17	4	51
T	79	89	43	211

Ho	C	POWER
0.00	17	0.0034
0.01	17	0.0034
0.02	17	0.0034

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 7/12

(A) ELEMENT 3/1

ELEMENT 3/2(A)-Min.

	0	1	2	T
2	20	51	34	105
1	20	24	6	50
0	39	14	3	56
T	79	89	43	211

Ho	C	POWER
0.00	18	0.0029
0.01	18	0.0029
0.02	18	0.0029

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 1/2-V (Retest)

ELEMENT 1/2-V

	0	1	2	T
2	9	13	145	167
1	1	4	19	24
0	9	1	10	20
T	19	18	174	211

Ho	C	POWER
0.00	9	0.9870
0.01	12	0.9144
0.02	14	0.7970

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

(C) ELEMENT 1/1(A)-V (Retest)

ELEMENT 1/1(A)-V

	0	1	2	T
2	4	8	143	155
1	5	0	3	8
0	25	7	16	48
T	34	15	162	211

Ho	C	POWER
0.00	7	0.9963
0.01	10	0.9608
0.02	13	0.8210

CONCLUSION This skill was acquired by a significant proportion of students in the process of attempting more complex capabilities.

TABLE 7/13

(A) ELEMENT 4/2-H

ELEMENT 4/3

	0	1	2	T
2	35	5	164	204
1	2	0	1	3
0	3	1	0	4
T	40	6	165	211

Ho	C	POWER
0.00	1	1.0000
0.01	7	0.9939
0.02	10	0.9433

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 4/2-V

ELEMENT 4/3

	0	1	2	T
2	30	6	168	204
1	2	0	1	3
0	4	0	0	4
T	36	6	169	211

Ho	C	POWER
0.00	1	1.0000
0.01	7	0.9953
0.02	10	0.9530

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 4/2-H

ELEMENT 1/3-H

	0	1	2	T
2	35	5	164	204
1	2	1	1	4
0	3	0	0	3
T	40	6	165	211

Ho	C	POWER
0.00	1	1.0000
0.01	7	0.9939
0.02	10	0.9433

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 7/14

(A) ELEMENT 4/2-V

ELEMENT 1/3-V	0	1	2	T
2	29	5	169	203
1	0	0	0	0
0	7	1	0	8
T	36	6	169	211

Ho	C	POWER
0.00	2	1.0000
0.01	7	0.9953
0.02	10	0.9534

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 4/1-H

ELEMENT 4/2-H	0	1	2	T
2	17	17	131	165
1	2	0	4	6
0	27	6	7	40
T	46	23	142	211

Ho	C	POWER
0.00	7	0.9848
0.01	10	0.8901
0.02	12	0.7411

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 4/1-V

ELEMENT 4/2-V	0	1	2	T
2	9	16	144	169
1	1	2	3	6
0	27	5	4	36
T	37	23	151	211

Ho	C	POWER
0.00	8	0.9813
0.01	10	0.9296
0.02	13	0.7331

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 7/15

(A) ELEMENT 4/1-H

ELEMENT 1/2-H	0	1	2	T
2	21	18	137	176
1	7	0	4	11
0	18	5	1	24
T	46	23	142	211

Ho	C	POWER
0.00	6	0.9909
0.01	8	0.9553
0.02	11	0.7836

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 4/1-V

ELEMENT 1/2-V	0	1	2	T
2	15	10	136	161
1	4	5	13	22
0	18	8	2	28
T	37	23	151	211

Ho	C	POWER
0.00	8	0.9816
0.01	11	0.8826
0.02	13	0.7352

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 5/3(Λ)

ELEMENT 5/4(Λ)	0	1	2	T
2	41	5	111	157
1	3	1	2	6
0	38	7	3	48
T	82	13	116	211

Ho	C	POWER
0.00	3	0.9978
0.01	6	0.9529
0.02	9	0.7454

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 7/16

(A) ELEMENT 5/2(A)

ELEMENT 5/3 (A)		0	1	2	T
	2	75	8	33	116
	1	11	0	2	13
	0	77	3	2	82
	T	163	11	37	211

Ho	C	POWER
0.00	3	0.5399
0.01	4	0.3432
0.02	5	0.1915

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B) ELEMENT 5/2(A)

ELEMENT 4/1-H		0	1	2	T
	2	97	8	30	135
	1	18	0	5	23
	0	48	3	2	53
	T	163	11	37	211

Ho	C	POWER
0.00	3	0.5561
0.01	4	0.3589
0.02	5	0.2037

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C) ELEMENT 5/2(A)

ELEMENT 4/1-V		0	1	2	T
	2	105	9	34	148
	1	9	0	0	9
	0	49	2	3	54
	T	163	11	37	211

Ho	C	POWER
0.00	2	0.7278
0.01	4	0.3247
0.02	5	0.1775

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is extremely low.

TABLE 7/17

(A) ELEMENT 5/2(B) × ELEMENT 5/3(B)

ELEMENT 5/3 (B)	0	1	2	T
2	27	2	92	121
1	12	5	4	21
0	65	3	1	69
T	104	10	97	211

Ho	C	POWER
0.00	5	0.9494
0.01	7	0.8168
0.02	9	0.5897

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 5/2(B) × ELEMENT 1/1(B)-H/C

ELEMENT 1/1(B)-H/C	0	1	2	T
2	64	9	89	162
1	7	1	8	16
0	33	0	0	33
T	104	10	97	211

Ho	C	POWER
0.00	3	0.9913
0.01	6	0.8707
0.02	8	0.6631

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 5/1 × ELEMENT 5/2(B)

ELEMENT 5/2 (B)	0	1	2	T
2	76	18	3	97
1	7	3	0	10
0	94	10	0	104
T	177	31	3	211

Ho	C	POWER
0.00	4	0.0017
0.01	4	0.0017
0.02	4	0.0017

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 7/18

(A) ELEMENT 5/1

ELEMENT 5/2(A)	0	1	2	T
2	19	10	3	32
1	10	8	0	18
0	148	13	0	161
T	177	31	3	211

Ho	C	POWER
0.00	5	0.0012
0.01	5	0.0012
0.02	5	0.0012

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 4/1-H (Retest)

ELEMENT 4/1-H	0	1	2	T
2	9	15	118	142
1	6	3	14	23
0	38	5	3	46
T	53	23	135	211

Ho	C	POWER
0.00	8	0.9662
0.01	10	0.1174
0.02	13	0.6379

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

(C) ELEMENT 4/1-V (Retest)

ELEMENT 4/1-V	0	1	2	T
2	10	6	135	151
1	9	2	12	23
0	35	1	1	37
T	54	9	148	211

Ho	C	POWER
0.00	5	0.9986
0.01	8	0.9761
0.02	11	0.8592

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

TABLE 7/19

(A) ELEMENT 5/2(A) (Retest)

ELEMENT 5/2(A)

	0	1	2	T
2	7	2	28	37
1	5	2	4	11
0	149	14	0	163
T	161	18	32	211

Ho	C	POWER
0.00	5	0.2246
0.01	6	0.1162
0.02	7	0.0537

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

(B) ELEMENT 6/4(B)

ELEMENT 6/5(B)

	0	1	2	T
2	30	23	151	204
1	1	1	4	6
0	1	0	0	1
T	32	24	155	211

Ho	C	POWER
0.00	2	0.9999
0.01	7	0.9729
0.02	9	0.9000

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 6/3(B)

ELEMENT 6/4(B)

	0	1	2	T
2	65	10	80	155
1	15	2	7	24
0	25	6	1	32
T	105	18	88	211

Ho	C	POWER
0.00	4	0.9569
0.01	7	0.7125
0.02	8	0.5831

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 7/20

(A) ELEMENT 6/2-S

ELEMENT 6/3(B)

	0	1	2	T
2	22	14	29	65
1	15	2	0	17
0	124	3	2	129
T	161	19	31	211

Ho	C	POWER
0.00	5	0.1829
0.01	6	0.0890
0.02	6	0.0890

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 6/2-S

ELEMENT 6/3(A)-S

	0	1	2	T
2	33	10	31	74
1	26	9	0	35
0	102	0	0	102
T	161	19	31	211

Ho	C	POWER
0.00	6	0.1481
0.01	7	0.0727
0.02	8	0.0322

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 6/2-S

ELEMENT 6/5(B).

	0	1	2	T
2	109	17	26	152
1	38	1	4	43
0	14	1	1	16
T	161	19	31	211

Ho	C	POWER
0.00	4	0.2744
0.01	5	0.1412
0.02	6	0.0639

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 7/21

(A) ELEMENT 6/2-C

ELEMENT 6/3(B)	0	1	2	T
2	28	16	25	69
1	7	2	1	10
0	129	2	1	132
T	164	20	27	211

Ho	C	POWER
0.00	4	0.2137
0.01	5	0.1009
0.02	5	0.1009

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 6/2-C

ELEMENT 6/3(A)-C	0	1	2	T
2	35	13	27	75
1	11	7	0	18
0	118	0	0	118
T	164	20	27	211

Ho	C	POWER
0.00	4	0.2349
0.01	5	0.1145
0.02	6	0.0490

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 6/2-C

ELEMENT 6/5(B)	0	1	2	T
2	110	18	24	152
1	39	2	2	43
0	15	0	1	16
T	164	20	27	211

Ho	C	POWER
0.00	4	0.1914
0.01	4	0.1914
0.02	5	0.0872

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 7/22

(A) ELEMENT 6/1-H/S

ELEMENT 6/2-S	0	1	2	T
2	11	5	15	31
1	7	2	10	19
0	160	1	0	161
T	178	8	25	211

Ho	C	POWER
0.00	6	0.0991
0.01	7	0.0387
0.02	7	0.0387

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 6/1-H/C

ELEMENT 6/2-C	0	1	2	T
2	6	5	16	27
1	11	2	7	20
0	161	2	1	164
T	178	9	24	211

Ho	C	POWER
0.00	7	0.0528
0.01	8	0.0219
0.02	8	0.0219

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 6/1-H/S

ELEMENT 1/1(B)-H/S	0	1	2	T
2	134	8	24	166
1	21	0	1	22
0	23	0	0	23
T	178	8	25	211

Ho	C	POWER
0.00	2	0.4793
0.01	3	0.2607
0.02	4	0.1196

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLE 7/23

(A) ELEMENT 6/1-H/C

ELEMENT 1/1(B)-H/C	0	1	2	T
2	147	8	23	178
1	7	1	1	9
0	24	0	0	24
T	178	9	24	211

Ho	C	POWER
0.00	1	0.6965
0.01	3	0.2237
0.02	4	0.0966

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(B) ELEMENT 6/2-S

ELEMENT 6/3(C)	0	1	2	T
2	25	9	31	65
1	28	10	0	38
0	108	0	0	108
T	161	19	31	211

Ho	C	POWER
0.00	7	0.1078
0.01	8	0.0519
0.02	9	0.0227

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 6/2-C

ELEMENT 6/3(C)	0	1	2	T
2	32	7	27	66
1	11	13	0	24
0	121	0	0	121
T	164	20	27	211

Ho	C	POWER
0.00	5	0.1529
0.01	6	0.0708
0.02	7	0.0292

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLES 7/24-7/28

Subdivisional Analysis Results for Programme II

(Victoria)

PRELIMINARY NOTES

1. The following results are presented in correlation matrix form, listing the number of questions correct for each element, and the appropriate marginal totals.

2. The classification code for each element is outlined in Tables 5/4-5/10, and a list of the relevant subdivisional question groups is presented in Table 6/2.

3. P represents the combined probability that the observed number of students in the 0/2 and 2/0 cells could have occurred through chance (or errors of measurement) under the null hypothesis that no-one can possess only one of the relevant subdivisional skills without also having the other.

TABLE 7/24

(A)

GROUP 1 \ GROUP 2	0	1	2	T
2	2	3	189	194
1	1	0	10	11
0	2	1	3	6
T	5	4	202	211

ELEMENT 1/3

TEST H/V (Position)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	4	13	150	167
1	6	7	4	17
0	10	4	13	27
T	20	24	167	211

ELEMENT 1/2

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	17	14	130	161
1	8	6	10	24
0	21	0	5	26
T	46	20	145	211

ELEMENT 1/1(B)

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(D)

GROUP 1 \ GROUP 3	0	1	2	T
2	3	4	154	161
1	15	1	8	24
0	23	1	2	26
T	41	6	164	211

ELEMENT 1/1(B)

TEST Straight Line/Curve

P = 0.0110

CONCLUSION Question groups 1 and 3 may represent the same subdivisional skill.

(A)

		GROUP 4: 0	1	2	T
GROUP 2	2	2	3	140	145
	1	2	4	14	20
	0	33	1	12	46
	T	37	8	166	211

ELEMENT 1/1(B)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 2 and 4 represent different subdivisional skills.

(B)

		GROUP 2: 0	1	2	T
GROUP 1	2	1	6	120	127
	1	4	4	10	18
	0	28	17	21	66
	T	33	27	151	211

ELEMENT 1/1(A)

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

		GROUP 3: 0	1	2	T
GROUP 1	2	2	9	116	127
	1	7	1	10	18
	0	44	5	17	66
	T	53	15	143	211

ELEMENT 1/1(A)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

(D)

		GROUP 4: 0	1	2	T
GROUP 2	2	6	3	142	151
	1	16	1	10	27
	0	26	4	3	33
	T	48	8	155	211

ELEMENT 1/1(A)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 2 and 4 represent different subdivisional skills.

TABLE 7/26

(A)

GROUP 2/1(A)-1 \ GROUP 2/1(B)-2	0	1	2	T
2	27	16	68	111
1	13	6	3	22
0	70	5	3	78
T	110	27	74	211

ELEMENT 2/1(A)-2/1(B)

TEST Interpolation/Extrapolation

P = 0.0000

CONCLUSION Elements 2/1(A) and 2/1(B) represent different basic skills.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	8	15	55	78
1	18	7	14	39
0	84	5	5	94
T	110	27	74	211

ELEMENT 2/1(B)

TEST Line/Points

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	2	8	95	105
1	22	25	8	55
0	32	17	2	51
T	56	50	105	211

ELEMENT 3/2(A)

TEST Max./Min. Values

P = 0.7069

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(D)

GROUP 1 \ GROUP 2	0	1	2	T
2	3	0	201	204
1	3	0	1	4
0	2	0	1	3
T	8	0	203	211

ELEMENT 1/3 (Retest)

TEST H/V (Position)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

TABLE 7/27

(A)

GROUP 1 \ GROUP 2	0	1	2	T
2	4	17	155	176
1	7	3	1	11
0	17	2	5	24
T	28	22	161	211

ELEMENT 1/2 (Retest)

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	3	2	160	165
1	1	0	5	6
0	32	4	4	40
T	36	6	169	211

ELEMENT 4/2

TEST H/V (Displacement)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	1	3	138	142
1	2	10	11	23
0	34	10	2	46
T	37	23	151	211

ELEMENT 4/1

TEST H/V (Displacement)

P = 0.1103

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(D)

GROUP 1 \ GROUP 3	0	1	2	T
2	2	5	159	166
1	2	3	17	22
0	20	1	2	23
T	24	9	178	211

ELEMENT 1/1(B) (Retest)

TEST Straight Line/Curve

P = 0.0011

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

TABLE 7/28

(A)

		GROUP 2: 0	1	2	T
GROUP 1	2	15	41	148	204
	1	0	2	4	6
	0	1	0	0	1
	T	16	43	152	211

ELEMENT 6/5 (B)

TEST Numerical Range

P = 0.0004

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(B)

		GROUP 2: 0	1	2	T
GROUP 1	2	7	9	58	74
	1	14	6	15	35
	0	97	3	2	102
	T	118	18	75	211

ELEMENT 6/3 (A)

TEST Straight Line/Curve

P = 0.0001

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

		GROUP 2: 0	1	2	T
GROUP 1	2	1	11	19	31
	1	4	7	8	19
	0	159	2	0	161
	T	164	20	27	211

ELEMENT 6/2

TEST Straight Line/Curve

P = 0.5057

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(D)

		GROUP 2: 0	1	2	T
GROUP 1	2	3	6	16	25
	1	1	1	6	8
	0	174	2	2	178
	T	178	9	24	211

ELEMENT 6/1

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

FIGURES 7.2-7.7

Outline of the Validated Learning Hierarchy for Programme II

(Victoria)

PRELIMINARY NOTES.

1. The classification code for each basic skill is outlined in Tables 5/4-5/10, and abbreviations used for the relevant subdivisional conditions are listed in the preliminary notes for Tables 6/4-6/25.

2. Lines representing hierarchical connections are classified according to the following key.

——————— (heavy solid line)	Connection accepted as valid at the absolute Ho level.
——————— (thin solid line)	Connection accepted as valid at weaker (0.01 and 0.02) Ho levels.
- - - - - - - (broken line)	Connection rejected as invalid at all three specified Ho levels.

FIGURE 7.2

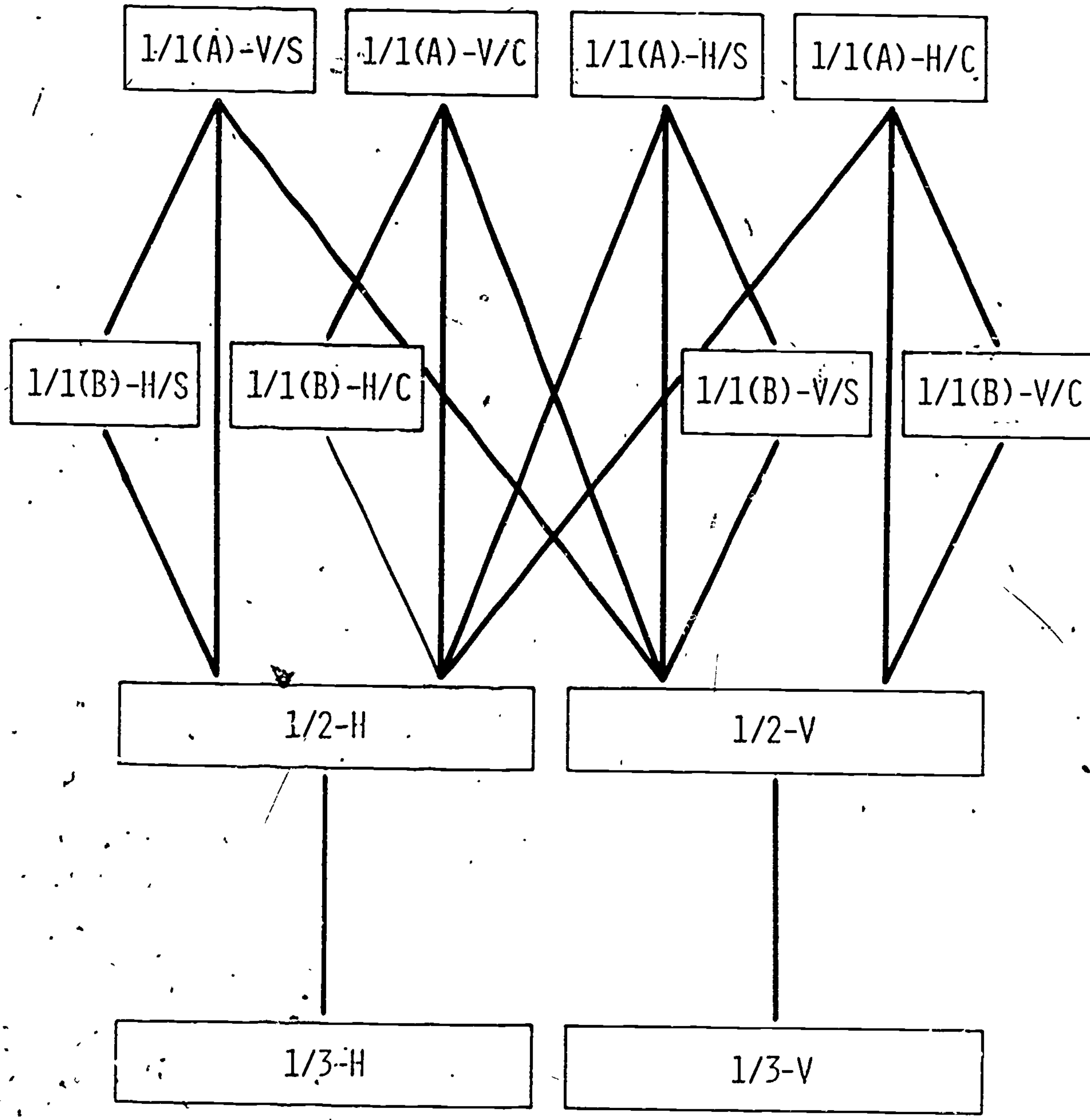

1/1(A)-V/S
1/1(A)-V/C
1/1(A)-H/S
1/1(A)-H/C
1/1(B)-H/S
1/1(B)-H/C
1/1(B)-V/S
1/1(B)-V/C
1/2-H
1/2-V
1/3-H
1/3-V

FIGURE 7.3

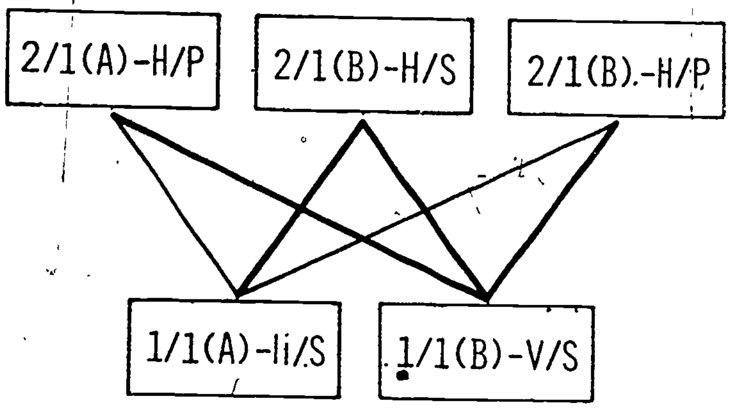


FIGURE 7.4

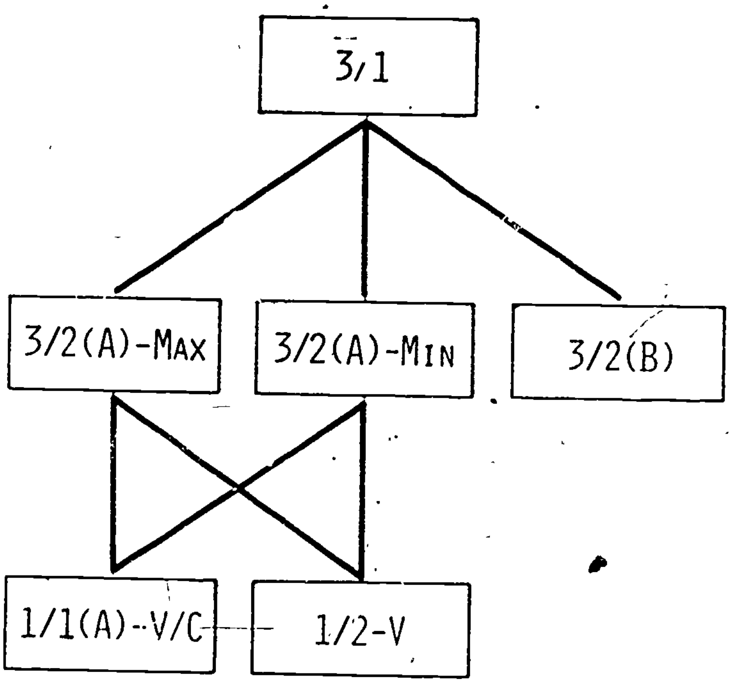


FIGURE 7.5

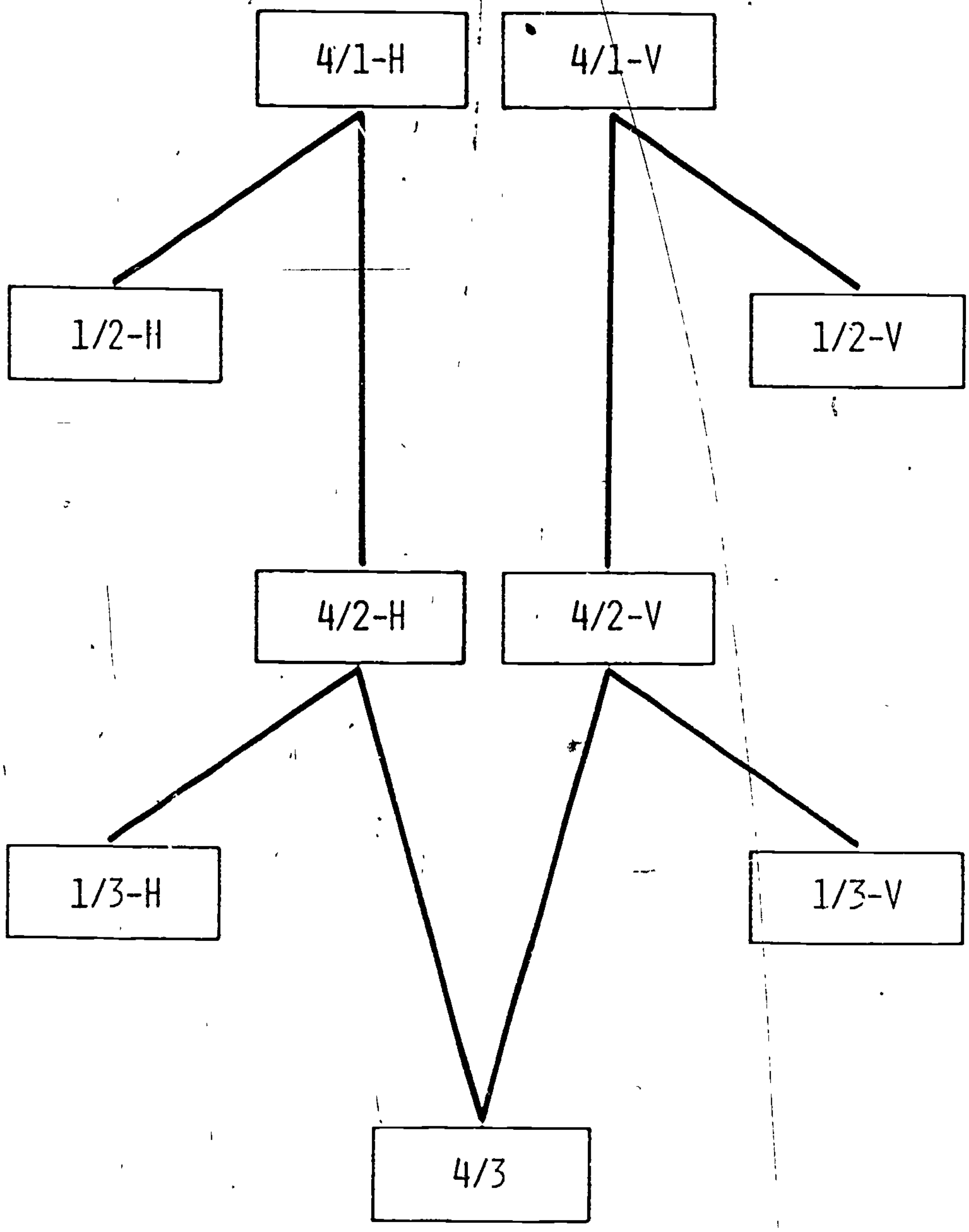


FIGURE 7.6

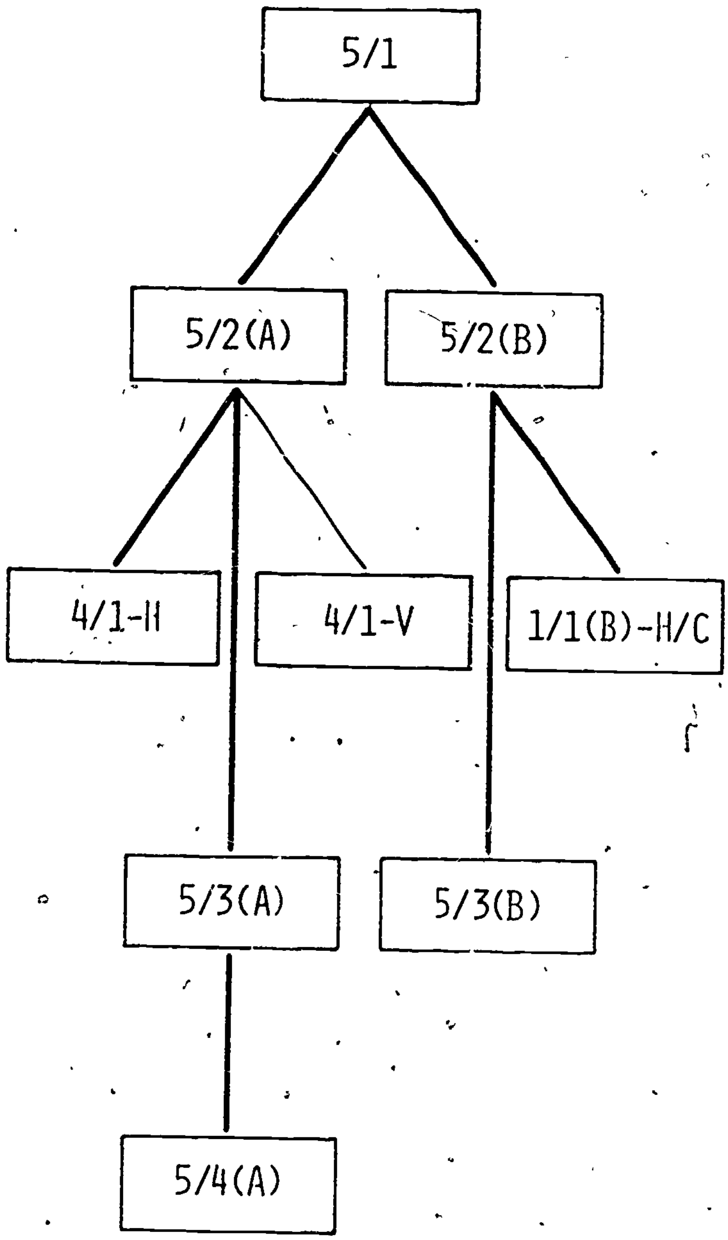
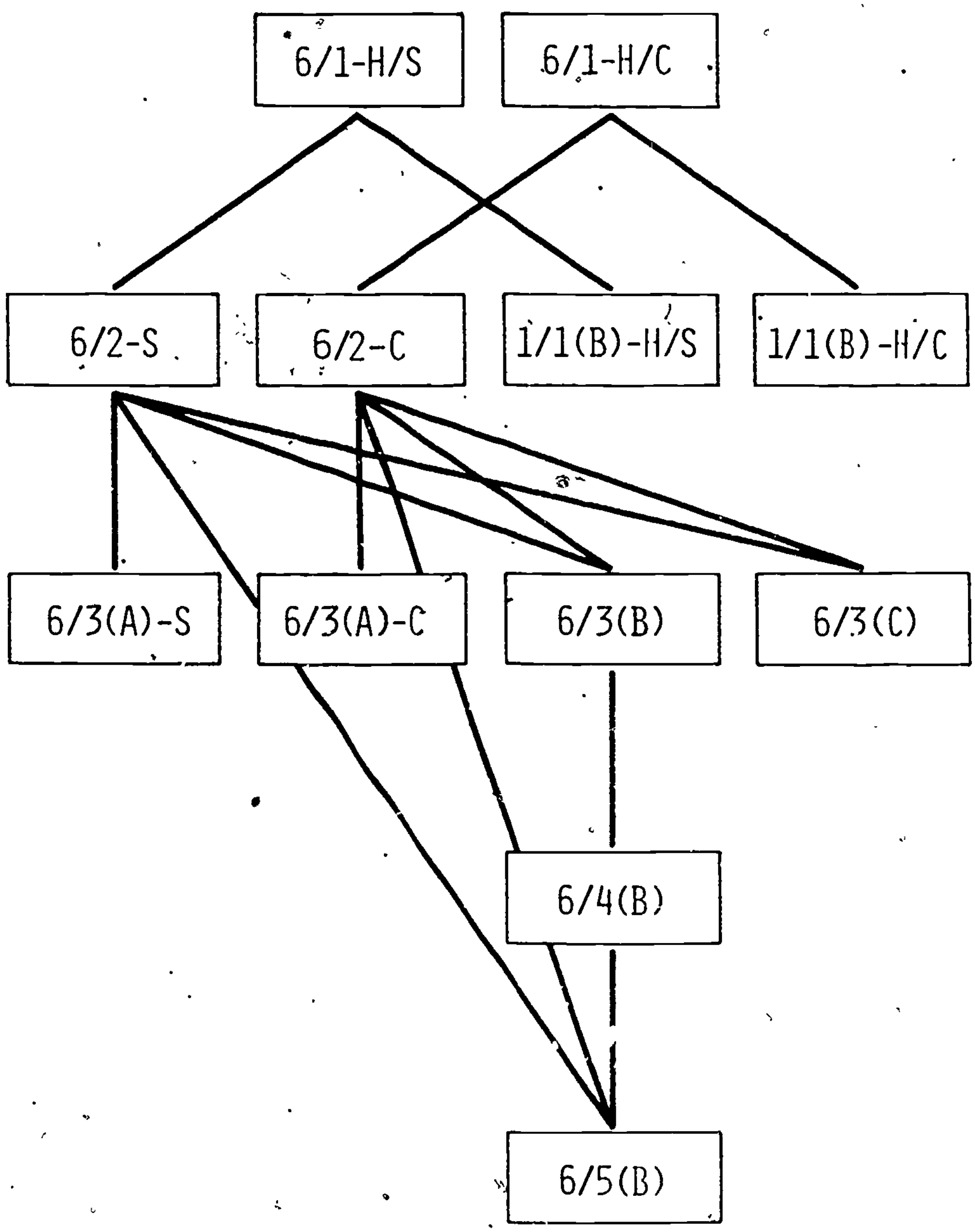


FIGURE 7.7



CHAPTER VIII

THE EFFECTS OF EXTENDED NUMERICAL RANGE ON THE POSTULATED LEARNING HIERARCHY

1. Introduction

One of the most important limiting conditions applied to introductory courses on graphical interpretation is the restriction of numerical range. With respect to the General (primary school) courses outlined in Chapter II (see courses 1-6 in Table 2/4), the use of numerical range in basic graphical skills often lags well behind the introduction of more complex and extensive number systems in other sections of the primary curriculum. Most of these courses, for example, are initially restricted to a relatively limited range of positive integers, although the South Australian course is based on a more extensive system of positive rational numbers, and the S.M.S.G. programme involves both positive and negative integers. All three of the high school Service courses outlined in Table 2/4 (no's 7-9) are based on positive number systems, although only one (B.S.C.S.) is restricted to integers, while the J.S.C.S. and A.S.E.P. programmes also cover both common fractions and decimal numbers. Negative numbers are rarely used at either primary or secondary level in introductory graphical exercises, and fractional numbers are seldom taken to more than a single decimal place.

The same conservative approach of restricting numerical range is also evident in many research studies concerned with hierarchical learning of both graphical interpretation skills and general computational procedures. In two early studies by Gagné, for example, (see Gagné & Paradise 1961, Gagné et al. 1962), all arithmetical calculations are restricted to relatively small integral numbers, although it could reasonably be assumed in both cases from the stated testing level (seventh grade) that the students would be experienced in computations with considerably larger or more complex numbers. Smith (1970) similarly restricts the numerical range, in a study of various graphical interpretation skills, to positive integral numbers, although in this case the testing level extends from grade three to grade six, so that the same assumptions of previous computational experience would probably not apply. In contrast with these studies, Gray (1969) examines, at the grade five level, a hierarchical network of both interpretative and computational skills involving fractional numbers corrected to the second decimal place. In the validation study by White (1971), however, directed at the form three (ninth grade) level, all positional and displacement skills are restricted to a limited range of integral numbers, while a few of the more complex skills involving calculations of quotient or gradient are extended, in terms of the relevant result, to include fractional or decimal numbers, with separate subdivisional skills defined for answers greater or less than one.

Although limiting with respect to potential generalisation, the conservative approach adopted by Gagné (1961, 1962), Smith (1970), White (1971) and many others in restricting the numerical range to relatively simple integral or rational numbers is no doubt logically sound, since the object of these studies is not to confuse the students with unnecessary computational complexity, but to establish a hierarchical network of logically related skills. Moreover in view of the subdivisional analysis results outlined in Chapter IV, this approach is also clearly essential on empirical grounds, since the use of integral and decimal numbers involves different subdivisional skills, with additional categories defined in terms of computational result. Thus interchanging these numerical systems at different levels of the learning hierarchy, as evident in the study by Kolb (1967/8), could invalidate the postulated sequence of skills.

Despite the necessary restrictions on numerical range for hierarchical validation, it seems in practice that the relevant skills of graphical interpretation must at some stage be extended to include the more complex number systems used in other areas of the science and mathematics curriculum at both primary and secondary levels. A review of current introductory courses (see Table 2/4 in Chapter II) suggests that these extensions are generally left to a somewhat haphazard, retrospective treatment in subsequent curriculum topics, rather than incorporated progressively throughout the learning programme. It seems reasonable to suggest, however, that extensions of numerical range would be more appropriately treated in the same systematic instructional programme as that used to teach the basic interpretative skills, provided that these modifications do not affect the overall hierarchical structure or sequence of skills. In order to examine the validity of this assumption, a third validation programme was prepared using both integral and rational numbers in each of the relevant interpretative skills. The preparation and administration of this programme are discussed below in section 2, with results and implications outlined in section 3.

2. The Preparation and Administration of Validation Programme III

In preparing the third validation programme, different numerical systems were used for Horizontal and Vertical co-ordinate positions. Horizontal co-ordinates were restricted to positive integers, while Vertical co-ordinates, also positive, were given (or estimated) to the nearest decimal place. This arrangement was adopted so that all calculations involving quotient and gradient would have an integral denominator, thus avoiding the computational complexities of long division, which might otherwise make the programme too difficult for form 1 students. Where estimation was involved, appropriate levels of tolerance were allowed for both positional and displacement skills (0.1 and 0.2 units respectively). In such cases exact results for division calculations could not be guaranteed, so that again an estimate was required to the nearest decimal place.

Apart from the differences in numerical range outlined above, which affected most, but not all of the postulated interpretative skills, the instructions, examples and questions incorporated in Programme III were similar to those prepared for Programme I, and the same symbolic notation was used in both validation programmes. The sequence of presentation for the basic intellectual skills, which was also common to both validation programmes, has already been outlined in Table 6/1, and the classification of relevant subdivisional conditions, redefined for Programme III, is presented in Table 8/1. A comprehensive copy of the third validation programme is included in Volume III.

The conditions of administration for Programme III were basically similar to those for Programmes I and II, and in this case involved a total of 202 form 1 students from twelve randomly selected co-educational high schools in Melbourne. This testing sample included 89 male and 113 female students, ranging in age from 11 to 15 years (taken to the nearest year) with a mean of 12.6. The number of students involved from each participating school is shown in Table 8/2. For reasons already explained in Chapter VI, only half a class of students was involved from most participating schools, with the rest of the class engaged in one of the alternative validation programmes.

Both the shortest and longest mean completion times for Programme III (see Table 8/2) are substantially higher than the corresponding values for Programmes I and II, but the range of individual results is also relatively large, so that the differences in average time are not statistically significant. The progression curve for Programme III (see Figure 8.1) also shows a generally slower working rate than the corresponding curves for Programmes I and II, but the same predominantly linear trend suggests at least that the rate is relatively constant to the point of first completion (approximately 60 minutes).

TABLE 8/1

The Classification of Subdivisional Skills

Included in Validation Programme III.

Element Number	Question Group	Relevant Subdivisional Conditions
1/3	1	Position H/I/+
	2	V/D/+
1/2	1	Required Co-ordinate H/I/+
	2	V/D/+
1/1(B)	1	Straight line, Given Co-ordinate H/I/+
	2	V/D/+
	3	Curve, Given Co-ordinate H/I/+
	4	V/D/+
1/1(A)	1	Straight line, Required Co-ordinate H/I/+
	2	V/D/+
	3	Curve, Required Co-ordinate H/I/+
	4	V/D/+
2/1(A)	1	Required Co-ordinate H/I/+
2/1(B)	1	Straight line, Required co-ordinate H/I/+
	2	Row of Points, Co-ordinate H/I/+
3/2(A)	1	Maximum Value V/D/+
	2	Minimum Value V/D/+
4/3	1	Numerical Variables I/+
	2	D/+
4/2	1	Displacement H/I/+
	2	V/D/+
4/1	1	Displacement H/I/+
	2	V/D/+
6/5(B)	1	Numerical Variables I/+ (<10), D/+ (<1)
	2	I/+ (>10), D/+ (<1)

Cont.

TABLE 8/1 (Cont.)

Element Number	Question Group	Relevant Subdivisional Conditions
8/3 (A)	1	Straight line segment
	2	Curve
6/2	1	Straight line segment
	2	Curve
6/1	1	Straight line segment
	2	Curve

TABLE 8/2

Sample Numbers and Completion Times for Validation Programme III

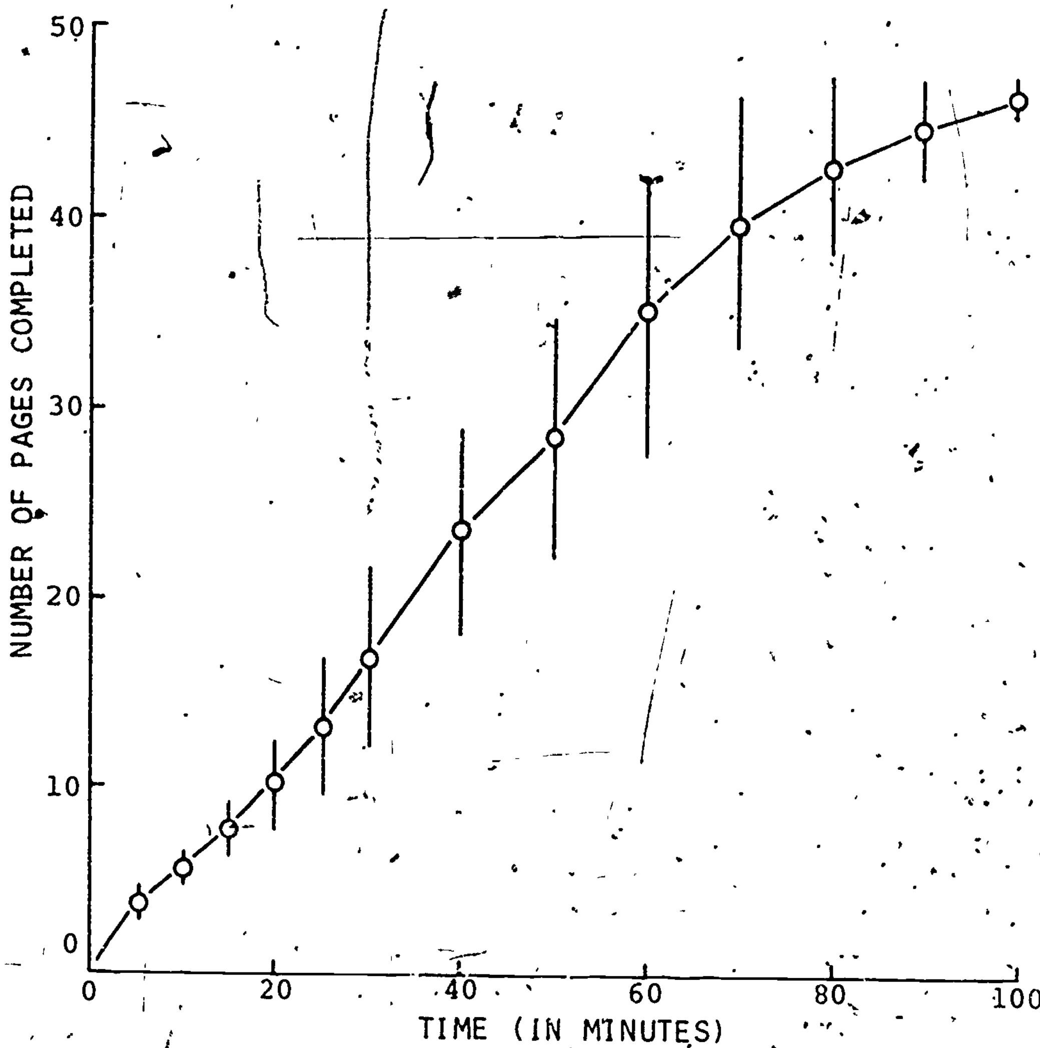
(Victoria)

HIGH SCHOOL	Number of Students in Sample	Shortest Completion Time (mins.)	Longest Completion Time (mins.)
Altona North	20	65	136
Collingwood	14	47	118
Donvale	15	52	102
Essendon	14	65	103
Heidelberg	12	73	152
Kew	12	58	119
Lakeside	17	69	116
Monash	12	57	109
Moorleigh	18	76	105
Parkdale	37	57	117
Vermont	16	73	114
Waverley	15	70	142
Mean Completion Time		63.5	119.4
Standard Deviation		9.2	15.9

FIGURE 8.1

Progression Rate for Programme III

(Parkdale High School)



NOTES

1. Circles indicate the mean number of pages completed at specified times.
2. Vertical lines represent the appropriate Standard Deviation.
3. Number of students involved = 37.

3. Results and Implications from Validation Programme III

The results from Validation Programme III were subjected to the same statistical analysis as those from Programmes I and II, presented respectively in Chapters VI and VII. The results and specific conclusions derived from the analysis of postulated hierarchical connections are presented in Tables 8/3-8/24, and those for the subsequent analysis of relevant subdivisional skills are outlined in Tables 8/25-8/29.

In statistical terms the most dramatic effects of the extended numerical range in Programme III involve marked increases (with respect to Programme I) in both element difficulty level and degree of response inconsistency. Unfortunately both of these effects combine to reduce the statistical power, as explained in Chapter VI, so that many individual tests of hierarchical dependence involved in Programme III are rendered virtually ineffective by the frequently substantial, and in some cases almost total loss of power. More or less subjective decisions on the validity of these postulated connections have been made in every case, based on the calculated critical number of 0/2 cell exceptions for each relevant correlation table, with regard also given to the difference between this and number of observed exceptions.

If this study is considered in isolation as a single validation experiment, many of these specific conclusions on the validity of postulated hierarchical connections could legitimately be questioned through the lack of statistical power, but these decisions should also be considered in relation to the corresponding tests for analogous validation experiments already outlined in Chapters VI and VII, and subsequently in Chapters IX-XI. Thus a pattern of general concurrence with respect to particular hierarchical connections may serve to substantiate individually questionable conclusions.

In spite of the general loss in statistical power, the validation results for Programme III were probably more consistent than those for the analogous programme (I) based on integral numbers alone. In area 1, for example, the parallel connections between corresponding subdivisional groups of elements 1/3 and 1/2 were accepted as valid at the absolute Ho level for Programme III (see Figure 8.2), but were previously accepted for Programme I (Figure 6.2) only at weaker levels. The postulated connections between various subdivisional groups of elements 1/2 and 1/1(A) were also more consistently accepted as valid in Programme III (Figure 8.2), as were those involved in areas 2 and 3, shown respectively in Figures 8.3 and 8.4. Results in areas 4-6 (see Figures 8.5-8.7) were the same for both validation programmes, with all of the postulated connections accepted as valid at the absolute Ho level.

Many of the subdivisional analysis results for Programme III were not directly comparable with those for the previous validation programmes, since the required Horizontal and Vertical co-ordinates were in this case based on different (integral and decimal) numerical systems, which were previously tested in Chapter IV and found to involve different subdivisional skills. The same result, derived from an analogous subdivisional test for element 4/3 in Programme III, is shown in Table 8/28(A). It follows from this result that the difference reflected on numerous occasions in Programme III between Horizontal and Vertical co-ordinate subdivisions (see Tables 8/25-8/29) actually represents a complex effect involving an additional variable of basic numerical range.

The other subdivisional analysis results derived from Programme III are generally consistent with those for Programmes I and II, although in this case no statistical distinction is made between interpolation and extrapolation skills (Table 8/27(A)), or between the different question groups defined and tested for element 2/1(B) (Table 8/27(B)). In the first of these cases, however, the postulated skills are both independently taught, so that the lack of subsequent discrimination is not necessarily an indication of immediate lateral transfer from one skill to the other, as suggested in the definition of subdivisional skills outlined in Chapter IV.

The results of this analysis clearly substantiate the suggestion in section 1 that although the extension from integral to rational (or decimal) numbers may involve more difficult computations (and in fact requires a different set of subdivisional skills), this change has no significant effect on the basic hierarchical structure or sequence of graphical interpretation skills. It seems reasonable to suggest, therefore, that the potential generalization of these interpretative skills could well be progressively extended at each hierarchical level by expanding the numerical range to the same limits established in other relevant curriculum areas. This suggestion is consistent with the current practice (discussed in

Chapter VII) of generalization through the use of different informational models, in that the same systematic approach with respect to numerical range would immediately extend the potential application of each basic intellectual skill.

The nature of informational model and extent of numerical range are both important situational variables in the learning of graphical interpretation skills. It has so far been established, however, that neither of these variables has any substantial effect on the postulated hierarchical organisation of these basic intellectual abilities, although they may in part determine the degree of potential generalization and relevant difficulty levels. Another class of variables, more personal in nature and including various characteristics of both cultural and curricular background, may also influence the learning of graphical interpretation skills, and the effects of these characteristics on the postulated learning hierarchy are examined in the next three chapters (IX-XI).

TABLES 8/3-8/24

Validation Results for Programme III

(Victoria)

PRELIMINARY NOTES

1. The following tables present the results for each of the postulated hierarchical connections between basic and subdivisional skills incorporated in Programme III. These results are presented in correlation matrix form, listing the number of questions correct for each element, and the appropriate marginal totals.

2. The critical number of exceptions (C) permitted in the 0/2 cell of the relevant correlation table is listed, together with the appropriate statistical power, for each of the null hypothesis levels defined in Chapter VI (see preliminary notes for Tables 6/4-6/25).

3. The classification code for each element is outlined in Tables 5/4-5/10, and the relevant subdivisional conditions are presented in Tables 6/4-6/25 (preliminary notes), except that each of the Vertical co-ordinates involved in Programme III is based on a decimal, rather than an integral number scale.

4. Element 6/3(C) (not previously defined in Chapter V) involves the skill of counting squares on a two-dimensional grid.

TABLE 8/3

(A) ELEMENT 1/2-H

ELEMENT 1/3-H	0	1	2	T
2	78	21	92	191
1	3	2	0	5
0	3	2	1	6
T	84	25	93	202

Ho	C	POWER
0.00	2	0.9949
0.01	5	0.8942
0.02	7	0.6903

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 1/2-V

ELEMENT 1/3-V	0	1	2	T
2	34	16	62	112
1	38	6	14	58
0	28	4	0	32
T	100	26	76	202

Ho	C	POWER
0.00	11	0.3654
0.01	12	0.2589
0.02	13	0.1731

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C) ELEMENT 1/1(B)-V/S

ELEMENT 1/2-V	0	1	2	T
2	15	13	48	76
1	13	5	8	26
0	78	12	10	100
T	106	30	66	202

Ho	C	POWER
0.00	9	0.4172
0.01	11	0.1959
0.02	12	0.1217

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is extremely low.

TABLE 8/4

(A)

ELEMENT 1/1(A)-H/S

ELEMENT 1/1(B)-V/S	0	1	2	T
2	22	2	42	66
1	12	18	0	30
0	103	3	0	106
T	137	23	42	202

Ho	C	POWER
0.00	8	0.1469
0.01	8	0.1469
0.02	9	0.0790

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B)

ELEMENT 1/1(A)-H/S

ELEMENT 1/2-V	0	1	2	T
2	32	11	33	76
1	18	3	5	26
0	87	9	4	100
T	137	23	42	202

Ho	C	POWER
0.00	6	0.3068
0.01	7	0.1832
0.02	8	0.0995

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C)

ELEMENT 1/1(A)-H/S

ELEMENT 1/2-H	0	1	2	T
2	48	14	31	93
1	18	2	5	25
0	71	7	6	84
T	137	23	42	202

Ho	C	POWER
0.00	5	0.4014
0.01	6	0.2405
0.02	7	0.1411

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is extremely low.

TABLE 8/5

(A) ELEMENT 1/1(B)-H/S

ELEMENT 1/2-H	0	1	2	T
2	35	8	50	93
1	15	2	8	25
0	71	3	10	84
T	121	13	68	202

Ho	C	POWER
0.00	6	0.6685
0.01	7	0.5267
0.02	9	0.2582

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(B) ELEMENT 1/1(A)-V/S

ELEMENT 1/1(B)-H/S	0	1	2	T
2	14	8	46	68
1	6	7	0	13
0	120	1	0	121
T	140	16	46	202

Ho	C	POWER
0.00	4	0.5975
0.01	6	0.2669
0.02	7	0.1531

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C) ELEMENT 1/1(A)-V/S

ELEMENT 1/2-H	0	1	2	T
2	46	12	35	93
1	18	2	5	25
0	76	2	6	84
T	140	16	46	202

Ho	C	POWER
0.00	5	0.4478
0.01	6	0.2918
0.02	7	0.1710

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is extremely low.

TABLE 8/6

(A) ELEMENT 1/1(A)-V/S

ELEMENT 1/2-V	0	1	2	T
2	31	11	34	76
1	17	2	7	26
0	92	3	5	100
T	140	16	46	202

Ho	C	POWER
0.00	6	0.3458
0.01	7	0.2141
0.02	8	0.1208

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B) ELEMENT 1/1(B)-V/C

ELEMENT 1/2-V	0	1	2	T
2	10	10	56	76
1	9	3	14	26
0	70	14	16	100
T	89	27	86	202

Ho	C	POWER
0.00	11	0.4902
0.01	12	0.3733
0.02	13	0.2695

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(C) ELEMENT 1/1(A)-H/C

ELEMENT 1/1(B)-V/C	0	1	2	T
2	29	5	52	86
1	14	13	0	27
0	86	3	0	89
T	129	21	52	202

Ho	C	POWER
0.00	6	0.4639
0.01	7	0.3160
0.02	9	0.1134

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLE 8/7

(A) ELEMENT 1/1(A)-H/C

ELEMENT 1/2-V	0	1	2	T
2	27	12	37	76
1	13	4	9	26
0	89	5	6	100
T	129	21	52	202

Ho	C	POWER
0.00	7	0.3452
0.01	8	0.2211
0.02	9	0.1303

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B) ELEMENT 1/1(A)-H/C

ELEMENT 1/2-H	0	1	2	T
2	42	14	37	93
1	14	3	8	25
0	73	4	7	84
T	129	21	52	202

Ho	C	POWER
0.00	6	0.4269
0.01	7	0.2828
0.02	8	0.1714

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is extremely low.

(C) ELEMENT 1/1(B)-H/C

ELEMENT 1/2-H	0	1	2	T
2	33	3	57	93
1	13	1	11	25
0	70	2	12	84
T	116	6	80	202

Ho	C	POWER
0.00	6	0.8039
0.01	8	0.5540
0.02	9	0.4193

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

TABLE 8/8

(A) ELEMENT 1/1(A)-V/C

ELEMENT 1/1(B)-H/C	0	1	2	T
2	15	7	58	80
1	4	2	0	6
0	113	3	0	116
T	132	12	58	202

Ho	C	POWER
0.00	3	0.8571
0.01	5	0.5647
0.02	6	0.4016

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(B) ELEMENT 1/1(A)-V/C

ELEMENT 1/2-H	0	1	2	T
2	42	7	44	93
1	15	2	8	25
0	75	3	6	84
T	132	12	58	202

Ho	C	POWER
0.00	5	0.6561
0.01	7	0.3482
0.02	8	0.2236

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is particularly low.

(C) ELEMENT 1/1(A)-V/C

ELEMENT 1/2-V	0	1	2	T
2	26	6	44	76
1	14	3	9	26
0	92	3	5	100
T	132	12	58	202

Ho	C	POWER
0.00	6	0.5616
0.01	8	0.2762
0.02	9	0.1718

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLE 8/9

(A)

ELEMENT 2/1(A)-H/P (columns); ELEMENT 1/1(A)-H/S (rows)

	0	1	2	T
2	7	12	23	42
1	10	7	6	23
0	99	30	8	137
T	116	49	37	202

Ho	C	POWER
0.00	14	0.0254
0.01	15	0.0124
0.02	15	0.0124

CONCLUSION The postulated connection is accepted s valid at the absolute Ho level, although the power is extremely low.

(B)

ELEMENT 2/1(A)-H/P (columns); ELEMENT 1/1(B)-V/S (rows)

	0	1	2	T
2	19	20	27	66
1	16	7	7	30
0	81	22	3	106
T	116	49	37	202

Ho	C	POWER
0.00	12	0.0319
0.01	12	0.0319
0.02	13	0.0152

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C)

ELEMENT 2/1(B)-H/S (columns); ELEMENT 1/1(A)-H/S (rows)

	0	1	2	T
2	7	14	21	42
1	11	5	7	23
0	116	13	8	137
T	134	32	36	202

Ho	C	POWER
0.00	10	0.0549
0.01	10	0.0549
0.02	11	0.0265

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 8/10

(A) ELEMENT 2/1(B)-H/S

ELEMENT 1/1(B)-V/S	0	1	2	T
2	23	17	26	66
1	18	5	7	30
0	93	10	3	106
T	134	32	36	202

Ho	C	POWER
0.00	8	0.1128
0.01	9	0.0574
0.02	10	0.0268

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 2/1(B)-H/P

ELEMENT 1/1(A)-H/S	0	1	2	T
2	10	13	19	42
1	12	4	7	23
0	118	10	9	137
T	140	27	35	202

Ho	C	POWER
0.00	9	0.0676
0.01	9	0.0676
0.02	10	0.0325

CONCLUSION: The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 2/1(B)-H/P

ELEMENT 1/1(B)-V/S	0	1	2	T
2	27	15	24	66
1	20	3	7	30
0	93	9	4	106
T	140	27	35	202

Ho	C	POWER
0.00	8	0.0790
0.01	8	0.0790
0.02	9	0.0374

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 8/11

(A) ELEMENT 3/2(A)-Max

ELEMENT 1/2-V		0	1	2	T
	2	11	30	45	86
	1	15	9	3	27
	0	61	10	18	89
	T	87	49	66	202

Ho	C	POWER
0.00	14	0.1294
0.01	15	0.0792
0.02	15	0.0792

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(B) ELEMENT 3/2(A)-Max

ELEMENT 1/1(A)-V/C		0	1	2	T
	2	5	19	36	60
	1	9	9	13	31
	0	73	21	17	111
	T	87	49	66	202

Ho	C	POWER
0.00	17	0.1087
0.01	18	0.0679
0.02	19	0.0404

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 3/2(A)-Min

ELEMENT 1/2-V		0	1	2	T
	2	17	16	53	86
	1	21	2	4	27
	0	58	13	18	89
	T	96	31	75	202

Ho	C	POWER
0.00	10	0.4179
0.01	11	0.3011
0.02	12	0.2043

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

TABLE 8/12

(A)

ELEMENT 3/2(A)-Min (columns); ELEMENT 1/1(A)-V/C (rows)

	0	1	2	T
2	7	10	43	60
1	10	4	17	31
0	79	17	15	111
T	96	31	75	202

Ho	C	POWER
0.00	13	0.3099
0.01	15	0.1454
0.02	16	0.0921

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is extremely low.

(B)

ELEMENT 3/1 (columns); ELEMENT 3/2(B) (rows)

	0	1	2	T
2	53	56	49	158
1	5	3	2	10
0	25	7	2	34
T	83	66	53	202

Ho	C	POWER
0.00	9	0.1147
0.01	10	0.0609
0.02	11	0.0299

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C)

ELEMENT 3/1 (columns); ELEMENT 3/2(A)-Max (rows)

	0	1	2	T
2	18	17	31	66
1	14	22	13	49
0	51	27	9	87
T	83	66	53	202

Ho	C	POWER
0.00	20	0.0231
0.01	21	0.0102
0.02	21	0.0102

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 8/13

(A) ELEMENT 3/1

ELEMENT 3/2(A)-Min

	0	1	2	T
2	22	22	31	75
1	9	12	10	31
0	52	32	12	96
T	83	66	53	202

Ho	C	POWER
0.00	19	0.0245
0.01	20	0.0132
0.02	20	0.0132

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 1/2-V (Retest)

ELEMENT 1/2-V

	0	1	2	T
2	15	7	54	76
1	9	4	13	26
0	65	16	19	100
T	89	27	86	202

Ho	C	POWER
0.00	11	0.4902
0.01	12	0.3733
0.02	13	0.2695

CONCLUSION This skill was acquired by a significant proportion of students in the process of attempting more complex capabilities.

(C) ELEMENT 1/1(A)-V (Retest)

ELEMENT 1/1(A)-V

	0	1	2	T
2	7	10	41	58
1	2	7	3	12
0	102	14	16	132
T	111	31	60	202

Ho	C	POWER
0.00	9	0.2972
0.01	10	0.1932
0.02	11	0.1170

CONCLUSION This skill was acquired by a significant proportion of students in the process of attempting more complex capabilities.

TABLE 8/14

(A) ELEMENT 4/2-H

ELEMENT 4/3-I		0	1	2	T
	2	35	7	151	193
	1	3	0	4	7
	0	2	0	0	2
	T	40	7	155	202

Ho	C	POWER
0.00	2	1.0000
0.01	7	0.9885
0.02	10	0.9097

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(B) ELEMENT 4/2-V

ELEMENT 4/3-D		0	1	2	T
	2	52	17	101	170
	1	11	2	5	18
	0	12	1	1	14
	T	75	20	107	202

Ho	C	POWER
0.00	4	0.9853
0.01	7	0.8541
0.02	9	0.6489

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 4/2-H

ELEMENT 1/3-H		0	1	2	T
	2	33	7	152	192
	1	1	0	2	3
	0	6	0	1	7
	T	40	7	155	202

Ho	C	POWER
0.00	2	1.0000
0.01	7	0.9885
0.02	10	0.9095

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 8/15

(A) ELEMENT 4/2-V

ELEMENT 1/3-V

	0	1	2	T
2	19	16	92	127
1	28	3	15	46
0	28	1	0	29
T	75	20	107	202

Ho	C	POWER
0.00	9	0.8447
0.01	11	0.6564
0.02	13	0.4300

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(B) ELEMENT 4/1-H

ELEMENT 4/2-H

	0	1	2	T
2	50	47	58	155
1	5	2	0	7
0	36	2	2	40
T	91	51	60	202

Ho	C	POWER
0.00	7	0.4968
0.01	9	0.1629
0.02	10	0.0927

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C) ELEMENT 4/1-V

ELEMENT 4/2-V

	0	1	2	T
2	29	26	52	107
1	10	6	4	20
0	62	11	2	75
T	101	43	58	202

Ho	C	POWER
0.00	9	0.2695
0.01	10	0.1634
0.02	11	0.0957

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 8/16

(A) ELEMENT 4/1-H

ELEMENT 1/2-H	0	1	2	T
2	8	29	49	86
1	5	6	6	17
0	78	16	5	99
T	91	51	60	202

Ho	C	POWER
0.00	13	0.1405
0.01	14	0.0856
0.02	15	0.0492

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 4/1-V

ELEMENT 1/2-V	0	1	2	T
2	13	17	52	82
1	5	8	3	16
0	83	18	3	104
T	101	43	58	202

Ho	C	POWER
0.00	11	0.1688
0.01	12	0.1020
0.02	13	0.0577

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 5/3(A)

ELEMENT 5/4(A)	0	1	2	T
2	8	3	47	58
1	4	2	3	9
0	109	22	4	135
T	121	27	54	202

Ho	C	POWER
0.00	7	0.3708
0.01	8	0.2425
0.02	9	0.1461

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLE 8/17

(A)

ELEMENT 5/2(A) (columns) × ELEMENT 5/3(A) (rows)

	0	1	2	T
2	36	11	7	54
1	22	5	0	27
0	102	18	1	121
T	160	34	8	202

Ho	C	POWER
0.00	6	0.0038
0.01	6	0.0038
0.02	6	0.0038

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B)

ELEMENT 5/2(A) (columns) × ELEMENT 4/1-H (rows)

	0	1	2	T
2	55	20	6	81
1	8	3	1	12
0	97	11	1	109
T	160	34	8	202

Ho	C	POWER
0.00	5	0.0065
0.01	6	0.0015
0.02	6	0.0015

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C)

ELEMENT 5/2 (A) (columns) × ELEMENT 4/1-V (rows)

	0	1	2	T
2	42	15	5	62
1	20	7	3	30
0	98	12	0	110
T	160	34	8	202

Ho	C	POWER
0.00	6	0.0027
0.01	6	0.0027
0.02	6	0.0027

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 8/18

(A)

ELEMENT 5/2(B) (columns); ELEMENT 5/3(B) (rows)

	0	1	2	T
2	35	6	58	99
1	8	2	3	13
0	87	3	0	90
T	130	11	61	202

Ho	C	POWER
0.00	3	0.8866
0.01	5	0.6230
0.02	7	0.3145

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(B)

ELEMENT 5/2(B) (columns); ELEMENT 1/1(B)-H/C (rows)

	0	1	2	T
2	39	4	49	92
1	10	2	9	21
0	81	5	3	89
T	130	11	61	202

Ho	C	POWER
0.00	5	0.6753
0.01	6	0.5200
0.02	8	0.2409

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(C)

ELEMENT 5/1 (columns); ELEMENT 5/2(B) (rows)

	0	1	2	T
2	39	16	6	61
1	10	1	0	11
0	124	6	0	130
T	173	23	6	202

Ho	C	POWER
0.00	4	0.0045
0.01	4	0.0045
0.02	4	0.0045

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 8/19

(A) ELEMENT 5/1

ELEMENT 5/2(A)		0	1	2	T
	2	1	4	6	11
	1	2	5	0	7
	0	170	14	0	184
	T	173	23	6	202

Ho	C	POWER
0.00	5	0.0044
0.01	5	0.0044
0.02	6	0.0009

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 4/1-H (Retest)

ELEMENT 4/1-H		0	1	2	T
	2	7	4	49	60
	1	17	5	29	51
	0	85	3	3	91
	T	109	12	81	202

Ho	C	POWER
0.00	17	0.2218
0.01	18	0.1539
0.02	19	0.1021

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

(C) ELEMENT 4/1-V (Retest)

ELEMENT 4/1-V		0	1	2	T
	2	5	13	40	58
	1	15	11	17	43
	0	90	6	5	101
	T	110	30	62	202

Ho	C	POWER
0.00	14	0.1588
0.01	15	0.1005
0.02	16	0.0602

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

TABLE 8/20

(A) ELEMENT 5/2(A) (retest)

ELEMENT 5/2(A)

	0	1	2	T
2	2	0	6	8
1	25	4	5	34
0	157	3	0	160
T	184	7	11	202

Ho	C	Power
0.00	13	0.0020
0.01	13	0.0020
0.02	14	0.0007

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

(B) ELEMENT 6/4(B)

ELEMENT 6/5(B)

	0	1	2	T
2	25	7	104	136
1	6	1	8	15
0	44	3	4	51
T	75	11	116	202

Ho	C	Power
0.00	4	0.9937
0.01	7	0.9182
0.02	9	0.7680

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 6/3(B)

ELEMENT 6/4(B)

	0	1	2	T
2	31	11	74	116
1	3	2	6	11
0	58	12	5	75
T	92	25	85	202

Ho	C	Power
0.00	6	0.8365
0.01	8	0.6045
0.02	9	0.4711

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

TABLE 8/21

(A) ELEMENT 6/2-S

ELEMENT 6/3(B)

	0	1	2	T
2	18	23	27	68
1	21	5	0	26
0	107	1	0	108
T	146	29	27	202

Ho	C	POWER
0.00	7	0.0496
0.01	7	0.0496
0.02	8	0.0203

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 6/2-S

ELEMENT 6/3(A)-S

	0	1	2	T
2	44	14	27	85
1	25	15	0	40
0	77	0	0	77
T	146	29	27	202

Ho	C	POWER
0.00	7	0.0489
0.01	7	0.0489
0.02	8	0.0199

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 6/2-S

ELEMENT 6/5(B)

	0	1	2	T
2	49	23	23	95
1	22	1	4	27
0	75	5	0	80
T	146	29	27	202

Ho	C	POWER
0.00	5	0.1461
0.01	6	0.0668
0.02	7	0.0271

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 8/22

(A) ELEMENT 6/2-C

ELEMENT 6/3(B)		0	1	2	T
	2	35	14	34	83
	1	13	2	0	15
	0	103	1	0	104
	T	151	17	34	202

Ho	C	POWER
0.00	4	0.3405
0.01	5	0.1894
0.02	6	0.0931

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B) ELEMENT 6/2-C

ELEMENT 6/3(A)-C		0	1	2	T
	2	35	12	34	81
	1	12	4	0	16
	0	104	1	0	105
	T	151	17	34	202

Ho	C	POWER
0.00	4	0.3483
0.01	5	0.1952
0.02	6	0.0969

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C) ELEMENT 6/2-C

ELEMENT 6/5(B)		0	1	2	T
	2	52	11	32	95
	1	21	4	2	27
	0	78	2	0	80
	T	151	17	34	202

Ho	C	POWER
0.00	5	0.2189
0.01	5	0.2189
0.02	6	0.1123

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 8/23

(A) ELEMENT 6/1-H/S

ELEMENT 6/2-S	0	1	2	T
2	7	12	8	27
1	18	6	5	29
0	143	2	1	146
T	168	20	14	202

Ho	C	POWER
0.00	8	0.0060
0.01	8	0.0060
0.02	8	0.0060

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 6/1-H/C

ELEMENT 6/2-C	0	1	2	T
2	13	5	16	34
1	11	1	5	17
0	143	7	1	151
T	167	13	22	202

Ho	C	POWER
0.00	5	0.0999
0.01	6	0.0412
0.02	7	0.0151

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 6/1-H/S

ELEMENT 1/1(B)-H/S	0	1	2	T
2	89	18	13	120
1	35	2	0	37
0	44	0	1	45
T	168	20	14	202

Ho	C	POWER
0.00	3	0.0912
0.01	4	0.0286
0.02	4	0.0286

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 8/24

(A) ELEMENT 6/1-H/C

ELEMENT 1/1(B)-H/C

	0	1	2	T
2	116	12	22	150
1	15	0	0	15
0	36	1	0	37
T	167	13	22	202

Ho	C	POWER
0.00	2	0.3958
0.01	3	0.1933
0.02	4	0.0789

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B) ELEMENT 6/2-S

ELEMENT 6/3(C)

	0	1	2	T
2	37	12	27	76
1	31	17	0	48
0	78	0	0	78
T	146	29	27	202

Ho	C	POWER
0.00	8	0.0378
0.01	8	0.0378
0.02	9	0.0156

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 6/2-C

ELEMENT 6/3(C)

	0	1	2	T
2	31	12	34	77
1	16	5	0	21
0	104	0	0	104
T	151	17	34	202

Ho	C	POWER
0.00	5	0.2246
0.01	6	0.1161
0.02	6	0.1161

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLES 8/25-8/29

Subdivisional Analysis Results for Programme III

(Victoria)

PRELIMINARY NOTES

1. The following results are presented in correlation-matrix form, listing the number of questions correct for each element, and the appropriate marginal totals.

2. The classification code for each element is outlined in Tables 5/4-5/10, and a list of the relevant subdivisional question groups is presented in Table 8/1.

3. P represents the combined probability that the observed number of students in the 0/2 and 2/0 cells could have occurred through chance (or errors of measurement) under the null hypothesis that no-one can possess only one of the relevant subdivisional skills without also having the other.

4. The H/V co-ordinate analysis for element 1/2 (Retest) is replaced in this case by a test of integral/decimal difference for element 4/3, presented in Table 8/28(A). The retest results for element 1/2 were consistent with those for the original H/V test.

TABLE 8/25

(A)

GROUP 1 \ GROUP 2	0	1	2	T
2	26	54	111	191
1	2	2	1	5
0	4	2	0	6
T	32	58	112	202

ELEMENT 1/3

TEST H/V (Position)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	17	14	62	93
1	11	7	7	25
0	72	5	7	84
T	100	26	76	202

ELEMENT 1/2

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	15	16	37	68
1	7	3	3	13
0	84	11	26	121
T	106	30	66	202

ELEMENT 1/1(B)

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(D)

GROUP 1 \ GROUP 3	0	1	2	T
2	4	1	63	68
1	4	2	7	13
0	108	3	10	121
T	116	6	80	202

ELEMENT 1/1(B)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

TABLE 8/26

(A)

GROUP 4 (columns) × GROUP 2 (rows)

GROUP 2	0	1	2	T
2	0	8	58	66
1	6	7	17	30
0	83	12	11	106
T	89	27	86	202

ELEMENT 1/1(B)

TEST Straight Line/Curve

P = 0.0004

CONCLUSION Question groups 2 and 4 represent different subdivisional skills.

(B)

GROUP 2 (columns) × GROUP 1 (rows)

GROUP 1	0	1	2	T
2	12	3	27	42
1	10	4	9	23
0	118	9	10	137
T	140	16	46	202

ELEMENT 1/1(A)

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

GROUP 3 (columns) × GROUP 1 (rows)

GROUP 1	0	1	2	T
2	3	7	32	42
1	7	3	13	23
0	119	11	7	137
T	129	21	52	202

ELEMENT 1/1(A)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

(D)

GROUP 4 (columns) × GROUP 2 (rows)

GROUP 2	0	1	2	T
2	3	2	41	46
1	6	3	7	16
0	123	7	10	140
T	132	12	58	202

ELEMENT 1/1(A)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 2 and 4 represent different subdivisional skills.

TABLE 8/27

(A)

GROUP 2/1(A)-1 \ GROUP 2/1(B)-2	0	1	2	T
2	5	11	21	37
1	25	11	13	49
0	110	5	1	116
T	140	27	35	202

ELEMENT 2/1(A)-2/1(B)

TEST Interpolation/Extrapolation

P = 0.1594

CONCLUSION Elements 2/1(A) and 2/1(B) represent the same skill.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	2	9	25	36
1	10	13	9	32
0	128	5	1	134
T	140	27	35	202

ELEMENT 2/1(B)

TEST Line/Points

P = 0.2253

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	5	9	52	66
1	12	16	21	49
0	79	6	2	87
T	96	31	75	202

ELEMENT 3/2(A)

TEST Max./Min. Values

P = 0.0584

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(D)

GROUP 1 \ GROUP 2	0	1	2	T
2	24	43	125	192
1	1	1	1	3
0	4	2	1	7
T	29	46	127	202

ELEMENT 1/3 (Retest)

TEST H/V (Position)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(A)

		GROUP 2: 0	1	2	T
GROUP 1	2	11	17	165	193
	1	1	1	5	7
	0	2	0	0	2
	T	14	18	170	202

ELEMENT 4/3

TEST I/D (Numbers)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(B)

		GROUP 2: 0	1	2	T
GROUP 1	2	34	19	102	155
	1	4	0	3	7
	0	37	1	2	40
	T	75	20	107	202

ELEMENT 4/2

TEST H/V (Displacement)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

		GROUP 2: 0	1	2	T
GROUP 1	2	5	19	36	60
	1	14	18	19	51
	0	82	6	3	91
	T	101	43	58	202

ELEMENT 4/1

TEST H/V (Displacement)

P = 0.2788

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(D)

		GROUP 3: 0	1	2	T
GROUP 1	2	2	5	113	120
	1	3	9	25	37
	0	32	1	12	45
	T	37	15	150	202

ELEMENT 1/1(B) (Retest)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

(A)

		GROUP 2: 0	1	2	T
GROUP 1	2	27	21	88	136
	1	7	4	4	15
	0	46	2	3	51
	T	80	27	95	202

ELEMENT 6/5(B)

TEST Numerical Range

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(B)

		GROUP 2: 0	1	2	T
GROUP 1	2	14	6	65	85
	1	23	5	12	40
	0	68	5	4	77
	T	105	16	81	202

ELEMENT 6/3(A)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

		GROUP 2: 0	1	2	T
GROUP 1	2	1	7	19	27
	1	12	6	11	29
	0	138	4	4	146
	T	151	17	34	202

ELEMENT 6/2

TEST Straight Line/Curve

P = 0.0047

CONCLUSION Question groups 1 and 2 may represent the same subdivisional skill.

(D)

		GROUP 2: 0	1	2	T
GROUP 1	2	1	0	13	14
	1	8	6	6	20
	0	158	7	3	168
	T	167	13	22	202

ELEMENT 6/1

TEST Straight Line/Curve

P = 0.0162

CONCLUSION Question groups 1 and 2 probably represent the same subdivisional skill.

FIGURES 8.2-8.7

Outline of the Validated Learning Hierarchy for Programme III

(Victoria)

PRELIMINARY NOTES

1. The classification code for each basic skill is outlined in Tables 5/4-5/10, and abbreviations used for the relevant subdivisional conditions are listed in the preliminary notes for Tables 6/4-6/25.
2. Lines representing hierarchical connections are classified according to the following key.

━━━━━━━━	Connection accepted as valid at the absolute Ho level.
────────	Connection accepted as valid at weaker (0.01 and 0.02) Ho levels.
- - - - - - -	Connection rejected as invalid at all three specified Ho levels.

FIGURE 8.2

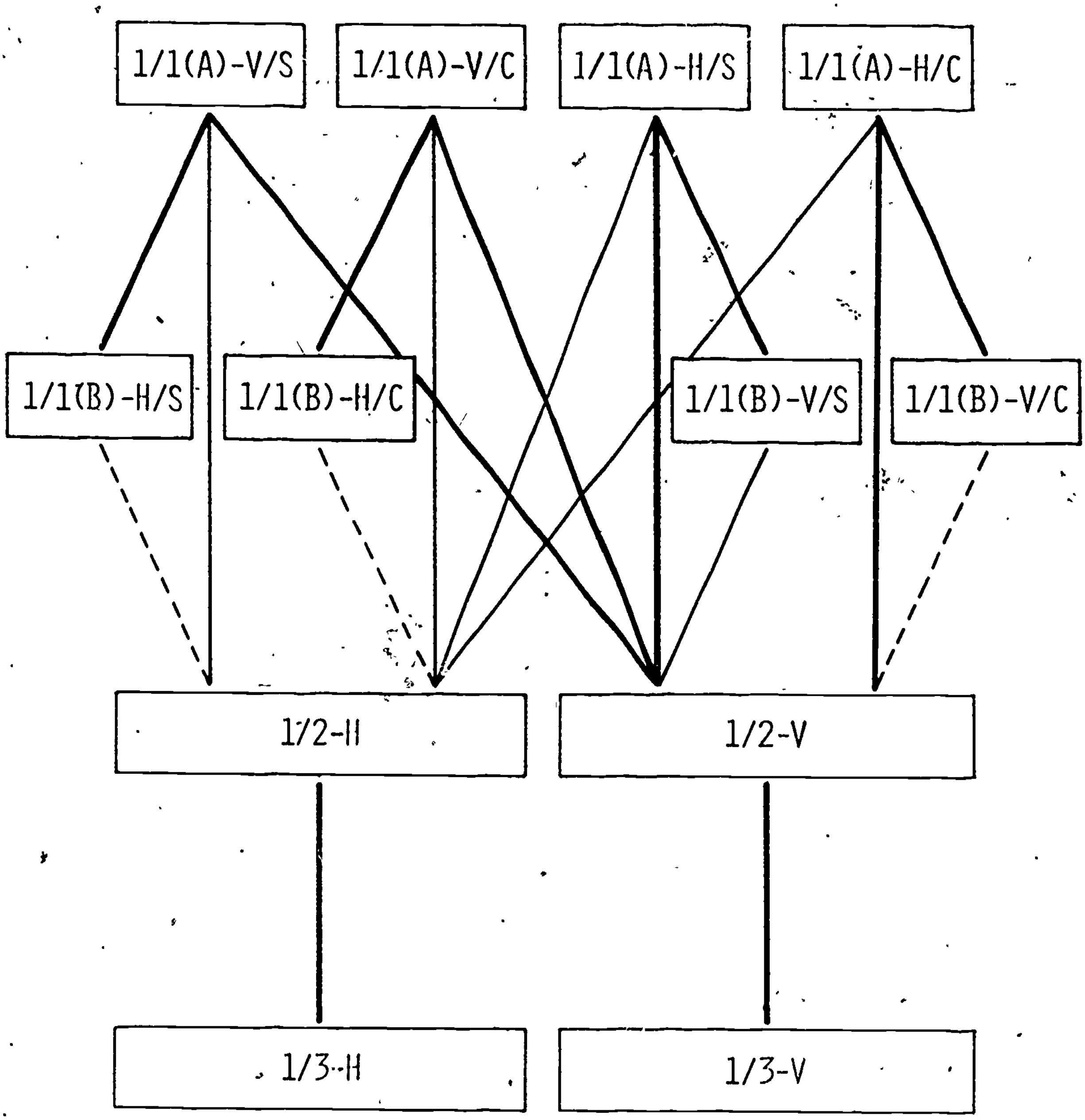

1/1(A)-V/S
1/1(A)-V/C
1/1(A)-H/S
1/1(A)-H/C
1/1(B)-H/S
1/1(B)-H/C
1/1(B)-V/S
1/1(B)-V/C
1/2-H
1/2-V
1/3-H
1/3-V

FIGURE 8.3

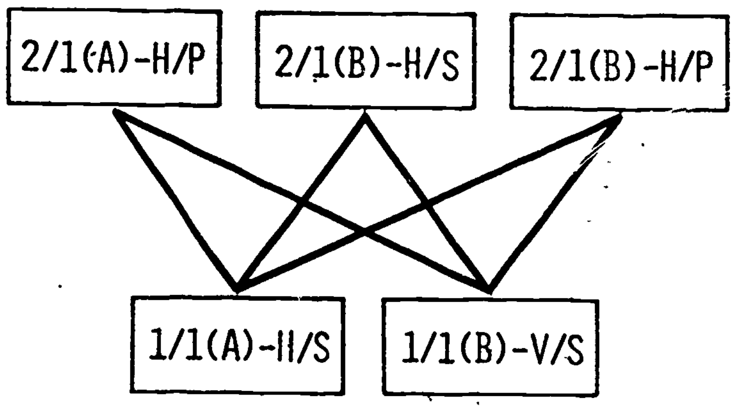


FIGURE 8.4

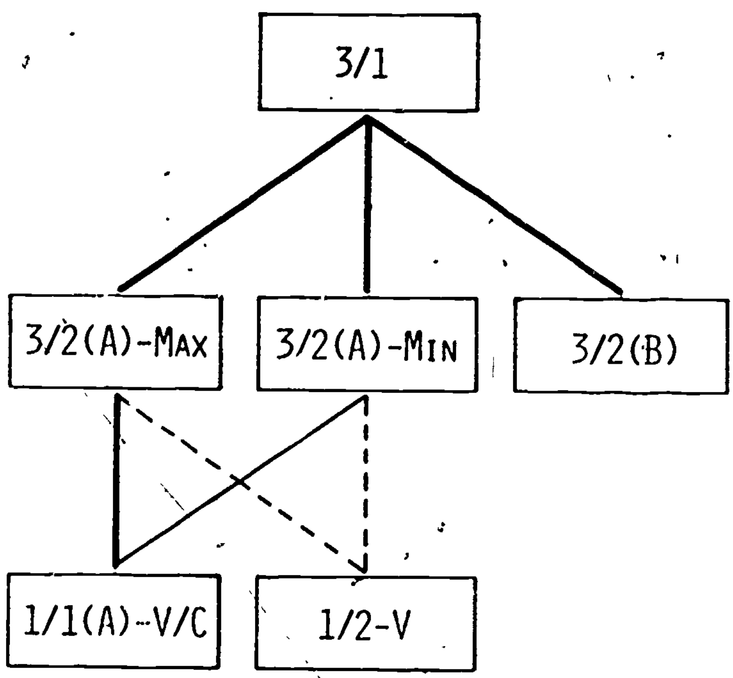


FIGURE 8.5

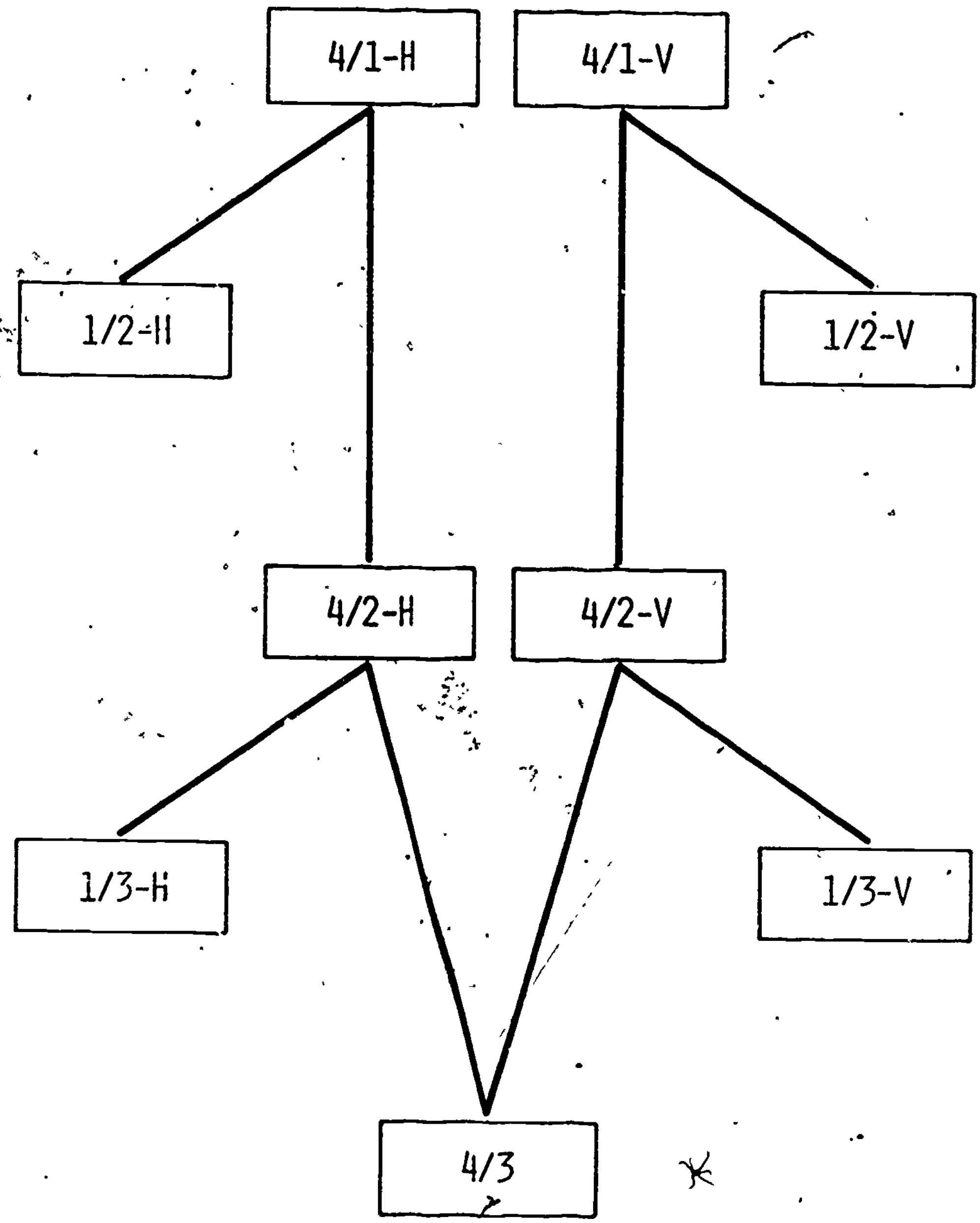


FIGURE 8.6

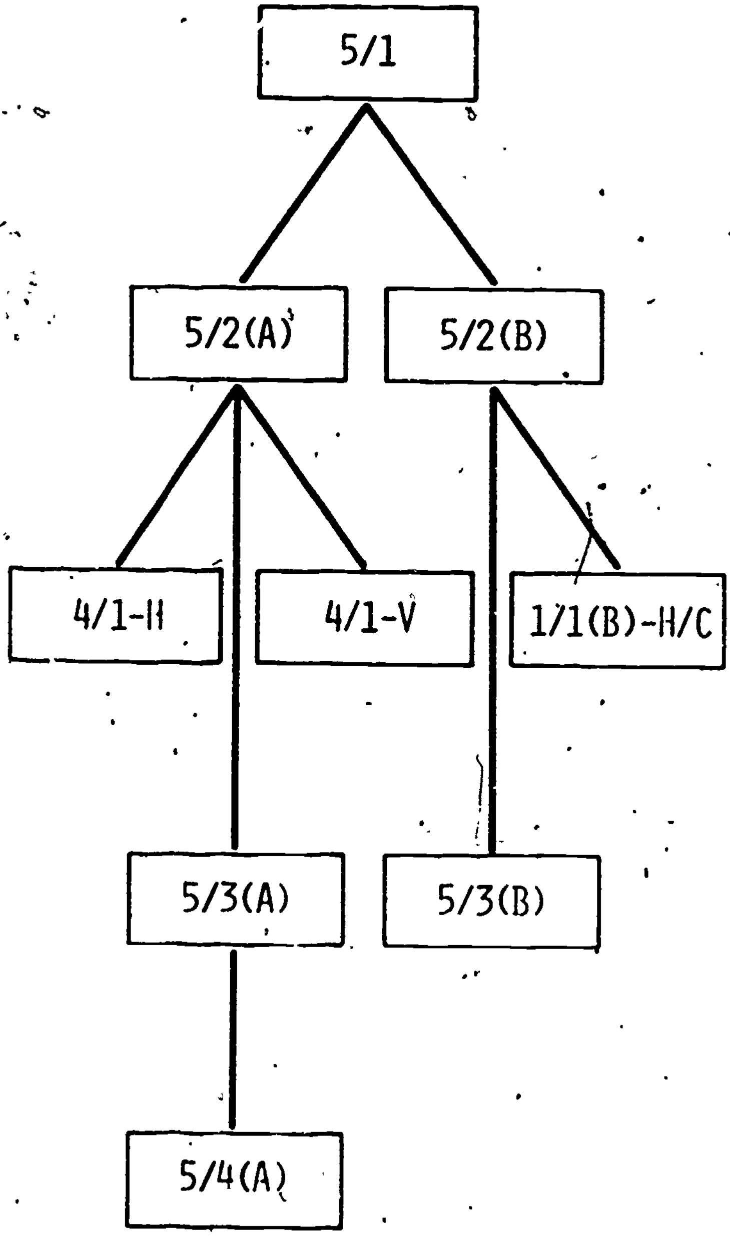
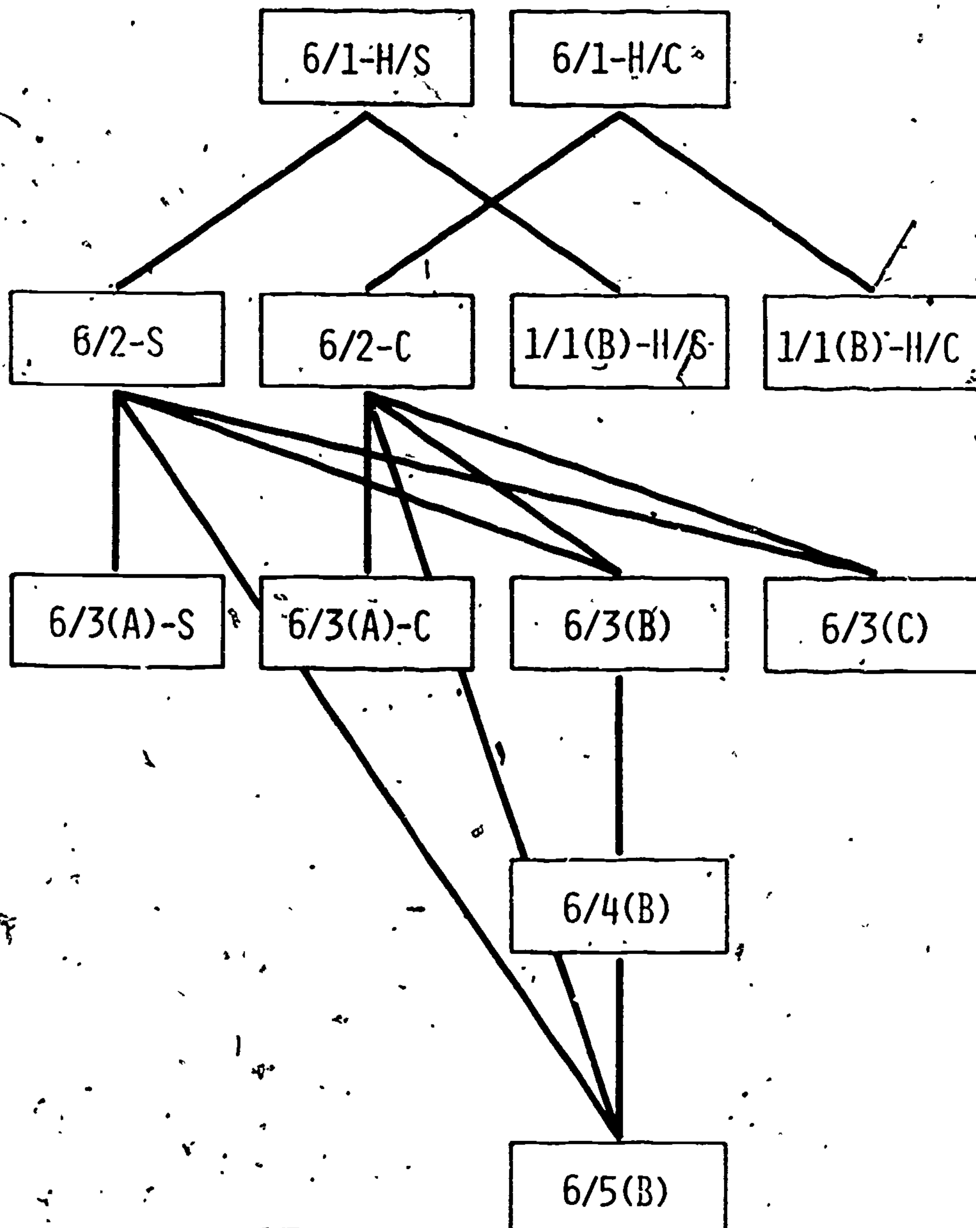


FIGURE 8.7



CHAPTER IX

THE EFFECTS OF DIFFERENT CURRICULAR BACKGROUND ON THE POSTULATED LEARNING HIERARCHY

1. Introduction

In order to determine the influence of different curricular background on the postulated learning hierarchy of graphical interpretation skills, it was decided to test the first validation programme in two other states of Australia. Queensland and South Australia were selected for this purpose, because of certain basic differences in the structure of the educational systems, and more specifically in approaches to the teaching of primary mathematics. With respect to the basic structural differences, both Queensland and South Australia have a five-year period of secondary school, preceded by a seven-year primary school system with no universal pre-school year, while Victoria has a more general pre-school year, a six-year primary system and another six years of secondary school. Interstate differences in degree of pre-school training also mean that equivalent years of formal schooling for different states do not indicate equivalence in mean student age. Differences in relevant curricular background are more difficult to define, and these are further discussed below.

The total characteristics of specific curricular background which influence the learning of new material can not be precisely determined for any individual student, much less a sizeable population. However estimates or assumptions of general capability can probably be made on a state-wide basis with respect to certain common characteristics of prescribed curricular experience. These estimates of general capability could be determined most effectively by a comprehensive pretest of relevant knowledge or skills, but this method w[illegible] be rather tedious, and might not in any case cover the range of potentially useful prerequisites for any given set of new intellectual skills. A weaker, but more practical alternative involves the analysis of content in previous courses of study, where these are defined in relatively specific terms, with the assumption that this would at least define the limits of relevant experience, if not particular levels of competence. Since the courses in primary mathematics are outlined in considerable detail for all three states concerned in this research, the method of curriculum content analysis was considered appropriate and sufficient to determine any fundamental differences in relevant content or approach. Thus a summary of the salient features for each curriculum programme is presented below, with a more detailed outline of graphical and statistical content presented in Tables 9/1-9/3.

The primary mathematics curriculum guide for Victoria (Education Department/Victoria 1965-1969) incorporates a series of progressively sophisticated sections of work in both Pure and Applied Number, with an independent segment on "Statistics and Graphs" in each Applied Number section. The general approach for each of these sections is based on the philosophy of conceptual development proposed initially by Piaget (1950) and more recently by Bruner (1960), in that the specified sequence of activities emphasises the gradual transition from manipulations with concrete objects to various forms of abstract representation (see Table 9/1). With respect to the segments on graphical skills, there is no explicit sequence of specifically defined constructional or interpretative abilities, and no consistent reference

TABLE 9/1

Outline of Graphical and Statistical Content for Victorian Primary Mathematics Curriculum

SECTION	CONTENT ("Statistics and Graphs")
A-C (Applied Number)	Comparison of rows with different numbers of objects; Recognition of symbols.
D-F (Applied Number)	Use of 3-D symbols (e.g. beads); 2-D symbols (bars and paper strips); Pictorial representation with charts, bar graphs and pictographs.
G (Mathematics)	Further use of bar graphs and pictographs, with examples based only on positive integers.
H-I (Mathematics)	Collection of tabular data; Construction and Interpretation of Simple Histograms; Introduction to line graphs; Measures of central tendency (Mean, median and mode.)

NOTES

1. Revisionary topics are not included in this table.
2. The sections listed above have no direct relationship with formal academic grades, but are intended to cover progressively all six primary years.

TABLE 9/2

Outline of Graphical and Statistical Content for Queensland Primary Mathematics Curriculum

STAGE (Grade)	CONTENT ("Statistics and Graphs")
3 (2-3)	Introduction to simple pictographs.
4 (3)	Pictographs (continued); Construction of simple histograms; Number line measurements; Histogram variations.
5 (4)	Horizontal and Vertical bar graphs; Introduction to co-ordinate mapping.
6 (5)	Complex bar graphs; Circle graphs; Cartesian co-ordinates and ordered pairs.
7 (6)	Broken line graphs with maximum and minimum values; Continuous line graphs; Interpolation and Extrapolation; Introduction to negative co-ordinates; Measures of central tendency.
8 (7)	Mapping and interpretation of simple mathematical relationships; Complex Histograms and frequency polygons; Probability and investigation of random events.

NOTE

Revisionary topics are not included in this table.

TABLE 9/3

Outline of Graphical and Statistical Content for South Australian Primary Mathematics Curriculum

GRADE	CONTENT ("Statistics and Graphs")
3	Introduction to Number lines; Collection and organisation of data; Construction of two-dimensional grids; Pictographs; Bar and column graphs; Linear scales.
4	Extension of earlier skills to cover fractions and decimal numbers.
5	Circle graphs; Two-dimensional co-ordinate mapping (with maximum and minimum values) and interpretation of simple mathematical relationships.
6	"Rounding off" numbers and choosing scales; Line graphs; Interpolation and extrapolation; Composite bar graphs; Circle graphs; Co-ordinates and ordered pairs; Graphical equations and truth sets.
7	Extension of line-segment graphs to cover negative and fractional numbers; Mapping simple linear functions; Introduction to Probability.

NOTE

Revisionary topics are not included in this table.

to any particular informational model, although an extensive list of general suggestions is given at a later stage. Moreover, no reference is made to the use of number lines in relation to graphical work, although they are widely used in Pure Number sections for basic numerical operations. In fact there is generally little correlation between developments arising from the Pure Number sections of the relevant curriculum guides and corresponding graphical or statistical applications.

The "Program in Mathematics for Primary Schools" in Queensland (Education Department/Queensland 1966-68) is divided into eight sequential stages covering seven primary grades, and incorporates within each stage (beginning at stage three for grades two and three) a separate section dealing with "Statisticsand Graphs." In contrast with the Victorian curriculum, this programme is based on a hierarchical approach consistent with Gagné's (1965) model of learning, and incorporates a logical sequence of specifically defined and progressively complex constructional and interpretative skills. The sequence of particular topics for each instructional stage is presented in Table 9/2. In contrast again with the Victorian curriculum, the abilities of abstract and pictorial representation associated with graphical skills are assumed in the Queensland programme even at the introductory level (stage three). Various informational models, of both general (or symbolic) and more specific nature, are used throughout the relevant sections of this programme. On the other hand, however, the numerical range used for graphical and statistical applications, although probably more extensive than the corresponding sections in the Victorian curriculum guide, is still considerably more restricted than in other similarly graded sections of the Queensland mathematics programme.

The "Course in Mathematics" for South Australian primary schools (Education Department/South Australia 1969-71) is similar in general approach to the Queensland programme mentioned above, although the sequence of basic graphical skills is certainly not the same. The sections on "Statistics and Graphs" for the South Australian course are introduced at the grade three level, and a comprehensive list of the topics covered in these sections is presented in Table 9/3. The differences in sequence between this and the Queensland programme can easily be determined by a comparative review of the respective curriculum outlines in Tables 9/3 and 9/2. All of the graphical skills for the South Australian course are introduced with simple (integral) number systems, then later reinforced and extended to a wider numerical range, although negative numbers are rarely used in any section of the course.

Perhaps the most fundamental difference between the various curriculum programmes outlined above, at least with respect to the treatment of statistics and graphs, is that of general approach between the Victorian course and those for the other two states. This difference in basic approach also has an important effect on the treatment and selection of more specific content areas, and thus in relation to these the Victorian course also differs from the other two. It incorporates, for example, no substantial coverage of cartesian co-ordinate mapping or the reading of two-dimensional line-segment graphs, which are both important aspects of graphical interpretation, and both covered in interstate curricula. In spite of the similarity in general approach for the Queensland and South Australian courses, and the fact that both contain a comparable range of constructional and interpretative skills, there are still considerable differences in respective presentation sequence which could influence the subsequent learning of more complex graphical skills.

It should be emphasised, perhaps, by way of a cautionary note, that all of the curriculum programmes outlined above are relatively recent publications, and that the materials they contain often represent significant changes in content, sequence or approach from the former respective curriculum guides. Thus all of these state curricula were, at the time of testing, in a more or less transitional phase of general implementation, and although most of the students involved in this experiment would have been exposed for at least one or two years to the current primary courses, their experience prior to that could not be clearly defined. Moreover it seems from informal discussions with teachers at most of the participating schools that, because of the inevitable confusion involved in curricular transition, these students would in general have covered very little by way of systematic practice or instruction in graphical interpretation skills. In addition, the high school curricular background of less than half a year was generally considered not to be closely related to the areas of graphical interpretation involved in the validation programme, and has therefore been ignored as a common influential factor for the purposes of this research. These points are made only to emphasise the distinction between actual student background experience and the potential limits inferred from curriculum content analysis.

2. Interstate Administration of Validation Programme I

The testing level chosen for interstate schools in Queensland and South Australia was again the first high school year. The interstate students were not, as a group, equivalent in age to those in the Victorian (Melbourne) sample, but as explained in section I there is no universal equivalence in age and level of schooling across these three states. The discrepancy is caused by certain structural differences in the respective educational systems, including the extent of pre-school training and acceptance of primary mid-year intake.

The schools for interstate testing in Queensland and South Australia were randomly selected from a list of metropolitan high schools in each of the respective capital cities. Since only one validation programme was used for both states, a full class of students was involved from each participating school, thus reducing to six the number of schools required to maintain an equivalent sample size of approximately 200 students. Although all of these schools were nominally co-educational, the particular classes involved did not always represent both sexes. Moreover these schools were in some cases academically streamed at the first year level, according to various criteria of subject preference or performance. A list of the relevant student characteristics and appropriate selection criteria for each participating school is presented in Tables 9/4 and 9/5.

The Queensland testing sample consisted of 204 first year students from six metropolitan high schools in Brisbane (see Table 9/4 for the number of students from each individual school). This group contained approximately equal numbers of male and female students, ranging in age from 12 to 14 years (taken to the nearest year) with a mean of 13.1. The South Australian group, consisting of 212 first year students from six high schools in Adelaide (see Table 9/5 for the number of students from each individual school), also contained approximately equal numbers of male and female students, but in this case ranging in age from 12 to 15 years with a mean of 13.2. Thus both of the interstate student groups were, on average, approximately six months older than the corresponding Victorian sample (see Chapter VI).

The mean programme completion times for both the Queensland and South Australian groups (shown respectively in Tables 9/4 and 9/5) were significantly shorter at the 0.01 level than those for the corresponding Victorian sample, based on Student's t-test for the difference of sample means (see Glass and Stanley 1970). This result was not unexpected, because of the differences (outlined above) in age and academic level. However as in the previously listed experiments, the working rate for tested classes in Queensland and South Australia was generally constant throughout the validation programme, and thus the respective progression graphs (Figures 9.1 and 9.2) are again approximately linear to the point of first completion.

6. Wavell - Co-educational class with students of low and average ability (top two classes only selected on the basis of academic ability).

6. Wavell - Co-educational class with students of low and average ability (top two classes only selected on the basis of academic ability).

TABLE 9/5

Sample Numbers, Completion Times and Class Selection Criteria for South Australian Schools (Programme I)

HIGH SCHOOL	Number of Students in Sample	Shortest Completion Time (mins.)	Longest Completion Time (mins.)
Campbelltown	36	32	83
Christies Beach	31	42	82
Elizabeth	38	41	75
Marion	37	36	66
Norwood	36	42	67
Underdale	34	34	77
Mean Completion Time		37.8	75.0
Standard Deviation		4.4	7.2

Class Characteristics and Selection Criteria

1. Campbelltown - Co-educational group, consisting of 3 students randomly selected from each of 12 academically graded first year classes.

2. Christies Beach - Co-educational class of average ability, streamed on the basis of primary results.

3. Elizabeth - Co-educational class selected only according to choice of foreign language.

4. Marion - Co-educational class based effectively on random allocation.

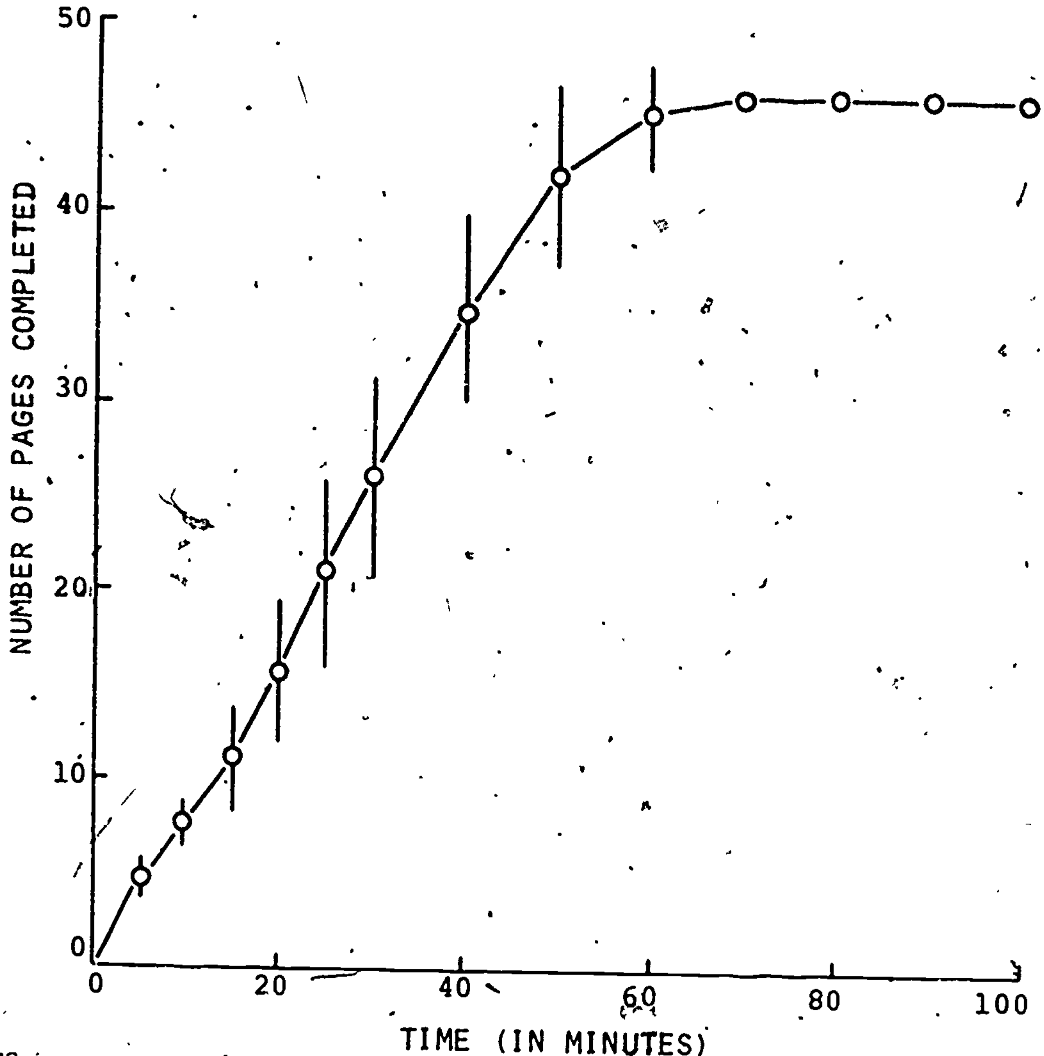
5. Norwood - Co-educational group, consisting of four students randomly selected from each of nine academically graded first year classes.

6. Underdale - Co-educational class of average ability, streamed on the basis of primary results.

FIGURE 9.1

Progression Rate for Programme I

(Oxley High School - Queensland)



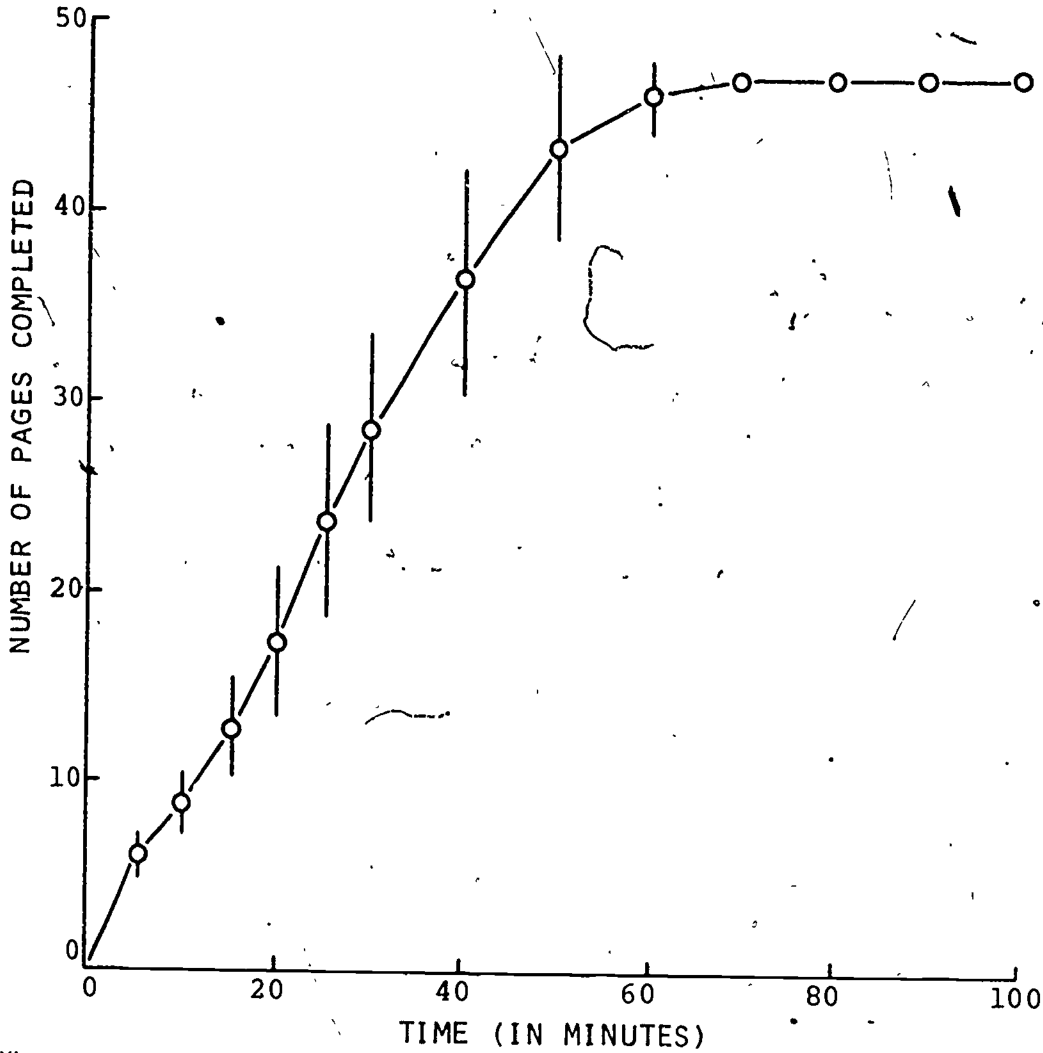
NOTES

1. Circles indicate the mean number of pages completed at specified times.
2. Vertical lines represent the appropriate Standard Deviation.
3. Number of students involved = 34.

FIGURE 9.2

Progression Rate for Programme I

(Campbelltown High School - South Australia)



NOTES.

1. Circles indicate the mean number of pages completed at specified times.
2. Vertical lines represent the appropriate Standard Deviation.
3. Number of students involved = 36.

3. Interstate Results for Validation Programme I

The interstate results for Programme I were subjected to the same statistical analysis as that described in Chapter VI for the local Victorian study. The validation results and specific conclusions derived from this analysis are presented for the Queensland group in Tables 9/6-9/27, and for the South Australian group in Tables 9/33-9/54. The analysis of relevant subdivisional skills is subsequently presented for Queensland in Tables 9/28-9/32, and for South Australia in Tables 9/55-9/59.

The levels of response inconsistency for both the Queensland and South Australian students were of the same order as those for Victorian students in each of the locally tested validation programmes. The statistical power for interstate results, however, was often considerably higher than that shown in the corresponding Victorian results for Programme I, probably because of the lower interstate difficulty levels for individual elements, which tended to increase the difference between the null and alternative hypothesis conditions with respect to the number of exceptions allowed for each hierarchical connection (see Chapter VI/section 2). Although encouraging in this respect, the combined effect observed in the interstate results of similar response inconsistency and lower difficulty levels also emphasised the deficiency in using only marginal totals to calculate the critical number of 0/2 cell exceptions for each correlation table. In Table 9/17 (B), for example, the calculated critical number is four at the absolute Ho level, obviously attributable to the many errors of measurement observed for the higher element, yet only one student was unable to answer either question for the lower skill. In this case, therefore, the postulated hierarchical connection could not possibly be rejected, since almost every student succeeded at the lower skill. Similar results were also observed in other validation tests, and these are shown in Tables 9/18(A), 9/18(C), 9/23(B), 9/44(B), 9/45(A), 9/50(B), 9/51(C) and 9/52(C). In each of these cases the postulated connection was tentatively accepted as valid, although the calculated power was clearly unrealistic.

Apart from the deficiencies mentioned above, the validation results for Queensland (Programme I) were generally quite consistent with those from the previous Victorian studies involving each of the three validation programmes. The Queensland results were also internally consistent with respect to the parallel connections between analogous subdivisional skills at different levels of the postulated learning hierarchy. In fact for the Queensland study almost every postulated hierarchical connection was accepted as valid at one of the specified Ho levels, and most were accepted at the absolute level. Almost all of the weaker connections occurred, as expected from the previous Victorian results, in areas 1-3 (Figures 9.3-9.5), where the repetition of instructions for simpler skills gave additional opportunities for the students to acquire those skills in the process of attempting more complex capabilities. This effect was particularly pronounced for element 1/1(A) (see Table 9/16(C)), but insignificant for all of the skills retested in areas 4-6 (Figures 9.6-9.8), which were covered in sections 2 and 3 of the same validation programme.

Many of the subdivisional analysis results for the Queensland testing programme (Tables 9/28-9/32) failed to differentiate between postulated subdivisional skills. This lack of discrimination was often due to extremely low difficulty levels, as shown for elements 1/3, 1/1(B) (Retest) and 4/2, and for these elements the results are inconsistent with those for analogous tests in the Victorian validation studies. In other cases, however, where no discrimination was made between postulated subdivisional skills, for example in elements 3/2(A), 4/1, 6/3(A) and 6/1, the results are generally consistent with those for the previous studies. Area 6 is probably an exceptional case, in that none of the validation experiments have so far produced internally consistent subdivisional analysis results for this set of basic skills.

The validation results for South Australia (Tables 9/33-9/54) were generally much less positive or clearly defined than those for the Queensland study, in that many of the postulated hierarchical connections for areas 1 and 2 were rejected as invalid at all three specified Ho levels, and several connections in other areas were accepted only at one of the weaker levels. In area 1, for example (see Figure 9.9), almost all of the parallel connections between element 1/2 and the relevant terminal skills (elements 1/1(A) and 1/1(B)) were rejected as invalid. A similar result, though less extreme, was also produced in the previous Victorian study with Validation Programme I (Chapter VI). Moreover the results for area 2 (see Figure 9.10 for the South Australian group) were almost identical for both of these validation studies, and again involved certain inconsistencies between supposedly parallel connections. The cause of these inconsistencies was obviously the same, and involved the repetition of certain basic instructions in progressively complex skills. Retesting results in area 1, for example, showed that a significant proportion of students were able to acquire the relevant skills for both elements 1/2 and 1/1(A), not previously possessed, in the process of attempting more complex capabilities (see Tables 9/43(B) and 9/43(C)). Although none of the postulated connections in areas 3-6 (Figures 9.11-9.14) were completely rejected, some were accepted as valid only at weaker Ho levels, and others (as explained above) could not possibly be rejected because of extremely low difficulty levels.

The subdivisional analysis results for South Australia (Tables 9/55-9/59) show a relatively consistent pattern of discrimination between postulated subdivisional skills. In some cases, however, for example in elements 1/3, 1/1(B) (Retest) and 4/2, the results are probably unreliable because of extremely low difficulty levels. In cases where the tests do not differentiate between postulated subdivisional skills, for example in elements 4/1, 6/3(A) and 6/1, the results are still consistent with those from the previous validation studies. Perhaps the most significant difference from the earlier studies is that in this case the calculation of maximum and minimum values (element 3/2(A)) appears to involve different subdivisional skills, while results for the analogous test in each of the previous studies show no effective difference in these abilities.

4. General Implications from the Interstate Validation Studies

Although the validation results for Queensland were clearly consistent with those from the previous Victorian studies, the South Australian results involved a number of specific inconsistencies. These inconsistencies, however, were largely confined to areas 1 and 2 (both incorporated in section 1 of the relevant validation programme), and may be explained, as suggested above, by the incidental acquisition of prerequisite or subordinate skills through subsequent repetition of instructional notes. Thus the postulated learning hierarchy was, at least for the larger part, similarly substantiated in all three specified states, in spite of obvious differences in specific curricular background (outlined in section 1), and other potential effects of differential age associated with the relevant student groups.

These results serve to establish, at least within a limited empirical framework, the existence of common hierarchical learning structures for students with different curricular background, and thus also serve to extend the potential application of validated learning hierarchies beyond the immediate sampling population. To this extent, the interstate validation studies confirm the feasibility of national curriculum planning based on localised evaluation programmes, in relation at least to those subjects where definite hierarchical structures of intellectual skills can be established.

One of the most important questions arising from these results concerns the limits to which learning hierarchies validated for a particular student population can be more generally applied. While the interstate studies above confirm some power of generalisation to different student groups of comparable age and academic level, they give no information on potential application to students with a different type of social or cultural background. Thus in order to test the potential application of a common learning hierarchy across substantial differences in both cultural and curricular background, the same validation programme (I) was given to a group of high-school students in Papua/New Guinea, where the influence of Western culture, and of formal education in the European sense, has only recently been extended to any real proportion of the indigenous population. The following chapter (X) provides a summary of the background to this international validation study, together with an outline of specific preparations and relevant administrative arrangements. This is followed by a comprehensive list of results, and discussion of the subsequent implications.

TABLES 9/6-9/27

Validation Results for Queensland

(Programme I)

PRELIMINARY NOTES

1. The following results are presented in correlation matrix form, listing the number of questions correct for each element, and the appropriate marginal totals.

2. The critical number of exceptions (C) permitted in the 0/2 cell of the relevant correlation table is listed, together with the appropriate statistical power, for each of the null hypothesis levels defined in Chapter VI (see preliminary notes for Tables 6/4-6/25).

3. The classification code for each element is outlined in Tables 5/4-5/10, and the relevant subdivisional conditions are presented in Tables 6/4-6/25 (preliminary notes).

TABLE 9/6

(A) ELEMENT 1/2-H

ELEMENT 1/3-H

	0	1	2	T
2	19	4	177	200
1	0	0	2	2
0	1	0	1	2
T	20	4	180	204

Ho	C	Power
0.00	1	1.0000
0.01	7	0.9977
0.02	11	0.9492

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 1/2-V

ELEMENT 1/3-V

	0	1	2	T
2	15	11	174	200
1	1	0	1	2
0	1	0	1	2
T	17	11	176	204

Ho	C	Power
0.00	2	1.0000
0.01	7	0.9943
0.02	10	0.9457

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(C) ELEMENT 1/1(B)-V/S

ELEMENT 1/2-V

	0	1	2	T
2	23	24	129	176
1	4	3	4	11
0	10	1	6	17
T	37	28	139	204

Ho	C	Power
0.00	6	0.9859
0.01	9	0.8865
0.02	11	0.7265

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 9/7

(A) ELEMENT 1/1(A)-H/S

ELEMENT 1/1(B)-V/S	0	1	2	T
2	6	10	123	139
1	8	20	0	28
0	36	1	0	37
T	50	31	123	204

Ho	C	POWER
0.00	10	0.8383
0.01	12	0.6557
0.02	14	0.4372

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(B) ELEMENT 1/1(A)-H/S

ELEMENT 1/2-V	0	1	2	T
2	33	24	119	176
1	6	4	1	11
0	11	3	3	17
T	50	31	123	204

Ho	C	POWER
0.00	5	0.9845
0.01	8	0.8656
0.02	10	0.6805

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 1/1(A)-H/S

ELEMENT 1/2-H	0	1	2	T
2	35	25	120	180
1	3	1	0	4
0	12	5	3	20
T	50	31	123	204

Ho	C	POWER
0.00	6	0.9652
0.01	8	0.8709
0.02	10	0.6895

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 9/8

(A) ELEMENT 1/1(B)-H/S

ELEMENT 1/2-H	0	1	2	T
2	15	19	146	180
1	1	0	3	4
0	6	5	9	20
T	22	24	158	204

Ho	C	POWER
0.00	9	0.9576
0.01	11	0.8710
0.02	13	0.7154

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 1/1(A)-V/S

ELEMENT 1/1(B)-H/S	0	1	2	T
2	8	5	145	158
1	9	15	0	24
0	20	2	0	22
T	37	22	145	204

Ho	C	POWER
0.00	7	0.9866
0.01	10	0.8993
0.02	12	0.7574

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 1/1(A)-V/S

ELEMENT 1/2-H	0	1	2	T
2	23	19	138	180
1	4	0	0	4
0	10	3	7	20
T	37	22	145	204

Ho	C	POWER
0.00	6	0.9914
0.01	9	0.9198
0.02	11	0.7891

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level.

TABLE 9/9

(A) ELEMENT 1/1(A)-V/S

ELEMENT 1/2-V	0	1	2	T
2	21	18	137	176
1	7	2	2	11
0	9	2	6	17
T	37	22	145	204

Ho	C	POWER
0.00	5	0.9968
0.01	8	0.9557
0.02	11	0.7844

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level.

(B) ELEMENT 1/1(B)-V/C

ELEMENT 1/2-V	0	1	2	T
2	16	15	145	176
1	4	1	6	11
0	6	4	7	17
T	26	20	158	204

Ho	C	POWER
0.00	7	0.9900
0.01	10	0.9186
0.02	12	0.7936

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 1/1(A)-H/C

ELEMENT 1/1(B)-V/C	0	1	2	T
2	10	4	144	158
1	9	11	0	20
0	24	2	0	26
T	43	17	144	204

Ho	C	POWER
0.00	6	0.9939
0.01	9	0.9372
0.02	12	0.7414

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 9/10

(A) ELEMENT 1/1(A)-H/C

ELEMENT 1/2-V

	0	1	2	T
2	26	13	137	176
1	8	1	2	11
0	9	3	5	17
T	43	17	144	204

Ho	C	POWER
0.00	4	0.9990
0.01	8	0.9554
0.02	10	0.8600

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level.

(B) ELEMENT 1/1(A)-H/C

ELEMENT 1/2-H

	0	1	2	T
2	29	13	138	180
1	4	0	0	4
0	10	4	6	20
T	43	17	144	204

Ho	C	POWER
0.00	4	0.9990
0.01	8	0.9550
0.02	10	0.8590

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level.

(C) ELEMENT 1/1(B)-H/C

ELEMENT 1/2-H

	0	1	2	T
2	25	4	151	180
1	0	1	3	4
0	8	1	11	20
T	33	6	165	204

Ho	C	POWER
0.00	2	1.0000
0.01	7	0.9943
0.02	11	0.9061

CONCLUSION The postulated connection is accepted as valid at the third (0.02) Ho level.

TABLE 9/11

(A)

ELEMENT 1/1(B)-H/C (rows) × ELEMENT 1/1(A)-V/C (columns)

	0	1	2	T
2	18	3	144	165
1	4	2	0	6
0	27	5	1	33
T	49	10	145	204

Ho	C	POWER
0.00	3	0.9998
0.01	7	0.9813
0.02	10	0.8728

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B)

ELEMENT 1/2-H (rows) × ELEMENT 1/1(A)-V/C (columns)

	0	1	2	T
2	36	5	139	180
1	2	1	1	4
0	11	4	5	20
T	49	10	145	204

Ho	C	POWER
0.00	3	0.9998
0.01	7	0.9797
0.02	10	0.8652

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level.

(C)

ELEMENT 1/2-V (rows) × ELEMENT 1/1(A)-V/C (columns)

	0	1	2	T
2	34	3	139	176
1	5	4	2	11
0	10	3	4	17
T	49	10	145	204

Ho	C	POWER
0.00	3	0.9998
0.01	7	0.9807
0.02	10	0.8695

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level.

TABLE 9/12

(A) ELEMENT 2/1(A)-H/P

ELEMENT 1/1(A)-H/S	0	1	2	T
2	14	5	104	123
1	5	7	19	31
0	23	10	17	50
T	42	22	140	204

Ho	C	POWER
0.00	11	0.9155
0.01	14	0.7090
0.02	16	0.5116

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(B) ELEMENT 2/1(A)-H/P

ELEMENT 1/1(B)-V/S	0	1	2	T
2	17	11	111	139
1	9	3	16	28
0	16	8	13	37
T	42	22	140	204

Ho	C	POWER
0.00	9	0.9562
0.01	12	0.7971
0.02	14	0.6111

CONCLUSION The postulated connection is accepted as valid at the third (0.02) Ho level, although the power at this level is particularly low.

(C) ELEMENT 2/1(B)-H/S

ELEMENT 1/1(A)-H/S	0	1	2	T
2	12	9	102	123
1	6	4	21	31
0	27	12	11	50
T	45	25	134	204

Ho	C	POWER
0.00	12	0.8307
0.01	14	0.6592
0.02	16	0.4547

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

TABLE 9/13

(A) ELEMENT 2/1(B)-H/S

ELEMENT 1/1(B)-V/S	0	1	2	T
2	14	11	114	139
1	9	6	13	28
0	22	8	7	37
T	45	25	134	204

Ho	C	POWER
0.00	9	0.9410
0.01	12	0.7521
0.02	14	0.5512

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 2/1(B)-H/P

ELEMENT 1/1(A)-H/S	0	1	2	T
2	15	19	89	123
1	9	5	17	31
0	33	6	11	50
T	57	30	117	204

Ho	C	POWER
0.00	1[illegible]	0.7661
0.01	13	0.5615
0.02	14	0.4519

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(C) ELEMENT 2/1(B)-H/P

ELEMENT 1/1(B)-V/S	0	1	2	T
2	19	21	99	139
1	11	6	11	28
0	27	3	7	37
T	57	30	117	204

Ho	C	POWER
0.00	9	0.8578
0.01	11	0.6776
0.02	13	0.4537

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

TABLE 9/14

(A) ELEMENT 3/2(A)-Max

ELEMENT 1/2-V	0	1	2	T
2	16	29	120	165
1	2	2	4	8
0	13	5	13	31
T	31	36	137	204

Ho	C	POWER
0.00	12	0.7573
0.01	14	0.5579
0.02	16	0.3506

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is particularly low.

(B) ELEMENT 3/2(A)-Max

ELEMENT 1/1(A)-V/C	0	1	2	T
2	18	29	129	176
1	6	3	8	17
0	7	4	0	11
T	31	36	137	204

Ho	C	POWER
0.00	7	0.9408
0.01	9	0.8176
0.02	11	0.6150

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 3/2(A)-Min

ELEMENT 1/2-V	0	1	2	T
2	14	30	121	165
1	2	[illegible]	3	8
0	7	11	13	31
T	23	44	137	204

Ho	C	POWER
0.00	17	0.3639
0.01	19	0.1992
0.02	20	0.1386

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLE 9/15

(A) ELEMENT 3/2(A)-Min

ELEMENT 1/1(A)-V/C	0	1	2	T
2	14	36	126	176
1	5	4	8	17
0	4	4	3	11
T	23	44	137	204

Ho	C	POWER
0.00	9	0.7304
0.01	11	0.4967
0.02	13	0.2751

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(B) ELEMENT 3/1

ELEMENT 3/2(B)	0	1	2	T
2	41	64	82	187
1	4	4	1	9
0	6	2	0	8
T	51	70	83	204

Ho	C	POWER
0.00	6	0.4377
0.01	7	0.2924
0.02	8	0.1789

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C) ELEMENT 3/1

ELEMENT 3/2(A)-Max	0	1	2	T
2	25	42	70	137
1	8	17	11	36
0	18	11	2	31
T	51	70	83	204

Ho	C	POWER
0.00	15	0.0698
0.01	16	0.0398
0.02	16	0.0398

CONCLUSION The postulated connection is accepted at the absolute Ho level, although the power is extremely low.

TABLE 9/16

(A) ELEMENT 3/1

ELEMENT 3/2(A)-Min

	0	1	2	T
2	23	47	67	137
1	15	14	15	44
0	13	9	1	23
T	51	70	83	204

Ho	C	POWER
0.00	13	0.1016
0.01	14	0.0588
0.02	15	0.0321

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 1/2-V (Retest)

ELEMENT 1/2-V

	0	1	2	T
2	16	7	153	176
1	4	1	6	11
0	11	0	6	17
T	31	8	165	204

Ho	C	POWER
0.00	3	1.0000
0.01	8	0.9871
0.02	11	0.9091

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

(C) ELEMENT 1/1(A)-V (Retest)

ELEMENT 1/1(A)-V

	0	1	2	T
2	4	4	137	145
1	2	3	5	10
0	5	10	34	49
T	11	17	176	204

Ho	C	POWER
0.00	20	0.9989
0.01	22	—
0.02	23	—

CONCLUSION This skill was acquired by a significant proportion of students in the process of attempting more complex capabilities.

TABLE 9/17

(A) ELEMENT 4/2-H

ELEMENT 4/3	0	1	2	T
2	5	4	188	197
1	2	1	3	6
0	1	0	0	1
T	8	5	191	204

Ho	C	POWER
0.00	2	1.0000
0.01	8	0.9948
0.02	11	0.9535

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(B) ELEMENT 4/2-V

ELEMENT 4/3	0	1	2	T
2	9	56	132	197
1	1	2	3	6
0	1	0	0	1
T	11	58	135	204

Ho	C	POWER
0.00	4	0.2379
0.01	5	0.1165
0.02	6	0.0501

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(C) ELEMENT 4/2-H

ELEMENT 1/3-H	0	1	2	T
2	5	5	191	201
1	1	0	0	1
0	2	0	0	2
T	8	5	191	204

Ho	C	POWER
0.00	2	1.0000
0.01	8	0.9949
0.02	11	0.9540

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

TABLE 9/18

(A) ELEMENT 4/2-V

ELEMENT 1/3-V

	0	1	2	T
2	9	56	134	199
1	0	2	0	2
0	2	0	1	3
T	11	58	135	204

Ho	C	POWER
0.00	7	0.0729
0.01	7	0.0729
0.02	8	0.0323

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 4/1-H

ELEMENT 4/2-H

	0	1	2	T
2	11	23	157	191
1	0	1	4	5
0	6	1	1	8
T	17	25	162	204

Ho	C	POWER
0.00	7	0.9724
0.01	9	0.8985
0.02	12	0.6478

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 4/1-V

ELEMENT 4/2-V

	0	1	2	T
2	7	10	118	135
1	4	9	45	58
0	5	1	5	11
T	16	20	168	204

Ho	C	POWER
0.00	15	0.8163
0.01	17	0.6557
0.02	19	0.4669

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

TABLE 9/19

(A) ELEMENT 4/1-H

ELEMENT 1/2-H

	0	1	2	T
2	7	18	148	173
1	3	3	4	10
0	7	4	10	21
T	17	25	162	204

Ho	C	POWER
0.00	11	0.9012
0.01	14	0.6773
0.02	16	0.4750

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 4/1-V

ELEMENT 1/2-V

	0	1	2	T
2	7	14	150	171
1	2	2	9	13
0	7	4	9	20
T	16	20	168	204

Ho	C	POWER
0.00	10	0.9555
0.01	13	0.8043
0.02	15	0.6277

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 5/3(A)

ELEMENT 5/4(A)

	0	1	2	T
2	13	9	161	183
1	0	0	2	2
0	12	0	7	19
T	25	9	170	204

Ho	C	POWER
0.00	4	0.9999
0.01	8	0.9898
0.02	11	0.9234

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level.

TABLE 9/20

(A) ELEMENT 5/2(A)

ELEMENT 5/3 (A)	0	1	2	T
2	71	16	83	170
1	3	3	3	9
0	20	3	2	25
T	94	22	88	204

Ho	C	POWER
0.00	3	0.9793
0.01	6	0.7902
0.02	8	0.5340

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 5/2(A)

ELEMENT 4/1-H	0	1	2	T
2	61	13	77	151
1	10	4	9	23
0	23	5	2	30
T	94	22	88	204

Ho	C	POWER
0.00	5	0.9062
0.01	7	0.7150
0.02	9	0.4519

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 5/2(A)

ELEMENT 4/1-V	0	1	2	T
2	63	16	81	160
1	9	1	5	15
0	22	5	2	29
T	94	22	88	204

Ho	C	POWER
0.00	4	0.9503
0.01	6	0.8038
0.02	8	0.5539

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 9/21

(A) ELEMENT 5/2(B)

ELEMENT 5/3(B)		0	1	2	T
	2	14	3	104	121
	1	18	5	13	36
	0	43	4	0	47
	T	75	12	117	204

Ho	C	Power
0.00	8	0.9313
0.01	10	0.8050
0.02	13	0.4943

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 5/2(B)

ELEMENT 1/1(B)-H/C		0	1	2	T
	2	53	9	110	172
	1	5	2	6	13
	0	17	1	1	19
	T	75	12	117	204

Ho	C	Power
0.00	3	0.9979
0.01	6	0.9544
0.02	9	0.7502

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 5/1

ELEMENT 5/2(B)		0	1	2	T
	2	61	32	24	117
	1	7	3	2	12
	0	55	17	3	75
	T	123	52	29	204

Ho	C	Power
0.00	9	0.0185
0.01	9	0.0185
0.02	9	0.0185

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 9/22

(A) ELEMENT 5/1

ELEMENT 5/2 (A)

	0	1	2	T
2	36	28	25	89
1	21	8	3	32
0	66	16	1	83
T	123	52	29	204

Ho	C	POWER
0.00	10	0.0181
0.01	10	0.0181
0.02	11	0.0074

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 4/1-H (Retest)

ELEMENT 4/1-H

	0	1	2	T
2	7	18	137	162
1	7	5	13	25
0	16	0	1	17
T	30	23	151	204

Ho	C	POWER
0.00	8	0.9750
0.01	10	0.9111
0.02	13	0.6884

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

(C) ELEMENT 4/1-V (Retest)

ELEMENT 4/1-V

	0	1	2	T
2	8	13	147	168
1	6	2	12	20
0	15	0	1	16
T	29		160	204

Ho	C	POWER
0.00	6	0.9974
0.01	9	0.9671
0.02	12	0.8334

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

TABLE 9/23

(A) ELEMENT 5/2(A) (Retest)

ELEMENT 5/2(A)		0	1	2	T
	2	3	5	80	88
	1	8	7	7	22
	0	72	20	2	94
	T	83	32	89	204

Ho	C	POWER
0.00	11	0.5124
0.01	12	0.3948
0.02	14	0.2002

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

(B) ELEMENT 6/4(B)

ELEMENT 6/5(B)		0	1	2	T
	2	5	9	185	199
	1	0	0	4	4
	0	0	0	1	1
	T	5	9	190	204

Ho	C	POWER
0.00	3	0.9998
0.01	7	0.9815
0.02	10	0.9734

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(C) ELEMENT 6/3(B)

ELEMENT 6/4(B)		0	1	2	T
	2	26	9	155	190
	1	1	2	6	9
	0	3	0	2	5
	T	30	11	163	204

Ho	C	POWER
0.00	3	0.9999
0.01	7	0.9921
0.02	11	0.8833

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 9/24

(A) ELEMENT 6/2-S

ELEMENT 6/3(B)	0	1	2	T
2	23	32	82	137
1	12	7	2	21
0	46	0	0	46
T	81	39	84	204

Ho	C	POWER
0.00	8	0.6388
0.01	10	0.3800
0.02	11	0.2675

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B) ELEMENT 6/2-S

ELEMENT 6/3(A)-S	0	1	2	T
2	25	20	84	129
1	21	19	0	40
0	35	0	0	35
T	81	39	84	204

Ho	C	POWER
0.00	9	0.5690
0.01	11	0.3222
0.02	12	0.2219

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C) ELEMENT 6/2-S

ELEMENT 6/5(B)	0	1	2	T
2	63	33	66	162
1	12	6	16	34
0	6	0	2	8
T	81	39	84	204

Ho	C	POWER
0.00	5	0.8599
0.01	7	0.6255
0.02	9	0.3526

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

TABLE 9/25

(A) ELEMENT 6/2-C

ELEMENT 6/3(B)	0	1	2	T
2	28	19	103	150
1	5	5	0	10
0	43	0	1	44
T	76	24	104	204

Ho	C	POWER
0.00	5	0.9646
0.01	8	0.7693
0.02	10	0.5351

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 6/2-C

ELEMENT 6/3(A)-C	0	1	2	T
2	17	14	104	135
1	15	10	0	25
0	44	0	0	44
T	76	24	104	204

Ho	C	POWER
0.00	7	0.8924
0.01	9	0.7170
0.02	11	0.4803

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(C) ELEMENT 6/2-C

ELEMENT 6/5(B)	0	1	2	T
2	58	17	87	162
1	12	6	16	34
0	6	1	1	8
T	76	24	104	204

Ho	C	POWER
0.00	6	0.9263
0.01	8	0.7738
0.02	10	0.5413

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 9/26

(A)

ELEMENT 6/1-H/S

ELEMENT 6/2-S	0	1	2	T
2	24	15	45	84
1	12	9	18	39
0	70	7	4	81
T	106	31	67	204

Ho	C	POWER
0.00	11	0.2684
0.01	12	0.1777
0.02	13	0.1107

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B)

ELEMENT 6/1-H/C

ELEMENT 6/2-C	0	1	2	T
2	21	16	67	104
1	8	5	11	24
0	71	4	1	76
T	100	25	79	204

Ho	C	POWER
0.00	7	0.7185
0.01	9	0.4561
0.02	10	0.3310

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(C)

ELEMENT 6/1-H/S

ELEMENT 1/1(B)-H/S	0	1	2	T
2	99	31	65	195
1	5	0	1	6
0	2	0	1	3
T	106	31	67	204

Ho	C	POWER
0.00	2	0.9570
0.01	5	0.6241
0.02	6	0.4635

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 9/27

(A) ELEMENT 6/1-H/C

ELEMENT 1/1(B)-H/C	0	1	2	T
2	95	25	78	198
1	4	0	1	5
0	1	0	0	1
T	100	25	79	204

Ho	C	POWER
0.00	1	0.9964
0.01	5	0.7820
0.02	7	0.5021

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(B) ELEMENT 6/2-S

ELEMENT 6/3(C)	0	1	2	T
2	23	19	84	126
1	22	20	0	42
0	36	0	0	36
T	81	39	84	204

Ho	C	POWER
0.00	9	0.4668
0.01	10	0.3463
0.02	11	0.2423

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C) ELEMENT 6/2-C

ELEMENT 6/3(C)	0	1	2	T
2	16	13	104	133
1	15	11	0	26
0	45	0	0	45
T	76	24	104	204

Ho	C	POWER
0.00	7	0.5969
0.01	9	0.7254
0.02	11	0.4907

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

TABLES 9/28-9/32

Subdivisional Analysis Results for Queensland

(Programme I)

PRELIMINARY NOTES

1. The following results are presented in correlation matrix form, listing the number of questions correct for each element, and the appropriate marginal totals.

2. The classification code for each element is outlined in Tables 5/4-5/10, and a list of the relevant subdivisional question groups is presented in Table 6/2.

3. P represents the combined probability that the observed number of students in the 0/2 and 2/0 cells could have occurred through chance (or errors of measurement) under the null hypothesis that no-one can possess only one of the relevant subdivisional skills without also having the other.

TABLE 9/28

(A)

		GROUP 2: 0	1	2	T
GROUP 1	2	0	2	198	200
	1	0	0	2	2
	0	2	0	0	2
	T	2	2	200	204

ELEMENT 1/3

TEST H/V (Position)

P = 1.0000

CONCLUSION Question groups 1 and 2 may represent the same subdivisional skill.

(B)

		GROUP 2: 0	1	2	T
GROUP 1	2	1	4	175	180
	1	0	4	0	4
	0	16	3	1	20
	T	17	11	176	204

ELEMENT 1/2

TEST H/V (Co-ordinates)

P = 0.0130

CONCLUSION Question groups 1 and 2 probably represent the same subdivisional skill.

(C)

		GROUP 2: 0	1	2	T
GROUP 1	2	15	17	126	158
	1	10	6	8	24
	0	12	5	5	22
	T	37	28	139	204

ELEMENT 1/1(B)

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(D)

		GROUP 3: 0	1	2	T
GROUP 1	2	5	2	151	158
	1	11	3	10	24
	0	17	1	4	22
	T	33	6	165	204

ELEMENT 1/1(B)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

TABLE 9/29

(A)

		GROUP 4			
		0	1	2	T
GROUP 2	2	3	4	132	139
	1	4	10	14	28
	0	19	6	12	37
	T	26	20	158	204

ELEMENT 1/1(B)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 2 and 4 represent different subdivisional skills.

(B)

		GROUP 2			
		0	1	2	T
GROUP 1	2	8	4	111	123
	1	7	5	19	31
	0	22	13	15	50
	T	37	22	145	204

ELEMENT 1/1(A)

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

		GROUP 3			
		0	1	2	T
GROUP 1	2	4	4	115	123
	1	4	7	20	31
	0	35	6	9	50
	T	43	17	144	204

ELEMENT 1/1(A)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

(D)

		GROUP 4			
		0	1	2	T
GROUP 2	2	11	3	131	145
	1	14	1	7	22
	0	24	6	7	37
	T	49	10	145	204

ELEMENT 1/1(A)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 2 and 4 represent different subdivisional skills.

TABLE 9/30

(A) GROUP 2/1(B)-2 (columns); GROUP 2/1(A)-1 (rows)

	0	1	2	T
2	16	24	100	140
1	11	3	8	22
0	30	3	9	42
T	57	30	117	204

ELEMENT 2/1(A)-2/1(B)

TEST Interpolation/Extrapolation

P = 0.0000

CONCLUSION Elements 2/1(A) and 2/1(B) represent different basic skills.

(B) GROUP 2 (columns); GROUP 1 (rows)

	0	1	2	T
2	15	17	102	134
1	5	11	9	25
0	37	2	6	45
T	57	30	117	204

ELEMENT 2/1(B)

TEST Line/Points

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivision skills.

(C) GROUP 2 (columns); GROUP 1 (rows)

	0	1	2	T
2	2	19	116	137
1	6	11	19	36
0	15	14	2	31
T	23	44	137	204

ELEMENT 3/2(A)

TEST Max./ Min. Values

P = 0.3906

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(D) GROUP 2 (columns); GROUP 1 (rows)

	0	1	2	T
2	1	1	199	201
1	0	1	0	1
0	2	0	0	2
T	3	2	199	204

ELEMENT 1/3 (Retest)

TEST H/V (Position)

P = 0.0118

CONCLUSION Question groups 1 and 2 probably represent the same subdivisional skill.

TABLE 9/31

(A)

		GROUP 2: 0	1	2	T
GROUP 1	2	0	11	162	173
	1	0	2	8	10
	0	20	0	1	21
	T	20	13	171	204

ELEMENT 1/2 (Retest)

TEST H/V (Co-ordinates)

P = 0.1489

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(B)

		GROUP 2: 0	1	2	T
GROUP 1	2	4	55	132	191
	1	1	2	2	5
	0	6	1	1	8
	T	11	58	135	204

ELEMENT 4/2

TEST H/V (Displacement)

P = 0.2241

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(C)

		GROUP 2: 0	1	2	T
GROUP 1	2	1	7	154	162
	1	2	9	14	25
	0	13	4	0	17
	T	16	20	168	204

ELEMENT 4/1

TEST H/V (Displacement)

P = 0.3630

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(D)

		GROUP 3: 0	1	2	T
GROUP 1	2	0	4	191	195
	1	0	1	5	6
	0	1	0	2	3
	T	1	5	198	204

ELEMENT 1/1 (B) (Retest)

TEST Straight Line/Curve

P = 0.1199

CONCLUSION Question groups 1 and 3 may represent the same subdivisional skill.

TABLE 9/32

(A)

GROUP 1 \ GROUP 2	0	1	2	T
2	7	33	159	199
1	0	1	3	4
0	1	0	0	1
T	8	34	162	204

ELEMENT 6/5(B)

TEST Numerical Range

P = 0.0131

CONCLUSION Question groups 1 and 2 probably represent the same subdivisional skill.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	3	13	113	129
1	13	8	19	40
0	28	4	3	35
T	44	25	135	204

ELEMENT 6/3(A)

TEST Straight Line/Curve

P = 0.0423

CONCLUSION Question groups 1 and 2 probably represent the same subdivisional skill.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	1	11	72	84
1	6	9	24	39
0	69	4	8	81
T	76	24	104	204

ELEMENT 6/2

TEST Straight Line/Curve

P = 0.0026

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(D)

GROUP 1 \ GROUP 2	0	1	2	T
2	0	10	57	67
1	4	10	17	31
0	96	5	5	106
T	100	25	79	204

ELEMENT 6/1

TEST Straight Line/Curve

P = 0.0329

CONCLUSION Question groups 1 and 2 probably represent the same subdivisional skill.

TABLES 9/33-9/54

Validation Results for South Australia

(Programme I)

RY NOTES

ollowing results are presented in correlation matrix form, ng the number of questions correct for each element, and the priate marginal totals.

ritical number of exceptions (C) permitted in the 0/2 cell e relevant correlation table is listed, together with the priate statistical power, for each of the null hypothesis s defined in Chapter VI (see preliminary notes for Tables /25).

lassification code for each element is outlined in Tables /10, and the relevant subdivisional conditions in Tables /25 (preliminary notes).

TABLE 9/33

(A) ELEMENT 1/2-H

ELEMENT 1/3-H	0	1	2	T
2	29	7	173	209
1	0	0	0	0
0	2	0	1	3
T	31	7	174	212

Ho	C	POWER
0.00	1	1.0000
0.01	7	0.9964
0.02	11	0.9310

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 1/2-V

ELEMENT 1/3-V	0	1	2	T
2	25	10	174	209
1	0	0	0	0
0	3	0	0	3
T	28	10	174	212

Ho	C	POWER
0.00	2	1.0000
0.01	7	0.9958
0.02	11	0.9234

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 1/1(B)-V/S

ELEMENT 1/2-V	0	1	2	T
2	34	16	124	174
1	7	1	2	10
0	12	2	14	28
T	53	19	140	212

Ho	C	POWER
0.00	5	0.9963
0.01	8	0.9509
0.02	11	0.7697

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

TABLE 9/34

(A)

ELEMENT 1/1(B)-V/S \ ELEMENT 1/1(A)-H/S	0	1	2	T
2	5	6	129	140
1	6	13	0	19
0	49	4	0	53
T	60	23	129	212

Ho	C	POWER
0.00	8	0.9488
0.01	10	0.8444
0.02	12	0.6655

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B)

ELEMENT 1/2-V \ ELEMENT 1/1(A)-H/S	0	1	2	T
2	40	18	116	174
1	5	3	2	10
0	15	2	11	28
T	60	23	129	212

Ho	C	POWER
0.00	5	0.9919
0.01	8	0.9144
0.02	10	0.7704

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(C)

ELEMENT 1/2-H \ ELEMENT 1/1(A)-H/S	0	1	2	T
2	41	19	114	174
1	4	0	3	7
0	15	4	12	31
T	60	23	129	212

Ho	C	POWER
0.00	5	0.9921
0.01	8	0.9158
0.02	10	0.7732

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(A) ELEMENT 1/1(B)-H/S; rows: ELEMENT 1/2-H

ELEMENT 1/2-H	0	1	2	T
2	21	17	136	174
1	3	2	2	7
0	9	4	18	31
T	33	23	156	212

Ho	C	POWER
0.00	8	0.9846
0.01	11	0.8968
0.02	13	0.7597

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(B) ELEMENT 1/1(A)-V/S; rows: ELEMENT 1/1(B)-H/S

ELEMENT 1/1(B)-H/S	0	1	2	T
2	6	3	147	156
1	10	13	0	23
0	31	2	0	33
T	47	18	147	212

Ho	C	POWER
0.00	7	0.9896
0.01	10	0.9164
0.02	12	0.7895

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 1/1(A)-V/S; rows: ELEMENT 1/2-H

ELEMENT 1/2-H	0	1	2	T
2	29	15	130	174
1	4	1	2	7
0	14	2	15	31
T	47	18	147	212

Ho	C	POWER
0.00	5	0.9978
0.01	8	0.9674
0.02	11	0.8251

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

TABLE 9/36

(A) ELEMENT 1/1(A)-V/S

ELEMENT 1/2-V	0	1	2	T
2	30	13	131	174
1	6	1	3	10
0	11	4	13	28
T	47	18	147	212

Ho	C	POWER
0.00	5	0.9978
0.01	8	0.9669
0.02	11	0.8233

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(B) ELEMENT 1/1(B)-V/C

ELEMENT 1/2-V	0	1	2	T
2	24	10	140	174
1	3	4	3	10
0	12	1	15	28
T	39	15	158	212

Ho	C	POWER
0.00	5	0.9991
0.01	9	0.9639
0.02	11	0.8866

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(C) ELEMENT 1/1(A)-H/C

ELEMENT 1/1(B)-V/C	0	1	2	T
2	12	4	142	158
1	7	6	2	15
0	36	3	0	39
T	55	13	144	212

Ho	C	POWER
0.00	5	0.9976
0.01	8	0.9647
0.02	11	0.8154

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 9/37

(A) ELEMENT 1/1(A)-H/C

ELEMENT 1/2-V	0	1	2	T
2	32	12	130	174
1	5	0	5	10
0	18	1	9	28
T	55	13	144	212

Ho	C	POWER
0.00	4	0.9991
0.01	7	0.9804
0.02	10	0.8684

CONCLUSION The postulated connection is accepted as valid at the third (0.02) Ho level, although the power at this level is relatively low.

(B) ELEMENT 1/1(A)-H/C

ELEMENT 1/2-[illegible]	0	1	2	T
2	34	12	128	174
1	2	0	5	7
0	19	1	11	31
T	55	13	144	212

Ho	C	POWER
0.00	4	0.9991
0.01	7	0.9802
0.02	10	0.8675

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(C) ELEMENT 1/1(B)-H/C

ELEMENT 1/2-H	0	1	2	T
2	23	3	148	174
1	4	0	3	7
0	11	1	19	31
T	38	4	170	212

Ho	C	POWER
0.00	2	1.0000
0.01	7	0.9961
0.02	11	0.9268

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

TABLE 9/38

(A) ELEMENT 1/1(A)-V/C

ELEMENT 1/1(B)-H/C	0	1	2	T
2	16	0	154	170
1	1	3	0	4
0	32	5	1	38
T	49	8	155	212

Ho	C	POWER
0.00	3	0.9999
0.01	7	0.9897
0.02	10	0.9167

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 1/1(A)-V/C

ELEMENT 1/2-H	0	1	2	T
2	32	4	138	174
1	4	1	2	7
0	13	3	15	31
T	49	8	155	212

Ho	C	POWER
0.00	3	0.9999
0.01	7	0.9897
0.02	10	0.9165

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(C) ELEMENT 1/1(A)-V/C

ELEMENT 1/2-V	0	1	2	T
2	31	3	140	174
1	5	3	2	10
0	13	2	13	28
T	49	8	155	212

Ho	C	POWER
0.00	3	0.9999
0.01	7	0.9899
0.02	10	0.9179

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

TABLE 9/39

(A) ELEMENT 2/1(A)-H/P

ELEMENT 1/1(A)-H/S	0	1	2	T
2	20	15	94	129
1	9	3	11	23
0	32	9	19	60
T	61	27	124	212

Ho	C	POWER
0.00	9	0.9150
0.01	12	0.6857
0.02	14	0.4711

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(B) ELEMENT 2/1(A)-H/P

ELEMENT 1/1(B)-V/S	0	1	2	T
2	25	16	99	140
1	5	4	10	19
0	31	7	15	53
T	61	27	124	212

Ho	C	POWER
0.00	8	0.9401
0.01	11	0.7372
0.02	13	0.5248

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(C) ELEMENT 2/1(B)-H/S

ELEMENT 1/1(A)-H/S	0	1	2	T
2	15	12	102	129
1	8	4	11	23
0	34	8	18	60
T	57	24	131	212

Ho	C	POWER
0.00	9	0.9378
0.01	11	0.8266
0.02	14	0.5408

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(A) ELEMENT 2/1(B)-H/S

ELEMENT 1/1(B)-V/S	0	1	2	T
2	19	14	107	140
1	4	2	13	19
0	34	8	11	53
T	57	24	131	212

Ho	C	POWER
0.00	8	0.9574
0.01	10	0.8650
0.02	13	0.5944

CONCLUSION The postulated connection is accepted as valid at the third (0.02) Ho level, although the power at this level is particularly low.

(B) ELEMENT 2/1(B)-H/P

ELEMENT 1/1(A)-H/S	0	1	2	T
2	24	23	82	129
1	6	4	13	23
0	35	13	12	60
T	65	40	107	212

Ho	C	POWER
0.00	12	0.5875
0.01	13	0.4748
0.02	15	0.2700

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C) ELEMENT 2/1(B)-H/P

ELEMENT 1/1(B)-V/S	0	1	2	T
2	29	25	86	140
1	4	4	11	19
0	32	11	10	53
T	65	40	107	212

Ho	C	POWER
0.00	10	0.7392
0.01	12	0.5183
0.02	14	0.3015

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

TABLE 9/41

(A) ELEMENT 3/2(A)-Max.

ELEMENT 1/2-V	0	1	2	T
2	29	33	98	160
1	4	2	8	14
0	12	11	15	38
T	45	46	121	212

Ho	C	POWER
0.00	11	0.6658
0.01	13	0.4487
0.02	15	0.2537

CONCLUSION The postulated connection is accepted as valid at the third (0.02) Ho level, although the power at this level is extremely low.

(B) ELEMENT 3/2(A)-Max.

ELEMENT 1/1(A)-V/C	0	1	2	T
2	28	28	113	169
1	9	7	4	20
0	8	11	4	23
T	45	46	121	212

Ho	C	POWER
0.00	10	0.7177
0.01	11	0.6079
0.02	13	0.3792

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(C) ELEMENT 3/2(A)-Min.

ELEMENT 1/2-V	0	1	2	T
2	23	34	103	160
1	6	1	7	14
0	13	10	15	38
T	42	45	125	212

Ho	C	POWER
0.00	13	0.6138
0.01	15	0.4002
0.02	16	0.3030

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is particularly low.

TABLE 9/42

(A) ELEMENT 3/2(A)-Min.

ELEMENT 1/1(A)-V/C

	0	1	2	T
2	28	30	111	169
1	6	7	7	20
0	8	8	7	23
T	42	45	125	212

Ho	C	Power
0.00	10	0.7563
0.01	12	0.5401
0.02	14	0.3213

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(B) ELEMENT 3/1

ELEMENT 3/2(B)

	0	1	2	T
2	52	55	89	196
1	5	3	0	8
0	5	3	0	8
T	62	61	89	212

Ho	C	Power
0.00	5	0.7622
0.01	7	0.4750
0.02	8	0.3352

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(C) ELEMENT 3/1

ELEMENT 3/2(A)-Max.

	0	1	2	T
2	25	34	62	121
1	16	15	15	46
0	21	12	12	45
T	62	61	89	212

Ho	C	Power
0.00	16	0.1577
0.01	17	0.1027
0.02	18	0.0637

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(A) ELEMENT 3/1

ELEMENT 3/2(A)-Min.	0	1	2	T
2	32	31	62	125
1	11	18	16	45
0	19	12	11	42
T	62	61	89	212

Ho	C	POWER
0.00	15	0.1912
0.01	16	0.1266
0.02	17	0.0798

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 1/2-V (Retest)

ELEMENT 1/2-V	0	1	2	T
2	21	9	144	174
1	3	3	4	10
0	14	2	12	28
T	38	14	160	212

Ho	C	POWER
0.00	5	0.9992
0.01	8	0.9843
0.02	11	0.8954

CONCLUSION This skill was acquired by a significant proportion of students in the process of attempting more complex capabilities.

(C) ELEMENT 1/1(A)-V (Retest)

ELEMENT 1/1(A)-V	0	1	2	T
2	5	5	145	155
1	4	2	2	8
0	14	13	22	49
T	23	20	169	212

Ho	C	POWER
0.00	13	0.9300
0.01	15	0.8308
0.02	17	0.6767

CONCLUSION This skill was acquired by a significant proportion of students in the process of attempting more complex capabilities.

TABLE 9/44

(A) ELEMENT 4/2-H

ELEMENT 4/3	0	1	2	T
2	22	3	180	205
1	1	0	3	4
0	0	1	2	3
T	23	4	185	212

Ho	C	Power
0.00	1	1.0000
0.01	8	0.9958
0.02	11	0.9609

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level.

(B) ELEMENT 4/2-V

ELEMENT 4/3	0	1	2	T
2	21	56	128	205
1	1	2	1	4
0	0	1	2	3
T	22	59	131	212

Ho	C	Power
0.00	5	0.7205
0.01	7	0.4215
0.02	8	0.2865

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(C) ELEMENT 4/2-H

ELEMENT 1/3-H	0	1	2	T
2	22	4	185	211
1	0	0	0	0
0	1	0	0	1
T	23	4	185	212

Ho	C	Power
0.00	1	1.0000
0.01	7	0.9984
0.02	11	0.9603

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

TABLE 9/45

(A) ELEMENT 4/2-V

ELEMENT 1/3-V	0	1	2	T
2	21	57	130	208
1	1	1	0	2
0	0	1	1	2
T	22	59	131	212

Ho.	C	POWER
0.00	4	0.8126
0.01	6	0.5223
0.02	8	0.2429

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(B) ELEMENT 4/1-H

ELEMENT 4/2-H	0	1	2	T
2	24	15	146	185
1	2	0	2	4
0	19	1	3	23
T	45	16	151	212

Ho.	C	POWER
0.00	4	0.9994
0.01	8	0.9700
0.02	11	0.8351

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 4/1-V

ELEMENT 4/2-V	0	1	2	T
2	17	7	107	131
1	8	4	47	59
0	15	4	3	22
T	40	15	157	212

Ho	C	POWER
0.00	15	0.8725
0.01	17	0.7398
0.02	19	0.5650

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

TABLE 9/46

(A) ELEMENT 4/1-H

ELEMENT 1/2-H	0	1	2	T
2	20	12	135	167
1	2	1	10	13
0	23	3	6	32
T	45	16	151	212

Ho	C	POWER
0.00	5	0.9986
0.01	9	0.9519
0.02	11	0.8577

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level.

(B) ELEMENT 4/1-V

ELEMENT 1/2-V	0	1	2	T
2	15	11	146	172
1	3	0	5	8
0	22	4	6	32
T	40	15	157	212

Ho	C	POWER
0.00	5	0.9990
0.01	9	0.9631
0.02	12	0.8198

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level.

(C) ELEMENT 5/3(A)

ELEMENT 5/4(A)	0	1	2	T
2	29	7	150	186
1	2	1	8	11
0	14	1	0	15
T	45	9	158	212

Ho	C	POWER
0.00	3	0.9999
0.01	7	0.9912
0.02	11	0.8758

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 9/47

(A) ELEMENT 5/2(A)

ELEMENT 5/3(A)	0	1	2	T
2	87	10	61	158
1	8	1	0	9
0	43	2	0	45
T	138	13	61	212

Ho	C	POWER
0.00	2	0.9484
0.01	5	0.5871
0.02	6	0.4246

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 5/2(A)

ELEMENT 4/1-II	0	1	2	T
2	72	7	51	130
1	19	2	8	29
0	47	4	2	53
T	138	13	61	212

Ho	C	POWER
0.00	5	0.6650
0.01	6	0.5085
0.02	8	0.2318

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C) ELEMENT 5/2(A)

ELEMENT 4/1-V	0	1	2	T
2	80	8	51	139
1	14	1	8	23
0	44	4	2	50
T	138	13	61	212

Ho	C	POWER
0.00	4	0.7780
0.01	6	0.4709
0.02	7	0.3226

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

TABLE 9/48

(A)

ELEMENT 5/3(B) (rows) × ELEMENT 5/2(B) (columns)

	0	1	2	T
2	18	8	109	135
1	10	11	6	27
0	45	2	3	50
T	73	21	118	212

Ho	C	POWER
0.00	7	0.9540
0.01	10	0.7658
0.02	12	0.5526

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B)

ELEMENT 5/1(B)-H/C (rows) × ELEMENT 5/2(B) (columns)

	0	1	2	T
2	42	14	113	169
1	13	4	4	21
0	18	3	1	22
T	73	21	118	212

Ho	C	POWER
0.00	5	0.9840
0.01	8	0.8631
0.02	10	0.6764

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C)

ELEMENT 5/2(B) (rows) × ELEMENT 5/1 (columns)

	0	1	2	T
2	76	25	17	118
1	15	3	3	21
0	70	3	0	73
T	161	31	20	212

Ho	C	POWER
0.00	5	0.0417
0.01	5	0.0417
0.02	6	0.0139

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 9/49

(A) ELEMENT 5/1

ELEMENT 5/2(A)	0	1	2	T
2	32	14	17	63
1	26	3	0	29
0	103	14	3	120
T	161	31	20	212

Ho	C	POWER
0.00	7	0.0201
0.01	7	0.0201
0.02	8	0.0070

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 4/1-H (Retest)

ELEMENT 4/1-H	0	1	2	T
2	10	22	119	151
1	3	4	9	16
0	40	3	2	45
T	53	29	130	212

Ho	C	POWER
0.00	9	0.9147
0.01	11	0.7793
0.02	13	0.5794

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

(C) ELEMENT 4/1-V (Retest)

ELEMENT 4/1-V	0	1	2	T
2	7	18	132	157
1	8	1	6	15
0	35	4	1	40
T	50	23	139	212

Ho	C	POWER
0.00	7	0.9829
0.01	10	0.8806
0.02	12	0.7246

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

TABLE 9/50

(A). ELEMENT 5/2(A) (Retest)

ELEMENT 5/2(A)	0	1	2	T
2	2	4	55	61
1	5	2	6	13
0	113	23	2	138
T	120	29	63	212

Ho	C	POWER
0.00	8	0.4306
0.01	9	0.3016
0.02	11	0.1197

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

(B) ELEMENT 6/4(B)

ELEMENT 6/5(B)	0	1	2	T
2	9	13	187	209
1	0	0	2	2
0	0	1	0	1
T	9	14	189	212

Ho	C	POWER
0.00	3	0.9999
0.01	7	0.9852
0.02	10	0.8921

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(C) ELEMENT 6/3(B)

ELEMENT 6/4(B)	0	1	2	T
2	38	11	140	189
1	7	1	6	14
0	6	1	2	9
T	51	13	148	212

Ho	C	POWER
0.00	3	0.9998
0.01	7	0.9830
0.02	10	0.8809

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

TABLE 9/51

(A)

ELEMENT 6/2-S

ELEMENT 6/3 (B)		0	1	2	T
	2	33	28	62	123
	1	15	9	1	25
	0	63	0	1	64
	T	111	37	64	212

Ho	C	POWER
0.00	7	0.5108
0.01	9	0.2477
0.02	10	0.1544

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B)

ELEMENT 6/2-S

ELEMENT 6/3 (A)		0	1	2	T
	2	38	16	64	118
	1	19	21	0	40
	0	54	0	0	54
	T	111	37	64	212

Ho	C	POWER
0.00	9	0.3061
0.01	10	0.2004
0.02	11	0.1224

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C)

ELEMENT 6/2-S

ELEMENT 6/5 (B)		0	1	2	T
	2	96	32	61	189
	1	12	5	3	20
	0	3	0	0	3
	T	111	37	64	212

Ho	C	POWER
0.00	3	0.8667
0.01	5	0.5830
0.02	6	0.4204

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

TABLE 9/52

(A) ELEMENT 6/2-C

ELEMENT 6/3 (B)	0	1	2	T
2	47	19	79	145
1	6	1	0	7
0	60	0	0	60
T	113	20	79	212

Ho	C	POWER
0.00	4	0.9152
0.01	6	0.7149
0.02	8	0.4352

CONCLUSION. The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 6/2-C

ELEMENT 6/3 (A)	0	1	2	T
2	30	7	79	116
1	18	13	0	31
0	65	0	0	65
T	113	20	79	212

Ho	C	POWER
0.00	7	0.6999
0.01	8	0.5685
0.02	10	0.3108

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(C) ELEMENT 6/2-C

ELEMENT 6/5 (B)	0	1	2	T
2	97	18	74	189
1	13	2	5	20
0	3	0	0	3
T	113	20	79	212

Ho	C	POWER
0.00	3	0.9591
0.01	5	0.8100
0.02	7	0.5435

CONCLUSION. The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

TABLE 9/53

(A)

ELEMENT 6/1-H/S (columns); ELEMENT 6/2-S (rows)

	0	1	2	T
2	17	13	34	64
1	20	11	6	37
0	104	5	2	111
T	141	29	42	212

Ho	C	POWER
0.00	10	0.0814
0.01	11	0.0420
0.02	11	0.0420

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B)

ELEMENT 6/1-H/C (columns); ELEMENT 6/2-C (rows)

	0	1	2	T
2	29	16	34	79
1	9	2	9	20
0	105	6	2	113
T	143	24	45	212

Ho	C	POWER
0.00	6	0.3204
0.01	7	0.1939
0.02	8	0.1069

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C)

ELEMENT 6/1-H/S (columns); ELEMENT 1/1(B)-H/S (rows)

	0	1	2	T
2	125	29	42	196
1	6	0	0	6
0	10	0	0	10
T	141	29	42	212

Ho	C	POWER
0.00	2	0.7805
0.01	4	0.3930
0.02	5	0.2310

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

TABLE 9/54

(A) ELEMENT 6/1-H/C

ELEMENT 1/1(B)-H/C

	0	1	2	T
2	132	24	44	200
1	3	0	1	4
0	8	0	0	8
T	143	24	45	212

Ho	C	POWER
0.00	2	0.8208
0.01	4	0.4544
0.02	5	0.2832

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(B) ELEMENT 6/2-S

ELEMENT 6/3(C)

	0	1	2	T
2	34	15	64	113
1	22	22	0	44
0	55	0	0	55
T	111	37	64	212

Ho	C	POWER
0.00	9	0.3478
0.01	10	0.2350
0.02	11	0.1483

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C) ELEMENT 6/2-C

ELEMENT 6/3(C)

	0	1	2	T
2	25	5	79	109
1	20	15	0	35
0	68	0	0	68
T	113	20	79	212

Ho	C	POWER
0.00	8	0.6182
0.01	9	0.4858
0.02	11	0.2493

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLES 9/55-9/59

Subdivisional Analysis Results for South Australia

(Programme I)

PRELIMINARY NOTES

1. The following results are presented in correlation matrix form, listing the number of questions correct for each element, and the appropriate marginal totals.

2. The classification code for each element is outlined in Tables 5/4-5/10, and a list of the relevant subdivisional question groups is presented in Table 6/2.

3. P represents the combined probability that the observed number of students in the 0/2 and 2/0 cells could have occurred through chance (or errors of measurement) under the null hypothesis that no-one can possess only one of the relevant subdivisional skills without also having the other.

TABLE 9/55

(A)

GROUP 1 \ GROUP 2	0	1	2	T
2	1	0	208	209
1	0	0	0	0
0	2	0	1	3
T	3	0	209	212

ELEMENT 1/3

TEST H/V (Position)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	1	4	169	174
1	1	3	3	7
0	26	3	2	31
T	28	10	174	212

ELEMENT 1/2

TEST H/V (Co-ordinates)

P = 0.0008

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	17	13	126	156
1	10	4	9	23
0	26	2	5	33
T	53	19	140	212

ELEMENT 1/1(B)

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(D)

GROUP 1 \ GROUP 3	0	1	2	T
2	1	0	155	156
1	11	3	9	23
0	26	1	6	33
T	38	4	170	212

ELEMENT 1/1(B)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

TABLE 9/56

(A)

GROUP 2 \ GROUP 4	0	1	2	T
2	3	2	135	140
1	2	6	11	19
0	34	7	12	53
T	39	15	158	212

ELEMENT 1/1(B)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 2 and 4 represent different subdivisional skills.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	6	8	115	129
1	9	1	13	23
0	32	9	19	60
T	47	18	147	212

ELEMENT 1/1(A)

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 3	0	1	2	T
2	6	4	119	129
1	6	4	13	23
0	43	5	12	60
T	55	13	144	212

ELEMENT 1/1(A)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

(D)

GROUP 2 \ GROUP 4	0	1	2	T
2	8	0	139	147
1	8	2	8	18
0	33	6	8	47
T	49	8	155	212

ELEMENT 1/1(A)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 2 and 4 represent different subdivisional skills.

TABLE 9/57

(A)

GROUP 2/1(B)-2

GROUP 2/1(A)-1	0	1	2	T
2	14	20	90	124
1	11	10	6	27
0	40	10	11	61
T	65	40	107	212

ELEMENT 2/1(A)-2/1(B)

TEST Interpolation/Extrapolation

P = 0.0000

CONCLUSION Elements 2/1(A) and 2/1(B) represent different basic skills.

(B)

GROUP 2

GROUP 1	0	1	2	T
2	15	21	95	131
1	10	8	6	24
0	40	11	6	57
T	65	40	107	212

ELEMENT 2/1(B)

TEST Line/Points

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

GROUP 2

GROUP 1	0	1	2	T
2	7	16	98	121
1	9	18	19	46
0	26	11	8	45
T	42	45	125	212

ELEMENT 3/2(A)

TEST Max./Min. Values

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(D)

GROUP 2

GROUP 1	0	1	2	T
2	2	1	208	211
1	0	0	0	0
0	0	1	0	1
T	2	2	208	212

ELEMENT 1/3 (Retest)

TEST H/V (Position)

P = 0.0001

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

TABLE 9/58

(A)

GROUP 1 \ GROUP 2	0	1	2	T
2	0	6	161	167
1	1	2	10	13
0	31	0	1	32
T	32	8	172	212

ELEMENT 1/2 (Retest)

TEST H/V (Co-ordinates)

P = 0.1817

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	1	55	129	185
1	0	2	2	4
0	21	2	0	23
T	22	59	131	212

ELEMENT 4/2

TEST H/V (Displacement)

P = 0.9951

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	0	2	149	151
1	1	9	6	16
0	39	4	2	45
T	40	15	157	212

ELEMENT 4/1

TEST H/V (Displacement)

P = 0.1318

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(D)

GROUP 1 \ GROUP 3	0	1	2	T
2	0	2	194	196
1	0	2	4	6
0	8	0	2	10
T	8	4	200	212

ELEMENT 1/1(B) (Retest)

TEST Straight Line/Curve

P = 0.0139

CONCLUSION Question groups 1 and 3 probably represent the same subdivisional skill.

TABLE 9/59

(A)

GROUP 1 \ GROUP 2	0	1	2	T
2	2	20	187	209
1	0	0	2	2
0	1	0	0	1
T	3	20	189	212

ELEMENT 6/5(B)

TEST Numerical Range

P = 0.1270

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	4	19	95	118
1	13	9	18	40
0	48	3	3	54
T	65	31	116	212

ELEMENT 6/3(A)

TEST Straight Line/Curve

P = 0.0220

CONCLUSION Question groups 1 and 2 probably represent the same subdivisional skill.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	3	11	50	64
1	7	6	24	37
0	103	3	5	111
T	113	20	79	212

ELEMENT 6/2

TEST Straight Line/Curve

P = 0.0023

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(D)

GROUP 1 \ GROUP 2	0	1	2	T
2	3	8	31	42
1	11	7	11	29
0	129	9	3	141
T	143	24	45	212

ELEMENT 6/1

TEST Straight Line/Curve

P = 0.0035

CONCLUSION Question groups 1 and 2 may represent the same subdivisional skill.

FIGURES 9.3-9.8

Outline of the Validated Learning Hierarchy for Queensland (Programme I)

PRELIMINARY NOTES

1. The classification code for each basic skill is outlined in Tables 5/4-5/10, and abbreviations used for the relevant subdivisional conditions are listed in the preliminary notes for Tables 6/4-6/25.
2. Lines representing hierarchical connections are classified according to the following key.

———— (solid thick line)	Connection accepted as valid at the absolute Ho level.
———— (solid thin line)	Connection accepted as valid at weaker (0.01 and 0.02) Ho levels.
– – – – (broken line)	Connection rejected as invalid at all three specified Ho levels.

FIGURE 9.3

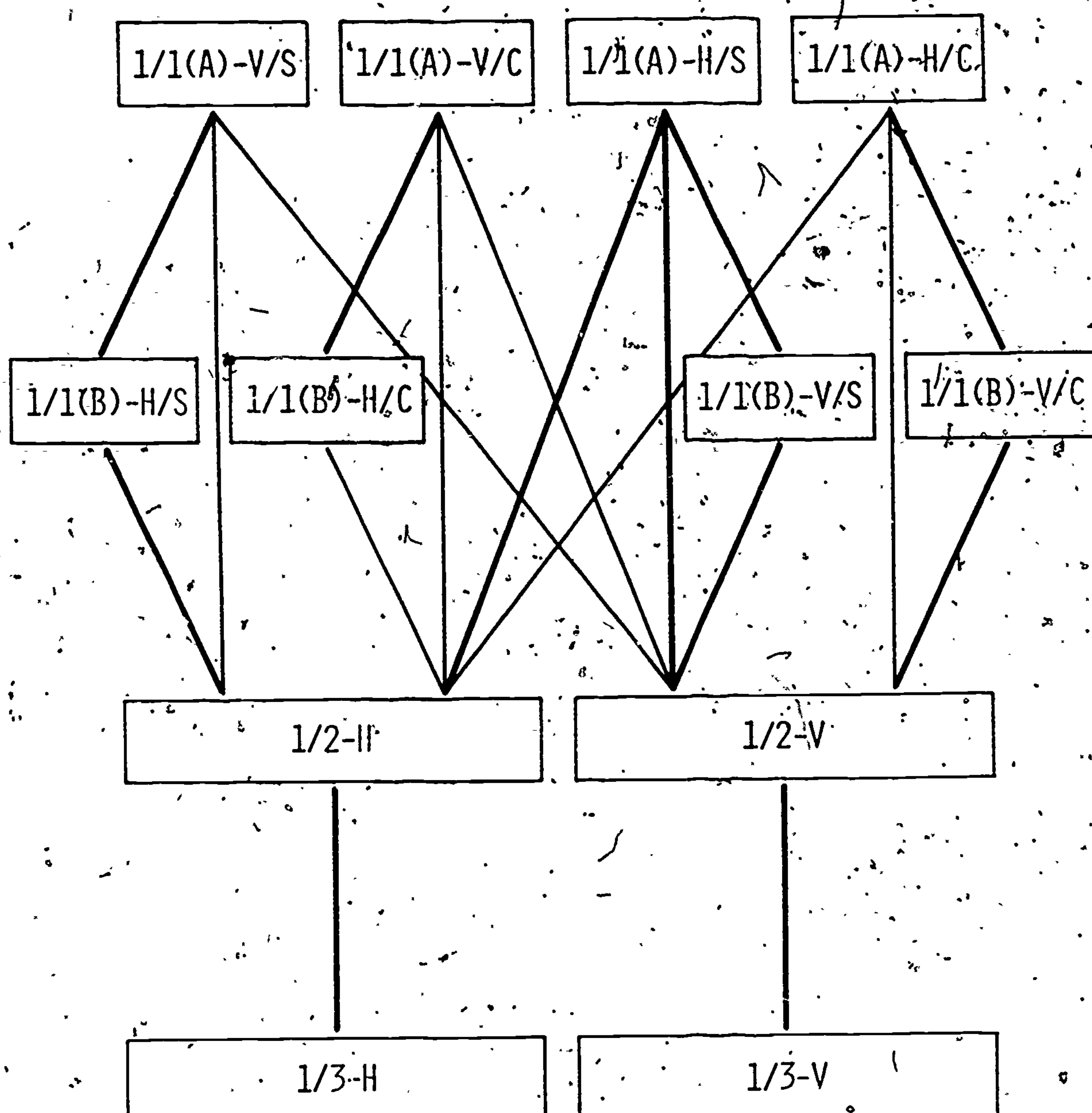

1/1(A)-V/S
1/1(A)-V/C
1/1(A)-H/S
1/1(A)-H/C
1/1(B)-H/S
1/1(B)-H/C
1/1(B)-V/S
1/1(B)-V/C
1/2-H
1/2-V
1/3-H
1/3-V

FIGURE 9.4

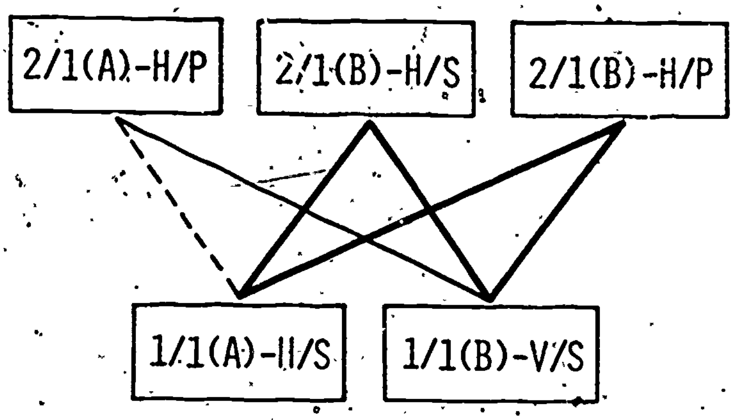


FIGURE 9.5

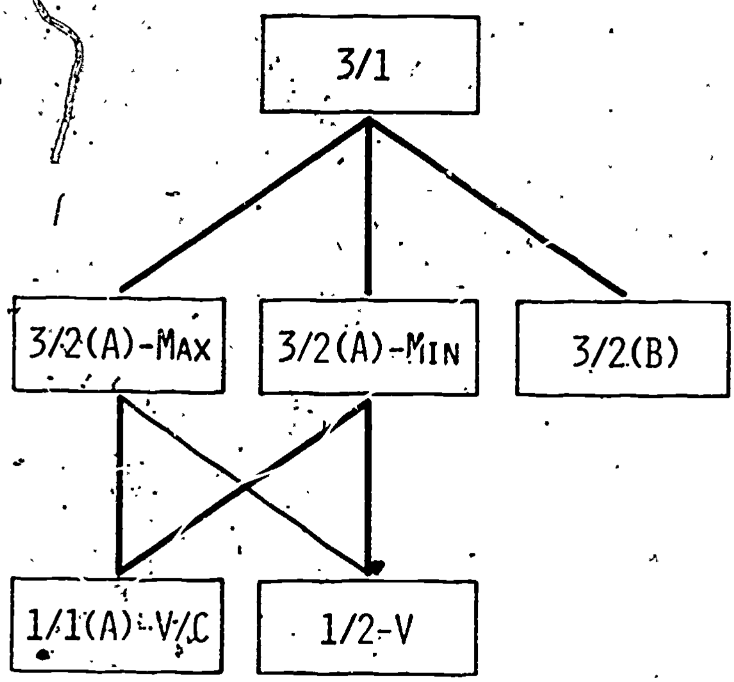


FIGURE 9-6

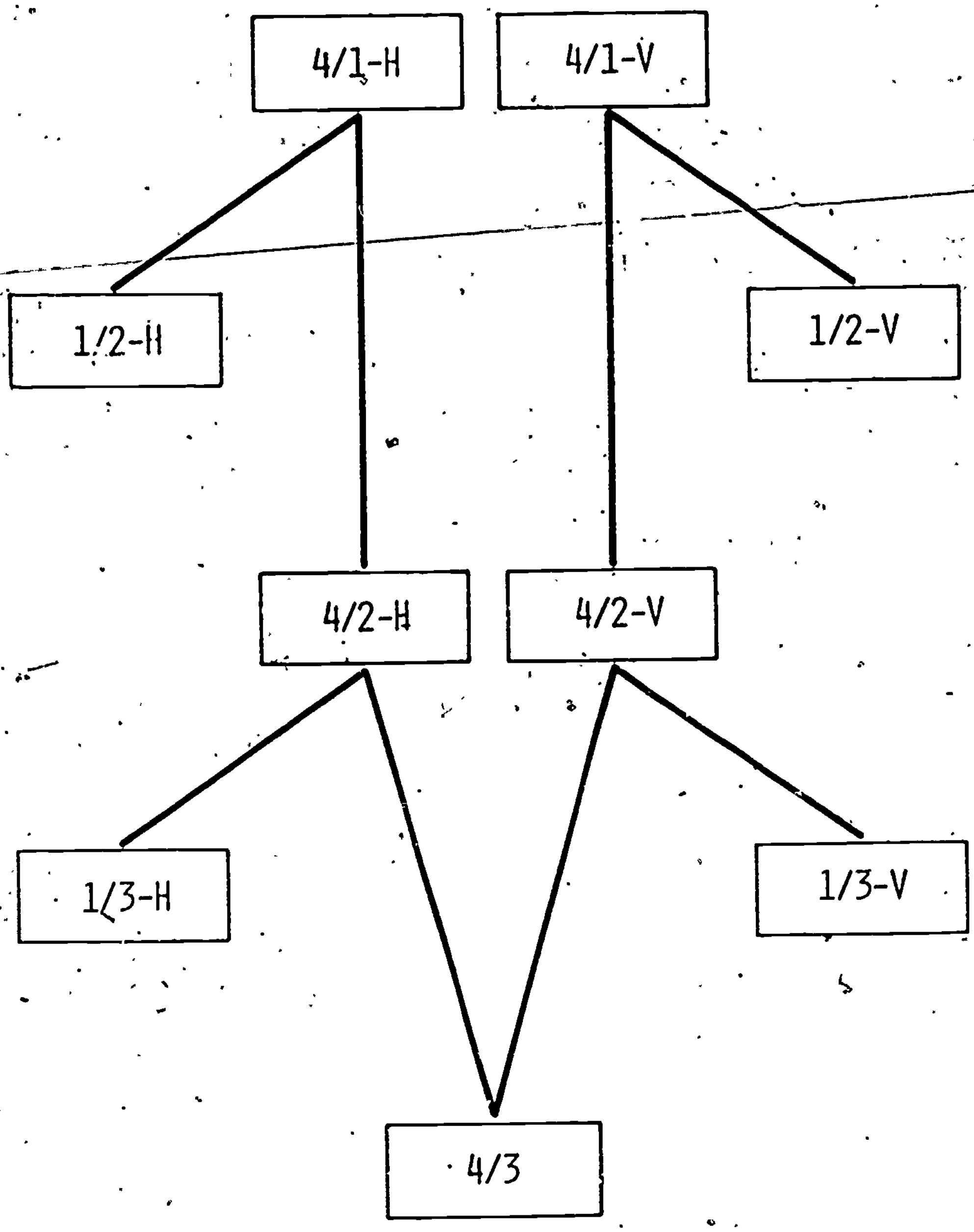


FIGURE 9.7

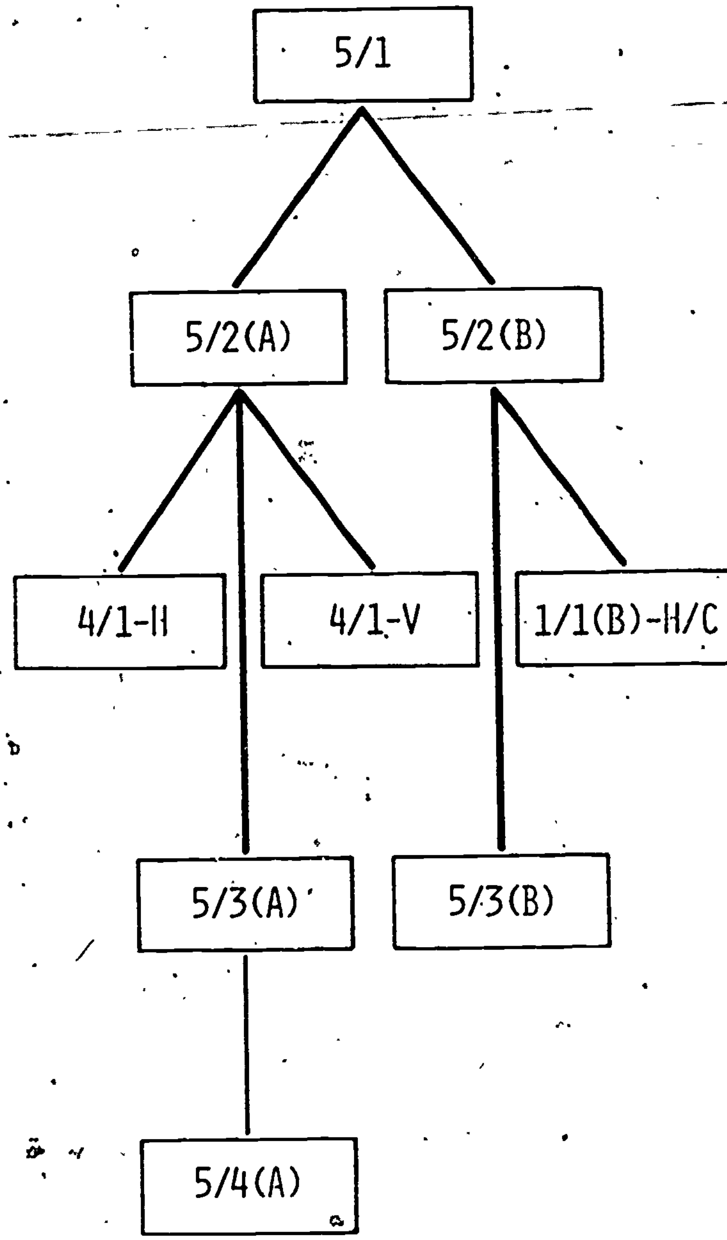
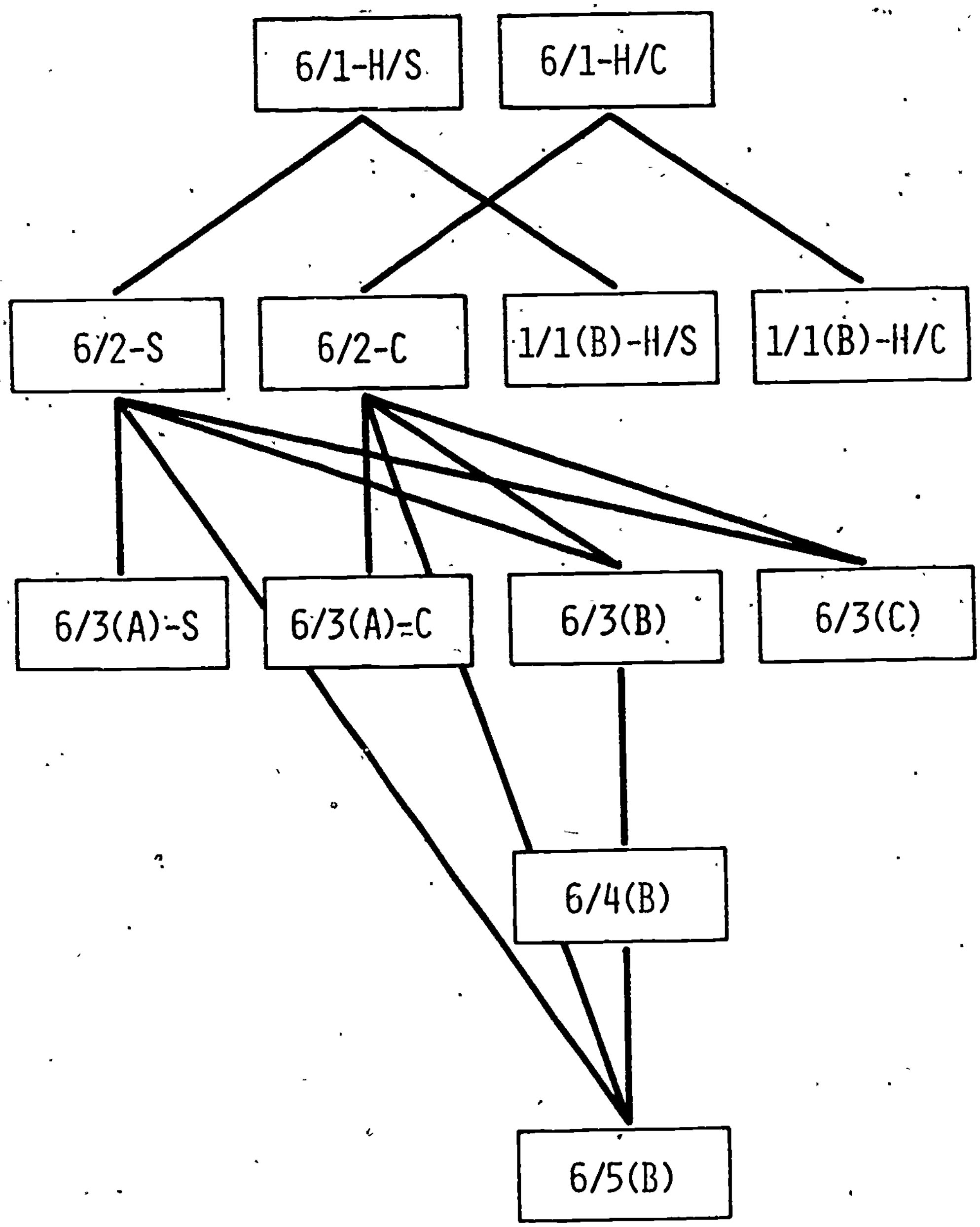


FIGURE 9.8



FIGURES 9.9-9.14

Outline of the Validated Learning Hierarchy for South Australia (Programme I)

PRELIMINARY NOTES

1. The classification code for each basic skill is outlined in Tables 5/4-5/10, and abbreviations used for the relevant subdivisional conditions are listed in the preliminary notes for Tables 6/4-6/25.

2. The lines representing hierarchical connections are classified according to the following key.

Line	Meaning
(thick solid line)	Connection accepted as valid at the absolute Ho level.
(thin solid line)	Connection accepted as valid at weaker (0.01 and 0.02) Ho levels.
(dashed line)	Connection rejected as invalid at all three specified Ho levels.

FIGURE 9.9

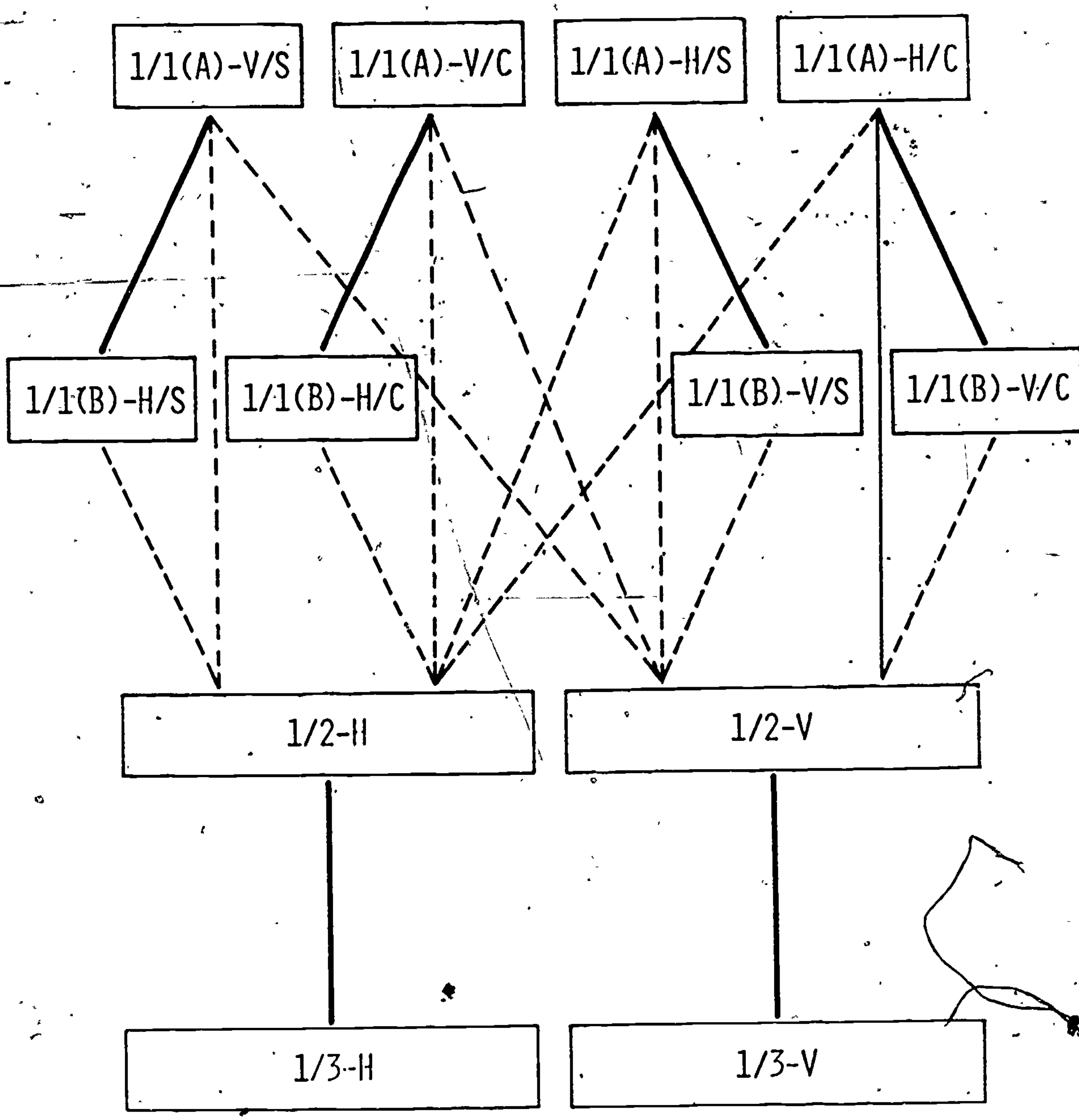

1/1(A)-V/S
1/1(A)-V/C
1/1(A)-H/S
1/1(A)-H/C
1/1(B)-H/S
1/1(B)-H/C
1/1(B)-V/S
1/1(B)-V/C
1/2-H
1/2-V
1/3-H
1/3-V

FIGURE 9.10

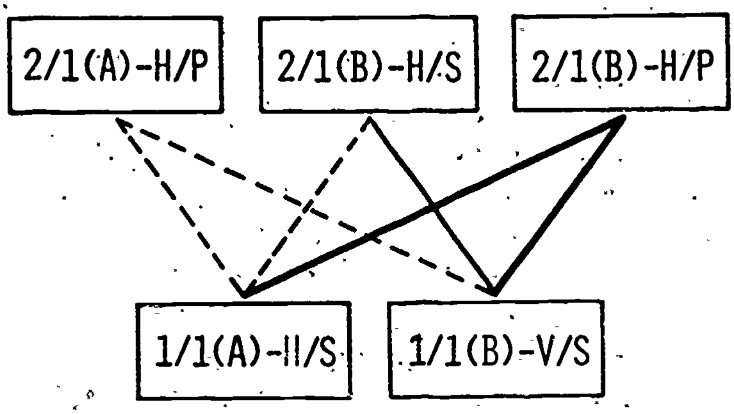


FIGURE 9.11

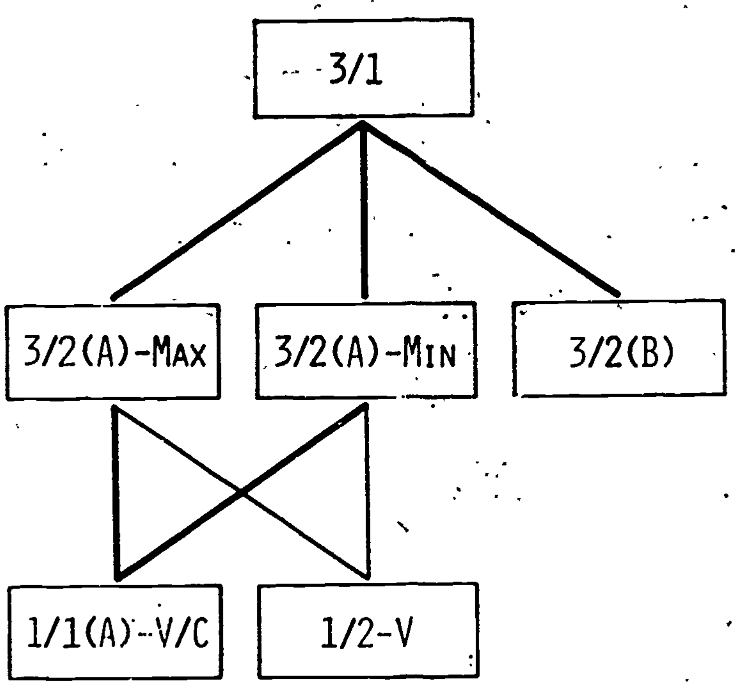


FIGURE 9.12

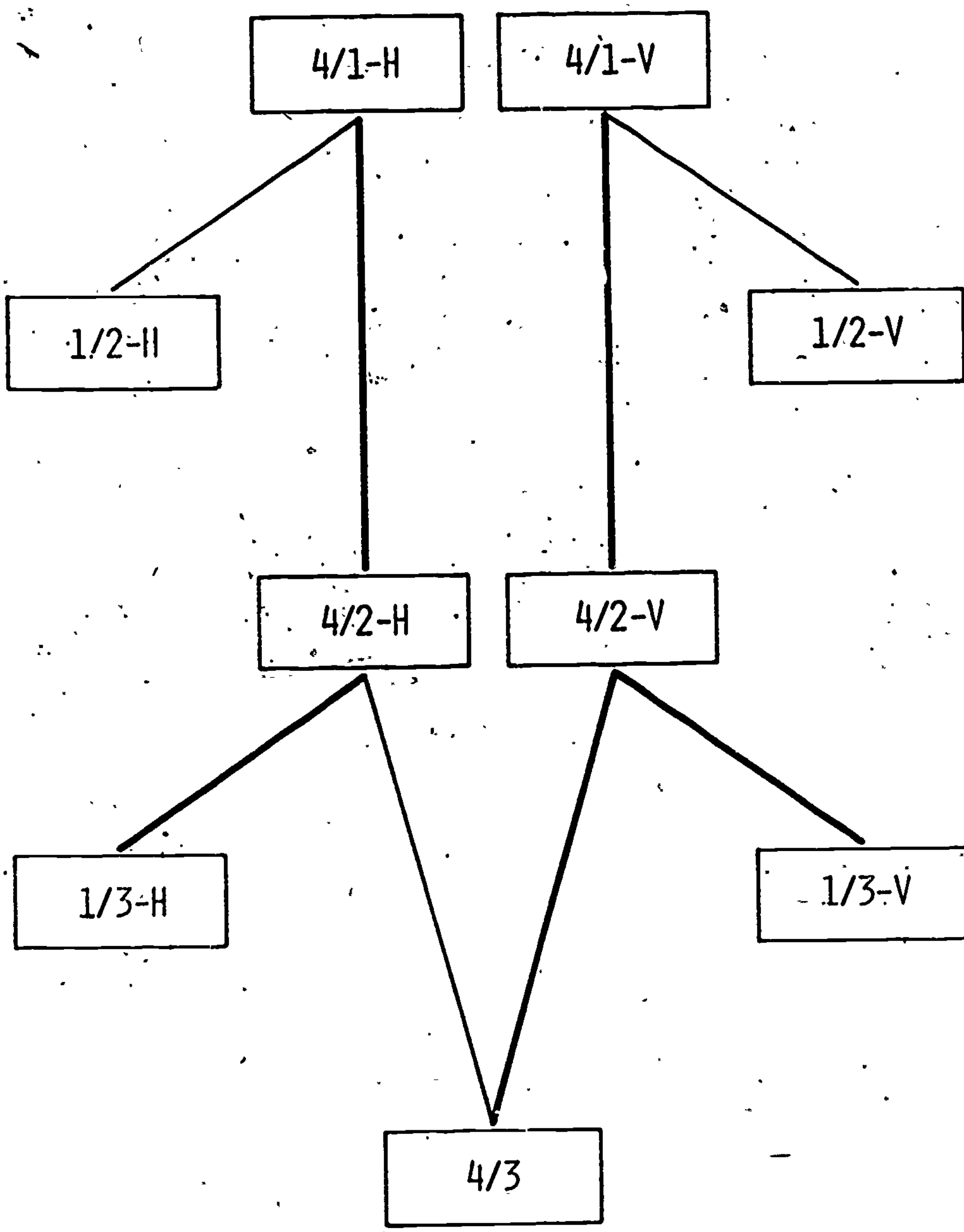


FIGURE 9.13

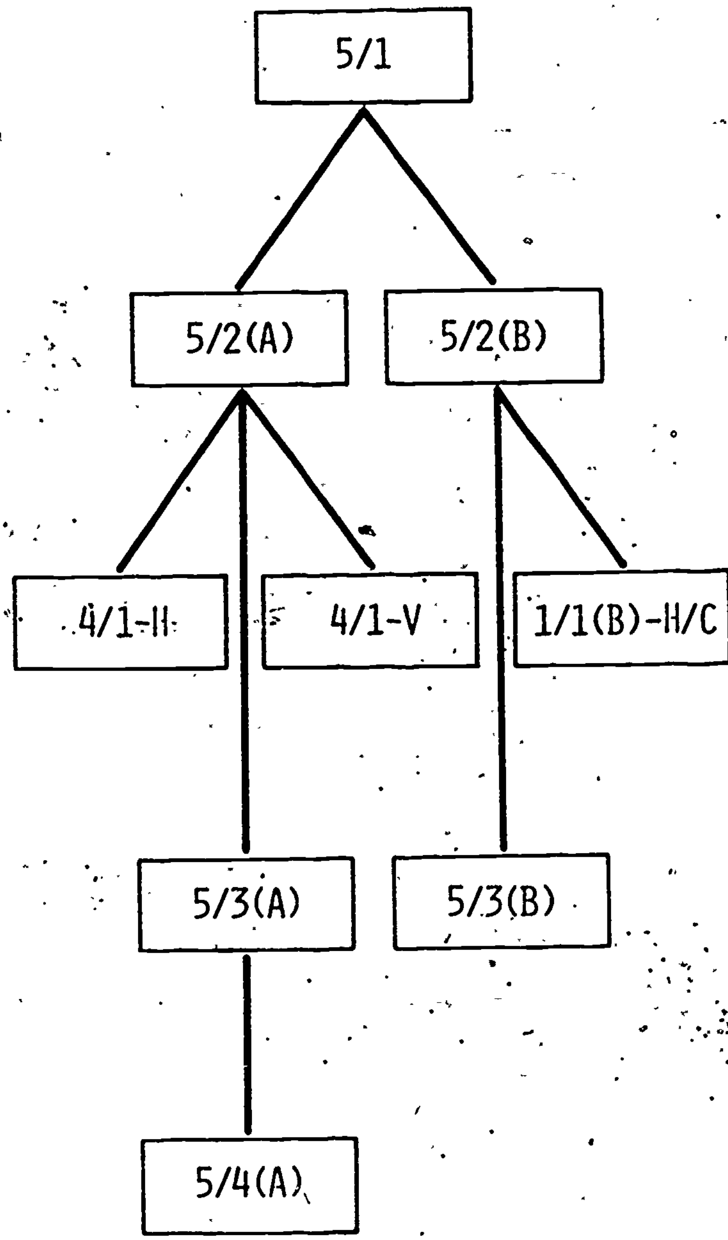
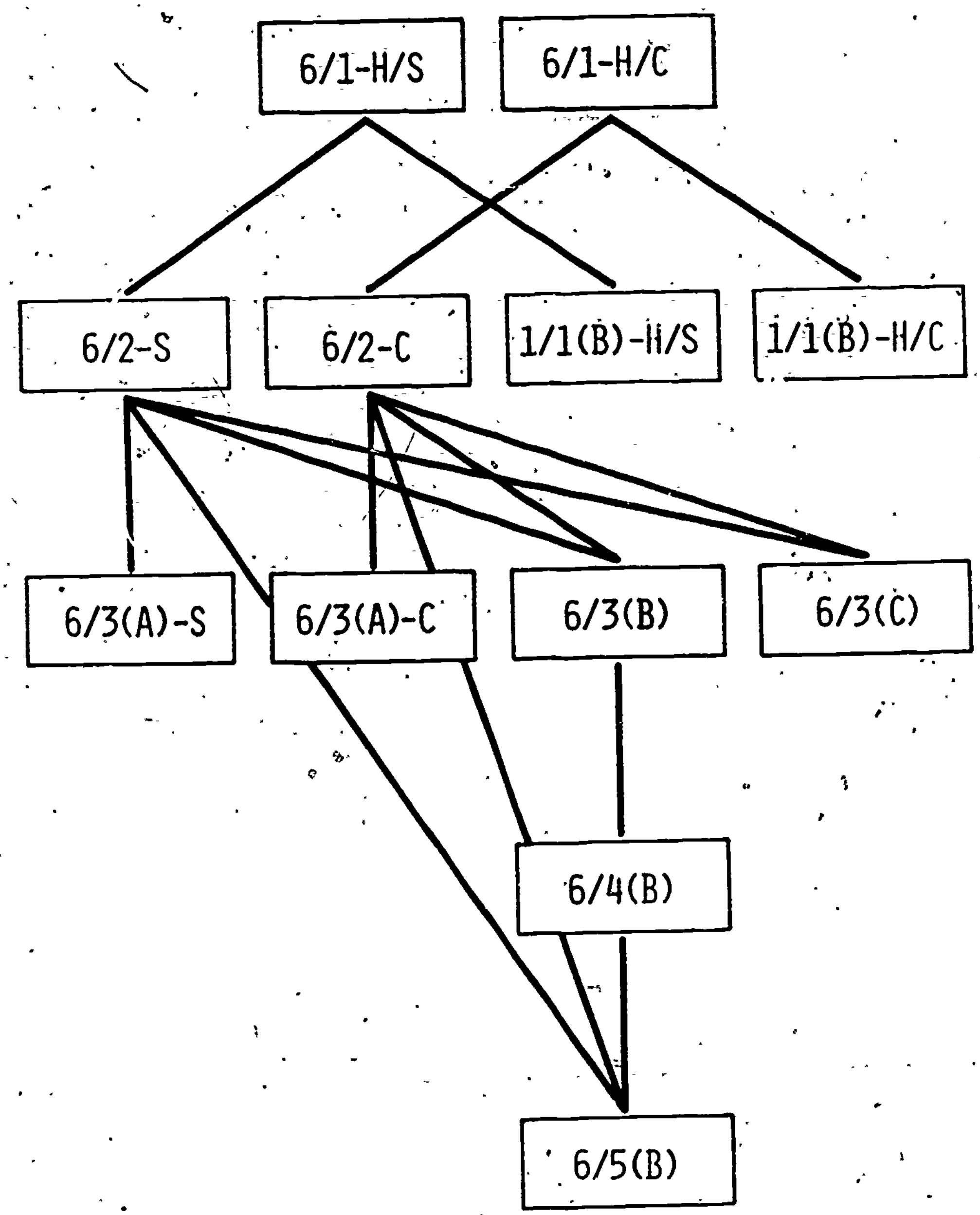


FIGURE 9.14



CHAPTER X

THE EFFECTS OF DIFFERENT CULTURAL BACKGROUND ON THE POSTULATED LEARNING HIERARCHY

1. Introduction and General Background

(Much of the following background information was derived from an unpublished information bulletin prepared by the Papua/New Guinea Education Department in 1970, and held in the Research Library, Konedobu, Port Moresby. Other sources of information are specified at appropriate points, and listed in the final Reference section.)

The first substantial administrative influence of Western civilisation in Papua/New Guinea probably began in 1884 with the independent proclamation of Papua and New Guinea respectively as British and German Protectorates. In 1920, however, these two territories were joined under Australian administration, and have remained so until the present eve of independence, although a considerable degree of self-government has already been in force for several years. The most significant Australian influence on Papua/New Guinea, at least in economic terms, was probably initiated only during the years of post war reconstruction (since 1945), and thus there has been relatively little opportunity for the development of educational resources on a national scale, so that many indigenous communities have only recently been exposed to any formal education in the Western or European sense.

The indigenous inhabitants of Papua/New Guinea comprise an extremely large number of different language and cultural groups, often located in remote jungle areas, and this has caused serious problems in the development of a common educational system. Magico-religious beliefs are an integral part of the traditional indigenous cultures, and these are both numerous and diverse in character. Many of the people have also been receptive to the evangelistic work of the Christian missions, who have for many years played a significant role in the establishment of primary, and to a lesser degree secondary education in the country. From the range of approximately 700 indigenous languages, Polis Motu and Melanesian Pidgin are probably the most widely understood, although because of the early British and Australian influence, English has been used as the official language of formal education. For most indigenous students, however, the use of English is largely still restricted to the school environment.

Because of severe limitations in national educational resources, formal education is not yet available to all school-age children in Papua/New Guinea, and progressively fewer people can be accommodated at higher levels, so that the number of students is controlled at various stages by stringent selection procedures, generally applied on grounds of academic performance. With respect to the indigenous population, only half the number of school-age children can be accommodated at primary school, and of those who are accepted, less than 40% proceed to secondary school (Papua/New Guinea Education Department - Official Statistics for 1971). The first stage of secondary education extends for only two years, at which a further (internal) selection is made for the second two-year stage. Beyond this the academic opportunities extend to a single senior high school (forms 5 and 6), several technical schools, colleges and vocational institutes, and the Teachers College or University, but the number of places (and students) at each of these institutions is extremely limited. The same conditions do not necessarily apply to Australian and European students in Papua/New Guinea, who normally attend a limited number of urban schools which follow a different (Australian) curriculum.

Although the Papua/New Guinea Education Department has outlined a national curriculum in various subject areas for both primary and secondary schools, many of these schools (particularly primary) follow alternative Australian or Overseas curricula (Papua/New Guinea Education Department - Official Statistics 1972), and thus it is impossible to define any substantial areas of common curricular experience for students at lower secondary levels. Moreover for many subjects, including secondary science and mathematics (see Education Department - Papua New Guinea 1971 for current syllabus outlines), the national curriculum has itself been considerably revised in recent years, and is at present in a more or less transitional phase of general implementation. Certain topics, however, including those of graphical interpretation and construction, have not been substantially changed in the new curriculum, and would therefore presumably not be affected by the general curricular transition. An outline of these topics from the high school mathematics syllabus (1971) is presented in Table 10/1. These graphical skills are not explicitly reinforced in the secondary science curriculum, and from informal discussions with teachers at the various schools participating in this study, are often somewhat neglected even in mathematics.

It should be evident from the discussion above that the present general cultural and educational environment in Papua/New Guinea is

TABLE 10/1

Outline of Graphical Skills for the Secondary Mathematics Curriculum in Papua/New Guinea

FORM	GRAPHICAL SKILLS
1	General introduction to various graphical forms, including pictographs, bar and column graphs, line-segment graphs and circle or sector graphs. (Emphasis on interpretation rather than construction).
2	Construction of circle graphs, and interpretation of straight line travel graphs introducing the concepts of rate and continuity.
3	Conversion graphs and the mapping of co-ordinate pairs. Construction and interpretation of simple linear and quadratic functions, including intercept and gradient for straight line graphs.
4	Graphical representation and the solution of various linear and quadratic functions, including circles and conical sections, with emphasis on interpretative rather than constructional skills.

completely different from that existing in Australia, and this difference has often been expressed in previous educational reviews and research reports (see Drover 1967, Prince 1969, Joynt 1969 and Johnson 1968). Although there may be certain common features in specific school curricula, which have largely been prepared by Australian and Overseas expatriate teachers, there is still a unique and overriding influence of particular national needs and personal characteristics arising from the relatively recent combination of Western and traditional cultures. These things considered, it was decided to examine the potential application of a common learning hierarchy of graphical interpretation skills to both Australian and Papuan/New Guinean students. The relevant Australian studies involving Programme I have already been described in Chapters VI and IX. The preparation and administration of the corresponding validation study for Papua/New Guinea is outlined in section 2 below, and the results and implications are presented in section 3.

2. Preparation and Administration of the Papua/New Guinea Validation Study (Programme I)

Before the major validation study was undertaken in Papua/New Guinea, a number of specific preparations and administrative decisions had to be made to account for local difficulties in transport and communication between widely separated schools, and for various differences in student background, both within the country and in relation to Australian students. It was decided, largely for the former reason, to restrict the validation study to the central region (south coast), where a sufficient sample of indigenous high school students could readily be engaged from local schools.

Since little information was available on levels of reading ability for high school students in Papua/New Guinea, the same validation programme was applied (Programme I) as that used previously for Australian students. A preliminary test was made, however, at three consecutive high school levels (forms 1-3) in order to examine for each level the assumptions of equivalent, or at least comparable reading ability, and thus to select the most appropriate level or the major validation study. It should also be noted, perhaps, that the levels of understanding in Papua/New Guinea for certain relevant scientific concepts, examined in a previous study by Gardner (1971), were considered in the initial preparation of the validation programme, although these levels of understanding had only been determined for relatively senior high school students.

The preliminary test witn Validation Programme I in Papua/New Guinea was conducted at Kwikila High School, and involved a sample of ten students at each of three consecutive levels from form 1 to form 3. It was obvious from the results of this limited test that the questions and instructions were both poorly understood at the form 1 level, and that many form 2 students would also have some difficulty in comprehension, so that in spite of the inevitable differences in age from the Australian student groups, form 3 was selected as the most suitable testing level.

The major validation study in Papua/New Guinea involved a total of 200 indigenous form 3 students from all six Central District high schools following the national curriculum. This sample represented almost half the total number of indigenous students at that level in the Central District, and contained 139 male and 61 female students, the combined group ranging in age from 13 to 19 years (taken to the nearest year) with a mean of 15.5. The number of students involved from each participating school is shown in Table 10/2. Not all of these schools were co-educational, nor did they represent the same administrative authority, so that these and other relevant characteristics are also listed for each school in Table 10/2.

The conditions of administration for the major validation study in Papua/New Guinea were similar to those outlined for Victorian schools in Chapter VI, and involved consecutive presentation of the three constituent sections, with Programmes I and II (the latter discussed in Chapter XI) given simultaneously to different students. The mean completion times for Programme I (shown in Table 10/2) were not significantly different at the 0.05 level from those for Victorian form 1 students (t-test for difference of sample means), in spite of considerable differences in age and nominal academic level. Moreover as indicated previously for each of the Australian studies, the working rate (based on regular timing results for a single class of students) appeared to be relatively constant throughout the validation programme (see Figure 10.1).

TABLE 10/2

Sample Numbers, Completion Times and High School Characteristics for Papua/New Guinea (Programme I)

HIGH SCHOOL (and class)		Number of Students in Sample	Shortest Completion Time (mins.)	Longest Completion Time (mins.)
Badihagwa	3A	19	62	109
	3B	15	45	85
Bomana		18	74	124
Iarowari	3A	18	53	92
	3B	16	50	105
Kila Kila	3A	26	57	82
	3C	18	45	91
Kwikila	3A	18	-	-
	3B	16	47	88
	3C	16	-	-
Marianville		20	76	97
Mean Completion Time			56.0	97.0
Standard Deviation			11.9	13.5

High School Characteristics

1. Badihagwa - Co-educational Administration (Education Department) day school located within the Port Moresby district.

2. Bomana - Catholic day and residential school for male students only, located close to (but not within) Port Moresby.

3. Iarowari - Co-educational Administration school, predominantly residential, and located in a rural area about 15 miles from Port Moresby.

4. Kila Kila - Co-educational Administration day school located in Port Moresby.

5. Kwikila - Co-educational Administration school, predominantly residential, located in a rural area about 60 miles from Port Moresby.

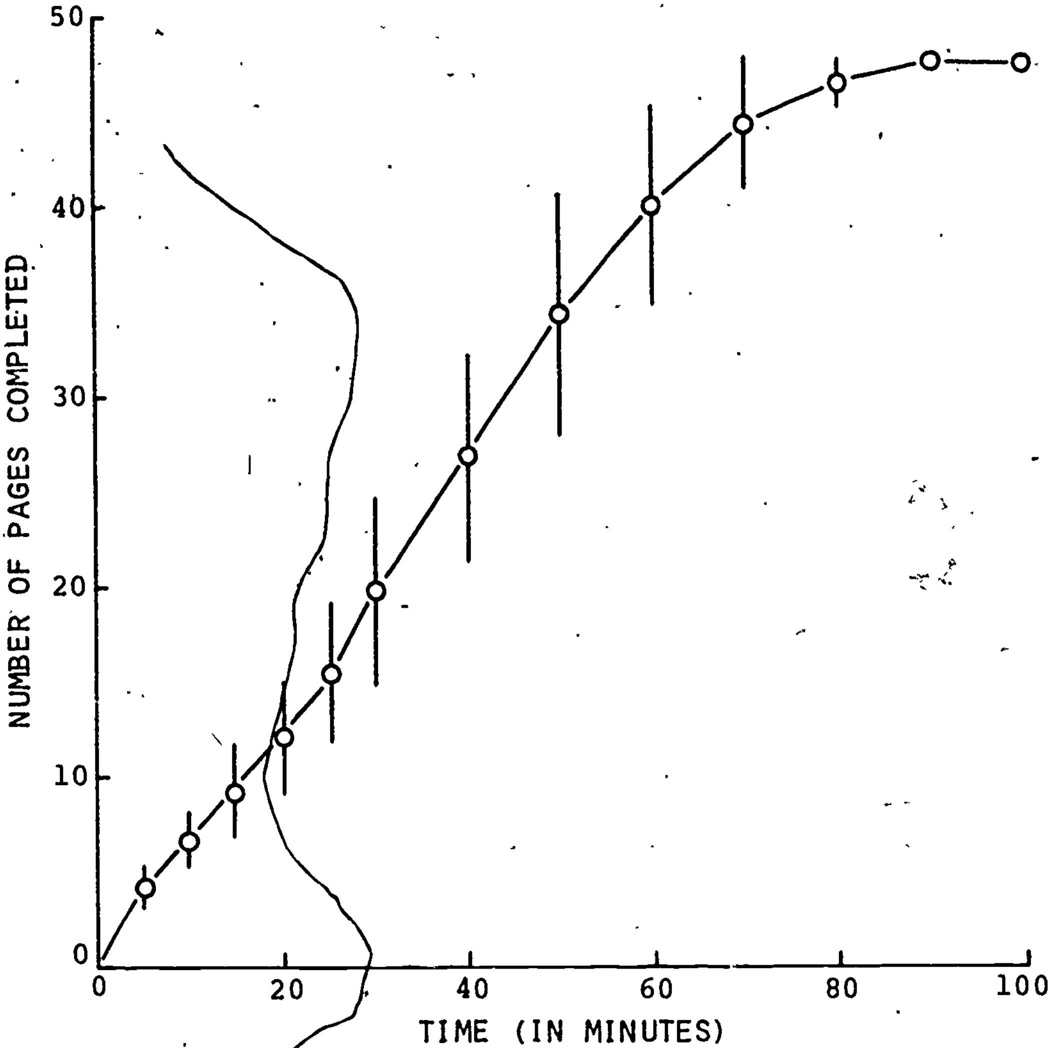
6. Marianville - Catholic day and residential school for female students only, located close to (but not within) Port Moresby.

Each of these schools covers only forms 1 to 4, and the students at each level are streamed on the basis of previous academic results.

FIGURE 10.1

Progression Rate for Programme I

(Kwikila High School - Papua/New Guinea)



NOTES

1. Circles indicate the mean number of pages completed at specified times.
2. Vertical lines represent the appropriate Standard Deviation.
3. Number of students involved = 51.

3. Results and Implications from the Papua/New Guinea Validation Study (Programme I)

The validation results for Papua/New Guinea (Programme I) were subjected to the same statistical analysis as those for the previous Australian studies, outlined in Chapters VI-IX. The results of this analysis are presented in Tables 10/3-10/24, and those for the subsequent analysis of relevant subdivisional skills are presented in Tables 10/25-10/29.

Apart from area 2, where most of the postulated hierarchical connections were rejected as invalid at all three specified Ho levels (see Figure 10.3), the validation results for Papua/New Guinea were generally consistent with those from each of the previous Australian studies. The anomalous results for area 2 were probably caused by incidental acquisition of the subordinate skills 1/1(A) and 1/1(B) during subsequent attempts at more complex capabilities, and this is shown by retest results for element 1/1(A) presented in Table 10/13(C). The results for areas 1 and 3 (Figures 10.2 and 10.4 respectively) were more positive than those for the analogous validation studies in Victoria (Chapter VI) and South Australia (Chapter IX), since all of the relevant connections were accepted as valid at one of the various Ho levels, and most were accepted at the absolute level. The same result was reported for Programme I in the Queensland study (Chapter IX). All of the postulated connections in areas 4-6 (Figures 10.5-10.7) were accepted as valid at the absolute Ho level. Although the power for these validation tests was often particularly low, the conclusions are probably substantiated by the fact that each of the previous studies produced almost exactly the same results for these interpretative areas.

The range of difficulty levels and degree of response inconsistency were both of a similar order in the Papua/New Guinea study to that already described for Programme I in Victoria (Chapter VI), and the resultant statistical problems were the same for both validation studies. Where the difficulty levels for subordinate skills were exceptionally low, the postulated connections could not possibly be rejected, and the power was unrealistically high (see Tables 10/14, 10/15(A), 10/20(B) and 10/21(C)). However where the difficulty levels and response inconsistency were both relatively high, the resultant statistical power was exceptionally low.

The subdivisional analysis results for Programme I in Papua/New Guinea were also generally consistent with those for the previous Australian studies. No discrimination occurred in this case between the postulated subordinate skills for elements 1/3 and 1/2 in either the initial or retest si ations, but this inconsistency was probably attributable to the very low difficulty levels. The results for other elements (3/2(A), 4/2, 4/1 and 6/5(B)) in which no discrimination occurred between postulated subordinate skills were consistent with analogous results from most of the other studies.

This study clearly shows that the same hierarchical network of graphical interpretation skills, previously validated in several Australian states, is also valid for indigenous high school students in Papua/New Guinea, but at a different age and nominal academic level.

Thus in a limited sense this study provides useful cross-cultural evidence to substantiate Gagné's (1965) model of hierarchical learning, on which the validation programme was originally based, although the implications are probably tempered by the fact that the testing population of third form students in Papua/New Guinea probably represents an academic élite. It should also be remembered that most of the primary and secondary school curricula were prepared by Australian and Overseas expatriate teachers, and that most of the current high school teachers in Papua/New Guinea are similarly Overseas expatriates (Papua/New Guinea Education Department - Official Statistics 1972). These elements of common educational influence in Australia and Papua/New Guinea probably moderate the potential generalisation of this result, but do not diminish its importance in establishing a common hierarchical network of basic intellectual skills for students with completely different social and cultural backgrounds.

Much of the previous educational research in Papua/New Guinea has emphasised the differences between traditional indigenous and western cultures. Prince (1969), for example, concludes that "western scientific concepts are almost non-existent in indigenous culture, and mathematical concepts are demonstrably even more rudimentary," and Johnson (1968) also claims that concepts such as quantity, space and time "are not expressed in indigenous New Guinean culture or its languages." The emphasis on cultural differences between Papua/New Guinea and other countries has often led to criticism of local curriculum planning based on overseas experience (see King 1970), and in fact this approach to curriculum planning is rejected by Drover

(1967) as "unreal." Evidence from the present study, however, suggests that this approach is not unreal, and contrary to the doubt expressed by King (1970) that children in Papua/New Guinea would form mathematical concepts "either in the same order or way or at the same chronological age as their counterparts in modern western society", it seems at least that the order or sequence of acquisition with respect to certain intellectual skills may be the same.

In view of the previous emphasis in Papua/New Guinea on the relationship between cultural background and concept development in science and mathematics (see Drover 1967, Johnson 1968, King 1970 and Prince 1969), it was decided to extend this cross-cultural experiment with a parallel validation study based on a different informational model. The second validation study, involving more specific variables of Time and Annual Birth Rate (Programme II), was thus intended to determine the interactive influence of a different cultural background and specific informational model on the postulated learning hierarchy of graphical interpretation skills. A comprehensive outline of this study is presented in Chapter XI.

TABLES 10/3-10/24

Validation Results for Papua/New Guinea

(Programme I)

PRELIMINARY NOTES

1. The following results are presented in correlation matrix form, listing the number of questions correct for each element, and the appropriate marginal totals.

2. The critical number of exceptions (C) permitted in the 0/2 cell of the relevant correlation table is listed, together with the appropriate statistical power, for each of the null hypothesis levels defined in Chapter VI (see preliminary notes for Tables 6/4-6/25).

3. The classification code for each element is outlined in Tables 5/4-5/10, and the relevant subdivisional conditions are presented in Tables 6/4-6/25 (preliminary notes).

TABLE 10/3

(A) ELEMENT 1/2-H

ELEMENT 1/3-H	0	1	2	T
2	17	10	163	190
1	1	0	4	5
0	1	1	3	5
T	19	11	170	200

Ho	C	POWER
0.00	3	1.0000
0.01	8	0.9844
0.02	11	0.8957

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 1/2-V

ELEMENT 1/3-V	0	1	2	T
2	16	10	165	191
1	0	0	3	3
0	3	0	3	6
T	19	10	171	200

Ho	C	POWER
0.00	3	1.0000
0.01	8	0.9865
0.02	11	0.9057

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 1/1(B)-V/S

ELEMENT 1/2-V	0	1	2	T
2	39	20	112	171
1	3	1	6	10
0	9	4	6	19
T	51	25	124	200

Ho	C	POWER
0.00	5	0.9869
0.01	8	0.8800
0.02	10	0.7053

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is relatively low.

TABLE 10/4

(A) ELEMENT 1/1(A)-H/S

ELEMENT 1/1(B)-V/S	0	1	2	T
2	7	2	115	124
1	10	15	0	25
0	42	9	0	51
T	59	26	115	200

Ho	C	POWER
0.00	9	0.8636
0.01	11	0.6872
0.02	13	0.4643

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(B) ELEMENT 1/1(A)-H/S

ELEMENT 1/2-V	0	1	2	T
2	45	20	106	171
1	3	2	5	10
0	11	4	4	19
T	59	26	115	200

Ho	C	POWER
0.00	5	0.9761
0.01	7	0.8957
0.02	10	0.6087

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 1/1(A)-H/S

ELEMENT 1/2-H	0	1	2	T
2	43	18	109	170
1	6	3	2	11
0	10	5	4	19
T	59	26	115	200

Ho	C	POWER
0.00	5	0.9764
0.01	7	0.8966
0.02	10	0.6106

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 10/5

(A) ELEMENT 1/1(B)-H/S

ELEMENT 1/2-H	0	1	2	T
2	22	21	127	170
1	5	1	5	11
0	7	7	5	19
T	34	29	137	200

Ho	C	POWER
0.00	7	0.9676
0.01	10	0.8141
0.02	12	0.6193

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 1/1(A)-V/S

ELEMENT 1/1(B)-H/S	0	1	2	T
2	9	4	124	137
1	10	19	0	29
0	28	6	0	34
T	47	29	124	200

Ho	C	POWER
0.00	10	0.8410
0.01	12	0.6597
0.02	14	0.4415

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(C) ELEMENT 1/1(A)-V/S

ELEMENT 1/2-H	0	1	2	T
2	33	20	117	170
1	7	1	3	11
0	7	8	4	19
T	47	29	124	200

Ho	C	POWER
0.00	6	0.9684
0.01	8	0.8799
0.02	11	0.5933

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 10/6

(A) ELEMENT 1/1(A)-V/S

ELEMENT 1/2-V

	0	1	2	T
2	34	21	116	171
1	4	1	5	10
0	9	7	3	19
T	47	29	124	200

Ho	C	POWER
0.00	6	0.9670
0.01	8	0.8789
0.02	11	0.5913

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 1/1(B)-V/C

ELEMENT 1/2-V

	0	1	2	T
2	27	14	130	171
1	0	2	8	10
0	8	1	10	19
T	35	17	148	200

Ho	C	POWER
0.00	5	0.9977
0.01	8	0.9651
0.02	11	0.8163

CONCLUSION The postulated connection is accepted as valid at the third (0.02) Ho level, although the power at this level is relatively low.

(C) ELEMENT 1/1(A)-H/C

ELEMENT 1/1(B)-V/C

	0	1	2	T
2	12	8	128	148
1	5	12	0	17
0	34	1	0	35
T	51	21	128	200

Ho	C	POWER
0.00	6	0.9842
0.01	9	0.8769
0.02	11	0.7096

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 10/7

(A)

ELEMENT 1/1(A)-H/C

ELEMENT 1/2-V	0	1	2	T
2	36	19	116	171
1	3	1	6	10
0	12	1	6	19
T	51	21	128	200

Ho	C	POWER
0.00	4	0.9967
0.01	8	0.9013
0.02	10	0.7445

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level.

(B)

ELEMENT 1/1(A)-H/C

ELEMENT 1/2-H	0	1	2	T
2	34	18	118	170
1	5	2	4	11
0	12	1	6	19
T	51	21	128	200

Ho	C	POWER
0.00	4	0.9967
0.01	8	0.9022
0.02	10	0.7462

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level.

(C)

ELEMENT 1/1(B)-H/C

ELEMENT 1/2-H	0	1	2	T
2	38	9	123	170
1	4	0	7	11
0	12	1	6	19
T	54	10	136	200

Ho	C	POWER
0.00	3	0.9996
0.01	7	0.9676
0.02	10	0.8138

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level.

TABLE 10/8

(A)

ELEMENT 1/1(B)-H/C (rows) × ELEMENT 1/1(A)-V/C (columns)

	0	1	2	T
2	12	2	122	136
1	5	4	1	10
0	46	8	0	54
T	63	14	123	200

Ho	C	POWER
0.00	5	0.9895
0.01	8	0.8973
0.02	10	0.7370

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B)

ELEMENT 1/2-H (rows) × ELEMENT 1/1(A)-V/C (columns)

	0	1	2	T
2	47	10	113	170
1	5	1	5	11
0	11	3	5	19
T	63	14	123	200

Ho	C	POWER
0.00	3	0.9987
0.01	7	0.9327
0.02	9	0.7991

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level.

(C)

ELEMENT 1/2-V (rows) × ELEMENT 1/1(A)-V/C (columns)

	0	1	2	T
2	49	10	112	171
1	3	0	7	10
0	11	4	4	19
T	63	14	123	200

Ho	C	POWER
0.00	3	0.9987
0.01	7	0.9320
0.02	9	0.7976

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level.

TABLE 10/9

(A) ELEMENT 2/1(A)-H/P

ELEMENT 1/1(A)-H/S	0	1	2	T
2	21	13	81	115
1	14	8	4	26
0	30	10	19	59
T	65	31	104	200

Ho	C	POWER
0.00	10	0.7338
0.01	12	0.5111
0.02	14	0.2946

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(B) ELEMENT 2/1(A)-H/P

ELEMENT 1/1(B)-V/S	0	1	2	T
2	24	15	85	124
1	16	4	5	25
0	25	12	14	51
T	65	31	104	200

Ho	C	POWER
0.00	9	0.7895
0.01	11	0.5744
0.02	13	0.3456

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(C) ELEMENT 2/1(B)-H/S

ELEMENT 1/1(A)-H/S	0	1	2	T
2	23	17	75	115
1	14	4	8	26
0	35	9	15	59
T	72	30	98	200

Ho	C	POWER
0.00	9	0.7488
0.01	11	0.5198
0.02	13	0.2951

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

TABLE 10/10

(A) ELEMENT 2/1(B)-H/S

ELEMENT 1/1(B)-V/S	0	1	2	T
2	28	17	79	124
1	12	4	9	25
0	32	9	10	51
T	72	30	98	200

Ho	C	POWER
0.00	8	0.8108
0.01	10	0.5935
0.02	12	0.3556

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is particularly low.

(B) ELEMENT 2/1(B)-H/P

ELEMENT 1/1(A)-H/S	0	1	2	T
2	30	15	70	115
1	17	3	6	26
0	37	5	17	59
T	84	23	93	200

Ho	C	POWER
0.00	7	0.8438
0.01	9	0.6317
0.02	11	0.3842

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

(C) ELEMENT 2/1(B)-H/P

ELEMENT 1/1(B)-V/S	0	1	2	T
2	34	16	74	124
1	15	3	7	25
0	35	4	12	51
T	84	23	93	200

Ho	C	POWER
0.00	7	0.8232
0.01	9	0.5991
0.02	10	0.4720

CONCLUSION The postulated connection is rejected as invalid at all three specified Ho levels.

TABLE 10/11

(A) ELEMENT 3/2(A)-Max.

ELEMENT 1/2-V	0	1	2	T
2	30	31	91	152
1	9	3	5	17
0	12	6	13	31
T	51	40	109	200

Ho	C	POWER
0.00	9	0.7664
0.01	11	0.5429
0.02	13	0.3160

CONCLUSION The postulated connection is accepted as valid at the third (0.02) Ho level, although the power at this level is extremely low.

(B) ELEMENT 3/2(A)-Max.

ELEMENT 1/1(A)-V/C	0	1	2	T
2	32	29	95	156
1	8	3	7	18
0	11	8	7	26
T	51	40	109	200

Ho	C	POWER
0.00	9	0.7309
0.01	10	0.6178
0.02	12	0.3800

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(C) ELEMENT 3/2(A)-Min.

ELEMENT 1/2-V	0	1	2	T
2	30	39	83	152
1	8	3	6	17
0	13	9	9	31
T	51	51	98	200

Ho	C	POWER
0.00	11	0.4469
0.01	12	0.3323
0.02	14	0.1557

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLE 10/12

(A) ELEMENT 3/2(A)-Min.

ELEMENT 1/1(A)-V/C		0	1	2	T
	2	32	38	86	156
	1	6	5	7	18
	0	13	8	5	26
	T	51	51	98	200

Ho	C	POWER
0.00	10	0.5024
0.01	11	0.3802
0.02	13	0.1835

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B) ELEMENT 3/1

ELEMENT 3/2(B)		0	1	2	T
	2	56	79	43	178
	1	2	2	2	6
	0	5	10	1	16
	T	63	91	46	200

Ho	C	POWER
0.00	9	0.0063
0.01	10	0.0021
0.02	10	0.0021

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 3/1

ELEMENT 3/2(A)-Max.		0	1	2	T
	2	30	51	28	109
	1	13	20	7	40
	0	20	20	11	51
	T	63	91	46	200

Ho	C	POWER
0.00	20	0.0016
0.01	20	0.0016
0.02	20	0.0016

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 10/13

(A) ELEMENT 3/1

ELEMENT 3/2(A)-Min.

	0	1	2	T
2	31	44	23	98
1	14	22	15	51
0	18	25	8	51
T	63	91	46	200

Ho	C	POWER
0.00	20	0.0020
0.01	20	0.0020
0.02	20	0.0020

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 1/2-V (Retest)

ELEMENT 1/2-V

	0	1	2	T
2	19	13	139	171
1	3	1	6	10
0	9	3	7	19
T	31	17	152	200

Ho	C	POWER
0.00	5	0.9983
0.01	9	0.9451
0.02	11	0.8421

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

(C) ELEMENT 1/1(A)-V (Retest)

ELEMENT 1/1(A)-V

	0	1	2	T
2	5	4	114	123
1	3	4	7	14
0	18	10	35	63
T	26	18	156	200

Ho	C	POWER
0.00	13	0.9057
0.01	15	0.7857
0.02	17	0.6136

CONCLUSION This skill was acquired by a significant proportion of students in the process of attempting more complex capabilities.

TABLE 10/14

(A) ELEMENT 4/2-H

ELEMENT 4/3		0	1	2	T
	2	13	6	176	195
	1	1	0	3	4
	0	1	0	0	1
	T	15	6	179	200

Ho	C	POWER
0.00	1	1.0000
0.01	7	0.9969
0.02	11	0.9369

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(B) ELEMENT 4/2-V

ELEMENT 4/3		0	1	2	T
	2	12	47	136	195
	1	1	1	2	4
	0	1	0	0	1
	T	14	48	138	200

Ho	C	POWER
0.00	4	0.7485
0.01	5	0.5930
0.02	7	0.2860

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(C) ELEMENT 4/2-H

ELEMENT 1/3-H		0	1	2	T
	2	13	6	177	196
	1	1	0	1	2
	0	1	0	1	2
	T	15	6	179	200

Ho	C	POWER
0.00	2	1.0000
0.01	7	0.9969
0.02	11	0.9373

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

TABLE 10/15

(A) ELEMENT 4/2-V

ELEMENT 1/3-V	0	1	2	T
2	12	47	137	196
1	1	1	1	3
0	1	0	0	1
T	14	48	138	200

Ho	C	POWER
0.00	4	0.7482
0.01	5	0.5926
0.02	7	0.2856

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(B) ELEMENT 4/1-H

ELEMENT 4/2-H	0	1	2	T
2	11	25	143	179
1	3	0	3	6
0	9	5	1	15
T	23	30	147	200

Ho	C	POWER
0.00	9	0.8964
0.01	11	0.7448
0.02	13	0.5338

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(C) ELEMENT 4/1-V

ELEMENT 4/2-V	0	1	2	T
2	11	21	106	138
1	3	6	39	48
0	8	5	1	14
T	22	32	146	200

Ho	C	POWER
0.00	13	0.7117
0.01	15	0.5082
0.02	17	0.3098

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

TABLE 10/16

(A) ELEMENT 4/1-H

ELEMENT 1/2-H

	0	1	2	T
2	11	25	141	177
1	4	2	4	10
0	8	3	2	13
T	23	30	147	200

Ho	C	POWER
0.00	8	0.9346
0.01	10	0.8121
0.02	12	0.6164

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 4/1-V

ELEMENT 1/2-V

	0	1	2	T
2	11	26	134	171
1	5	1	11	17
0	6	5	1	12
T	22	32	146	200

Ho	C	POWER
0.00	9	0.8681
0.01	11	0.6945
0.02	13	0.4729

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(C) ELEMENT 5/3(A)

ELEMENT 5/4(A)

	0	1	2	T
2	8	8	177	193
1	0	0	2	2
0	2	2	1	5
T	10	10	180	200

Ho	C	POWER
0.00	4	0.9998
0.01	8	0.9851
0.02	11	0.8988

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 10/17

(A)

ELEMENT 5/2(A) (columns); ELEMENT 5/3(A) (rows)

	0	1	2	T
2	110	13	57	180
1	8	1	1	10
0	9	1	0	10
T	127	15	58	200

Ho	C	POWER
0.00	2	0.9316
0.01	4	0.6920
0.02	6	0.3622

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B)

ELEMENT 5/2(A) (columns); ELEMENT 4/1-H (rows)

	0	1	2	T
2	76	11	50	137
1	12	1	5	18
0	39	3	3	45
T	127	15	58	200

Ho	C	POWER
0.00	3	0.8593
0.01	5	0.5688
0.02	7	0.2642

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(C)

ELEMENT 5/2(A) (columns); ELEMENT 4/1-V (rows)

	0	1	2	T
2	66	10	46	122
1	26	2	10	38
0	35	3	2	40
T	127	15	58	200

Ho	C	POWER
0.00	6	0.5222
0.01	7	0.3710
0.02	8	0.2426

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLE 10/18

(A) ELEMENT 5/2(B)

ELEMENT 5/3(B)	0	1	2	T
2	13	6	99	118
1	13	10	7	30
0	47	4	1	52
T	73	20	107	200

Ho	C	POWER
0.00	8	0.8749
0.01	10	0.6364
0.02	12	0.4660

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(B) ELEMENT 5/2(B)

ELEMENT 1/1(B)-H/C	0	1	2	T
2	52	17	102	171
1	5	2	5	12
0	16	1	0	17
T	73	20	107	200

Ho	C	POWER
0.00	3	0.9950
0.01	6	0.9171
0.02	9	0.6389

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 5/1

ELEMENT 5/2(B)	0	1	2	T
2	48	39	20	107
1	16	3	1	20
0	61	12	0	73
T	125	54	21	200

Ho	C	POWER
0.00	9	0.0060
0.01	9	0.0060
0.02	9	0.0060

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 10/19

(A) ELEMENT 5/1

ELEMENT 5/2(A)	0	1	2	T
2	24	23	17	64
1	19	12	3	34
0	82	19	1	102
T	125	54	21	200

Ho	C	POWER
0.00	11	0.0072
0.01	12	0.0027
0.02	12	0.0027

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 4/1-H (Retest)

ELEMENT 4/1-H	0	1	2	T
2	18	11	118	147
1	11	5	14	30
0	16	2	5	23
T	45	18	137	200

Ho	C	POWER
0.00	7	0.9830
0.01	10	0.8808
0.02	12	0.7246

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

(C) ELEMENT 4/1-V (Retest)

ELEMENT 4/1-V	0	1	2	T
2	15	27	104	146
1	8	10	14	132
0	17	1	4	22
T	40	38	122	200

Ho	C	POWER
0.00	10	0.7820
0.01	12	0.5739
0.02	14	0.3528

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

TABLE 10/20

(A) ELEMENT 5/2(A) (Retest)

ELEMENT 5/2(A)		0	1	2	T
	2	3	6	49	58
	1	1	4	10	15
	0	98	24	5	127
	T	102	34	64	200

Ho	C	POWER
0.00	11	0.2218
0.01	12	0.1412
0.02	13	0.0844

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

(B) ELEMENT 6/4(B)

ELEMENT 6/5(B)		0	1	2	T
	2	7	5	185	197
	1	0	0	2	2
	0	1	0	0	1
	T	8	5	187	200

Ho	C	POWER
0.00	2	1.0000
0.01	7	0.9973
0.02	11	0.9436

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the poweris unrealistically high.

(C) ELEMENT 6/3(B)

ELEMENT 6/4(B)		0	1	2	T
	2	27	11	149	187
	1	4	0	1	5
	0	7	0	1	8
	T	38	11	151	200

Ho	C	POWER
0.00	2	1.0000
0.01	7	0.9844
0.02	10	0.8875

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 10/21

(A) ELEMENT 6/2-S

ELEMENT 6/3 (B)

	0	1	2	T
2	32	32	63	127
1	11	8	0	19
0	52	2	0	54
T	95	42	63	200

Ho	C	POWER
0.00	8	0.3592
0.01	9	0.2391
0.02	10	0.1477

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B) ELEMENT 6/2-S

ELEMENT 6/3 (A)

	0	1	2	T
2	30	16	63	109
1	27	26	0	53
0	38	0	0	38
T	95	42	63	200

Ho	C	POWER
0.00	11	0.1765
0.01	12	0.1075
0.02	13	0.0614

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 6/2-S

ELEMENT 6/5 (B)

	0	1	2	T
2	88	41	61	190
1	5	1	2	8
0	2	0	0	2
T	95	42	63	200

Ho	C	POWER
0.00	2	0.9278
0.01	4	0.6811
0.02	6	0.3500

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

TABLE 10/22

(A) ELEMENT 6/2-C

ELEMENT 6/3(B)	0	1	2	T
2	40	18	78	136
1	9	1	0	10
0	52	2	0	54
T	101	21	78	200

Ho	C	POWER
0.00	4	0.9151
0.01	6	0.7143
0.02	8	0.4342

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 6/2-C

ELEMENT 6/3(A)	0	1	2	T
2	33	9	78	120
1	13	12	0	25
0	55	0	0	55
T	101	21	78	200

Ho	C	POWER
0.00	6	0.7726
0.01	8	0.5092
0.02	9	0.3750

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(C) ELEMENT 6/2-C

ELEMENT 6/5(B)	0	1	2	T
2	94	21	75	190
1	5	0	3	8
0	2	0	0	2
T	101	21	78	200

Ho	C	POWER
0.00	2	0.9837
0.01	5	0.7820
0.02	7	0.5019

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

TABLE 10/23

(A)

ELEMENT 6/1-H/S (columns); ELEMENT 6/2-S (rows)

	0	1	2	T
2	36	12	15	63
1	29	3	10	42
0	89	4	2	95
T	154	19	27	200

Ho	C	POWER
0.00	8	0.0355
0.01	8	0.0355
0.02	9	0.0145

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B)

ELEMENT 6/1-H/C (columns); ELEMENT 6/2-C (rows)

	0	1	2	T
2	41	12	25	78
1	16	3	2	21
0	97	3	1	101
T	154	18	28	200

Ho	C	POWER
0.00	5	0.1270
0.01	5	0.1270
0.02	6	0.0558

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C)

ELEMENT 6/1-H/S (columns); ELEMENT 1/1(B)-H/S (rows)

	0	1	2	T
2	139	18	27	184
1	8	0	0	8
0	7	1	0	8
T	154	19	27	200

Ho	C	POWER
0.00	1	0.5002
0.01	2	0.2789
0.02	3	0.1314

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLE 10/24

(A) ELEMENT 6/1-H/C

ELEMENT 1/1(B)-H/C

	0	1	2	T
2	142	18	28	188
1	8	0	0	8
0	4	0	0	4
T	154	18	28	200

Ho	C	POWER
0.00	1	0.7645
0.01	3	0.2992
0.02	4	0.1451

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(B) ELEMENT 6/2-S

ELEMENT 6/3(C)

	0	1	2	T
2	27	13	62	102
1	23	29	1	53
0	45	0	0	45
T	95	42	63	200

Ho	C	POWER
0.00	11	0.2207
0.01	12	0.1404
0.02	13	0.0838

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 6/2-C

ELEMENT 6/3(C)

	0	1	2	T
2	27	3	78	108
1	16	18	0	34
0	58	0	0	58
T	101	21	78	200

Ho	C	POWER
0.00	8	0.6007
0.01	9	0.4672
0.02	10	0.3413

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLES 10/25-10/29

Subdivisional Analysis Results for Papua/New Guinea

(Programme I)

PRELIMINARY NOTES

1. The following results are presented in correlation matrix form, listing the number of questions correct for each element, and the appropriate marginal totals.

2. The classification code for each element is outlined in Tables 5/4-5/10, and a list of the relevant subdivisional question groups is presented in Table 6/2.

3. P represents the combined probability that the observed number of students in the 0/2 and 2/0 cells could have occurred through chance (or errors of measurement) under the null hypothesis that no-one can possess only one of the relevant subdivisional skills without also having the other.

TABLE 10/25

(A)

GROUP 1 \ GROUP 2	0	1	2	T
2	0	1	189	190
1	1	2	2	5
0	5	0	0	5
T	6	3	191	200

ELEMENT 1/3

TEST H/V (Position)

P = 1.0000

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	1	4	165	170
1	2	4	5	11
0	16	2	1	19
T	19	10	171	200

ELEMENT 1/2

TEST H/V (Co-ordinates)

P = 0.0166

CONCLUSION Question groups 1 and 2 probably represent the same subdivisional skill.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	11	15	111	137
1	17	6	6	29
0	23	4	7	34
T	51	25	124	200

ELEMENT 1/1(B)

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(D)

GROUP 1 \ GROUP 3	0	1	2	T
2	9	4	124	137
1	16	3	10	29
0	29	3	2	34
T	54	10	136	200

ELEMENT 1/1(B)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

TABLE 10/26

(A)

GROUP 2 \ GROUP 4	0	1	2	T
2	2	3	119	124
1	5	7	13	25
0	28	7	16	51
T	35	17	148	200

ELEMENT 1/1(B)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 2 and 4 represent different subdivisional skills.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	9	8	98	115
1	6	7	13	26
0	32	14	13	59
T	47	29	124	200

ELEMENT 1/1(A)

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 3	0	1	2	T
2	3	6	106	115
1	10	3	13	26
0	38	12	9	59
T	51	21	128	200

ELEMENT 1/1(A)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

(D)

GROUP 2 \ GROUP 4	0	1	2	T
2	12	6	106	124
1	13	2	14	29
0	38	6	3	47
T	63	14	123	200

ELEMENT 1/1(A)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 2 and 4 represent different subdivisional skills.

TABLE 10/27

(A)

GROUP 2/1(B)-2

GROUP 2/1(A)-1	0	1	2	T.
2	16	14	74	104
1	22	4	5	31
0	46	5	14	65
T	84	23	93	200

ELEMENT 2/1(A)-2/1(B)

TEST Interpolation/Extrapolation

P = 0.0000

CONCLUSION Elements 2/1(A) and 2/1(B) represent different basic skills.

(B)

GROUP 2

GROUP 1	0	1	2	T
2	9	10	79	98
1	16	7	7	30
0	59	6	7	72
T	84	23	93	200

ELEMENT 2/1(B)

TEST Line/Points

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

GROUP 2

GROUP 1	0	1	2	T
2	5	20	84	109
1	10	20	10	40
0	36	11	4	51
T	51	51	98	200

ELEMENT 3/2(A)

TEST Max./Min. Values

P = 0.0377

CONCLUSION Question groups 1 and 2 probably represent the same subdivisional skill.

(D)

GROUP 2

GROUP 1	0	1	2	T
2	0	0	196	196
1	0	2	0	2
0	1	1	0	2
T	1	3	196	200

ELEMENT 1/3 (Retest)

TEST H/V (Position)

P = 1.0000

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

TABLE 10/28

(A)

GROUP 1 \ GROUP 2	0	1	2	T
2	0	10	167	177
1	3	5	2	10
0	9	2	2	13
T	12	17	171	200

ELEMENT 1/2 (Retest)

TEST H/V (Co-ordinates)

P = 0.0145

CONCLUSION Question groups 1 and 2 probably represent the same subdivisional skill.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	1	46	132	179
1	0	1	5	6
0	13	1	1	15
T	14	48	138	200

ELEMENT 4/2

TEST H/V (Displacement)

P = 0.3690

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	2	16	129	147
1	3	12	15	30
0	17	4	2	23
T	22	32	146	200

ELEMENT 4/1

TEST H/V (Displacement)

P = 0.1165

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(D)

GROUP 1 \ GROUP 3	0	1	2	T
2	2	2	180	184
1	0	2	6	8
0	2	4	2	8
T	4	8	188	200

ELEMENT 1/1(B) (Retest)

TEST Straight Line/Curve

P = 0.0001

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

TABLE 10/29

(A) GROUP 2

GROUP 1	0	1	2	T
2	1	8	188	197
1	0	0	2	2
0	1	0	0	1
T	2	8	190	200

ELEMENT 6/5(B)

TEST Numerical Range

P = 0.1008

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(B) GROUP 2

GROUP 1	0	1	2	T
2	8	13	88	109
1	15	10	28	53
0	32	2	4	38
T	55	25	120	200

ELEMENT 6/3(A)

TEST Straight Line/Curve

P = 0.0021

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C) GROUP 2

GROUP 1	0	1	2	T
2	3	11	49	63
1	12	9	21	42
0	86	1	8	95
T	101	21	78	200

ELEMENT 6/2

TEST Straight Line/Curve

P = 0.0001

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(D) GROUP 2

GROUP 1	0	1	2	T
2	3	6	18	27
1	6	5	8	19
0	145	7	2	154
T	154	18	28	200

ELEMENT 6/1

TEST Straight Line/Curve

P = 0.0007

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

FIGURES 10.2-10.7

Outline of the Validated Learning Hierarchy for Papua/New Guinea

(Programme I)

PRELIMINARY NOTES

1. The classification code for each basic skill is outlined in Tables 5/4-5/10, and abbreviations used for the relevant subdivisional conditions are listed in the preliminary notes for Tables 6/4-6/25.

2. Lines representing hierarchical connections are classified according to the following key.

———— (thick solid line)	Connection accepted as valid at the absolute Ho level.
———— (thin solid line)	Connection accepted as valid at weaker (0.01 and 0.02) Ho levels.
- - - - - - - (broken line)	Connection rejected as invalid at all three specified Ho levels.

FIGURE 10.2

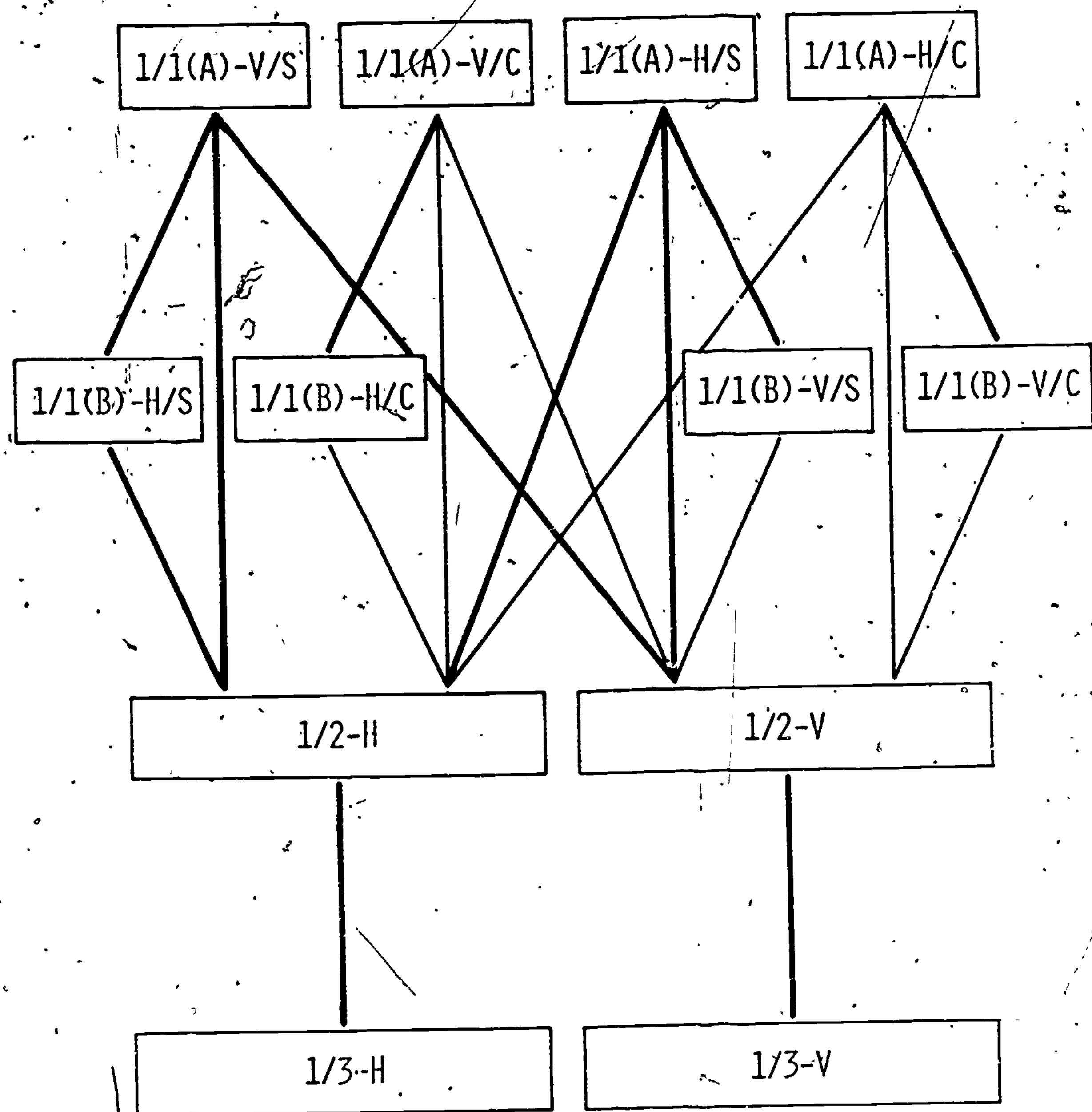

1/1(A)-V/S
1/1(A)-V/C
1/1(A)-H/S
1/1(A)-H/C
1/1(B)-H/S
1/1(B)-H/C
1/1(B)-V/S
1/1(B)-V/C
1/2-H
1/2-V
1/3-H
1/3-V

FIGURE 10.3

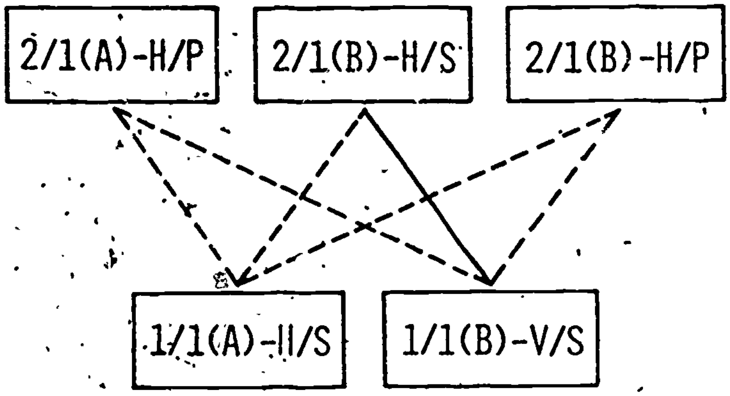


FIGURE 10.4

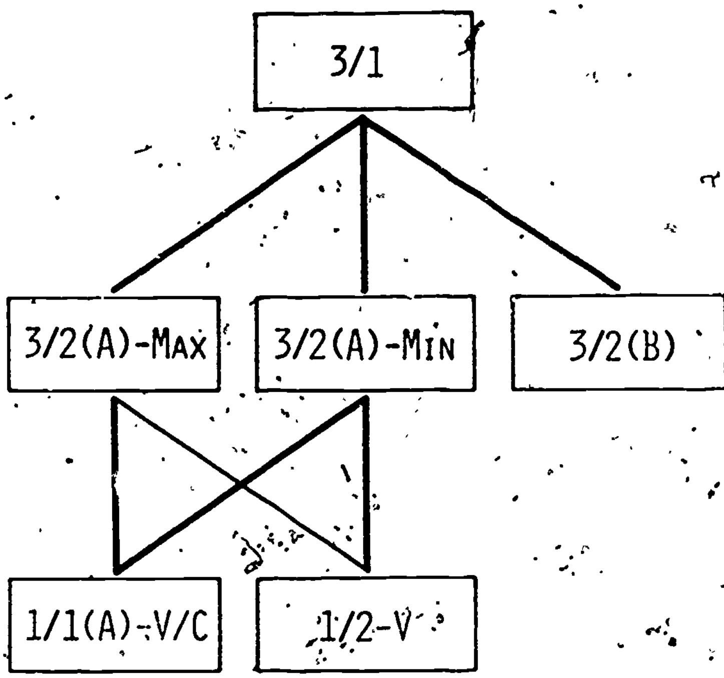


FIGURE 10.5

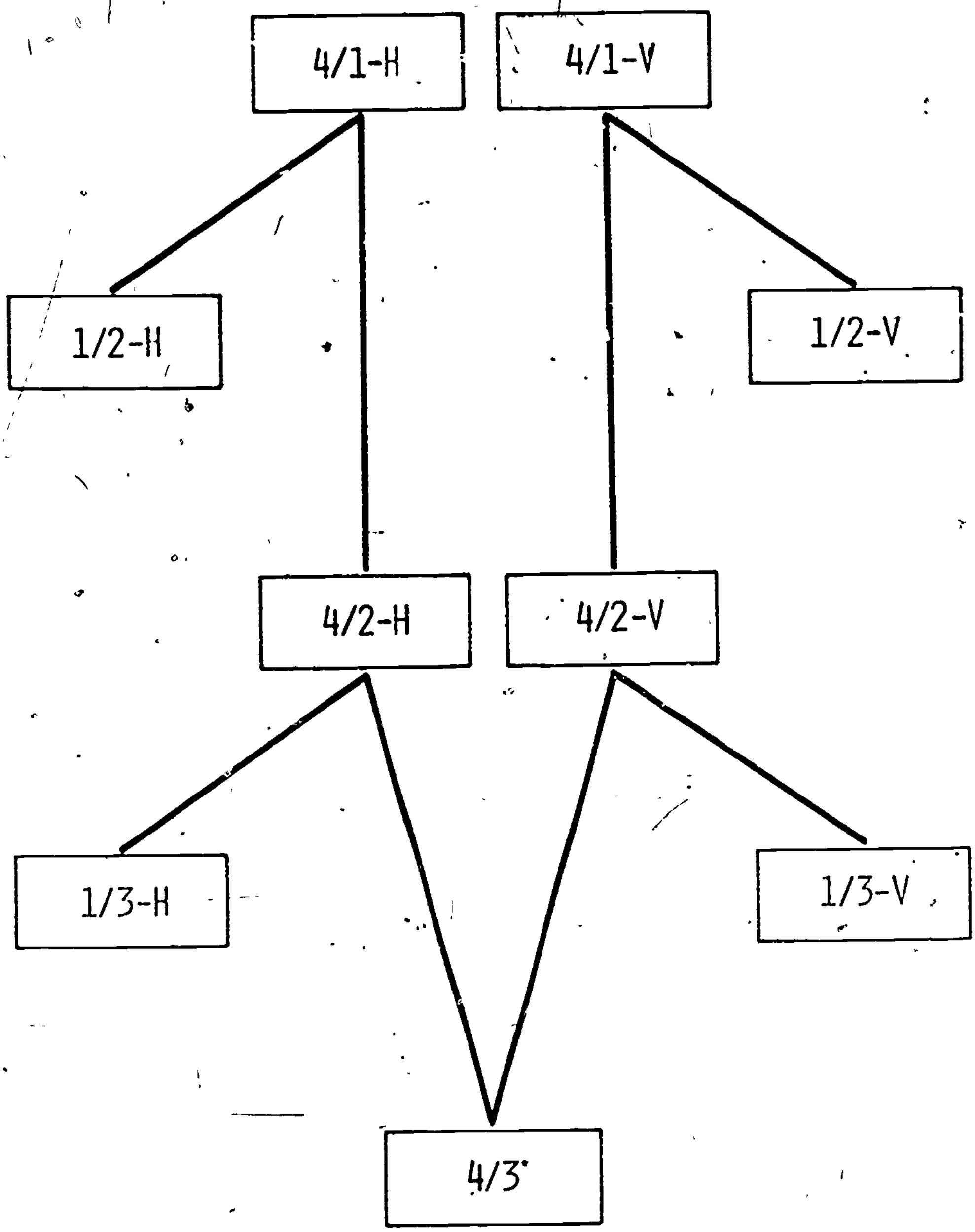


FIGURE 10.6

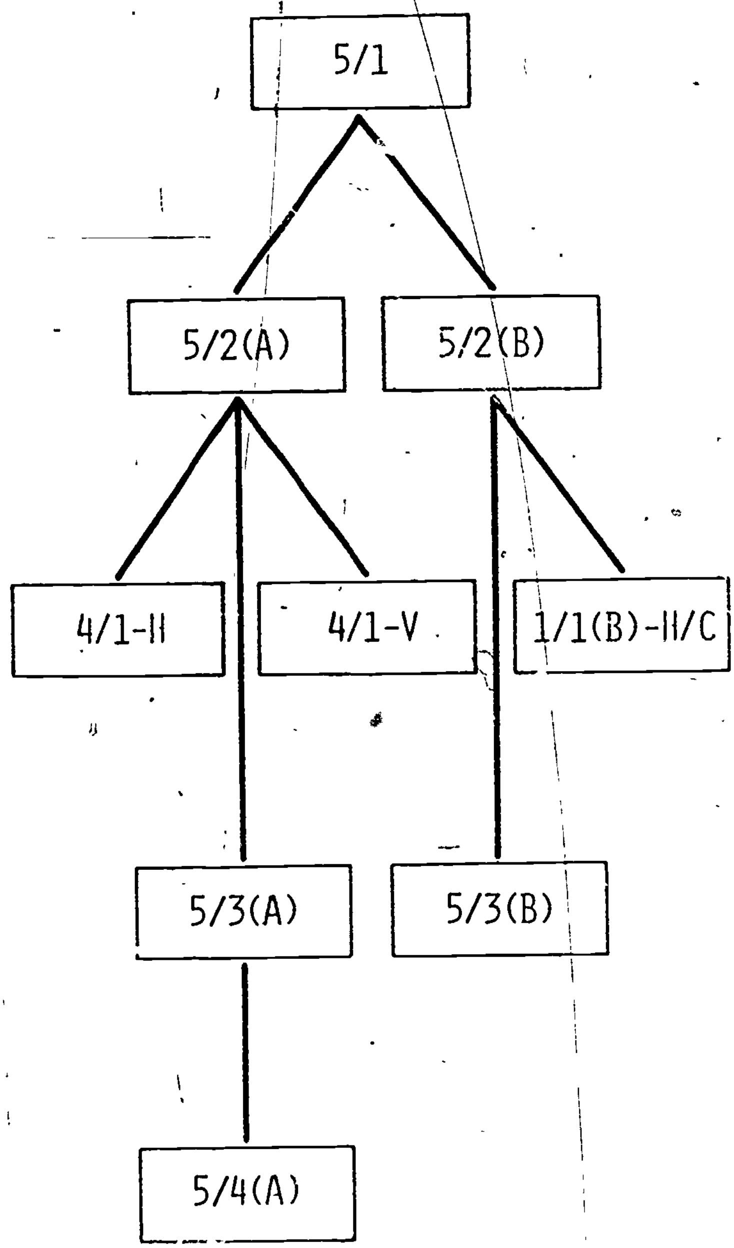
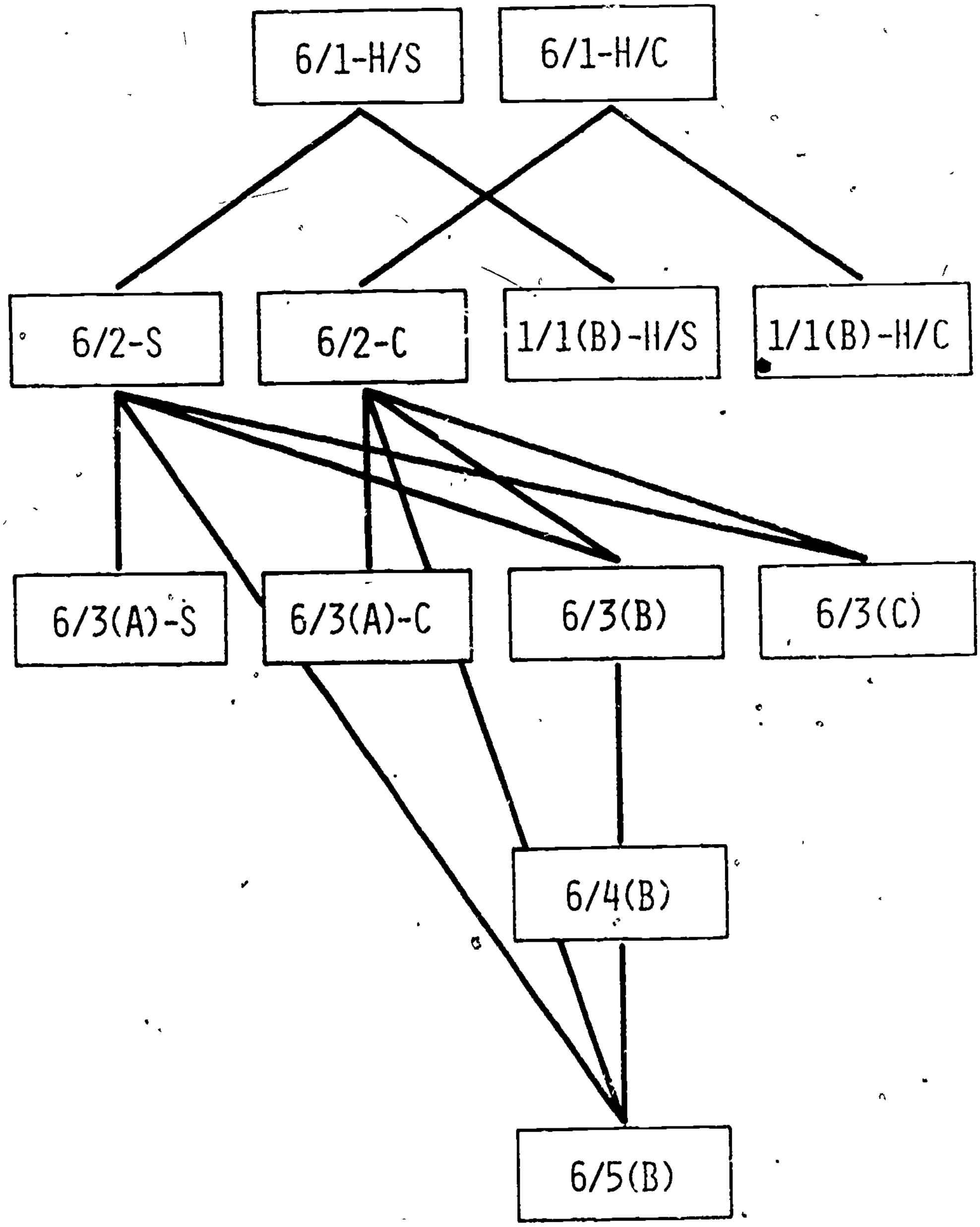


FIGURE 10.7



CHAPTER XI

THE INTERACTIVE EFFECTS OF A DIFFERENT CULTURAL BACKGROUND AND SPECIFIC INFORMATIONAL MODEL ON THE POSTULATED LEARNING HIERARCHY

1. Introduction

The influence of traditional culture on indigenous students in Papua/New Guinea has often been suggested as a source of learning difficulties with respect to certain mathematical and scientific concepts fundamental to Western language and culture (Johnson 1968; Prince 1967 and 1969), and it seems that these difficulties are still apparent at relatively senior academic levels (Mackay and Gardner 1969). Time has been mentioned on several occasions as a source of particular conceptual difficulties (see Johnson 1968; Prince 1969, 1970; Mackay and Gardner 1969), and since this was one of the major variables incorporated in the second validation programme, it was decided to test this programme in Papua/New Guinea with a similar group of high school students to that involved in the validation study with Programme I. Thus the object of this test with Programme II was to determine whether possible conceptual difficulties with specific informational variables, presumably attributable in the general sense to some aspect of the cultural background, would influence the acquisition sequence of certain graphical interpretation skills associated with these variables.

2. Preparation and Administration

The preparation of Programme II, which incorporated Time and Annual Birth Rate as the basic informational variables, has already been described in Chapter VII. The sequence of computational and interpretative skills was the same as that outlined for Programme I (Table 6/1), and the range of associated subdivisional skills (listed in Tables 6/1 and 6/2) was also common to both validation programmes.

The administration of Programme II in Papua/New Guinea, which was performed in conjunction with Programme I (see Chapter X), involved a total of 191 indigenous form 3 students from all six Central District high schools following the national curriculum. This group contained 132 male and 59 female students, together ranging in age from 14 to 18 years (taken to the nearest year) with a mean of 15.5. Thus in terms of average age and range, this group was almost identical to that involved in the validation study with Programme I, and, as expected from the difference in academic level, considerably older than any of the Australian form 1 or first year high school groups. The number of students involved from each participating school is shown in Table 11/1, and the relevant school charac teristics of location and controlling authority, co-educational and residential status have already been outlined in Table 10/2 (Chapter X).

The mean completion times for Programme II in Papua/New Guinea (shown in Table 11/1. were not significantly different at the 0.05 level (t-test) f om th se reported earlier for Programme I (Chapter X). A similar result was also reported for Programmes I and II in the relevant Victorian validation studies, and in fact the mean completion times for Victoria were effectively the same as those for Papua/New Guinea, in spite of substantial differences in student age and nominal academic level. As in all of the previous validation studies, the progression rate for Programme II (Figure 11.1) was relatively constant for the single testing group in Papua/New Guinea,

TABLE 11/1

Sample Numbers and Completion Times for Programme II

(Papua/New Guinea)

HIGH SCHOOL (and class)		Number of Students in Sample	Shortest Completion Time (mins.)	Longest Completion Time (mins.)
Badihagwa	3A	12	50	104
	3B	15	45	85
Bomana		17	62	112
Iarowari	3A	16	56	104
	3B	16	54	107
Kila Kila	3B	29	46	101
	3C	17	43	100
Kwikila	3A	13	-	-
	3B	12	45	107
	3C	23	-	-
Marianville		21	88	130
Mean Completion Time			54.3	105.6
Standard Deviation			14.1	11.8

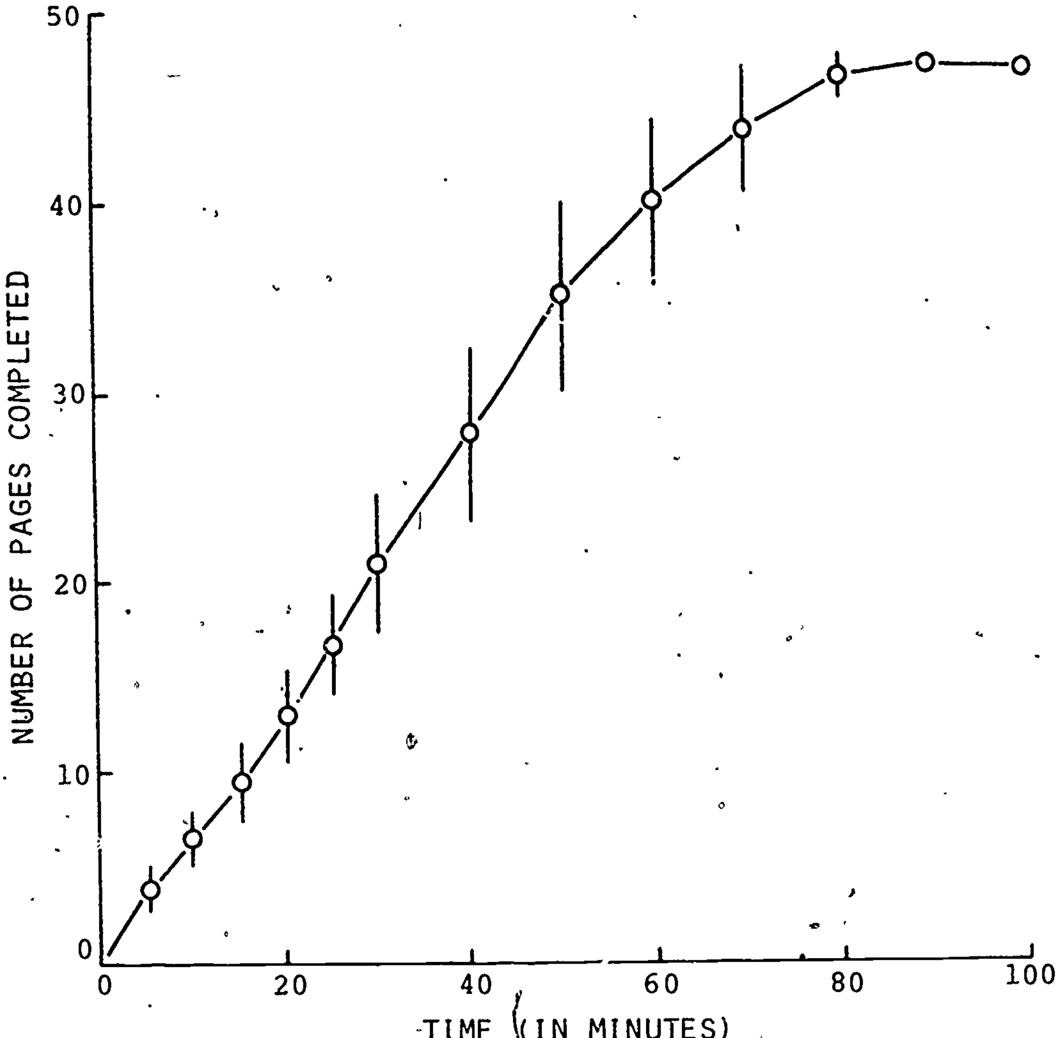
NOTE

The controlling authority, co-educational status, location and residential characteristics for each of the schools above is presented in Table 10/2 (Chapter X).

FIGURE 11.1

Progression Rate for Programme II

(Kwikila High School - Papua/New Guinea)



NOTES

1. Circles indicate the mean number of pages completed at specified times.
2. Vertical lines represent the appropriate Standard Deviation.
3. Number of students involved = 48.

and thus the relevant graph was linear to the point of first completion.

3. Results and Implications

The statistical analysis of validation results for Programme II in Papua/New Guinea was similar to that outlined for each of the previous validation studies. The results of this analysis are presented in Tables 11/2-11/23, and those for the subsequent analysis of relevant subdivisional skills are presented in Tables 11/24-11/28.

The validation results for Programme II in Papua/New Guinea were generally consistent with those from previous validation studies, and in fact were almost identical with those from the analogous Victorian study outlined in Chapter VII, in that all of the postulated hierarchical connections were accepted as valid at one of the specified null hypothesis levels (see Figures 11.2-11.7). For many individual tests, however, the power was particularly low, caused partly by the substantial degree of response inconsistency, and accentuated in some cases by high difficulty levels for superordinate skills. Both of these problems have already been explained in Chapter VI, and were also mentioned in the other validation studies.

The difficulty levels in Papua/New Guinea for individual elements incorporated in Programme II were generally lower than those for Programme I, and in many cases the total number of students who failed a particular subordinate skill was lower than the calculated critical number of 0/2 cell exceptions (see Tables 11/2(A) and (B), 11/11(B), 11/13-15, 11/19(B), 11/20(C) and 11/21(C)), so that the relevant hierarchical connection could not possibly be rejected, even at the absolute Ho level. In cases such as this the connection was tentatively accepted as valid, although the calculation of statistical power was by definition independent of the subordinate skill difficulty level, and therefore unrealistically high. The same difference in difficulty levels between corresponding elements in Programmes I and II was also reported for the previous Victorian studies (see Chapter VII/Section 3), although the results for simpler skills were in these studies generally less extreme, and so the problem of statistical power outlined above was less apparent.

The subdivisional analysis results for Programme II in Papua/ New Guinea were generally consistent with those for previous validation studies, the most obvious exceptional case being that for element 1/3 (see Tables 11/24(A) and 11/26(D)), in which the difficulty level was much too low for effective discrimination between the postulated subdivisional skills. The results for area 6 did not show any positive discrimination, but were not in this respect entirely inconsistent with analogous results from previous studies, which were often inconclusive and internally inconsistent.

The results from this validation study serve both to substantiate and to extend several important conclusions derived from the previous studies in Australia and Papua/New Guinea. In the first place they reaffirm the existence (established earlier in Chapter X) of a common hierarchical network of graphical interpretation skills for students from very different cultural and educational backgrounds, and secondly re-establish the independence of this hierarchy of intellectual skills from the specific informational context within which the skills are presented (see also Chapter VII/Section 3). It should be mentioned in this respect, however, that these intellectual skills are defined in purely operational terms, and incorporate no conditions of meaningful interpretation with respect to specific concepts such as Time or Annual Birth Rate. The calculation of a linear gradient in this context, for example, need not involve an understanding of its real scientific meaning as a constant rate of change in Annual Birth Rate. This important aspect of meaningful interpretation with respect to intellectual skills will be examined more closely in Chapter XII, together with a number of general implications arising from the various local, interstate and overseas validation studies.

TABLES 11/2-11/23

Validation Results for Papua/New Guinea

(Programme II)

PRELIMINARY NOTES

1. The following results are presented in correlation matrix form, listing the number of questions correct for each element, and the appropriate marginal totals.

2. The critical number of exceptions (C) permitted in the 0/2 cell of the relevant correlation table is listed, together with the appropriate statistical power, for each of the null hypothesis levels defined in Chapter VI (see preliminary notes for Tables 6/4-6/25).

3. The classification code for each element is outlined in Tables 5/4-5/10, and the relevant subdivisional conditions are presented in Tables 6/4-6/25 (preliminary notes).

TABLE 11/2

(A) ELEMENT 1/2-H

ELEMENT 1/3-H.	0	1	2	T
2	4	6	173	183
1	1	0	5	6
0	1	0	1	2
T	6	6	179	191

Ho	C	POWER
0.00	3	0.9999
0.01	7	0.9923
0.02	11	0.8855

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(B) ELEMENT 1/2-V

ELEMENT 1/3-V	0	1	2	T
2	3	11	170	184
1	0	1	2	3
0	2	0	2	4
T	5	12	174	191

Ho	C	POWER
0.00	6	0.9764
0.01	9	0.8377
0.02	11	0.6450

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(C) ELEMENT 1/1(B)-V/S

ELEMENT 1/2-V.	0	1	2	T
2	27	15	132	174
1	3	2	7	12
0	2	0	3	5
T	32	17	142	191

Ho	C	POWER
0.00	3	0.9996
0.01	7	0.9678
0.02	10	0.8144

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 11/3

(A) ELEMENT 1/1(A)-H/S

ELEMENT 1/1(B)-V/S

	0	1	2	T
2	4	3	135	142
1	5	12	0	17
0	26	6	0	32
T	35	21	135	191

Ho	C	POWER
0.00	8	0.9587
0.01	10	0.8677
0:02	13	0.5983

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 1/1(A)-H/S

ELEMENT 1/2-V

	0	1	2	T
2	29	19	126	174
1	4	1	7	12
0	2	1	2	5
T	35	21	135	191

Ho	C	POWER
0.00	4	0.9967
0.01	7	0.9482
0.02	10	0.7462

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 1/1(A)-H/S

ELEMENT 1/2-H

	0	1	2	T
2	31	20	128	179
1	3	0	3	6
0	1	1	4	6
T	35	21	135	191

Ho	C	POWER
0.00	3	0.9991
0.01	7	0.9470
0.02	10	0.7425

CONCLUSION The postulated connection is accepted as valid at the second (0:01) Ho level, although the power at this level is unrealistically high.

TABLE 11/4

(A) ELEMENT 1/1(B)-H/S

ELEMENT 1/2-H	0	1	2	T
2	15	14	150	179
1	1	1	4	6
0	2	1	3	6
T	18	16	157	191

Ho	C	POWER
0.00	4	0.9991
0.01	8	0.9575
0.02	11	0.7898

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 1/1(A)-V/S

ELEMENT 1/1(B)-H/S	0	1	2	T
2	1	6	150	157
1	5	11	0	16
0	16	2	0	18
T	22	19	150	191

Ho	C	POWER
0.00	8	0.9709
0.01	10	0.8997
0.02	13	0.6623

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 1/1(A)-V/S

ELEMENT 1/2-H	0	1	2	T
2	18	17	144	179
1	2	0	4	6
0	2	2	2	6
T	22	19	150	191

Ho	C	POWER
0.00	4	0.9985
0.01	8	0.9399
0.02	10	0.8235

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 11/5

(A) ELEMENT 1/1(A)-V/S

ELEMENT 1/2-V	0	1	2	T
2	19	18	137	174
1	1	[illegible]	10	12
0	2	0	3	5
T	22	19	150	191

Ho	C	POWER
0.00	4	0.9985
0.01	8	0.9402
0.02	10	0.8241

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 1/1(B)-V/C

ELEMENT 1/2-V	0	1	2	T
2	13	10	151	174
1	3	0	9	12
0	2	1	2	5
T	18	11	162	191

Ho	C	POWER
0.00	4	0.9996
0.01	8	0.9769
0.02	11	0.8616

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 1/1(A)-H/C

ELEMENT 1/1(B)-V/C	0	1	2	T
2	3	7	152	162
1	4	7	0	11
0	18	0	0	18
T	25	14	152	191

Ho	C	POWER
0.00	5	0.9983
0.01	9	0.9462
0.02	11	0.8443

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 11/6

(A) ELEMENT 1/1(A)-H/C

ELEMENT 1/2-V		0	1	2	T
	2	19	14	141	174
	1	3	0	9	12
	0	3	0	2	5
	T	25	14	152	191

Ho	C	POWER
0.00	4	0.9992
0.01	7	0.9818
0.02	10	0.8745

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 1/1(A)-H/C

ELEMENT 1/2-H.		0	1	2	T
	2	22	11	146	179
	1	0	2	4	6
	0	3	1	2	6
	T	25	14	152	191

Ho	C	POWER
0.00	3	0.9998
0.01	7	0.9811
0.02	10	0.8712

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C) ELEMENT 1/1(B)-H/C

ELEMENT 1/2-H		0	1	2	T
	2	15	1	163	179
	1	1	1	4	6
	0	2	0	4	6
	T	18	2	171	191

Ho	C	POWER
0.00	2	1.0000
0.01	7	0.9962
0.02	11	0.9285

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is unrealistically high.

TABLE 11/7

(A) ELEMENT 1/1(A)-V/C

ELEMENT 1/1(B)-H/C	0	1	2	T
2	8	2	161	171
1	0	2	0	2
0	16	2	0	18
T	24	6	161	191

Ho	C	POWER
0.00	3	0.9999
0.01	7	0.9926
0.02	11	0.8881

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B) ELEMENT 1/1(A)-V/C

ELEMENT 1/2-H	0	1	2	T
2	21	5	153	179
1	1	1	4	6
0	2	0	4	6
T	24	6	161	191

Ho	C	POWER
0.00	2	1.0000
0.01	7	0.9920
0.02	10	0.9305

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is unrealistically high.

(C) ELEMENT 1/1(A)-V/C

ELEMENT 1/2-V	0	1	2	T
2	19	6	149	174
1	3	0	9	12
0	2	0	3	5
T	24	6	161	191

Ho	C	POWER
0.00	3	0.9999
0.01	7	0.9926
0.02	11	0.8878

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 11/8

(A)

ELEMENT 1/1(A)-H/S (rows) × ELEMENT 2/1(A)-H/P (columns)

	0	1	2	T
2	12	8	115	135
1	13	0	8	21
0	17	8	10	35
T	42	16	133	191

Ho	C	POWER
0.00	7	0.9773
0.01	10	0.8539
0.02	12	0.6796

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is relatively low.

(B)

ELEMENT 1/1(B)-V/S (rows) × ELEMENT 2/1(A)-H/P (columns)

	0	1	2	T
2	13	10	119	142
1	11	1	5	17
0	18	5	9	32
T	42	16	133	191

Ho	C	POWER
0.00	6	0.9882
0.01	9	0.8993
0.02	11	0.7494

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is relatively low.

(C)

ELEMENT 1/1(A)-H/S (rows) × ELEMENT 2/1(B)-H/S (columns)

	0	1	2	T
2	20	14	101	135
1	9	5	7	21
0	19	13	3	35
T	48	32	111	191

Ho	C	POWER
0.00	9	0.8120
0.01	11	0.6063
0.02	13	0.3768

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

TABLE 11/9

(A) ELEMENT 2/1(B)-H/S

ELEMENT 1/1(B)-V/S	0	1	2	T
2	22	17	103	142
1	7	4	6	17
0	19	11	2	32
T	48	32	111	191

Ho	C	POWER
0.00	8	0.8655
0.01	10	0.6798
0.02	12	0.4465

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(B) ELEMENT 2/1(B)-H/P

ELEMENT 1/1(A)-H/S	0	1	2	T
2	24	18	93	135
1	13	4	4	21
0	24	3	8	35
T	61	25	105	191

Ho	C	POWER
0.00	7	0.8897
0.01	9	0.7114
0.02	11	0.4730

CONCLUSION The postulated connection is accepted as valid at the second (0.01) Ho level, although the power at this level is relatively low.

(C) ELEMENT 2/1(B)-H/P

ELEMENT 1/1(B)-V/S	0	1	2	T
2	26	20	96	142
1	10	4	3	17
0	25	1	6	32
T	61	25	105	191

Ho	C	POWER
0.00	6	0.9335
0.01	8	0.7898
0.02	10	0.5630

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 11/10

(A) ELEMENT 3/2(A)-Max.

ELEMENT 1/2-V

	0	1	2	T
2	29	45	102	176
1	0	4	2	6
0	2	4	3	9
T	31	53	107	191

Ho	C	POWER
0.00	8	0.4885
0.01	9	0.3550
0.02	10	0.2409

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B) ELEMENT 3/2(A)-Max.

ELEMENT 1/1(A)-V/C

	0	1	2	T
2	25	43	100	168
1	1	4	4	9
0	5	6	3	14
T	31	53	107	191

Ho	C	POWER
0.00	10	0.3730
0.01	11	0.2611
0.02	12	0.1717

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C) ELEMENT 3/2(A)-Min.

ELEMENT 1/2-V

	0	1	2	T
2	34	37	105	176
1	0	1	5	6
0	2	4	3	9
T	36	42	113	191

Ho	C	POWER
0.00	6	0.8735
0.01	8	0.6676
0.02	10	0.4106

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

TABLE 11/11

(A) ELEMENT 3/2(A)-Min.

ELEMENT 1/1(A)-V/C

	0	1	2	T
2	29	35	104	168
1	2	2	5	9
0	5	5	4	14
T	36	42	113	191

Ho	C	POWER
0.00	8	0.7439
0.01	9	0.6271
0.02	11	0.3791

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(B) ELEMENT 3/1

ELEMENT 3/2(B)

	0	1	2	T
2	59	87	30	176
1	2	8	0	10
0	3	2	0	5
T	64	97	30	191

Ho	C	POWER
0.00	5	—
0.01	5	—
0.02	5	—

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 3/1

ELEMENT 3/2(A)-Max.

	0	1	2	T
2	27	59	21	107
1	20	25	8	53
0	17	13	1	31
T	64	97	30	191

Ho	C	POWER
0.00	14	—
0.01	14	—
0.02	14	—

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 11/12

(A) ELEMENT 3/1

ELEMENT 3/2(A)-Min.

	0	1	2	T
2	35	59	19	113
1	15	21	6	42
0	14	17	5	36
T	64	97	30	191

Ho	C	POWER
0.00	16	—
0.01	16	—
0.02	16	—

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 1/2-V (Retest)

ELEMENT 1/2-V

	0	1	2	T
2	7	5	162	174
1	1	1	10	12
0	1	0	4	5
T	9	6	176	191

Ho	C	POWER
0.00	4	0.9999
0.01	8	0.9894
0.02	11	0.9209

CONCLUSION This element was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

(C) ELEMENT 1/1(A)-V (Retest)

ELEMENT 1/1(A)-V

	0	1	2	T
2	1	5	155	161
1	1	1	4	6
0	12	3	9	24
T	14	9	168	191

Ho	C	POWER
0.00	7	0.9963
0.01	10	0.9609
0.02	13	0.8203

CONCLUSION This element was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

TABLE 11/13

(A) ELEMENT 4/2-H

ELEMENT 4/3

	0	1	2	T
2	8	7	169	184
1	0	0	6	6
0	0	0	1	1
T	8	7	176	191

Ho	C	POWER
0.00	2	1.0000
0.01	7	0.9919
0.02	10	0.9300

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(B) ELEMENT 4/2-V

ELEMENT 4/3

	0	1	2	T
2	9	6	169	184
1	0	0	6	6
0	0	0	1	1
T	9	6	176	191

Ho	C	POWER
0.00	2	1.0000
0.01	7	0.9944
0.02	10	0.9462

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(C) ELEMENT 4/2-H

ELEMENT 1/3-H

	0	1	2	T
2	7	7	173	187
1	0	0	2	2
0	1	0	1	2
T	8	7	176	191

Ho	C	POWER
0.00	3	0.9999
0.01	7	0.9922
0.02	10	0.9319

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

TABLE 11/14

(A) ELEMENT 4/2-V

ELEMENT 1/3-V

	0	1	2	T
2	8	6	174	188
1	0	0	2	2
0	1	0	0	1
T	9	6	176	191

Ho	C	POWER
0.00	2	1.0000
0.01	7	0.9942
0.02	10	0.9453

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(B) ELEMENT 4/1-H

ELEMENT 4/2-H

	0	1	2	T
2	4	35	137	176
1	0	0	7	7
0	4	1	3	8
T	8	36	147	191

Ho	C	POWER
0.00	11	0.2330
0.01	12	0.1497
0.02	13	0.0903

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 4/1-V

ELEMENT 4/2-V

	0	1	2	T
2	2	13	161	176
1	0	1	5	6
0	3	3	3	9
T	5	17	169	191

Ho	C	POWER
0.00	11	0.6456
0.01	13	0.4178
0.02	14	0.3127

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLE 11/15

(A) ELEMENT 4/1-H

ELEMENT 1/2-H

	0	1	2	T
2	6	34	142	182
1	0	1	2	3
0	2	1	3	6
T	8	36	147	191

Ho	C	POWER
0.00	10	0.2245
0.01	11	0.1401
0.02	12	0.0817

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 4/1-V

ELEMENT 1/2-V

	0	1	2	T
2	3	16	139	158
1	1	1	26	28
0	1	0	4	5
T	5	17	169	191

Ho	C	POWER
0.00	9	0.7541
0.01	11	0.5263
0.02	12	0.4082

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(C) ELEMENT 5/3(A)

ELEMENT 5/4(A)

	0	1	2	T
2	6	7	171	184
1	0	0	2	2
0	1	0	4	5
T	7	7	177	191

Ho	C	POWER
0.00	4	0.9998
0.01	8	0.9833
0.02	11	0.8902

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 11/16

(A)

ELEMENT 5/2(A) (columns); ELEMENT 5/3(A) (rows)

	0	1	2	T
2	137	13	27	177
1	7	0	0	7
0	6	1	0	7
T	150	14	27	191

Ho	C	POWER
0.00	1	0.7508
0.01	3	0.2821
0.02	4	0.1335

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(B)

ELEMENT 5/2(A) (columns); ELEMENT 4/1-H (rows)

	0	1	2	T
2	109	12	24	145
1	15	1	2	18
0	26	1	1	28
T	150	14	27	191

Ho	C	POWER
0.00	2	0.5318
0.01	4	0.1509
0.02	5	0.0637

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C)

ELEMENT 5/2(A) (columns); ELEMENT 4/1-V (rows)

	0	1	2	T
2	115	13	26	154
1	15	0	0	15
0	20	1	1	22
T	150	14	27	191

Ho	C	POWER
0.00	2	0.5217
0.01	3	0.2982
0.02	4	0.1444

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLE 11/17

(A)

		ELEMENT 5/2(B)			
		0	1	2	T
ELEMENT 5/3(B)	2	10	5	94	109
	1	12	3	16	31
	0	45	5	1	51
	T	67	13	111	191

Ho	C	POWER
0.00	8	0.9025
0.01	10	0.7465
0.02	12	0.5267

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(B)

		ELEMENT 5/2(B)			
		0	1	2	T
ELEMENT 1/1(B)-H/C	2	58	12	105	175
	1	3	0	6	9
	0	6	1	0	7
	T	67	13	111	191

Ho	C	POWER
0.00	2	0.9991
0.01	6	0.9300
0.02	8	0.7819

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

(C)

		ELEMENT 5/1			
		0	1	2	T
ELEMENT 5/2(B)	2	72	29	10	111
	1	12	1	0	13
	0	55	11	1	67
	T	139	41	11	191

Ho	C	POWER
0.00	6	0.0034
0.01	6	0.0034
0.02	6	0.0034

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

TABLE 11/18

(A) ELEMENT 5/1

ELEMENT 5/2(A)

	0	1	2	T
2	12	9	5	26
1	11	7	3	21
0	116	25	3	144
T	139	41	11	191

Ho	C	POWER
0.00	10	0.0015
0.01	10	0.0015
0.02	10	0.0015

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 4/1-H (Retest)

ELEMENT 4/1-H

	0	1	2	T
2	17	15	115	147
1	4	3	29	36
0	7	0	1	8
T	28	18	145	191

Ho	C	POWER
0.00	8	0.9725
0.01	11	0.8437
0.02	13	0.6714

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

(C) ELEMENT 4/1-V (Retest)

ELEMENT 4/1-V

	0	1	2	T
2	14	11	144	169
1	4	4	9	17
0	4	0	1	5
T	22	15	154	191

Ho	C	POWER
0.00	4	0.9993
0.01	8	0.9637
0.02	11	0.8109

CONCLUSION This skill was not acquired by any significant proportion of students in the process of attempting more complex capabilities.

TABLE 11/19

(A) ELEMENT 5/2(A) (Retest)

ELEMENT 5/2(A)

	0	1	2	T
2	7	1	19	27
1	6	2	6	14
0	131	18	1	150
T	144	21	26	191

Ho	C	POWER
0.00	7	0.0593
0.01	8	0.0252
0.02	8	0.0252

CONCLUSION This skill was not acquired by an significant proportion of students in the process of attempting more complex capabilities.

(B) ELEMENT 6/4(B)

ELEMENT 6/5(B)

	0	1	2	T
2	2	5	179	186
1	0	0	4	4
0	1	0	0	1
T	3	5	183	191

Ho	C	POWER
0.00	3	0.9998
0.01	7	0.9807
0.02	10	0.8694

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is unrealistically high.

(C) ELEMENT 6/3(B)

ELEMENT 6/4(B)

	0	1	2	T
2	58	10	115	183
1	4	0	1	5
0	1	1	1	3
T	63	11	117	191

Ho	C	POWER
0.00	2	0.9994
0.01	6	0.9486
0.02	9	0.7302

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 11/20

(A) ELEMENT 6/2-S

ELEMENT 6/3 (B)

	0	1	2	T
2	18	16	50	84
1	8	10	0	18
0	83	4	2	89
T	109	30	52	191

Ho	C	POWER
0.00	7	0.3465
0.01	8	0.2220
0.02	9	0.1309

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B) ELEMENT 6/2-S

ELEMENT 6/3(A)-S

	0	1	2	T
2	47	15	52	114
1	18	15	0	33
0	44	0	0	44
T	109	30	52	191

Ho	C	POWER
0.00	7	0.2925
0.01	8	0.1789
0.02	9	0.1004

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 6/2-S

ELEMENT 6/5(B)

	0	1	2	T
2	94	30	49	173
1	14	0	3	17
0	1	0	0	1
T	109	30	52	191

Ho	C	POWER
0.00	2	0.8814
0.01	4	0.5676
0.02	6	0.2406

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

TABLE 11/21

(A) ELEMENT 6/2-C

ELEMENT 6/3 (B)

	0	1	2	T
2	25	11	59	95
1	5	4	0	9
0	86	0	1	87
T	116	15	60	191

Ho	C	POWER
0.00	4	0.7649
0.01	6	0.4522
0.02	7	0.3052

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(B) ELEMENT 6/2-C

ELEMENT 6/3 (A)-C

	0	1	2	T
2	43	6	60	109
1	18	9	0	27
0	55	0	0	55
T	116	15	60	191

Ho	C	POWER
0.00	5	0.6748
0.01	7	0.3680
0.02	8	0.2400

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is relatively low.

(C) ELEMENT 6/2-C

ELEMENT 6/5 (B)

	0	1	2	T
2	102	14	57	173
1	13	1	3	17
0	1	0	0	1
T	116	15	60	191

Ho	C	POWER
0.00	2	0.9430
0.01	5	0.5651
0.02	6	0.4019

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level.

TABLE 11/22

(A) ELEMENT 6/1-H/S

ELEMENT 6/2-S	0	1	2	T
2	33	6	13	52
1	21	6	3	30
0	107	2	0	109
T	161	14	16	191

Ho	C	POWER
0.00	5	0.0385
0.01	6	0.0126
0.02	6	0.0126

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(B) ELEMENT 6/1-H/C

ELEMENT 6/2-C	0	1	2	T
2	37	7	16	60
1	12	1	2	15
0	114	1	1	116
T	163	9	19	191

Ho	C	POWER
0.00	3	0.1757
0.01	4	0.0692
0.02	5	0.0232

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is extremely low.

(C) ELEMENT 6/1-H/S

ELEMENT 1/1(B)-H/S	0	1	2	T
2	142	14	15	171
1	10	0	1	11
0	9	0	0	9
T	161	14	16	191

Ho	C	POWER
0.00	1	0.4746
0.01	3	0.0775
0.02	3	0.0775

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLE 11/23

(A) ELEMENT 6/1-H/C

ELEMENT 1/1(B)-H/C	0	1	2	T
2	154	9	19	182
1	2	0	0	2
0	7	0	0	7
T	163	9	19	191

Ho	C	POWER
0.00	1	0.5652
0.01	3	0.0230
0.02	3	0.0230

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(B) ELEMENT 6/2-S

ELEMENT 6/3(C)	0	1	2	T
2	42	14	52	108
1	22	16	0	38
0	45	0	0	45
T	109	30	52	191

Ho	C	POWER
0.00	7	0.3364
0.01	8	0.2138
0.02	9	0.1250

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

(C) ELEMENT 6/2-C

ELEMENT 6/3(C)	0	1	2	T
2	36	5	60	101
1	23	10	0	33
0	57	0	0	57
T	116	15	60	191

Ho	C	POWER
0.00	6	0.5818
0.01	8	0.2942
0.02	9	0.1858

CONCLUSION The postulated connection is accepted as valid at the absolute Ho level, although the power is particularly low.

TABLES 11/24-11/28

Subdivisional Analysis Results for Papua/New Guinea

(Programme II)

PRELIMINARY NOTES

1. The following results are presented in correlation matrix form, listing the number of questions correct for each element, and the appropriate marginal totals.
2. The classification code for each element is outlined in Tables 5/4-5/10, and a list of the relevant subdivisional question groups is presented in Table 6/2.
3. P represents the combined probability that the observed number of students in the 0/2 and 2/0 cells could have occurred through chance (or errors of measurement) under the null hypothesis that no-one can possess only one of the relevant subdivisional skills without also having the other.

TABLE 11/24

(A)

GROUP 1 \ GROUP 2	0	1	2	T
2	0	2	181	183
1	3	1	2	6
0	1	0	1	2
T	4	3	184	191

ELEMENT 1/3

TEST H/V (Position)

P = 0.3038

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	4	11	164	179
1	0	1	5	6
0	1	0	5	6
T	5	12	174	191

ELEMENT 1/2

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	9	11	137	157
1	9	5	2	16
0	14	1	3	18
T	32	17	142	191

ELEMENT 1/1(B)

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(D)

GROUP 1 \ GROUP 3	0	1	2	T
2	0	0	157	157
1	4	2	10	16
0	14	0	4	18
T	18	2	171	191

ELEMENT 1/1(B)

TEST Straight Line/Curve

P = 0.0005

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

TABLE 11/25

(A)

		GROUP 4			
		0	1	2	T
GROUP 2	2	1	4	137	142
	1	1	2	14	17
	0	16	5	11	32
	T	18	11	162	191

ELEMENT 1/1(B)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 2 and 4 represent different subdivisional skills.

(B)

		GROUP 2			
		0	1	2	T
GROUP 1	2	4	6	125	135
	1	3	6	12	21
	0	15	7	13	35
	T	22	19	150	191

ELEMENT 1/1(A)

TEST H/V (Co-ordinates)

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

		GROUP 3			
		0	1	2	T
GROUP 1	2	2	6	127	135
	1	6	2	13	21
	0	17	6	12	35
	T	25	14	152	191

ELEMENT 1/1(A)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

(D)

		GROUP 4			
		0	1	2	T
GROUP 2	2	4	2	144	150
	1	6	1	12	19
	0	14	3	5	22
	T	24	6	161	191

ELEMENT 1/1(A)

TEST Straight Line/Curve

P = 0.0000

CONCLUSION Question groups 2 and 4 represent different subdivisional skills.

TABLE 11/26

(A)

GROUP 2/1(A)-1 \ GROUP 2/1(B)-2	0	1	2	T
2	21	20	92	133
1	9	0	7	16
0	31	5	6	42
T	61	25	105	191

ELEMENT 2/1(A)-2/1(B)

TEST Interpolation/Extrapolation

P = 0.0000

CONCLUSION Elements 2/1(A) and 2/1(B) represent different basic skills.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	10	15	86	111
1	12	6	14	32
0	39	4	5	48
T	61	25	105	191

ELEMENT 2/1(B)

TEST Line/Points

P = 0.0000

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	7	8	92	107
1	14	22	17	53
0	15	12	4	31
T	36	42	113	191

ELEMENT 3/2(A)

TEST Max./Min. Values

P = 0.0133

CONCLUSION Question groups 1 and 2 probably represent the same subdivisional skill.

(D)

GROUP 1 \ GROUP 2	0	1	2	T
2	0	2	185	187
1	0	0	2	2
0	1	0	1	2
T	1	2	188	191

ELEMENT 1/3 (Retest)

TEST H/V (Position)

P = 0.1651

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

TABLE 11/27

(A)

GROUP 1 \ GROUP 2	0	1	2	T
2	2	28	152	182
1	0	0	3	3
0	3	0	3	6
T	5	28	158	191

ELEMENT 1/2 (Retest)

TEST H/V (Co-ordinates)

P = 0.0006

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	2	3	171	176
1	0	2	5	7
0	7	1	0	8
T	9	6	176	191

ELEMENT 4/2

TEST H/V (Displacement)

P = 0.0020

CONCLUSION Question groups 1 and 2 represent different subdivisional skills.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	1	11	135	147
1	0	5	31	36
0	4	1	3	8
T	5	17	169	191

ELEMENT 4/1

TEST H/V (Displacement)

P = 0.0951

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(D)

GROUP 1 \ GROUP 3	0	1	2	T
2	1	0	170	171
1	1	0	10	11
0	5	2	2	9
T	7	2	182	191

ELEMENT 1/1(B) (Retest)

TEST Straight Line/Curve

P = 0.0003

CONCLUSION Question groups 1 and 3 represent different subdivisional skills.

TABLE 11/28

(A)

GROUP 1 \ GROUP 2	0	1	2	T
2	1	15	170	186
1	0	1	3	4
0	0	1	0	1
T	1	17	173	191

ELEMENT 6/5(B)

TEST Numerical Range

P = 0.3248

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

(B)

GROUP 1 \ GROUP 2	0	1	2	T
2	6	18	90	114
1	10	5	18	33
0	39	4	1	44
T	55	27	109	191

ELEMENT 6/3(A)

TEST Straight Line/Curve

P = 0.0088

CONCLUSION Question groups 1 and 2 may represent the same subdivisional skill.

(C)

GROUP 1 \ GROUP 2	0	1	2	T
2	3	6	43	52
1	12	2	16	30
0	101	7	1	109
T	116	15	60	191

ELEMENT 6/2

TEST Straight Line/Curve

P = 0.0377

CONCLUSION Question groups 1 and 2 probably represent the same subdivisional skill.

(D)

GROUP 1 \ GROUP 2	0	1	2	T
2	0	4	12	16
1	5	3	6	14
0	158	2	1	161
T	163	9	19	191

ELEMENT 6/1

TEST Straight Line/Curve

P = 0.1759

CONCLUSION Question groups 1 and 2 represent the same subdivisional skill.

FIGURES 11.2-11.7

Outline of the Validated Learning Hierarchy for Papua/New Guinea

(Programme II)

PRELIMINARY NOTES

1. The classification code for each basic skill is outlined in Tables 5/4-5/10, and abbreviations used for the relevant subdivisional conditions are listed in the preliminary notes for Tables 6/4-6/25.

2. Lines representing hierarchical connections are classified according to the following key.

━━━━━━━━ (heavy line)	Connection accepted as valid at the absolute Ho level.
———————— (light line)	Connection accepted as valid at weaker (0.01 and 0.02) Ho levels.
- - - - - - - (dashed line)	Connection rejected as invalid at all three specified Ho levels.

FIGURE 11.2

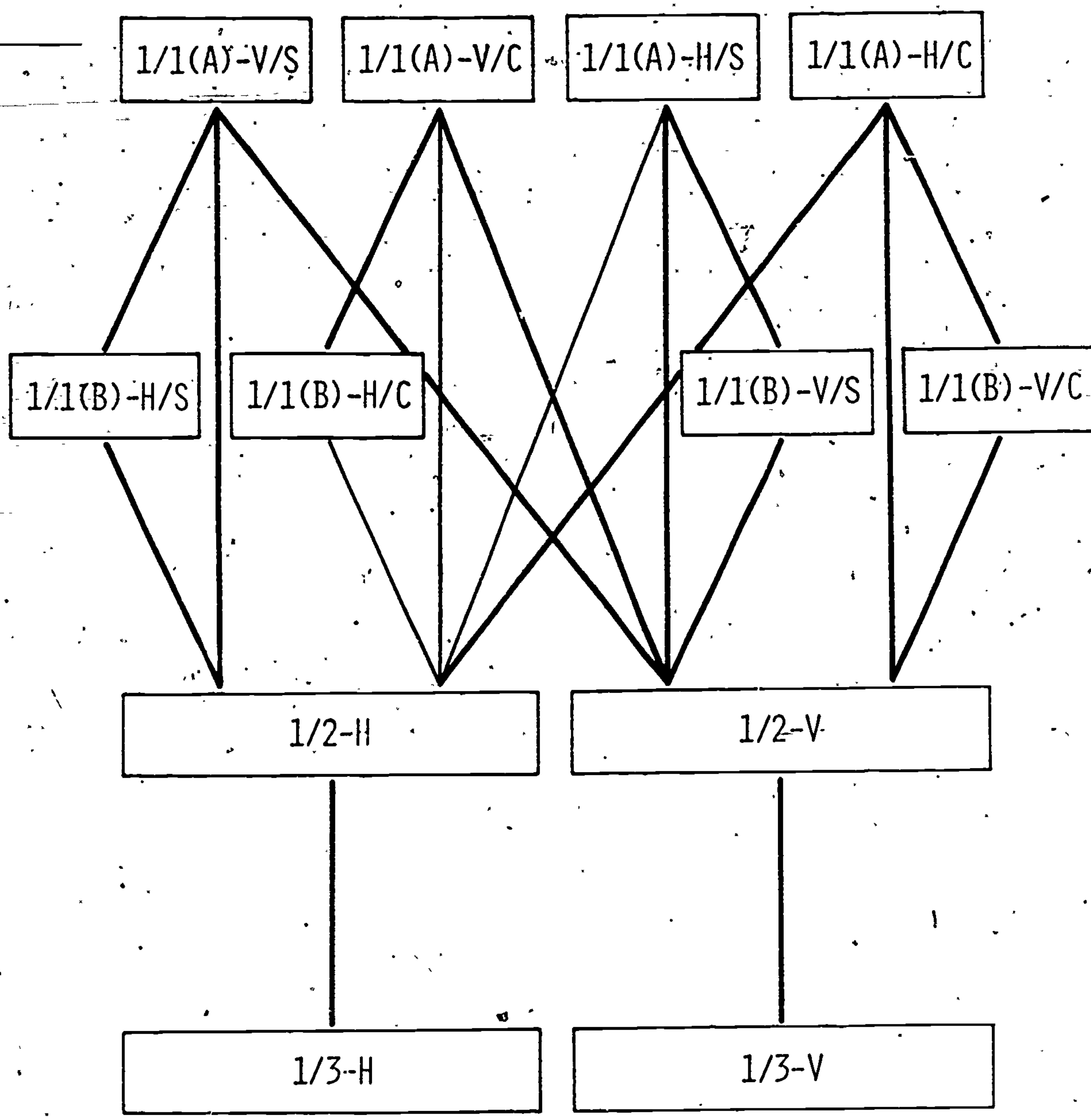

1/1(A)-V/S
1/1(A)-V/C
1/1(A)-H/S
1/1(A)-H/C
1/1(B)-H/S
1/1(B)-H/C
1/1(B)-V/S
1/1(B)-V/C
1/2-H
1/2-V
1/3-H
1/3-V

FIGURE 11.3

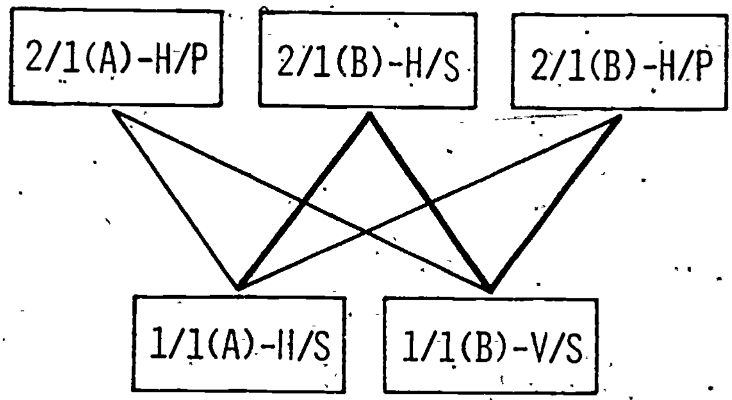


FIGURE 11.4

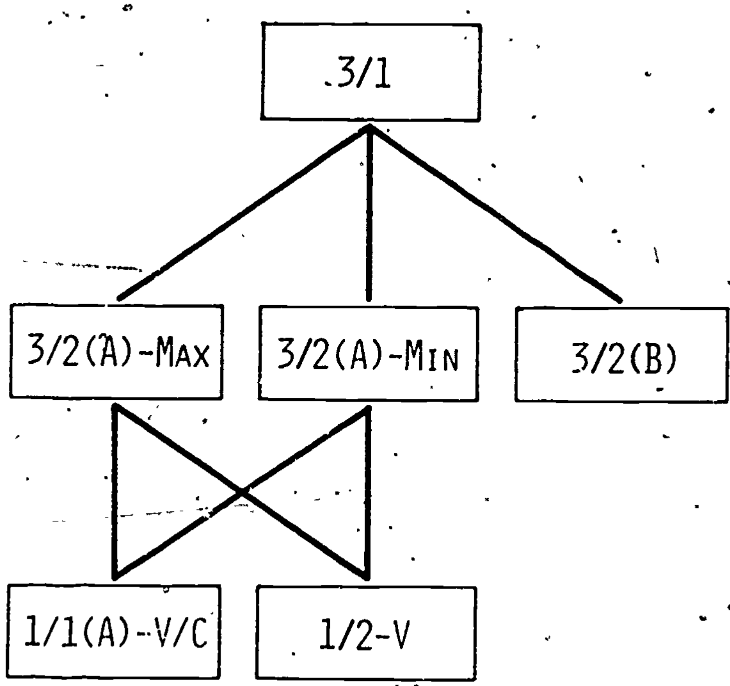


FIGURE 11.5

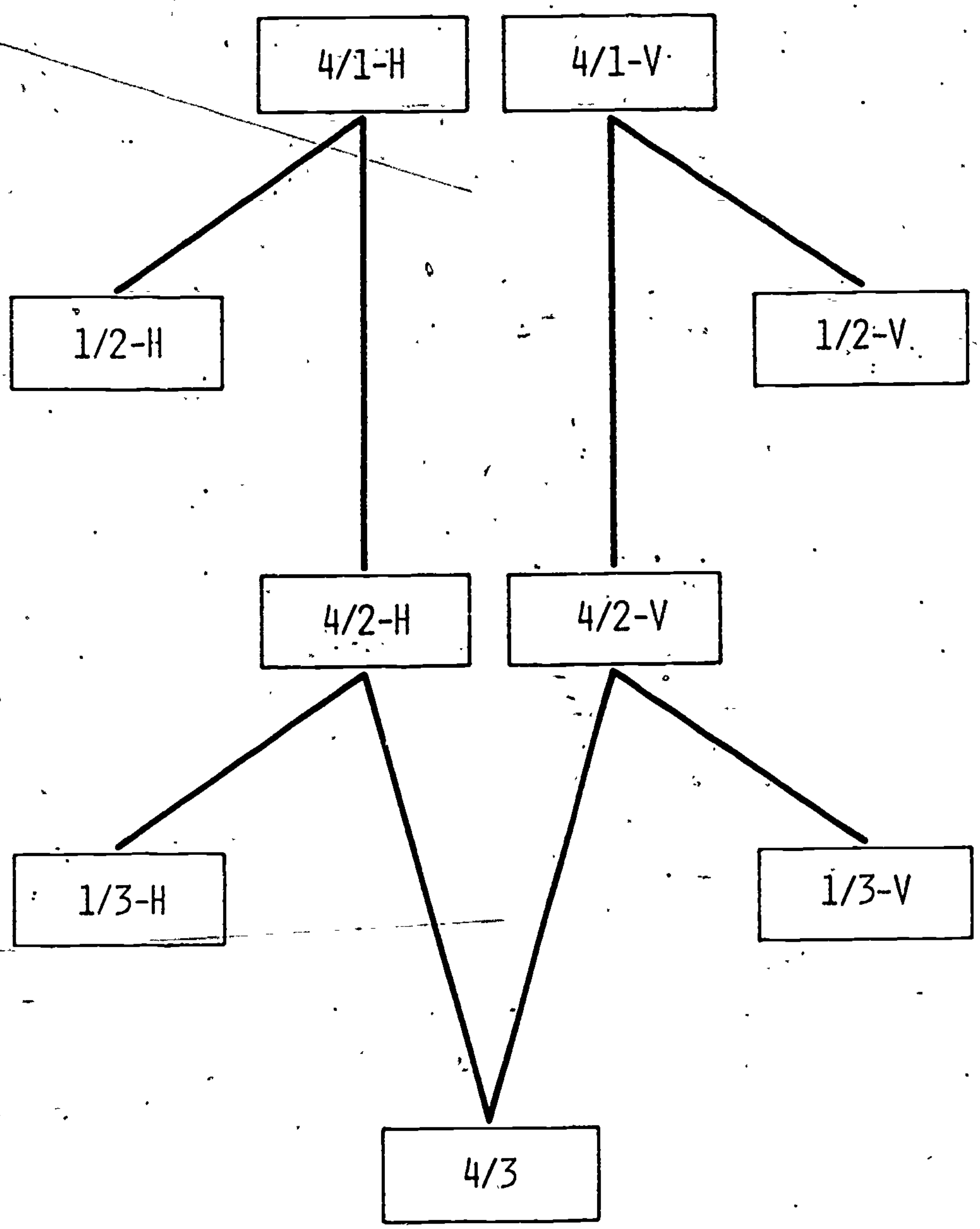


FIGURE 11.6

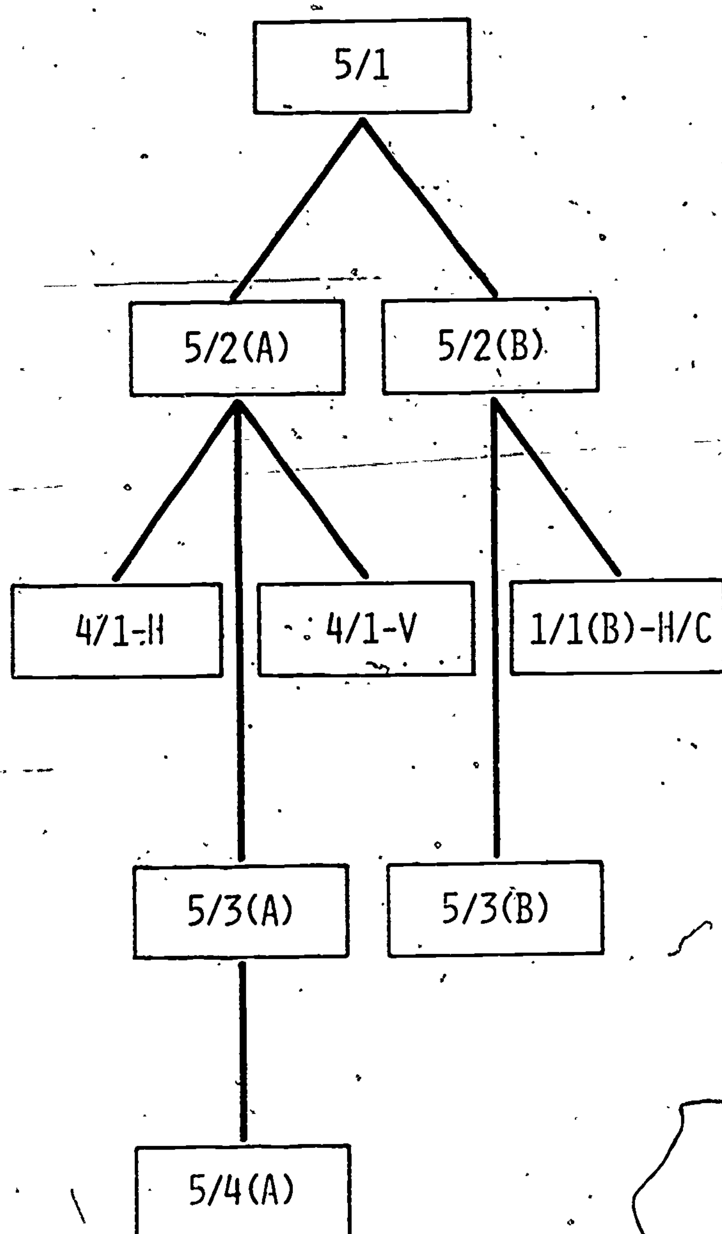
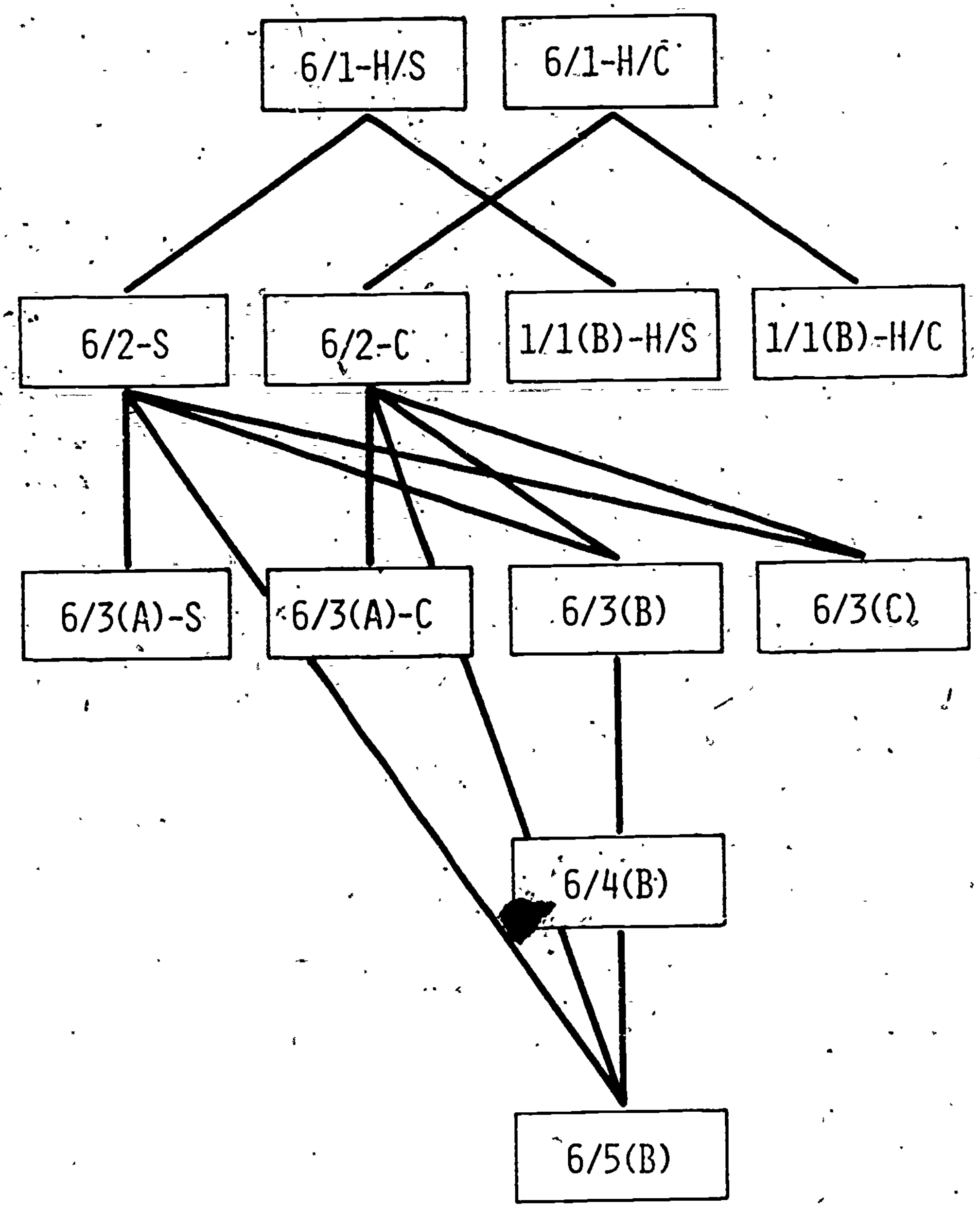


FIGURE 11.7



CHAPTER XII

GENERAL CONCLUSIONS AND IMPLICATIONS

1. Introduction and Theoretical Perspective

Apart from substantiating the postulated sequence of graphical interpretation skills (with occasional inconsistencies - outlined in Chapters VI-XI), the results of these validation studies have produced a number of important conclusions and general implications related to various aspects and conditions of hierarchical learning. In addition these results have also served to clarify certain basic definitions, and it may be useful to re-examine these in retrospect as a basis for more definitive integration of the various conclusions and implications with Gagné's (1965) theoretical model, and with other relevant findings from previous research.

It was explained in Chaptor I that Gagné's model of hierarchical learning, although initially proposed to cover in the same sense all categories of learning behaviour (Gagné 1965), was later qualified to account for certain fundamental differences between intellectual abilities or skills and elements of verbalised knowledge (Gagné 1968). Intellectual skills were subsequently described as general groups or classes of logically similar tasks, and defined in terms of basic operational characteristics. Thus an instruction to calculate the position of a specific point on a two-dimensional grid (element 1/2 in the postulated learning hierarchy) could be used to describe a number if individual or specific tasks, each referring to a different co-ordinate point, but all involving the same set of procedural steps. In contrast with this type of generalised skill, elements of verbalised knowledge (for example that A.B.R. represents Annual Birth Rate, and that Time is measured in years - see Programme II in Volume III) were defined as single or specific interpretative tasks.

Each of the basic intellectual abilities from the postulated learning hierarchy was shown in Chapter IV to incorporate a number of different subdivisional skills, more limited in scope of application, but similarly defined in procedural terms. The delineation of each subdivisional skill, which was determined by the practical limits of immediate lateral transfer from one sub-set of tasks to another, was initially proposed on logical grounds, and subsequently confirmed by empirical analysis. Thus the former intellectual skill of two-dimensional co-ordinate location (element 1/2, previously designated 1/1) was shown in Chapter IV to involve different subdivisional skills for Horizontal and Vertical position, for integral and rational numbers, and for positive and negative numerical sign.

The operational definitions outlined above for both basic intellectual and subdivisional skills can now be used to elaborate in practical terms on Gagné's (1965) general model of hierarchical learning. This model, as explained in Chapter I, is based on vertical or sequential learning transfer, and suggests that any complex intellectual skill may be systematically resolved to produce a comprehensive set of logically related and progressively simpler skills, hierarchically organised so that each in turn is dependent on the mastery (and recall) of a specified set of prerequisite or subordinate skills. However the extent to which a particular skill is theoretically dependent on its specified subordinates is not a matter of universal agreement. White (1971) maintains that the relationship is absolute, and comments on the "premature" weakening in Gagné's own position (see White 1971/p.327).

from an absolute relationship to one involving an unspecified but "substantial amount of positive transfer" (Gagné 1968). It was suggested in Chapter VI, however, that the latter position was probably more realistic, in that it allowed some flexibility for individual background differences and alternative learning pathways, although statistical information consistent with both absolute and weaker positions was provided for each of these validation studies.

Although there seems to be some disagreement on the extent of hierarchical relationship between intellectual skills, there is nevertheless general concurrence on the applicability of Gagné's model (see Chapter I/Section 3). There is also concurrence, however, that the same type of hierarchical model may be inappropriate for other forms of learning behaviour. The suggestion by Gagné (1968), for example, that elements of verbalised knowledge may not be learned in the same hierarchical manner as that proposed for intellectual skills was empirically substantiated in a recent study by White (1971). The same conclusion was also proposed by White (1971/pp.19,22) as a possible explanation for the breakdown of certain postulated hierarchical relationships in other research studies (for example see Kolb 1967/8 and Okey 1968). Additional evidence is provided by two of the present validation studies that although elements of specific terminology may be necessary to identify relevant intellectual skills (e.g. rate of change in A.B.R. = gradient for A.B.R./Time graph), the acquisition and application of these intellectual skills is apparently not dependent on any meaningful interpretation of the associated terminology (see Chapter VII/Section 3 and Chapter XI/Section 3).

It follows from this conclusion that the potential generalisation of a particular intellectual skill may readily be extended to any specific informational context by providing the appropriate terminology or instructional cues. Thus in the example given above that rate of change in A.B.R. = gradient for A.B.R./Time graph, the same intellectual skill (calculation of gradient at a specified point) may be applied to any other situation simply by substituting the appropriate variables for A.B.R. and Time. It follows conversely, however, that the successful application of a given intellectual skill does not guarantee any meaningful interpretation of the relevant result. Thus the calculation of gradient for a particular graph does not involve the ability to translate this result into any real or meaningful context. This point was mentioned earlier in Chapter XI, and emphasises what is perhaps the most serious limitation of intellectual learning skills, namely the lack of any requirement for meaningful interpretation. This problem appears to involve more than the influence of any limited set of specified prerequisite skills, and may therefore be more closely related to the "meaningful" dimension of Ausubel's (1968) theoretical model, rather than to Gagné's (1965) explicit hierarchical scheme. To the extent, however, that meaning is a function of "cognitive structure" (Ausubel and Robinson 1969/p.158), and that this in turn is a product of previous learning experience (p.158), Gagné's model is by no means irrelevant.

2. The Significance of Subdivisional Analysis

The recognition and empirical verification mentioned above of different subdivisional skills within each intellectual ability increases the complexity of relevant hierarchical relationships, and hence the danger of false rejection through comparison of different subdivisional skills at successive hierarchical levels. In these studies, for example, the postulated hierarchical connections were validated only between analogous subdivisions of related intellectual skills, and despite the provision of separate instructions and examples for each of these subdivisional skills, their difference (or independence) was confirmed at various levels in each validation programme. Perhaps the most important implication of this result, at least in practical terms, is that the potential application of any validated learning hierarchy is restricted to the limits of lateral transfer defined by the relevant subdivisional skills represented in the instructional programme. This result may also serve to explain some of the inconsistencies observed in previous hierarchical validation studies, where the lack of subdivisional classification and analysis may have led to imprecise definition of the basic intellectual skills (Ford & Meyer 1966; Kolb 1967/8; Okey 1968).

In a positive sense the definition of subdivisional skills may be used as a means to extend, on a systematic basis, the potential application of any basic intellectual ability or complex learning hierarchy. It was suggested, moreover, in Chapter VIII (Section 3), that this extension in scope was probably best achieved progressively at each level of the learning hierarchy, so that each intellectual ability would cover the same potential range of specific interpretative tasks. The evidence of random forgetting provided earlier by Gagné and Bassler (1963) reinforces this suggestion, since the extension in scope of isolated higher-level abilities to cover different subdivisional skills could not possibly be transferred to subordinate skills already forgotten, and even if all of the subordinate skills could be recalled, there is no evidence to suggest that this extension would immediately be transferred. This approach of systematic and progressive extension of basic intellectual skills is in contrast with many of the current practices in the teaching of graphical interpretation skills, at least with respect to numerical range (see also Chapter II/Section 2 and Chapter VIII/Section 1). It was also established in Chapter VIII (Section 3) that although an extension in scope of certain intellectual skills may affect the relevant difficulty levels, the basic hierarchical structure of interrelationships remains unchanged.

3. The Effects of Personal and Situational Variables on the Postulated Learning Hierarchy

In contrast with the limits on potential generalisation established by the analysis of subdivisional skills, it was shown in several of the major validation studies that differences in specific curricular background (Chapter IX), in general educational and cultural background (Chapters X, XI), and in age and nominal academic level (Chapters IX-XI) had no substantial influence on the acquisition sequence of intellectual skills in the postulated learning hierarchy. Thus in spite of possible differences in element difficulty levels, the potential generalisation of validated learning hierarchies may be largely independent of the variables, both personal (background, age and academic level) and situational (informational context), examined in these studies.

Although qualified by certain limitations (outlined in Chapters VI-XI), this conclusion has important implications for curriculum planning and development, since it follows that the postulation and empirical validation of certain basic learning hierarchies may be used to provide a nucleus for the development of relevant curriculum programmes on both a national and international scale. Many of the current programmes on graphical interpretation (e.g. Nuffield, B.S.C.S., I.S.C.S., S.M.S.G. - see Chapter II/Section 2) have already achieved national or international implementation, but in terms of presentation sequence these programmes are often incompatible, and none have so far been subjected to empirical validation.

The implications of common learning hierarchies across differences in background experience are equally important for curriculum evaluation, in that the same hierarchical structures may serve as a basis for both instructional and diagnostic testing purposes. It is important, however, to emphasise in this respect that the basic learning hierarchies mentioned above are essentially concerned with general mechanistic skills, and incorporate no conditions of meaningful interpretation, so that special adaptations would have to be made in the development of any curriculum programme to account for more specific conceptual difficulties arising from particular background characteristics. This has already been mentioned in the context of the Papua/New Guinea validation study with Programme II (Chapter XI), and is consistent with the implications of other relevant research (Mackay and Gardner 1969; Prince 1967, 1969, 1970).

4. Aspects of Methodological Significance

Apart from the general conclusions and implications outlined above, these validation studies have provided valuable information on a number of important methodological problems. In the statistical validation test, for example, the use of marginal totals instead of individual cell scores was in some cases shown to produce unrealistically high values for the calculated critical number of 0/2 cell exceptions (see for example Tables 6/15(B), 6/16(A), 7/14(C) and 7/15(A)). This problem was most apparent when the subordinate skill difficulty level was low, and the errors of measurement (or degree of response inconsistency) relatively high. In extreme situations the calculated critical number of 0/2 cell exceptions was higher than the actual number of students who failed the subordinate skill, so that the postulated hierarchical connection could not possibly be rejected. For most of these cases, however, the relevant connection was more effectively substantiated in alternative validation experiments, and thus the problem effectively resolved by replication, although this procedure would obviously be too tedious to recommend as a matter of routine.

In view of the correspondence in validation results across different academic, age and difficulty levels, it would probably be more appropriate to validate suitable sections of a given learning hierarchy with different groups of students, and thus avoid the complex statistical problems associated with extreme difficulty levels. Thus the present learning hierarchy might be validated more effectively in several different overlapping sections presented at different academic levels, with the comprehensive structure subsequently collated from results for the various constituent sections. It would be necessary, however, to ensure that students engaged in more complex sections of the hierarchy possessed all of the relevant prerequisite skills.

The calculation of statistical power for the test of hierarchical dependence was also affected in various ways by extreme difficulty levels and relatively large errors of measurement. Since the alternative hypothesis was associated with the proportion of students succeeding at the superordinate skill, the power was drastically reduced when the relevant difficulty level was particularly high (see Chapter VI/Section 2). On realistic expectations the power should also be associated with the subordinate skill difficulty level, and diminish as fewer students fail the subordinate skill (Chapter VI/Section 2). There seems no obvious reason, however, to relate the alternative hypothesis (or postulated proportion of exceptions) to the subordinate skill alone, since each exceptional student must also succeed at the higher skill. Thus a combination of alternative conditions may present the most appropriate solution, with the power of the test determined according to the most stringent or limiting hypothesis, and hence the most extreme difficulty level. This solution would obviously be modified by the degree of response inconsistency for both subordinate and superordinate skills, since any errors of measurement would invariably tend to reduce the statistical power.

The most significant problem with respect to general validation procedure concerned the omission of regular retesting segments in the preparation of the learning programme. The argument for this, outlined in Chapter V (Section 3), was that any students who acquired prerequisite skills in the process of attempting more complex capabilities should be classified as legitimate exceptions to the postulated hierarchical sequence. In some cases, however, the teaching of sequential skills required extensive repetition of certain basic instructions (see Programmes I-III/Section 1 in Volume III), so that the problem of incidental acquisition became particularly pronounced, and either forced the relaxation of null hypothesis conditions or resulted in outright rejection of the postulated hierarchical connections (see Outline of Validated Hierarchy for areas 1-3 in Chapters VI-XI). The contrary argument expressed by White (1971/p.31) that the incidental acquisition of a supposedly essential subordinate skill may still precede the more complex capability seems reasonable enough, but this is still inconsistent with the proposition that the simpler skill is, in its own right, an essential prerequisite capability, and thus does not provide a basis to set aside the relevant information. On the other hand, however, where the repetition of basic instructions provides an additional and essentially independent opportunity to learn a particular subordinate skill, this approach may well be justified on practical grounds to differentiate between the two related skills.

Apart from the practical relevance to graphical interpretation skills, the studies outlined in this research have provided valuable information on the nature and conditions of hierarchical learning, and have also produced a number of important methodological developments concerned with the validation of learning hierarchies and the analysis of subdivisional skills. These studies have also revealed, however, that there are many methodological deficiencies which have yet to be overcome.

There are, in addition to the various problems outlined in this research, a number of fundamental issues requiring further investigation. These include, for example, the relative efficiency of different instructional sequences, and of alternative learning hierarchies with the same or similar terminal skills, the necessity for systematic review in order to account for random forgetting, and above all the effects of meaningful interpretation on both immediate learning efficiency and long-term retention of basic intellectual skills. These problems are particularly important both in a theoretical sense, to provide further information on the nature and conditions of hierarchical learning, and in a practical sense to substantiate the application of learning hierarchies in curriculum planning and development. Each of these problems will of course involve its own methodological difficulties, but in terms of general implication should hold considerable promise for prospective research.

APPENDIX I

A TEST OF DIFFERENCE FOR DICHOTOMOUS DATA WHICH ACCOUNTS FOR ERRORS OF MEASUREMENT

A Test of Difference for Dichotomous Data which Accounts for Errors of Measurement

The following test was developed in collaboration with Dr. R. T. White (Faculty of Education, Monash University), and is based on a model developed earlier by White and Clark (1973, see also White 1971) for a test of hierarchical dependence.

Suppose that there are two abilities, designated I and II, so that in any population four relevant groups can be distinguished:- let the proportion with neither ability be P_0, with ability I only be P_I, with ability II only be P_{II}, and with both abilities be P_B. If the possession of either ability also implies possession of the other (that is, if both abilities are the same), then the proportion with only one ability will be zero. Thus the null hypothesis may be stated as -

$$Ho: \; P_I = P_{II} = 0$$

(The alternative hypothesis would probably involve $P_I > 0$ and/or $P_{II} > 0$, but because of more complex considerations, which include the possibility of differential proportions for each of these abilities, this matter has not yet been resolved.)

Suppose that a sample of size N is drawn from an infinite population, and that the members of this sample are given two questions to test each ability. These subjects can then be distributed, according to their results, on 3 x 3 contingency table (see Figure 13.1). If allowance is made for errors of measurement, there is some probability that a given member of the sample may be classified in any of the nine cells, even if Ho is true, but if Ho is false, then obviously the greatest difference between observed and expected distributions will occur in the 2/0 (top left) and 0/2 (bottom right) cells. Thus Ho may be tested by comparing the observed and expected number of subjects classified in these two cells.

Assume that chance errors or successes on all four questions are independent, and attributable solely to errors of measurement. Assume also that the probabilities of chance errors, or of chance successes, are equal for the two questions defining each ability.

Let θ_a represent the probability of someone with ability I answering correctly any question for that ability, and θ_b the probability that someone without ability I correctly answers any question for the same ability. Let θ_c and θ_d represent the corresponding probabilities for ability II. The probabilities of randomly selected members of the sample being classified in the 0/2 and 2/0 cells can now be calculated according to the following equations.

$$P_{02} = P_0 (1 - \theta_b)^2 \theta_d^2 + P_I (1 - \theta_a)^2 \theta_d^2 + P_{II} (1 - \theta_b)^2 \theta_c^2 + P_B (1 - \theta_a)^2 \theta_c^2 \quad [1]$$

$$P_{20} = P_0 \theta_b^2 (1 - \theta_d)^2 + P_I \theta_a^2 (1 - \theta_d)^2 + P_{II} \theta_b^2 (1 - \theta_c)^2 + P_B \theta_a^2 (1 - \theta_c)^2 \quad [2]$$

Estimates of the various P and θ parameters can readily be obtained from the observed marginal totals of the contingency table shown in Figure 13.1. More reliable estimates could probably be derived from individual cell frequencies, but the necessary calculations would be considerably more tedious. The expected marginal totals are presented in the following simultaneous equations.

Ability I: 2 Correct $[(\hat{P}_I+\hat{P}_B)\ \hat{\theta}_a^{\ 2} + (\hat{P}_0+\hat{P}_{II})\ \hat{\theta}_b^{\ 2}]\ N = a$ [3]

1 Correct $2[(\hat{P}_I+\hat{P}_B)\hat{\theta}_a\ (1-\hat{\theta}_a) + (\hat{P}_0+\hat{P}_{II})\ \hat{\theta}_b\ (1-\hat{\theta}_b)]\ N = b$ [4]

0 Correct $[(\hat{P}_I+\hat{P}_B)\ (1-\hat{\theta}_a)^2 + (\hat{P}_0+\hat{P}_{II})\ (1-\hat{\theta}_b)^2]\ N = c$ [5]

Ability II: 2 Correct $[(\hat{P}_I+\hat{P}_B)\ \hat{\theta}_c^{\ 2} + (\hat{P}_0+\hat{P}_{II})\ \hat{\theta}_d^{\ 2}]\ N = d$ [6]

1 Correct $2[(\hat{P}_I+\hat{P}_B)\ \hat{\theta}_c\ (1-\hat{\theta}_c) + (\hat{P}_0+\hat{P}_{II})\ \hat{\theta}_d\ (1-\hat{\theta}_d)]\ N = e$ [7]

0 Correct $[(\hat{P}_I+\hat{P}_B)\ (1-\hat{\theta}_c)^2 + (\hat{P}_0+\hat{P}_{II})\ (1-\hat{\theta}_d)^2]\ N = f$ [8]

One of the above equations for each ability is degenerate, and since $\hat{P}_0 + \hat{P}_I + \hat{P}_{II} + \hat{P}_B = 1$, and under Ho, $P_I = P_{II} = 0$, we are left with five equations in six unknowns. Thus an additional restriction must be specified in order to achieve a unique solution for each of these six unknowns. A range of alternative, and apparently reasonable restrictions could probably be applied, although some of these (e.g. $\theta_b = \theta_d$) have in practice proved extremely sensitive to discrepancies in corresponding marginal totals for the two abilities, and have therefore tended to produce quite unrealistic estimates of the other parameters. Two of the more promising alternative restrictions are presented below with appropriate rationale.

(1) $$\hat{\theta}_b = \tfrac{1}{2}\left[\frac{b}{N} + \left(\frac{b}{N}\right)^2\right] \qquad [9]$$

This expression stipulates that the probability of guessing a correct response for ability I without possessing the ability is given by half the maximum observed proportion of subjects who could possibly have made such a guess. This restriction gives equivalent weighting to each of the dichotomous groups for ability I, in that half of the observed experimental errors are proposed to arise through guessing by those without the ability, and half through chance mistakes by those who actually possess the relevant ability. It is a matter of arbitrary choice that θ_b is set instead of θ_d, and perhaps this is a logical weakness, although unless Ho is obviously false the two expressions should be substantially the same.

(2) $$\hat{P}_B = \tfrac{1}{2}\left[\frac{1}{N}\left(a + b\frac{a}{a+c}\right) + \frac{1}{N}\left(d + e\frac{d}{d+f}\right)\right] \qquad [10]$$

This reduces to -

$$\hat{P}_B = \tfrac{1}{2}\left(\frac{a}{a+c} + \frac{d}{d+f}\right) \qquad [11]$$

This expression involves the distribution of middle values (b and e) of the observed marginal totals between the upper and lower values in proportion, then takes the arithmetic mean of both estimates for $\hat{P}_B$, thus avoiding any arbitrary choice between the two abilities.

In practice both of these restrictions appear to produce sensible results for all parameters, ~~but since all of~~ the subdivisional analysis results reported in this research involved the use of restriction (1), the solutions for this alone are presented below.

Solutions for Restriction (1)

Note: $\hat{P}_0 = 1 - \hat{P}_B$ since $\hat{P}_0 + \hat{P}_I + \hat{P}_{II} + \hat{P}_B = 1$ and $P_I = P_{II} = 0$ under Ho.

$$\hat{\theta}_b = \tfrac{1}{2}\left[\frac{b}{N} + \left(\frac{b}{N}\right)^2\right] \qquad [9]$$

By adding twice equation [3] to equation [4], it can be shown on simplification according to the notes above that -

$$2\hat{P}_B\hat{\theta}_a + 2(1-\hat{P}_B)\hat{\theta}_b = \frac{2a+b}{N} \qquad [12]$$

This equation can now be solved simultaneously with equation [3] to produce the following unique solution for $\hat{P}_B$

$$\hat{P}_B = \frac{\left[\left(\frac{2a+b}{2N}\right) - \hat{\theta}_b\right]^2}{\left[\frac{a}{N} - \hat{\theta}_b\left(\frac{2a+b}{N}\right) + \hat{\theta}_b^{\,2}\right]} \qquad [13]$$

This expression, which also determines the value of $\hat{P}_0$, may then be used in equation [12] to solve for $\hat{\theta}_a$:

$$\hat{\theta}_a = \frac{1}{2\hat{P}_B}\left(\frac{2a+b}{N}\right) - \hat{\theta}_b\left(\frac{1-\hat{P}_B}{\hat{P}_B}\right) \qquad [14]$$

The addition of equation [7] to twice equation [6] produces a linear expression relating $\hat{\theta}_c$ and $\hat{\theta}_d$ as follows.

$$\hat{\theta}_d = \frac{1}{(1-\hat{P}_B)}\left(\frac{2d+e}{2N}\right) - \hat{\theta}_c\left(\frac{\hat{P}_B}{1-\hat{P}_B}\right) \qquad [15]$$

This expression may then be substituted in equation [6] to produce the following quadratic equation in $\hat{\theta}_c$.

$$\hat{\theta}_c^{\,2} - \hat{\theta}_c\left(\frac{2d+e}{N}\right) + \left[\frac{1}{4\hat{P}_B}\left(\frac{2d+e}{N}\right)^2 - \left(\frac{1-\hat{P}_B}{\hat{P}_B}\right)\frac{d}{N}\right] = 0 \qquad [16]$$

This equation produces two alternative solutions for $\hat{\theta}_c$, although in practice one of these consistently gives unrealistic estimates outside the range of 0 - 1, and many therefore be ignored. Thus we are left with the following unique solution.

$$\hat{\theta}_c = \tfrac{1}{2}\left(\frac{2d+e}{N}\right) + \tfrac{1}{2}\sqrt{\left(\frac{2d+e}{N}\right)^2 - \frac{1}{\hat{P}_B}\left(\frac{2d+e}{N}\right)^2 + 4\left(\frac{1-\hat{P}_B}{\hat{P}_B}\right)\frac{d}{N}} \qquad [17]$$

The value for $\hat{\theta}_c$ derived from this expression may then be used in equation [15] to solve for $\hat{\theta}_d$.

The values for each of the various P and θ parameters are now substituted in equations [1] and [2] to provide estimates of $\hat{p}_{02}$ and $\hat{p}_{20}$. The probability of x subjects being classified in the 0/2 cell is then given by the binomial expansion:-

$$Pr_{02}(x) = \binom{N}{x}\left(1-\hat{p}_{02}\right)^{N-x}\ \hat{p}_{02}^{\ x} \qquad [18]$$

If the observed values in the 0/2 and 2/0 cells are X and Y respectively, then the probabilities for each of these events, or events less deviant from that expected under Ho, are given by the cumulative probabilities:-

$$\sum_{x=0}^{X} Pr_{02}(x) \quad \text{and} \quad \sum_{y=0}^{Y} Pr_{20}(y)$$

The combined probability of these or less deviant events is then calculated according to the following expression.

$$P_{XY} = \sum_{x=0}^{X} Pr_{02}(x) \qquad \sum_{y=0}^{Y} Pr_{20}(y) \qquad [19]$$

Ho is rejected when P_{XY} is less than the value chosen for α, the probability of a Type I error.

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THE EFFECTS OF CERTAIN PERSONAL AND SITUATIONAL VARIABLES ON THE ACQUISITION SEQUENCE OF GRAPHICAL INTERPRETATION SKILLS

VOLUME II - APPENDIX

R D LINKE

THE EFFECTS OF CERTAIN PERSONAL AND SITUATIONAL VARIABLES ON THE ACQUISITION SEQUENCE OF GRAPHICAL INTERPRETATION SKILLS

VOLUME II - APPENDIX

Russell Dean Linke B.Sc.(Hons.)(Flinders)

Submitted in fulfilment of the requirements
for the degree of Doctor of Philosophy
Faculty of Education
Monash University
1973

TESTING MATERIALS USED FOR THE ANALYSIS OF SUBDIVISIONAL SKILLS

SEQUENCE OF PRESENTATION

ELEMENT OR BASIC SKILL	NUMBER OF POSTULATED SUBDIVISIONAL SKILLS	NUMBER OF QUESTIONS
1/1	6	12
1/2	6	12
2/1(A)	9	18
2/1(B)	11	22
3/1	7	14
3/2	2	4
4/1	8	16
4/2	8	16
4/3	7	14
5/2(A)	8	16
5/3(A)	8	16
5/4(A)	8	16
5/2(B)	9	18
5/3(B)	5	10
6/2	8	16
6/3(A)	2	4
6/3(B)	4	8
6/4(B)	4	8

NOTE

The definition and classification code for each element in this list is presented in Tables 3/1-3/6 (Volume I/Chapter III), and a comprehensive outline of subdivisional skills is presented in Tables 4/1-4/18 (Volume I/Chapter IV).

BASIC SKILLS OF GRAPHICAL INTERPRETATION

SUBDIVISION ANALYSIS SET 1/1

NAME ______________ AGE ______________

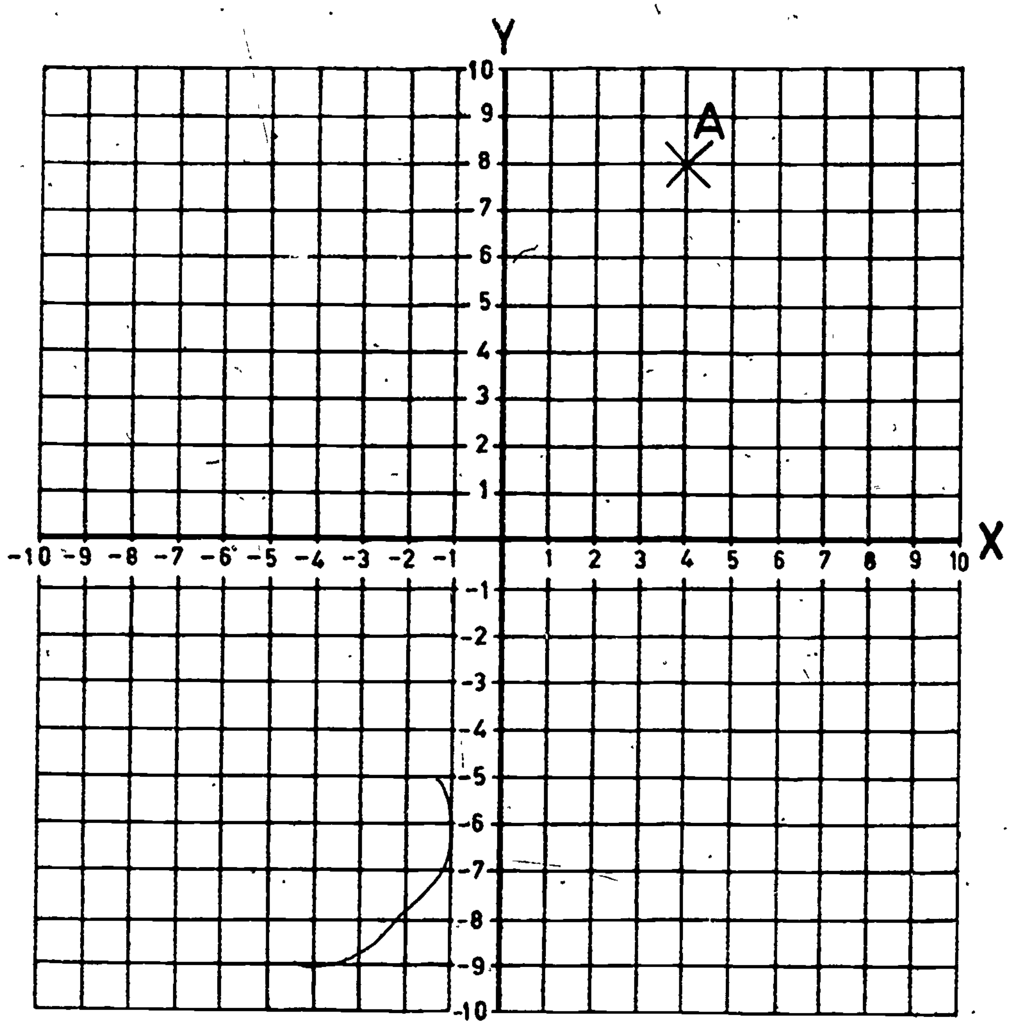
SEX ______________

SCHOOL ______________ CLASS ______________

DATE ______________

INSTRUCTIONS

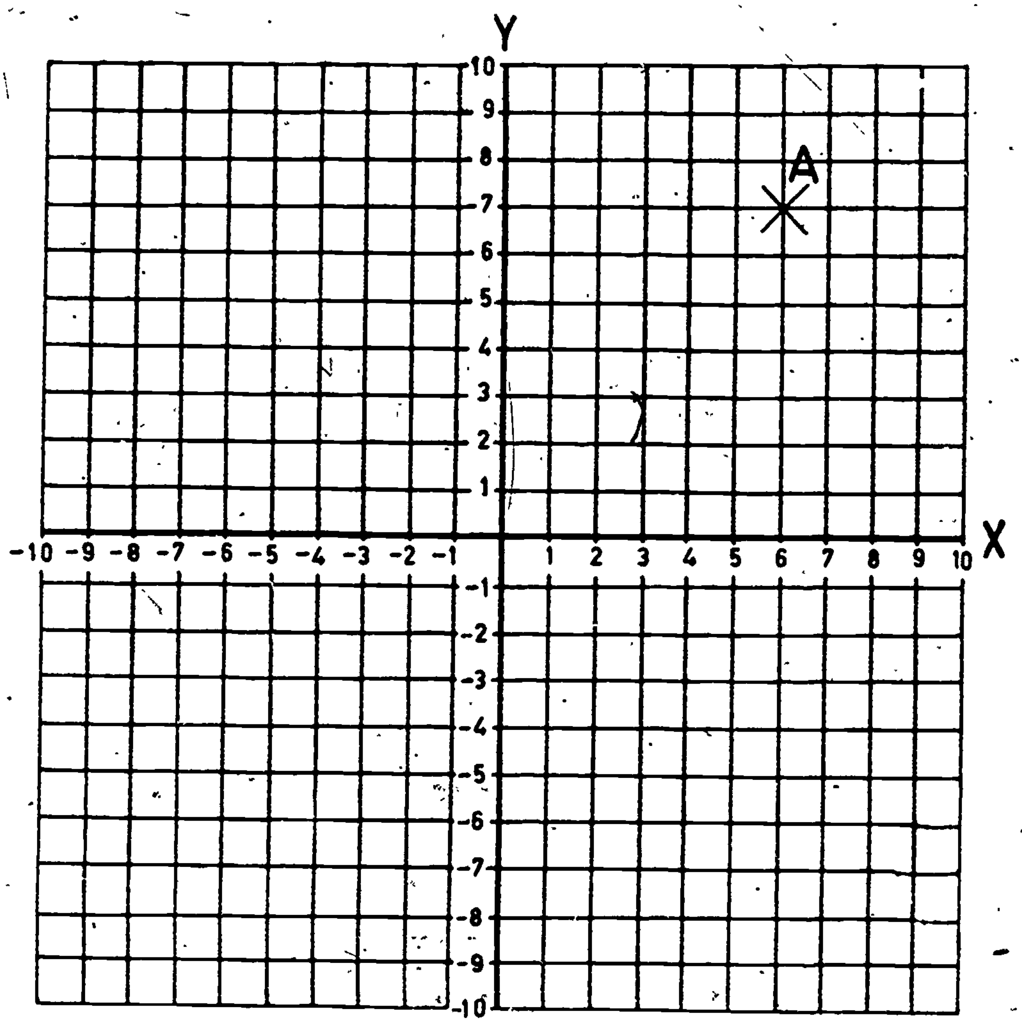
Read each question carefully, then write your answer in the space provided. Try to guess the answers to any questions you do not know, but do not waste time on more difficult problems. All answers should be given to the nearest decimal place, and any other calculations may be written on the back of the page. The sign of an answer, where this applies, should be either positive (+) or negative (-).



Calculate the horizontal (X) position of A.

ANSWER

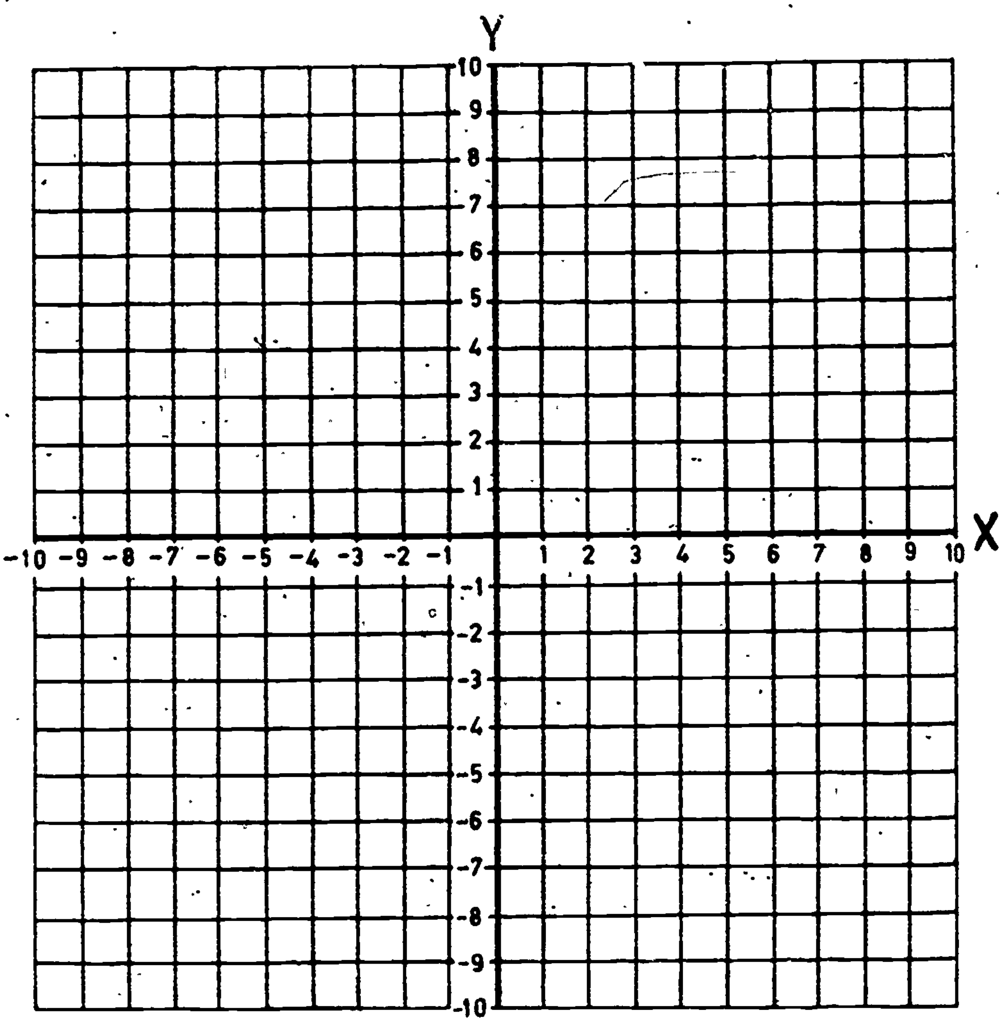
______ ______
(sign) (number)



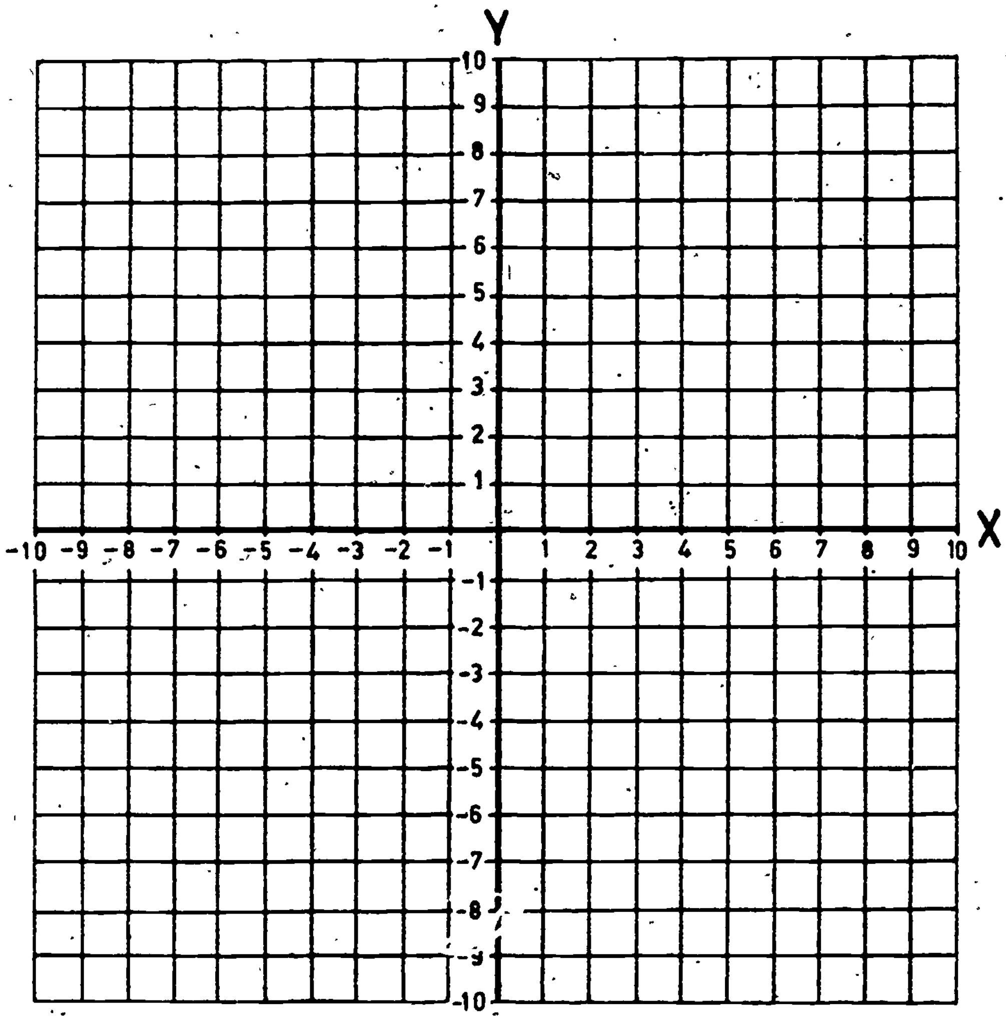
– Calculate the horizontal (X) position of A.

ANSWER

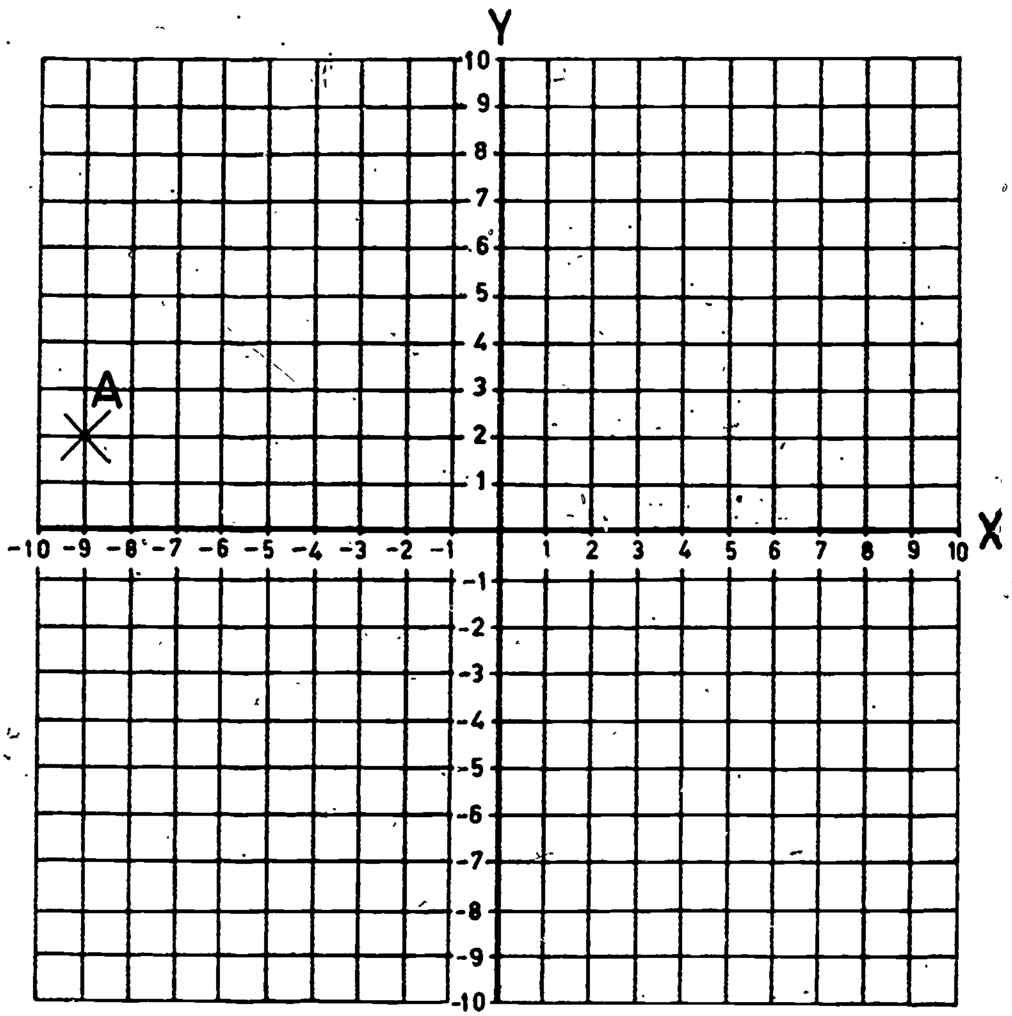
_______ (sign) _______ (number)



Place a mark (X) at the position (X = 4 / Y = 7) on the graph above.



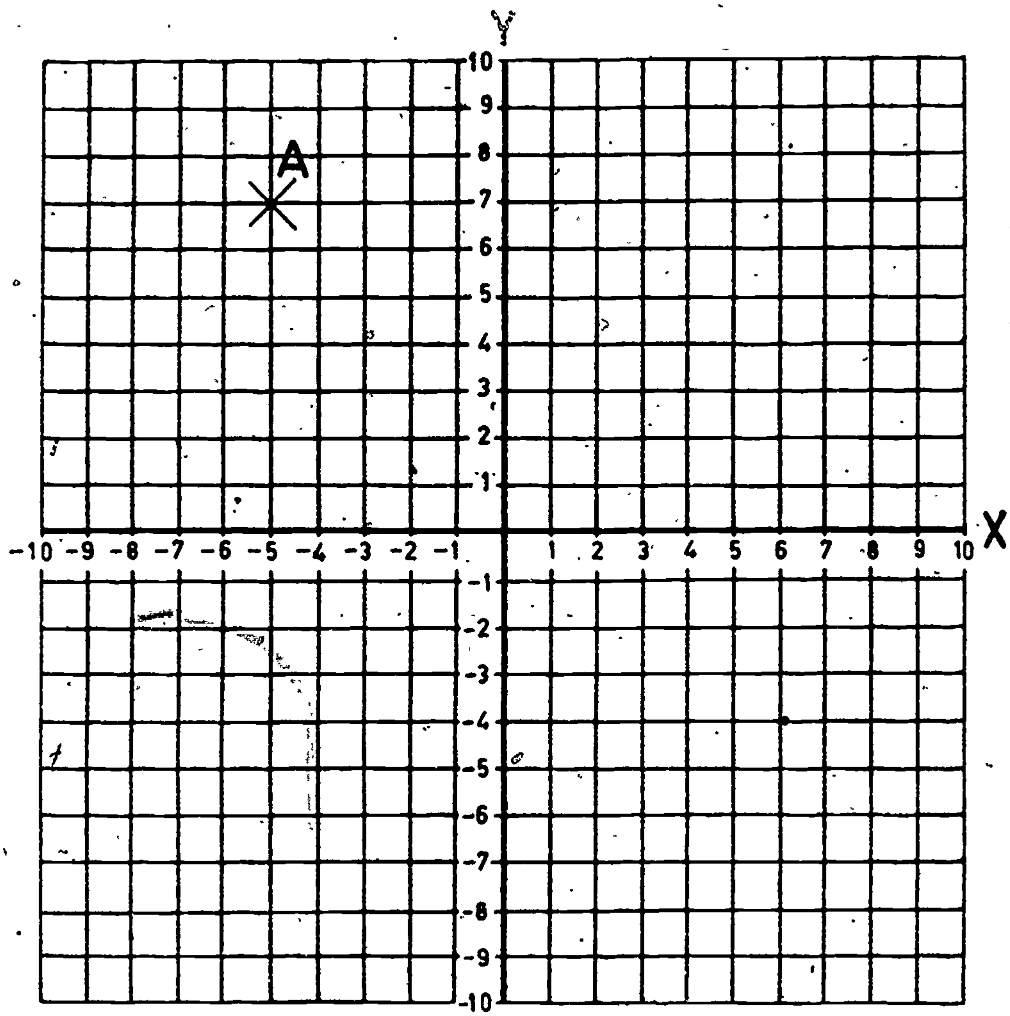
Place a mark (X) at the position (X = 9 / Y = 4) on the graph above.



Calculate the horizontal (X) position of A.

ANSWER

______ (sign) ______ (number)

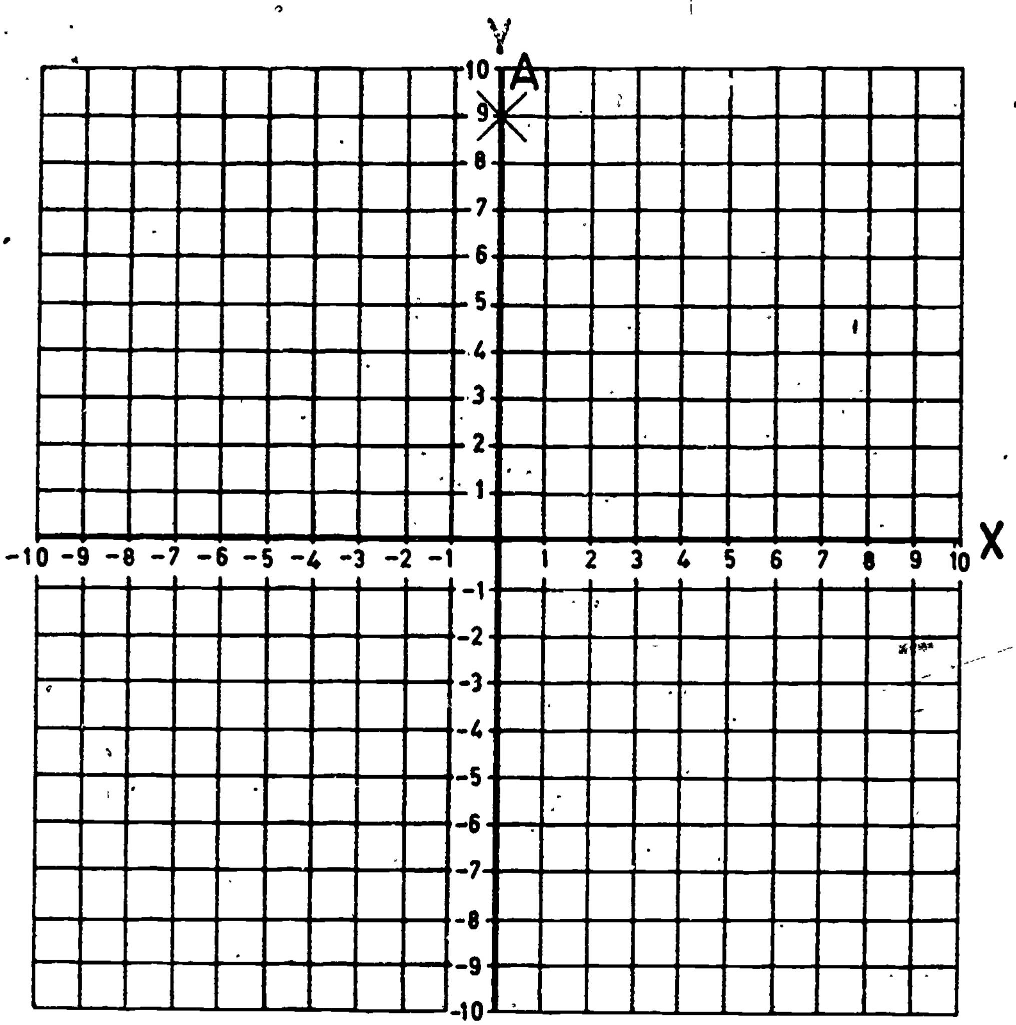


Calculate the horizontal (X) position of A.

ANSWER

______ ________

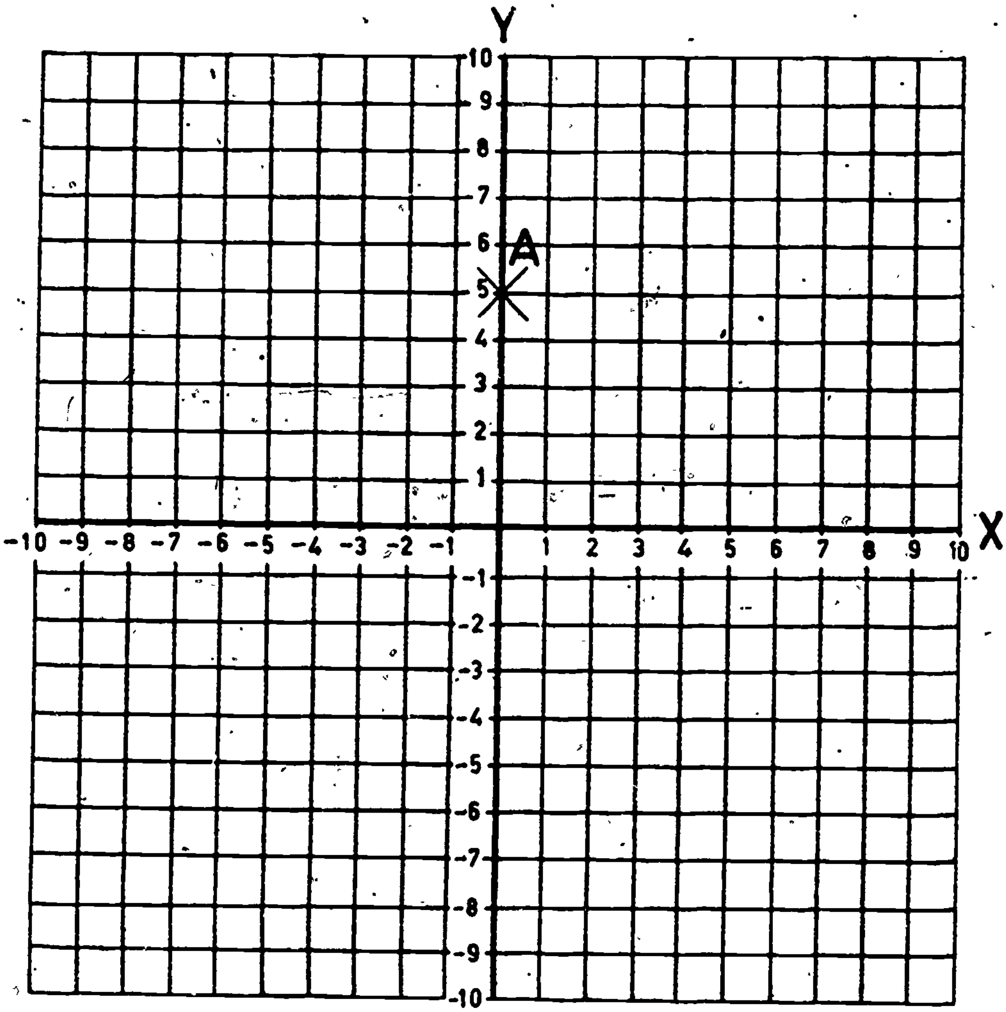
(sign) (number)



Calculate the horizontal (X) position of A.

ANSWER

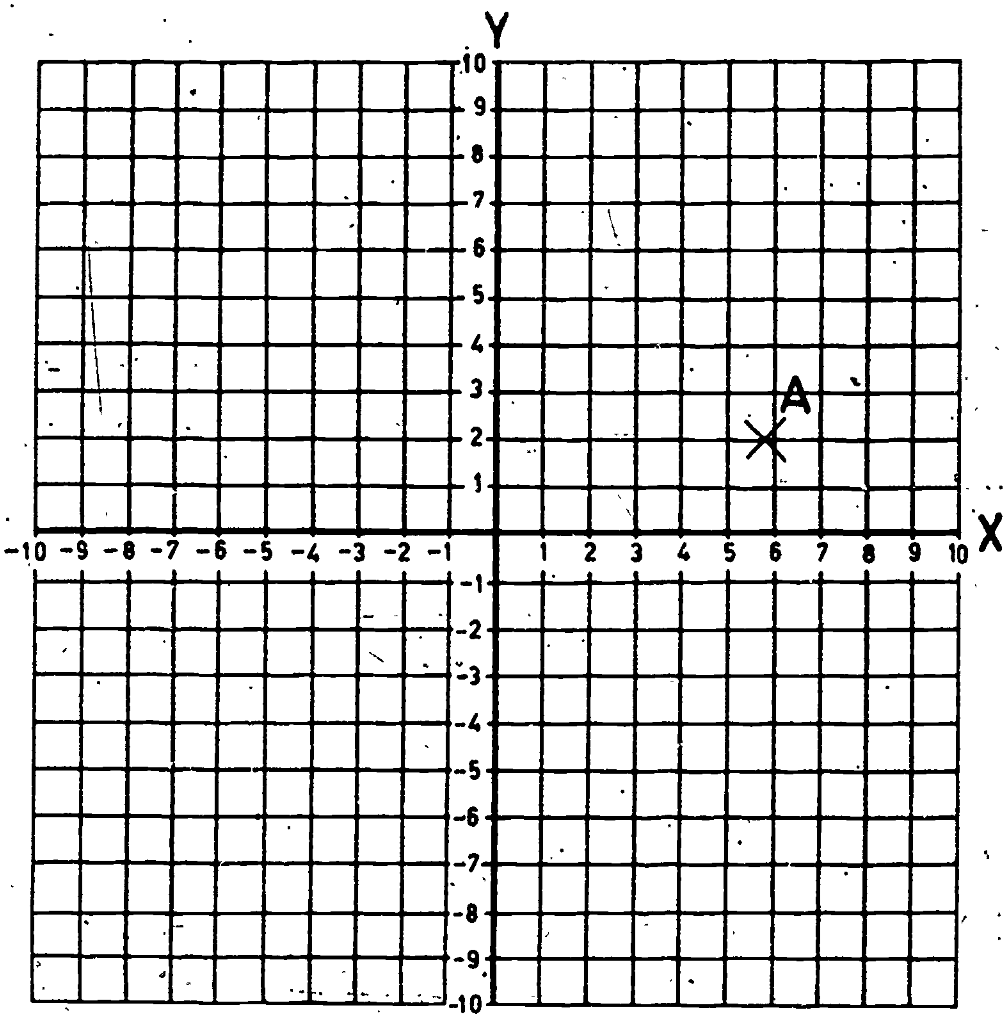
_______ (sign) _______ (number)



Calculate the horizontal (X) position of A.

ANSWER

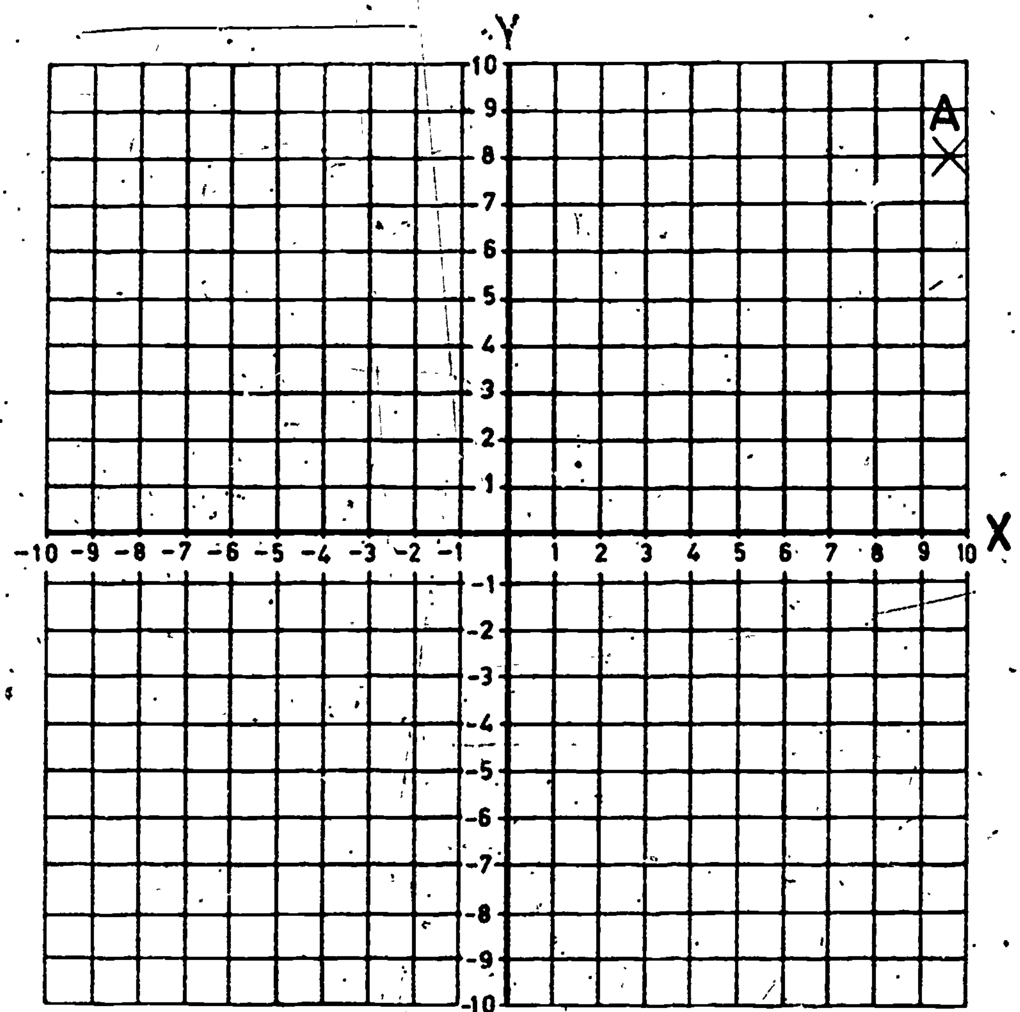
______ (sign) ______ (number)



Calculate the horizontal (X) position of A.

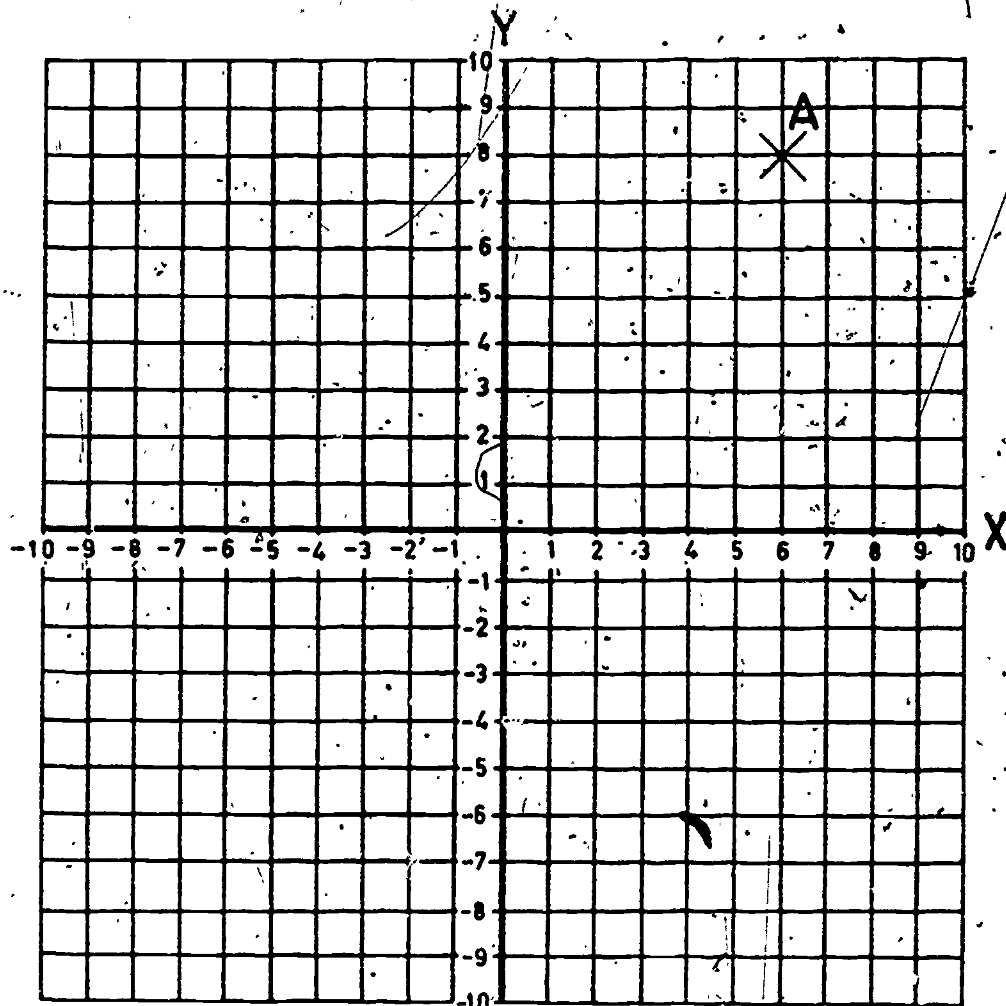
ANSWER

______ (sign) ______ (number)



Calculate the horizontal (X) position of A.

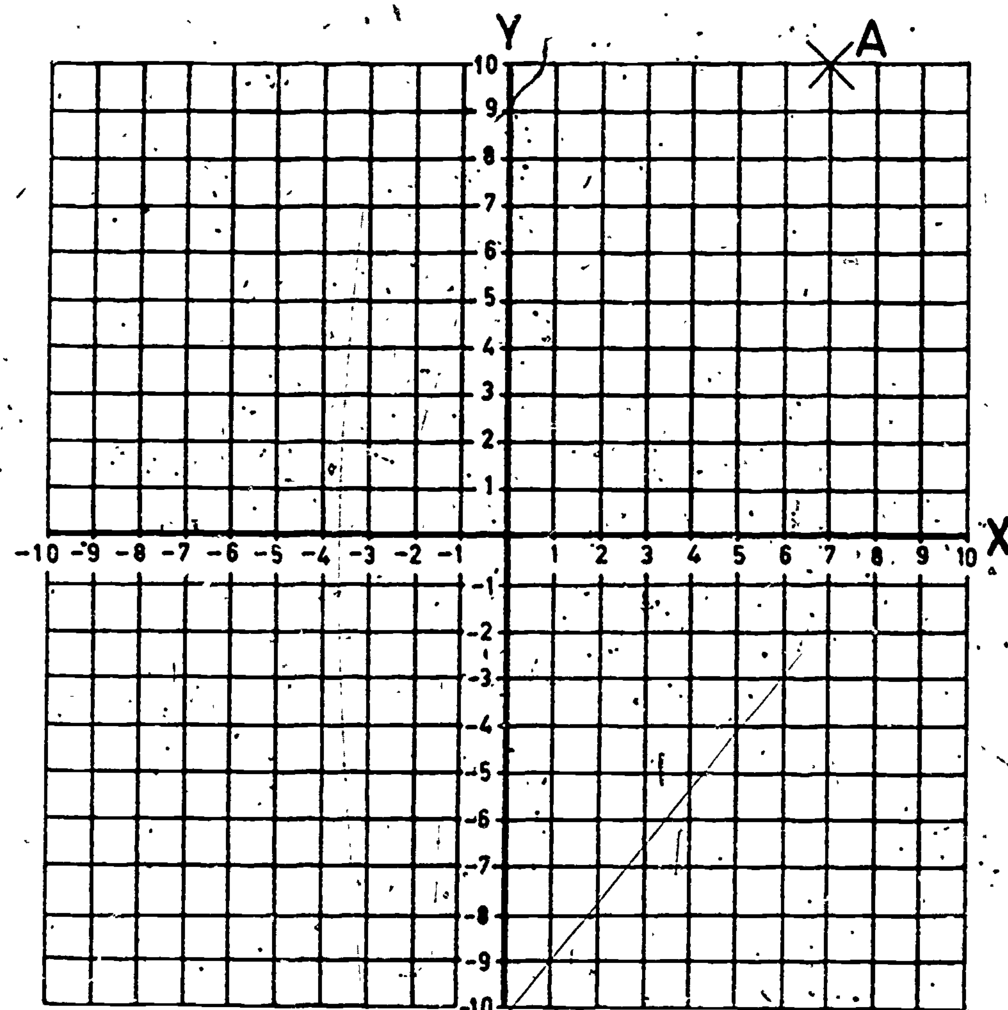
ANSWER ____ ____
(sign) (number)



Calculate the vertical (Y) position of A.

ANSWER

______ (sign) ________ (number)



Calculate the vertical (Y) position of A.

ANSWER

________ __________
(sign) (number)

BASIC SKILLS OF GRAPHICAL INTERPRETATION

SUBDIVISION ANALYSIS SET 1/2

NAME ______________________ AGE ____________

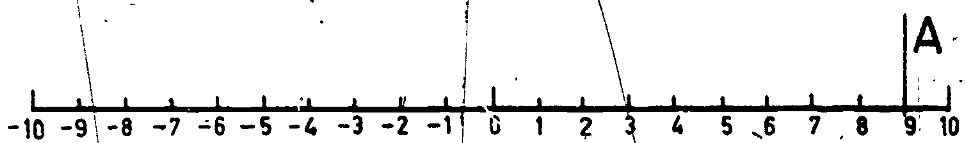
SEX ____________

SCHOOL ____________________ CLASS ____________

DATE ____________

INSTRUCTIONS

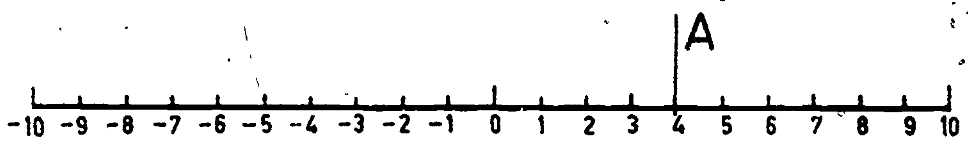
Read each question carefully, then write your answer in the space provided. Try to guess the answers to any questions you do not know, but do not waste time on more difficult problems. All answers should be given to the nearest decimal place, and any other calculations may be written on the back of the page. The sign of an answer, where this applies, should be either positive (+) or negative (-).



Calculate the position of A.

ANSWER

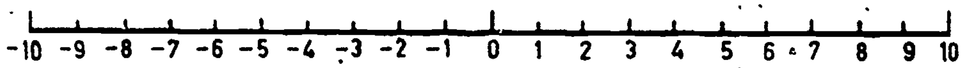
________ ___________
(sign) (number)



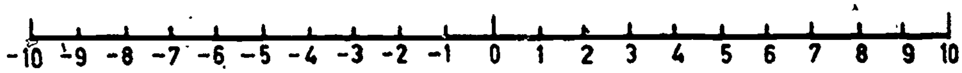
Calculate the position of A.

ANSWER

______ ______
(sign) (number)

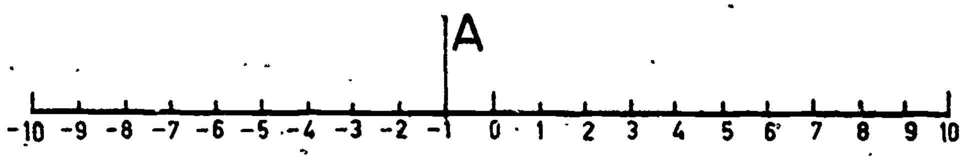


Place a mark (X) at the position (+ 2.0) on the number line above.



Place a mark (X) at the position (+ 7.0) on the number line above.

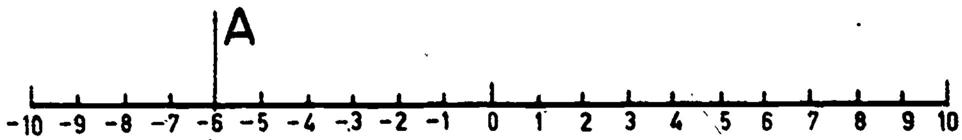
1/2-3(a)



Calculate the position of A.

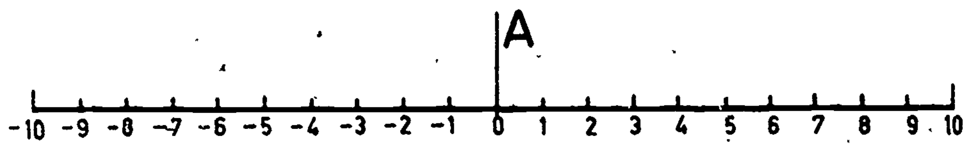
ANSWER ______ ______

(sign) (number)



Calculate the position of A.

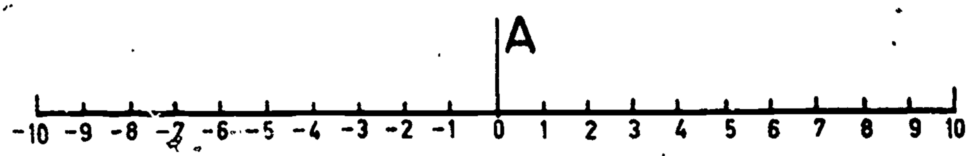
ANSWER ______ (sign) ______ (number)



Calculate the position of A.

ANSWER

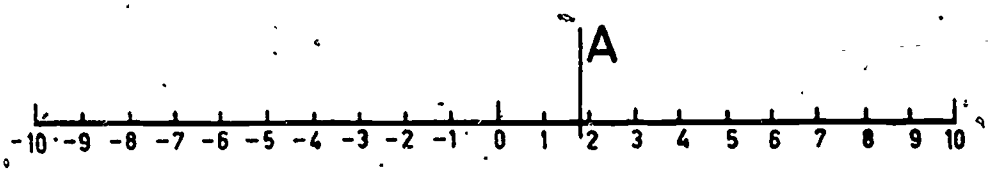
______ ______
(sign) (number)



Calculate the position of A.

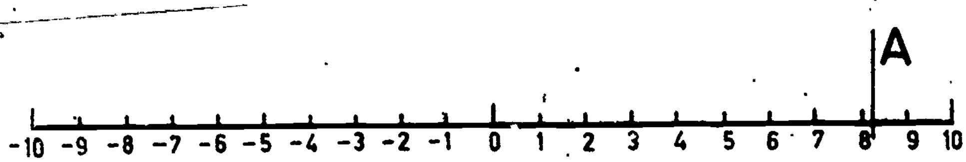
ANSWER

______ ______
(sign) (number)



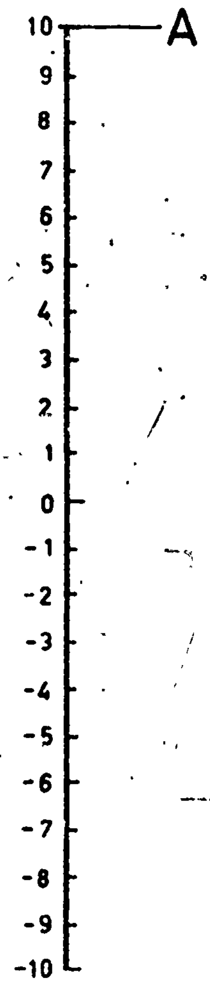
Calculate the position of A.

ANSWER ________ ________
(sign) (number)



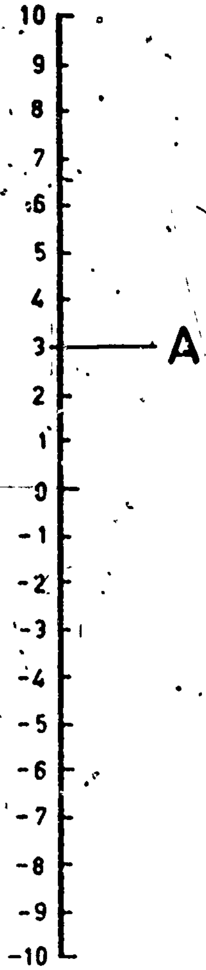
Calculate the position of A.

ANSWER ______ ______
(sign) (number)



Calculate the position of A.

ANSWER ______ ______
(sign) (number)



Calculate the position of A.

ANSWER ______ ______
(sign) (number)

BASIC SKILLS OF GRAPHICAL INTERPRETATION

SUBDIVISION ANALYSIS SET 2/1(A)

NAME ______________ AGE ______________

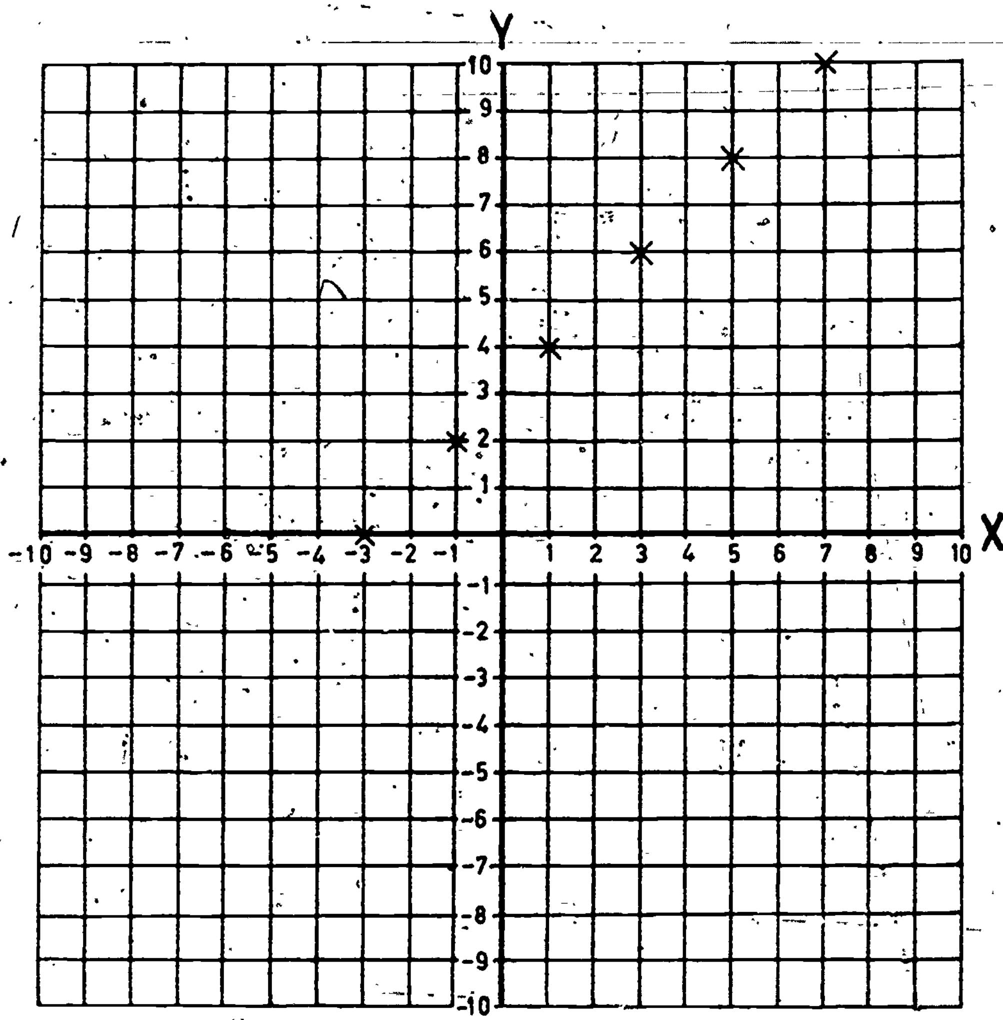
SEX ______________

SCHOOL ______________ CLASS ______________

DATE ______________

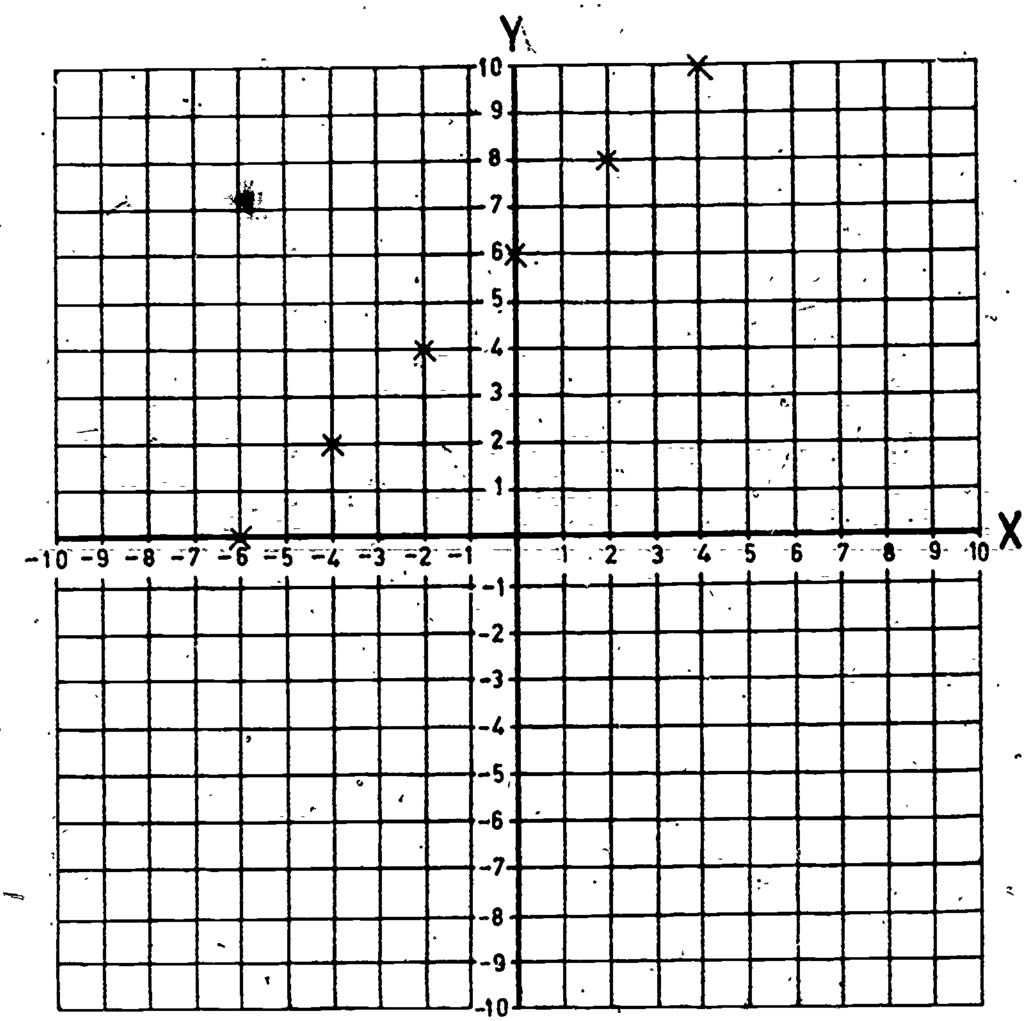
INSTRUCTIONS

Read each question carefully, then write your answer in the space provided. Try to guess the answers to any questions you do not know, but do not waste time on more difficult problems. All answers should be given to the nearest decimal place, and any other calculations may be written on the back of the page. The sign of an answer, where this applies, should be either positive (+) or negative (-).



Calculate the value of Y when X = 2.0

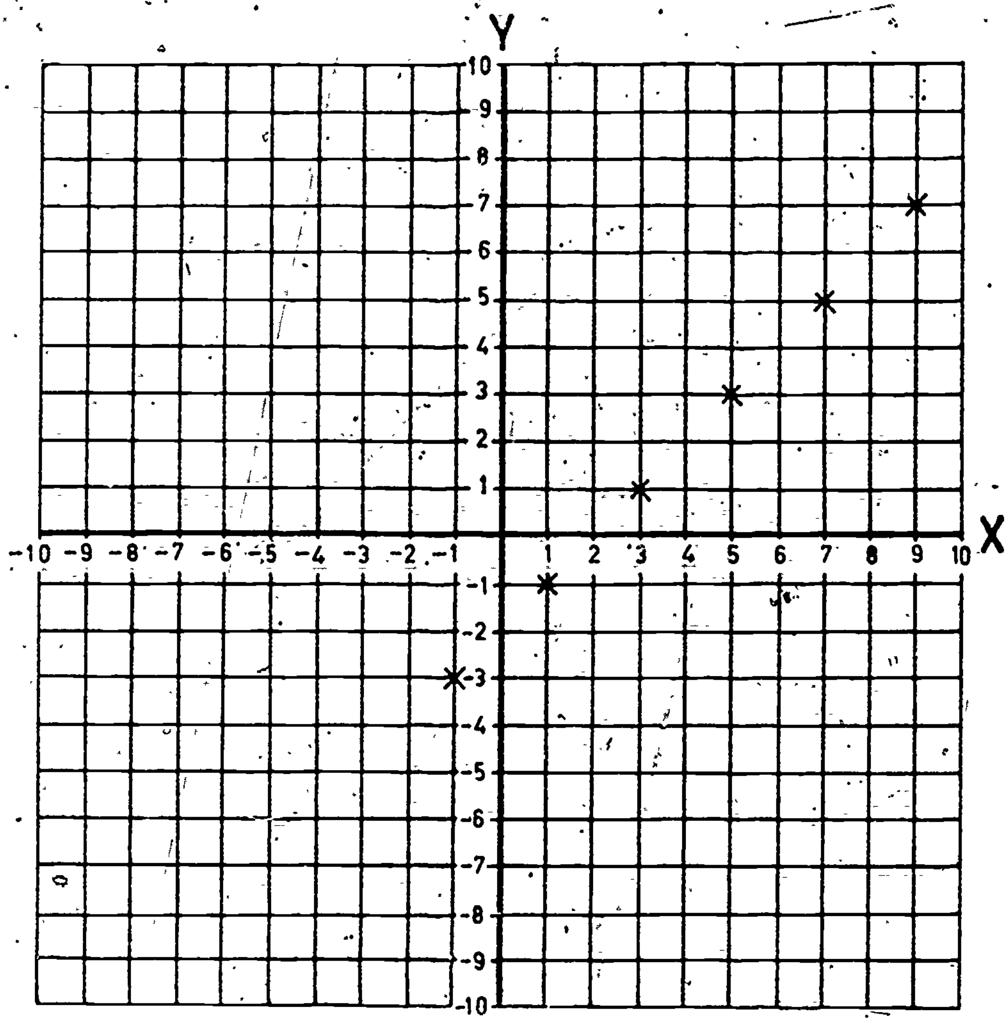
ANSWER ________ ________
(sign) (number)



Calculate the value of Y when X = 1.0

ANSWER

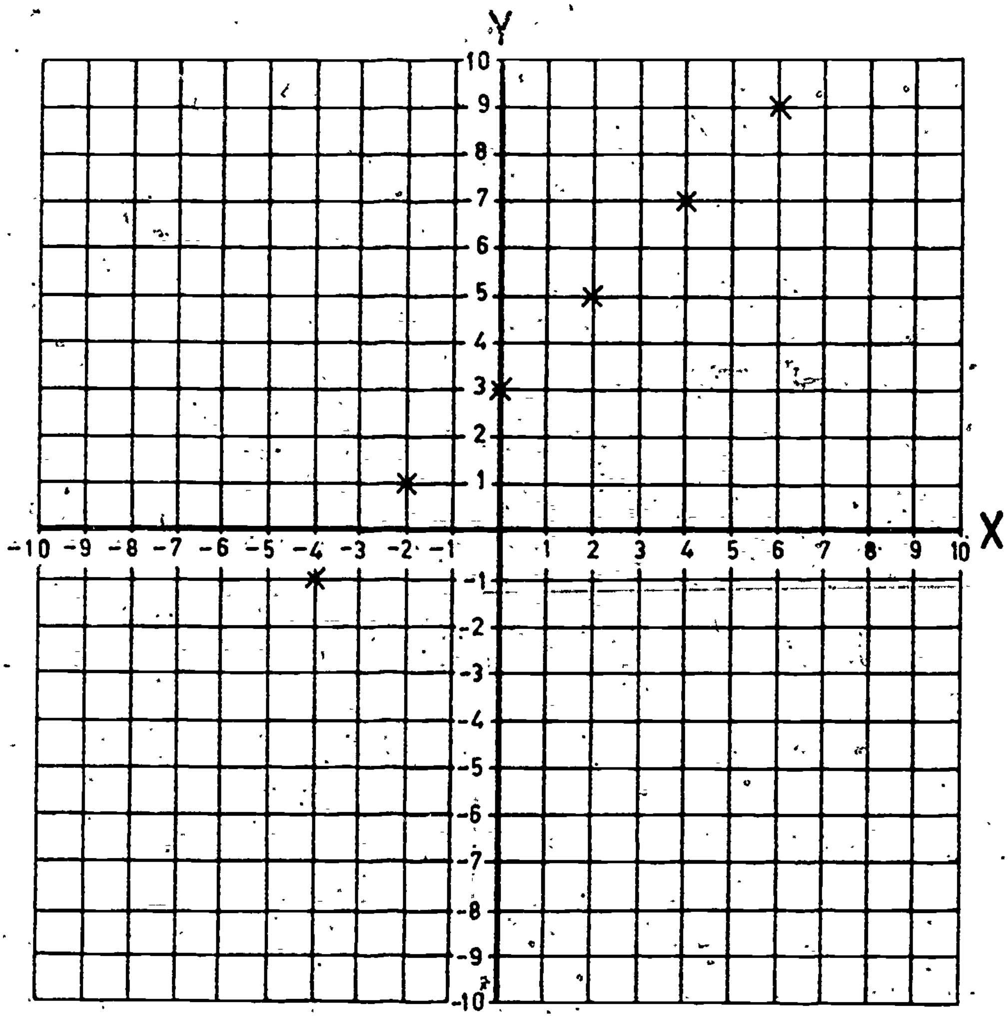
______ (sign) ______ (number)



Calculate the value of X when Y = 2.0

ANSWER

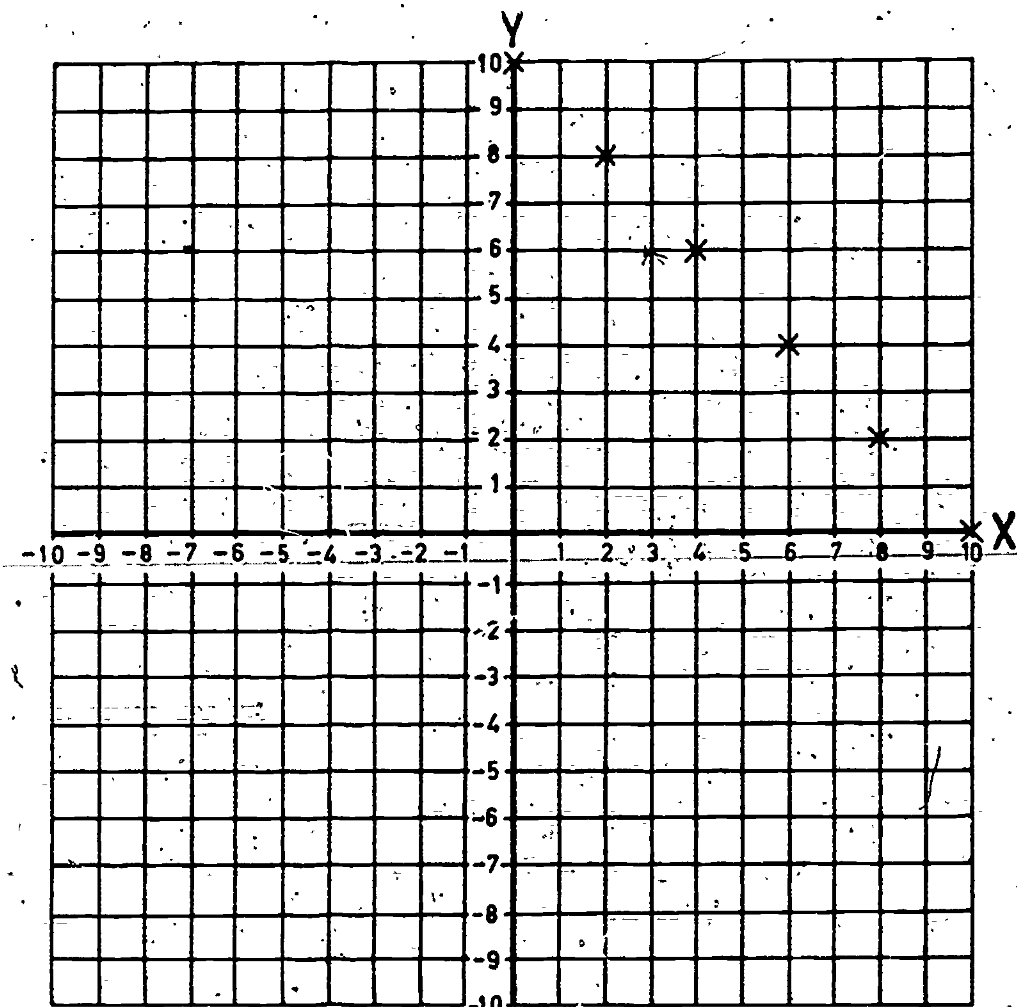
(sign) (number)



Calculate the value of X when Y = 6.0

ANSWER

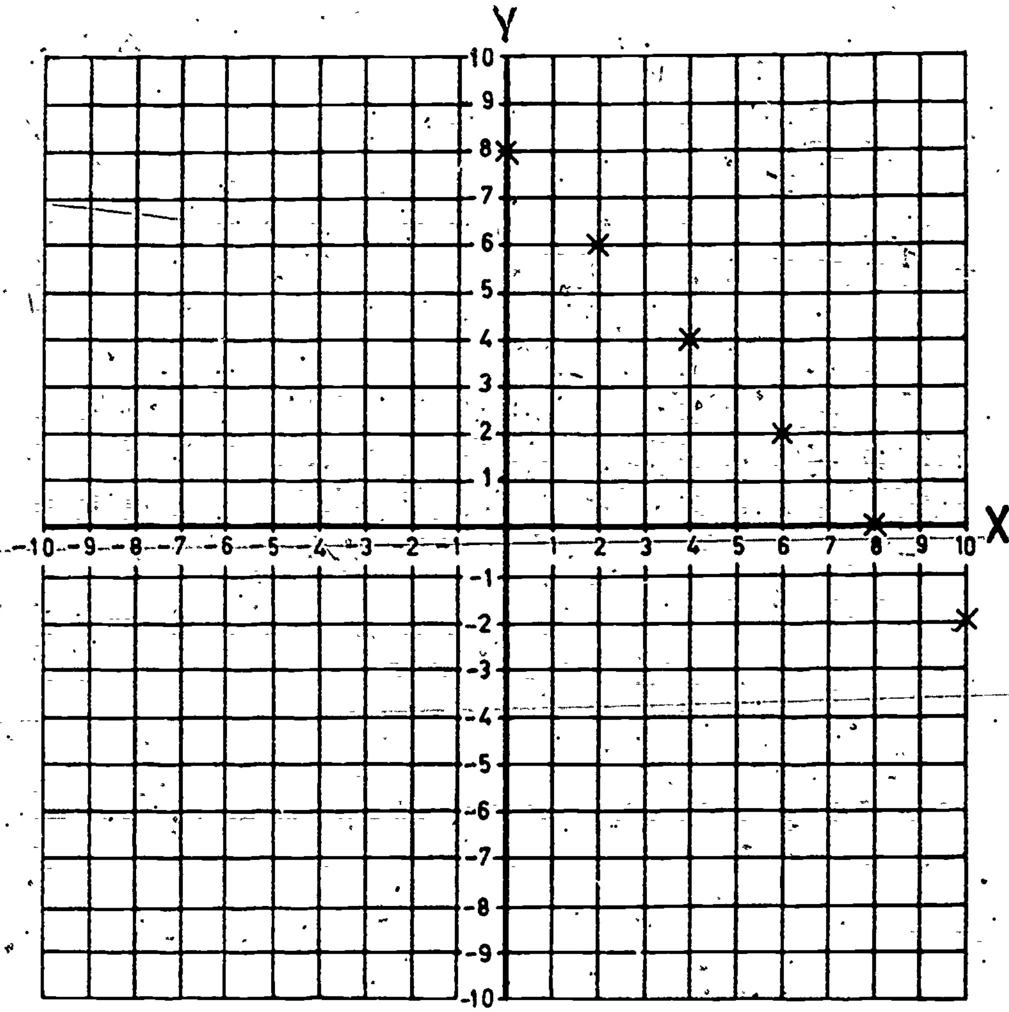
________ __________
(sign) (number)



Calculate the value of Y when X = 1.0

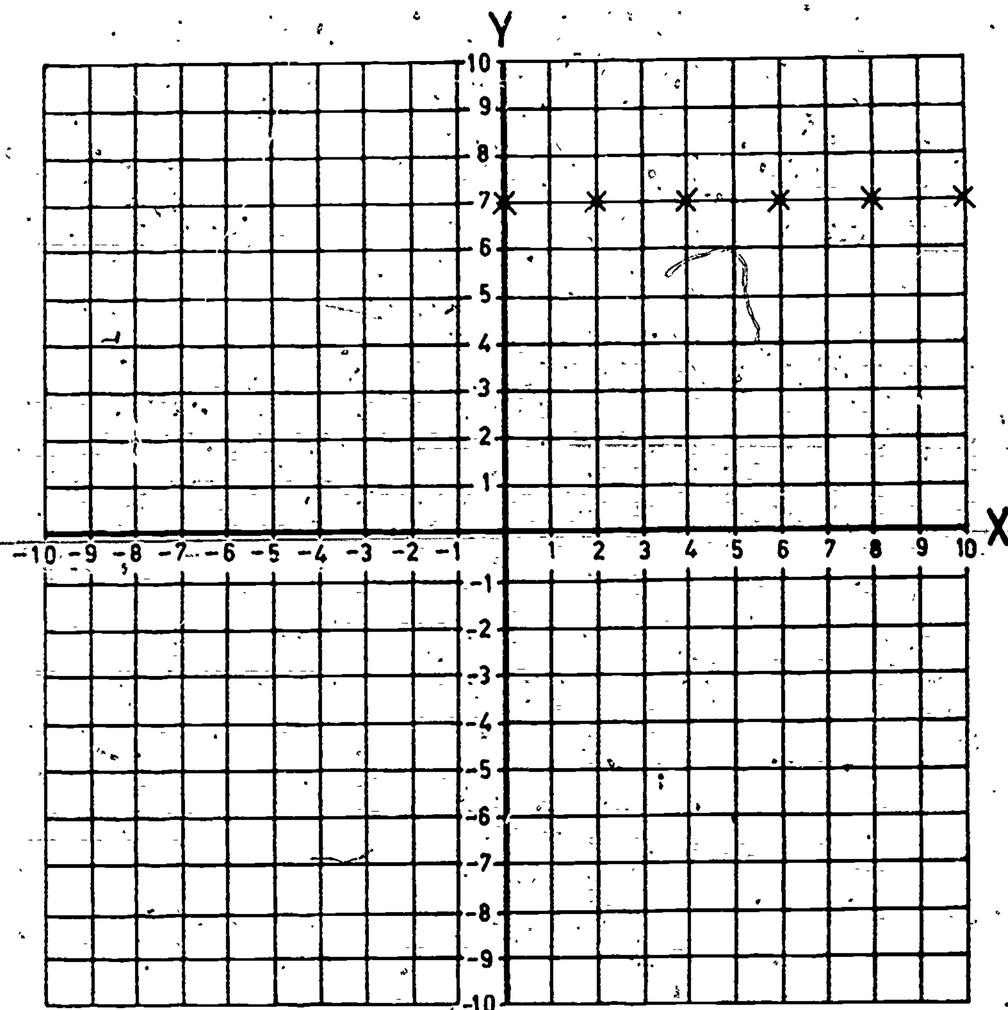
ANSWER

______ (sign) ______ (number)



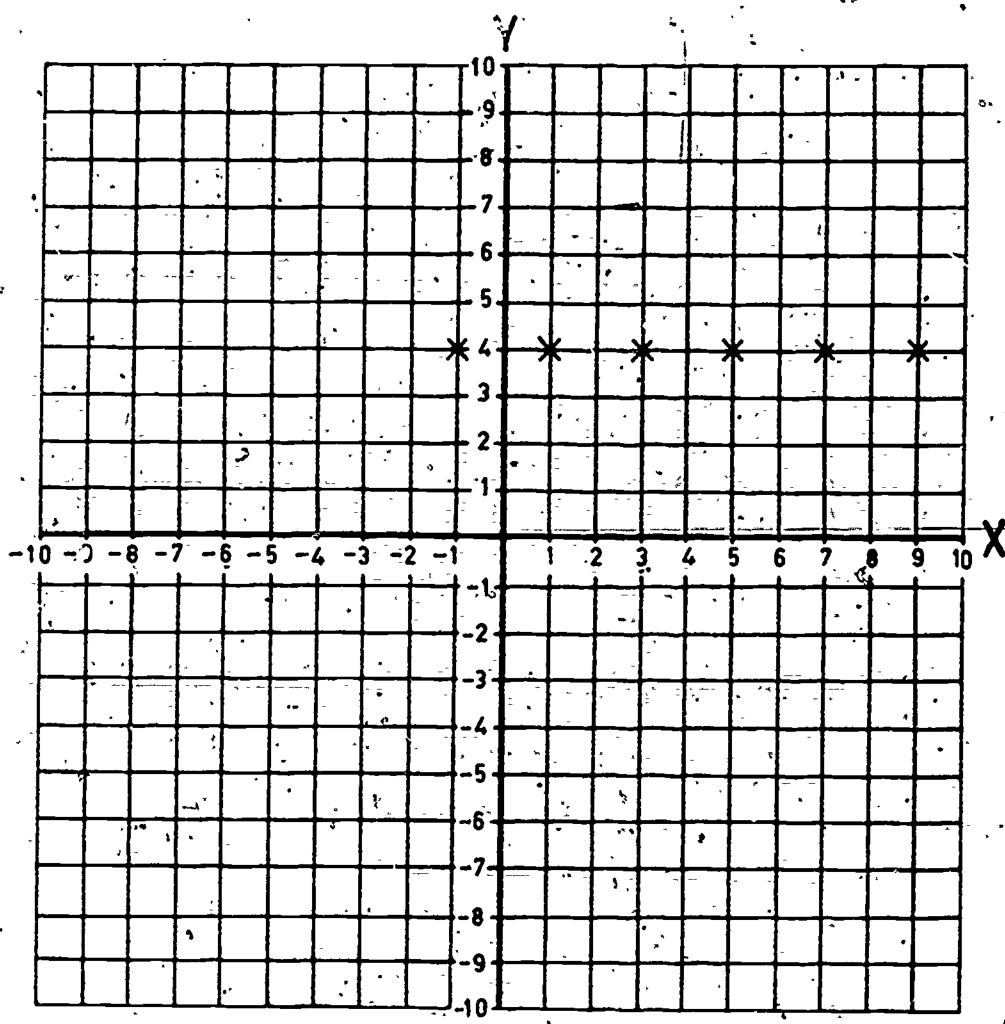
Calculate the value of Y when X = 5.0

ANSWER ______ ______
(sign) (number)



Calculate the value of Y when X = 9.0

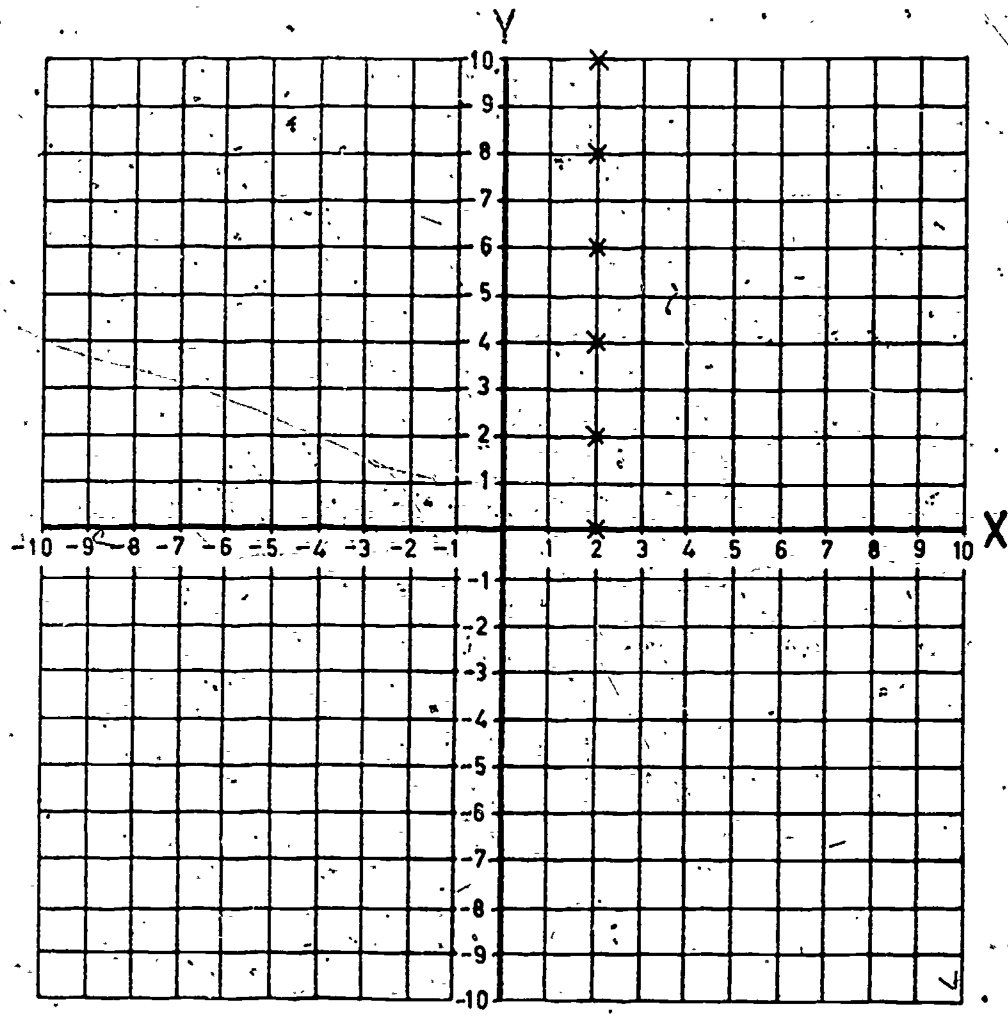
ANSWER ________ ________
(sign) (number)



Calculate the value of Y when X = 8.0

ANSWER

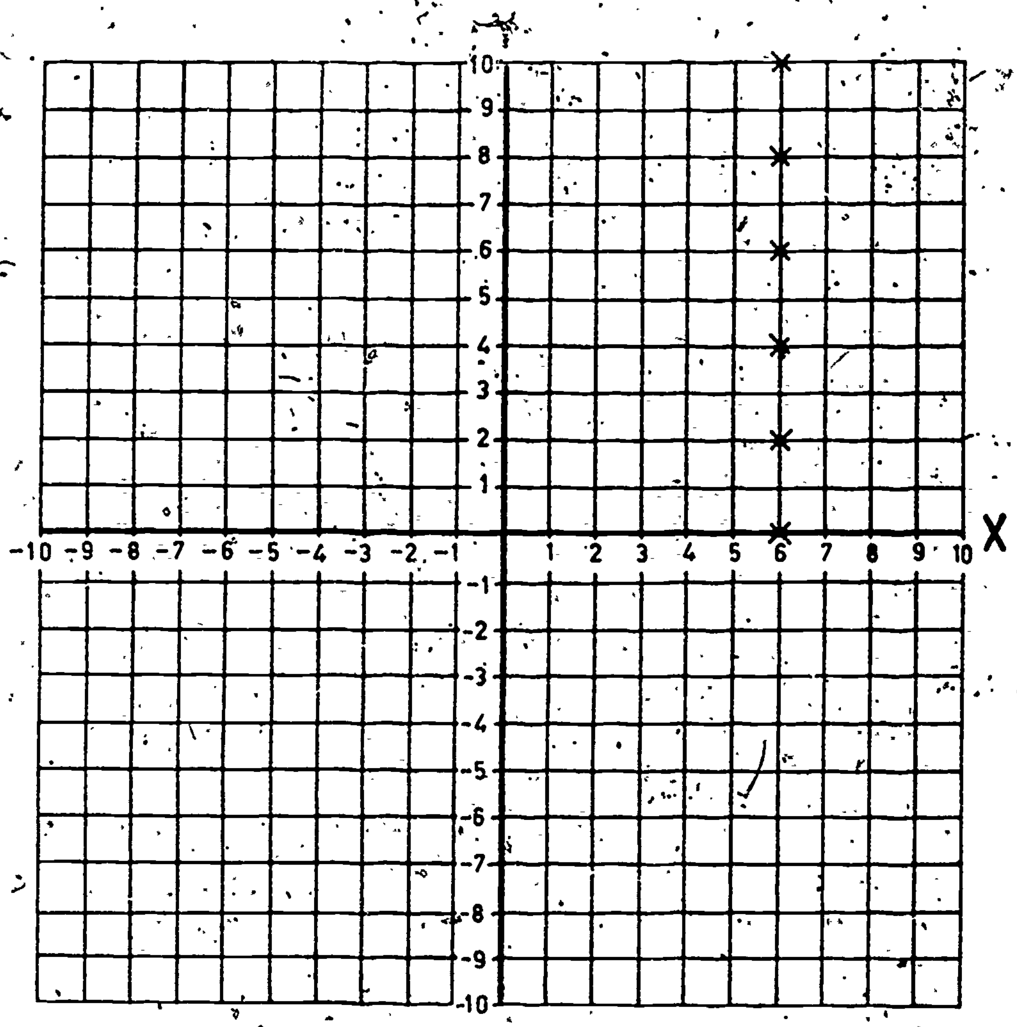
______ (sign) ______ (number)



Calculate the value of X when Y = 9.0

ANSWER ______ ______

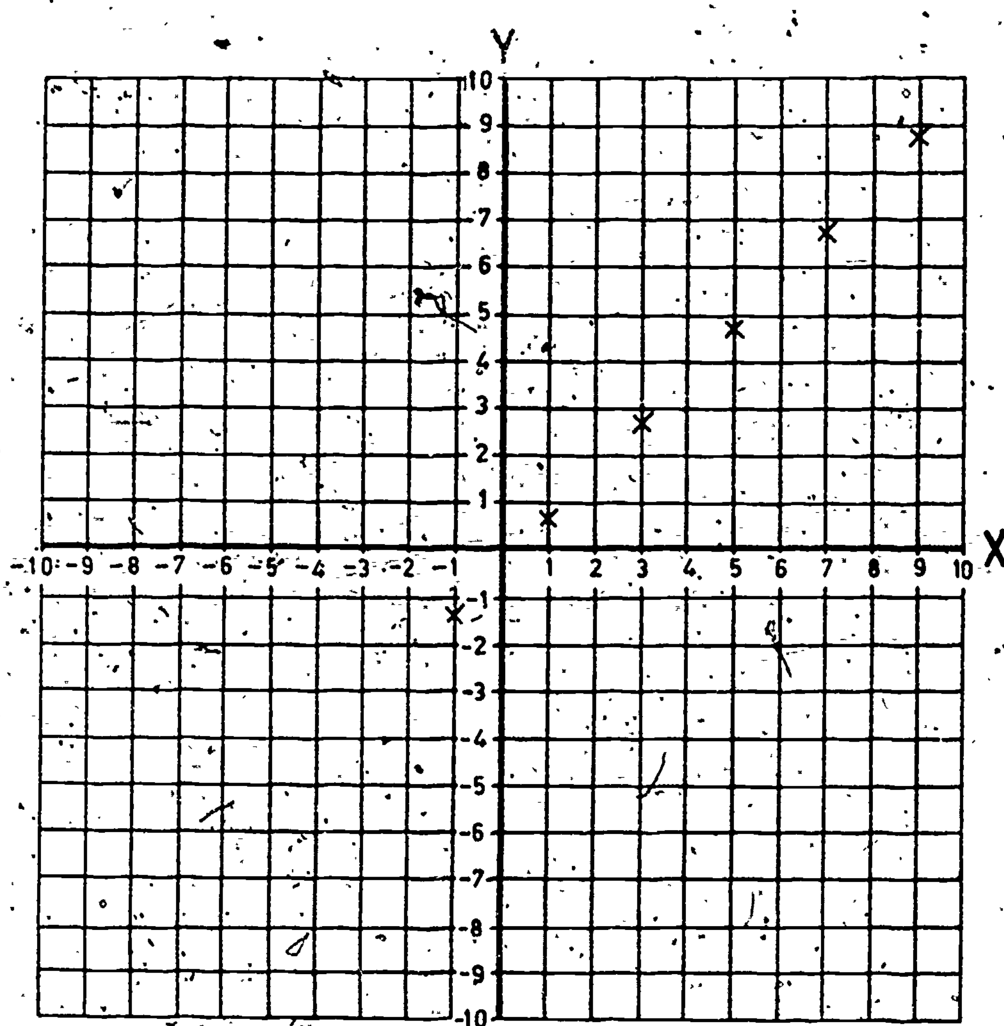
(sign) (number)



Calculate the value of X when Y = 3.0

ANSWER

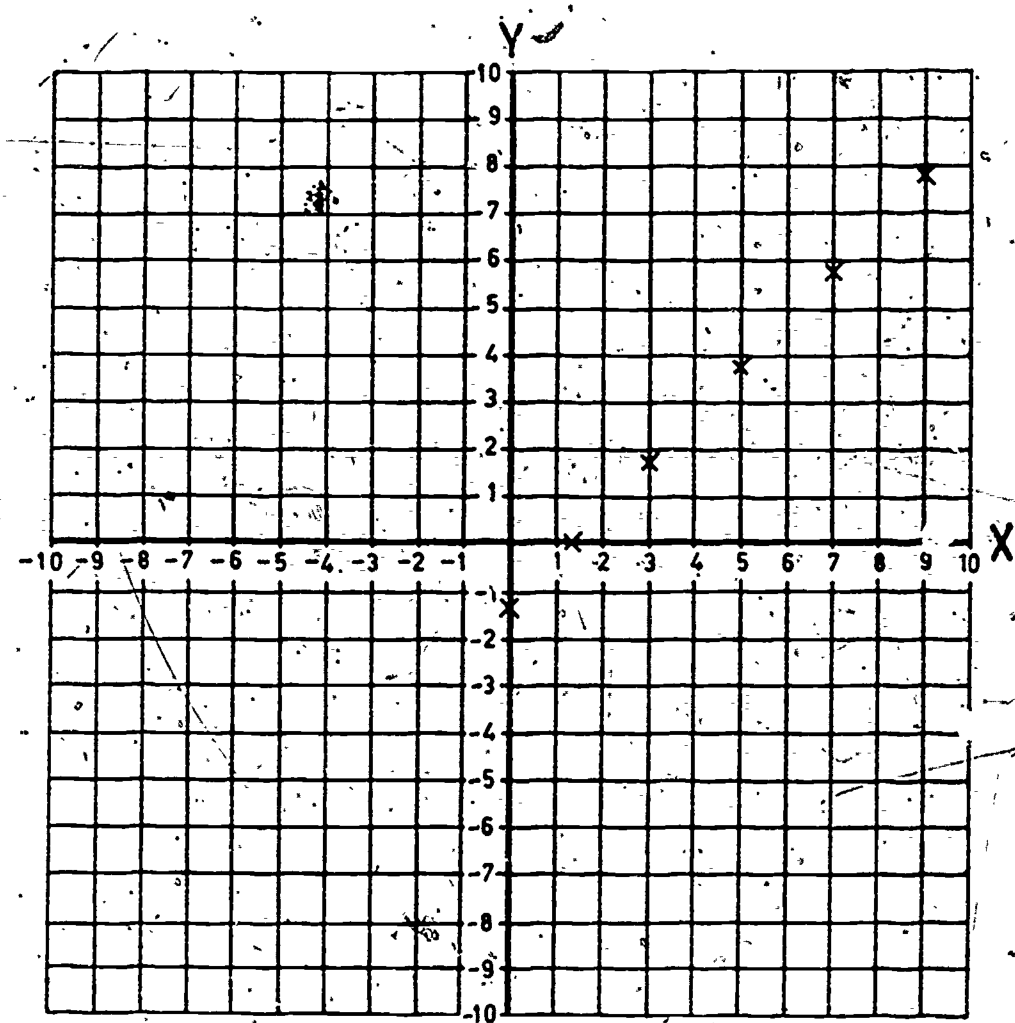
_______ _______
(sign) (number)



Calculate the value of Y when X = 4.0

ANSWER

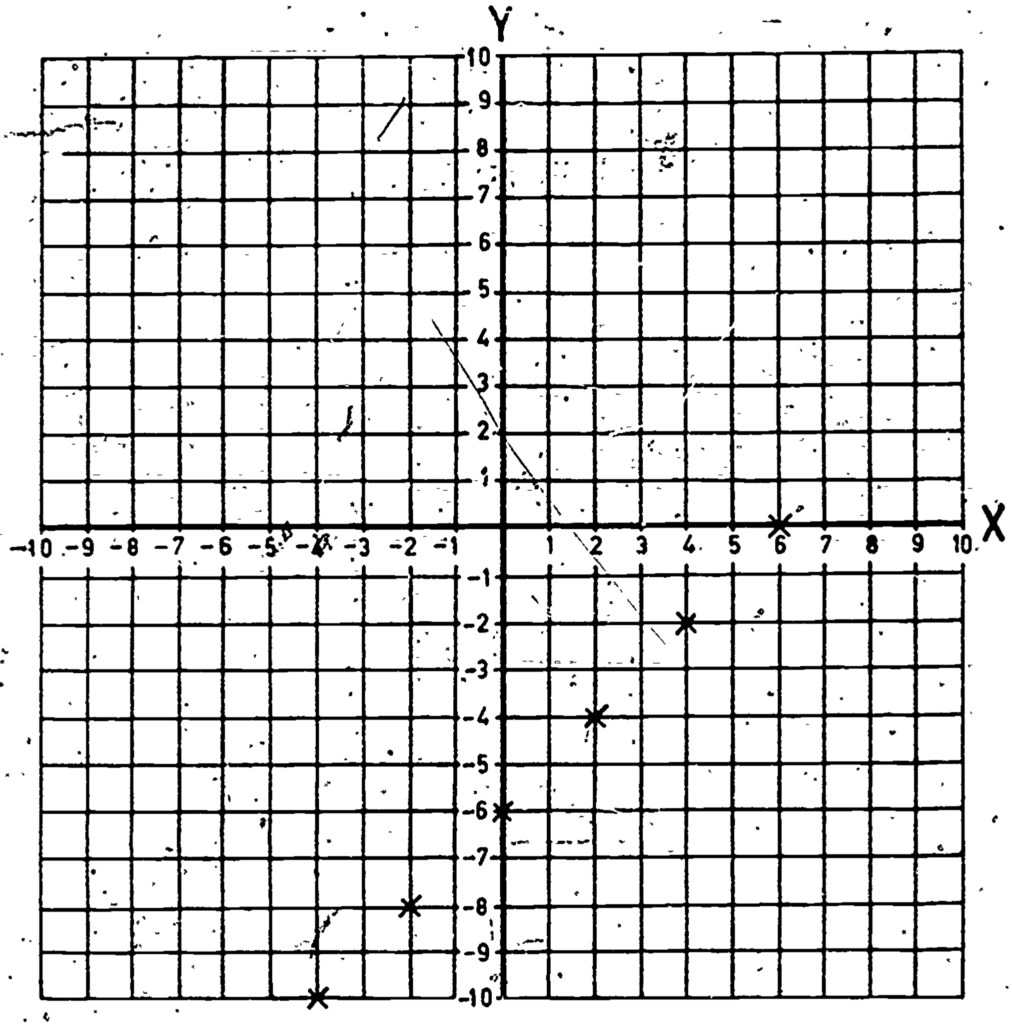
______ ______
(sign) (number)



Calculate the value of Y when X = 6.0

ANSWER

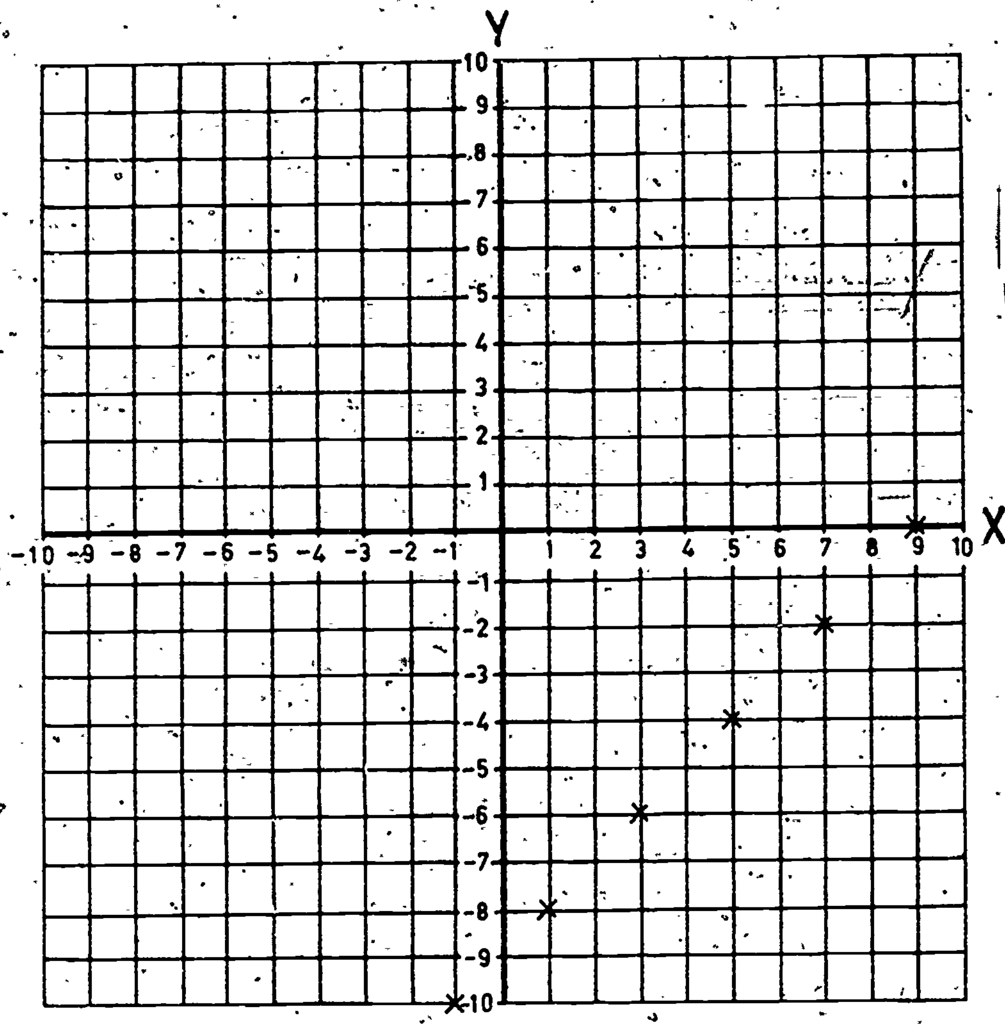
______ (sign) ______ (number)



Calculate the value of Y when X = 1.0

ANSWER

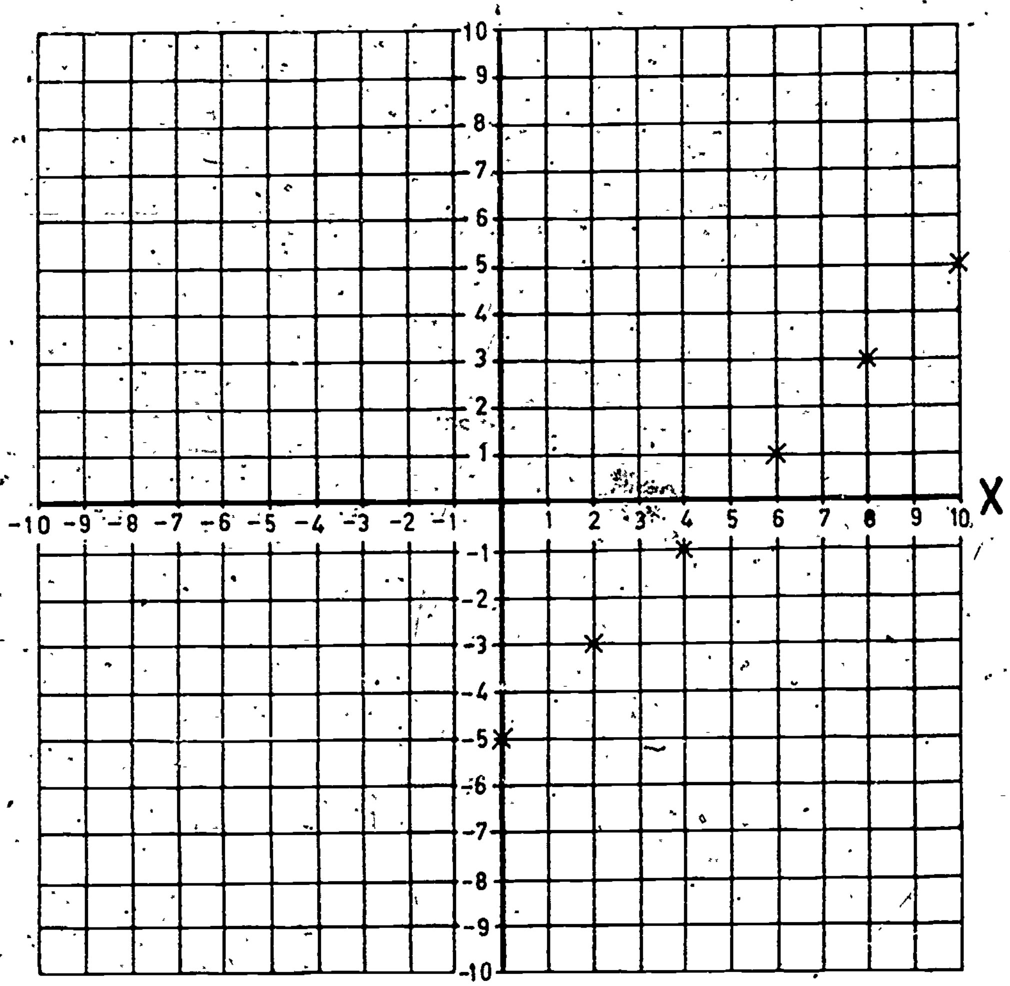
_______ _______
(sign) (number)



Calculate the value of Y when X = 2.0

ANSWER

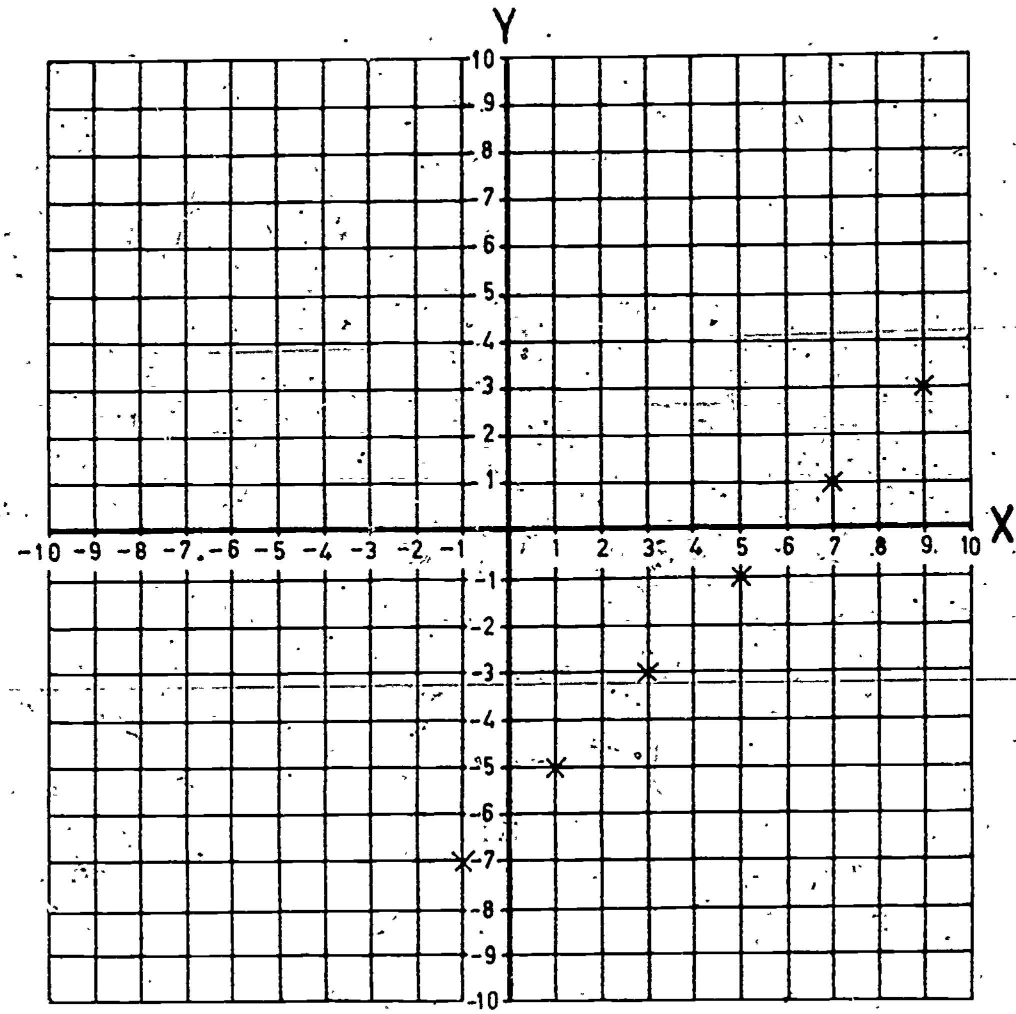
______ ______
(sign) (number)



Calculate the value of Y when X = 5.0 .

ANSWER

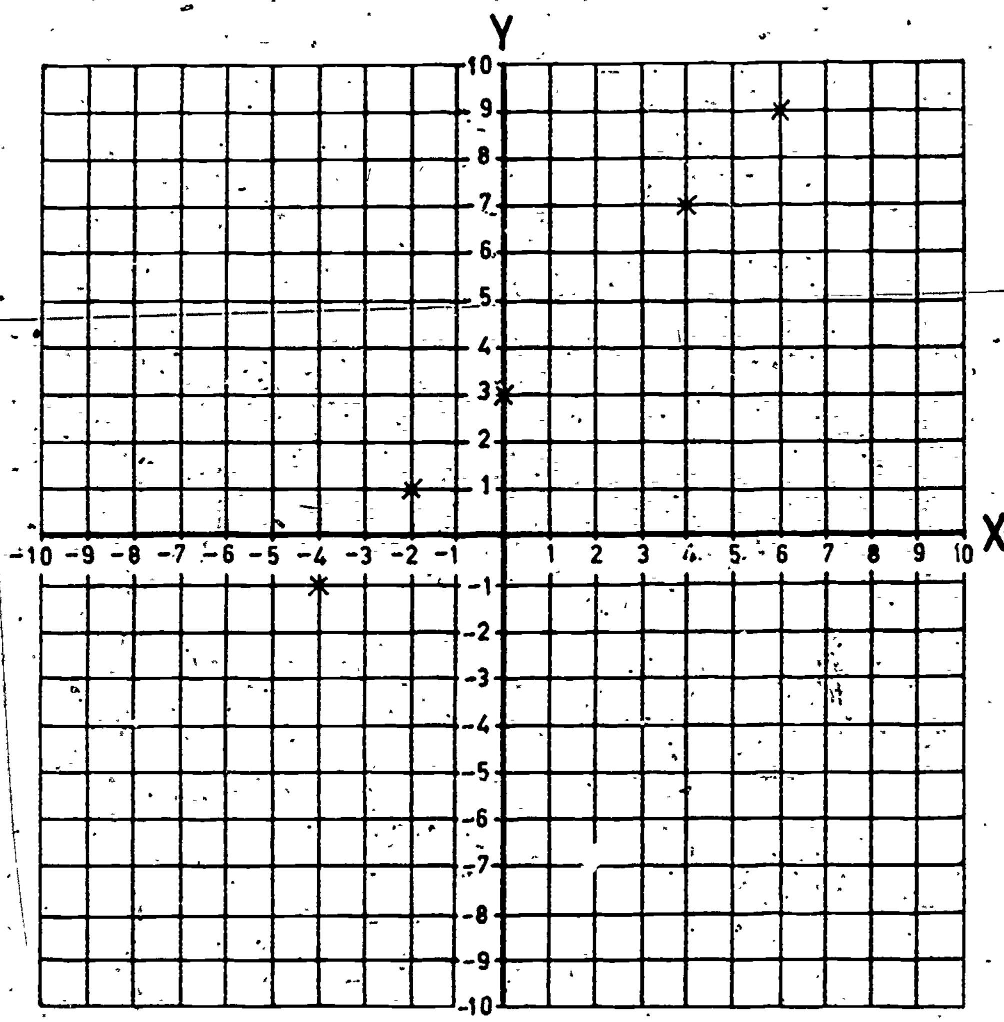
______ ______
(sign) (number)



Calculate the value of Y when X = 6.0

ANSWER

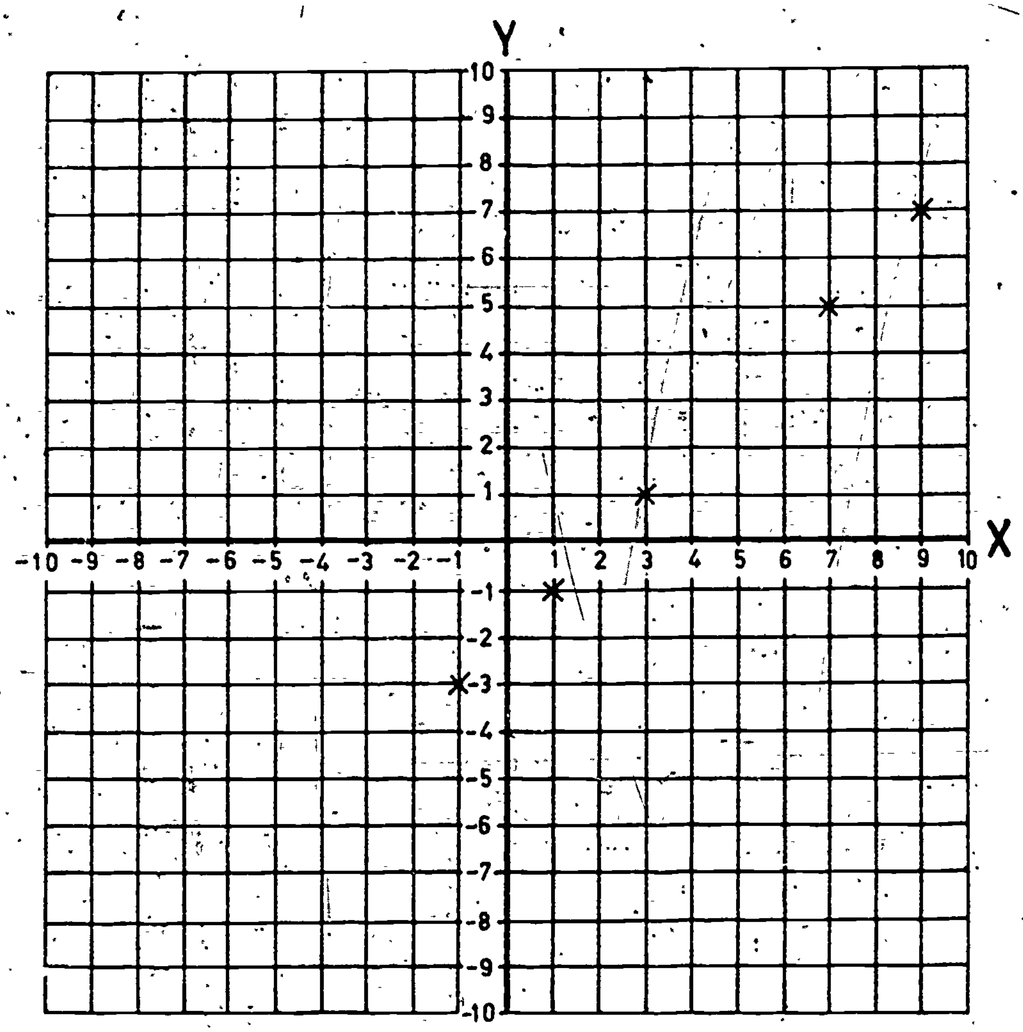
______ ______
(sign) (number)



Calculate the value of Y when X = 2.0

ANSWER

____ (sign) ____ (number)



Calculate the value of Y when X = 5.0

ANSWER

_______ (sign) _______ (number)

BASIC SKILLS OF GRAPHICAL INTERPRETATION

SUBDIVISION ANALYSIS SET 2/1(B)

NAME ______________ AGE ________

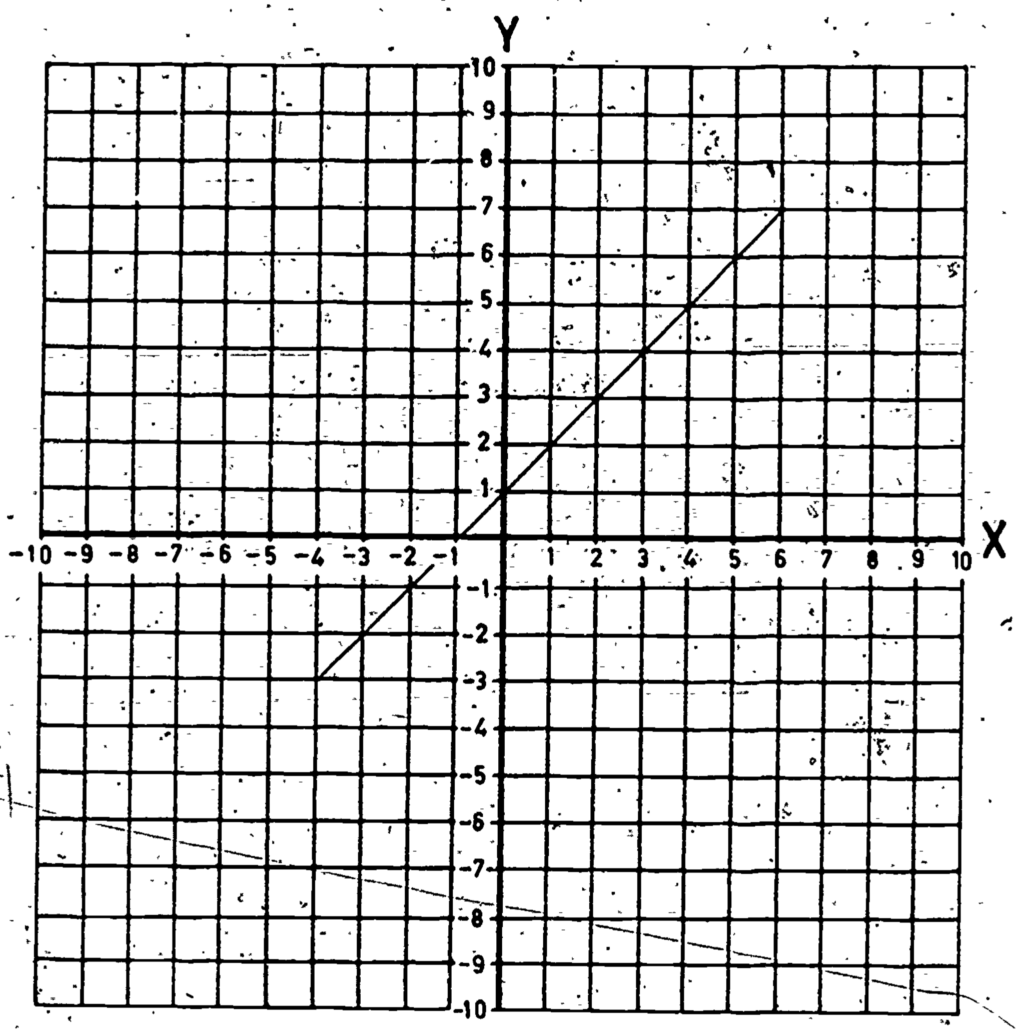
SEX ________

SCHOOL ______________ CLASS ________

DATE ________

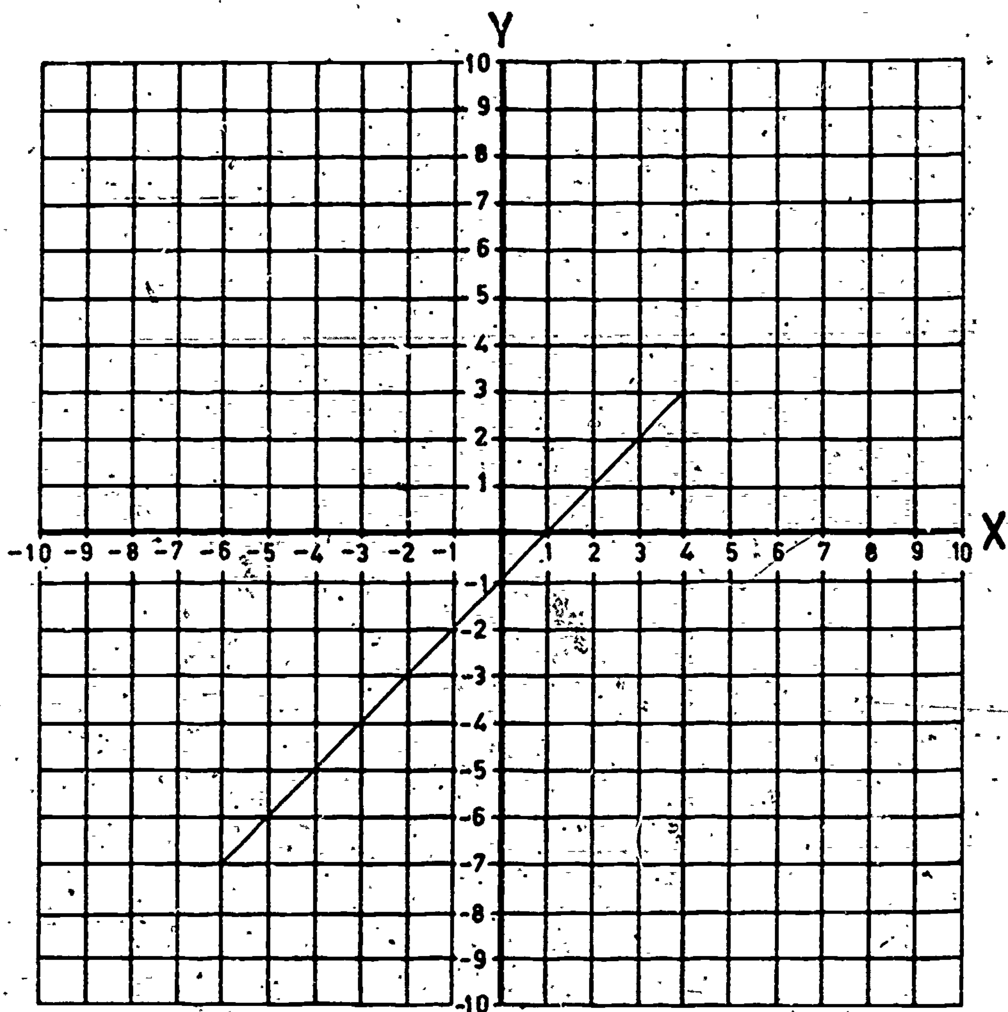
INSTRUCTIONS

Read each question carefully, then write your answer in the space provided. Try to guess the answers to any questions you do not know, but do not waste time on more difficult problems. All answers should be given to the nearest decimal place, and any other calculations may be written on the back of the page. The sign of an answer, where this applies, should be either positive (+) or negative (-).



Calculate the value of Y when X = 8.0

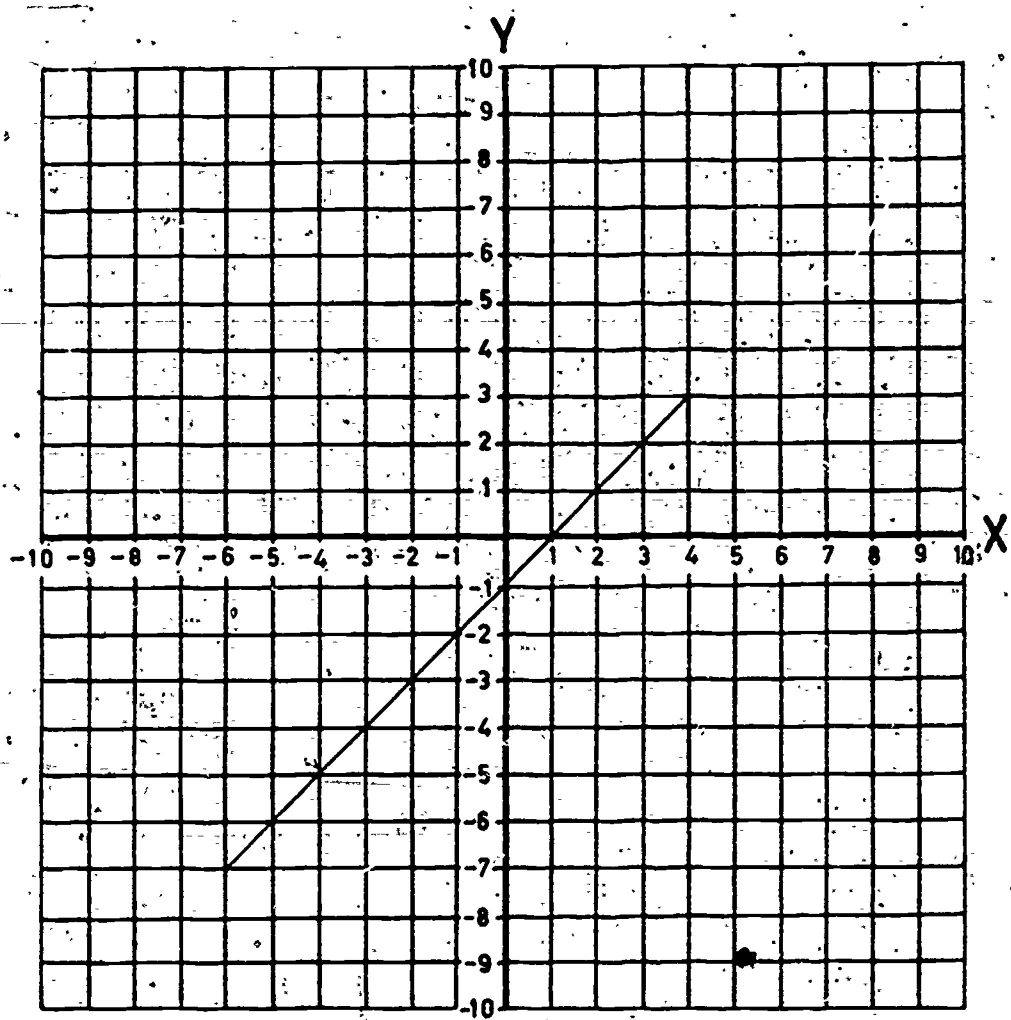
ANSWER ______ ______
(sign) (number)



Calculate the value of Y when X = 6.0

ANSWER

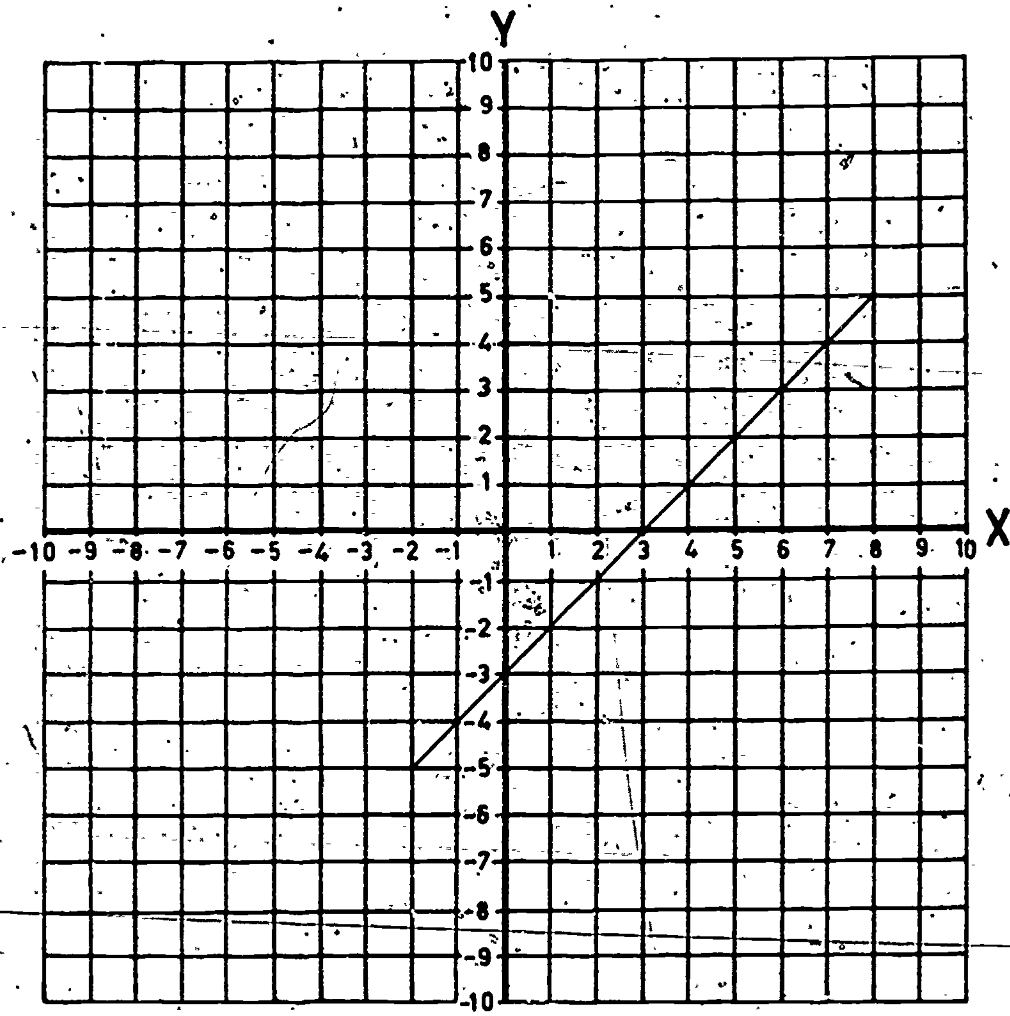
______ (sign) ______ (number)



Calculate the value of X when Y = 5.0

ANSWER

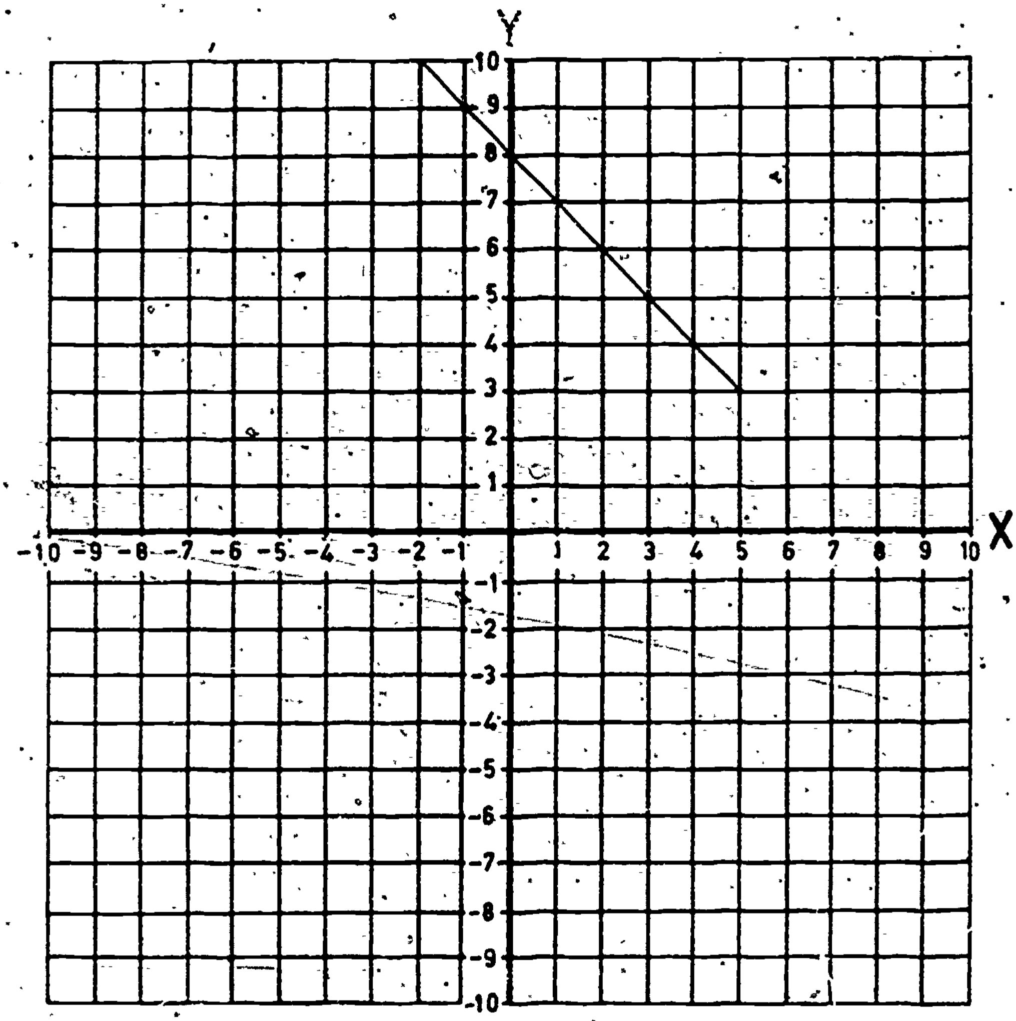
______ (sign) ______ (number)



Calculate the value of X when Y = 7.0

ANSWER

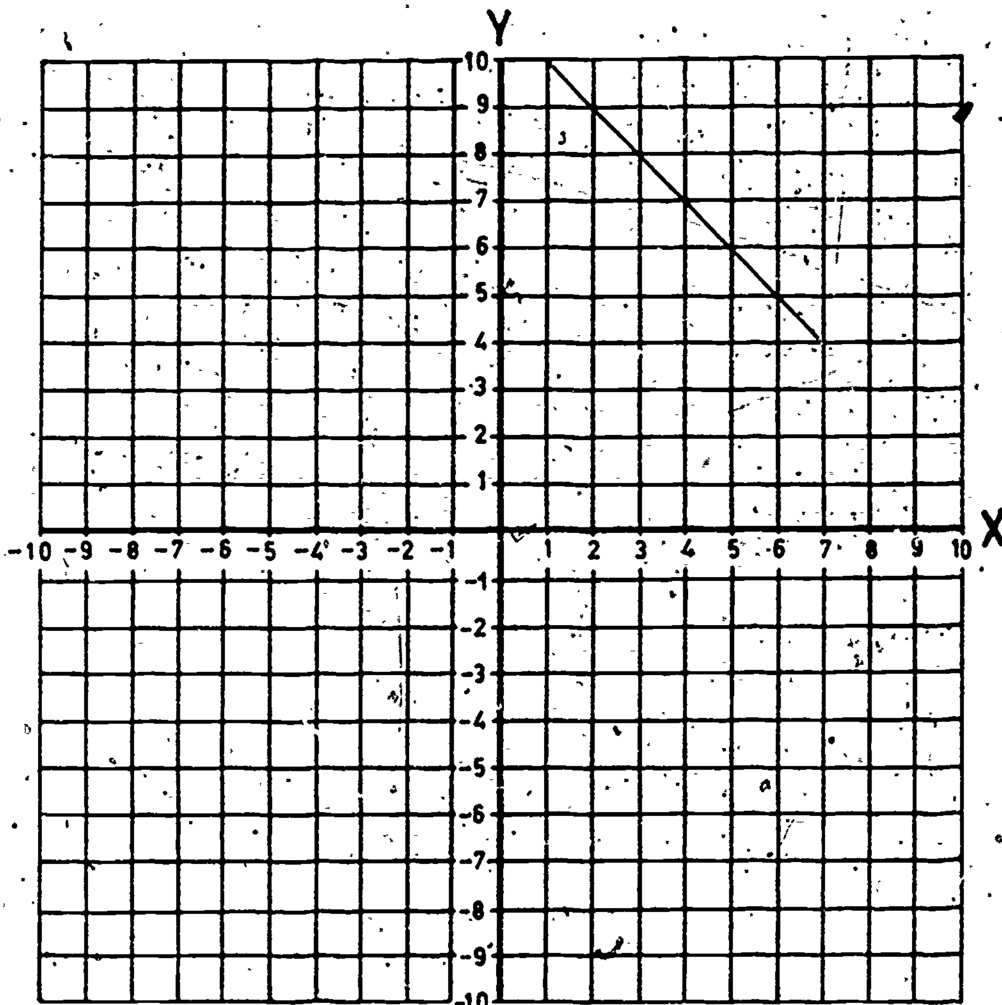
______ (sign) ______ (number)



Calculate the value of Y when X = 7.0

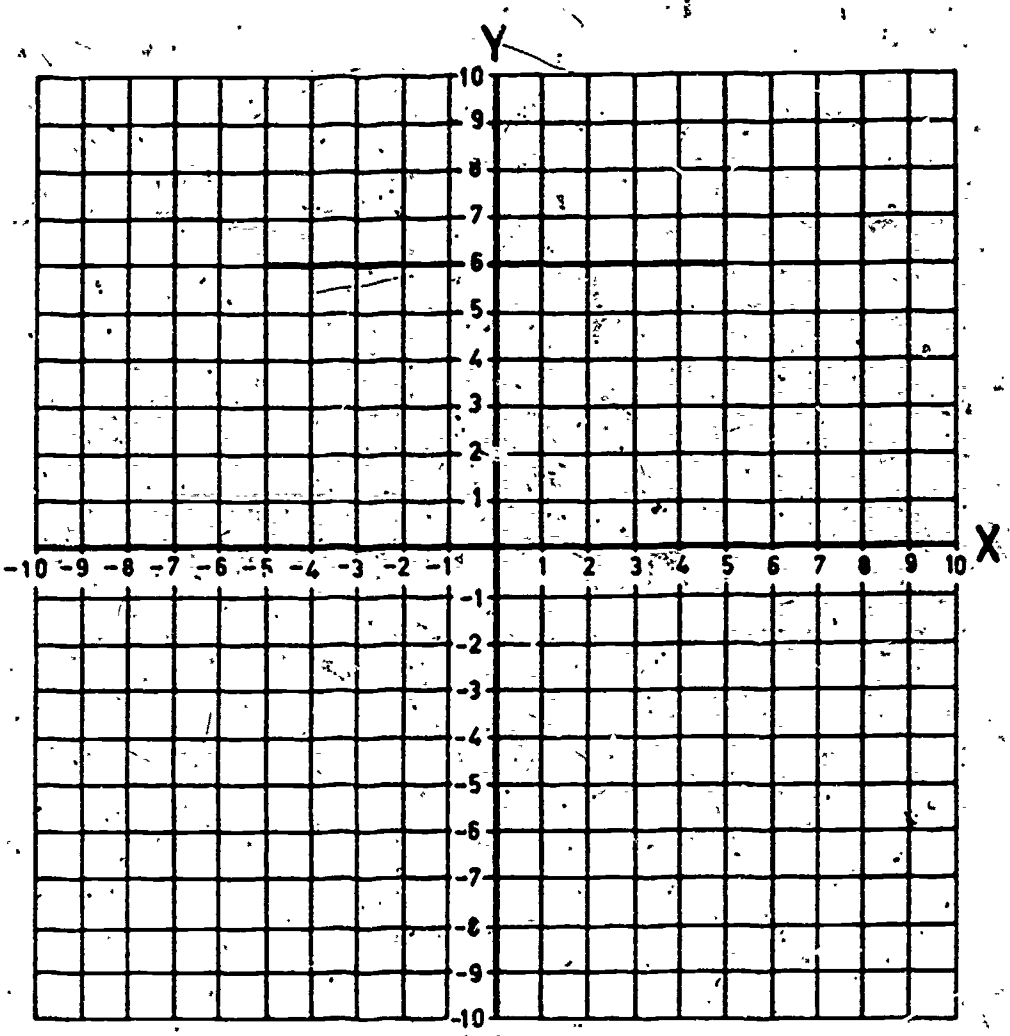
ANSWER

________ __________
(sign) (number)



Calculate the value of Y when X = 9.0

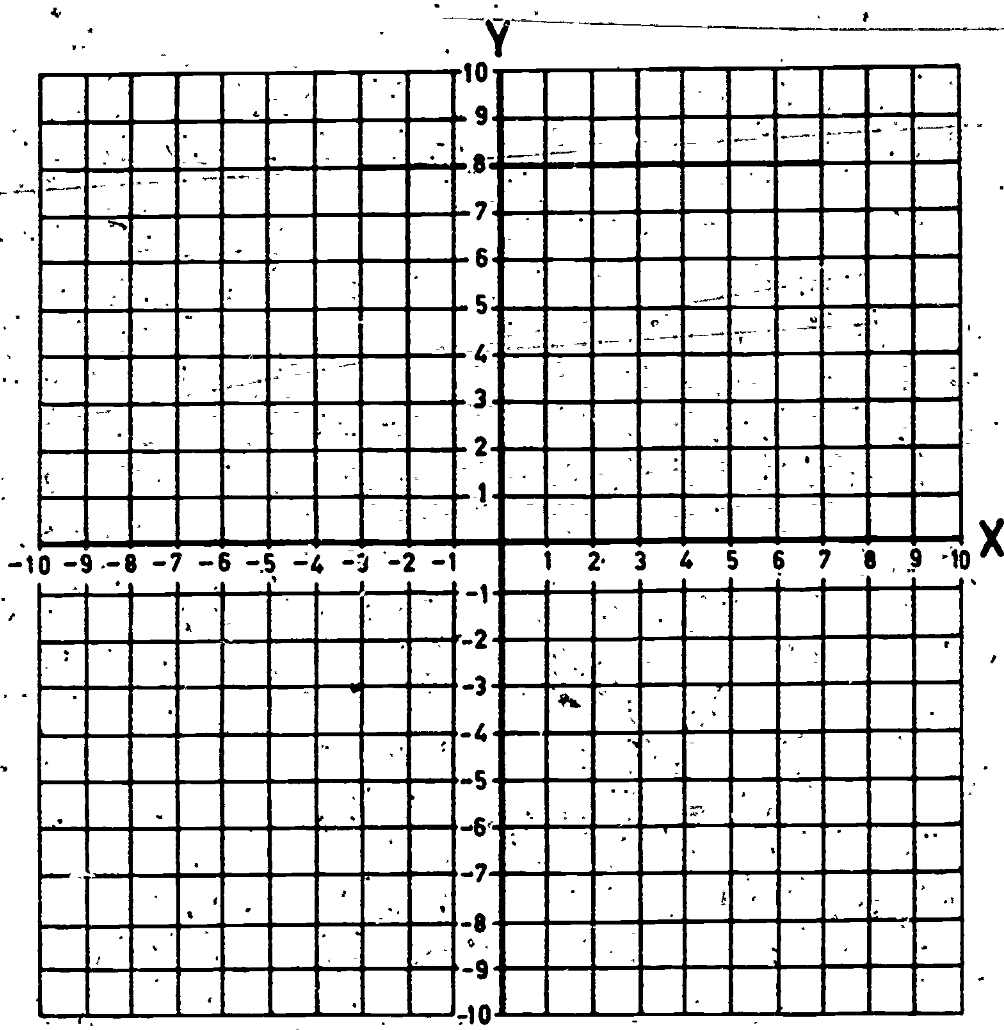
ANSWER ______ ______
(sign) (number)



Calculate the value of Y when X = 7.0

ANSWER

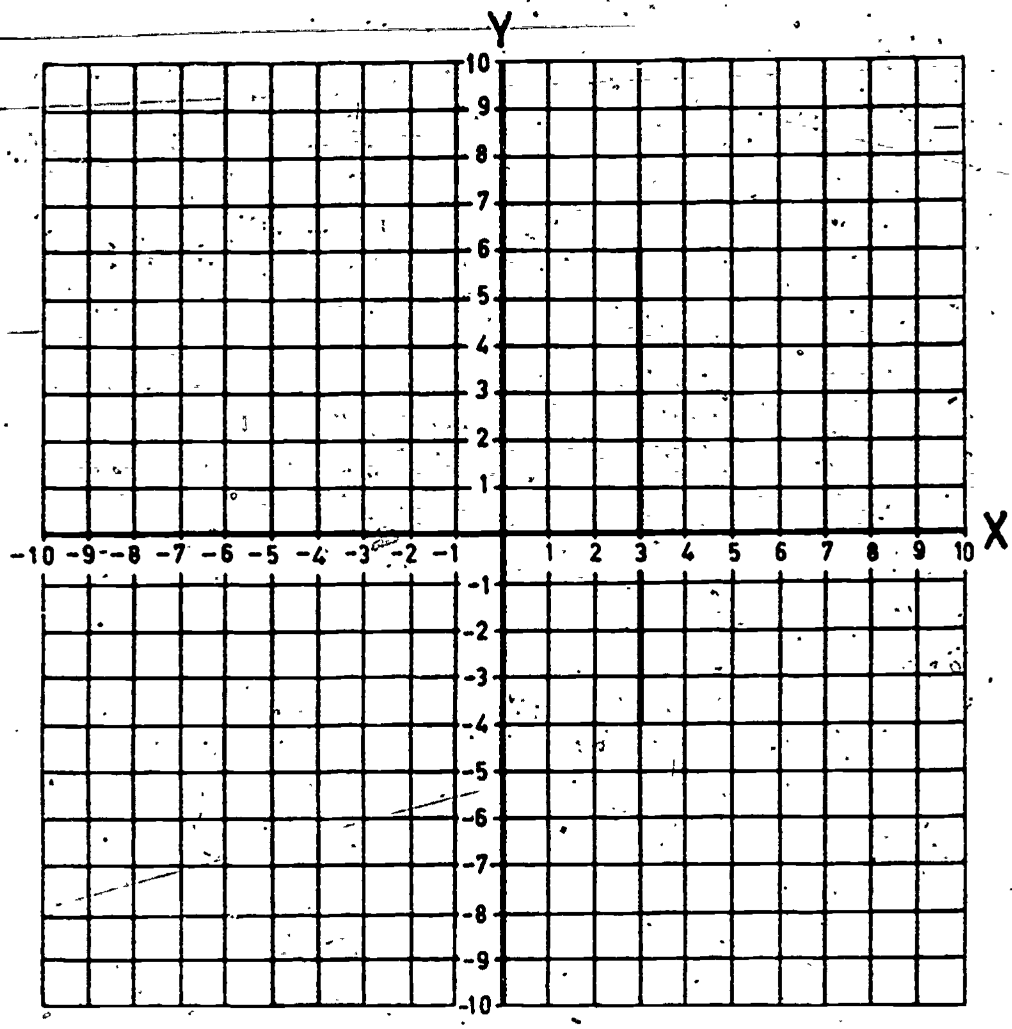
______ ______
(sign) (number)



Calculate the value of Y when X = 9.0

ANSWER

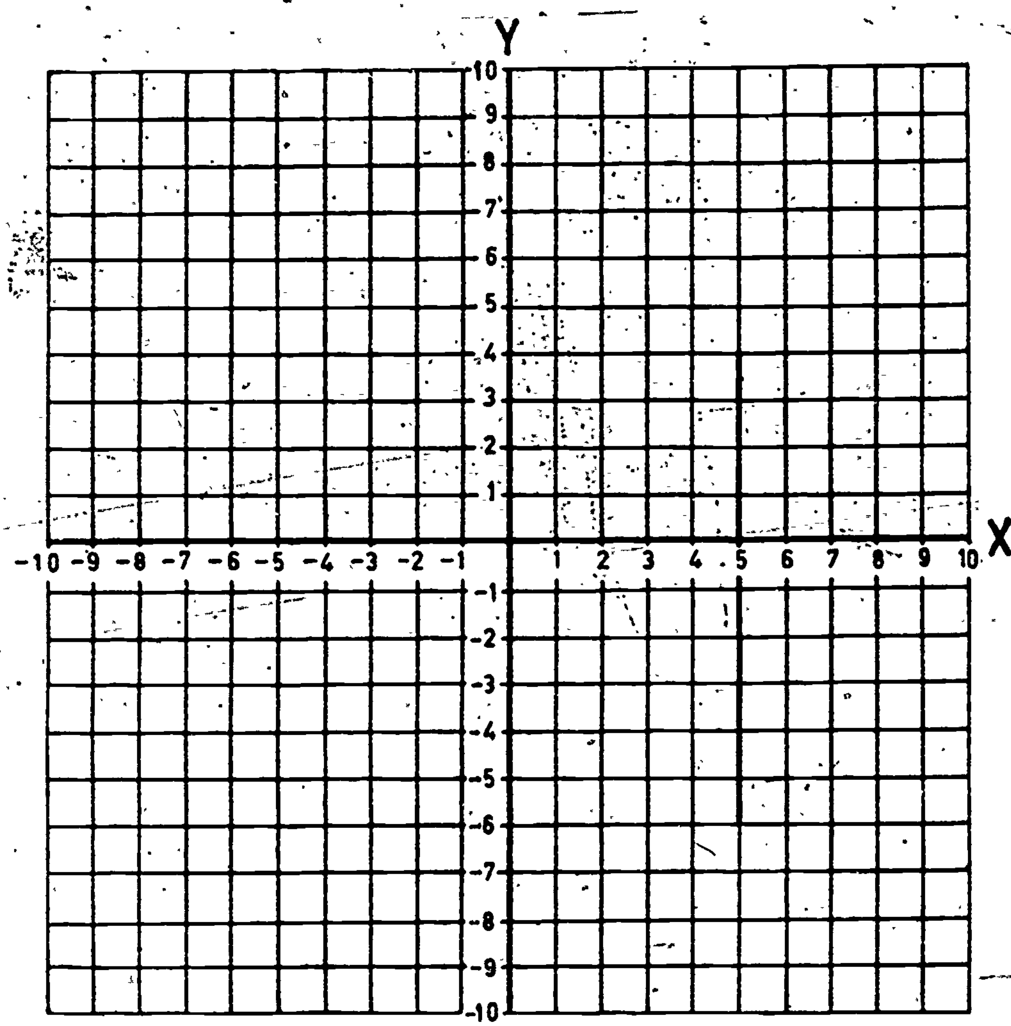
______ ______
(sign) (number)



Calculate the value of X when Y = 8.0

ANSWER

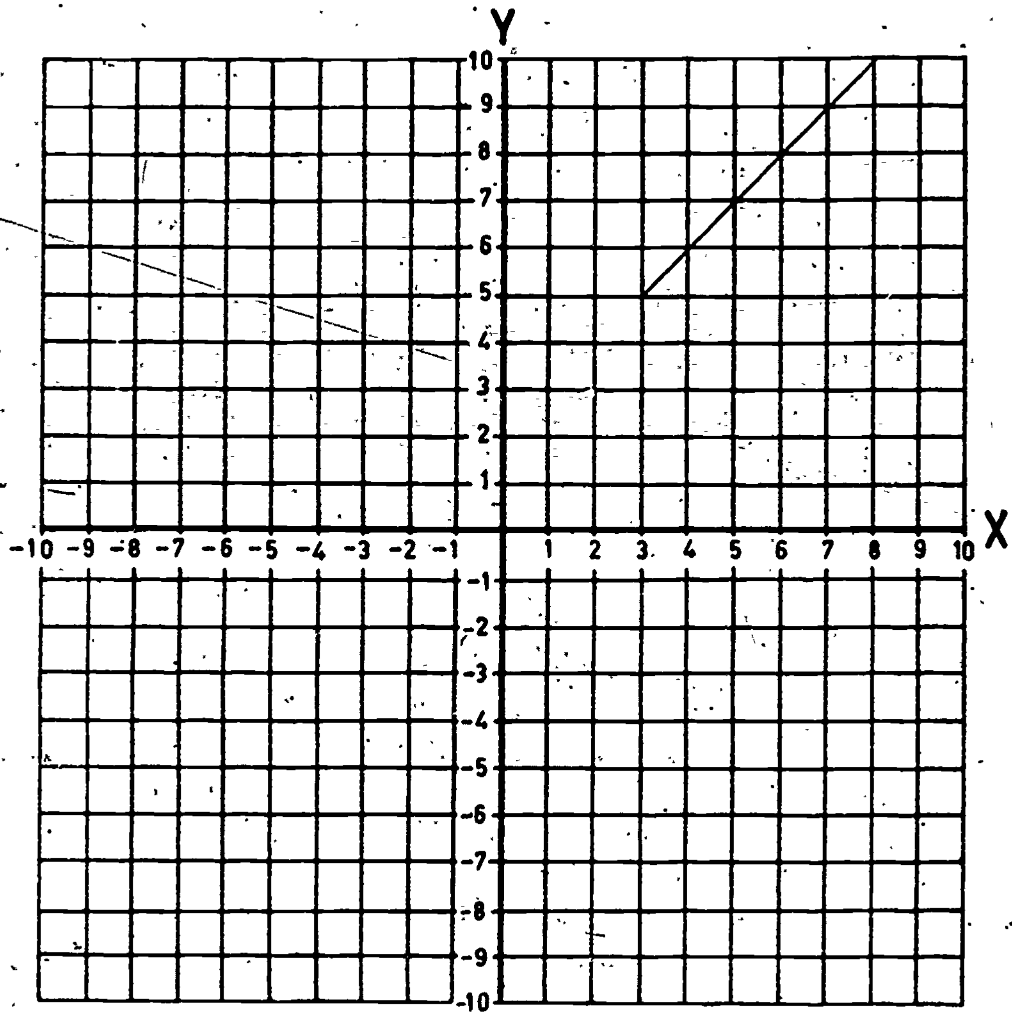
______ ________
(sign) (number)



Calculate the value of X when Y = 6.0

ANSWER

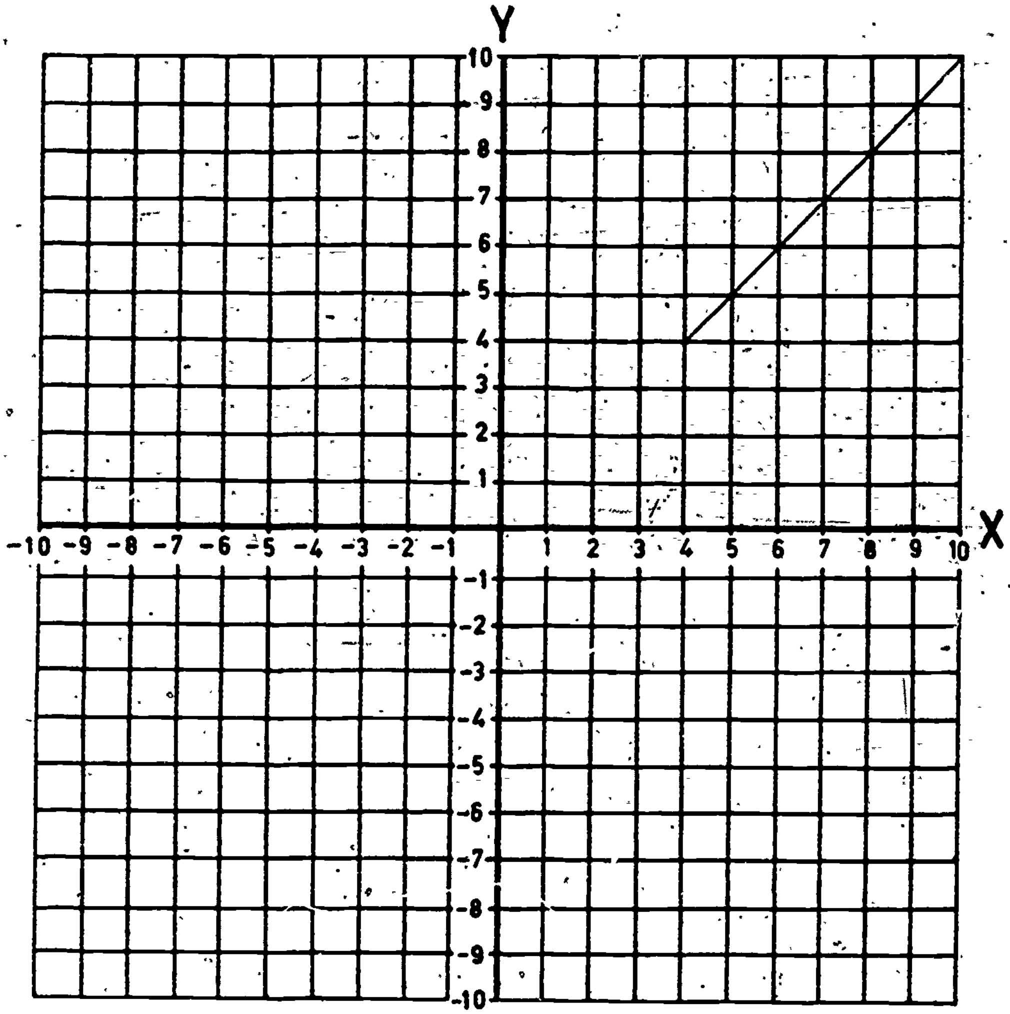
_______ _______
(sign) (number)



- Calculate the value of Y when X = 1.0

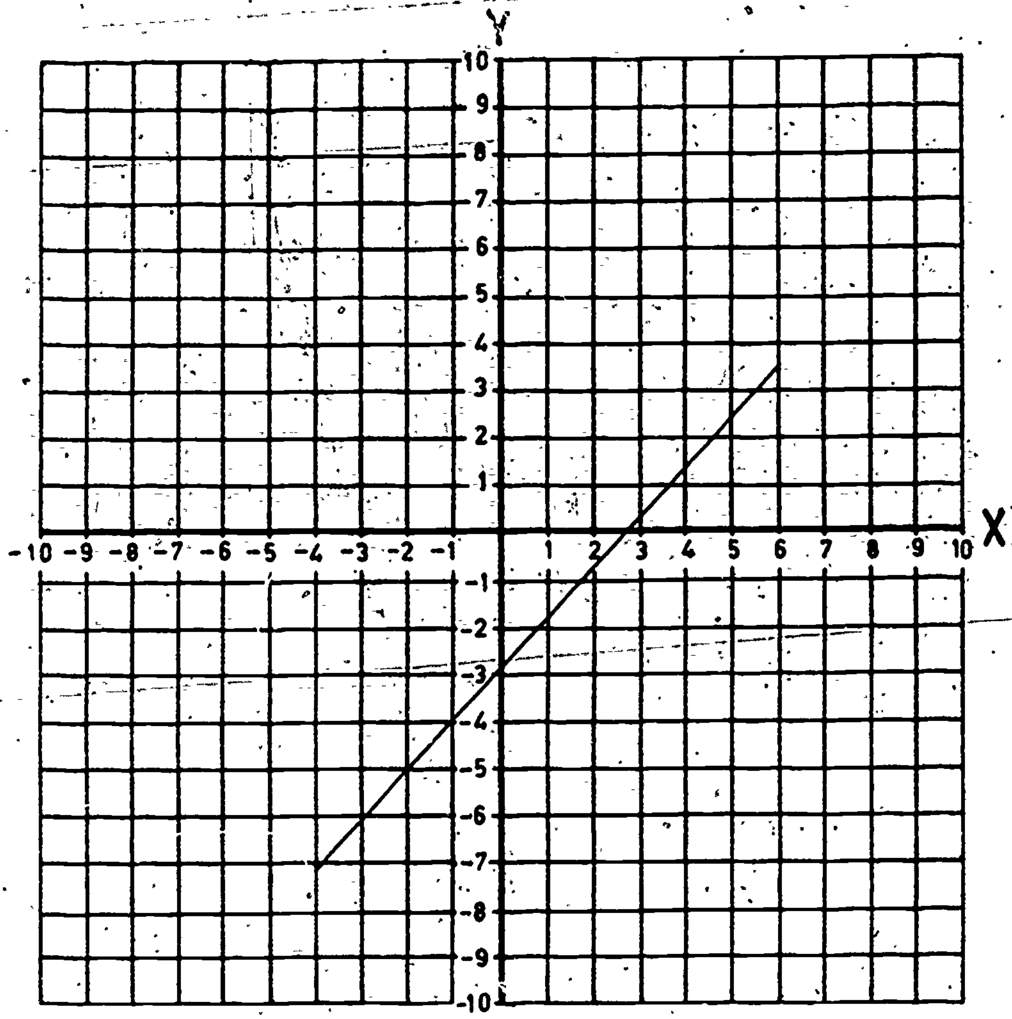
ANSWER

_______ _________
(sign) (number)



Calculate the value of Y when X = 2.0

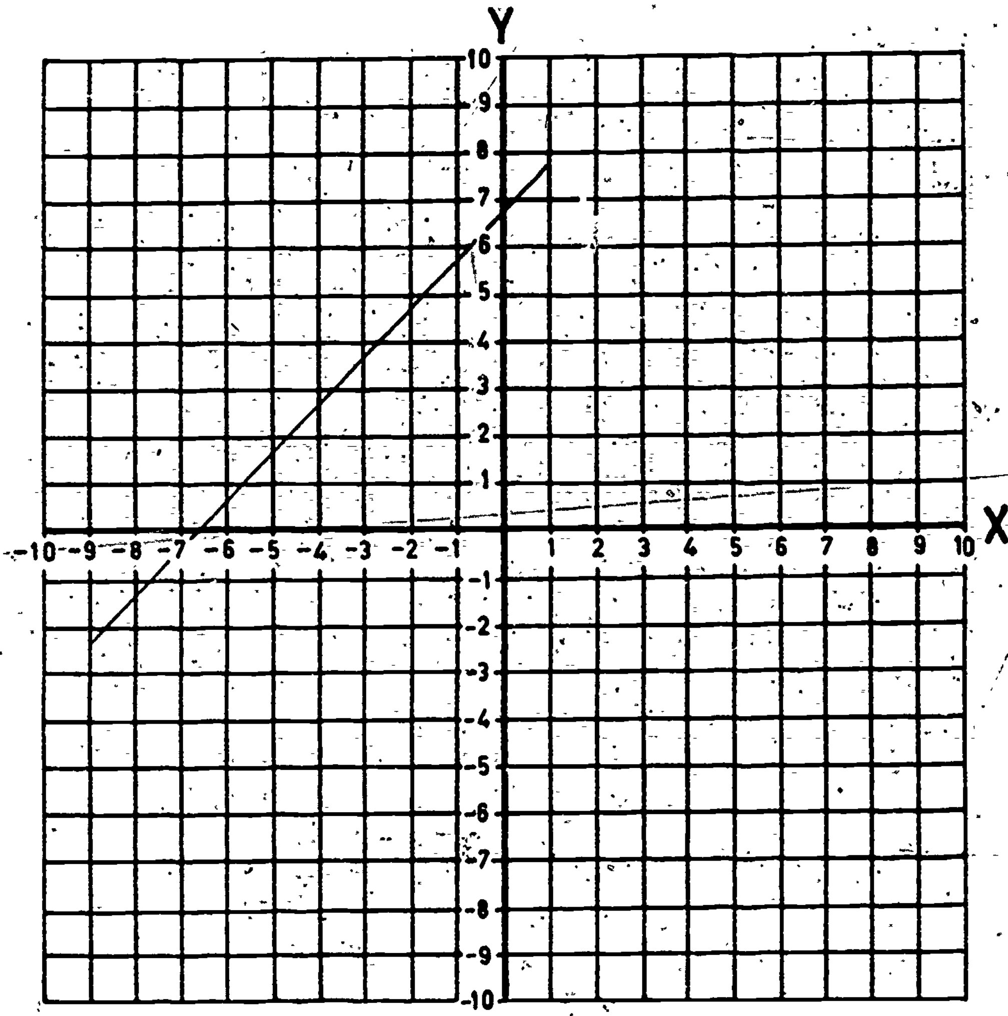
ANSWER ________ ________
(sign) (number)



Calculate the value of Y when X = 8.0

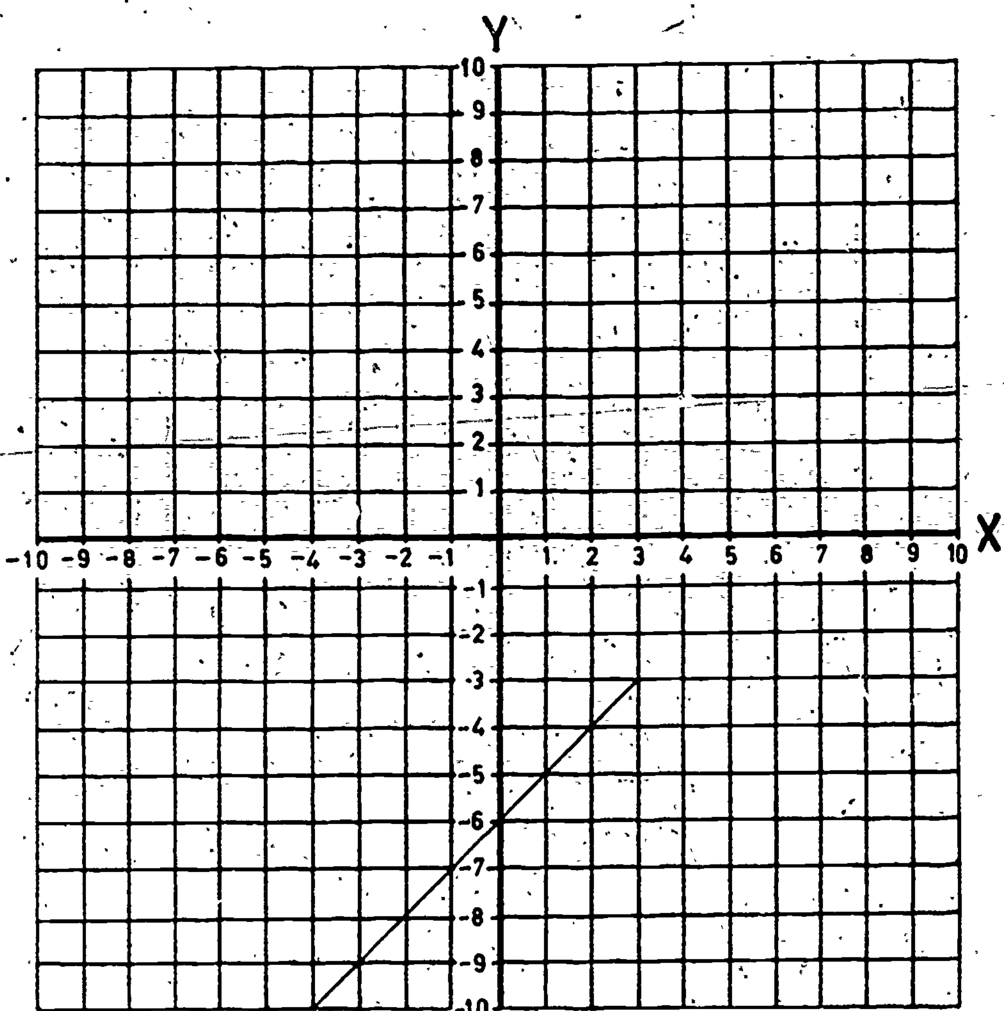
ANSWER

______ ______
(sign) (number)



Calculate the value of Y when X = 3.0

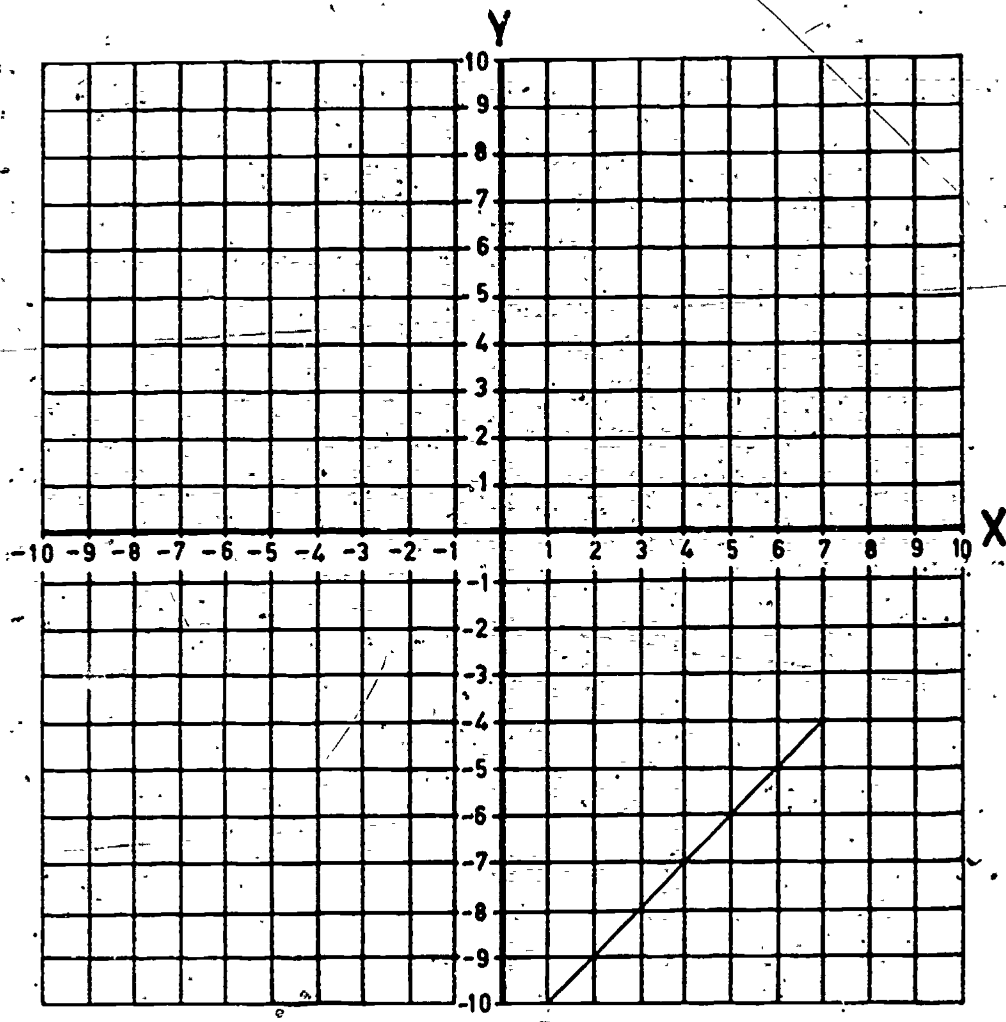
ANSWER: ______ ______
(sign) (number)



Calculate the value of Y when X = 5.0

ANSWER

_______ _______
(sign) (number)

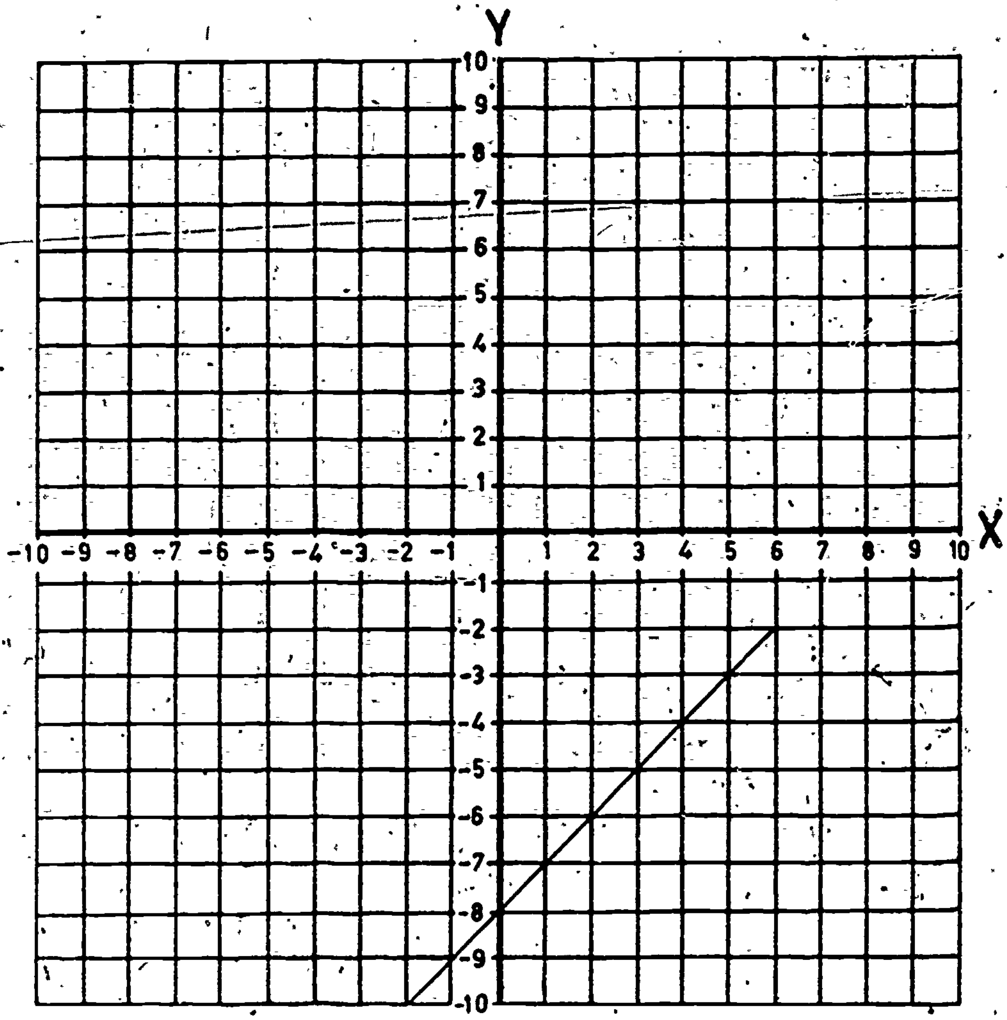


Calculate the value of Y when X = 9.0

ANSWER

________ ____________

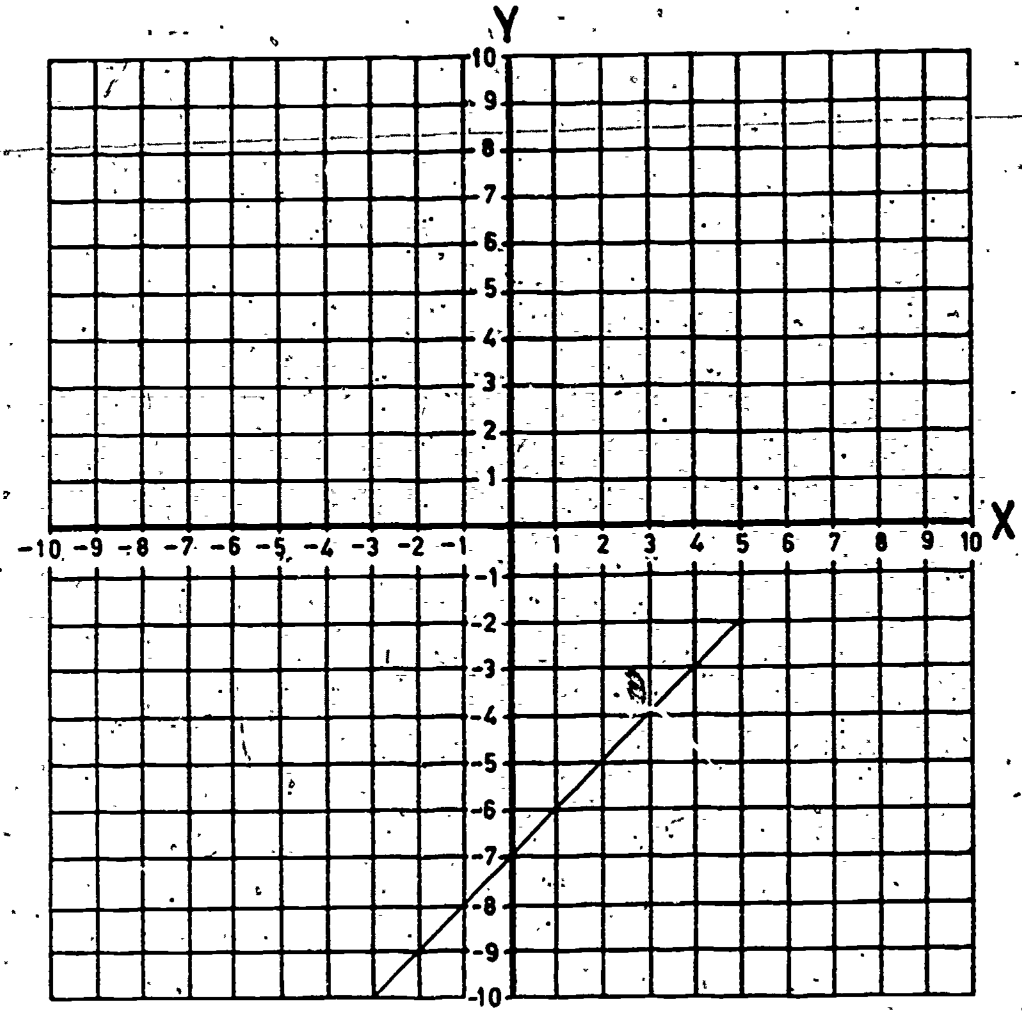
(sign) (number)



Calculate the value of Y when X = 8.0

ANSWER

______ ______
(sign) (number)

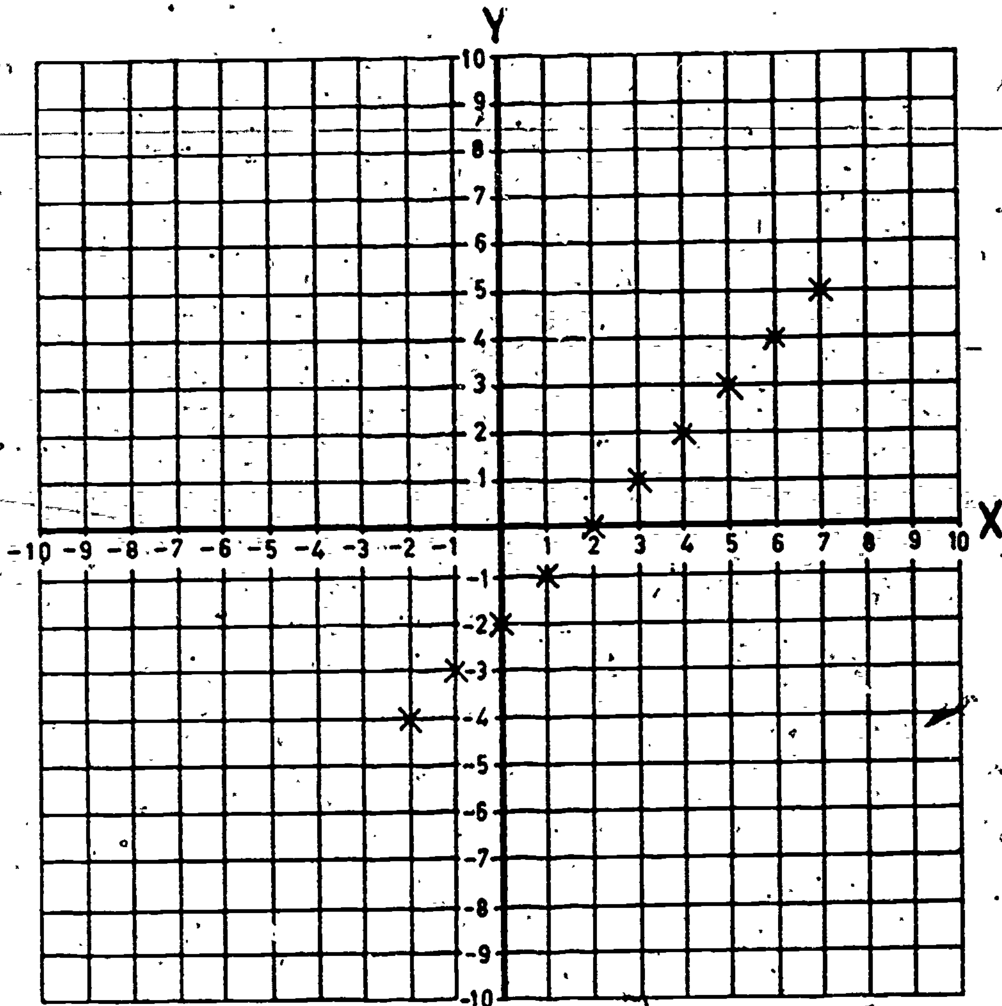


Calculate the value of Y when X = 7.0

ANSWER

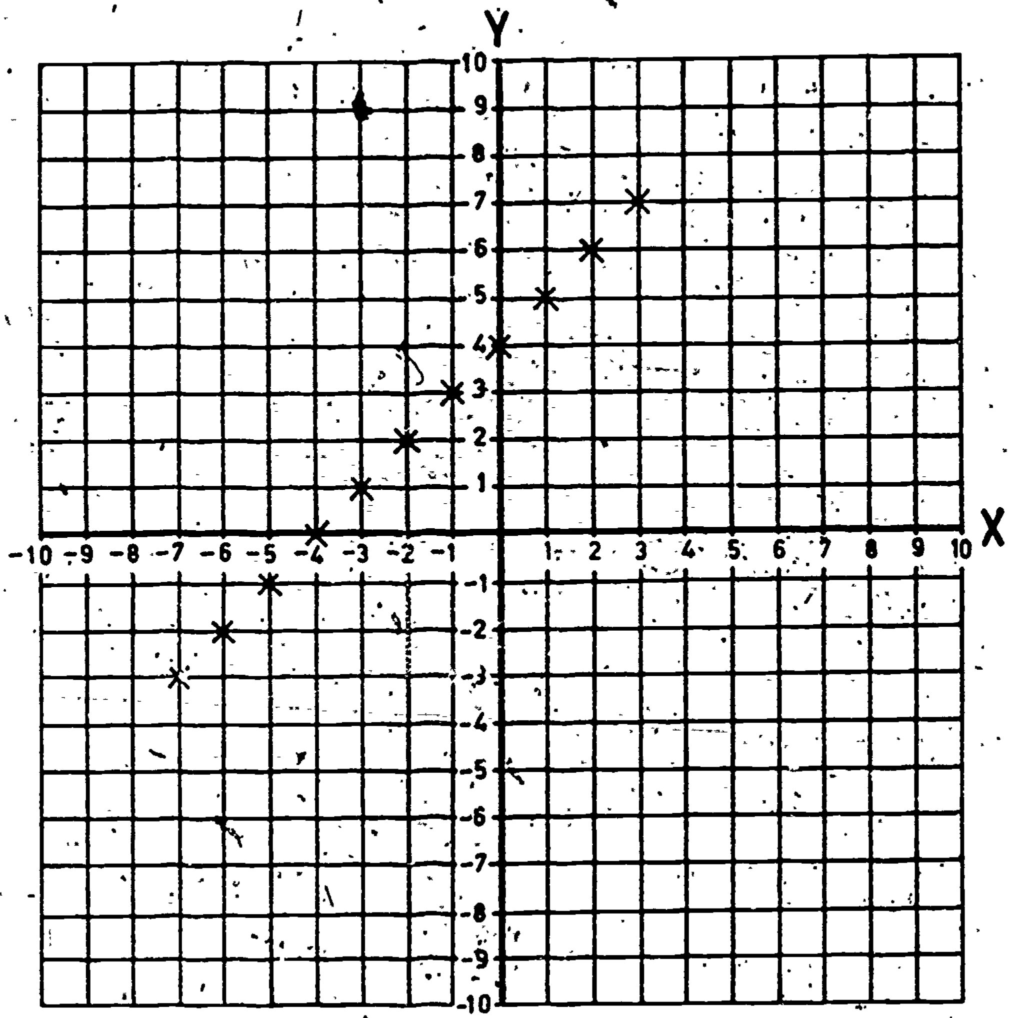
______ ______

(sign) (number)



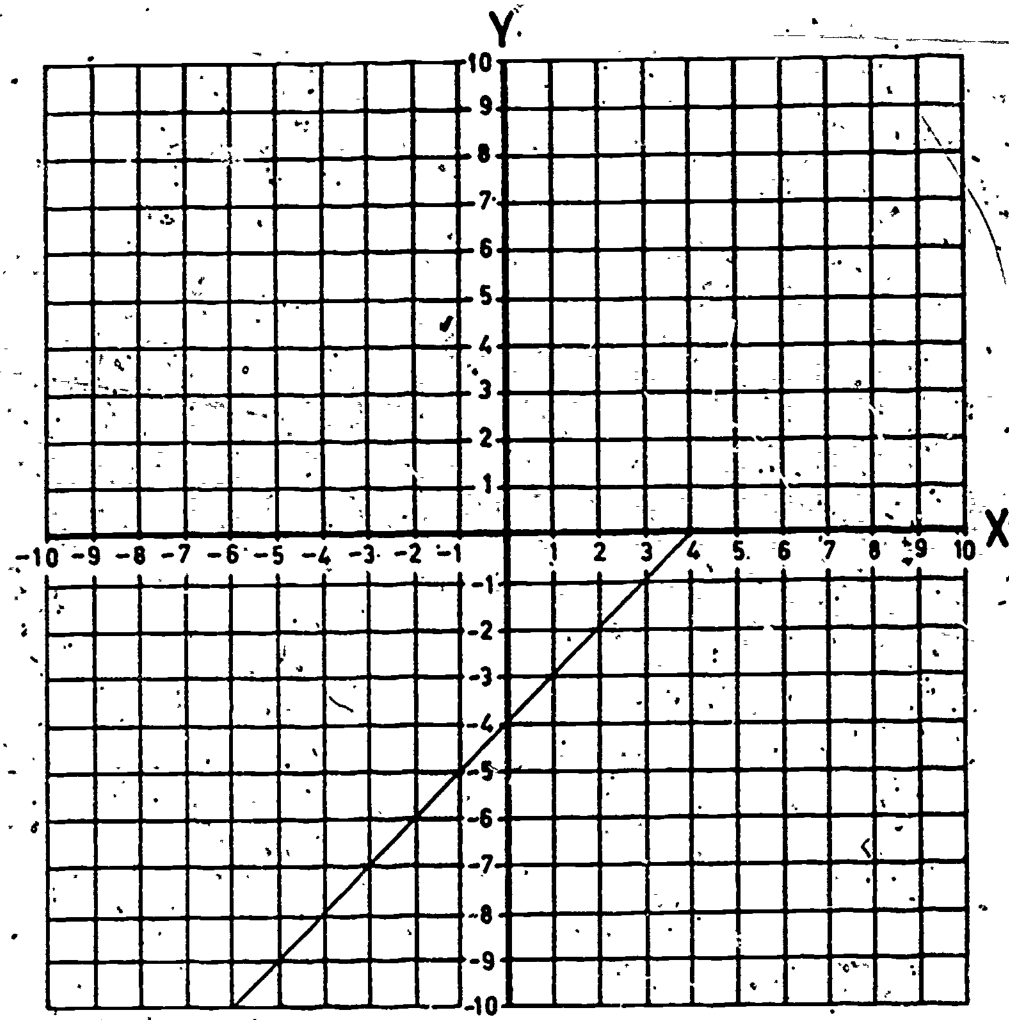
Calculate the value of Y when X = 9.0

ANSWER ______ ______
(sign) (number)



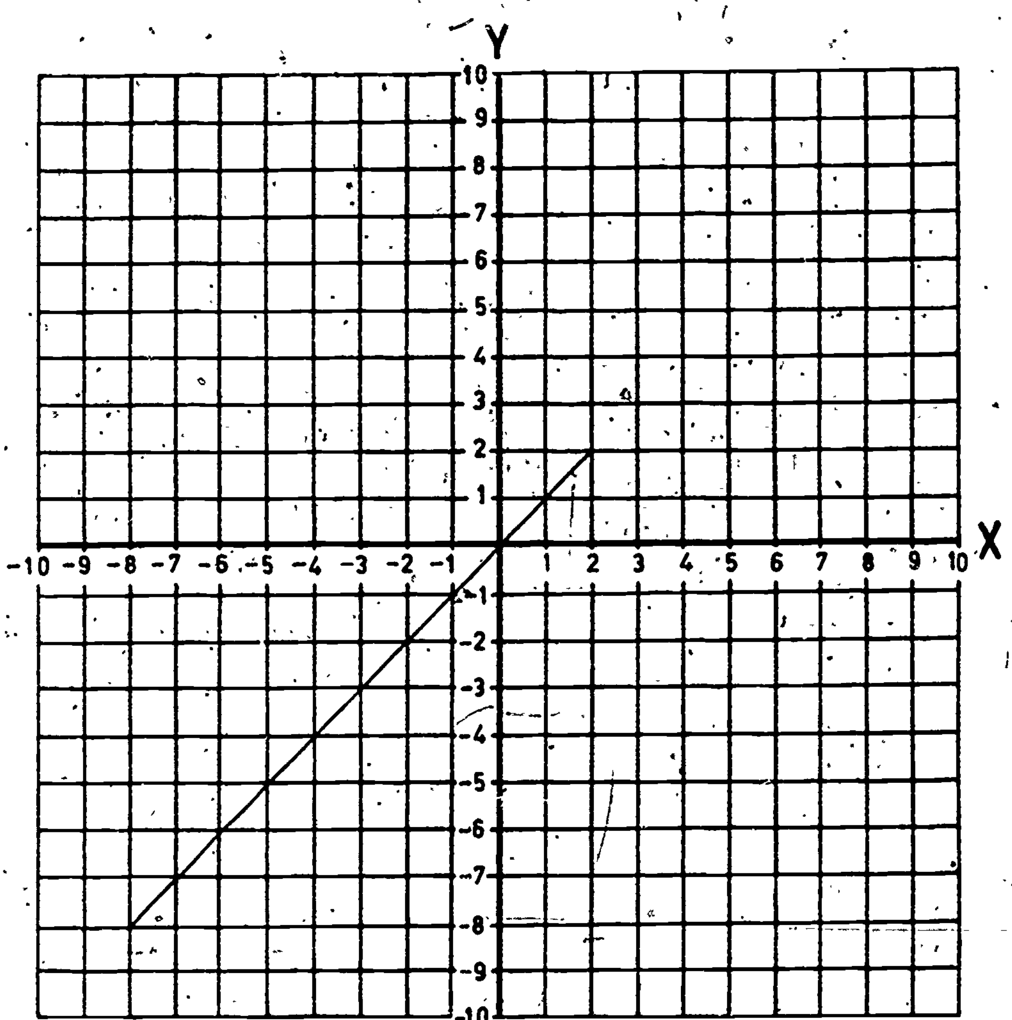
Calculate the value of Y when X = 5.0.

ANSWER ______ ______
(sign) (number)



Calculate the value of Y when X = 10.0

ANSWER ______ ______
(sign) (number)



Calculate the value of Y when X = 8.0

ANSWER

______ ______

(sign) (number)

BASIC SKILLS OF GRAPHICAL INTERPRETATION

SUBDIVISION ANALYSIS SET 3/1

NAME ______________ AGE ______

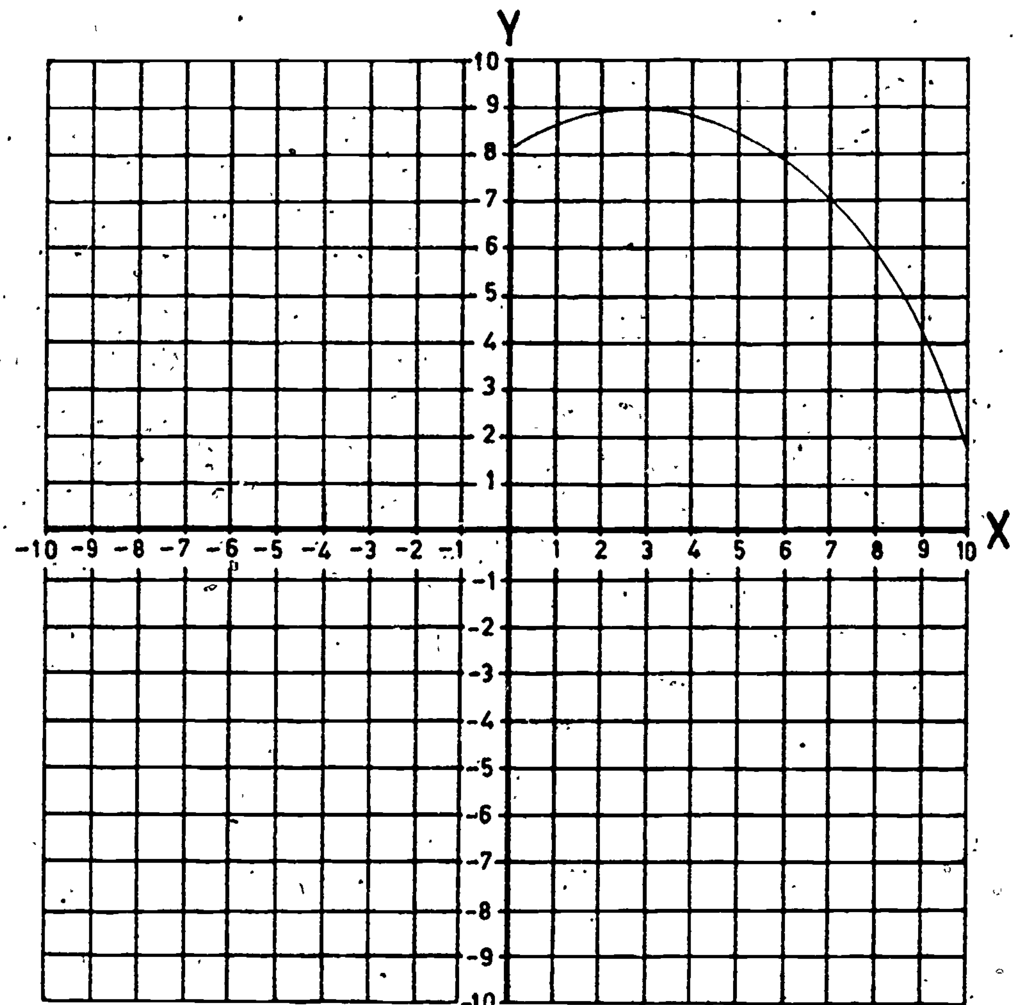
SEX ______

SCHOOL ______________ CLASS ______

DATE ______

INSTRUCTIONS

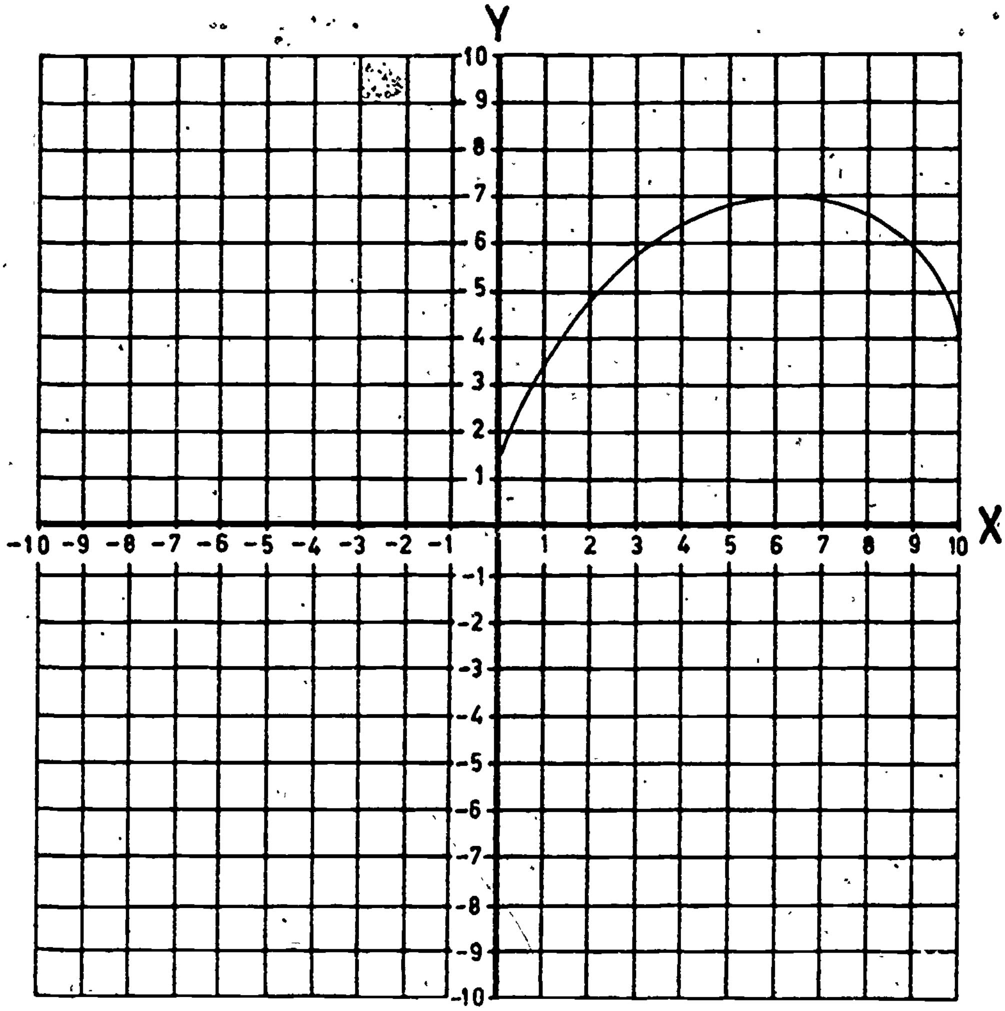
Read each question carefully, then write your answer in the space provided. Try to guess the answers to any questions you do not know, but do not waste time on more difficult problems. All answers should be given to the nearest decimal place, and any other calculations may be written on the back of the page. The sign of an answer, where this applies, should be either positive (+) or negative (-).



Calculate the maximum value of Y.

ANSWER

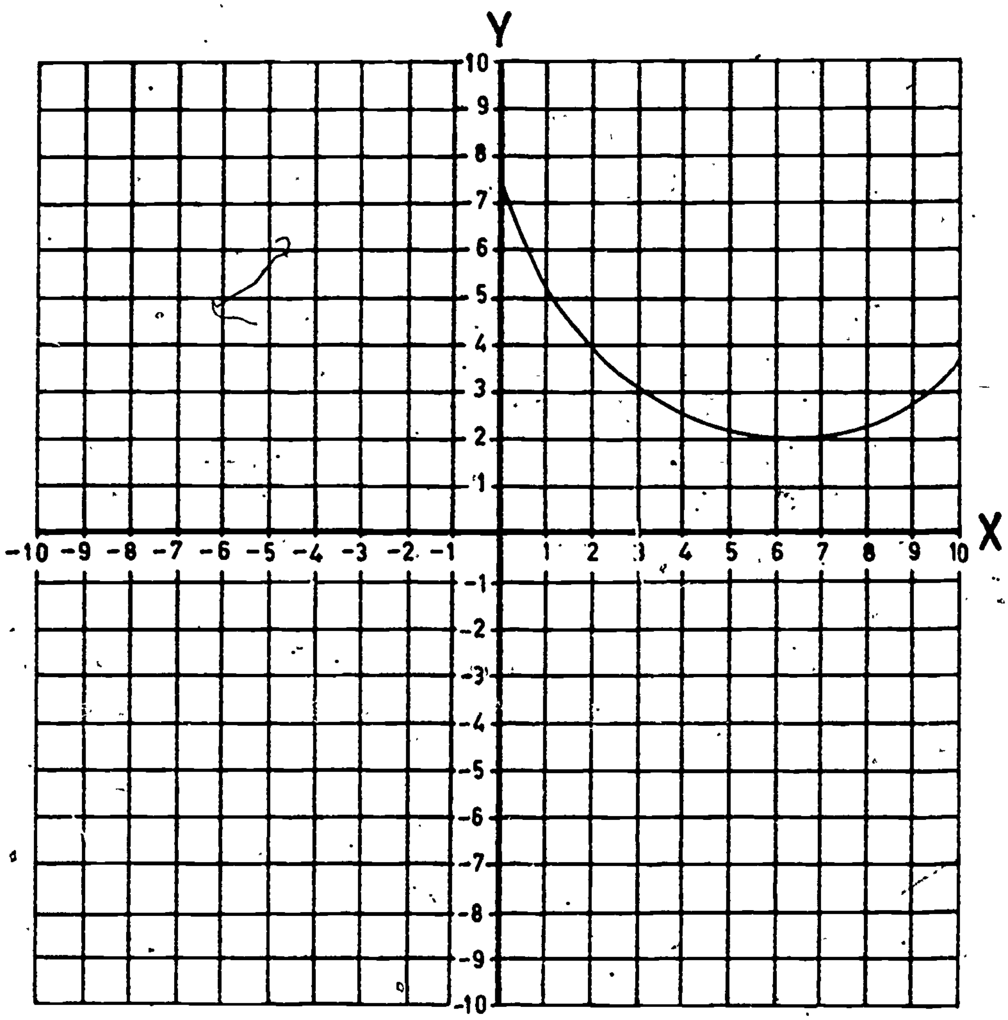
______ ______
(sign) (number)



Calculate the maximum value of Y.

ANSWER ______ ______

(sign) (number)

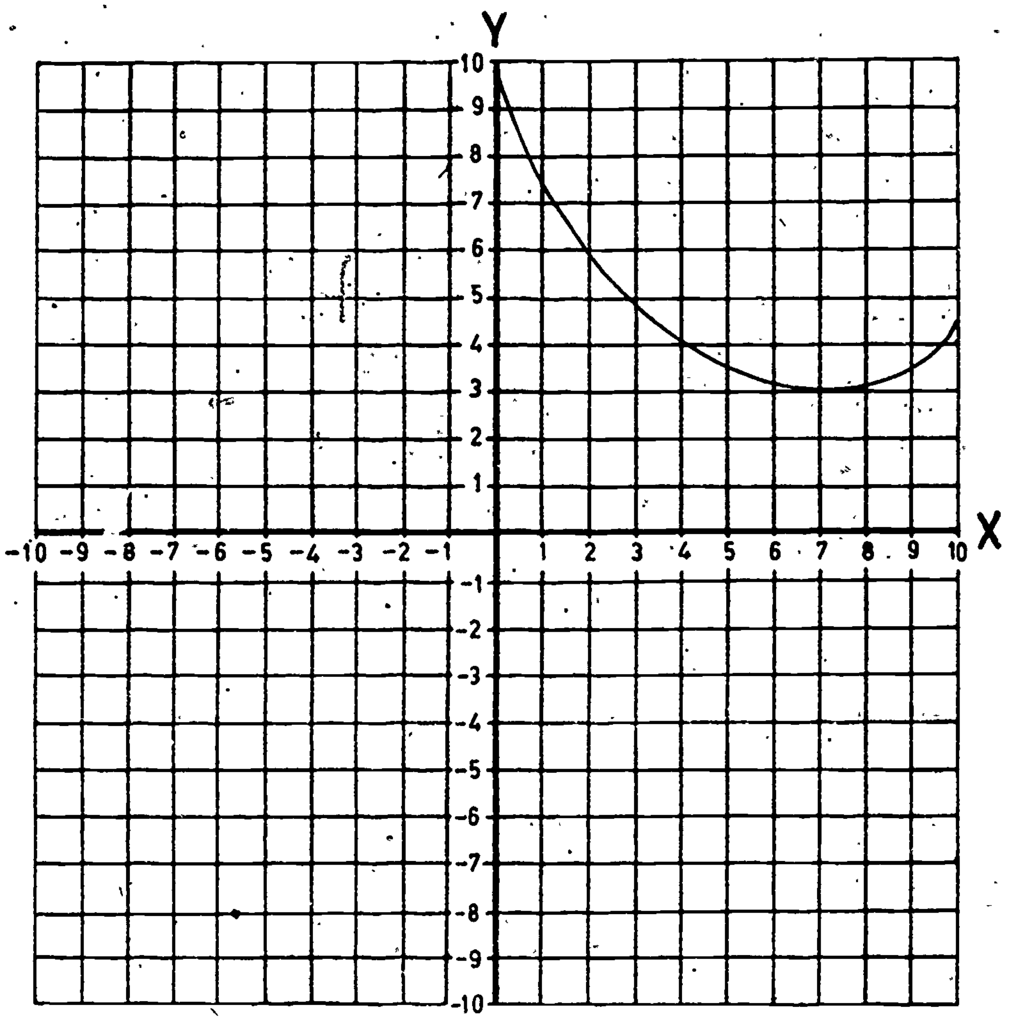


Calculate the minimum value of Y.

ANSWER

_______ _______

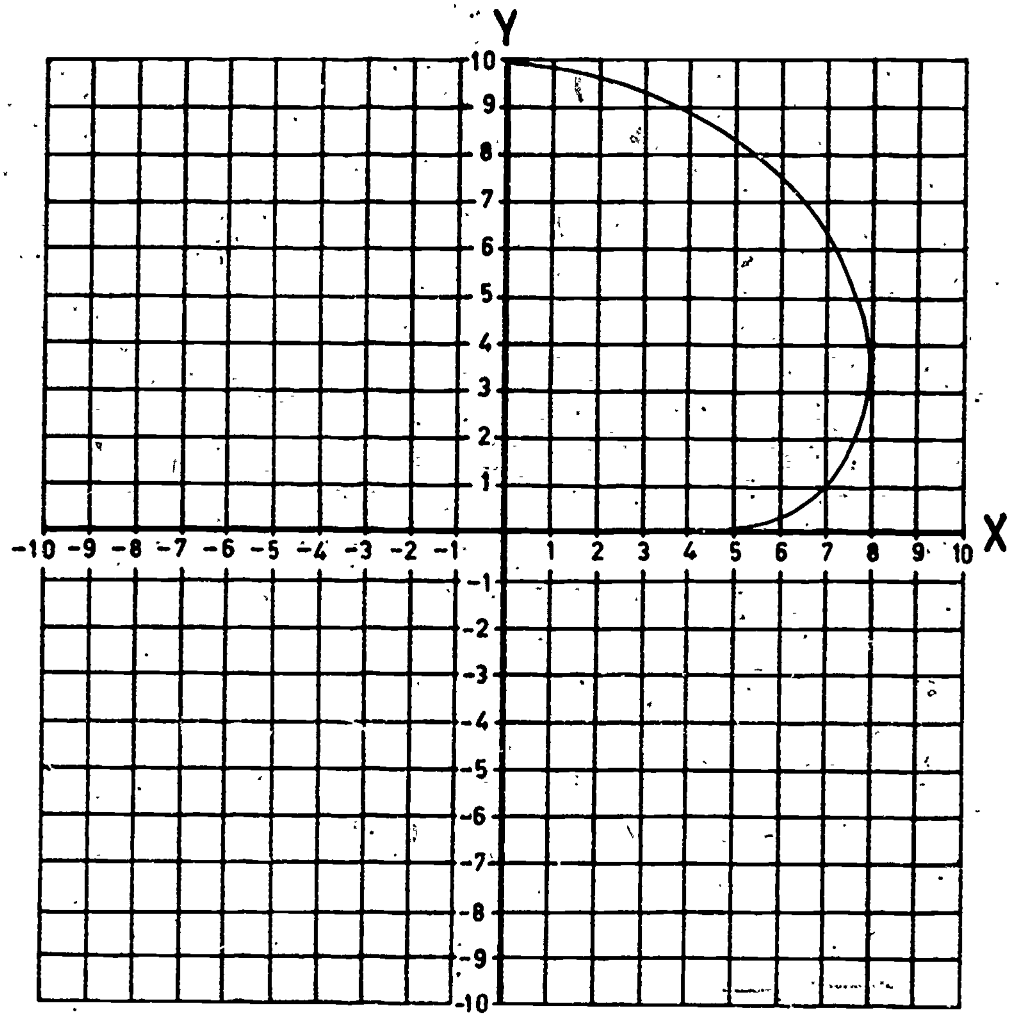
(sign) (number)



Calculate the minimum value of Y.

ANSWER

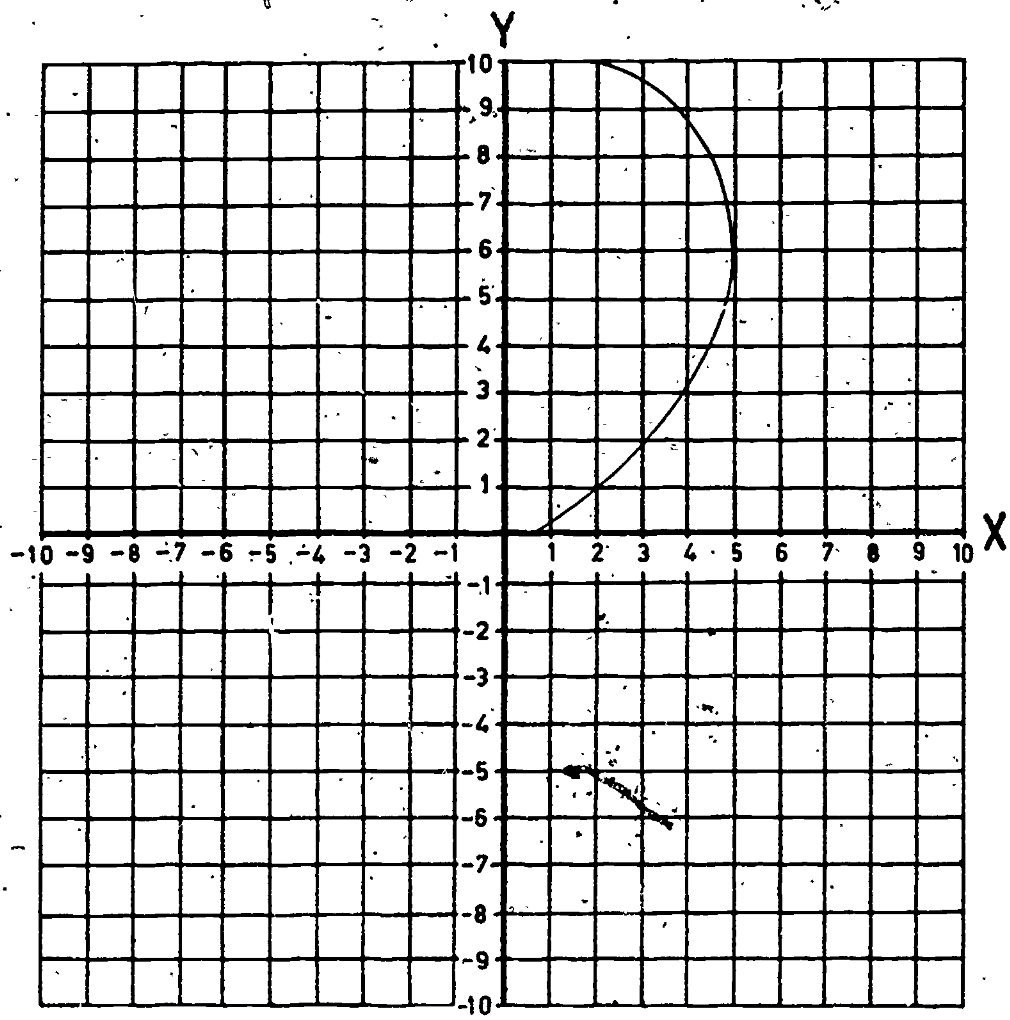
_______ (sign) _______ (number)



Calculate the maximum value of X.

ANSWER ______ ______

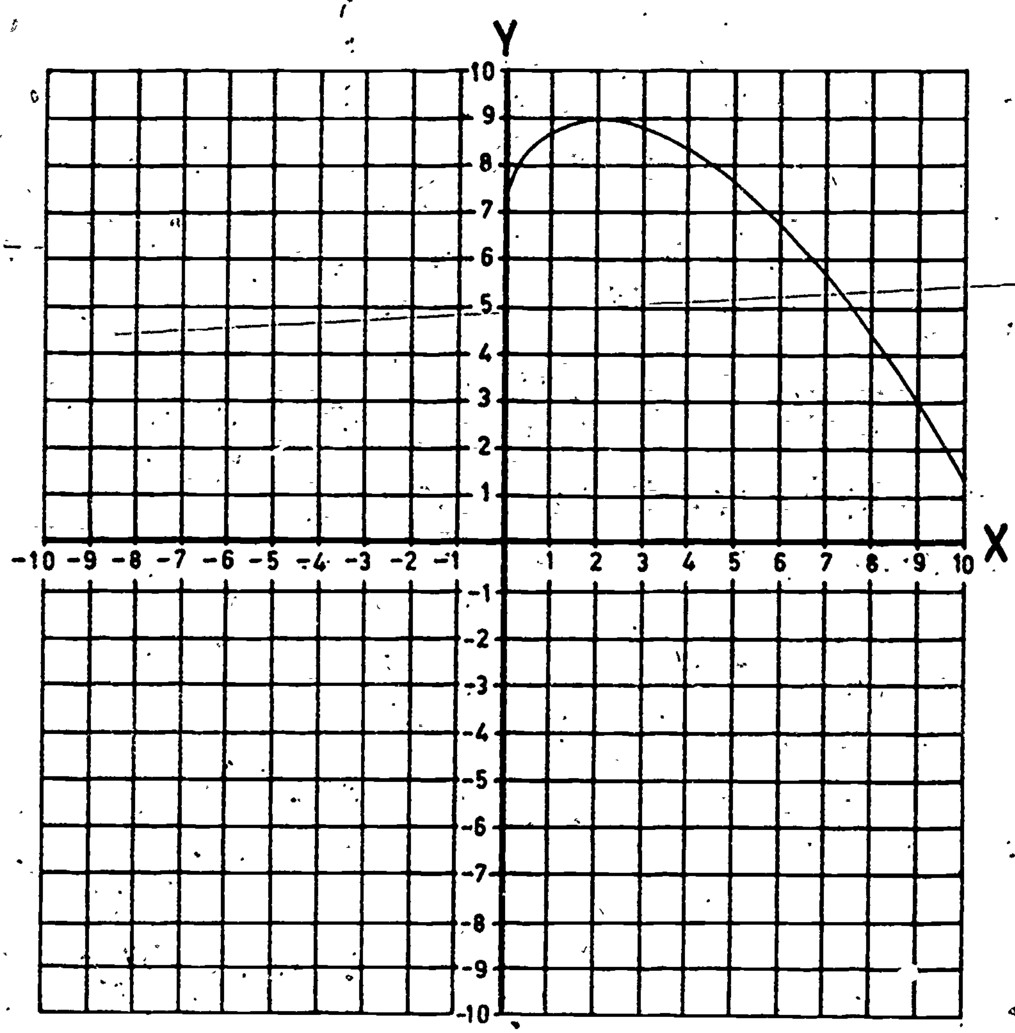
(sign) (number)



Calculate the maximum value of X.

ANSWER

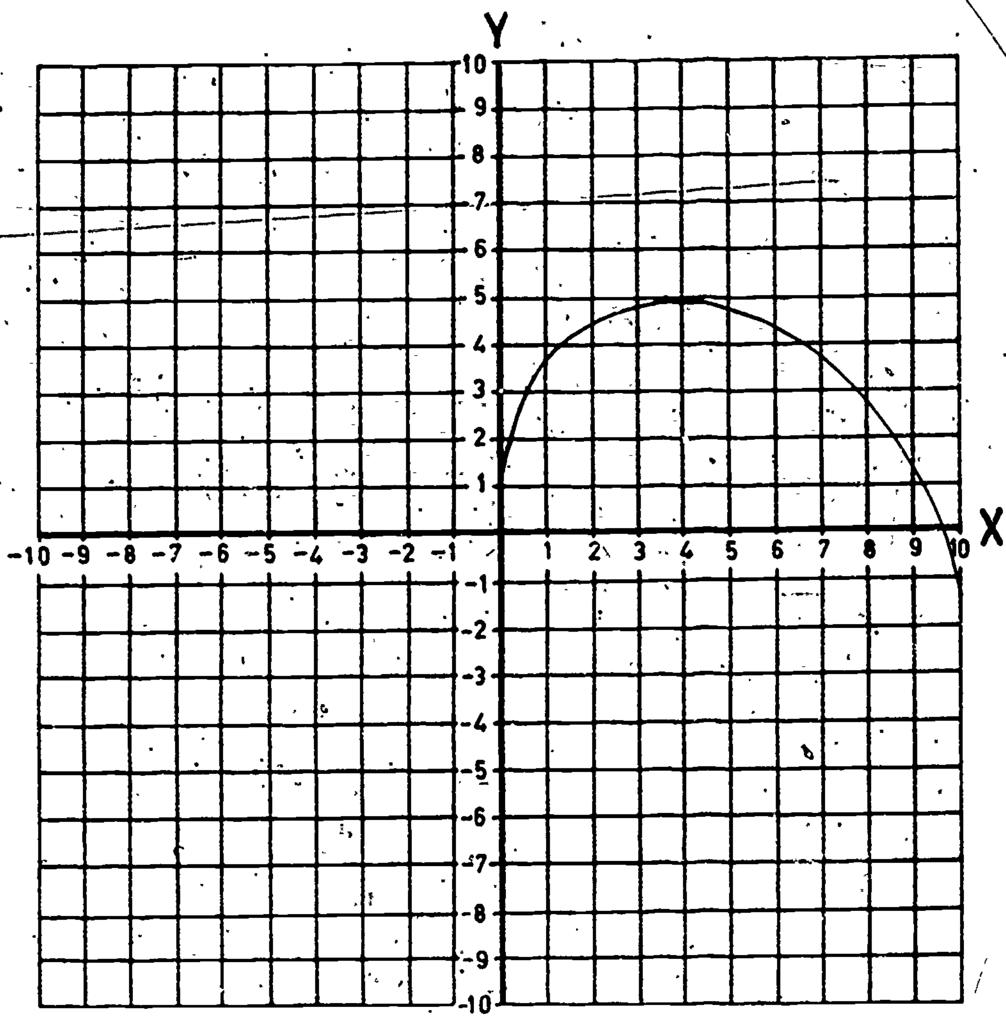
_______ (sign) _______ (number)



Calculate the value of X at the maximum turning point.

ANSWER

______ (sign) ________ (number)

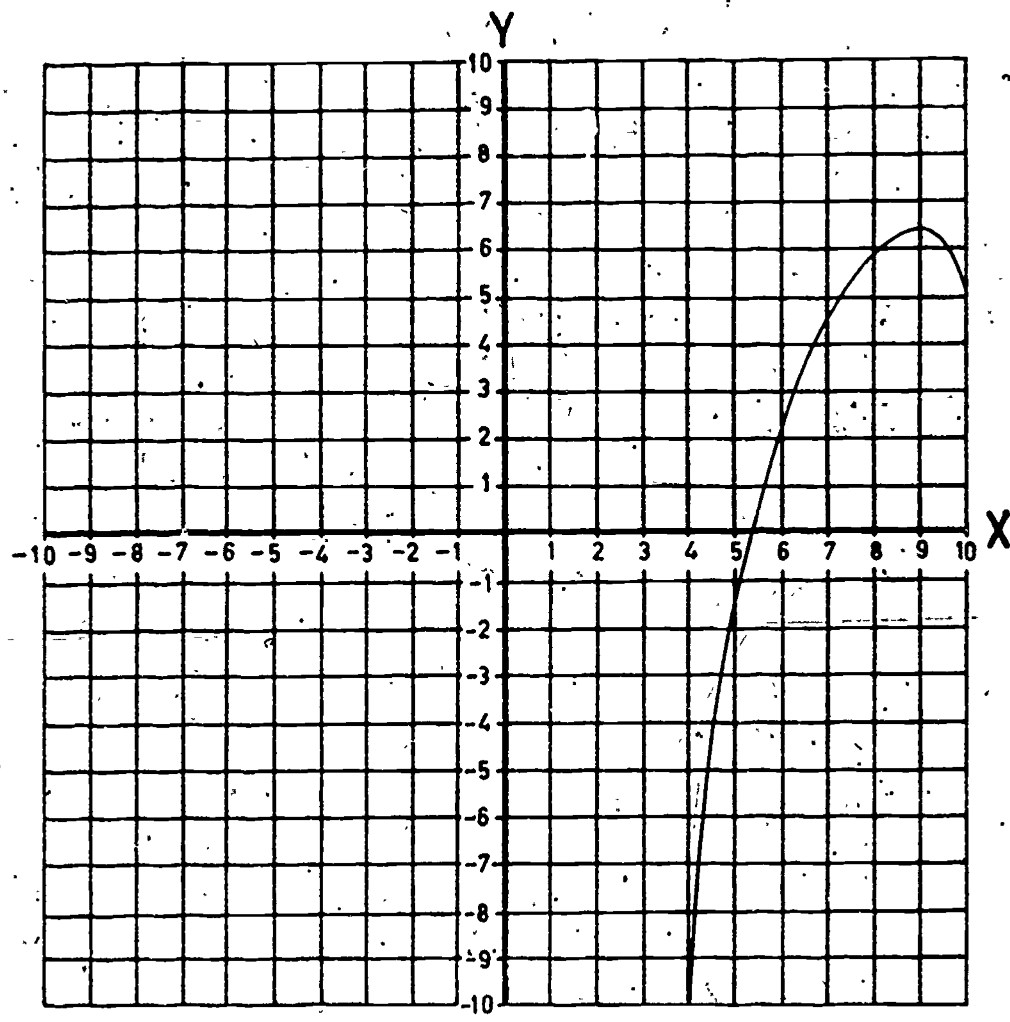


Calculate the value of X at the maximum turning point.

ANSWER

_______ _________

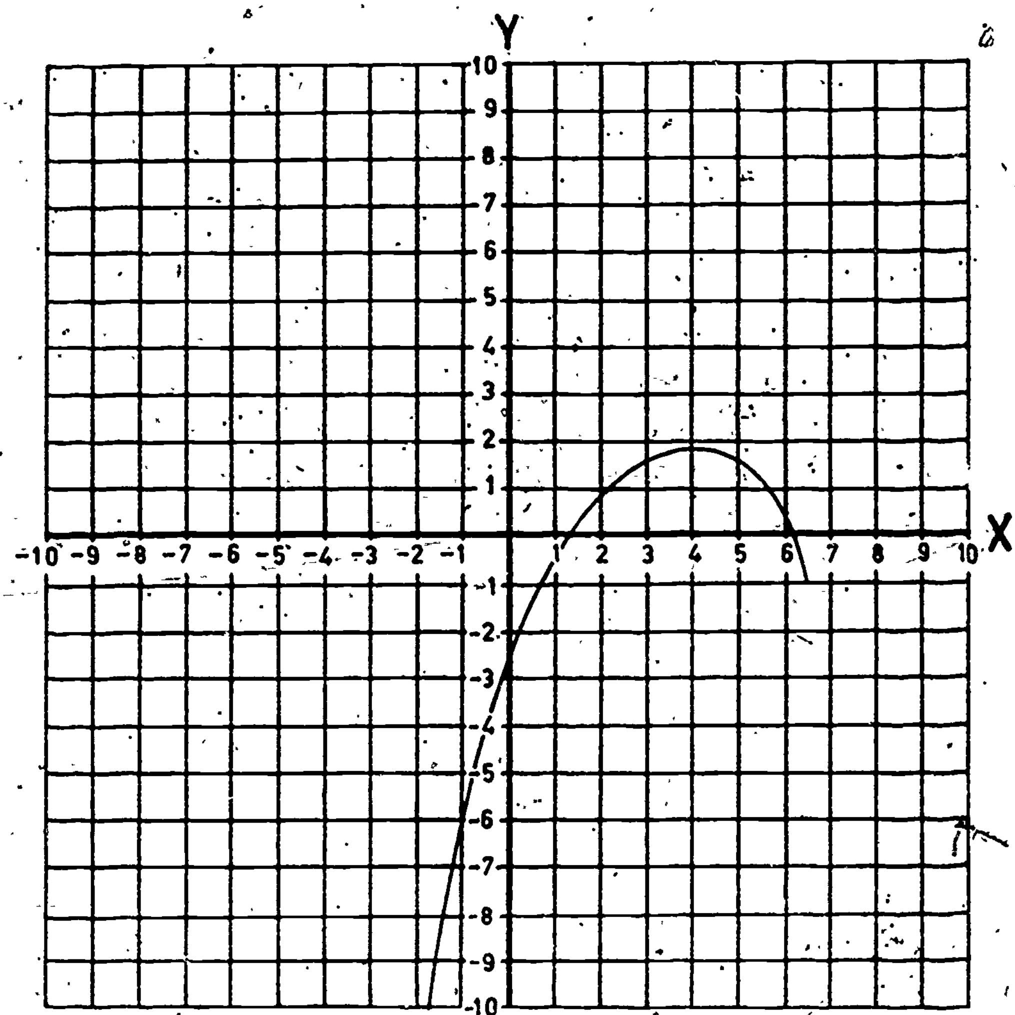
(sign) (number)



Calculate the maximum value of Y.

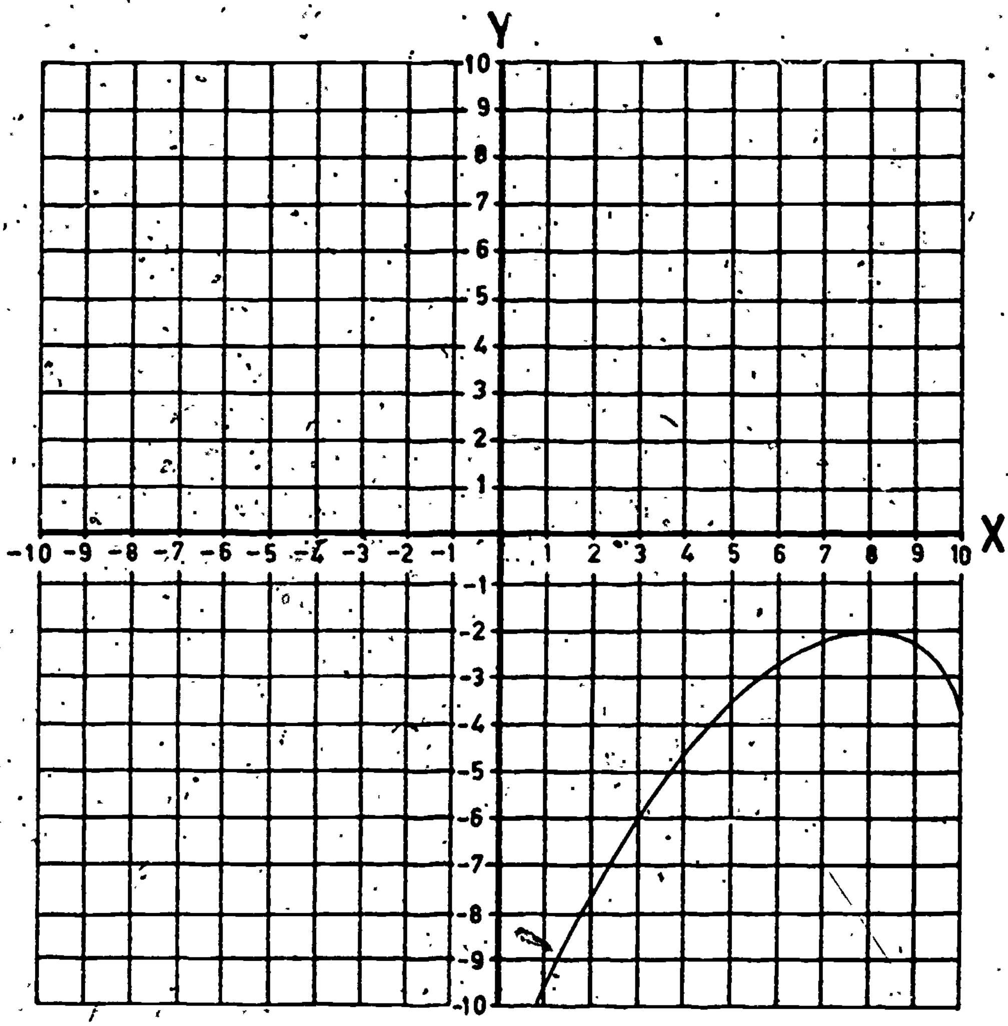
ANSWER

______ (sign) ______ (number)



Calculate the maximum value of Y.

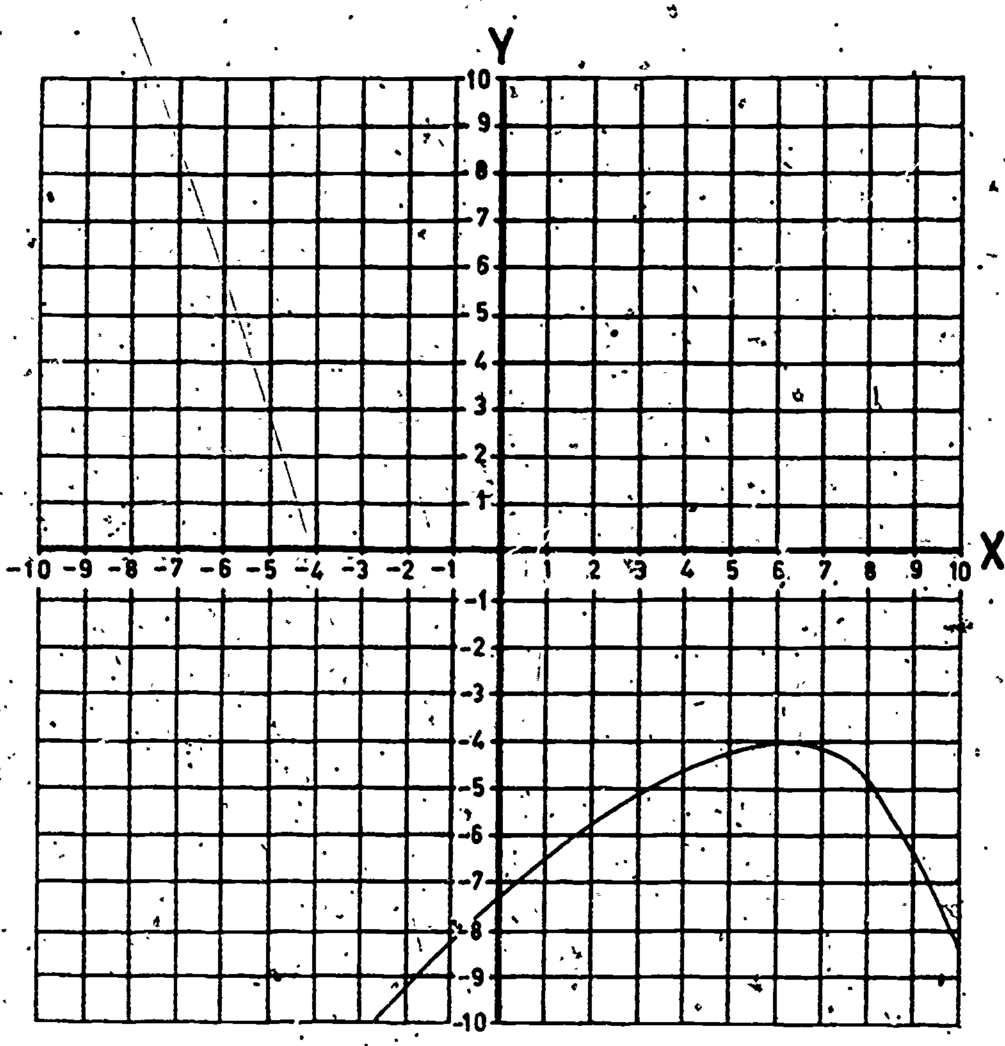
ANSWER ________ ________
(sign) (number)



Calculate the maximum value of Y.

ANSWER

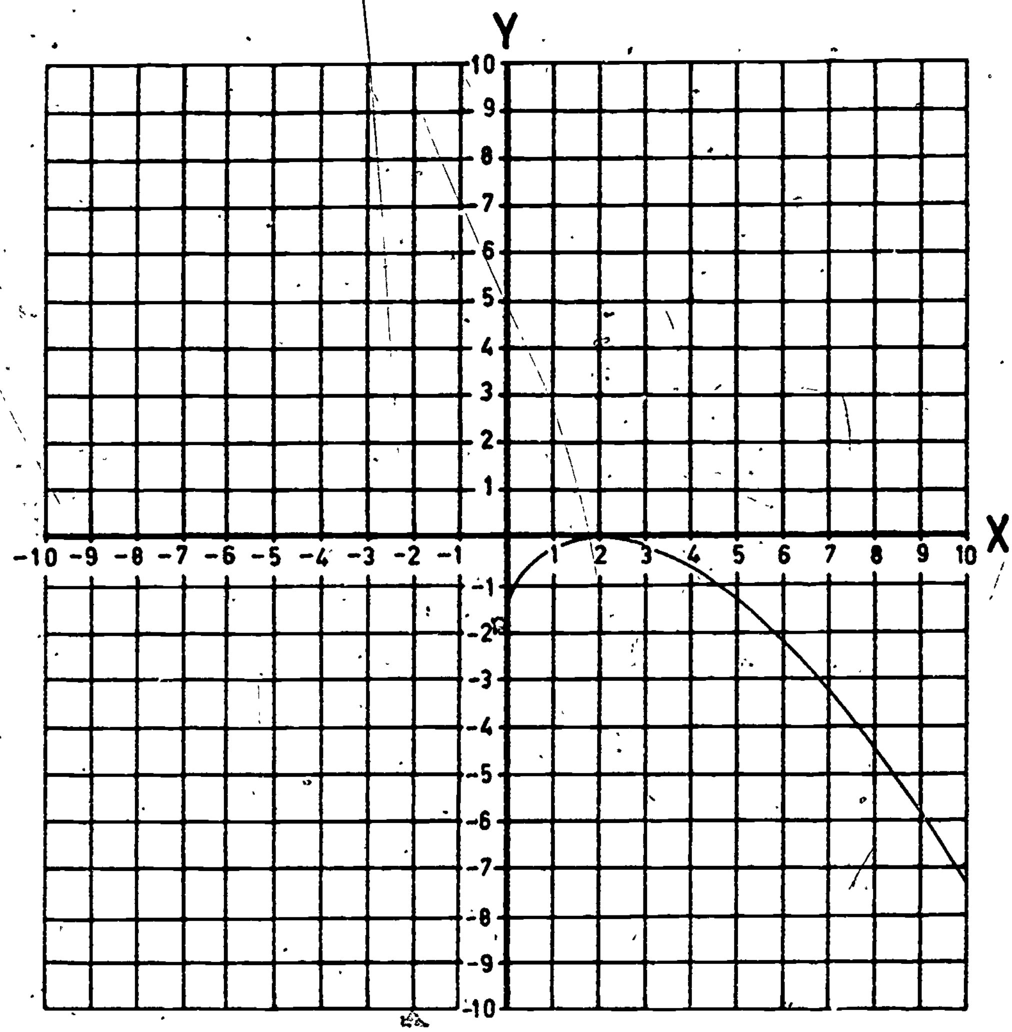
_______ (sign) _______ (number)



Calculate the maximum value of Y.

ANSWER

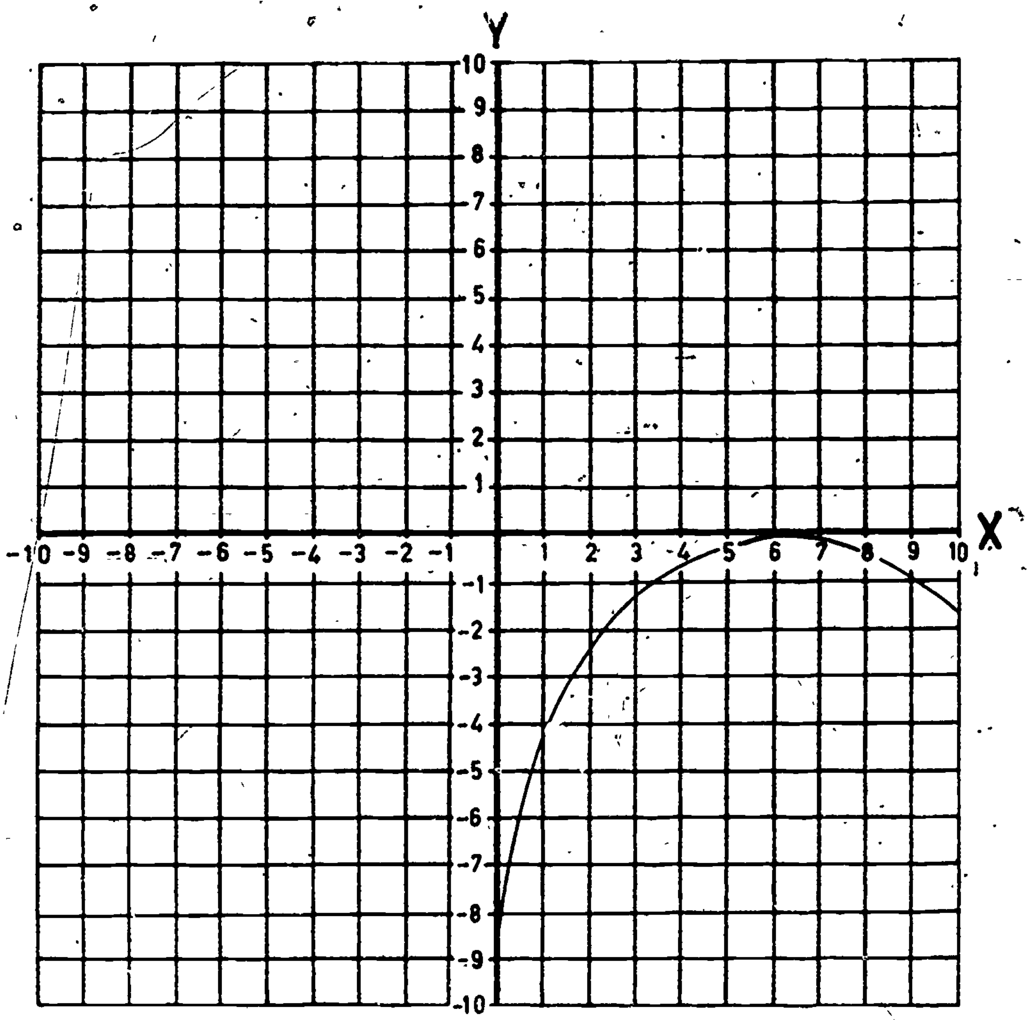
________ __________
(sign) (number)



Calculate the maximum value of Y.

ANSWER

_______ _________
(sign) (number)



Calculate the maximum value of Y.

ANSWER

______ (sign) ______ (number)

BASIC SKILLS OF GRAPHICAL INTERPRETATION

SUBDIVISION ANALYSIS SET 3/2

NAME ____________________ AGE __________

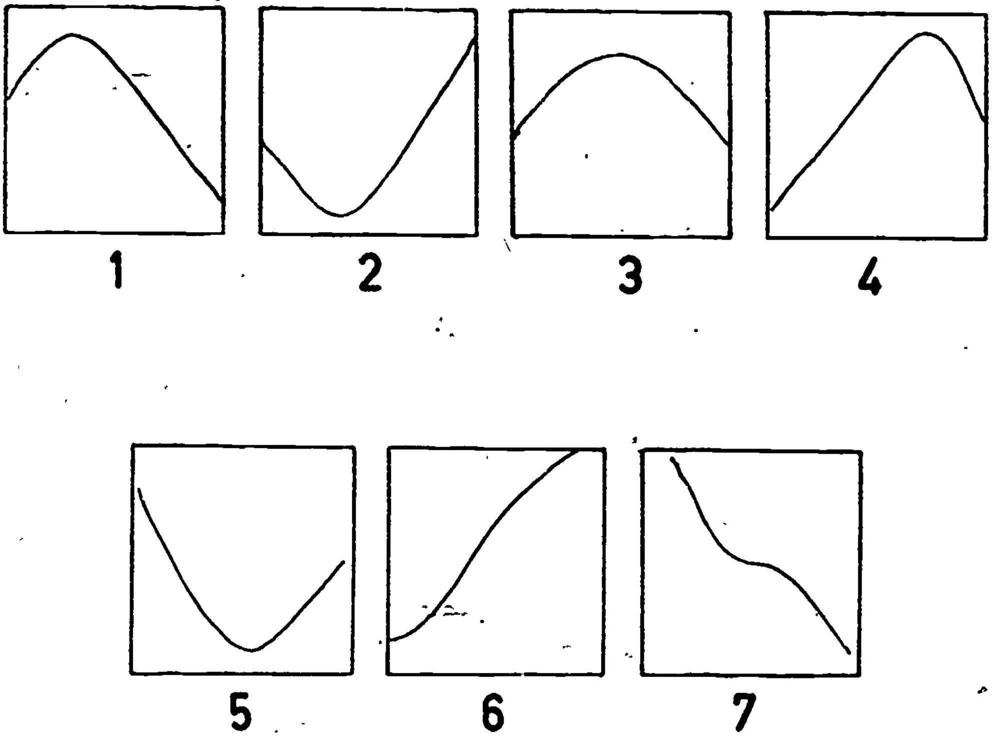
SEX __________

SCHOOL ____________________ CLASS __________

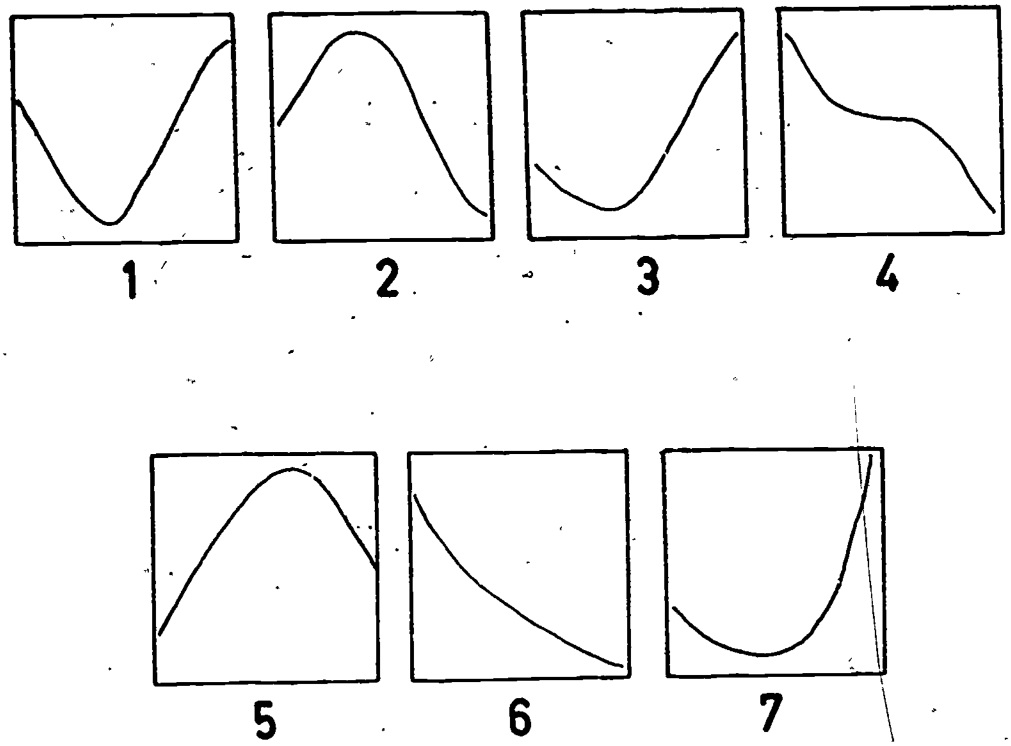
DATE __________

INSTRUCTIONS

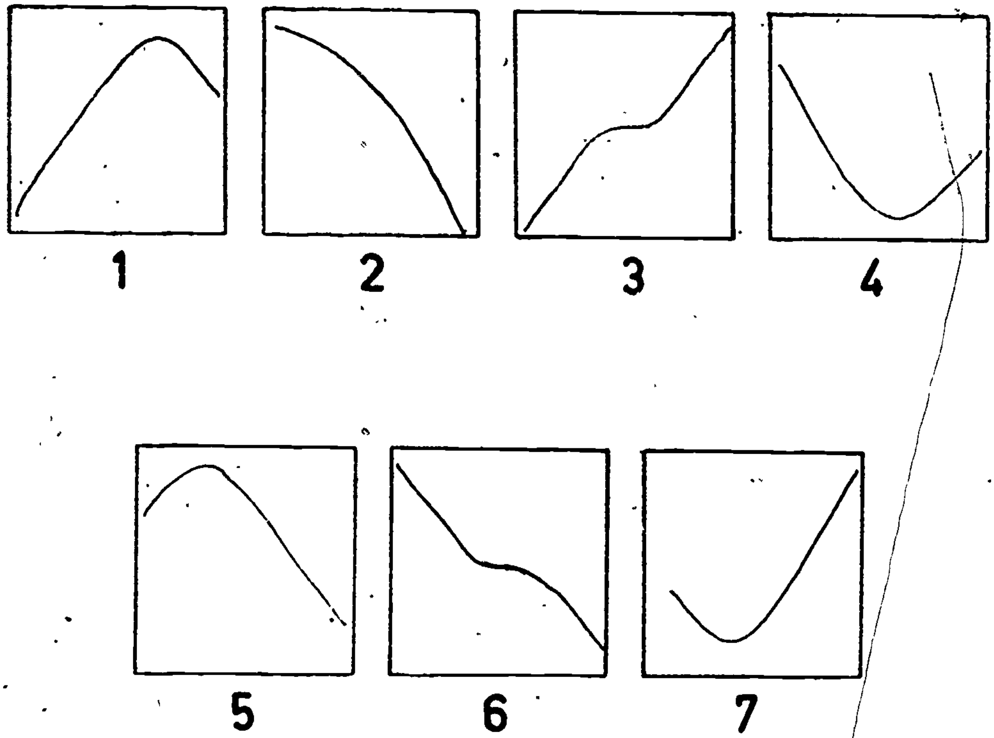
Read each question carefully, then write your answer in the space provided. Try to guess the answers to any questions you do not know, but do not waste time on more difficult problems. All answers should be given to the nearest decimal place, and any other calculations may be written on the back of the page. The sign of an answer, where this applies, should be either positive (+) or negative (-).



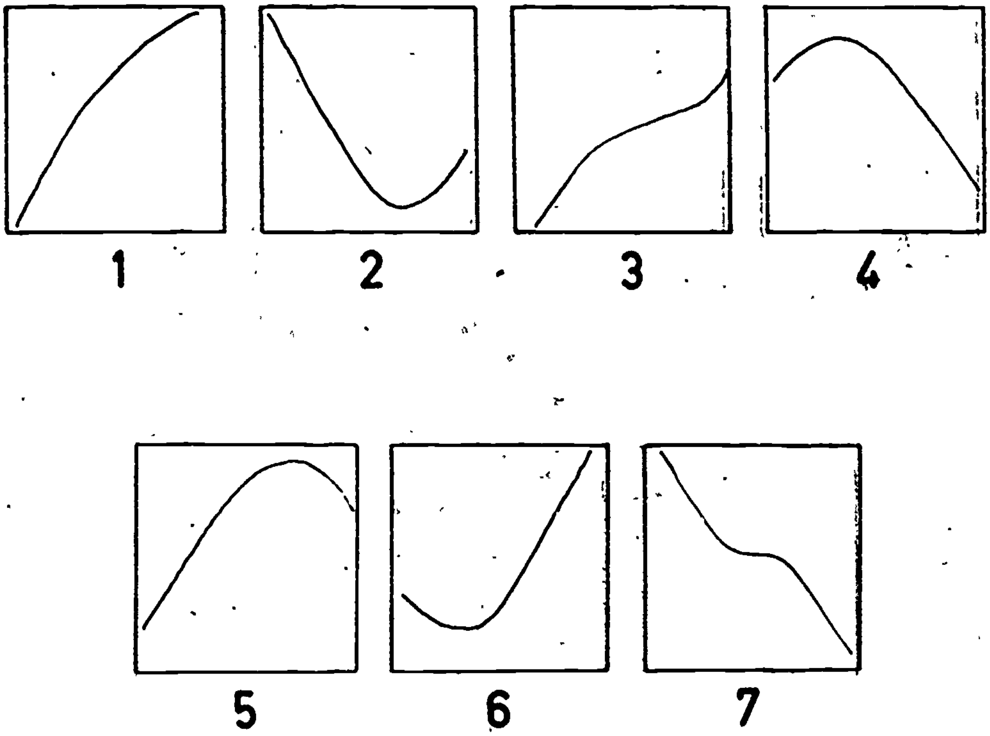
Mark with a circle the number of each curve above showing a MAXIMUM turning point.



Mark with a circle the number of each curve above showing a MAXIMUM turning point.



Mark with a circle the number of each curve above showing a MINIMUM turning point.



Mark with a circle the number of each curve above showing a MINIMUM turning point.

BASIC SKILLS OF GRAPHICAL INTERPRETATION

SUBDIVISION ANALYSIS SET 4/1

NAME ______________ AGE ________

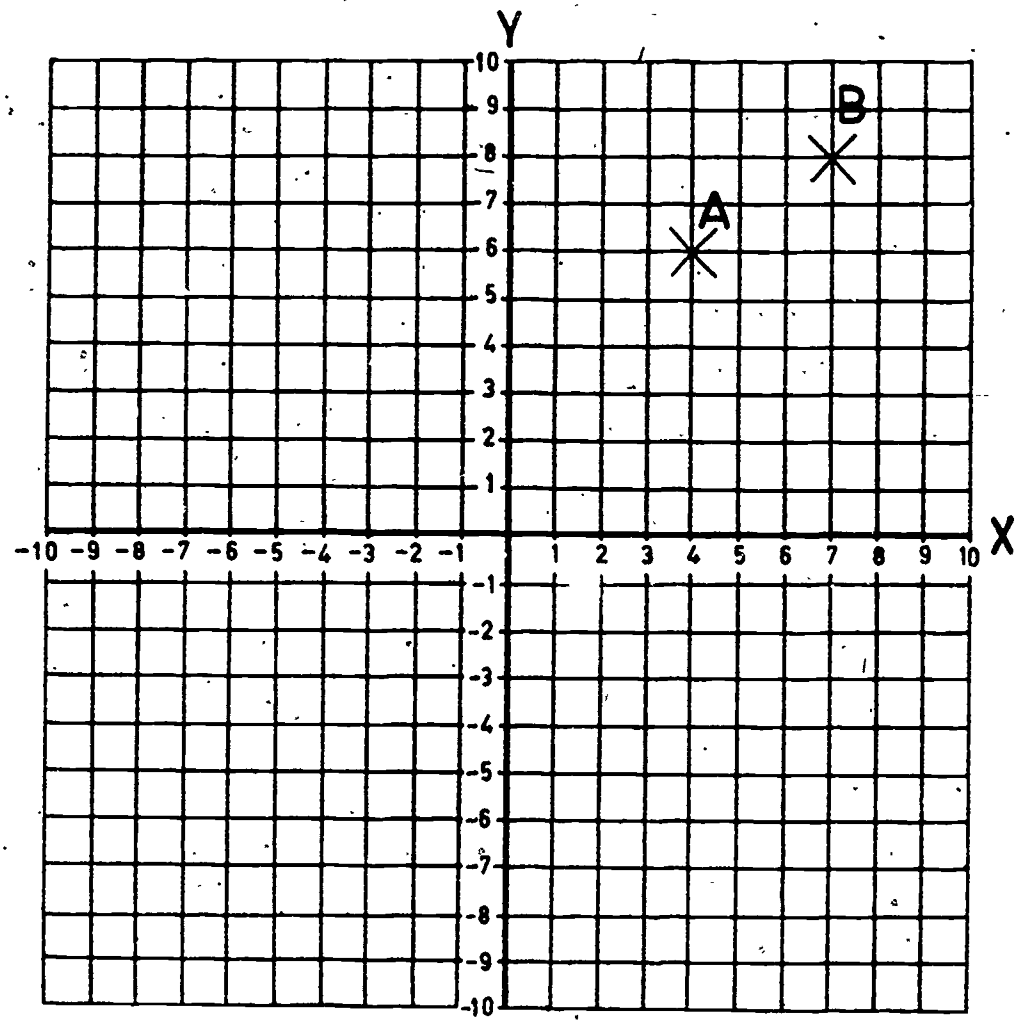
SEX ________

SCHOOL ______________ CLASS ________

DATE ________

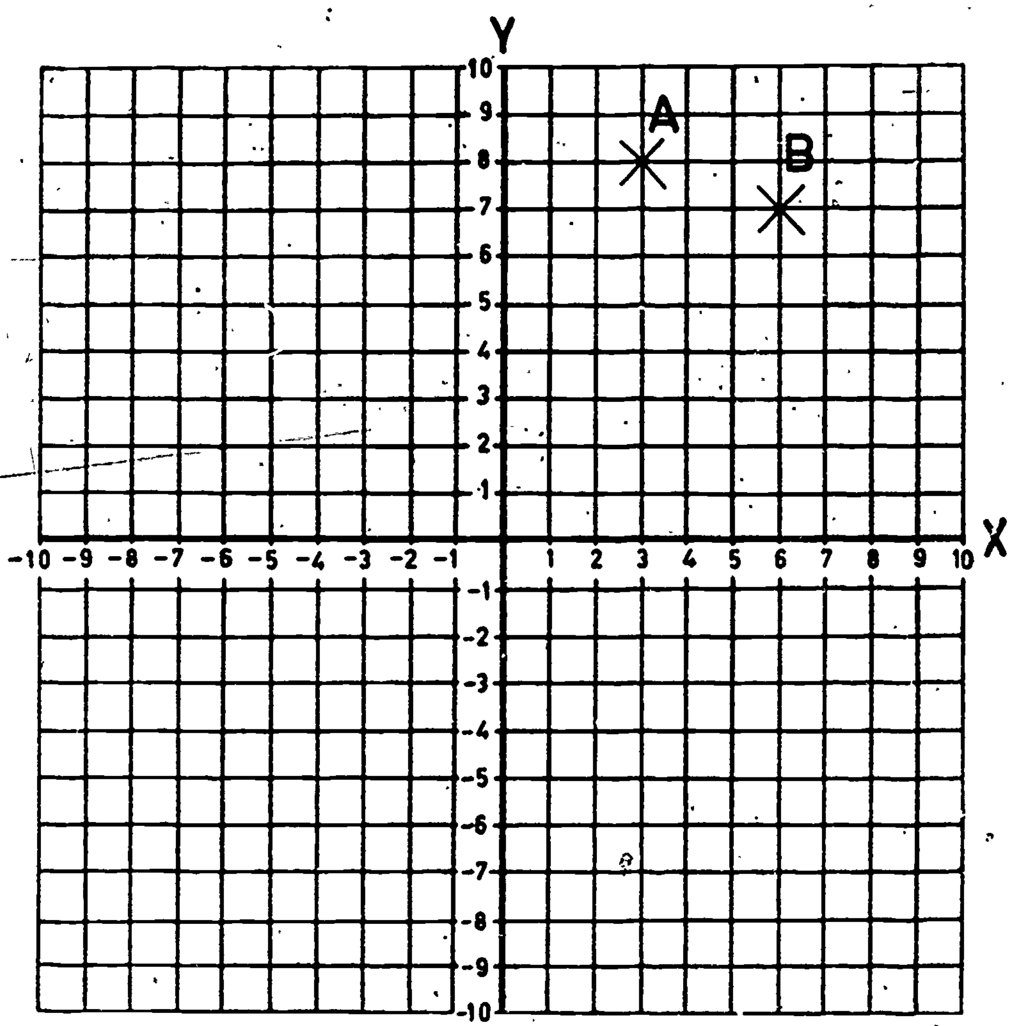
INSTRUCTIONS

Read each question carefully, then write your answer in the space provided. Try to guess the answers to any questions you do not know, but do not waste time on more difficult problems. All answers should be given to the nearest decimal place, and any other calculations may be written on the back of the page. The sign of an answer, where this applies, should be either positive (+) or negative (-).



Calculate the horizontal (X) displacement from A to B.

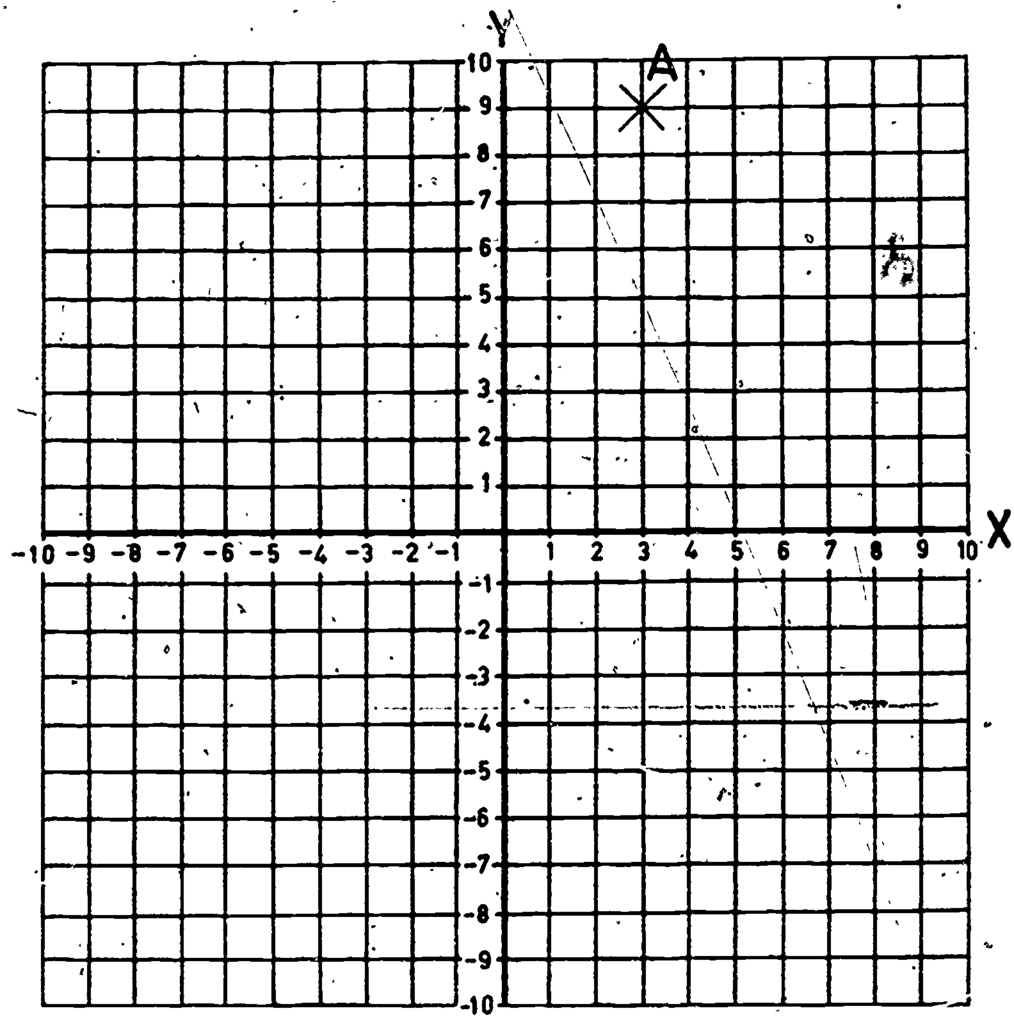
ANSWER ________ ________
(sign) (number)



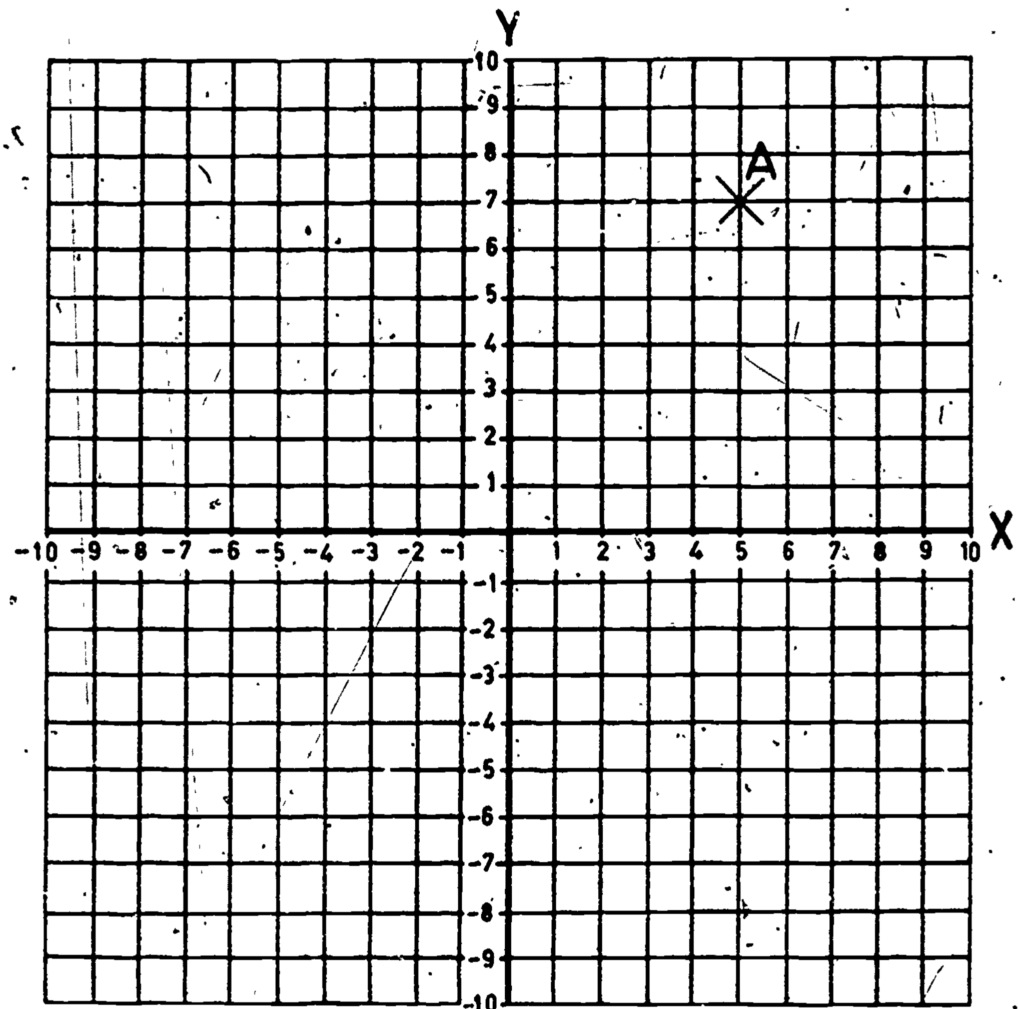
Calculate the horizontal (X) displacement from A to B.

ANSWER

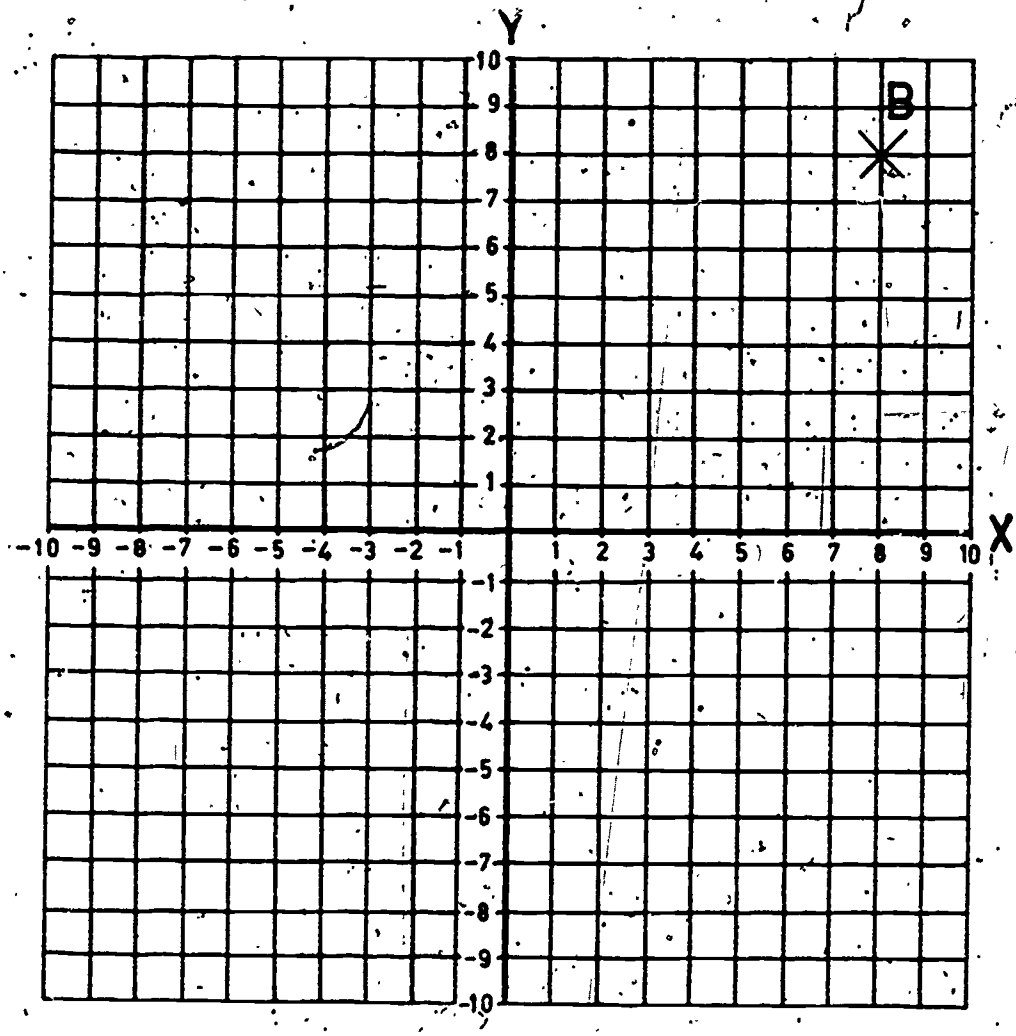
______ (sign) ______ (number)



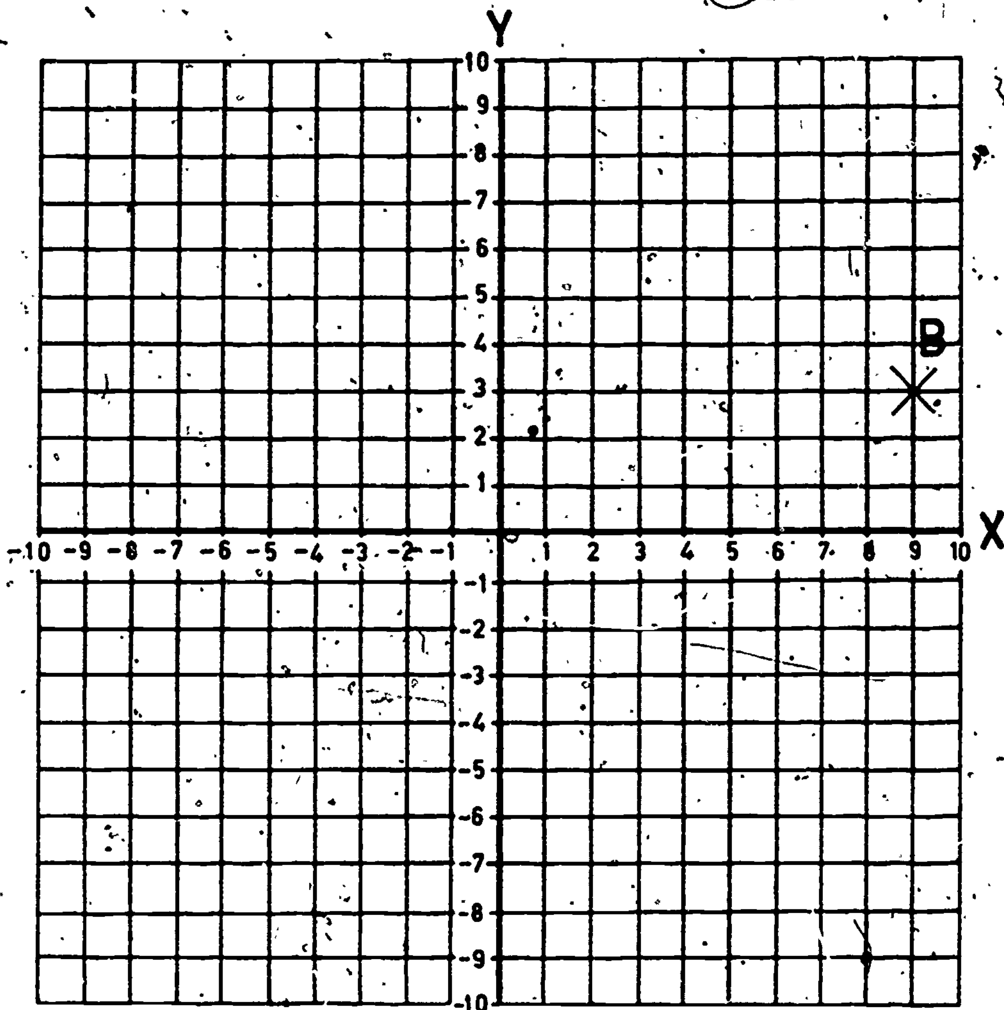
The displacement from A to B is + 5.0 units in the horizontal (X) direction, and both points have the same vertical (Y) position. Place a mark (X) at the position of B on the graph above.



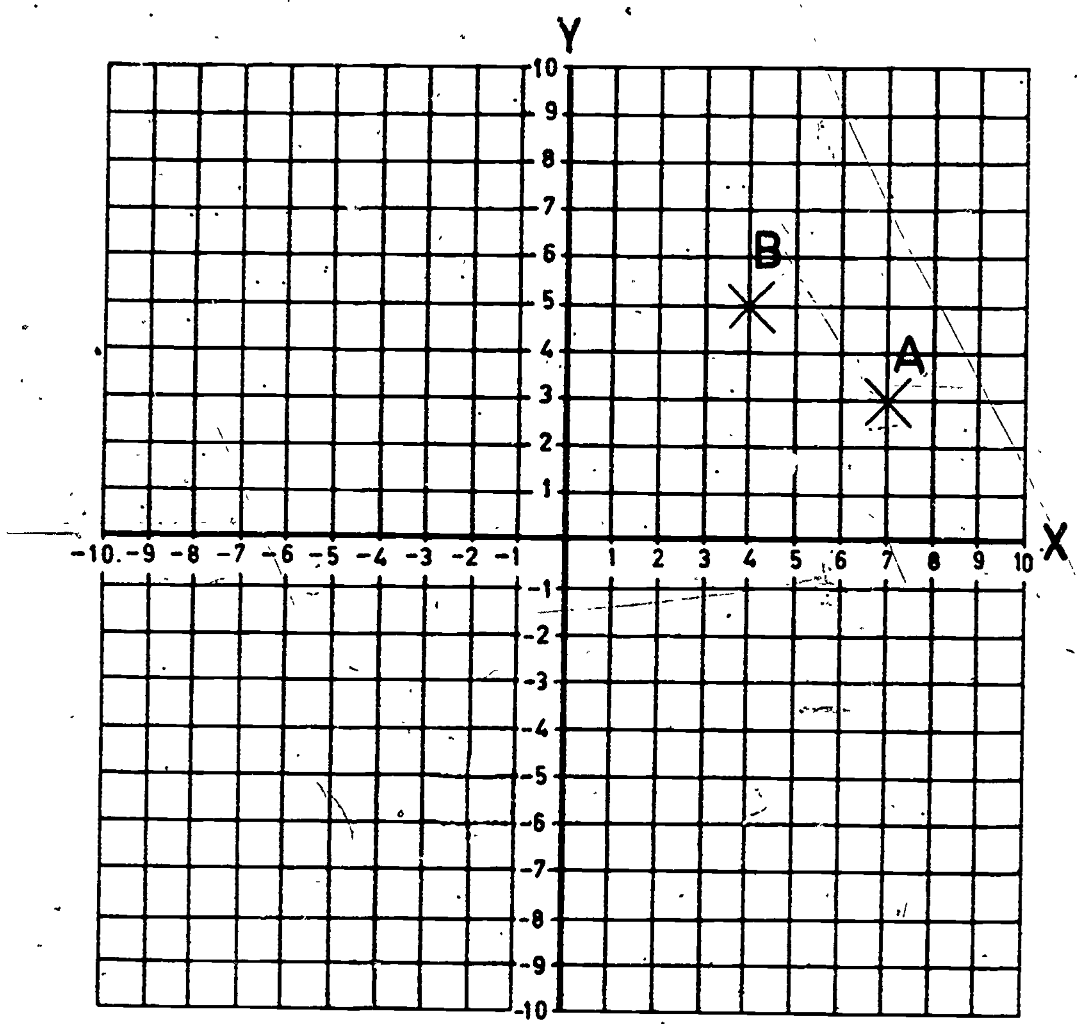
The displacement from A to B is + 5.0 units in the horizontal (X) direction, and both points have the same vertical (Y) position. Place a mark (X) at the position of B on the graph above.



The displacement from A to B is + 4.0 units in the horizontal (X) direction, and both points have the same vertical (Y) position. Place a mark (X) at the position of A on the graph above.



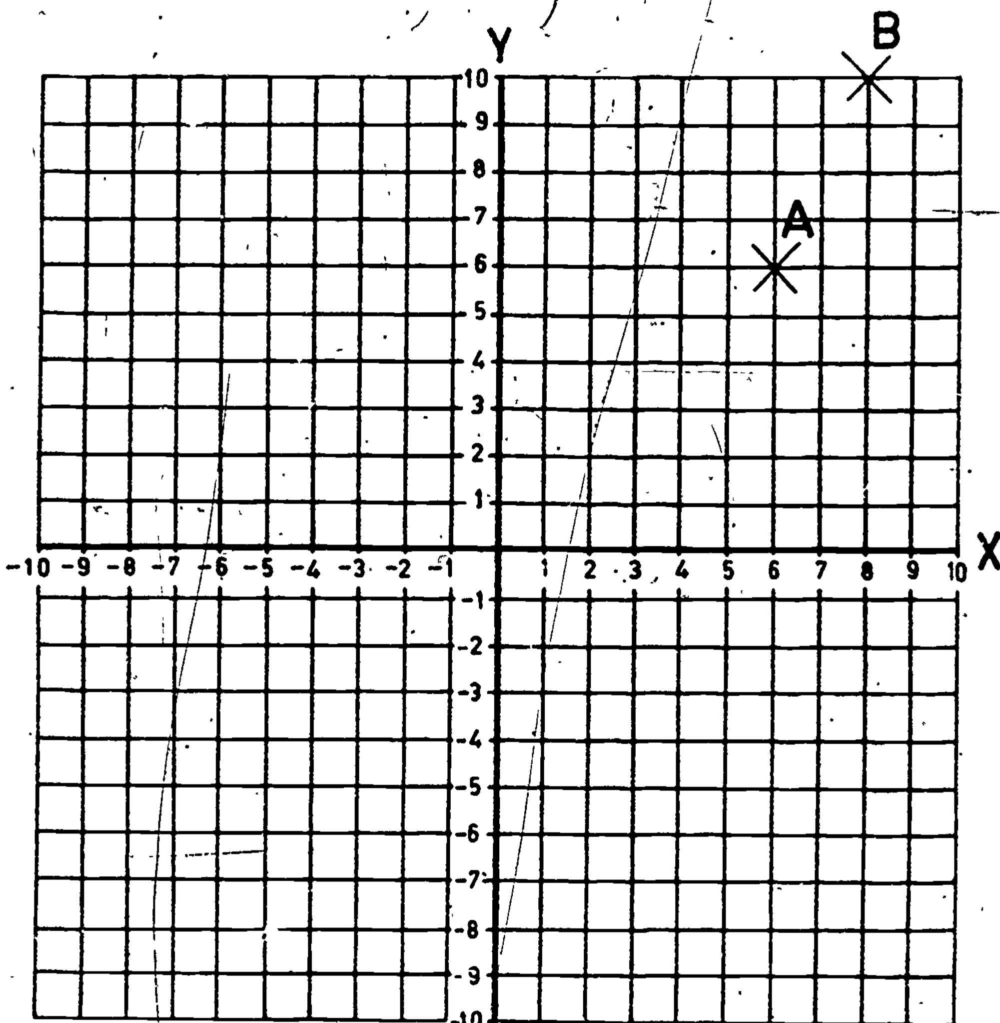
The displacement from A to B is + 3.0 units in the horizontal (X) direction, and both points have the same vertical (Y) position. Place a mark (X) at the position of A on the graph above.



Calculate the vertical (Y) displacement from A to B.

ANSWER

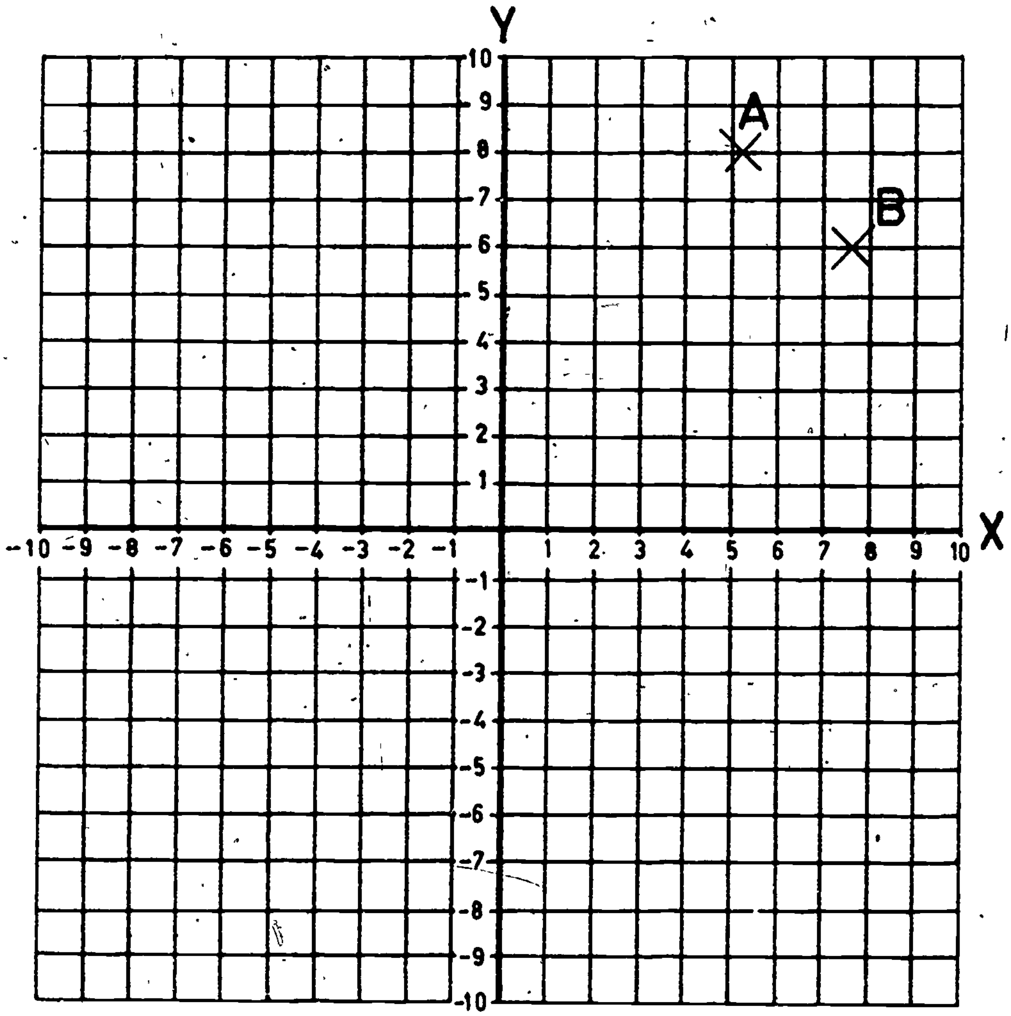
______ (sign) ______ (number)



Calculate the vertical (Y) displacement from A to B.

ANSWER

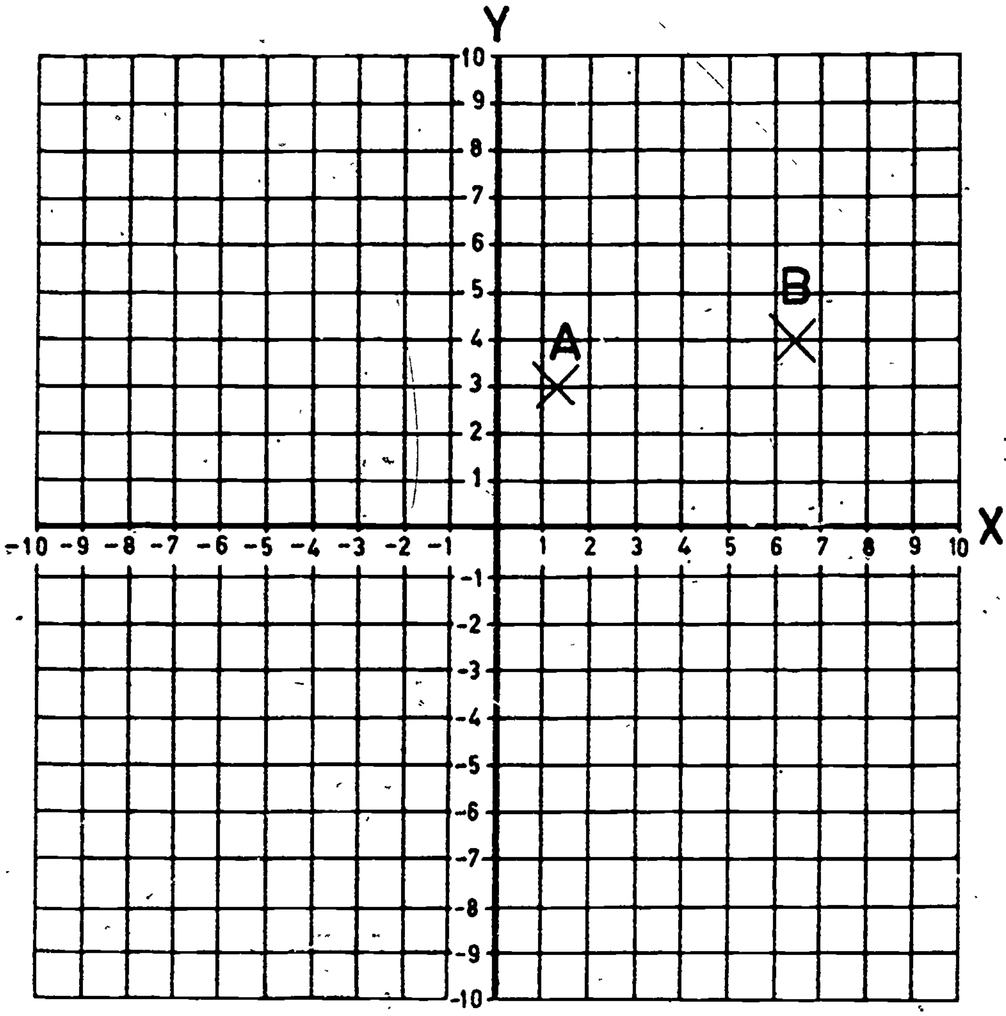
______ (sign) ______ (number)



Calculate the horizontal (X) displacement from A to B.

ANSWER

______ ______
(sign) (number)

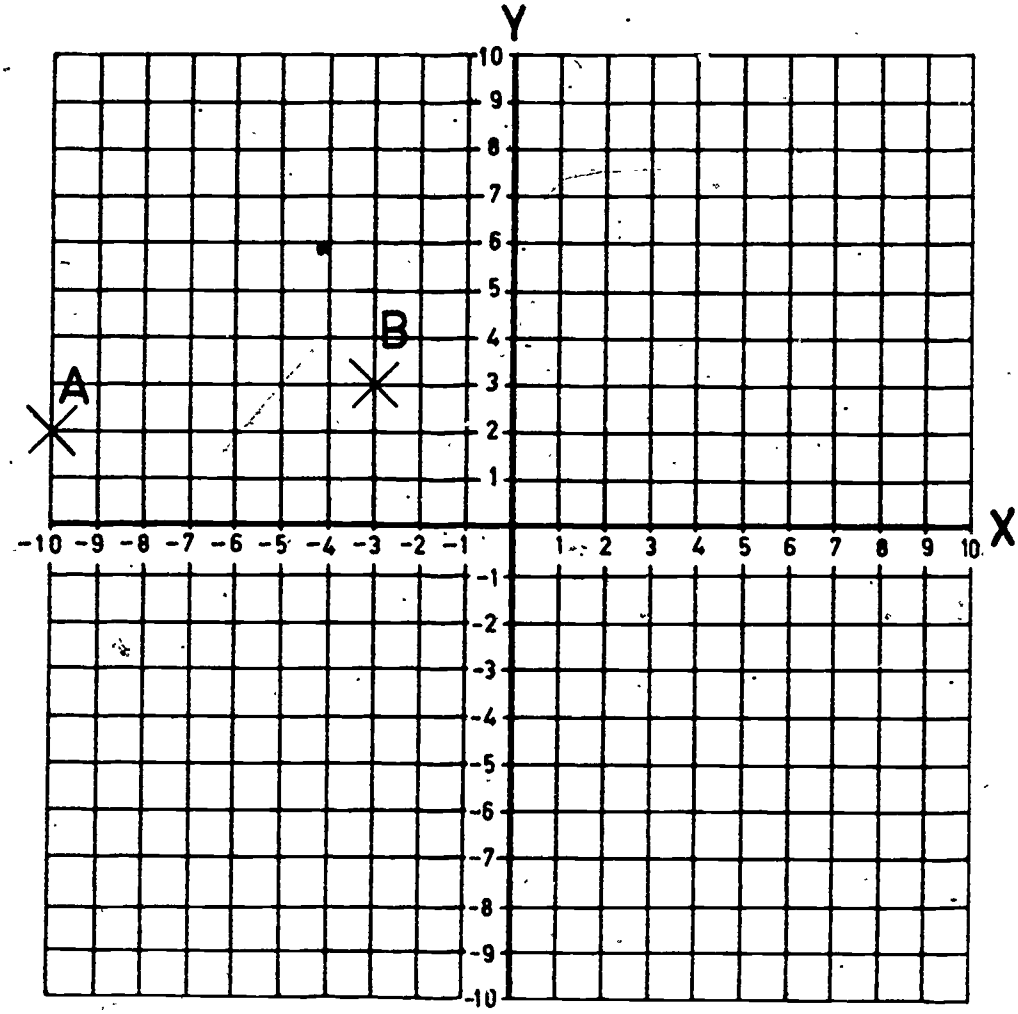


Calculate the horizontal (X) displacement from A to B.

ANSWER

______ ________

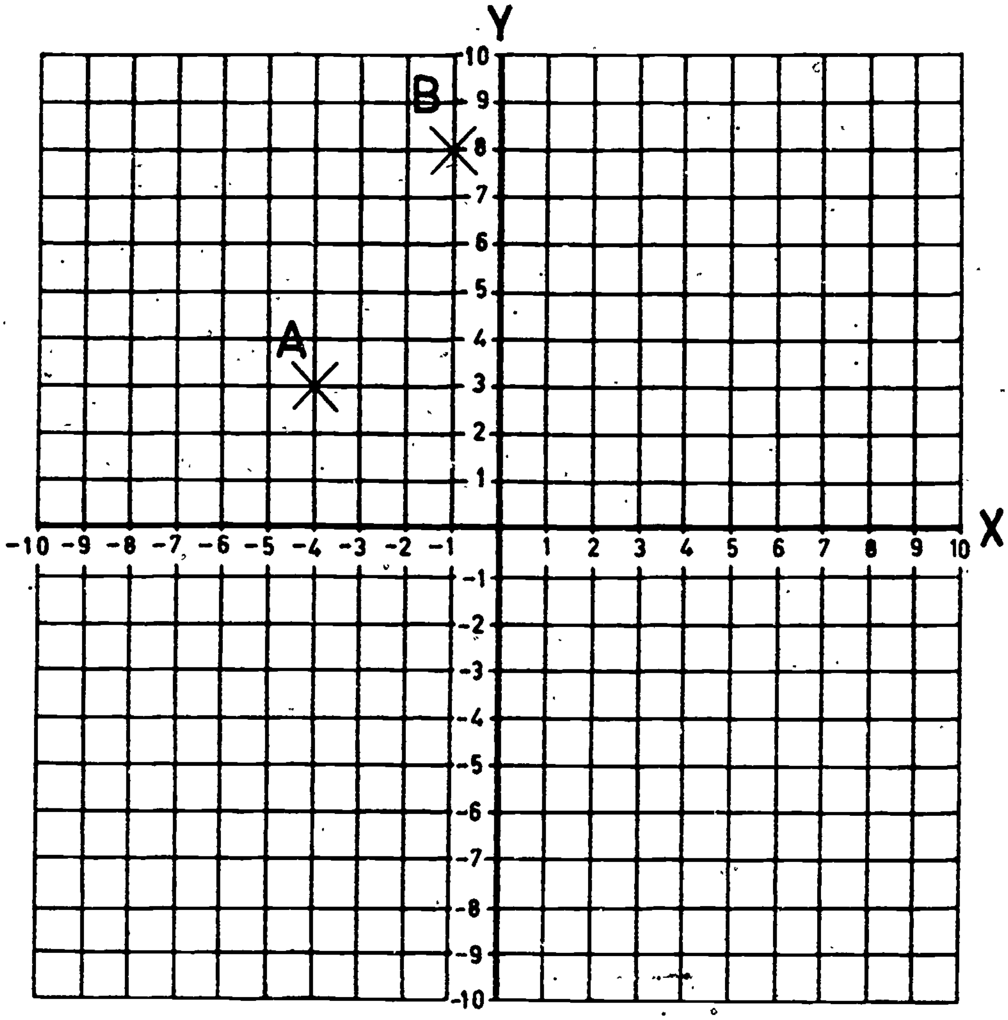
(sign) (number)



Calculate the horizontal (X) displacement from A to B.

ANSWER

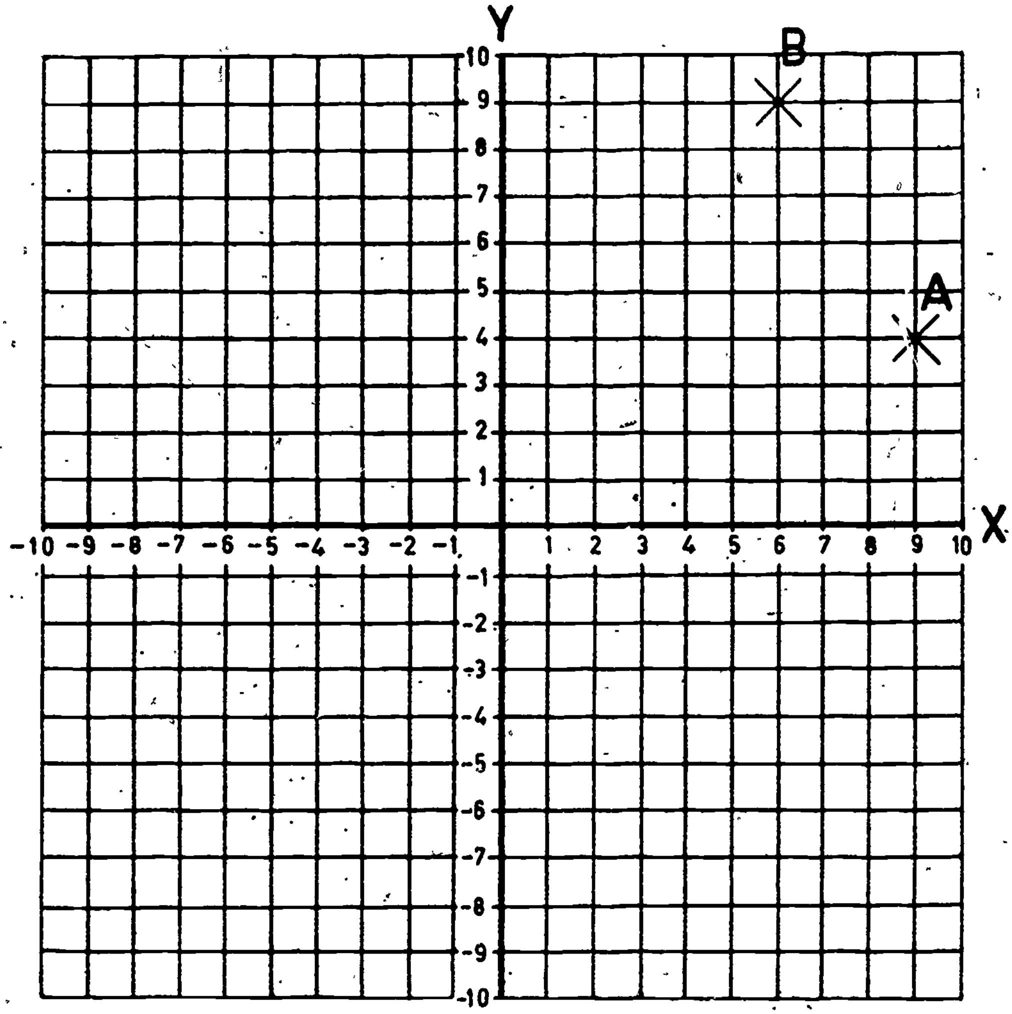
______ (sign) ______ (number)



Calculate the horizontal (X) displacement from A to B.

ANSWER

________ __________
(sign) (number)

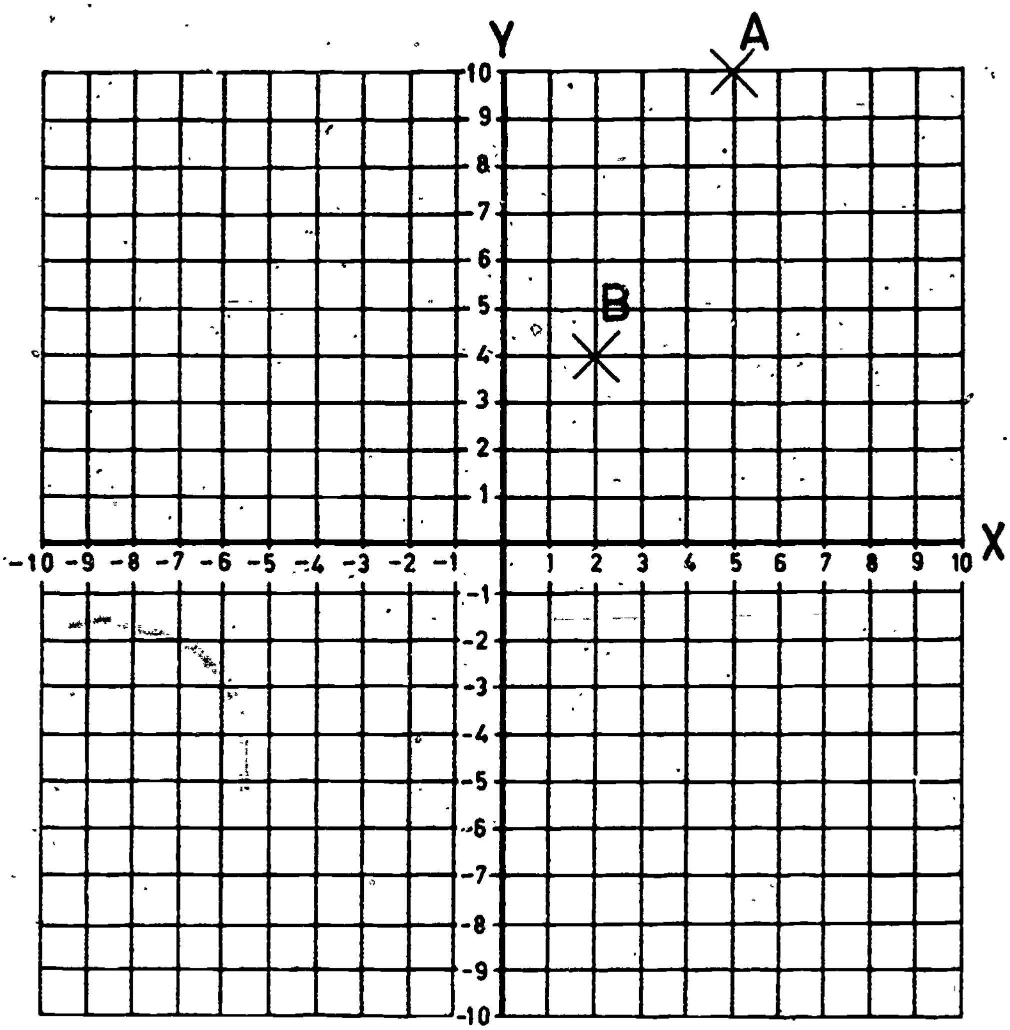


Calculate the horizontal (X) displacement from A to B.

ANSWER

_______ _________

(sign) (number)

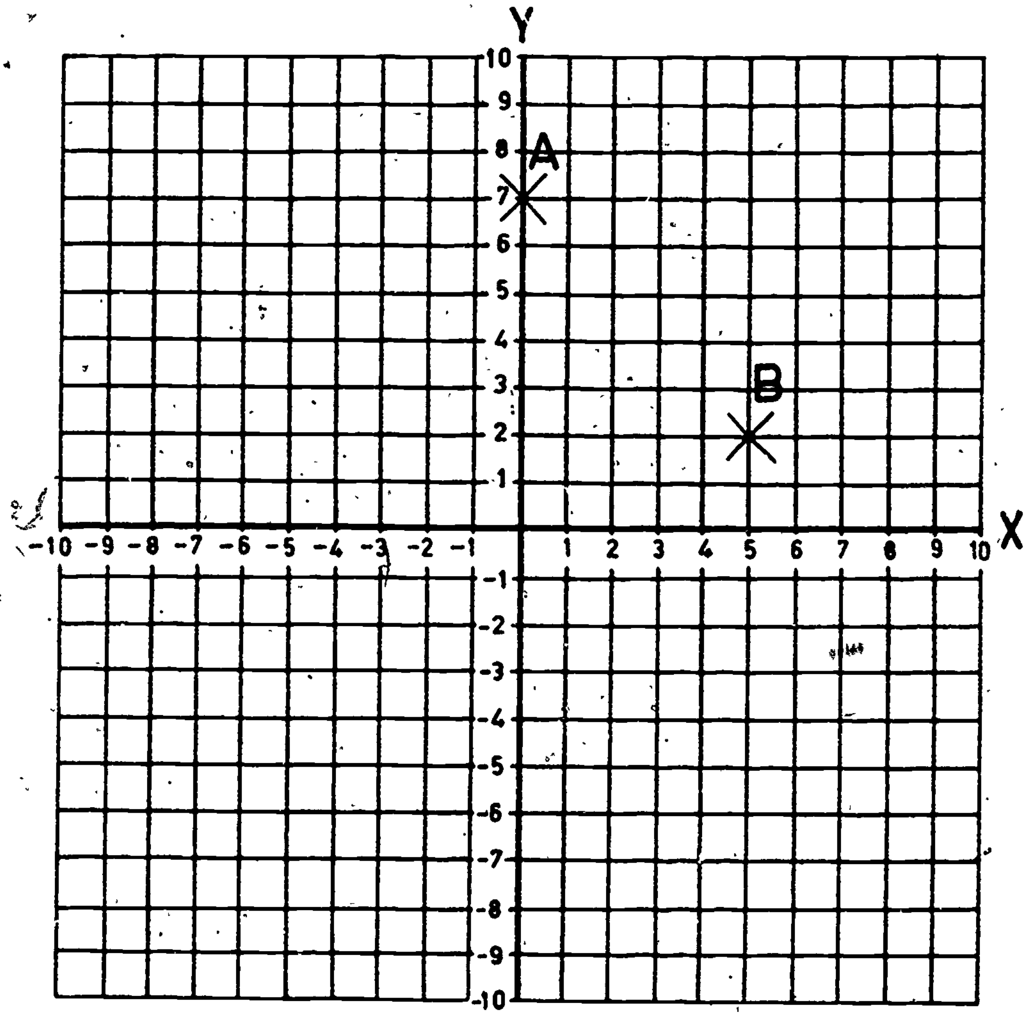


Calculate the horizontal (X) displacement from A to B.

ANSWER

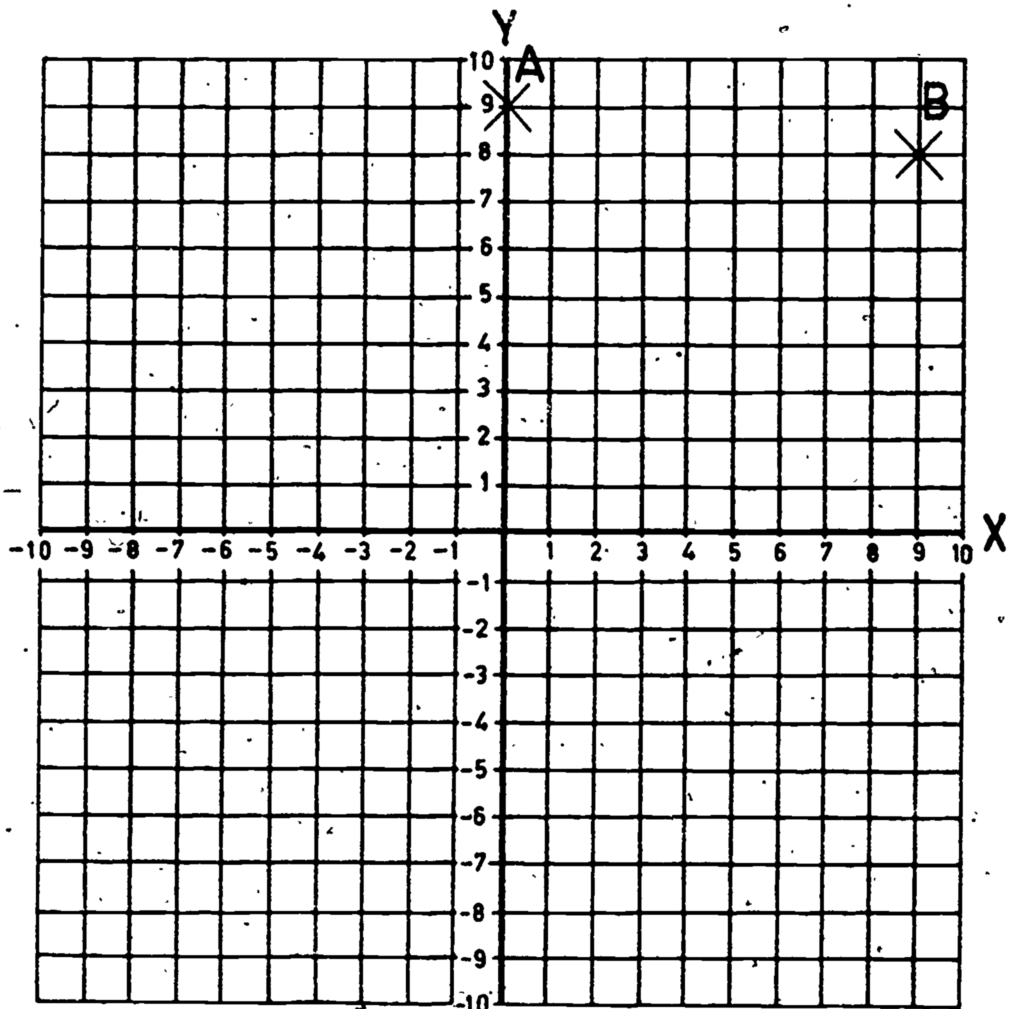
______ ________

(sign) (number)



Calculate the horizontal (X) displacement from A to B.

ANSWER ____ ________
(sign) (number)



Calculate the horizontal (X) displacement from A to B.

ANSWER

______ (sign) ______ (number)

BASIC SKILLS OF GRAPHICAL INTERPRETATION

SUBDIVISION ANALYSIS SET 4/2

NAME ________________ AGE ________

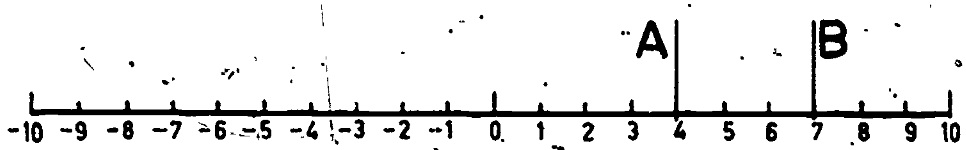
SEX ________

SCHOOL ________________ CLASS ________

DATE ________

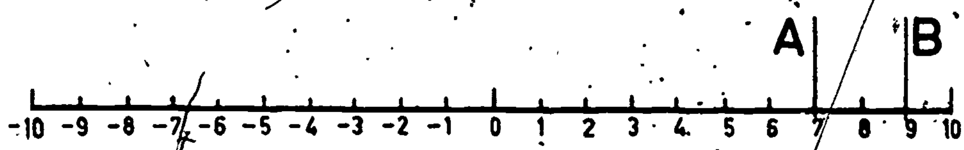
INSTRUCTIONS

Read each question carefully, then write your answer in the space provided. Try to guess the answers to any questions you do not know, but do not waste time on more difficult problems. All answers should be given to the nearest decimal place, and any other calculations may be written on the back of the ge. The sign of an answer, where this applies, should be either positive (+) or negative (-).



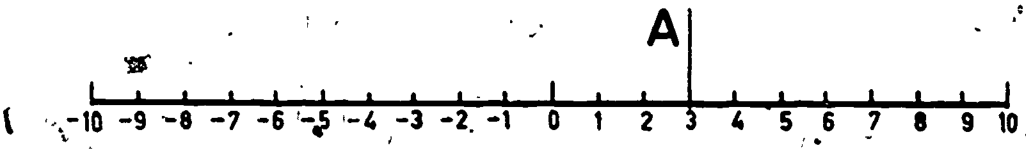
Calculate the displacement from A to B.

ANSWER ________ ________
(sign) (number)

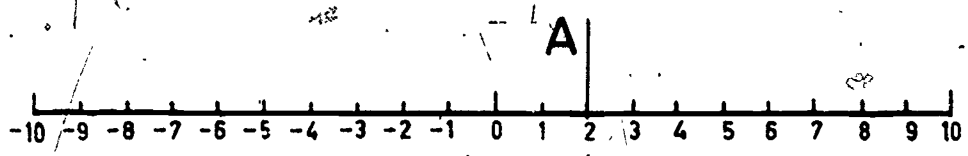


Calculate the displacement from A to B.

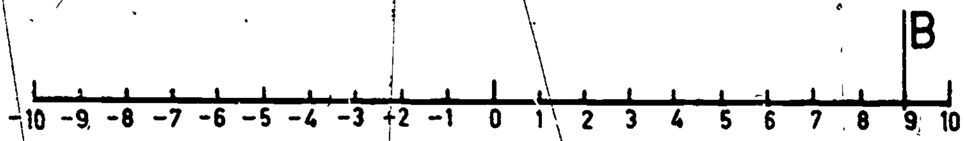
ANSWER ______ ______
(sign) (number)



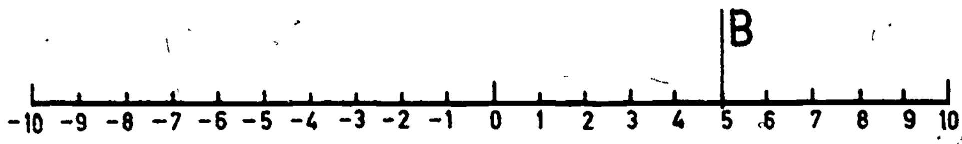
The displacement from A to B is + 5.0 units. Place a mark (X) at the position of B on the number line above.



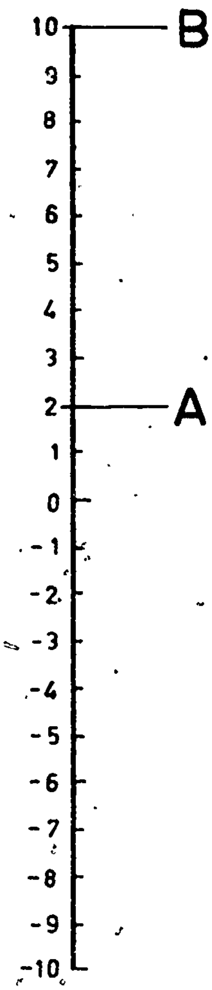
The displacement from A to B is + 3.0 units. Place a mark (X) at the position of B on the number line above.



The displacement from A to B is + 6.0 units. Place a mark (X) at the position of A on the number line above.

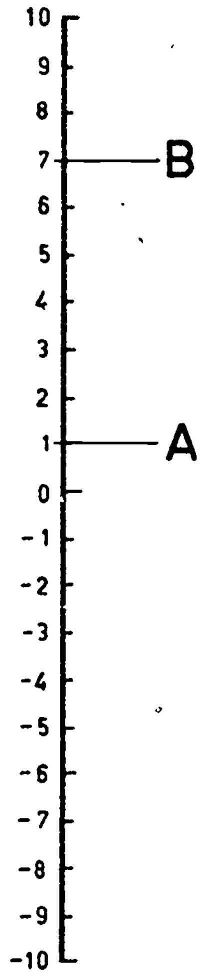


The displacement from A to B is + 4.0 units. Place a mark (X) at the position of A on the number line above.



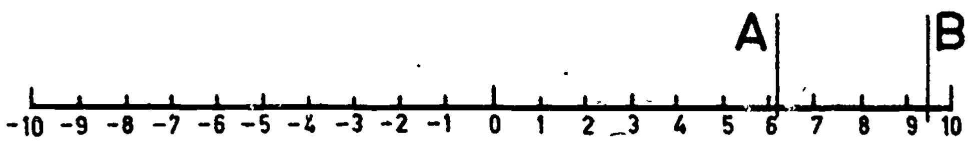
Calculate the displacement from A to B.

ANSWER ______ ______
(sign) (number)



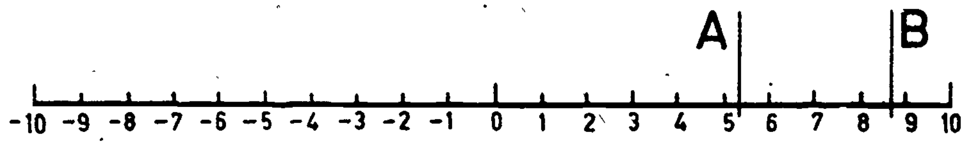
Calculate the displacement from A to B.

ANSWER ______ ______
(sign) (number)



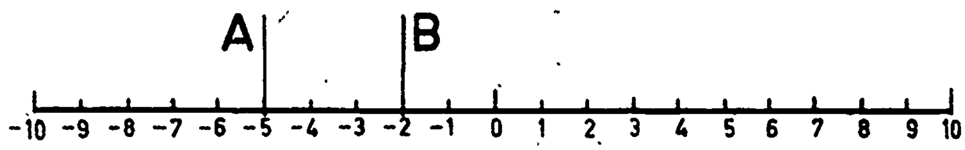
Calculate the displacement from A to B.

ANSWER ______ ______
(sign) (number)



Calculate the displacement from A to B.

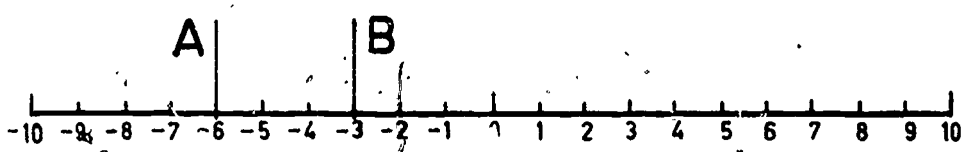
ANSWER ________ ________
(sign) (number)



Calculate the displacement from A to B.

ANSWER

_______ _______
(sign) (number)

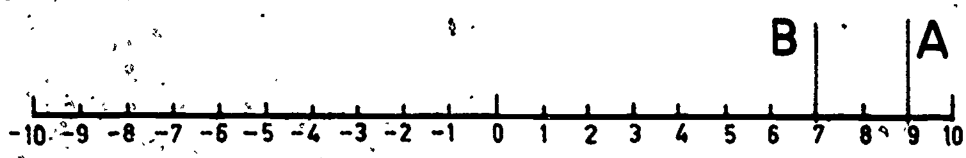


Calculate the displacement from A to B.

ANSWER

_______ _______

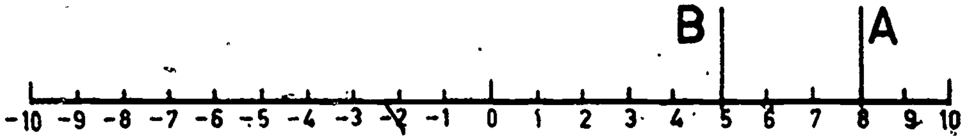
(sign) (number)



Calculate the displacement from A to B.

<u>ANSWER</u>

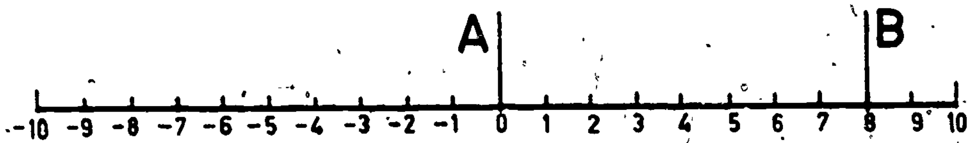
______ ______
(sign) (number)



Calculate the displacement from A to B.

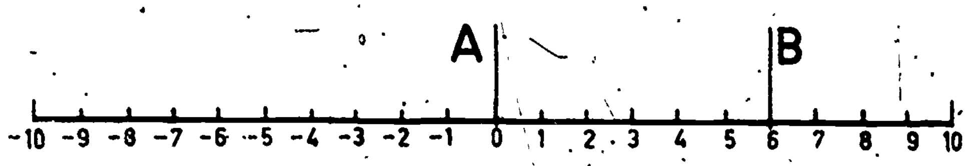
ANSWER

______ ______
(sign) (number)



Calculate the displacement from A to B.

ANSWER ______ ______
(sign) (number)



Calculate the displacement from A to B.

ANSWER

______ (sign) ______ (number)

BASIC SKILLS OF GRAPHICAL INTERPRETATION

SUBDIVISION ANALYSIS - SET 4/3

NAME ______________________ AGE __________

____

SEX __________

SCHOOL ______________________ CLASS __________

DATE __________

INSTRUCTIONS

Read each question carefully, then write your answer in the space provided. Try to guess the answers to any questions you do not know, but do not waste time on more difficult problems. All answers should be given to the nearest decimal place, and any other calculations may be written on the back of the page. The sign of an answer, where this applies, should be either positive (+) or negative (-).

Complete the following calculation.

$6 - 3 =$ ____

Complete the following calculation.

8 - 5 = ___

Complete the following calculation.

$$\_\_\_\_ - 2 = 7$$

Complete the following calculation.

$$\_\_\_ - 5 = 3$$

Complete the following calculation.

9 - ___ = 2

Complete the following calculation.

8 - ___ = 7

Complete the following calculation.

5.4 - 3.2 = ___

Complete the following calculation.

9.7 - 7.3 = ____

Complete the following calculation.

$-5 - (-9) = \_\_\_$

Complete the following calculation.

$$-2 - (-6) = \underline{\quad}$$

Complete the following calculation.

4 - 6 = ____

Complete the following calculation.

$2 - 4 = \underline{\quad}$

Complete the following calculation.

6 - 0 = 7

Complete the following calculation.

3 - 0 = ____

BASIC SKILLS OF GRAPHICAL INTERPRETATION

SUBDIVISION ANALYSIS SET 5/2(A)

NAME ______________ AGE ________

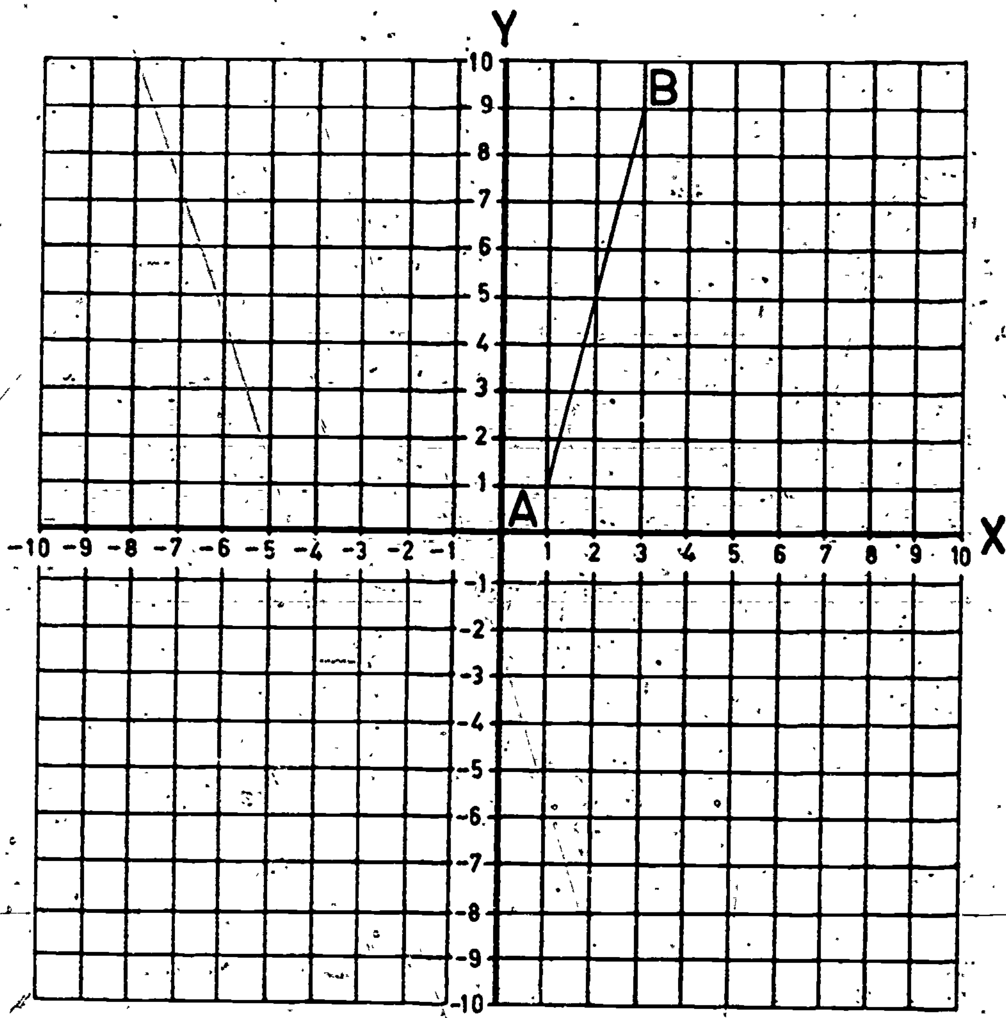
SEX ________

SCHOOL ______________ CLASS ________

DATE ________

INSTRUCTIONS

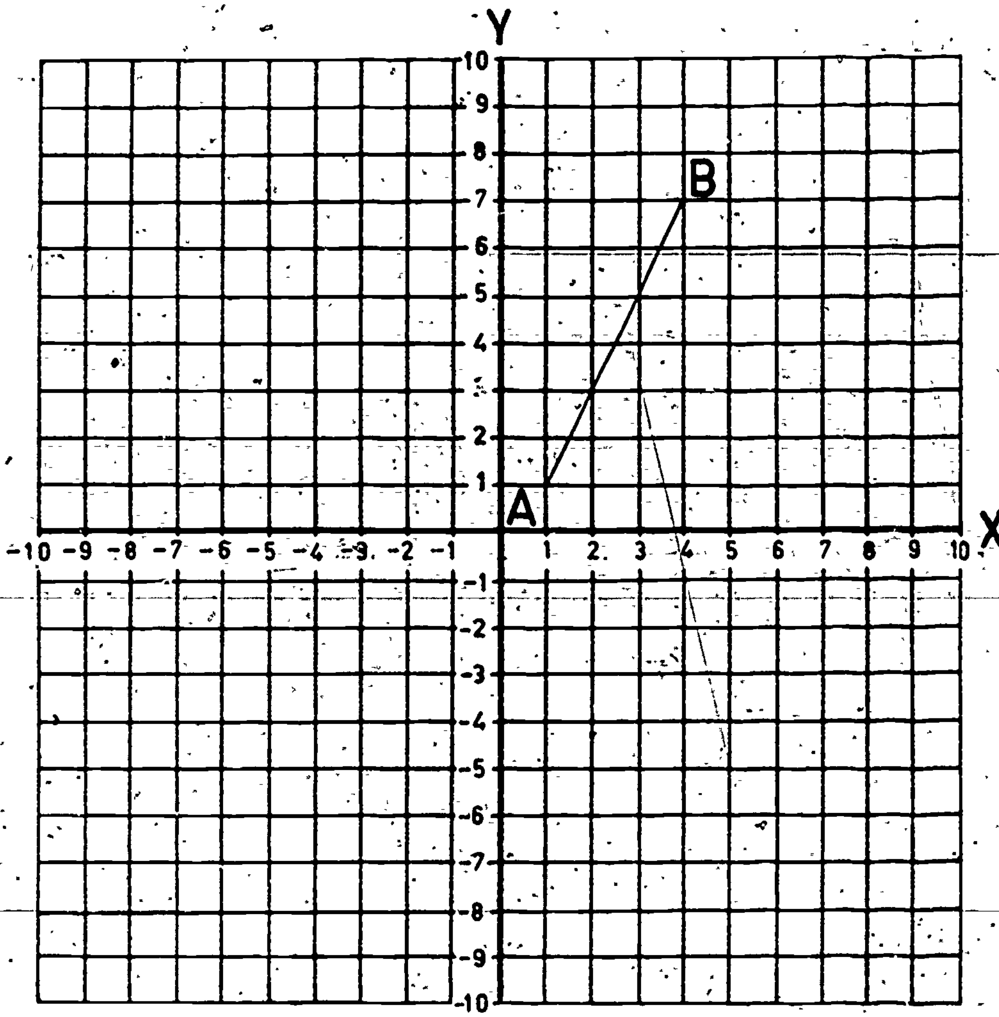
Read each question carefully, then write your answer in the space provided. Try to guess the answers to any questions you do not know, but do not waste time on more difficult problems. All answers should be given to the nearest decimal place, and any other calculations may be written on the back of the page. The sign of an answer, where this applies, should be either positive (+) or negative (-).



Calculate the gradient of the line AB.

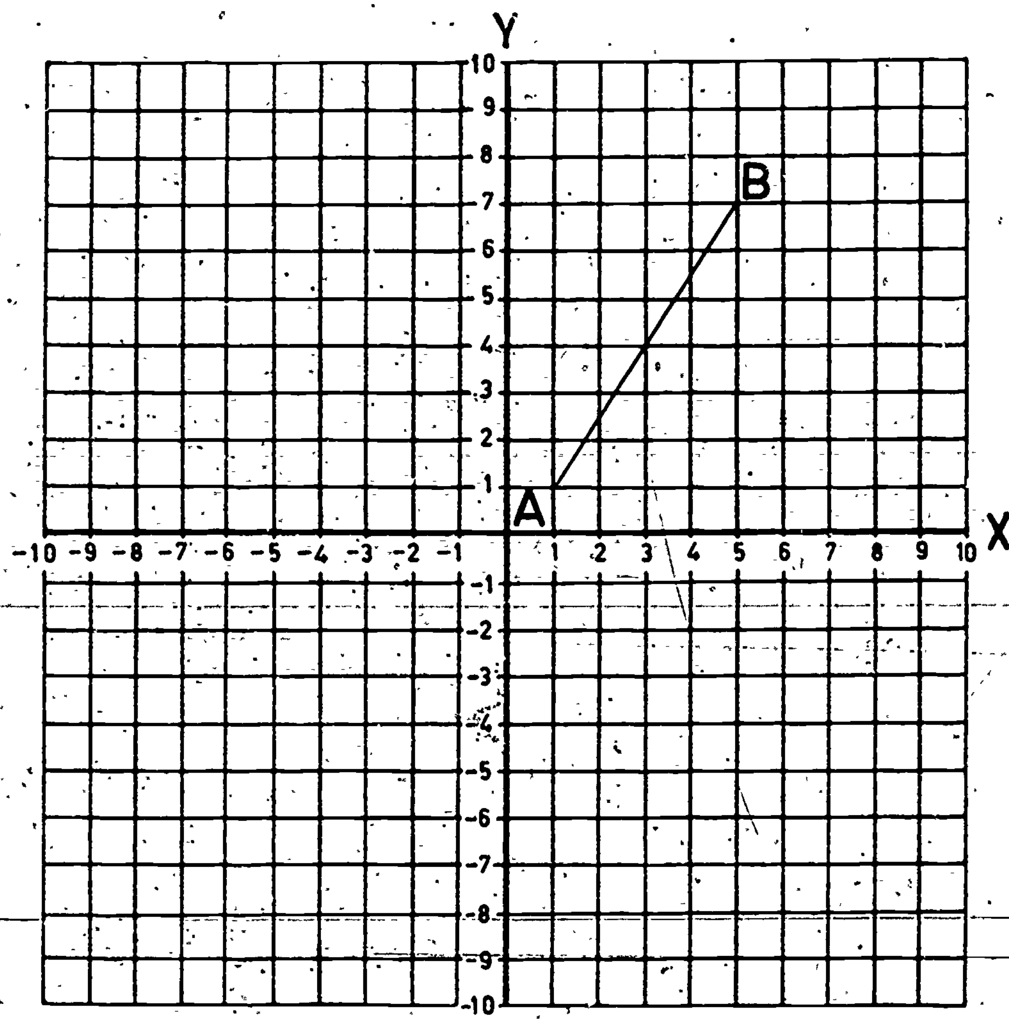
ANSWER

______ (sign) ______ (number)



Calculate the gradient of the line AB.

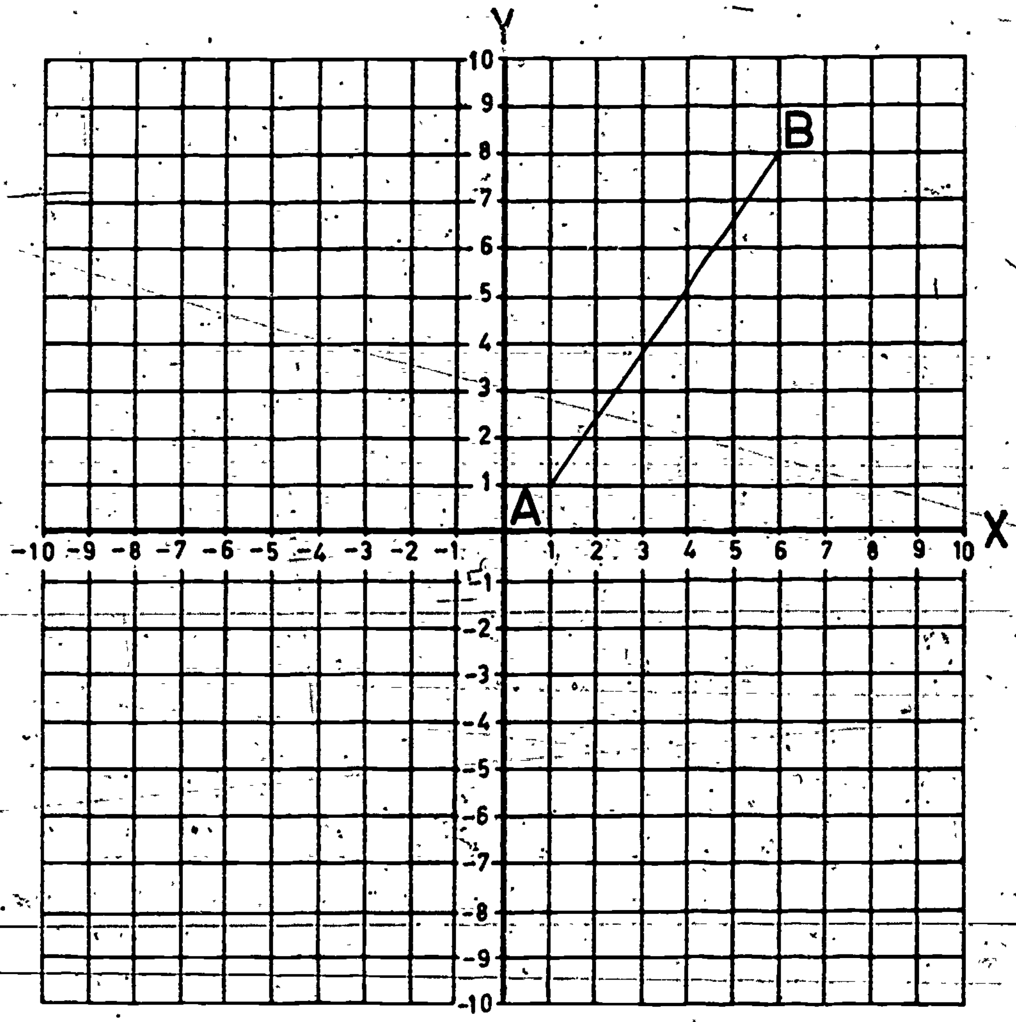
ANSWER ________ ________
(sign) (number)



Calculate the gradient of the line AB.

ANSWER

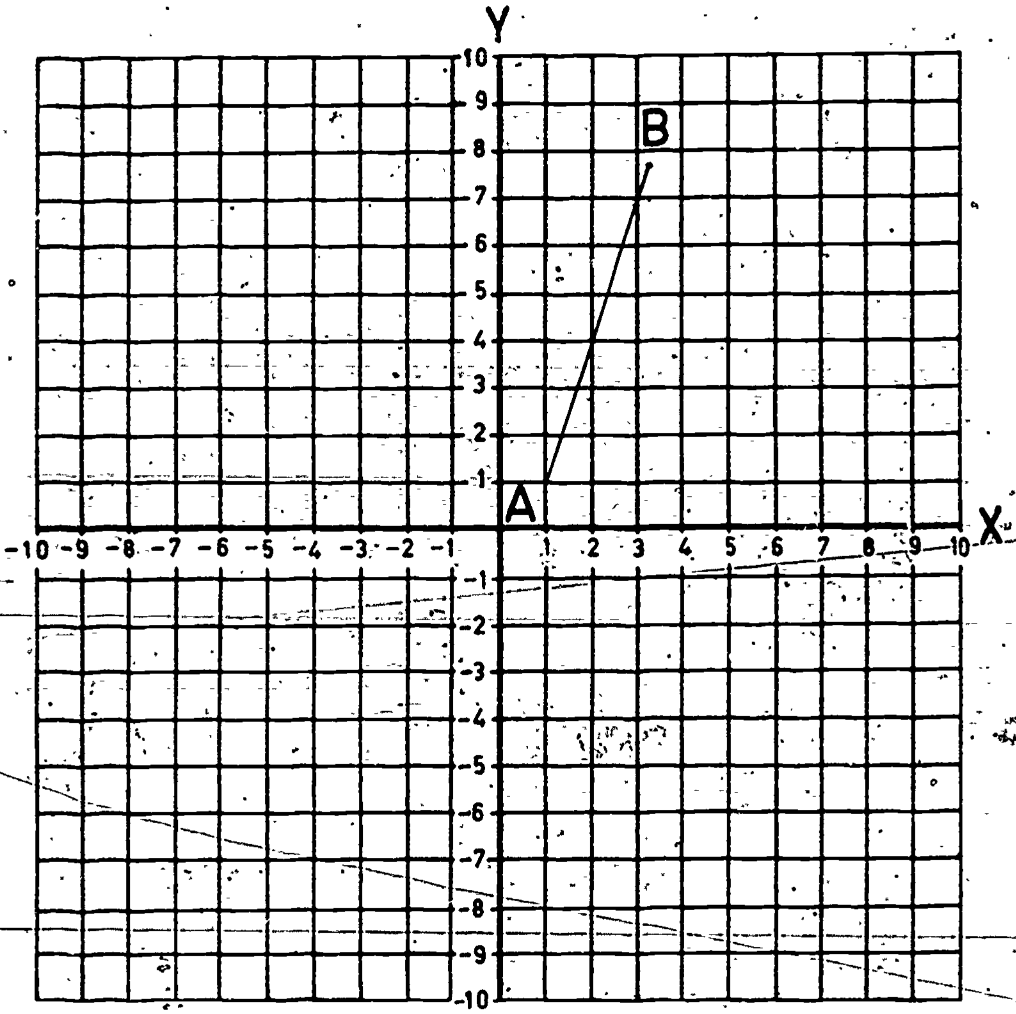
______ (sign) ______ (number)



Calculate the gradient of the line AB.

ANSWER

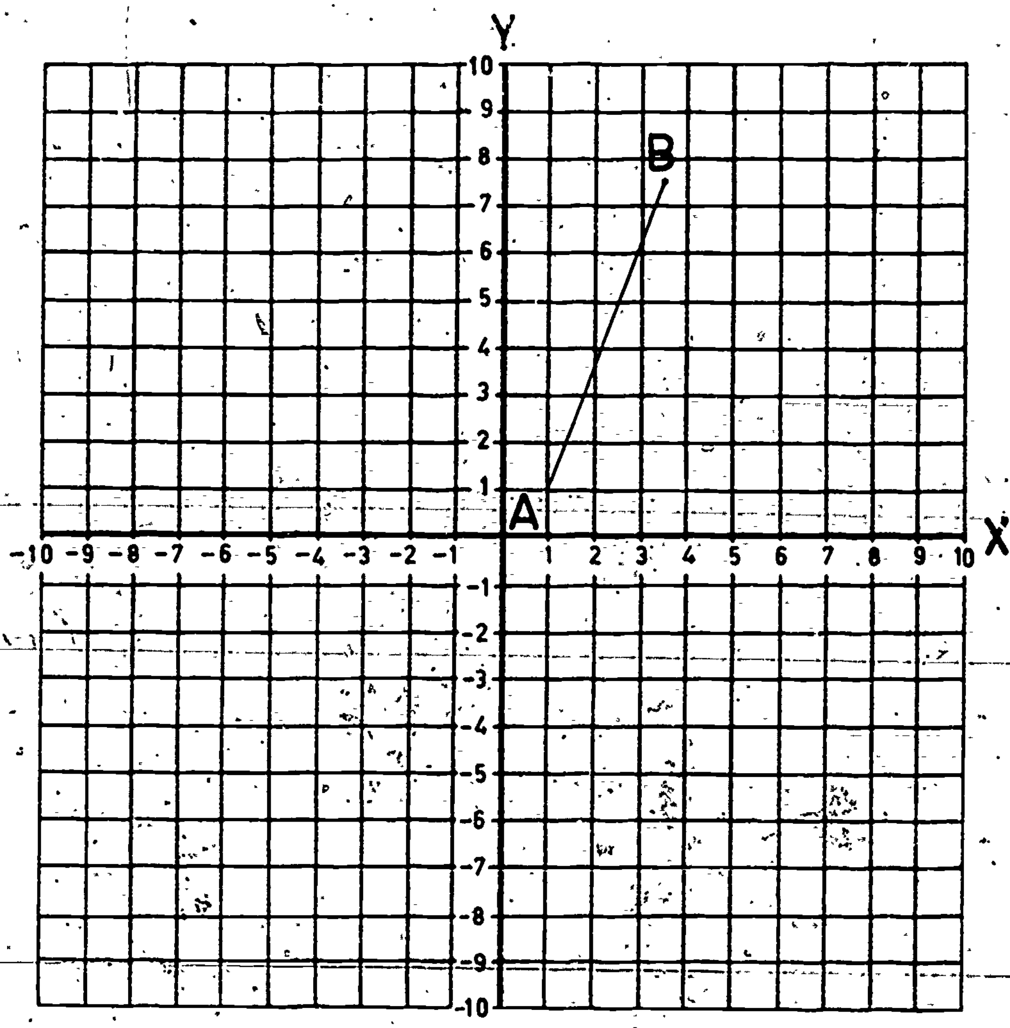
______ ______
(sign) (number)



Calculate the gradient of the line AB.

ANSWER

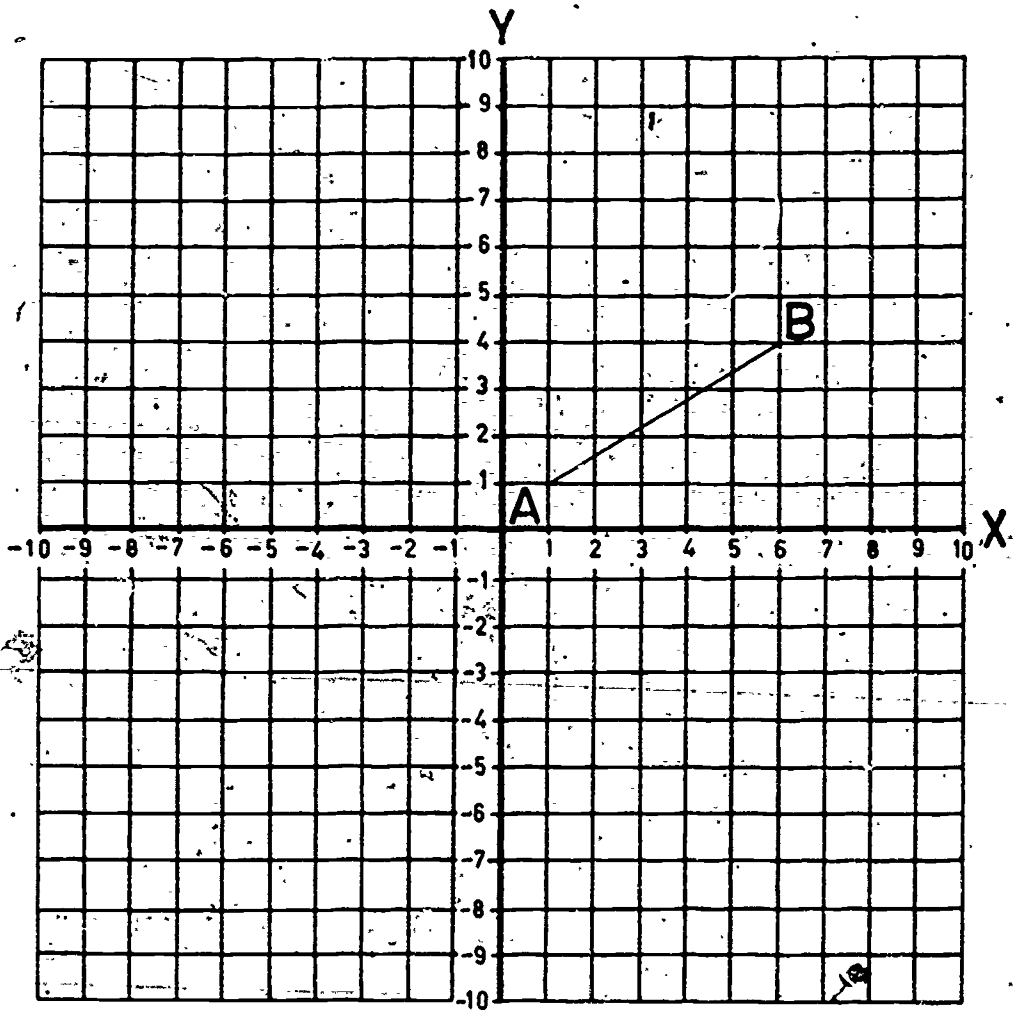
______ (sign) ______ (number)



Calculate the gradient of the line AB.

ANSWER

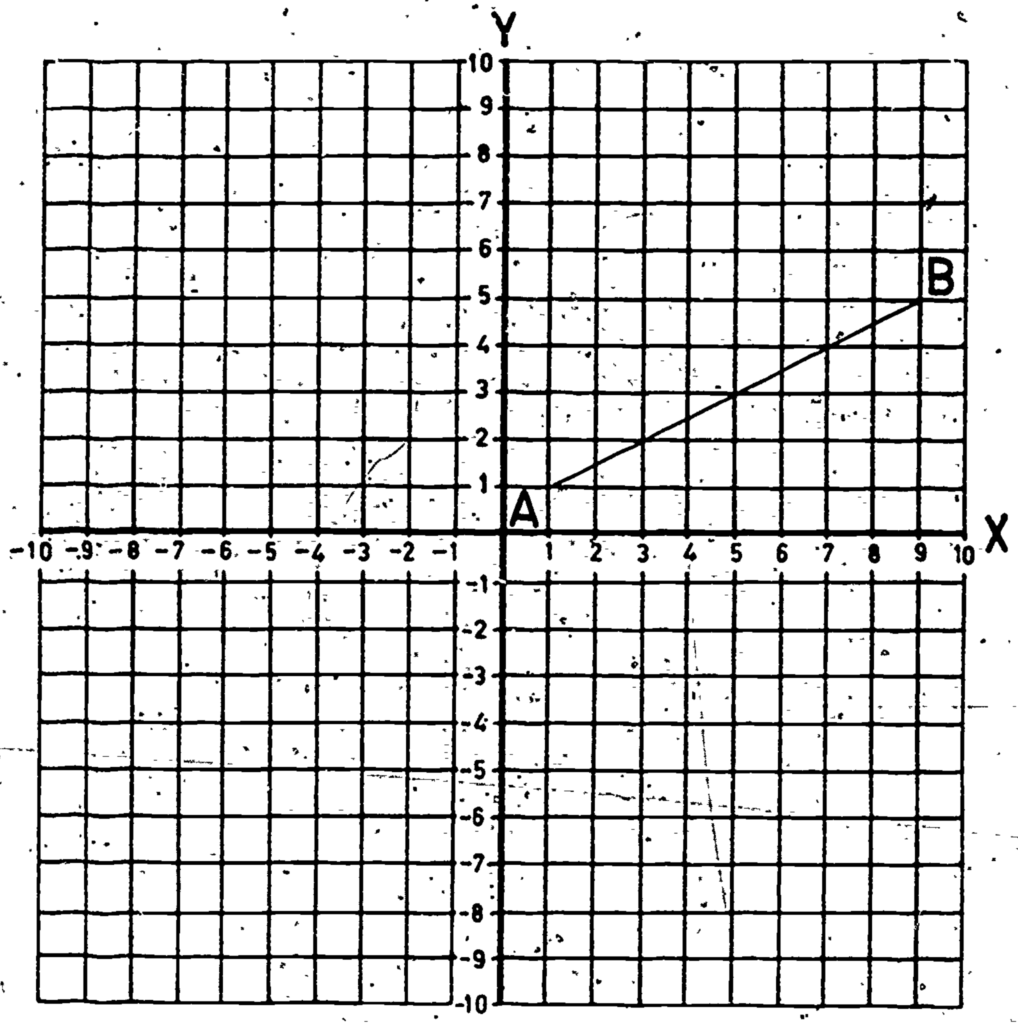
______ (sign) ______ (number)



Calculate the gradient of the line AB.

ANSWER

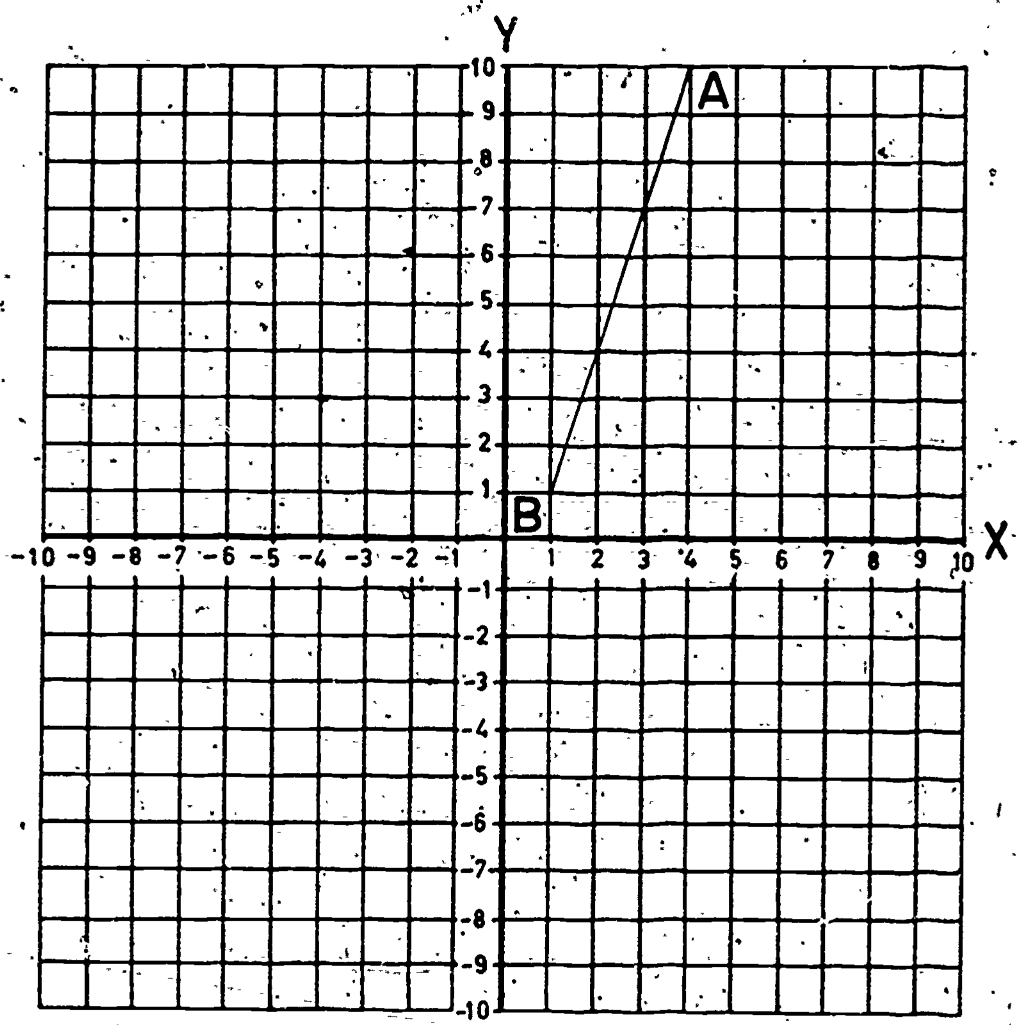
______ (sign) ______ (number)



Calculate the gradient of the line AB.

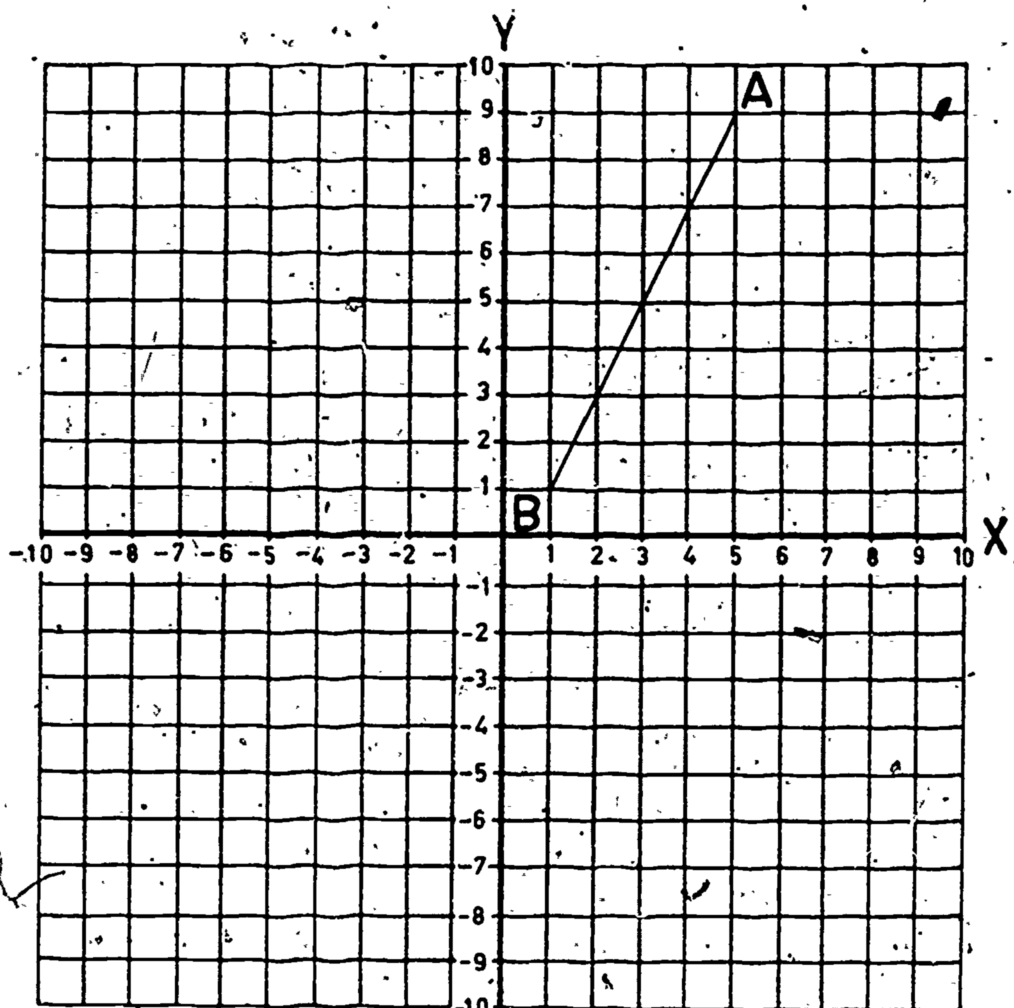
ANSWER

______ ______
(sign) (number)



Calculate the gradient of the line AB.

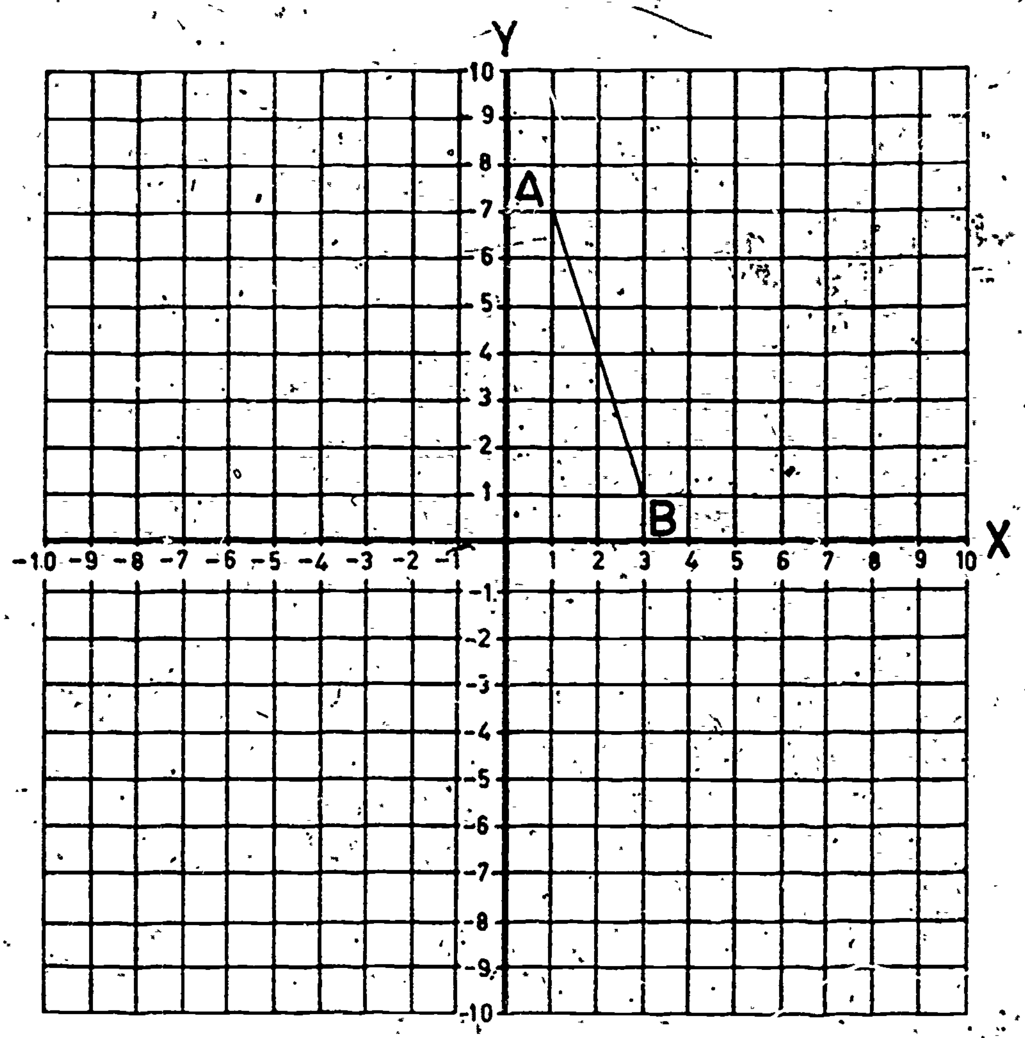
ANSWER ________ ________
(sign) (number)



Calculate the gradient of the line AB.

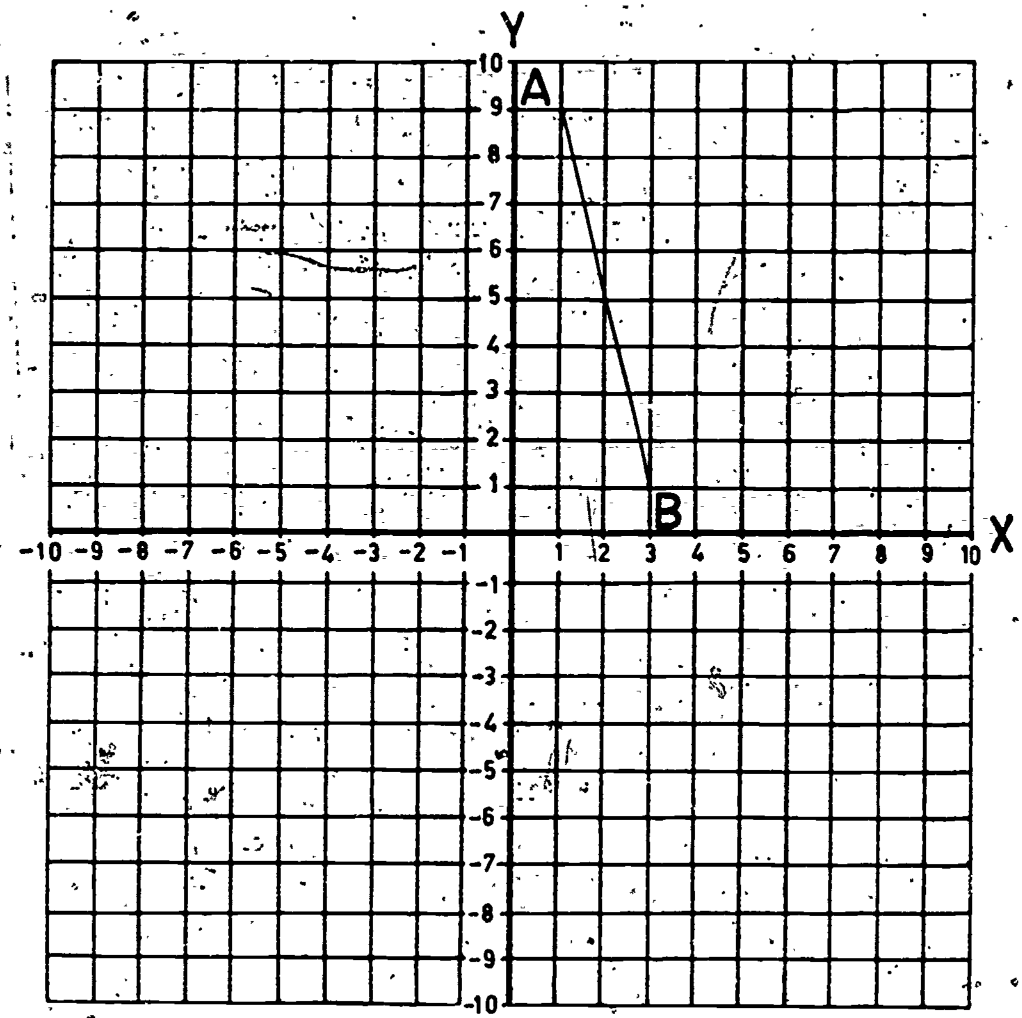
ANSWER

______ (sign) ______ (number)



Calculate the gradient of the line AB.

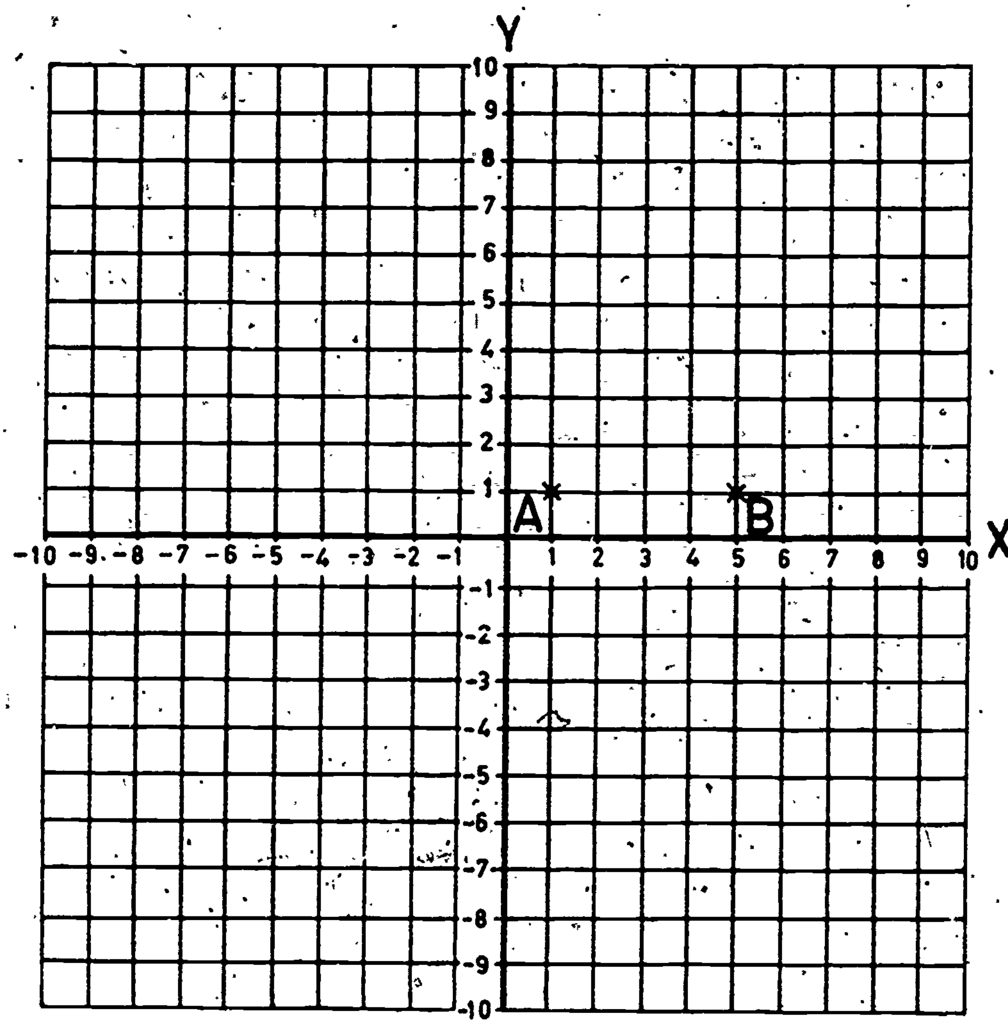
ANSWER. ______ ______
(sign) (number)



Calculate the gradient of the line AB.

ANSWER

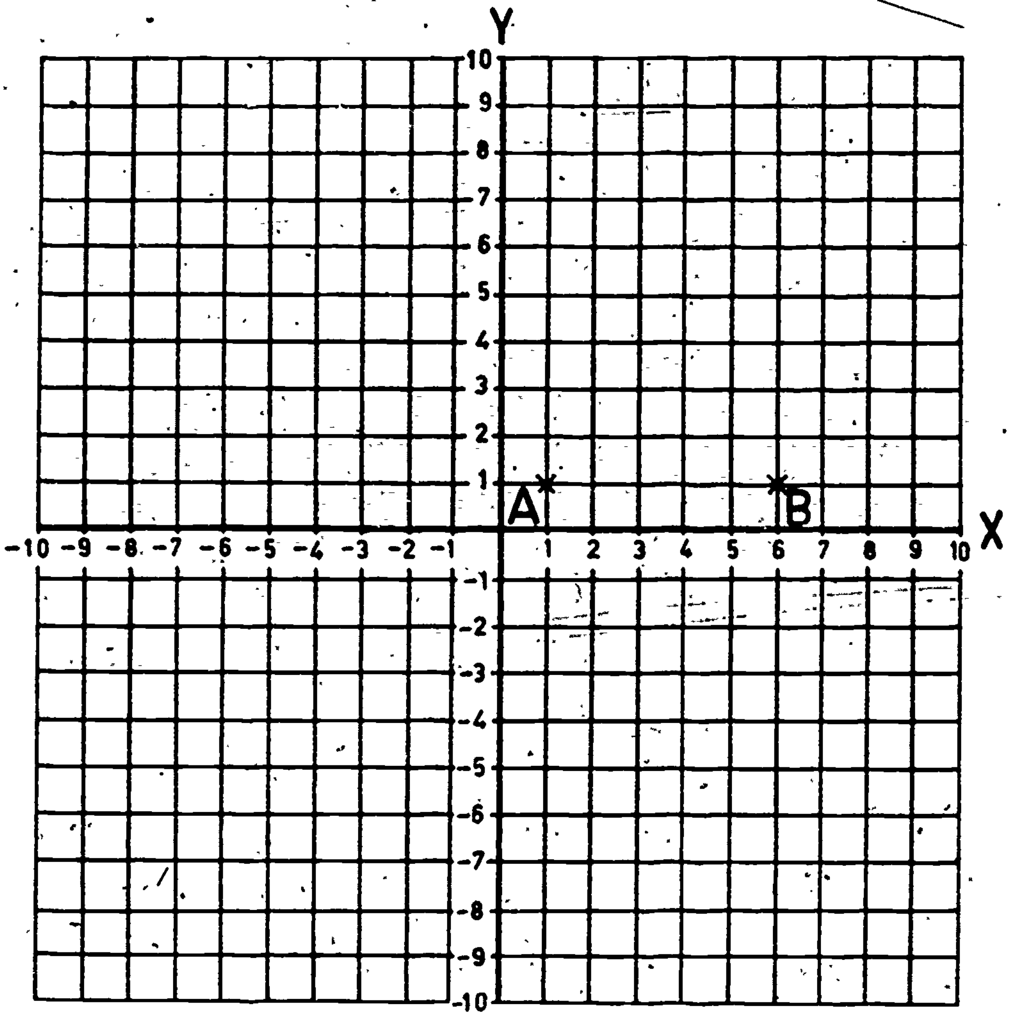
______ ______
(sign) (number)



Calculate the gradient of the line AB.

ANSWER

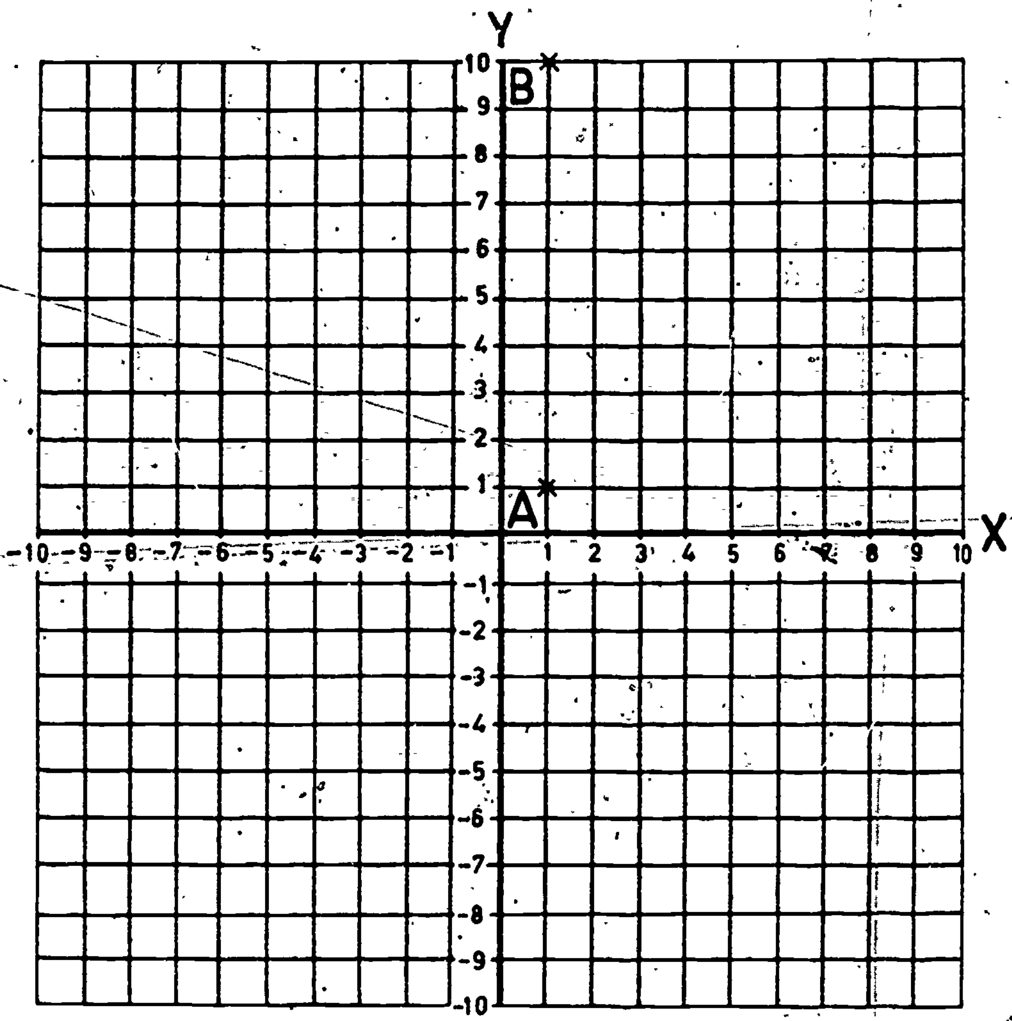
______ ______
(sign) (number)



Calculate the gradient of the line AB.

ANSWER

_______ _________
(sign) (number)

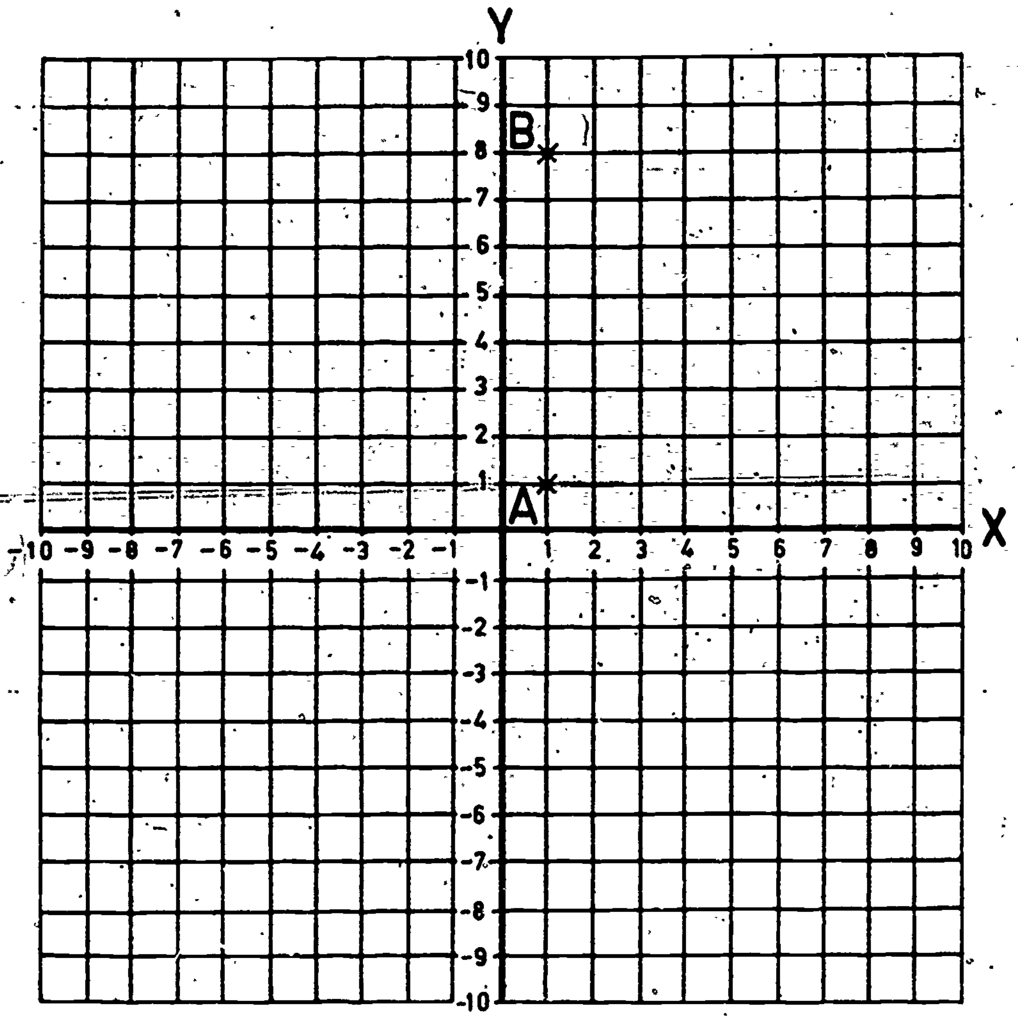


Calculate the gradient of the line AB.

ANSWER

______ ______

(sign) (number)



Calculate the gradient of the line AB.

ANSWER

______ ______
(sign) (number)

BASIC SKILLS OF GRAPHICAL INTERPRETATION

SUBDIVISION ANALYSIS SET 5/3(A)

NAME ______________ AGE ______

SEX ______

SCHOOL ______________ CLASS ______

DATE ______

INSTRUCTIONS

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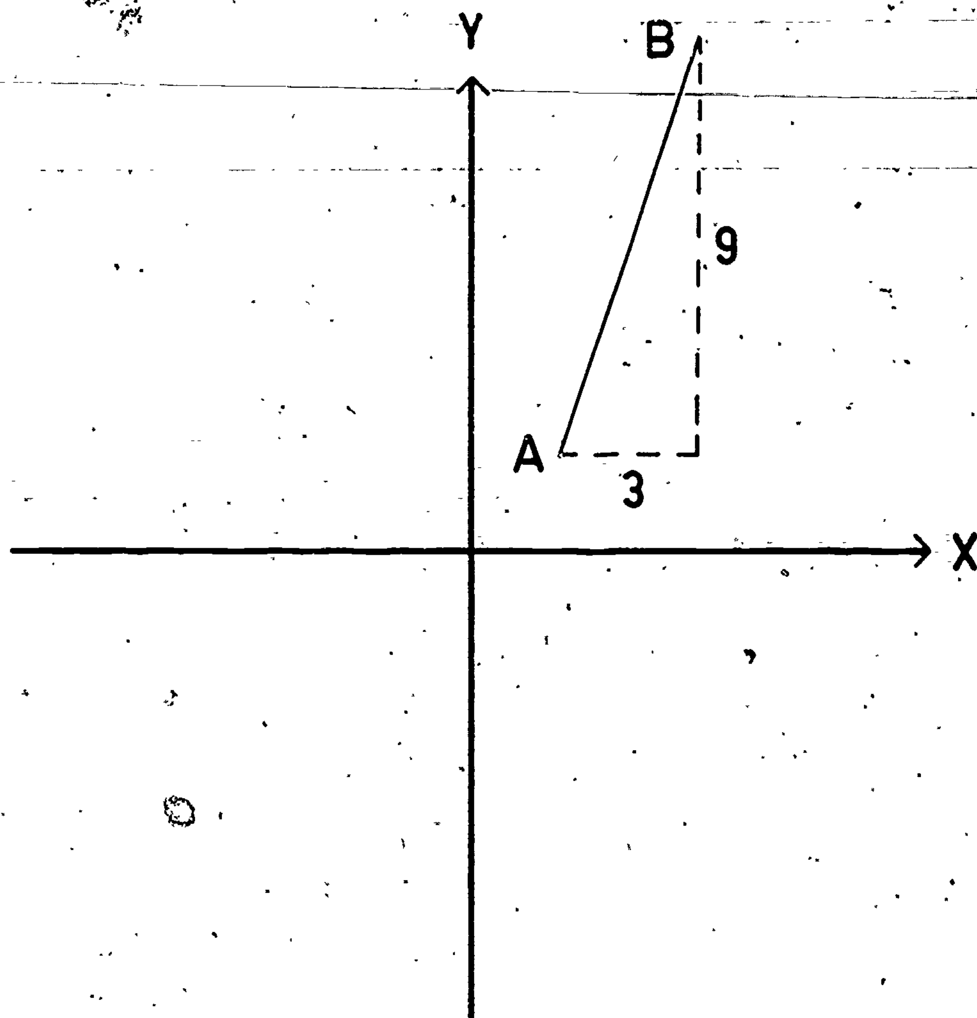
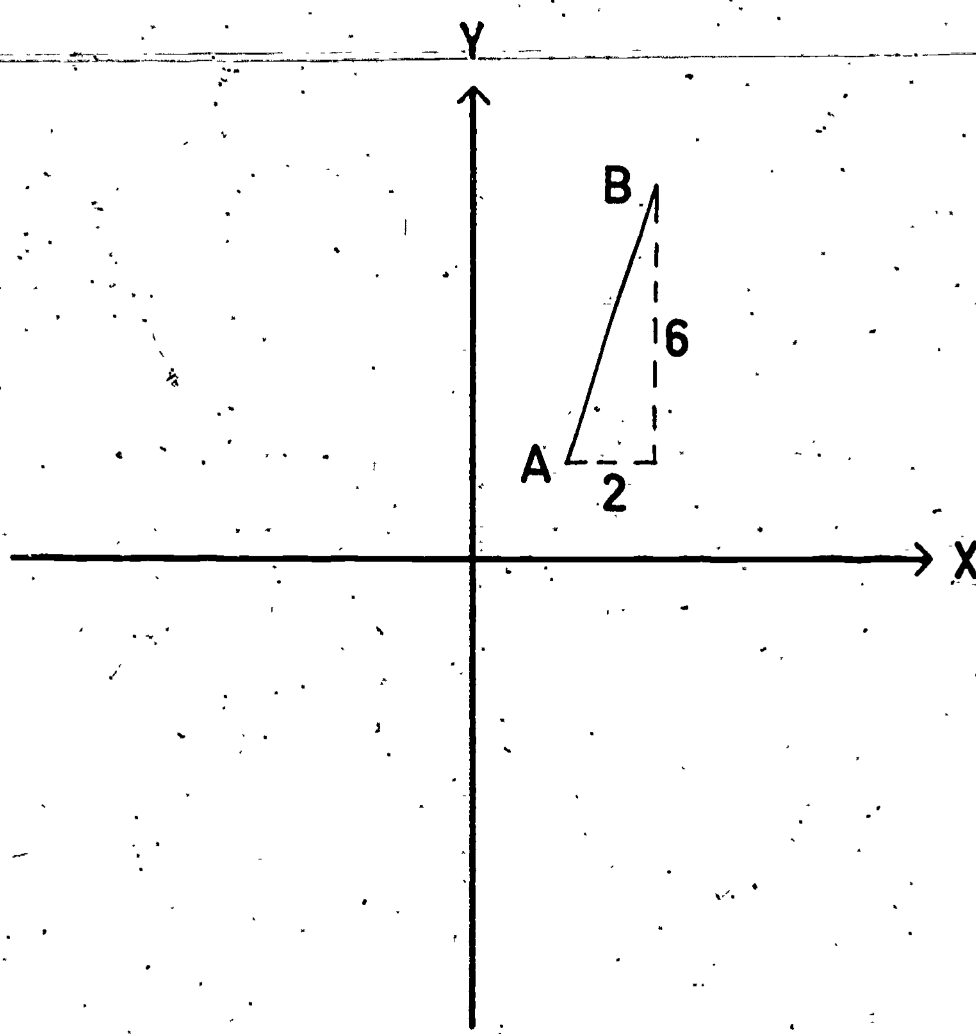


Calculate the gradient of the line AB.

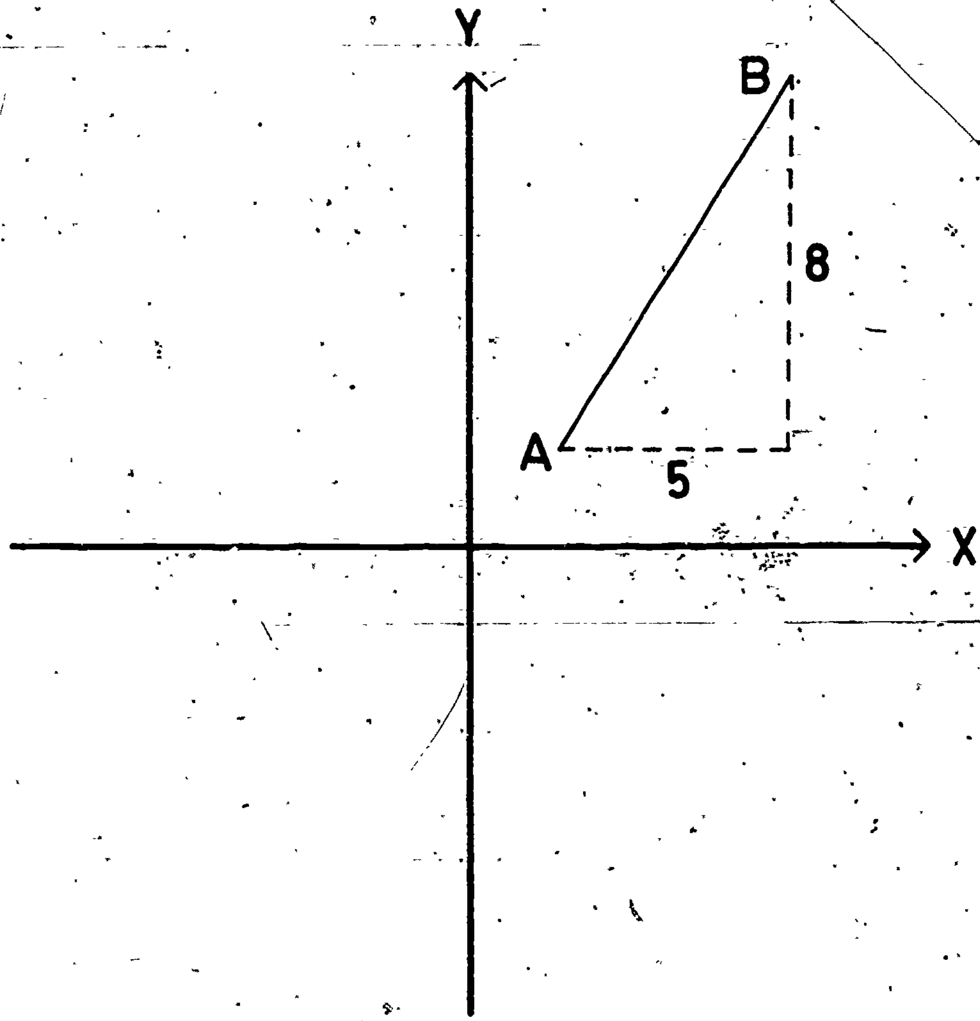
ANSWER -

______ ______
(sign) (number)



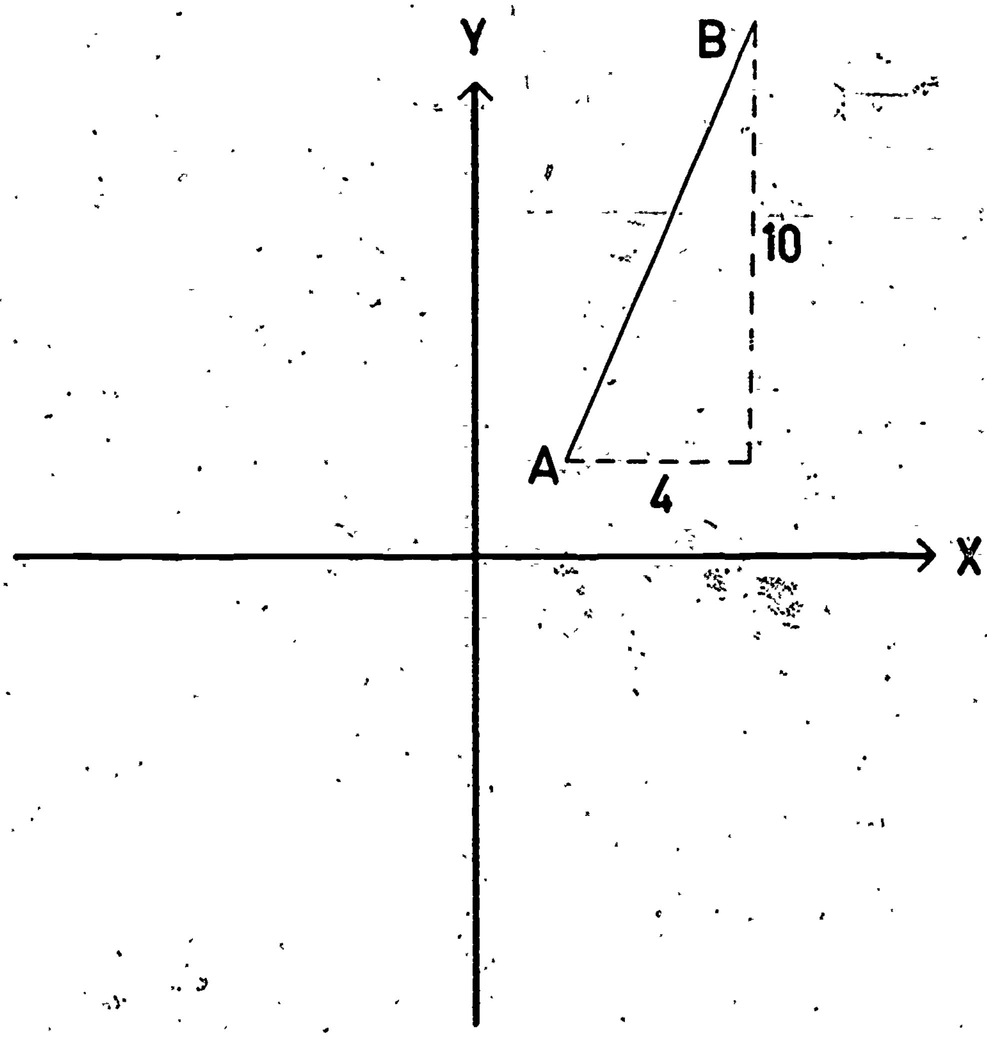
Calculate the gradient of the line AB.

ANSWER ________ ________
(sign) (number)



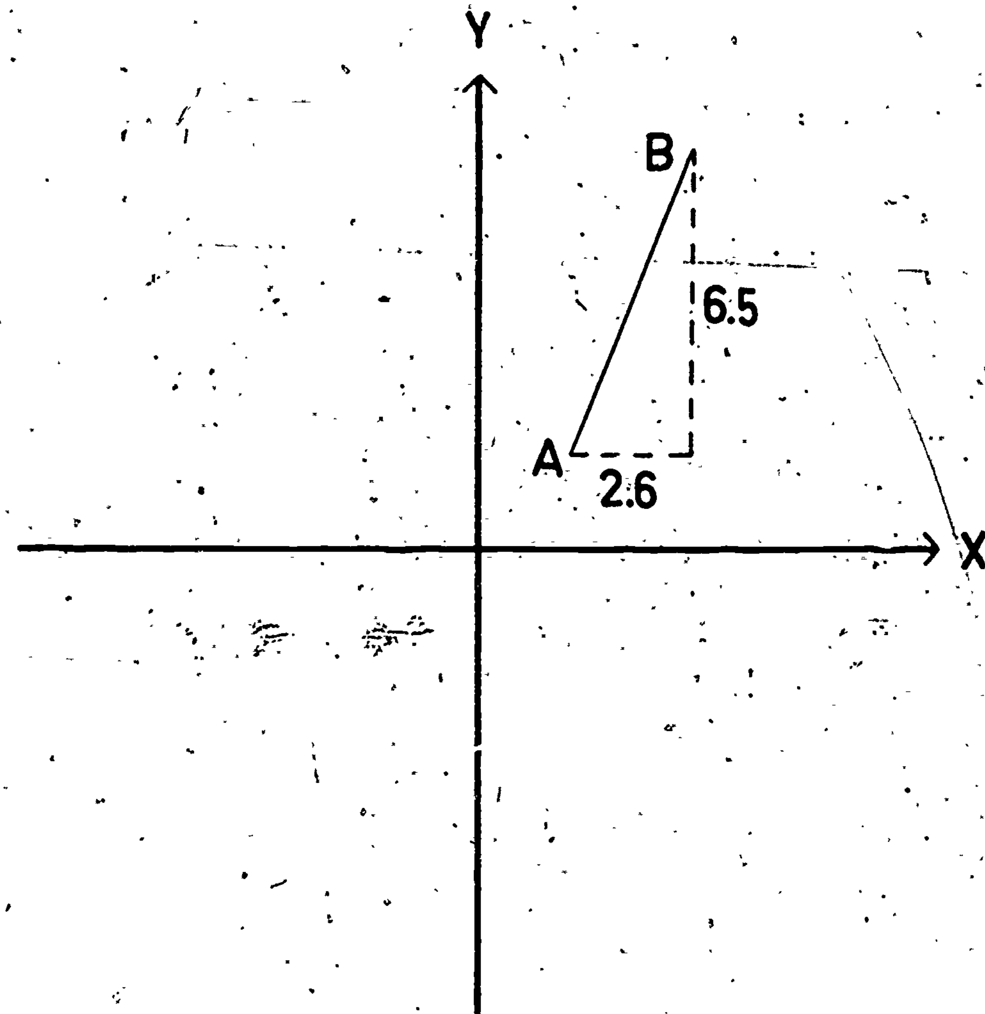
Calculate the gradient of the line AB.

ANSWER. _______ _________
(sign) (number)



Calculate the gradient of the line AB.

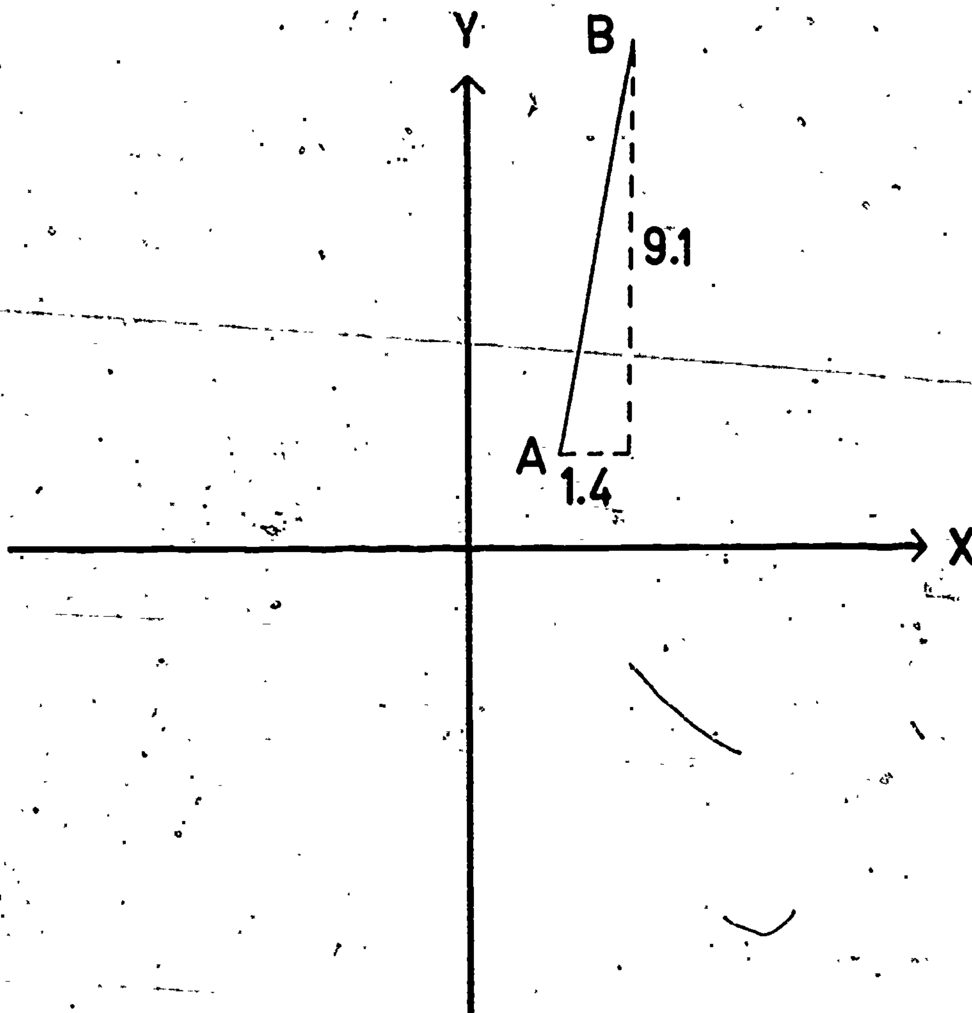
ANSWER ______ ______
(sign) (number)



Calculate the gradient of the line AB.

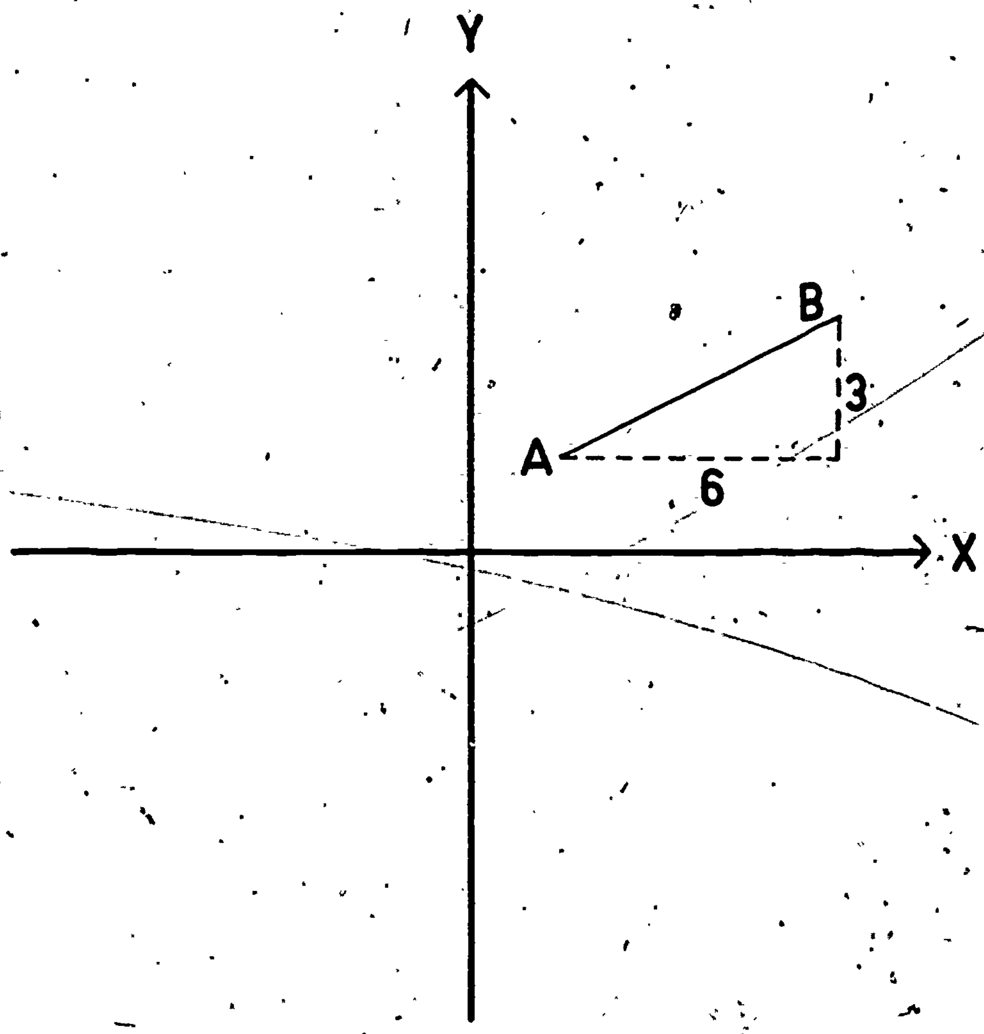
ANSWER

______ ______
(sign) (number)



Calculate the gradient of the line AB.

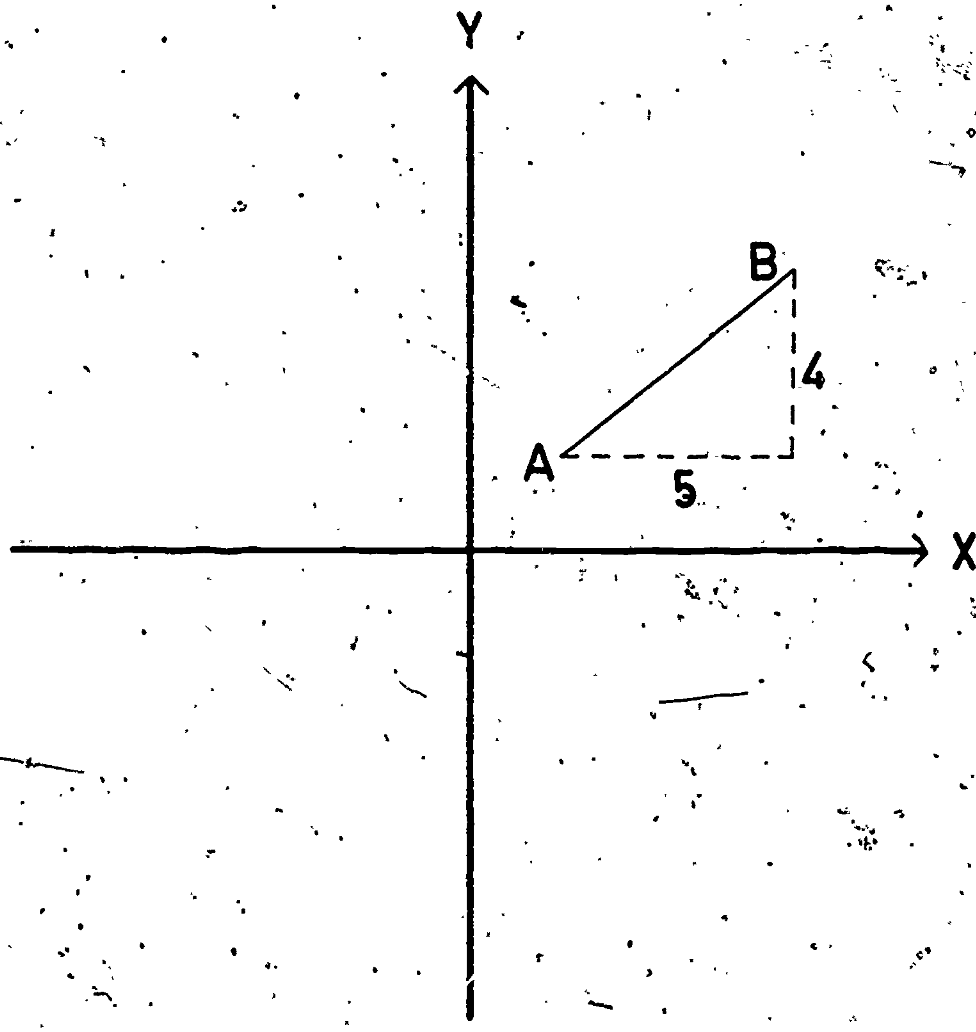
ANSWER ______ ______
(sign) (number)



Calculate the gradient of the line AB.

<u>ANSWER</u>

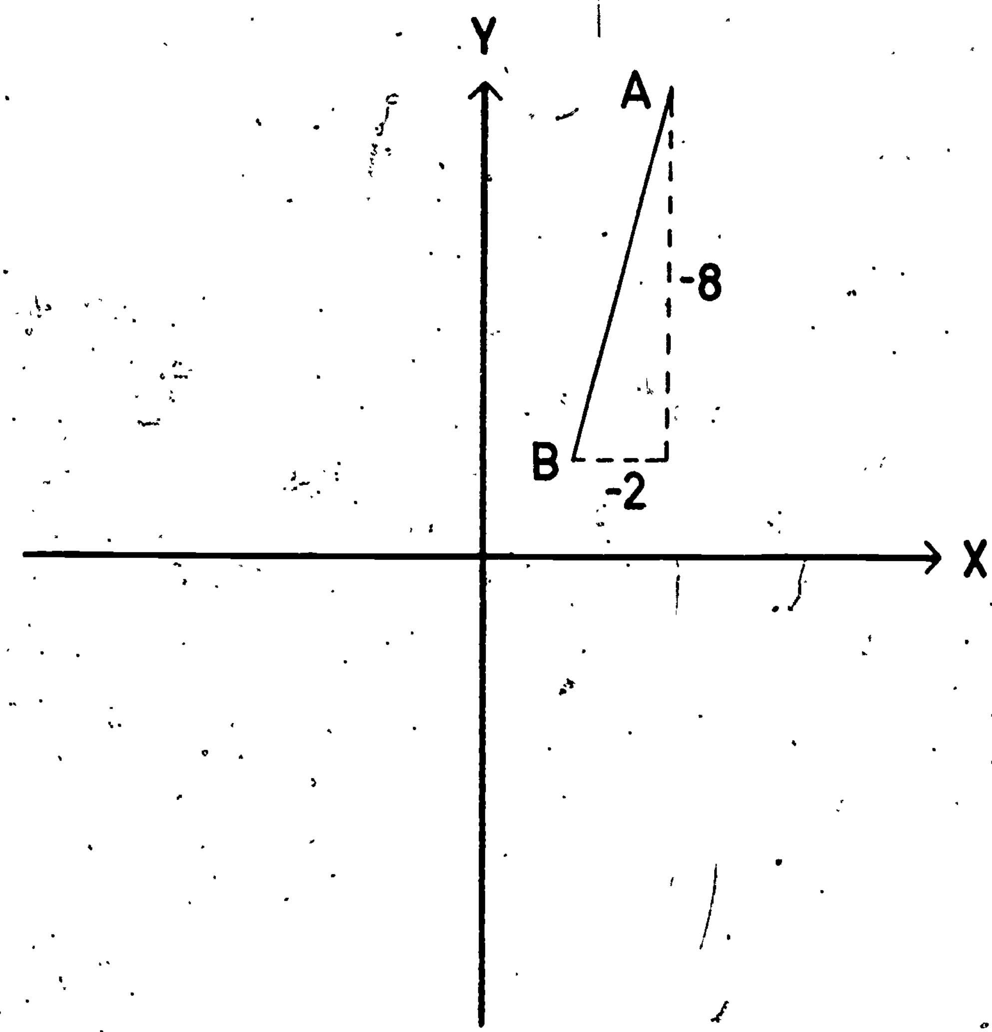
_______ _________
(sign) (number)



Calculate the gradient of the line AB.

ANSWER

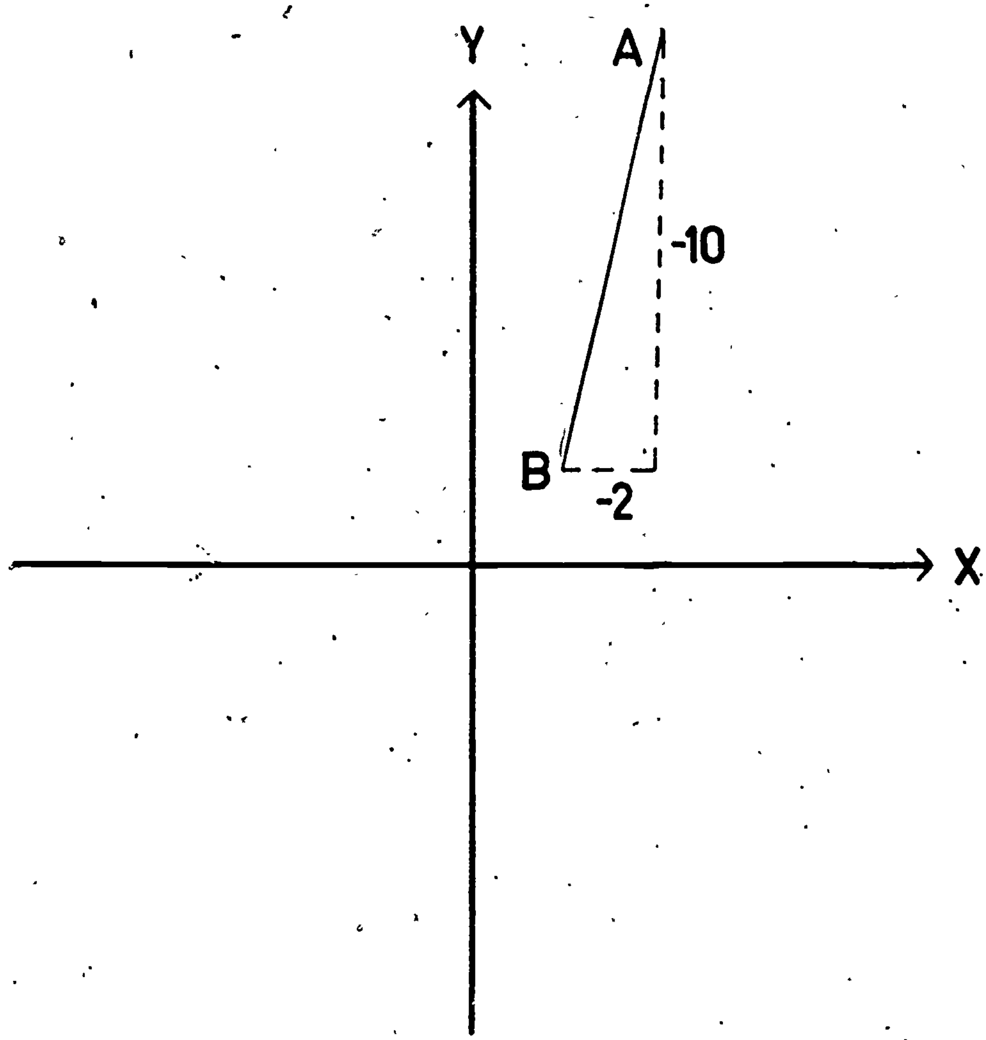
_______ (sign) _______ (number)



Calculate the gradient of the line AB.

<u>ANSWER</u>

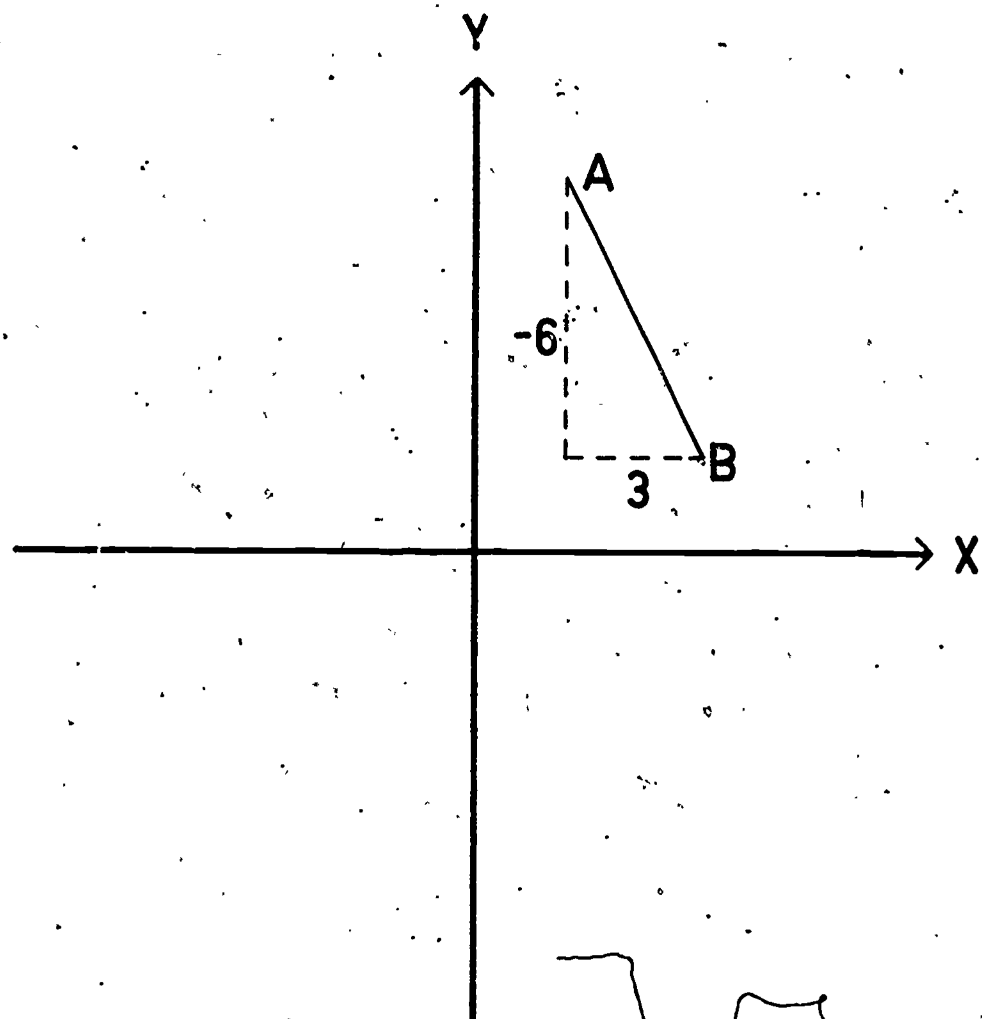
_____ (sign) _____ (number)



Calculate the gradient of the line AB.

ANSWER

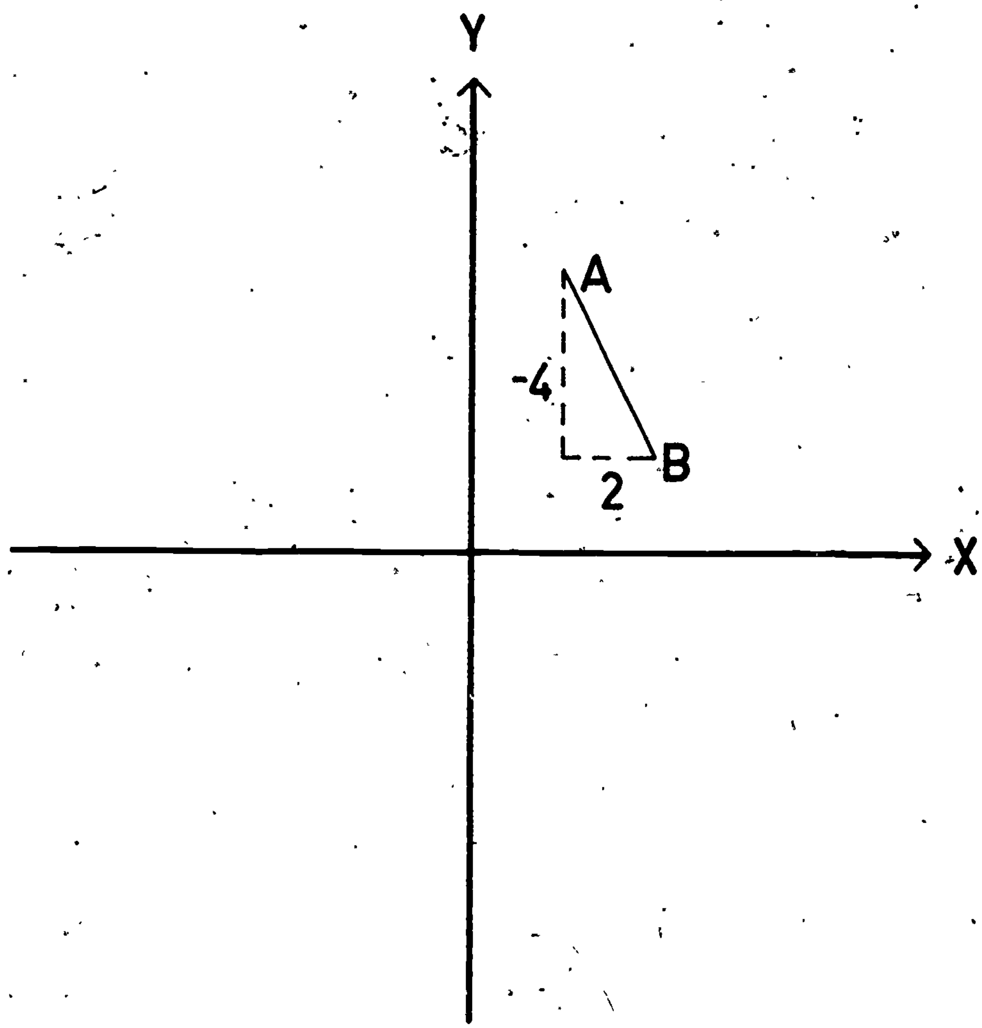
______ ________
(sign) (number)



Calculate the gradient of the line AB.

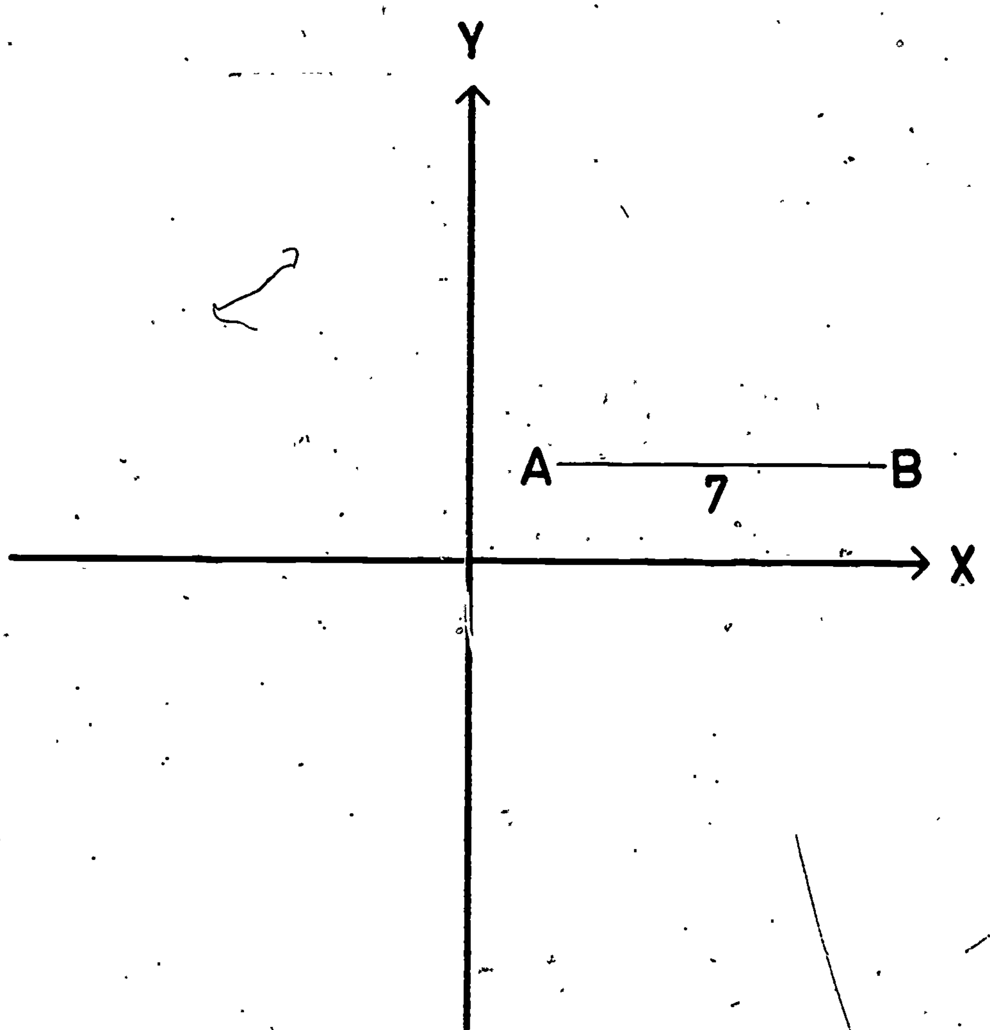
ANSWER

______ ______
(sign) (number)



Calculate the gradient of the line AB.

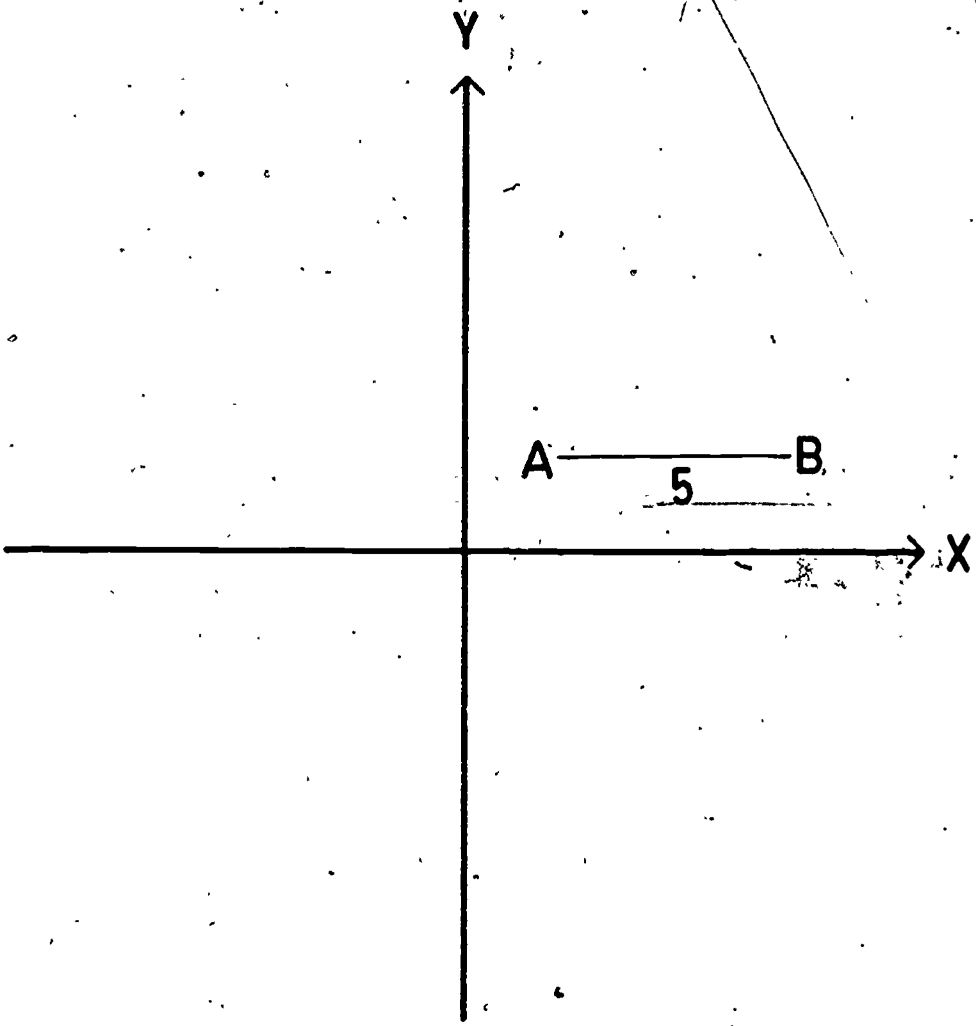
ANSWER ______ ______
(sign) (number)



Calculate the gradient of the line AB.

ANSWER

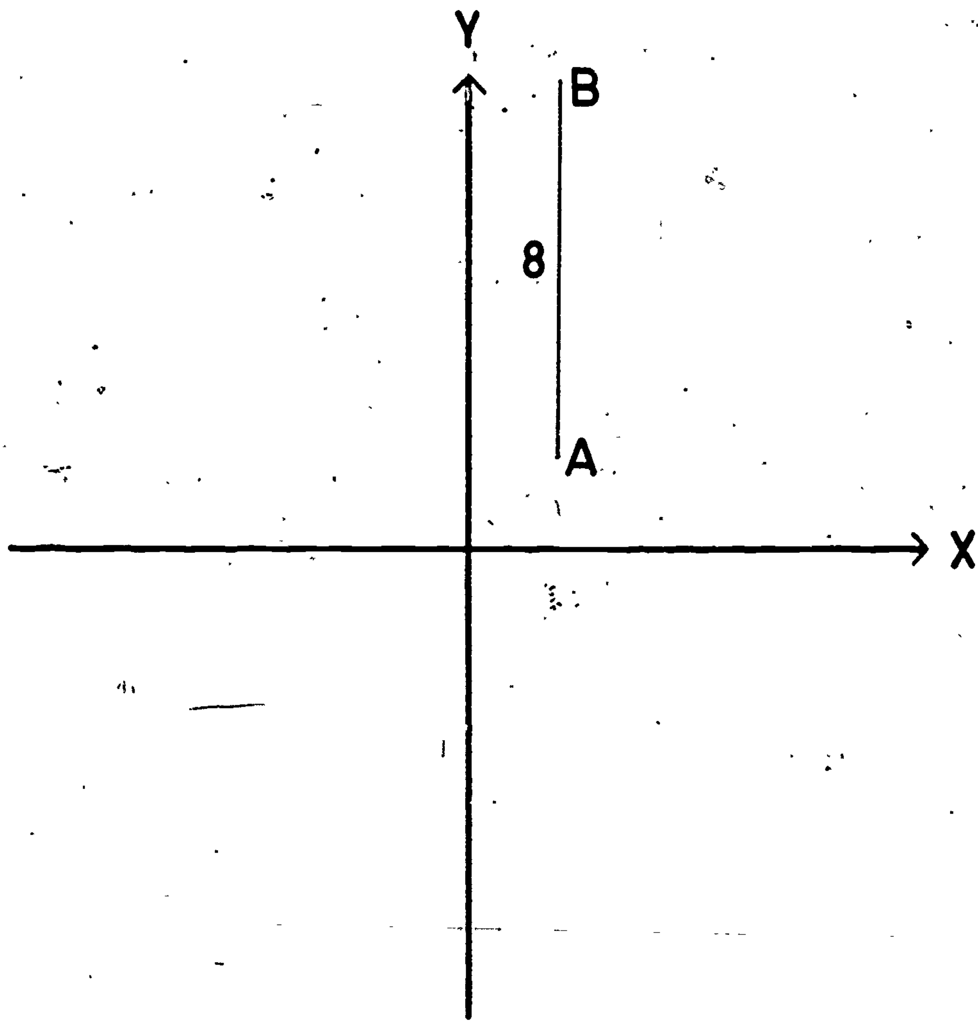
______ ________
(sign) (number)



Calculate the gradient of the line AB.

ANSWER

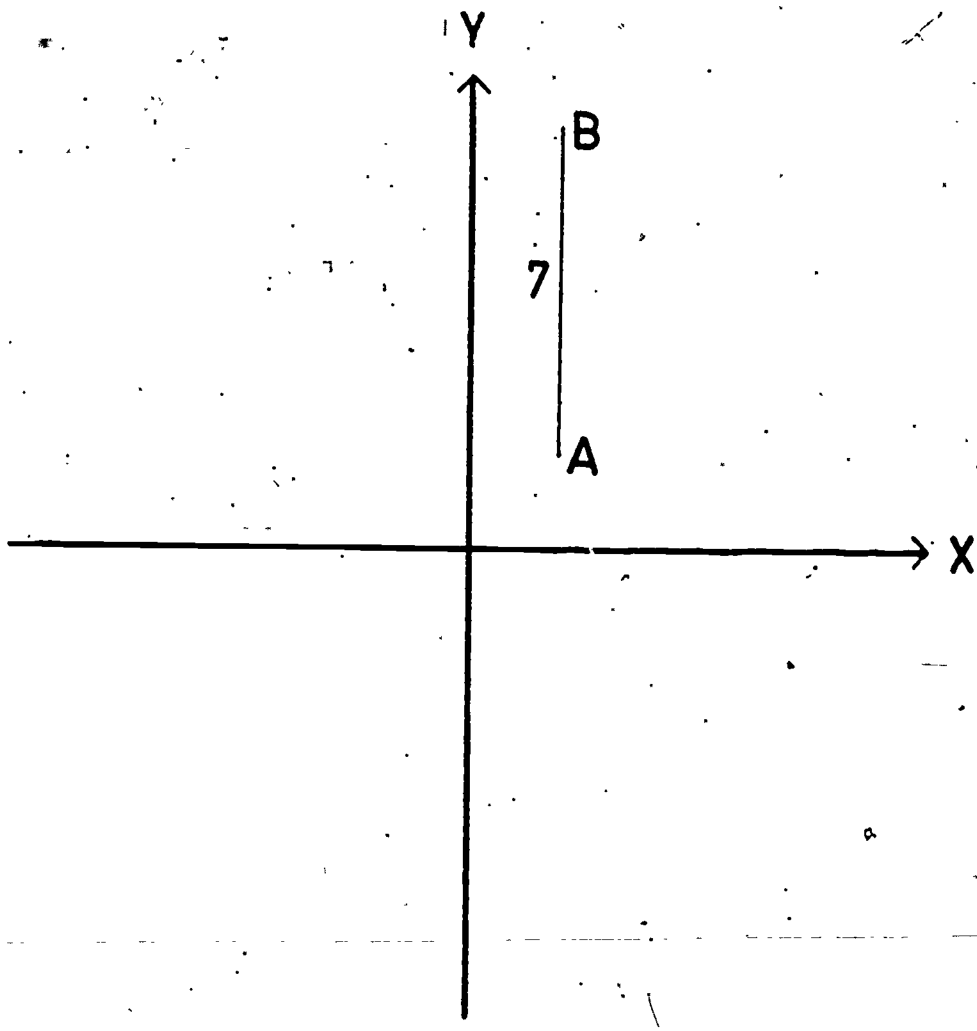
______ ______
(sign) (number)



Calculate the gradient of the line AB.

ANSWER

_____ _____
(sign) (number)



Calculate the gradient of the line AB.

ANSWER

______ ______
(sign) (number)

BASIC SKILLS OF GRAPHICAL INTERPRETATION

SUBDIVISION ANALYSIS SET 5/4(A)

NAME ____________ AGE ____________

SEX ____________

SCHOOL ____________ CLASS ____________

DATE ____________

INSTRUCTIONS

Read each question carefully, then write your answer in the space provided. Try to guess the answers to any questions you do not know, but do not waste time on more difficult problems. All answers should be given to the nearest decimal place, and any other calculations may be written on the back of the page. The sign of an answer, where this applies, should be either positive (+) or negative (-).

Complete the following calculation.

$6 \div 3 =$ ____

Complete the following calculation.

$8 \div 2 =$ ____

Complete the following calculation.

$9 \div 6 =$ ____

Complete the following calculation.

$10 \div 4 =$ ____

Complete the following calculation.

$$6.3 \div 1.8 = \_\_\_$$

Complete the following calculation.

7.2 ÷ 1.6 = ____

Complete the following calculation.

$4 \div 8 =$ ____

Complete the following calculation.

$2 \div 5 =$ ____

Complete the following calculation.

$-6 \div (-2) =$ ___

Complete the following calculation.

$-9 \div (-3) =$ ____

Complete the following calculation.

$$-10 \div 2 = \underline{\quad\quad}$$

Complete the following calculation.

$-8 \div 4 =$ ____

Complete the following calculation.

$0 \div 7 =$ ____

Complete the following calculation.

$0 \div 6 = \_\_\_\_$

Complete the following calculation.

$6 \div 0 = \_\_\_$

A

Complete the following calculation.

$5 \div 0 =$ ____

BASIC SKILLS OF GRAPHICAL INTERPRETATION

SUBDIVISION ANALYSIS SET 5/2(B)

NAME ______________ AGE ________

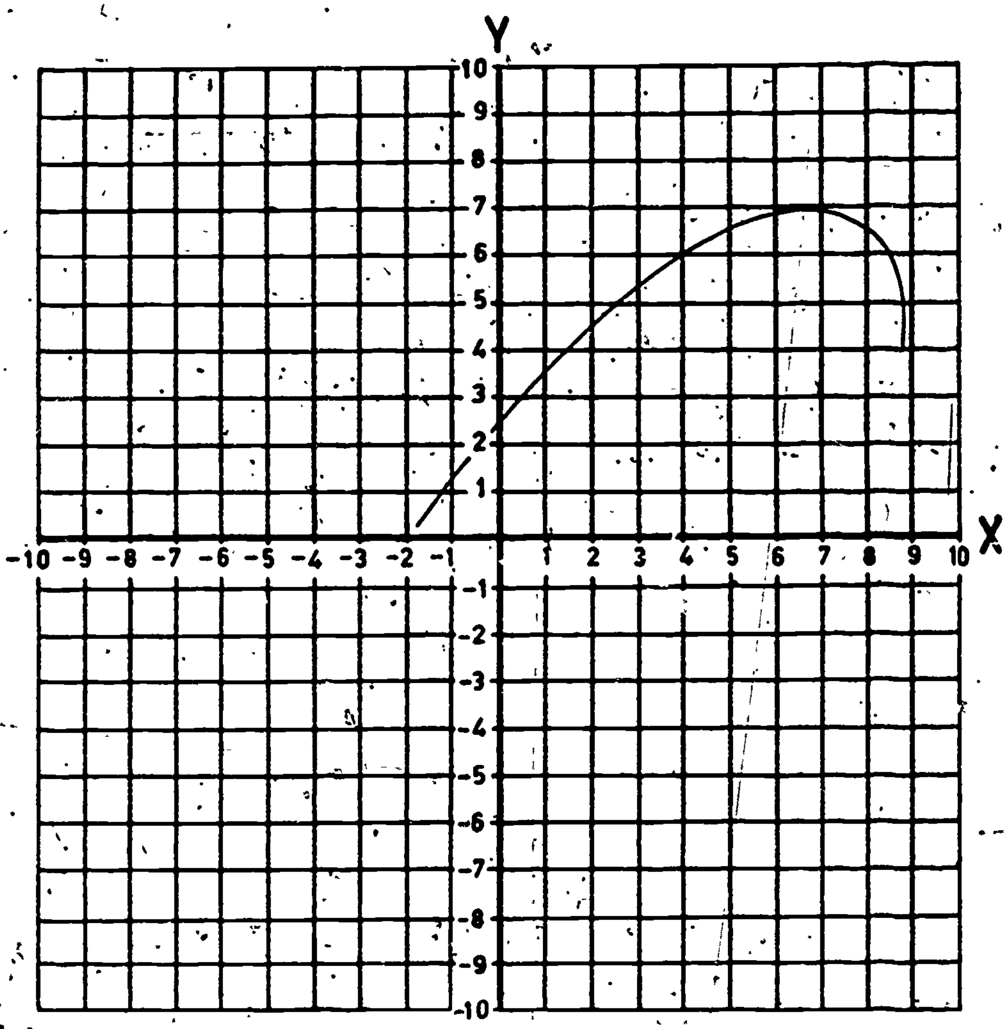
SEX ________

SCHOOL ______________ CLASS ________

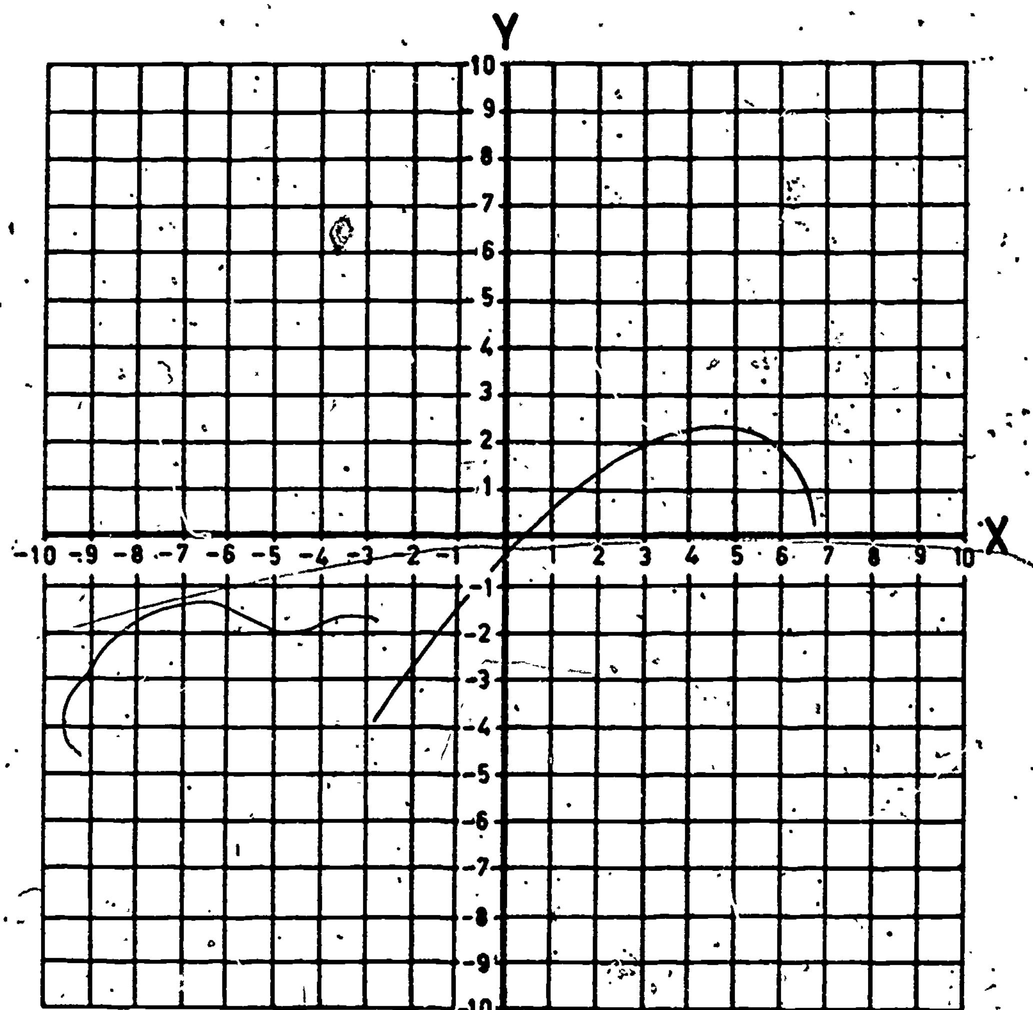
DATE ________

INSTRUCTIONS

Read each question carefully, then write your answer in the space provided. Try to guess the answers to any questions you do not know, but do not waste time on more difficult problems. All answers should be given to the nearest decimal place, and any other calculations may be written on the back of the page. The sign of an answer, where this applies, should be either positive (+) or negative (-).

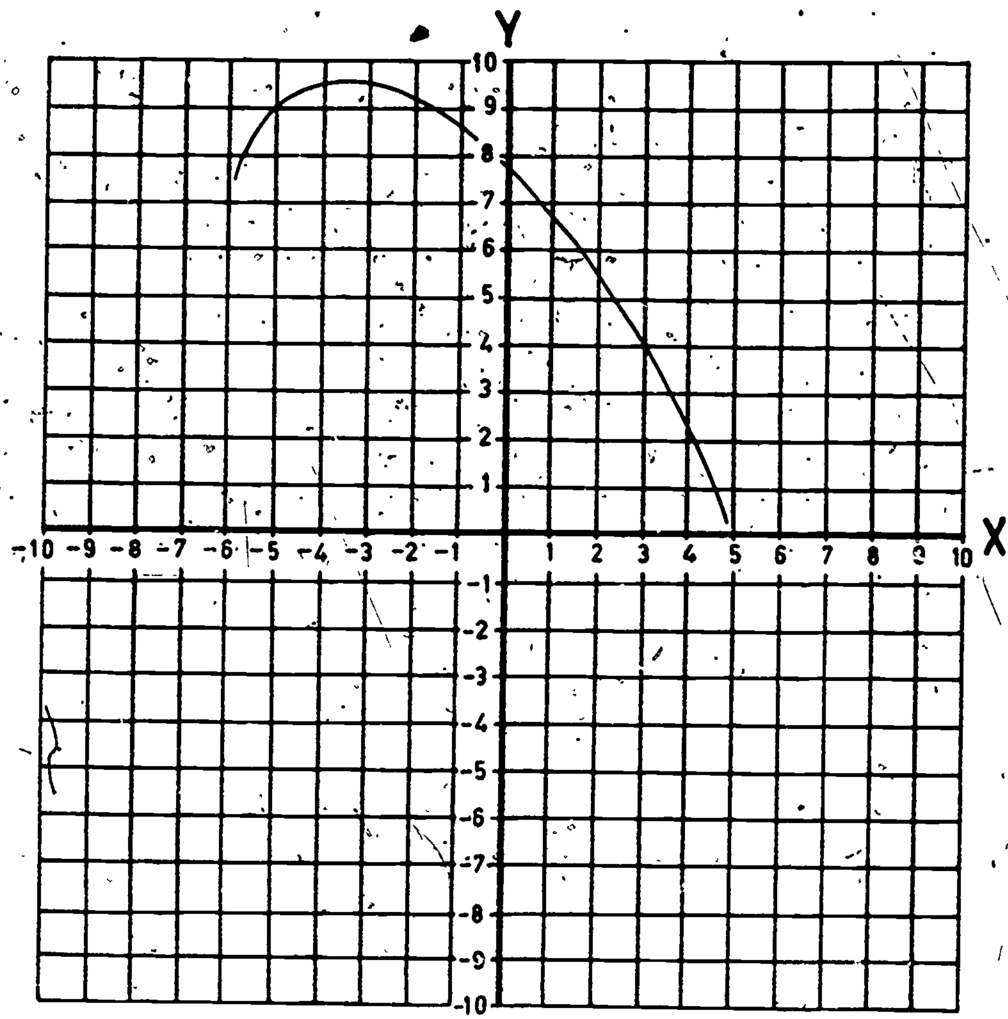


Rule a tangent to the curve above at the point where X = 4.0

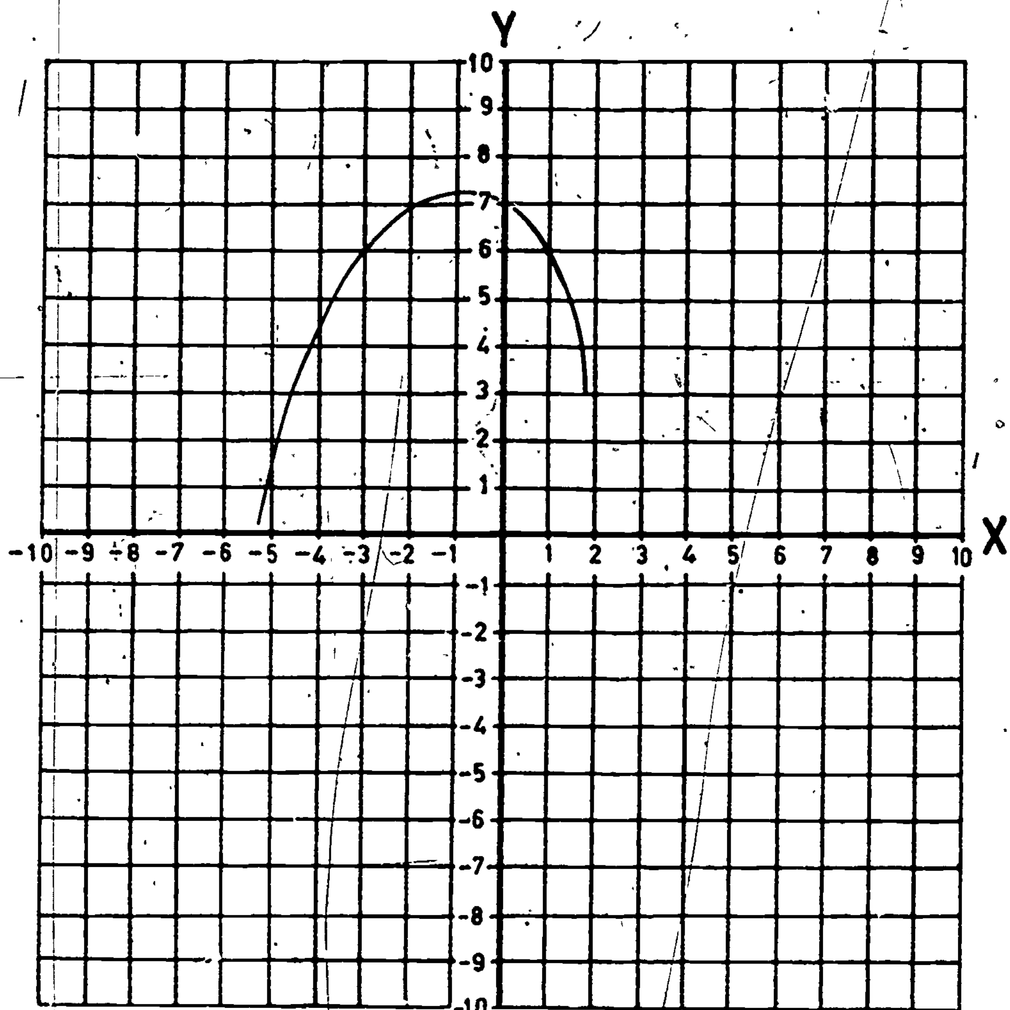


Rule a tangent to the curve above at the point where

X = 3.0

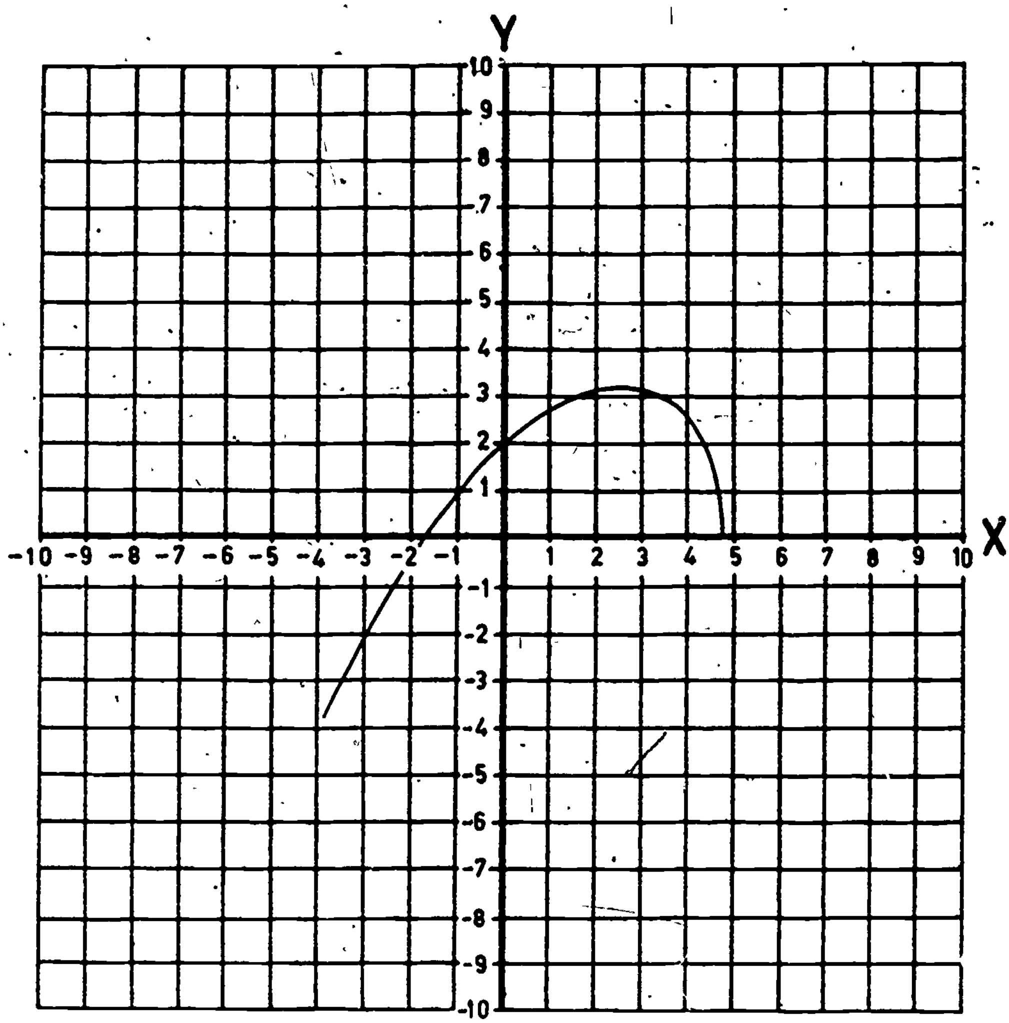


Rule a tangent to the curve above at the point where $X = -5.0$

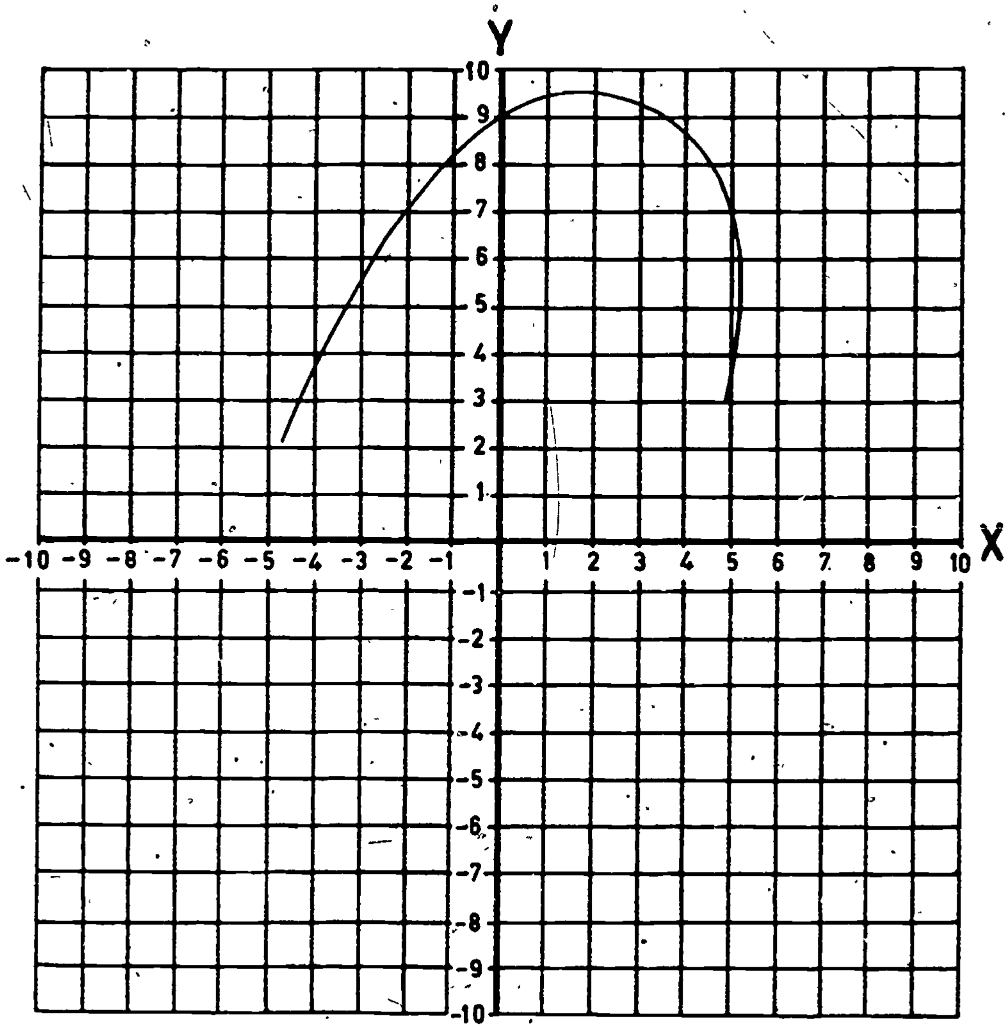


Rule a tangent to the curve above at the point where

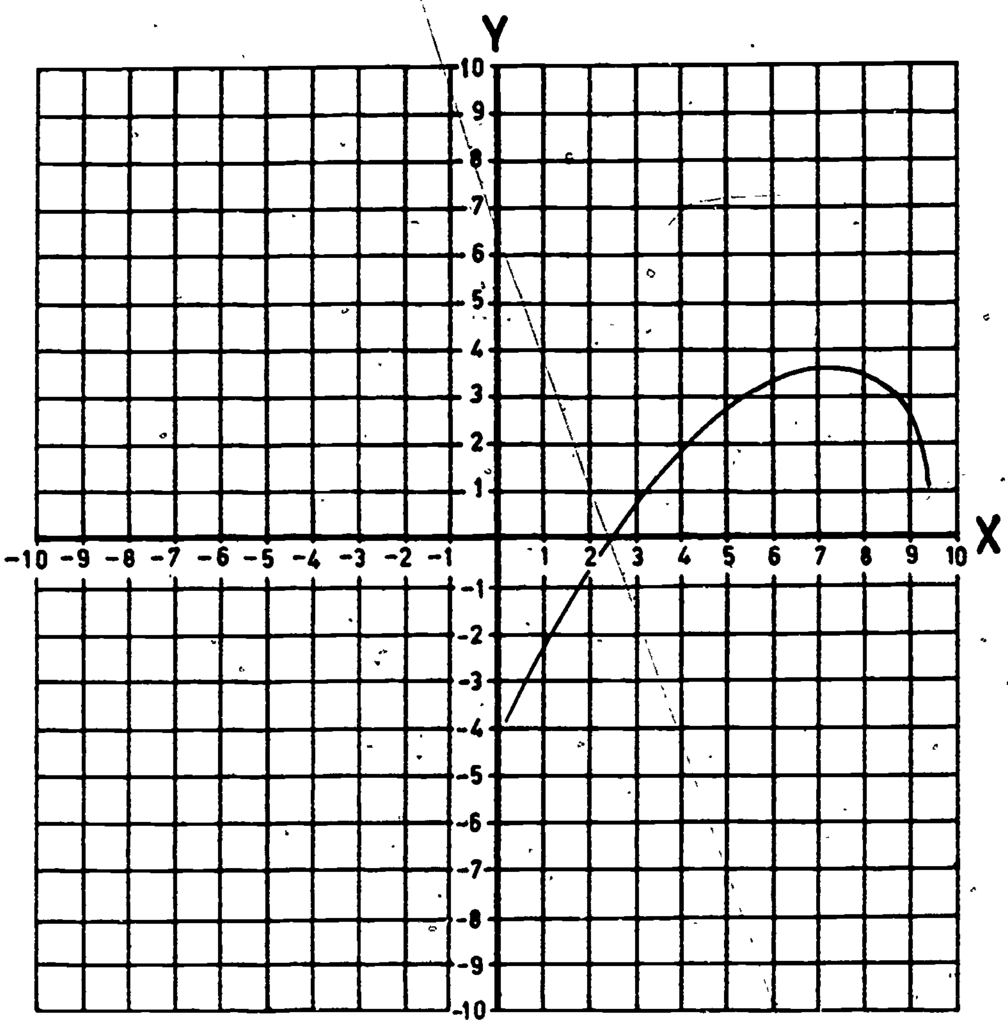
X = - 3.0



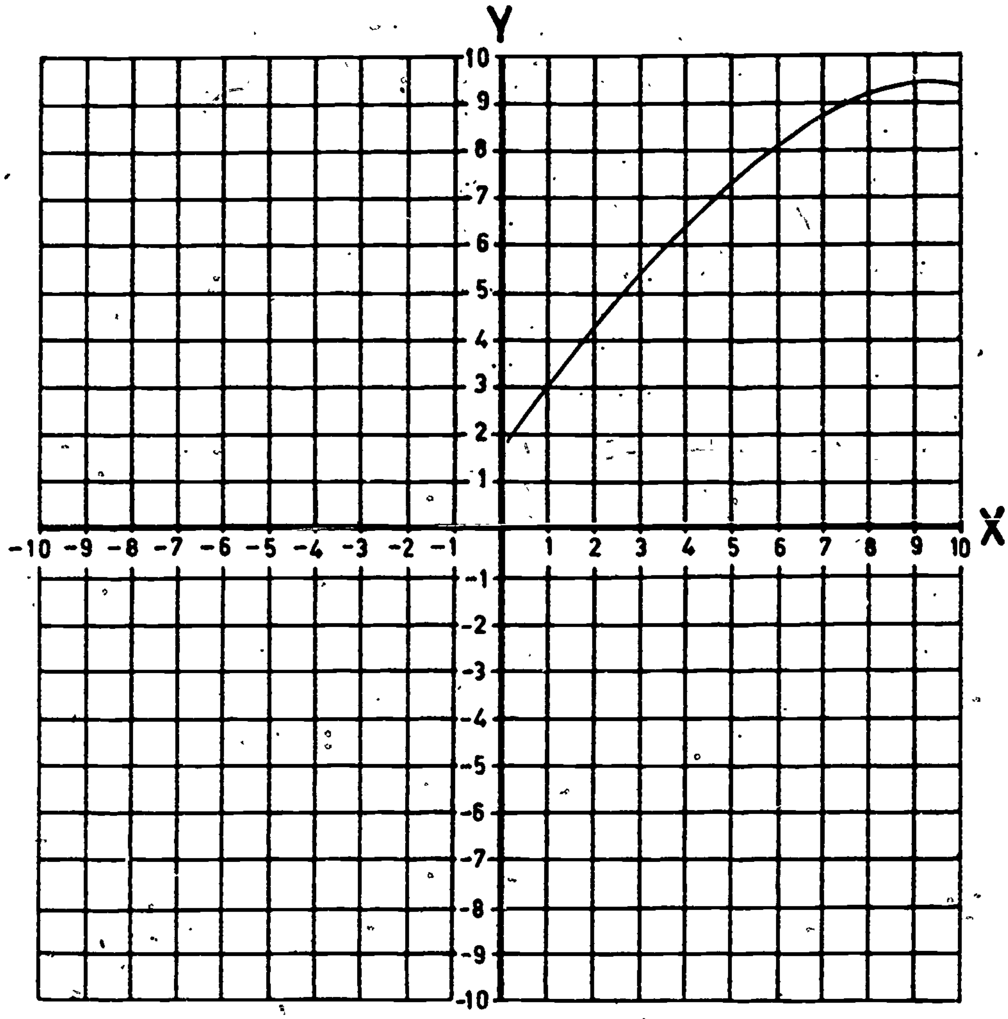
Rule a tangent to the curve above at the point where X = 0.



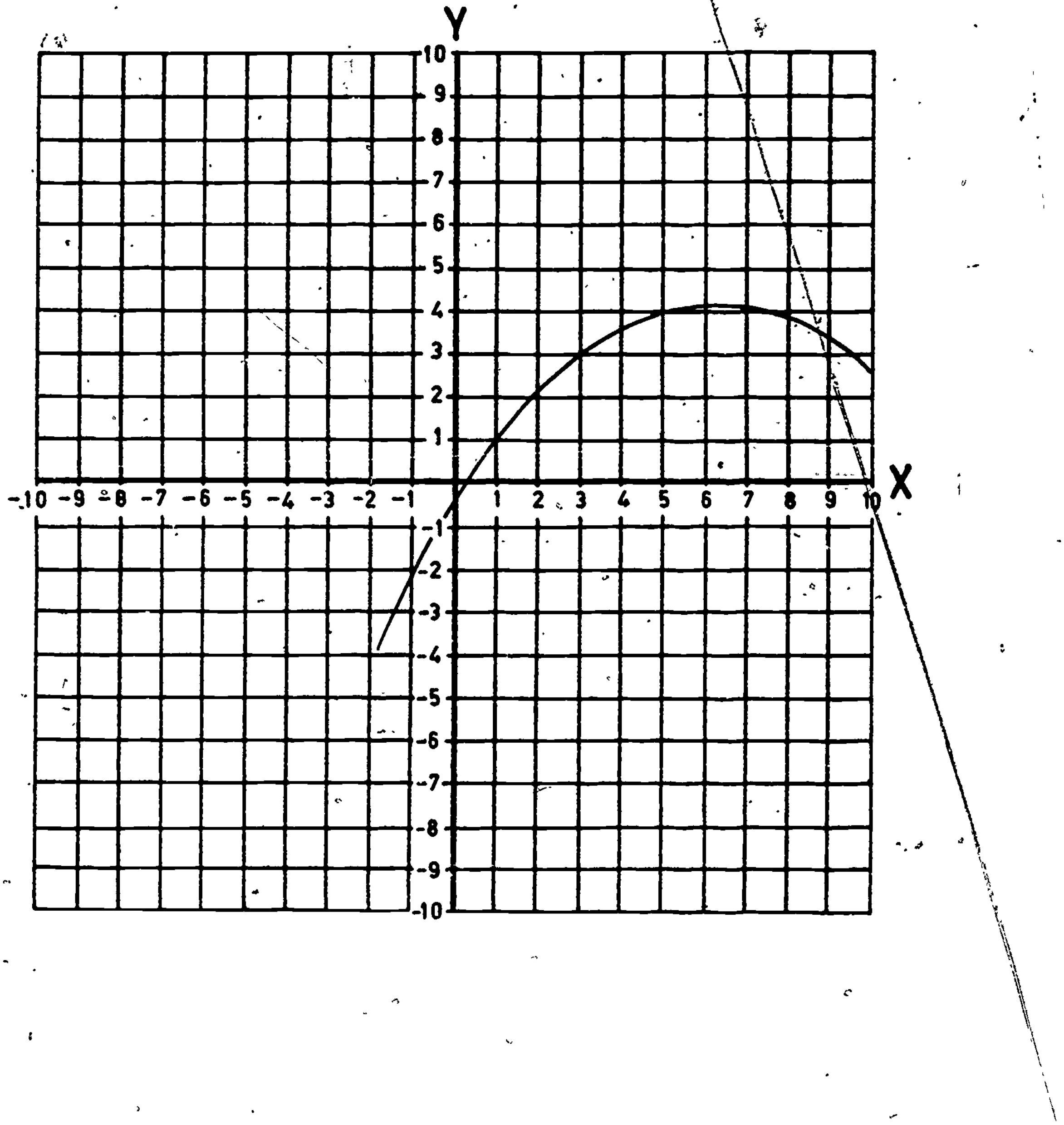
Rule a tangent to the curve above at the point where X = 0.



Rule a tangent to the curve above at the point where X = 5.4

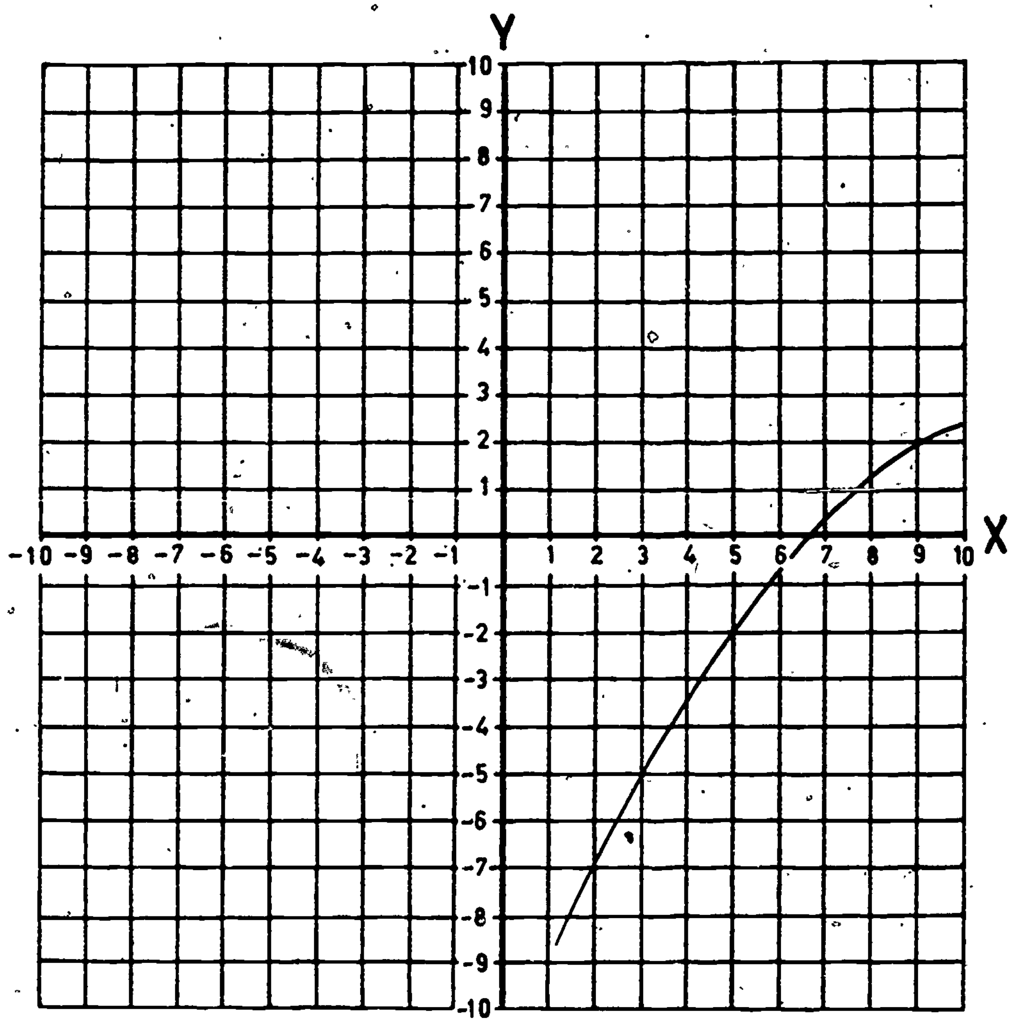


Rule a tangent to the curve above at the point where X = 7.5



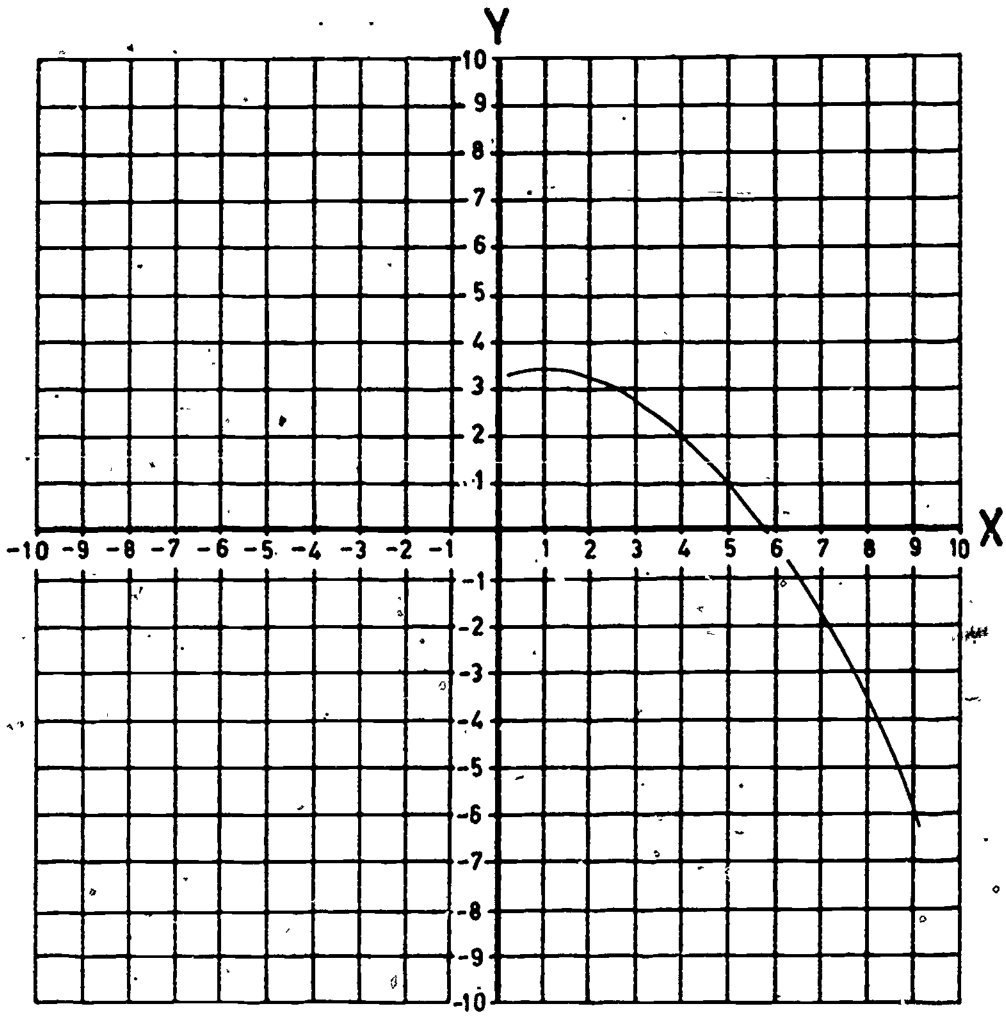
Rule a tangent to the curve above at the point where

Y = 4.0

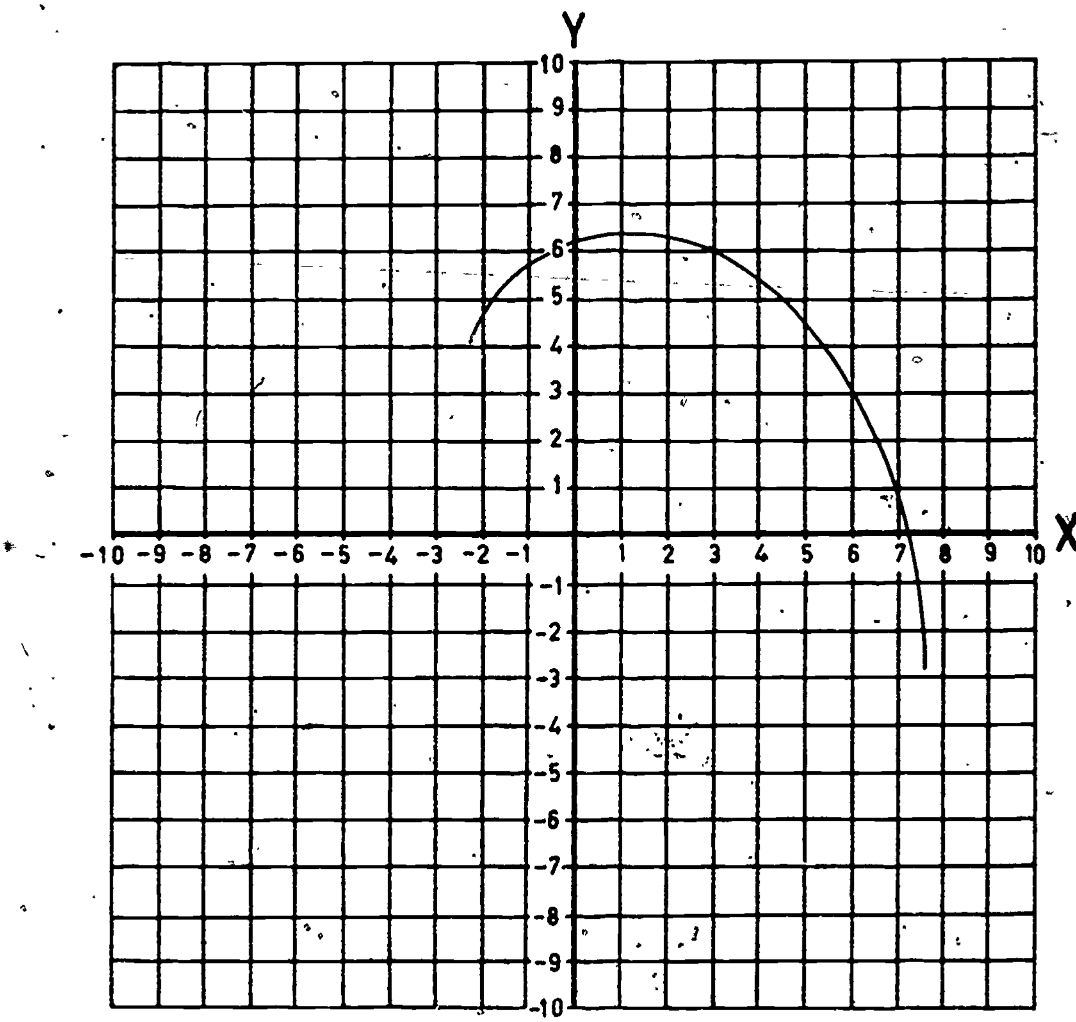


Rule a tangent to the curve above at the point where

Y = 2.0

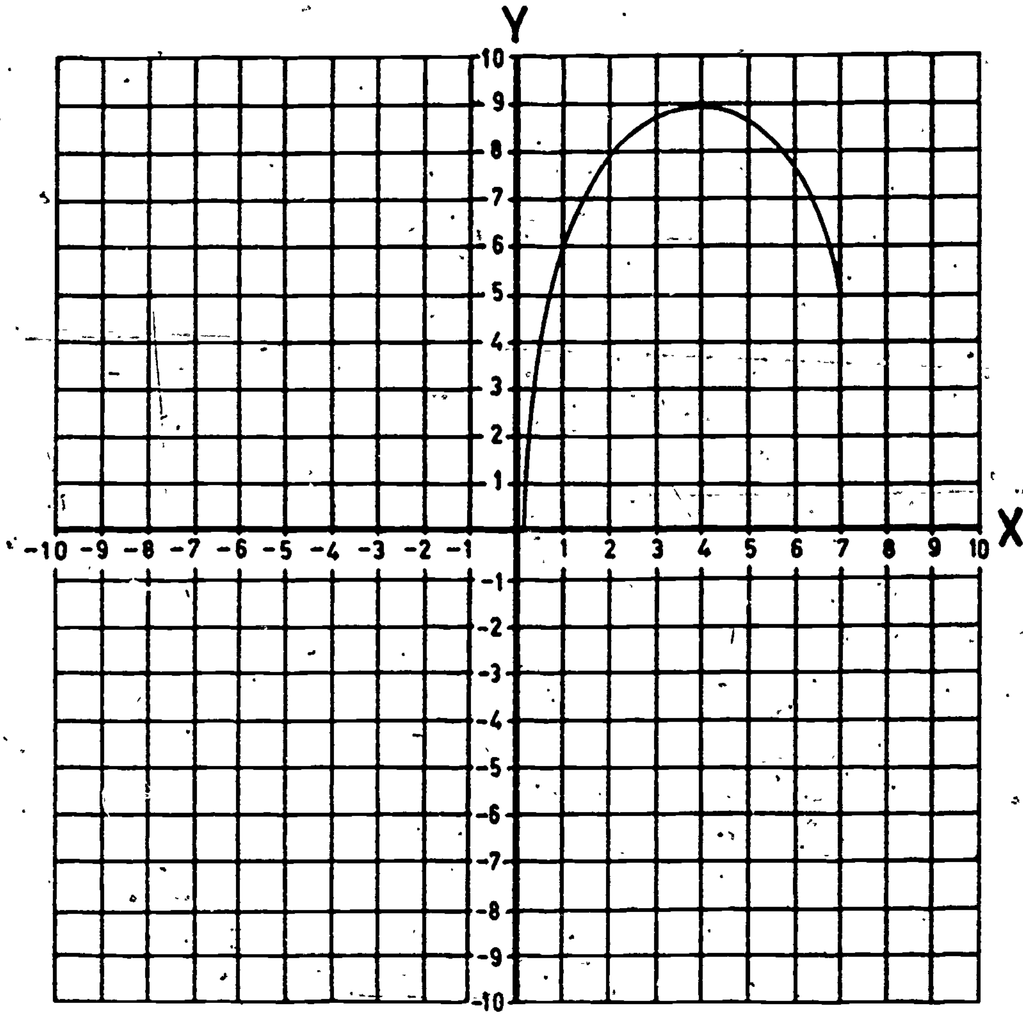


Rule a tangent to the curve above at the point where X = 4.0

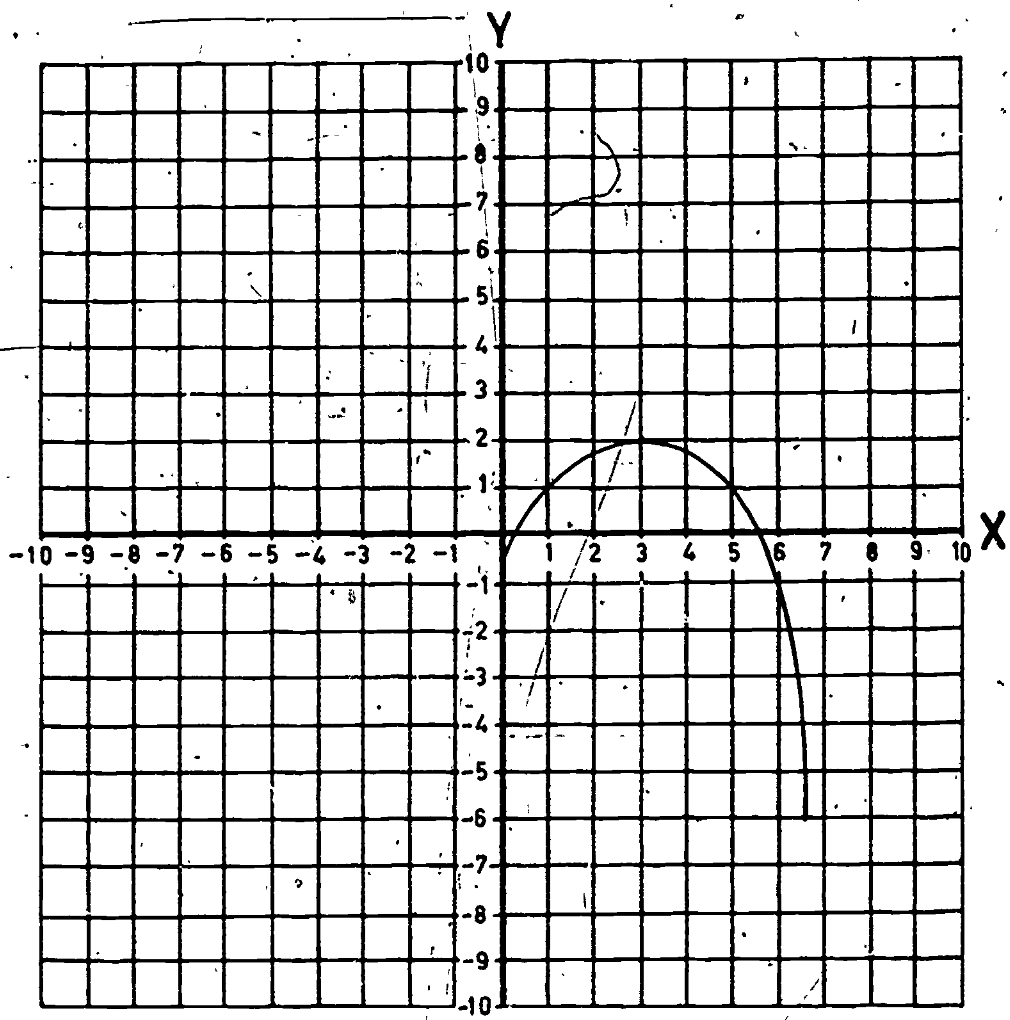


Rule a tangent to the curve above at the point where

X = 3.0

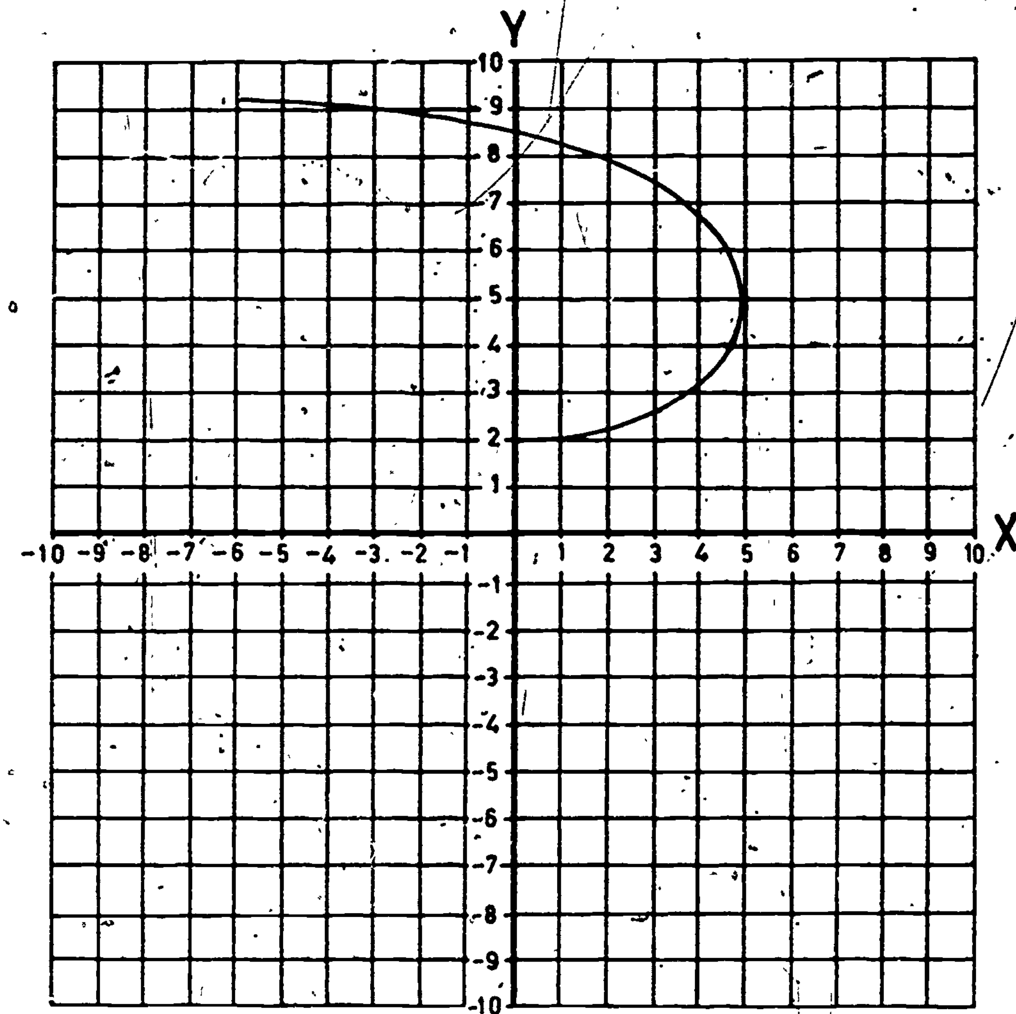


Rule a tangent to the curve above at the point where X = 4.0

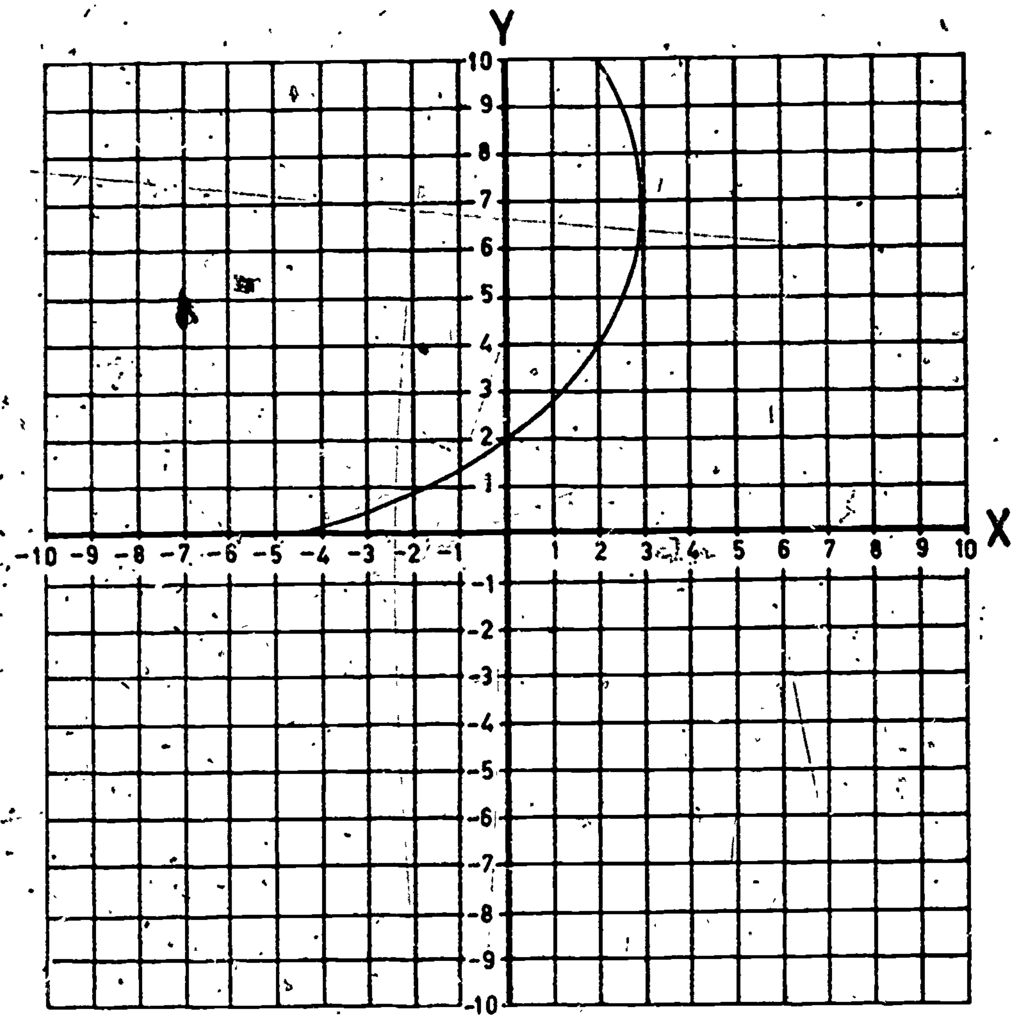


Rule a tangent to the curve above at the point where

X = 3.0

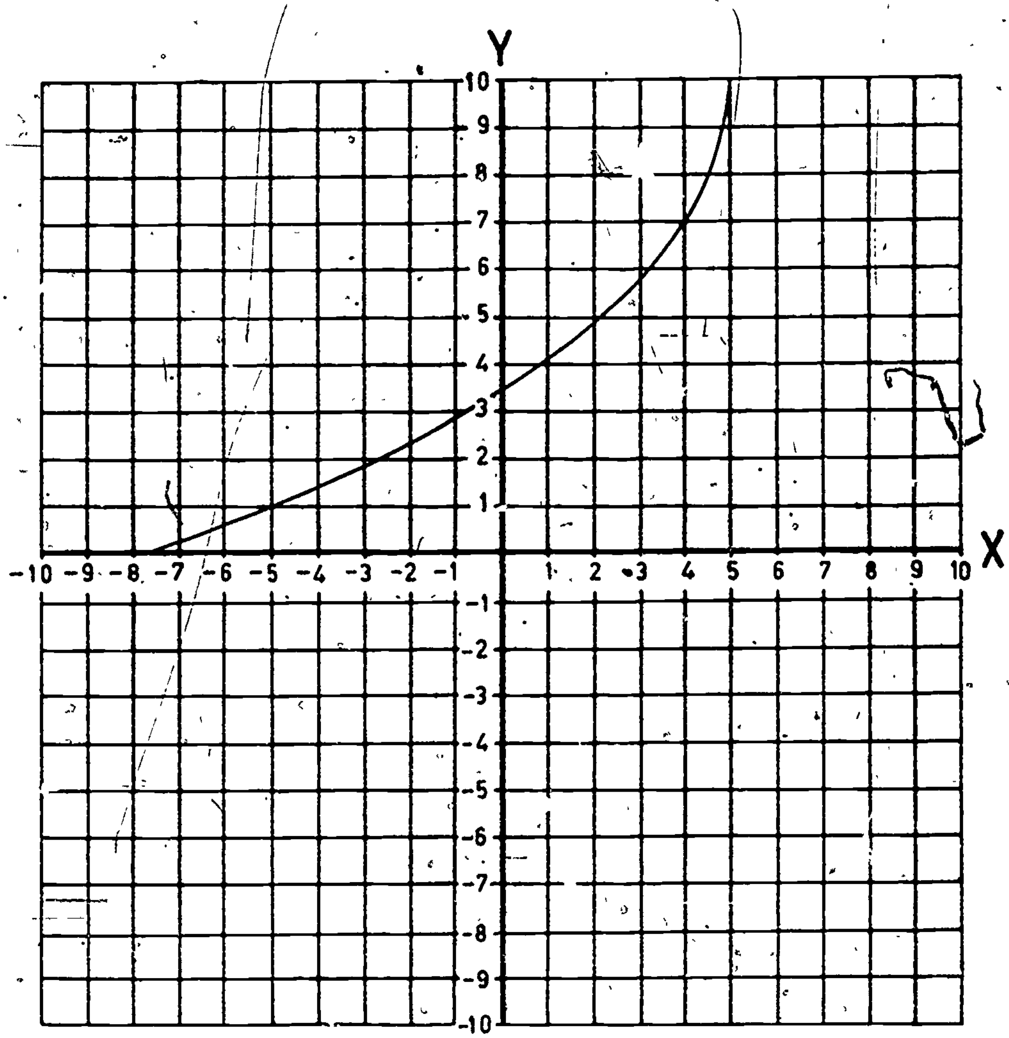


Rule a tangent to the curve above at the point where X = 5.0

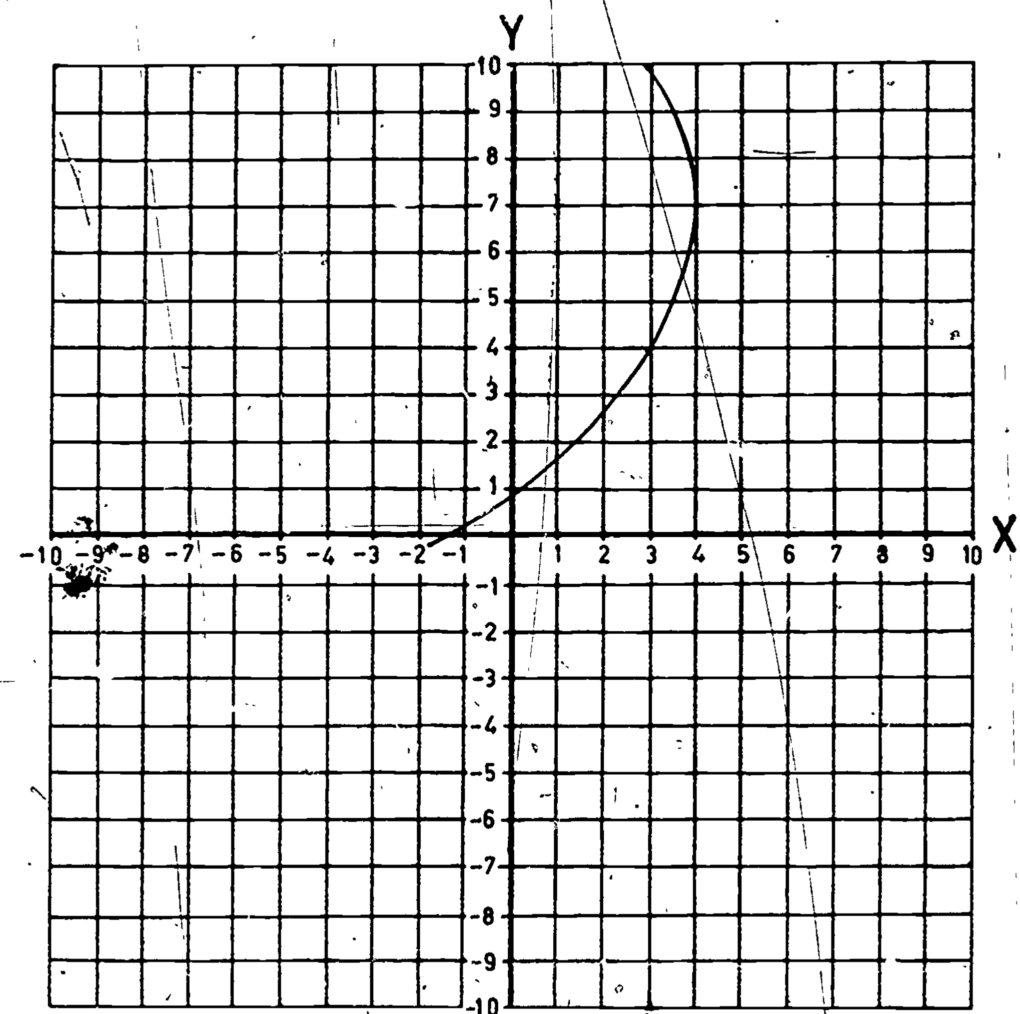


Rule a tangent to the curve above at the point where

X = 3.0



Rule a tangent to the curve above at the point where X = 4.0



Rule a tangent to the curve above at the point where

X = 3.0

BASIC SKILLS OF GRAPHICAL INTERPRETATION

SUBDIVISION ANALYSIS SET 5/3(B)

NAME ______________ AGE ______________

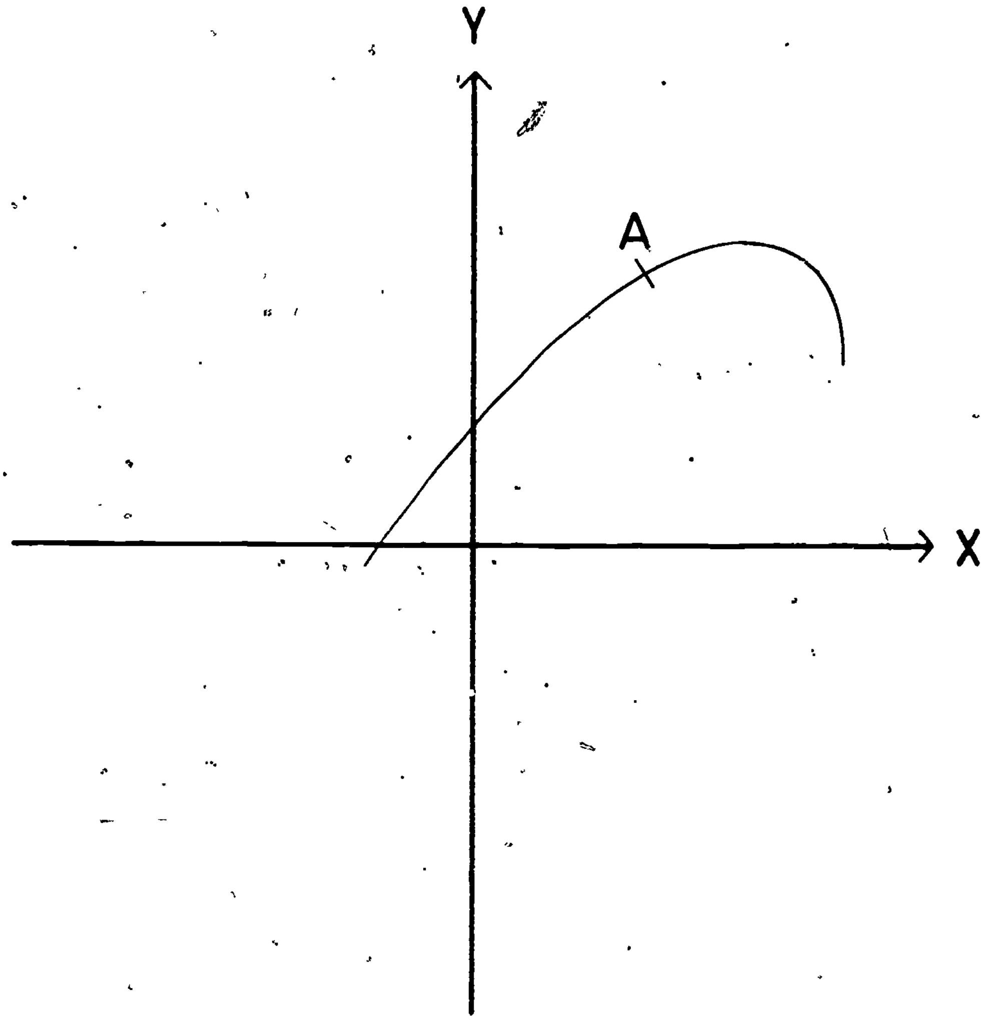
SEX ______________

SCHOOL ______________ CLASS ______________

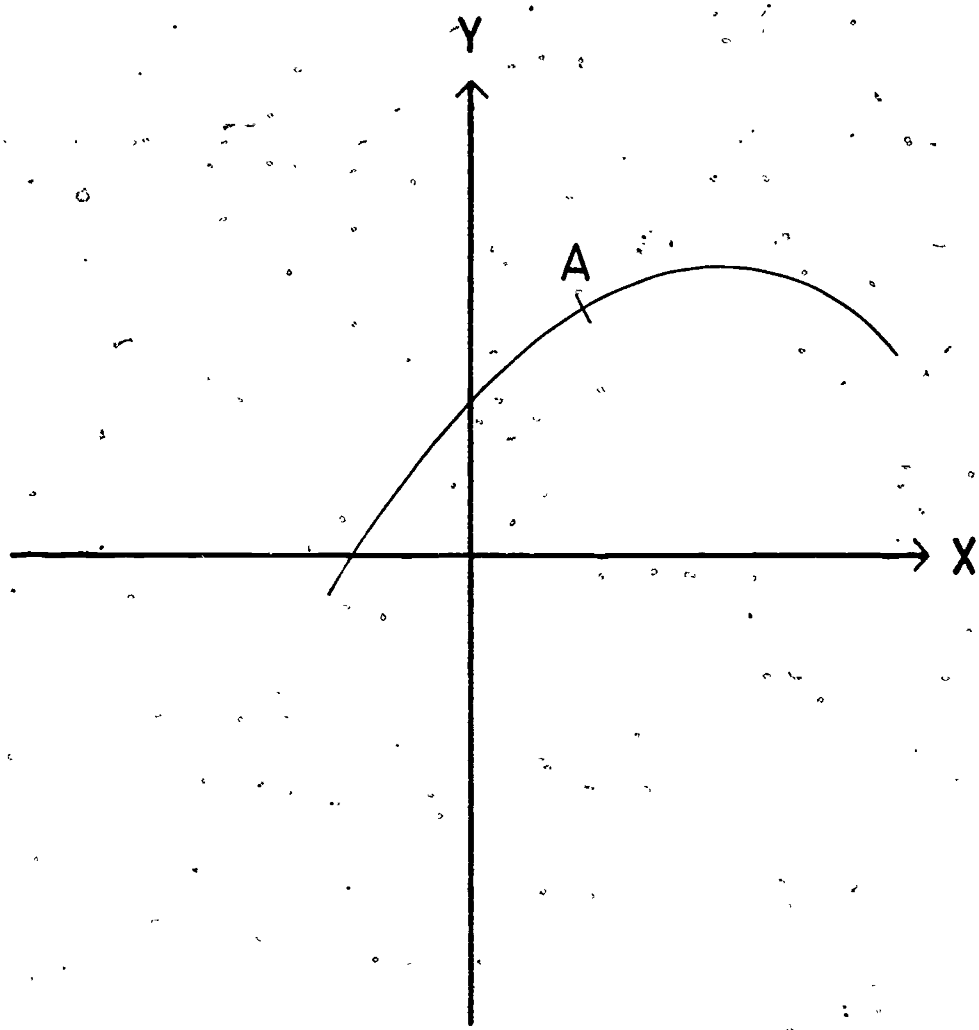
DATE ______________

INSTRUCTIONS

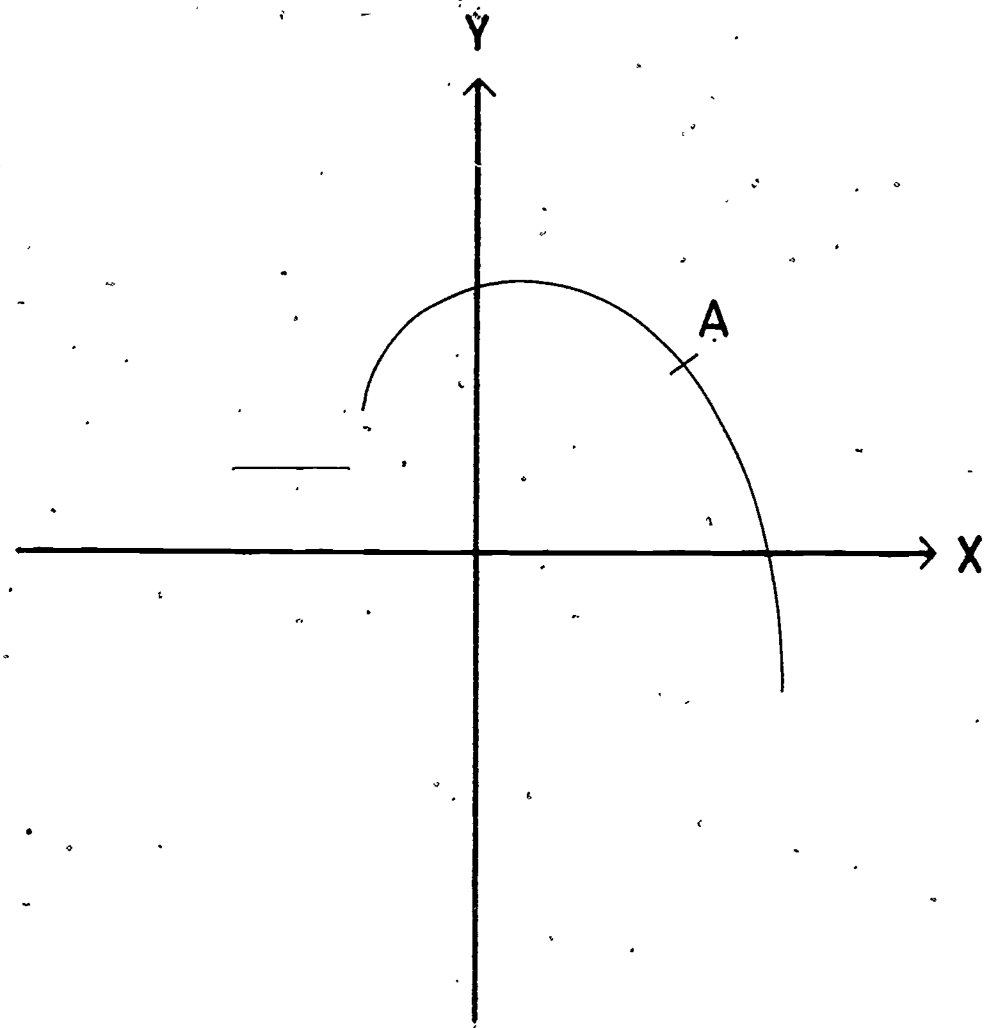
Read each question carefully, then write your answer in the space provided. Try to guess the answers to any questions you do not know, but do not waste time on more difficult problems. All answers should be given to the nearest decimal place, and any other calculations may be written on the back of the page. The sign of an answer, where this applies, should be either positive (+) or negative (-).



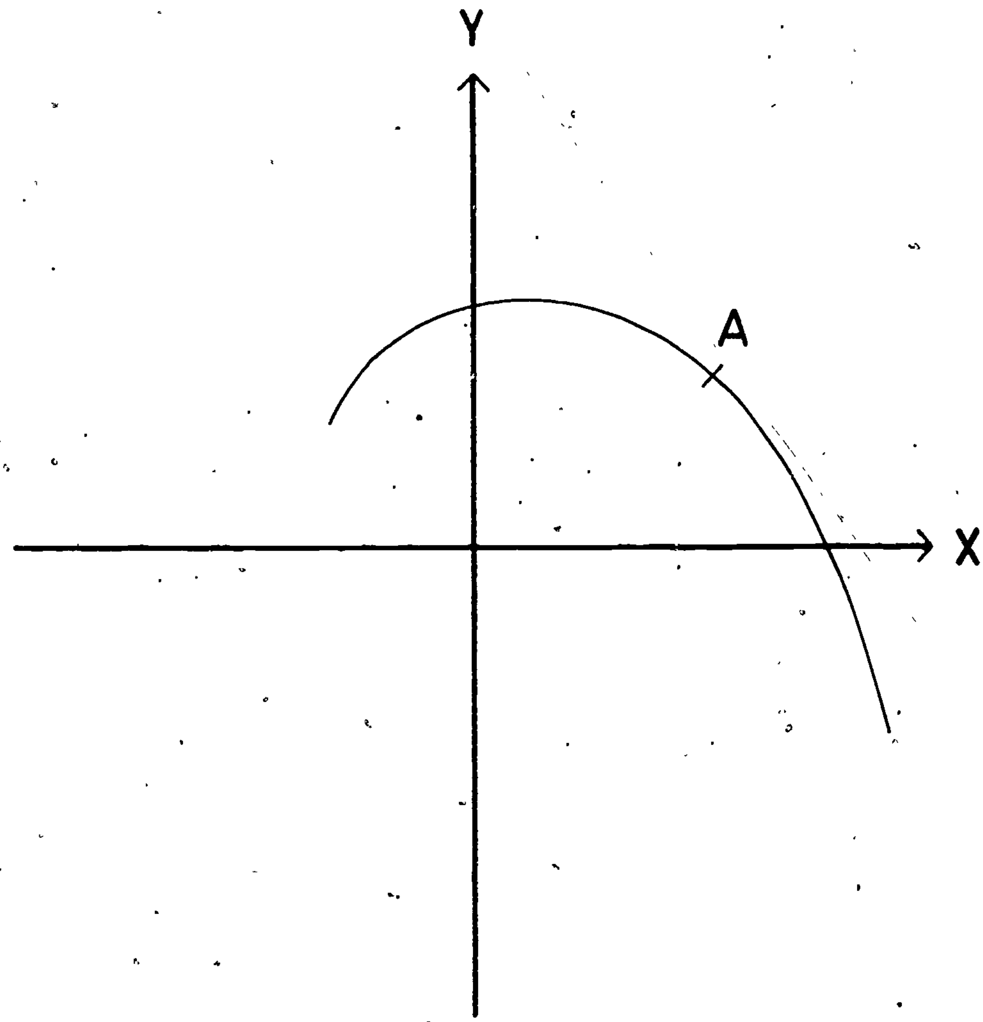
Rule a tangent to the curve above at A.



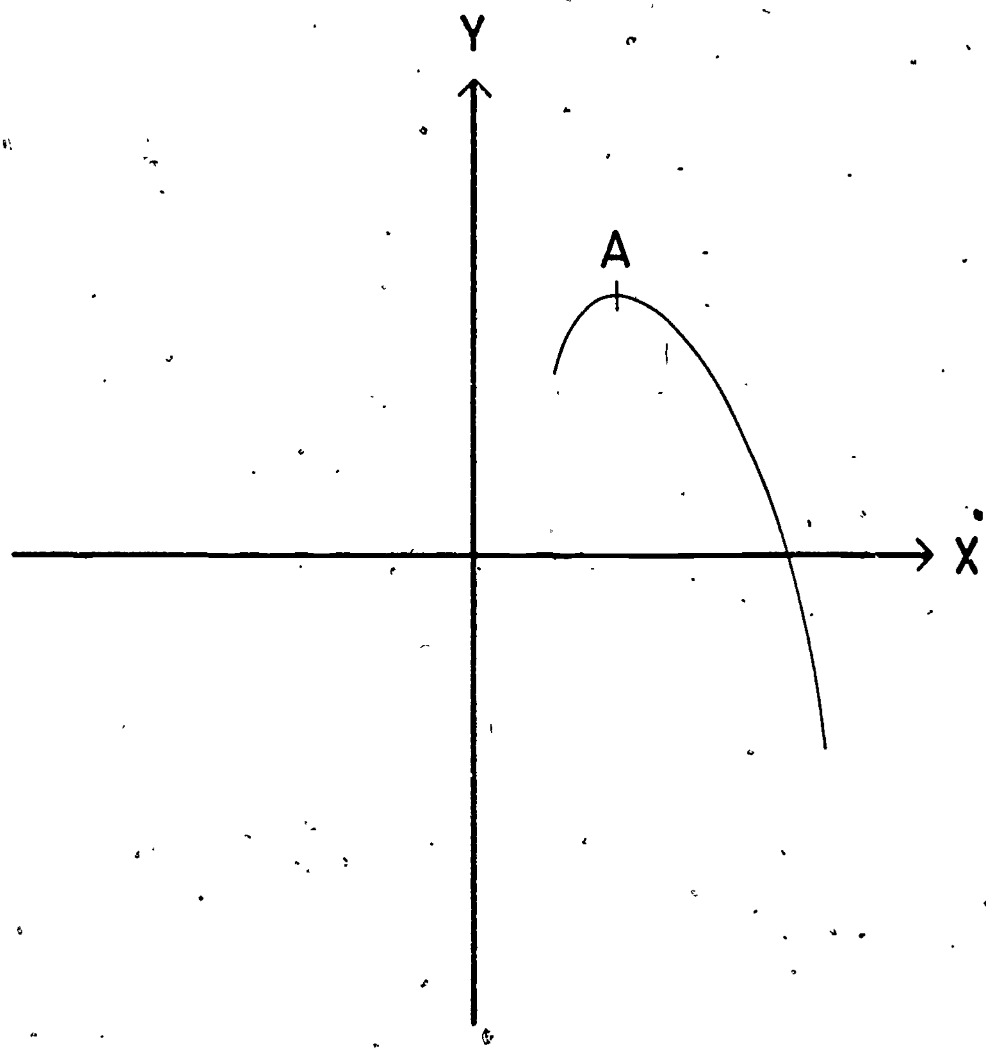
Rule a tangent to the curve above at A.



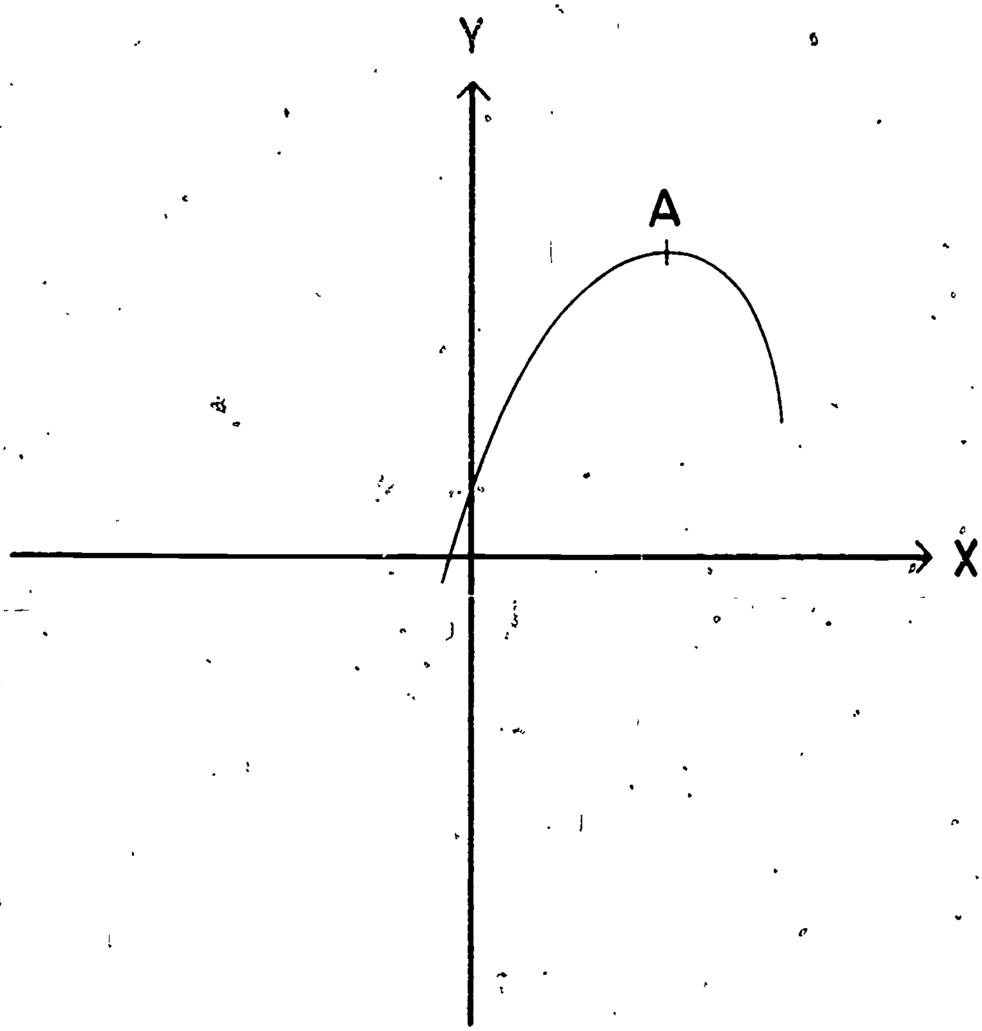
Rule a tangent to the curve above at A.



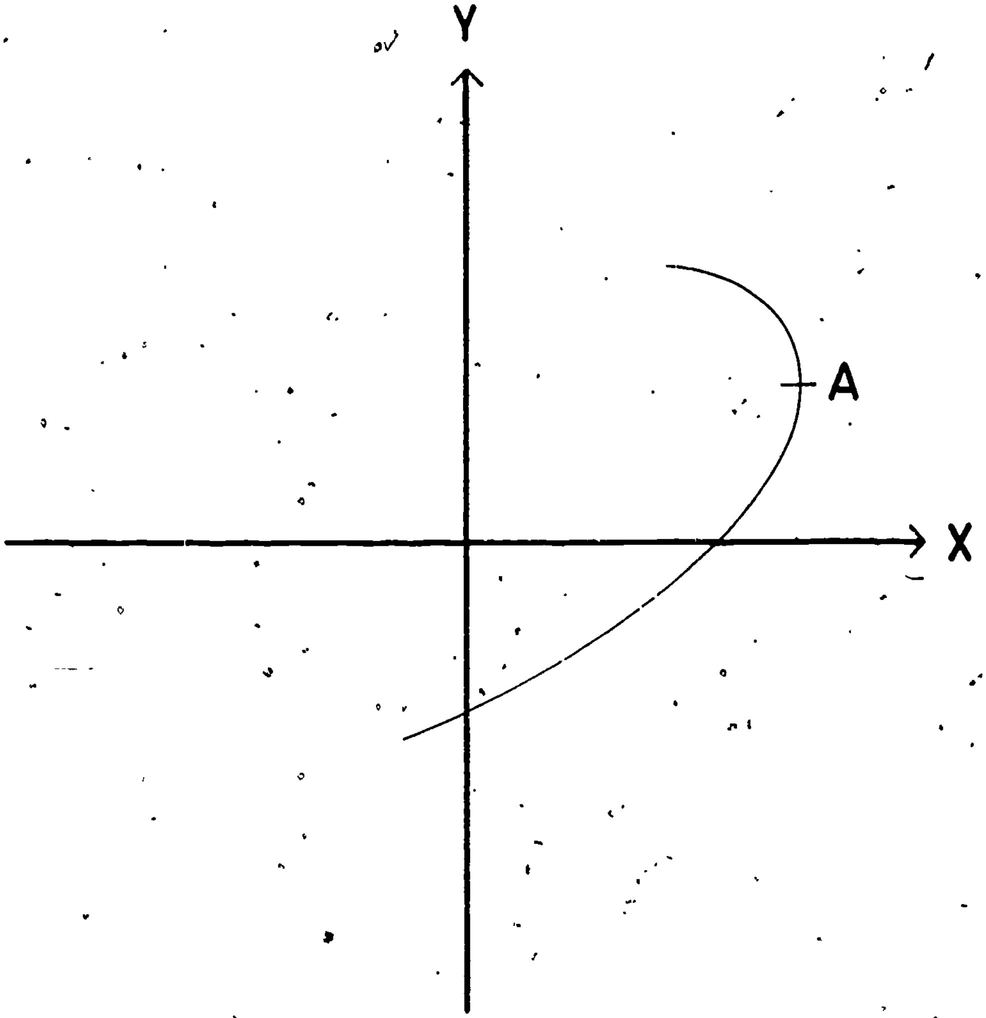
Rule a tangent to the curve above at A.



Rule a tangent to the curve above at A.



Rule a tangent to the curve above at A.



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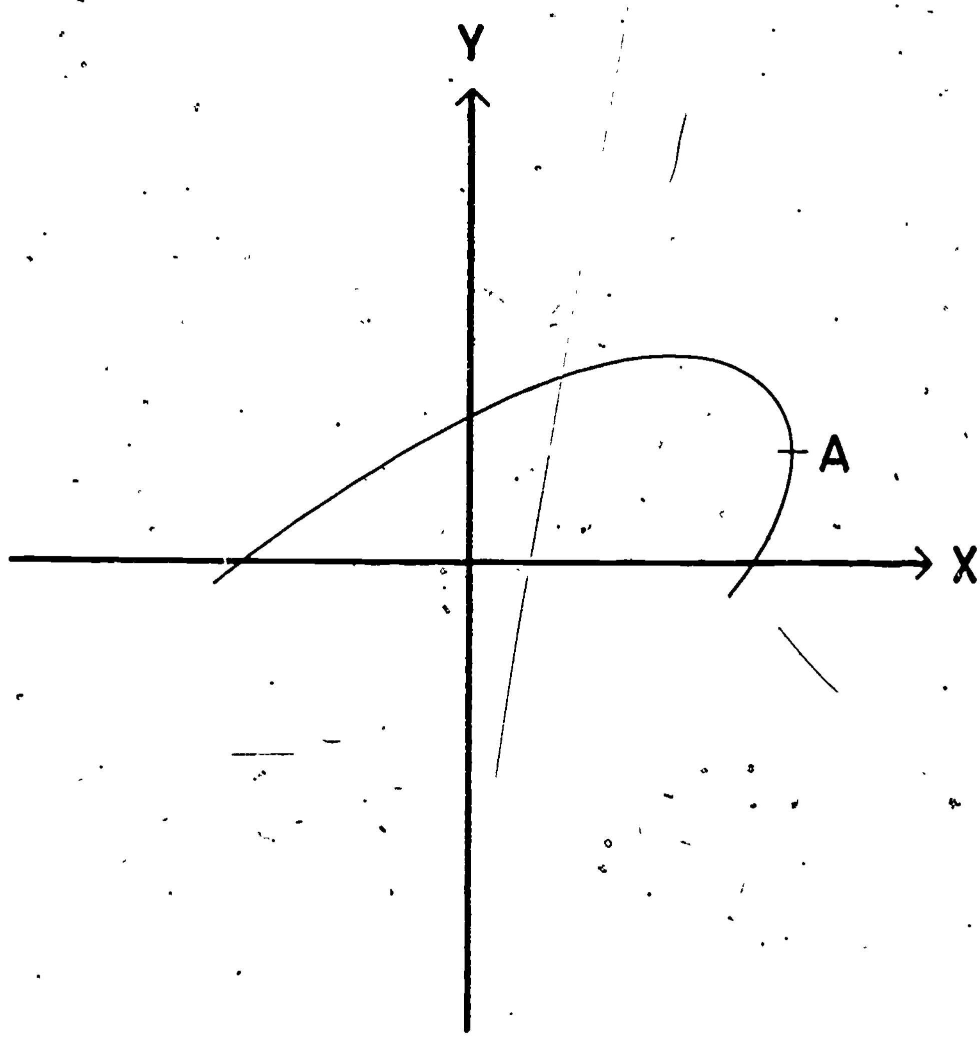
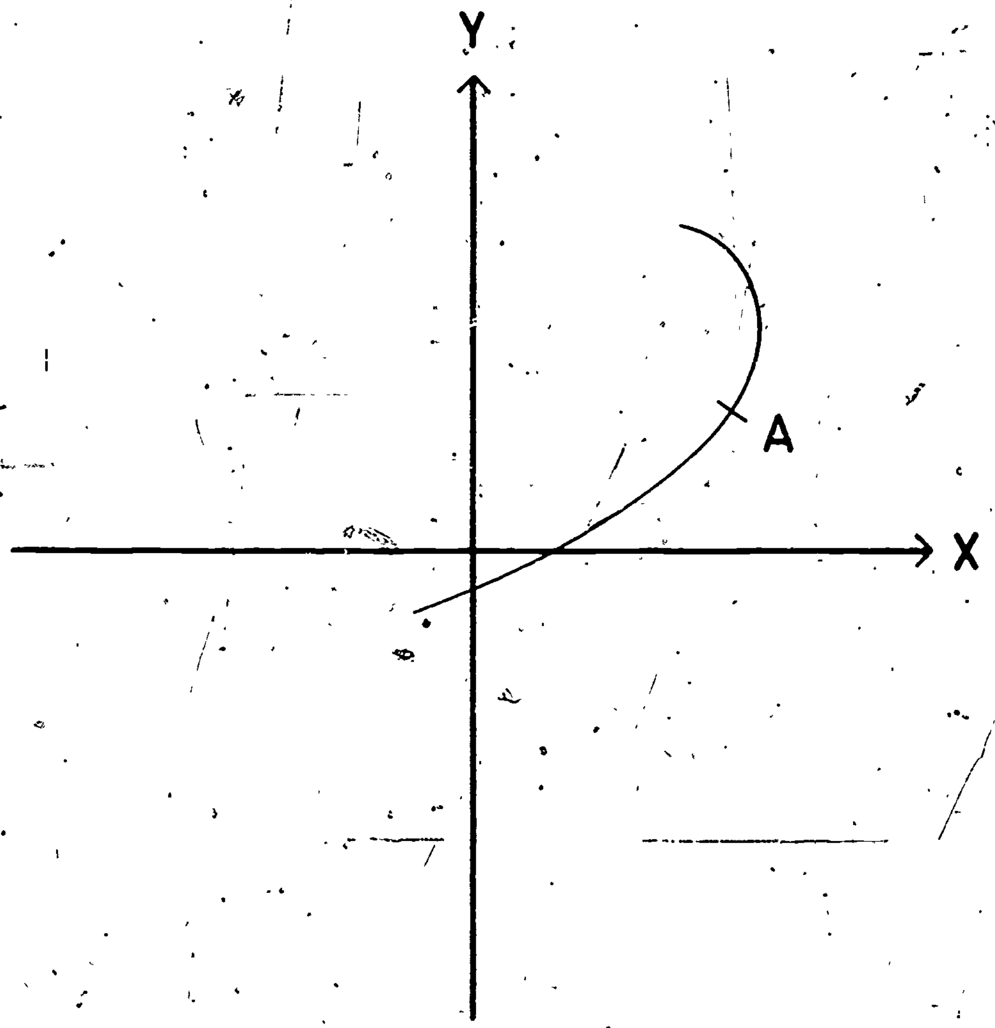
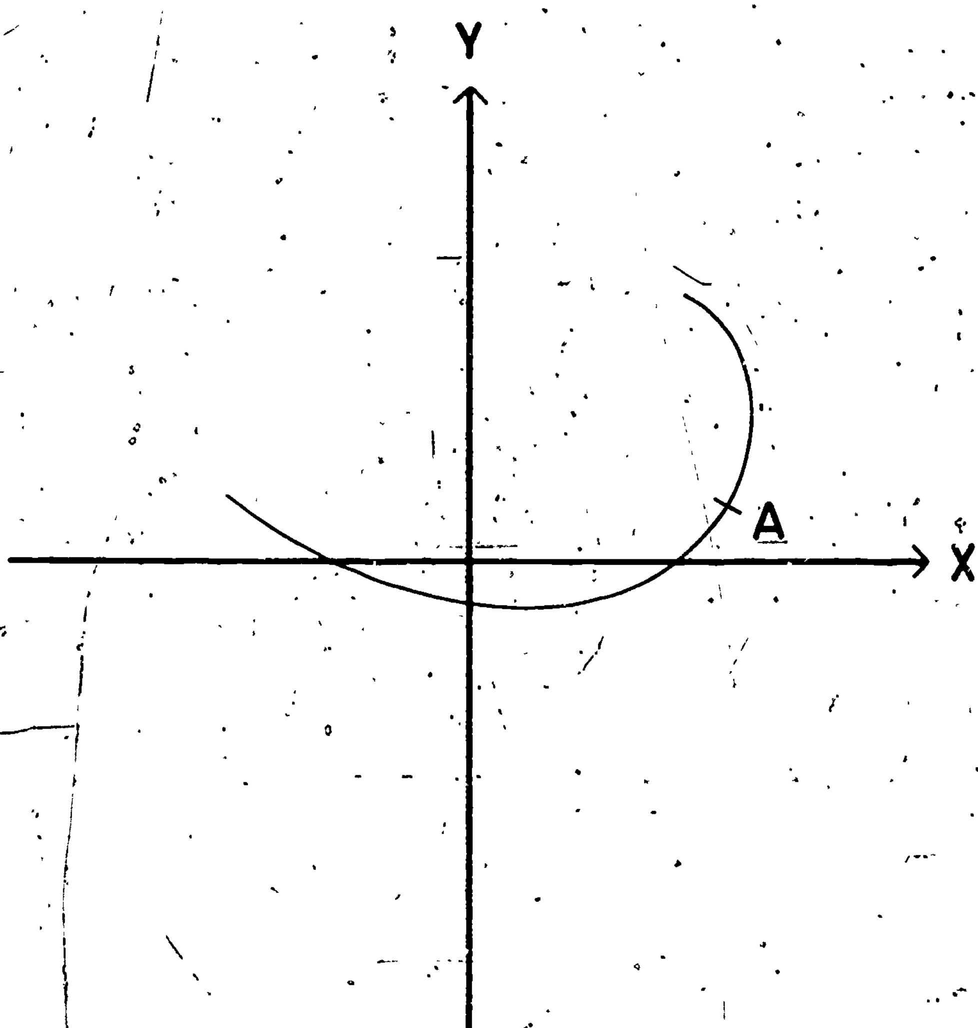


Rule a tangent to the curve above at A.



Rule a tangent to the curve above at A.



Rule a tangent to the curve above at A.

BASIC SKILLS OF GRAPHICAL INTERPRETATION

SUBDIVISION ANALYSIS SET 6/2

NAME ________ AGE ________

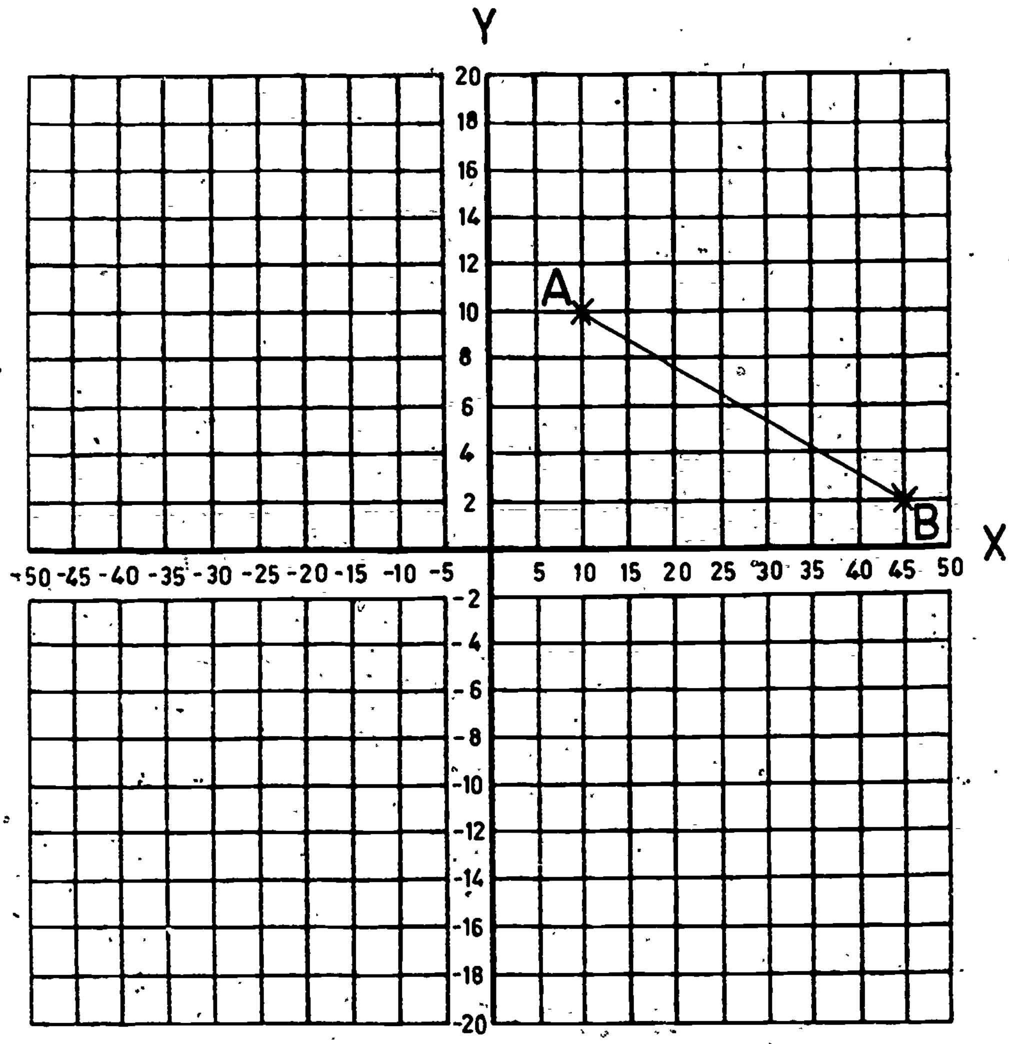
SEX ________

SCHOOL ________ CLASS ________

DATE ________

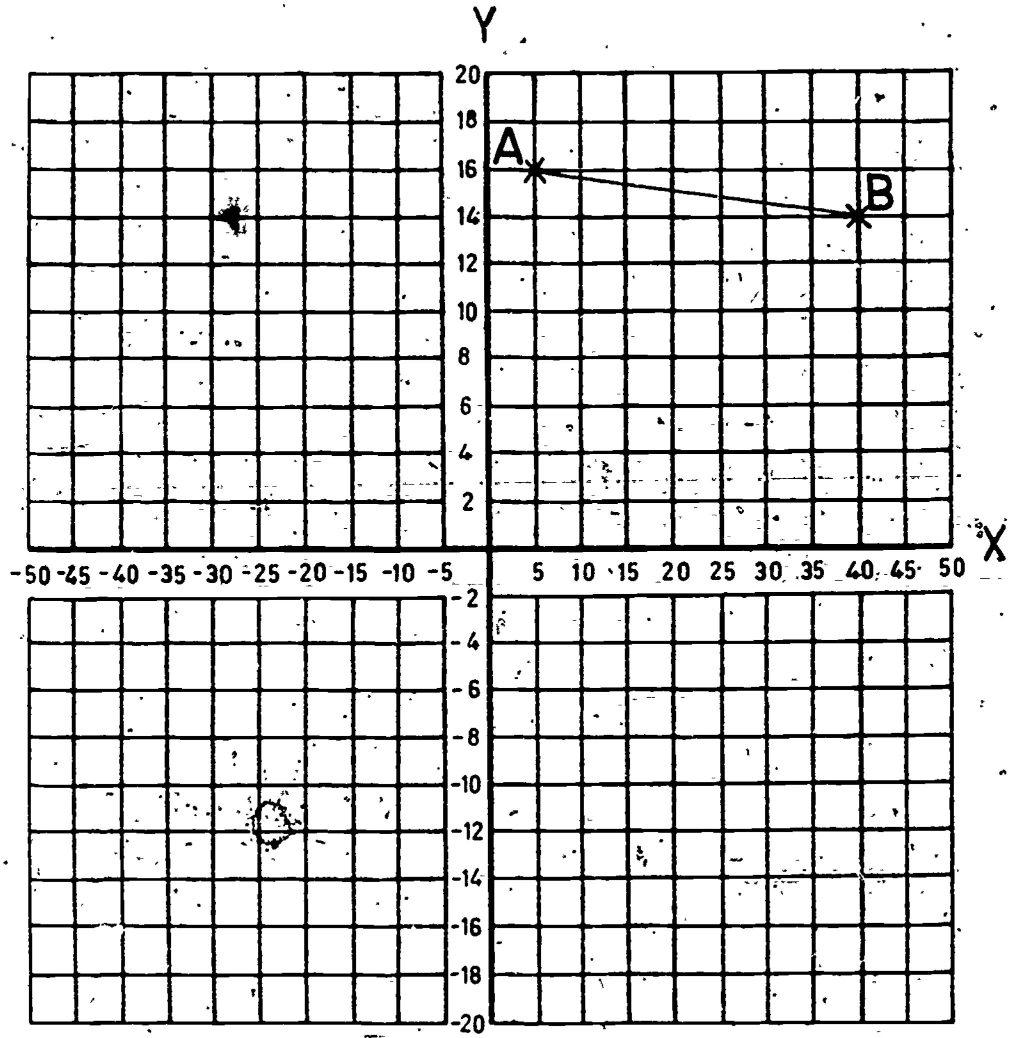
INSTRUCTIONS

Read each question carefully, then write your answer in the space provided. Try to guess the answers to any questions you do not know, but do not waste time on more difficult problems. All answers should be given to the nearest decimal place, and any other calculations may be written on the back of the page. The sign of an answer, where this applies, should be either positive (+) or negative (–).



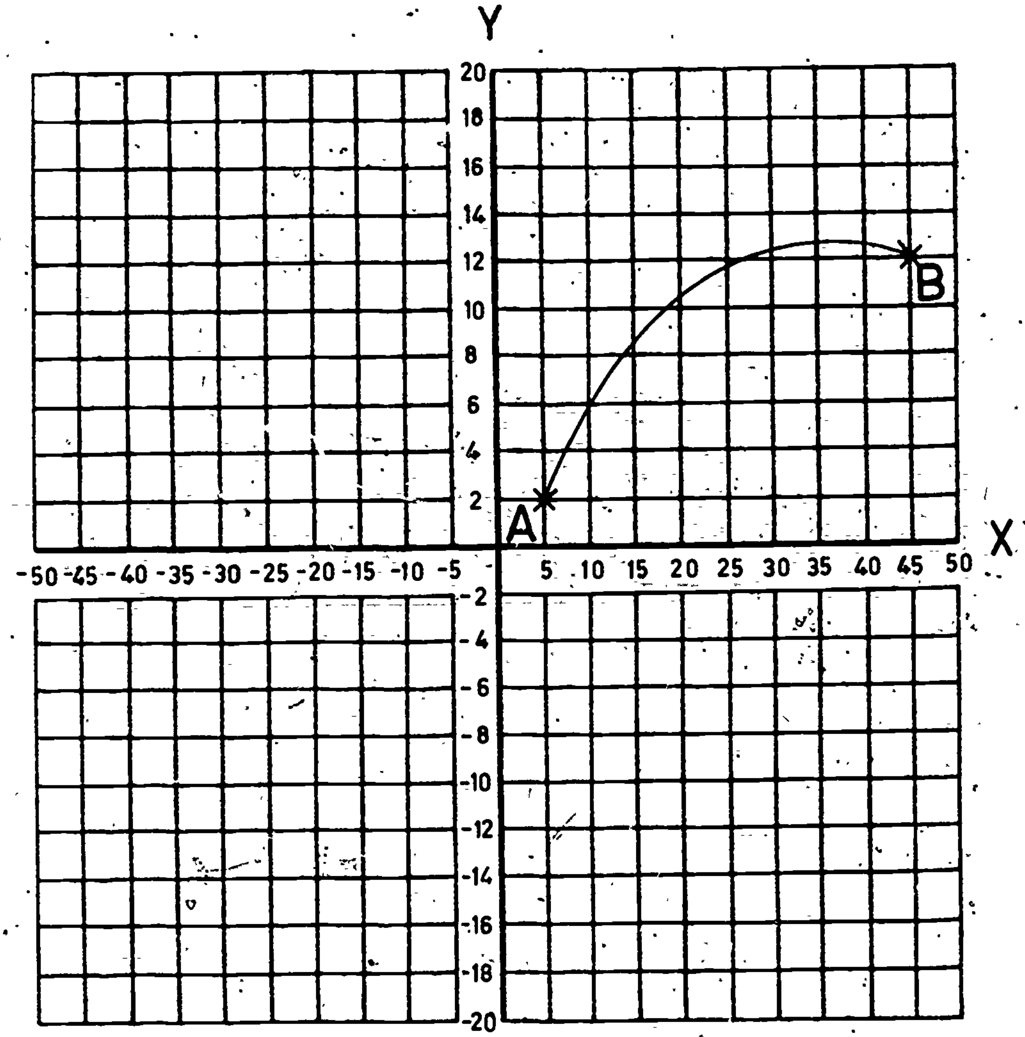
Calculate the area between the line AB and the horizontal (X) axis.

ANSWER ________
(number)



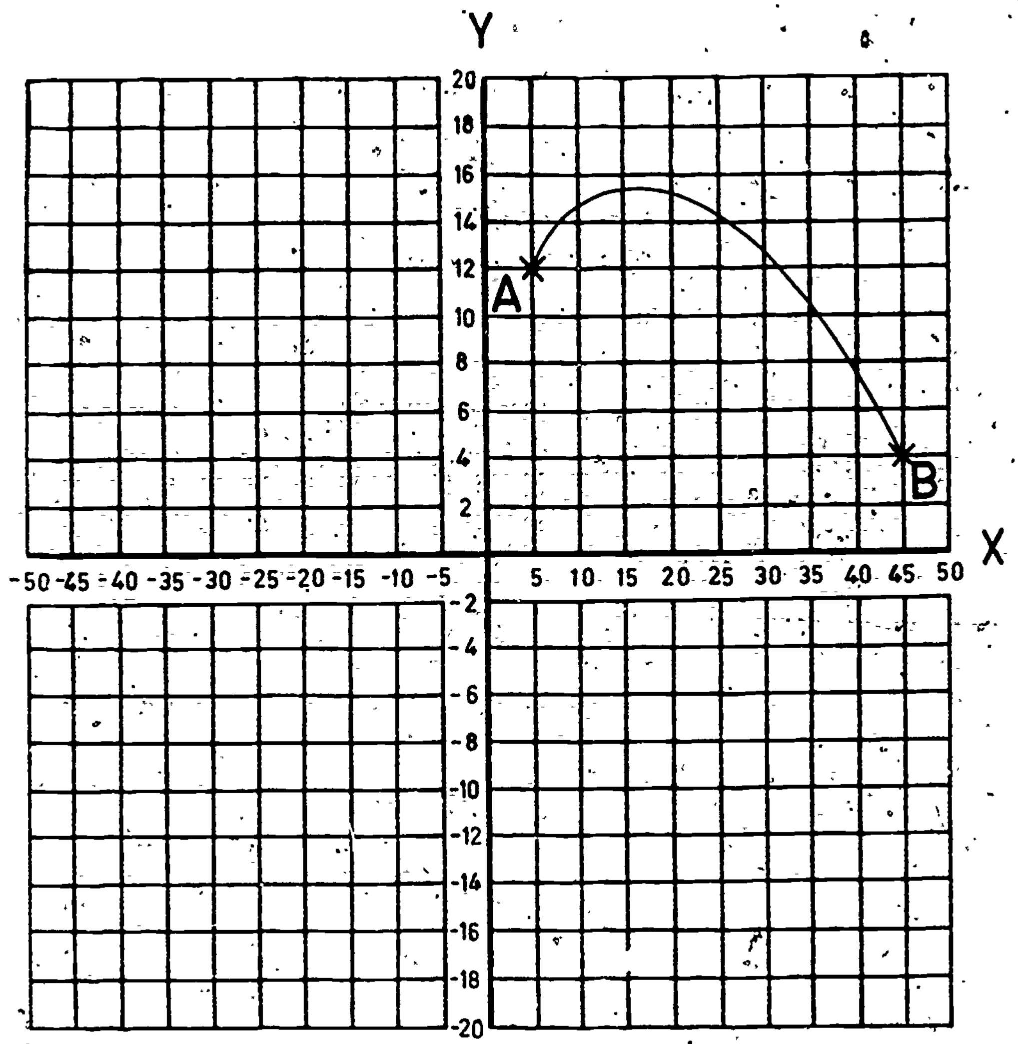
Calculate the area between the line AB and the horizontal (X) axis.

ANSWER ________
(number)



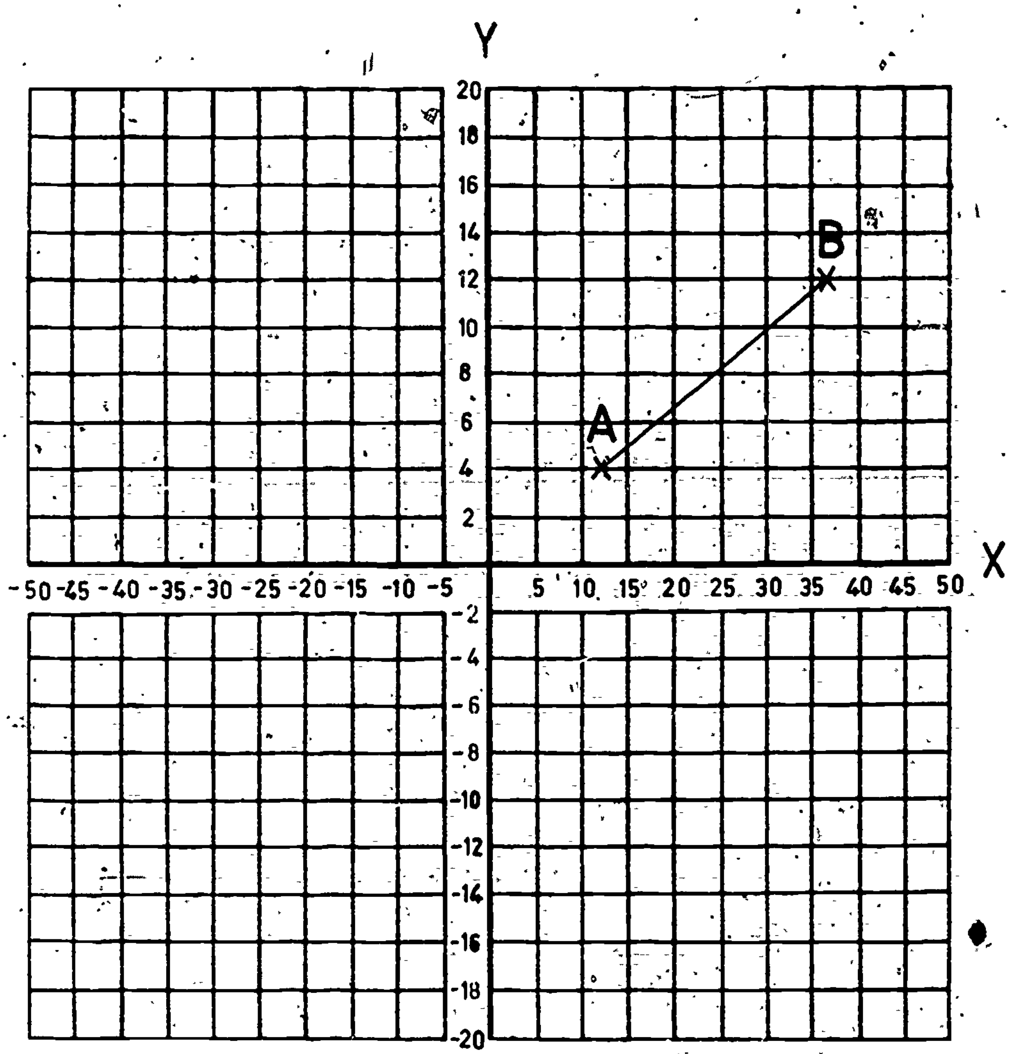
Calculate the area between the line AB and the horizontal (X) axis.

ANSWER ________
(number)



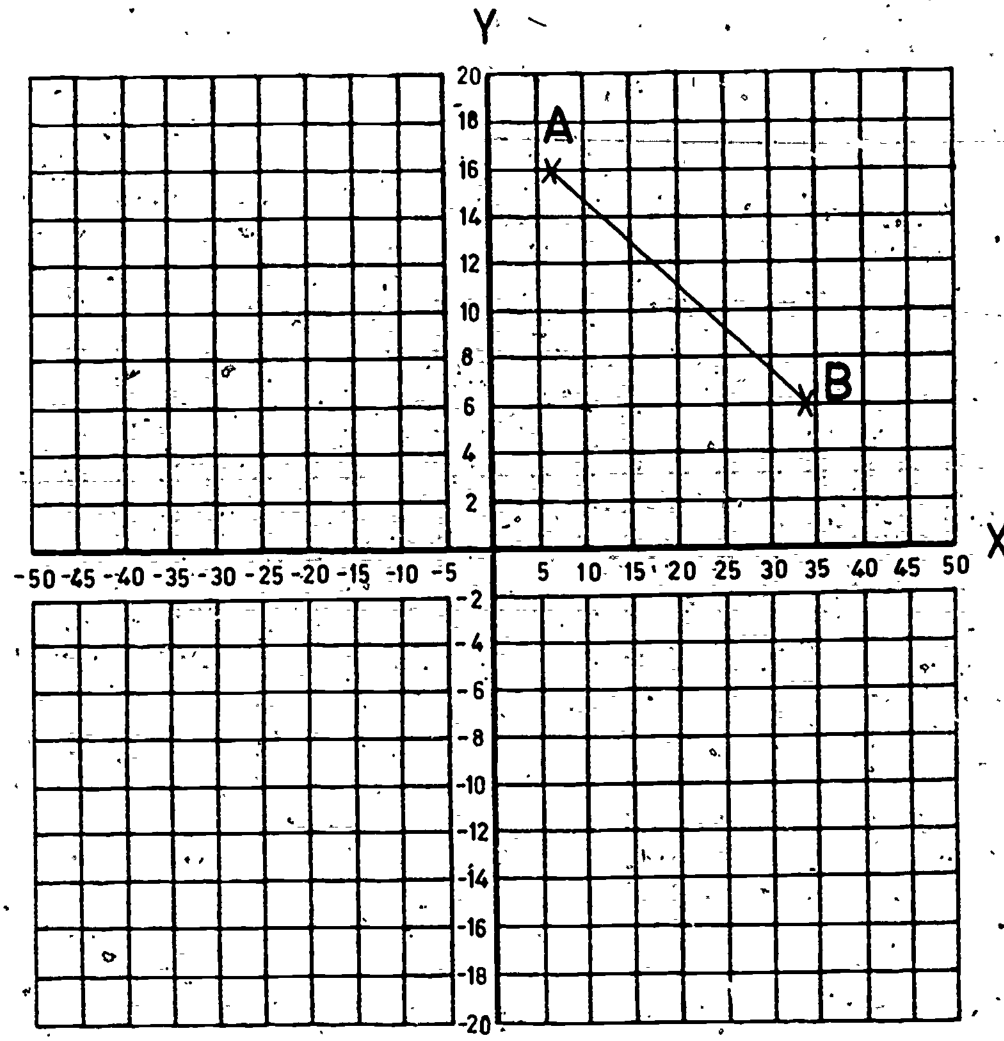
Calculate the area between the line AB and the horizontal (X) axis.

ANSWER ______
(number)



Calculate the area between the line AB and the horizontal (X) axis.

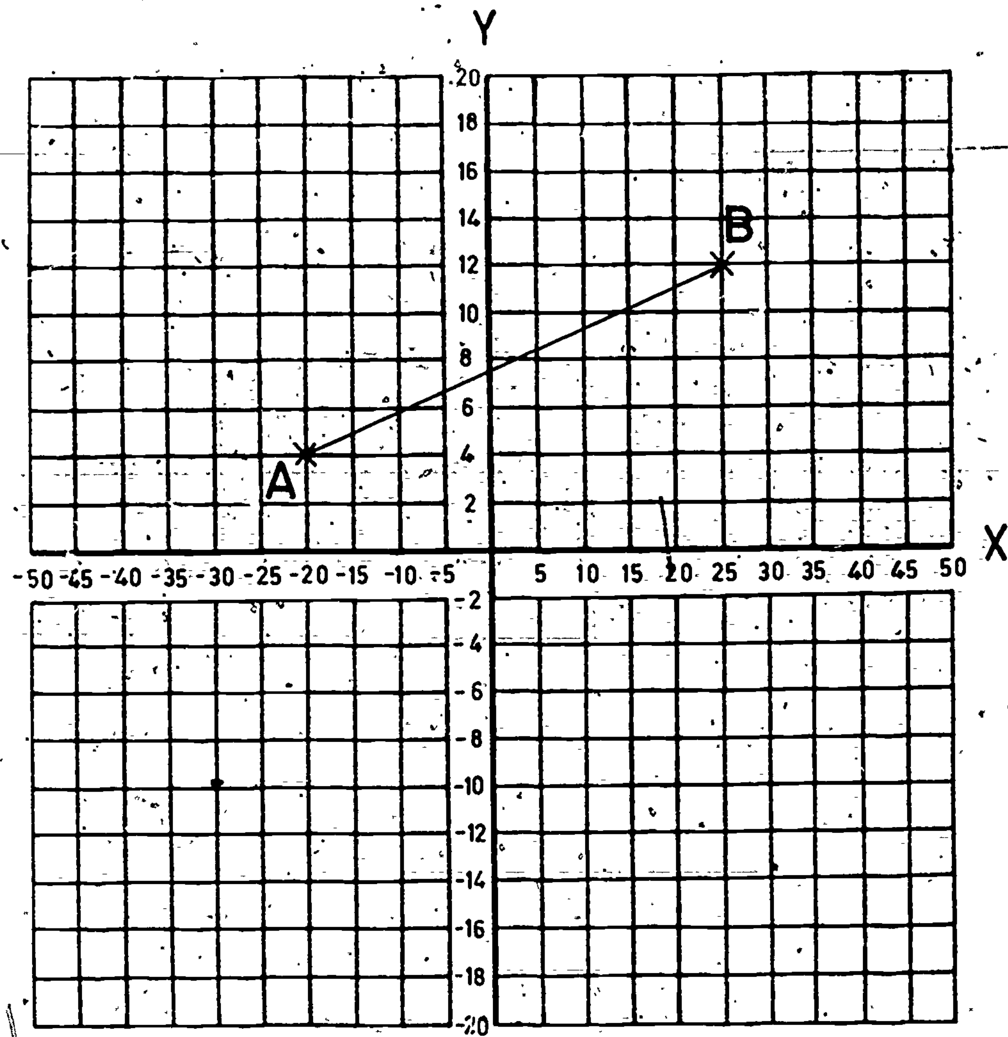
ANSWER ________
(number)



Calculate the area between the line AB and the horizontal (X) axis.

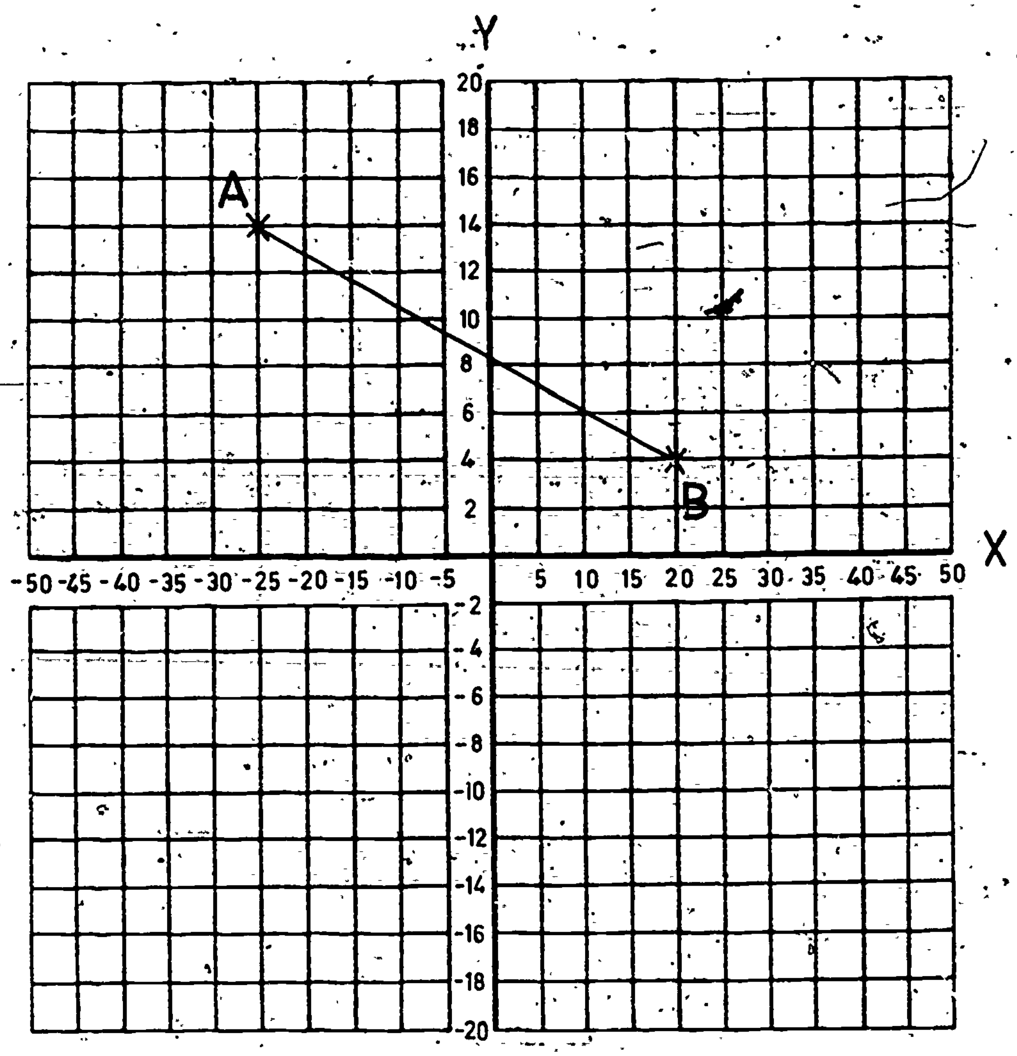
ANSWER ____________________

(number)



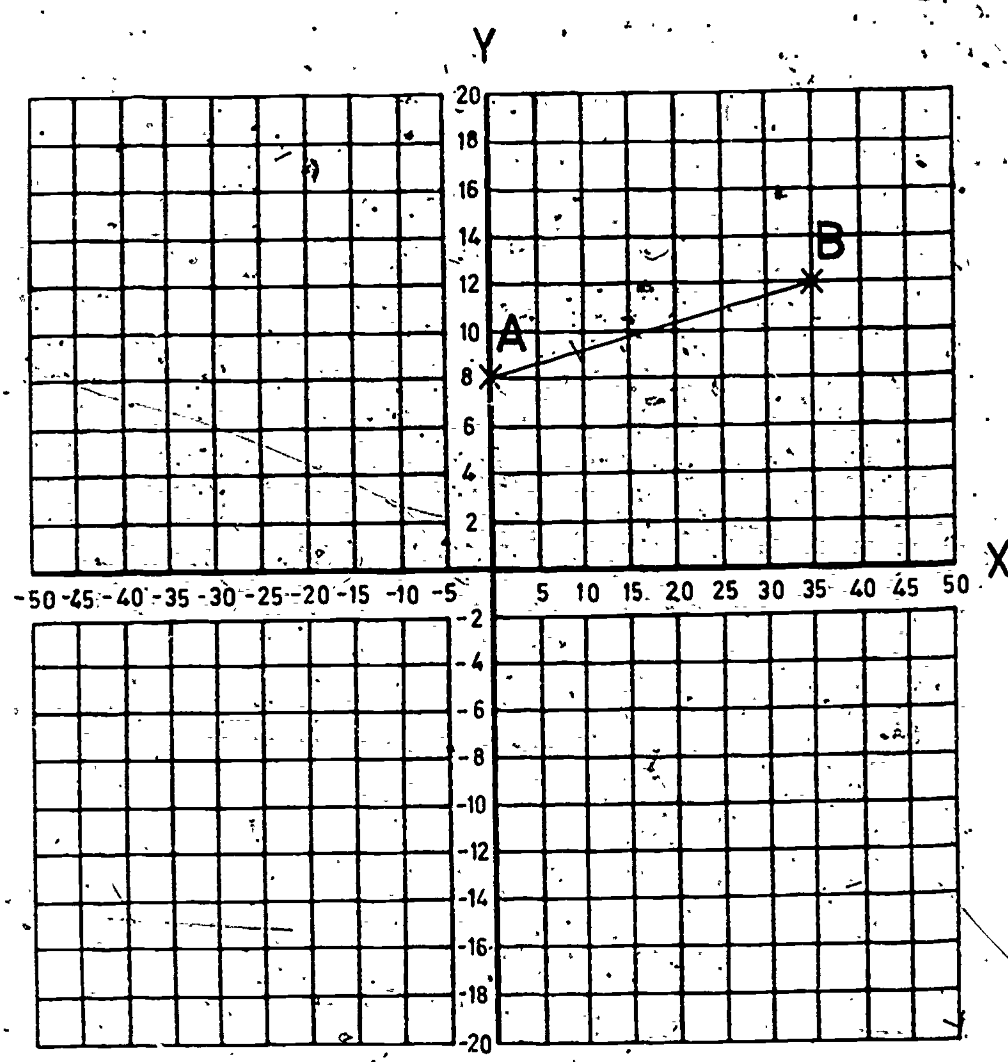
Calculate the area between the line AB and the horizontal (X) axis.

ANSWER ______
(number)



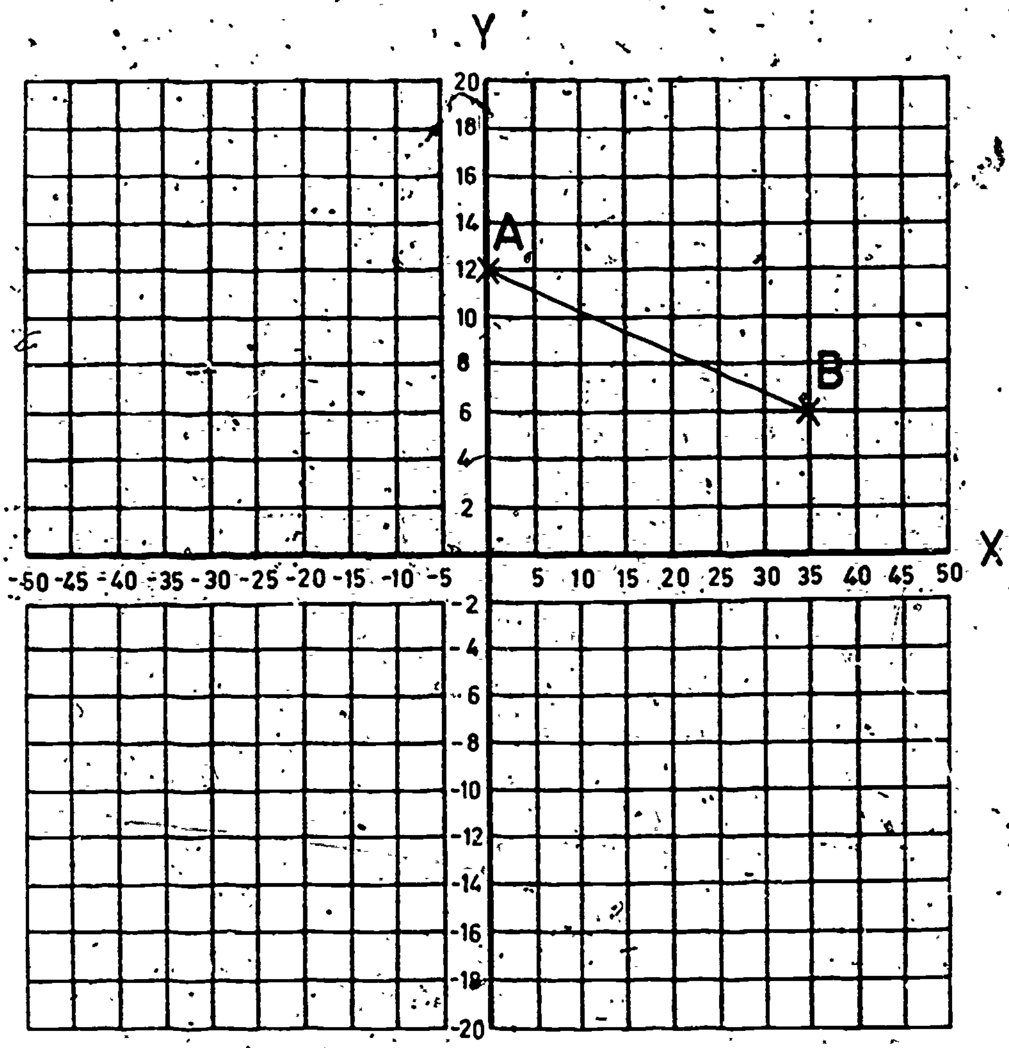
Calculate the area between the line AB and the horizontal (X) axis.

ANSWER ________
(number)



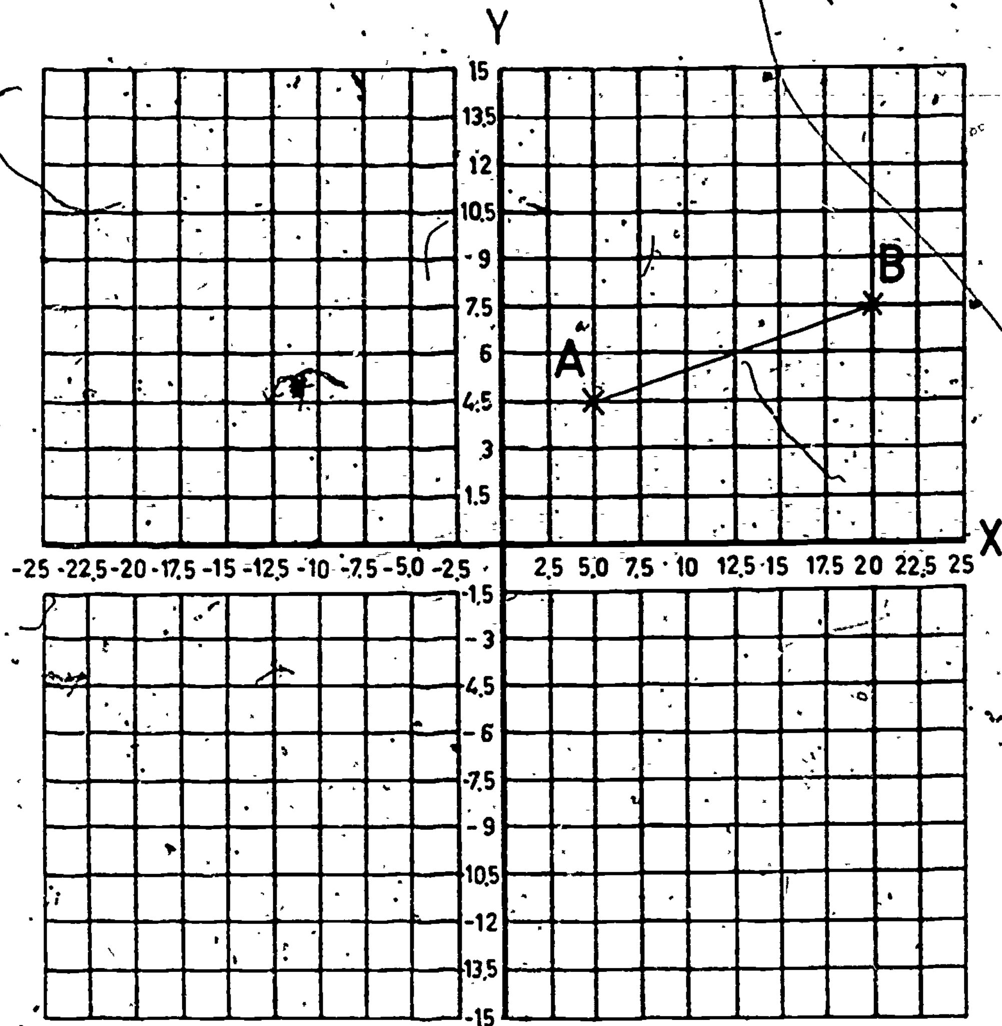
Calculate the area between the line AB and the horizontal (X) axis.

ANSWER ________
(number)



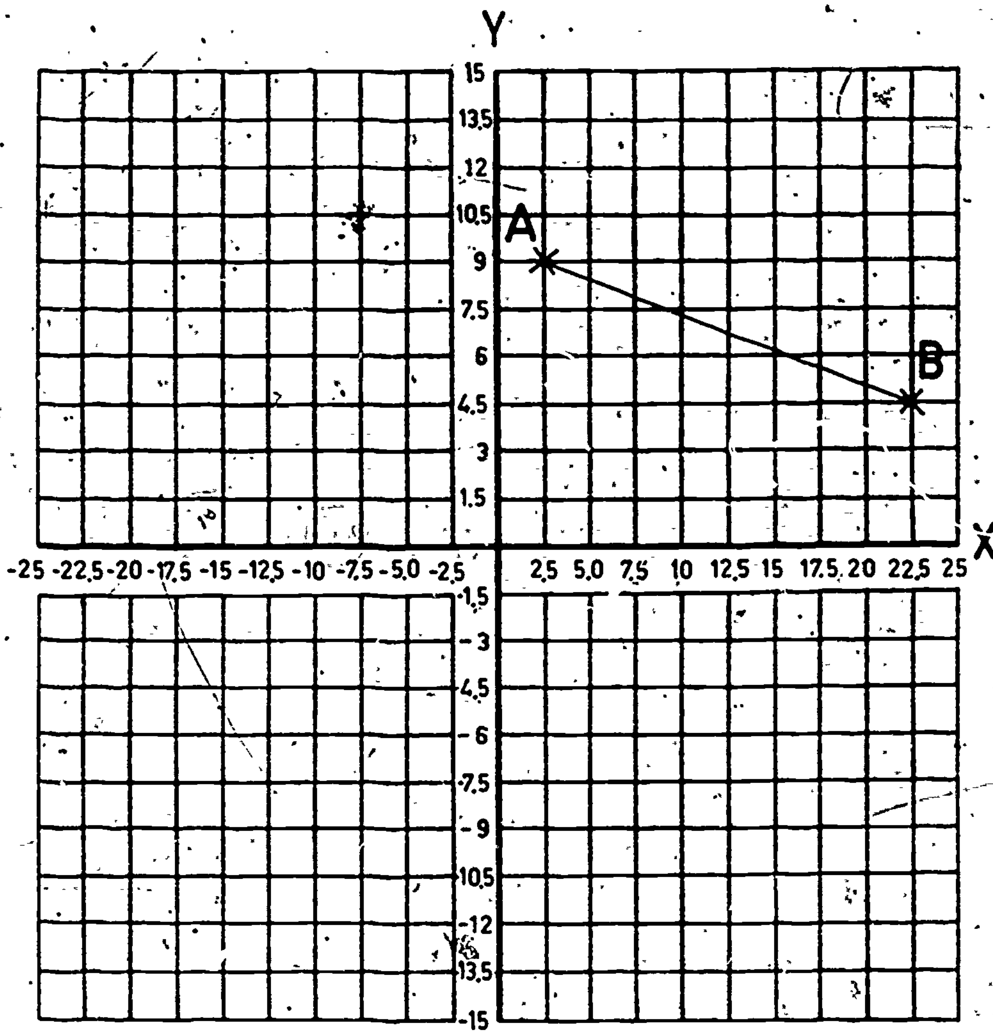
Calculate the area between the line AB and the horizontal (X) axis.

ANSWER ________
(number)



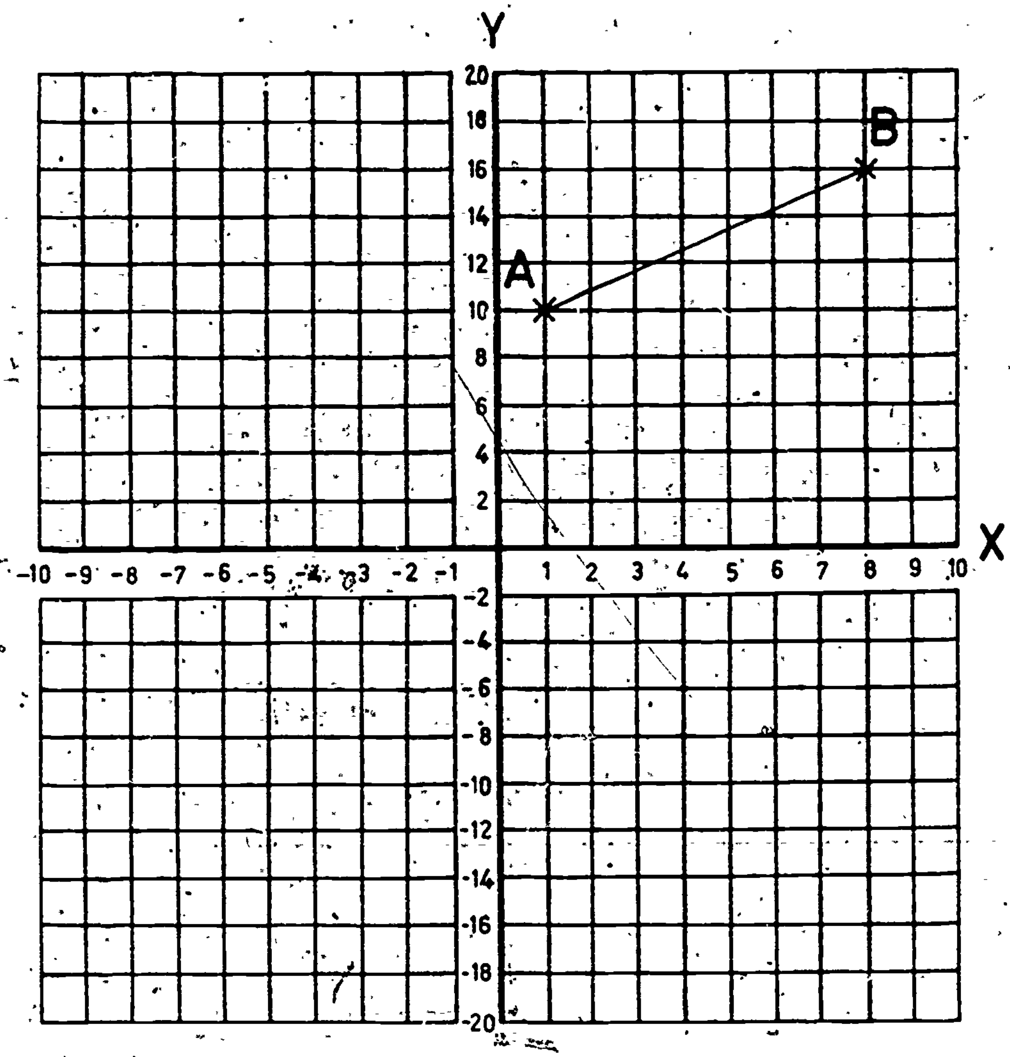
Calculate the area between the line AB and the horizontal (X) axis.

ANSWER ________
(number)



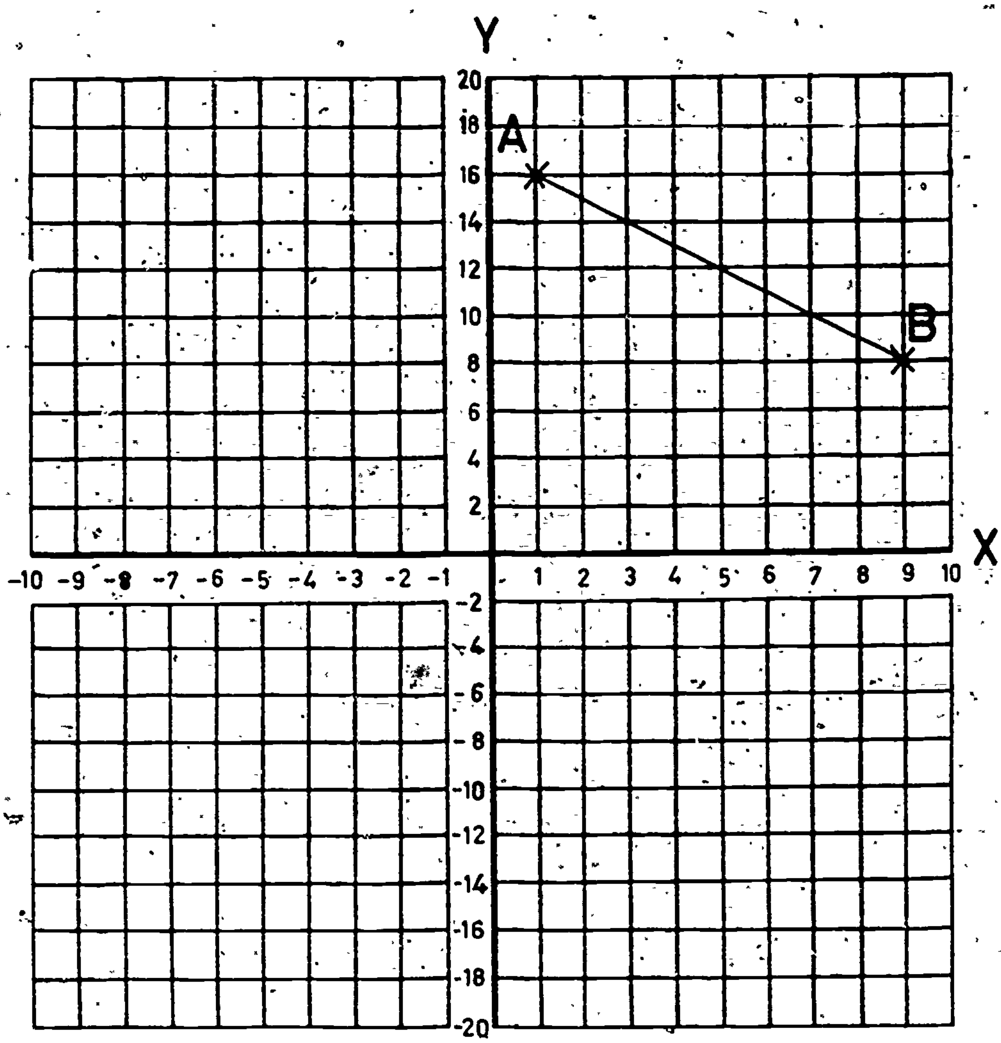
Calculate the area between the line AB and the horizontal (X) axis.

ANSWER ________
(number)



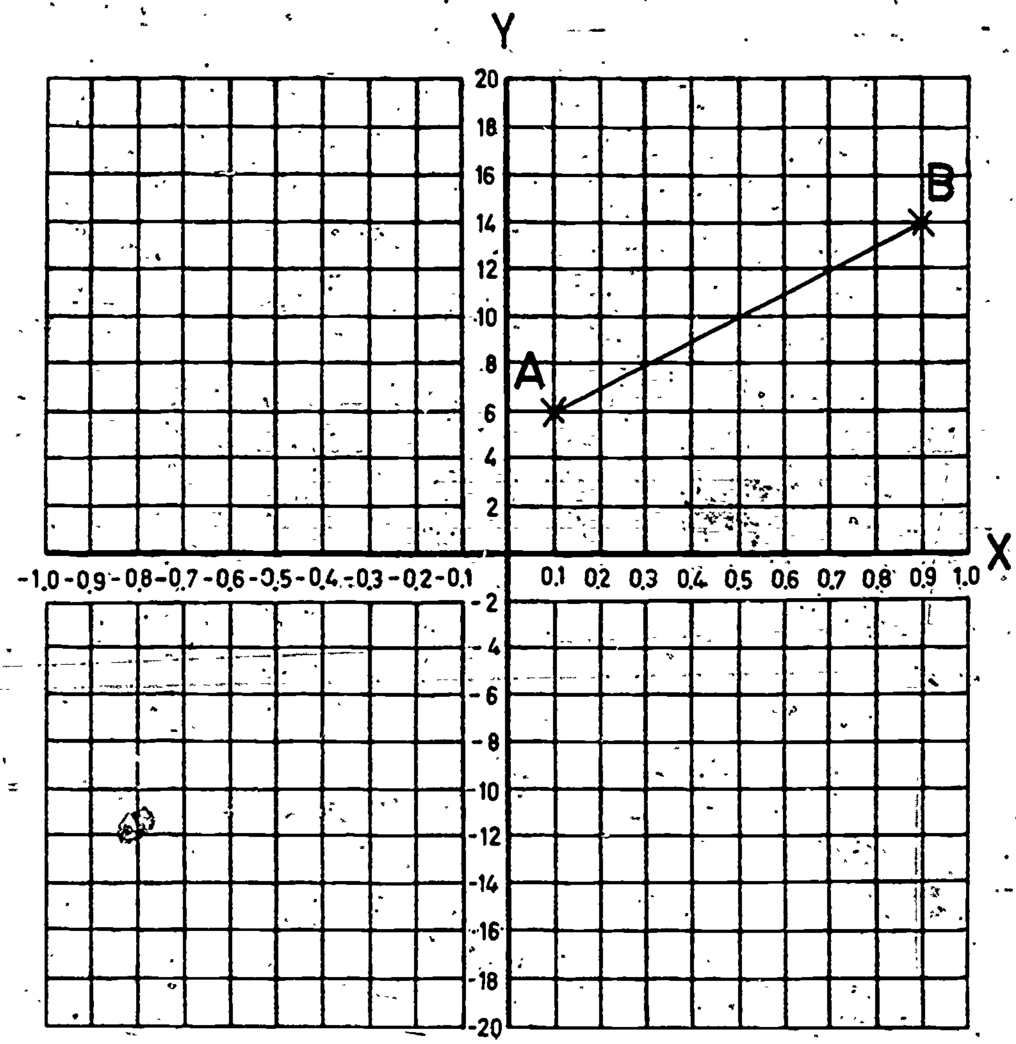
Calculate the area between the line AB and the horizontal (X) axis.

ANSWER ____________
(number)



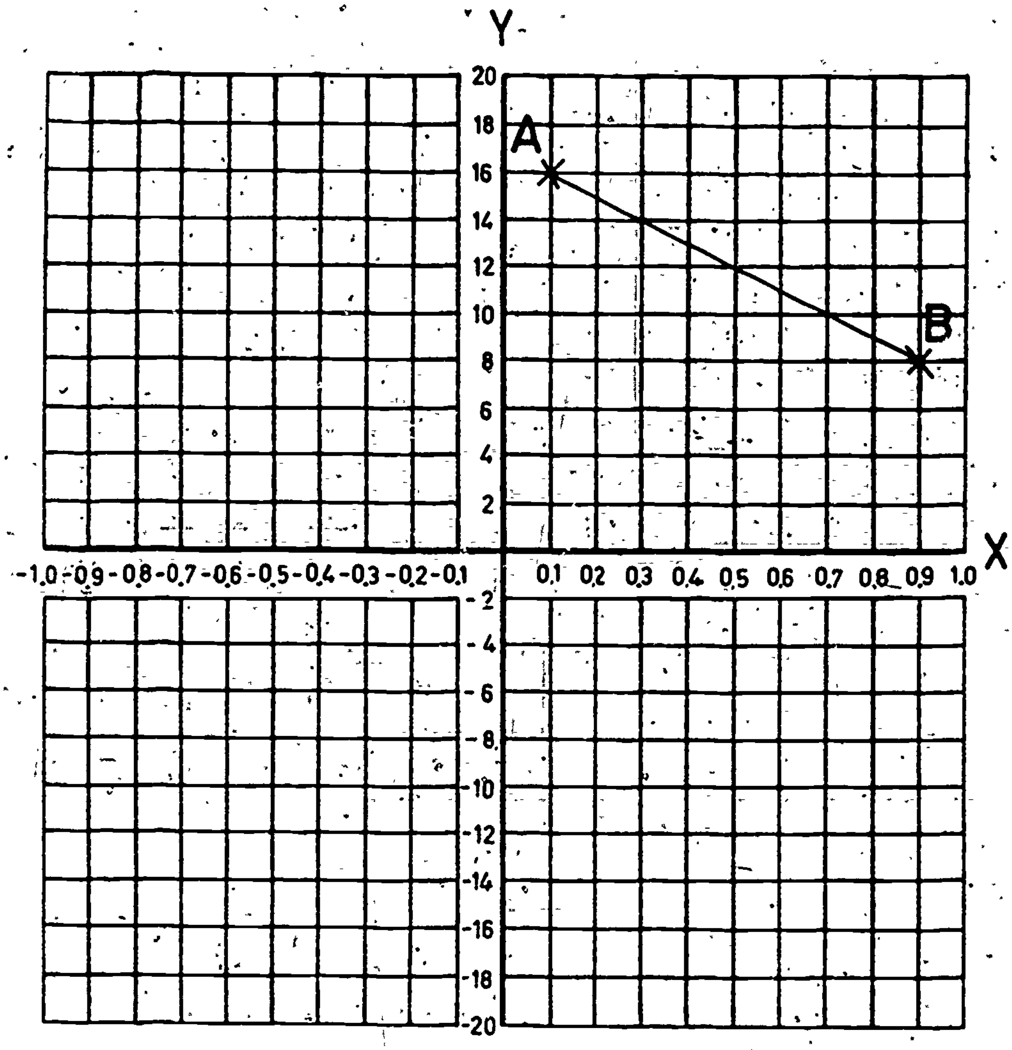
Calculate the area between the line AB and the horizontal (X) axis.

ANSWER ______
(number)



Calculate the area between the line AB and the horizontal (X) axis.

ANSWER ________
(number)



Calculate the area between the line AB and the horizontal (X) axis.

ANSWER

______
(number)

BASIC SKILLS OF GRAPHICAL INTERPRETATION

SUBDIVISION ANALYSIS SET 6/3(A)

NAME ______________________ AGE ____________

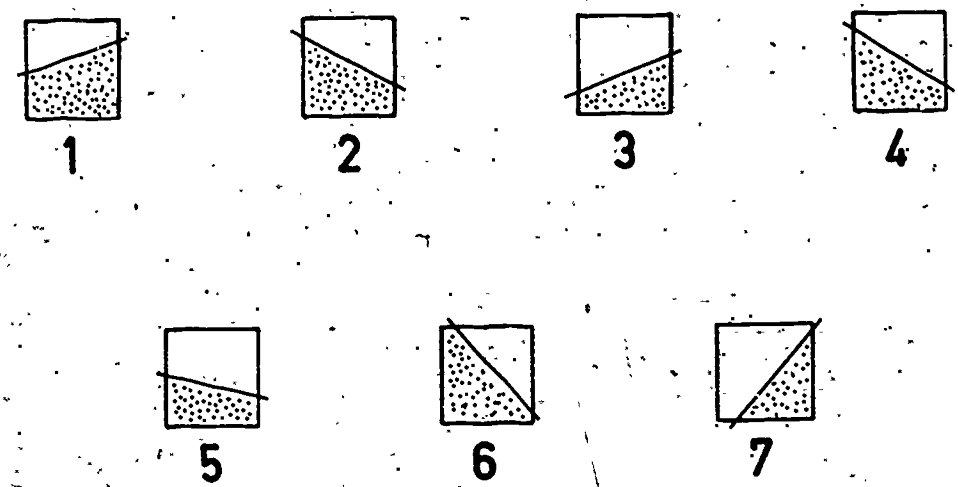
SEX ____________

SCHOOL __________________ CLASS ____________

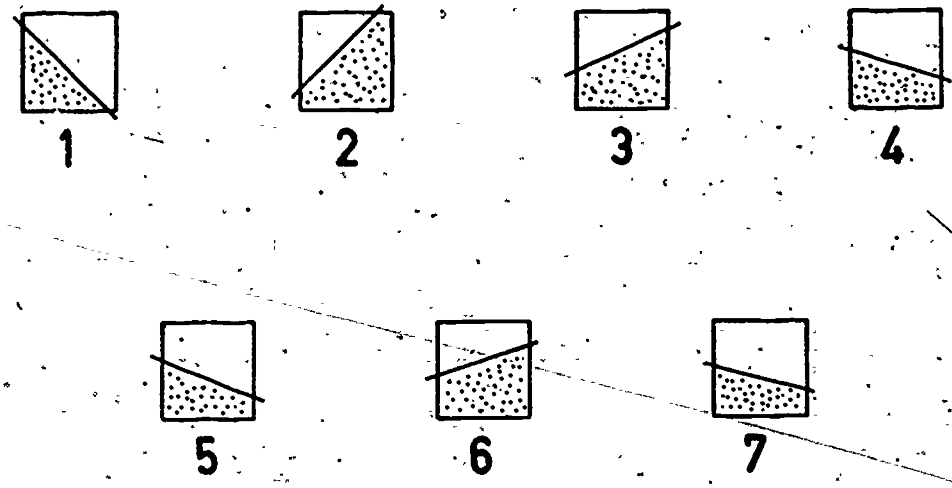
DATE ____________

INSTRUCTIONS

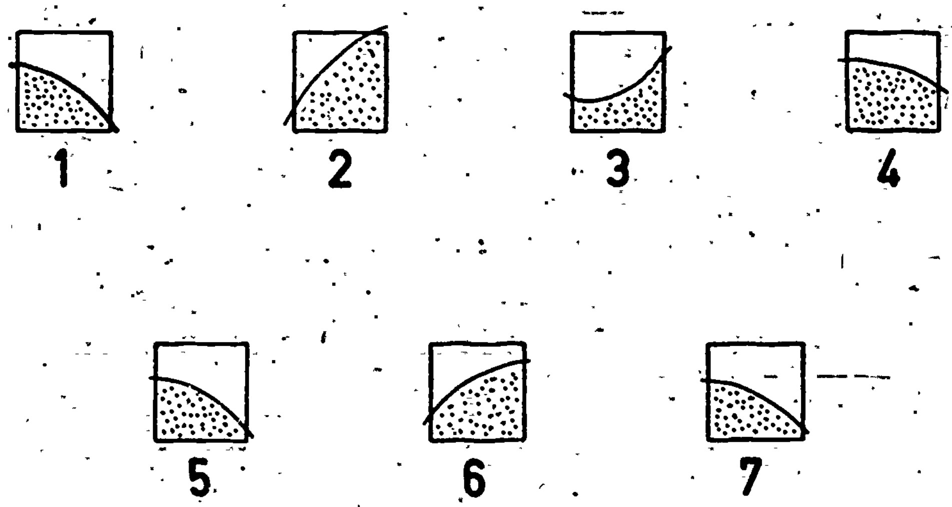
Read each question carefully, then write your answer in the space provided. Try to guess the answers to any questions you do not know, but do not waste time on more difficult problems. All answers should be given to the nearest decimal place, and any other calculations may be written on the back of the page. The sign of an answer, where this applies, should be either positive (+) or negative (-).



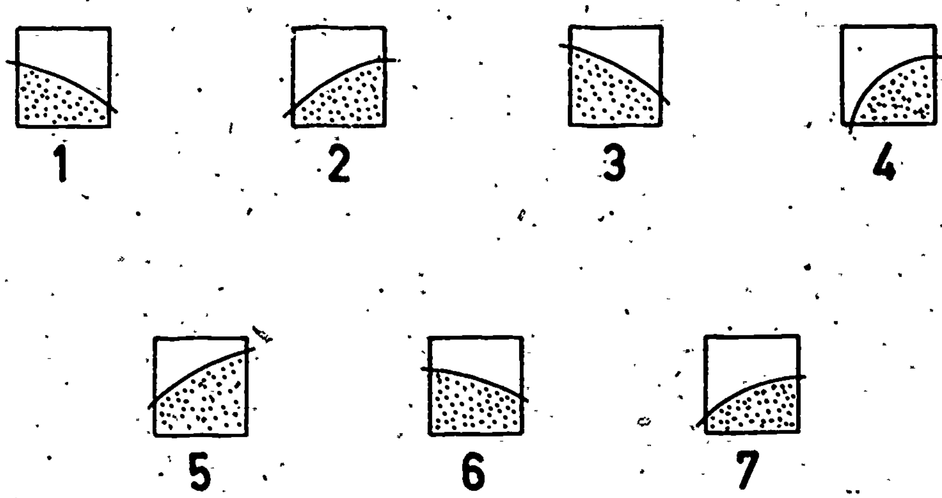
Mark with a circle the number of each square above in which the shaded area represents at least half the total area of the square.



Mark with a circle the number of each square above in which the shaded area represents at least half the total area of the square.



Mark with a circle the number of each square above in which the shaded area represents at least half the total area of the square.



Mark with a circle the number of each square above in which the shaded area represents at least half the total area of the square.

BASIC SKILLS OF GRAPHICAL INTERPRETATION

SUBDIVISION ANALYSIS SET 6/3(B)

NAME ______________ AGE ________

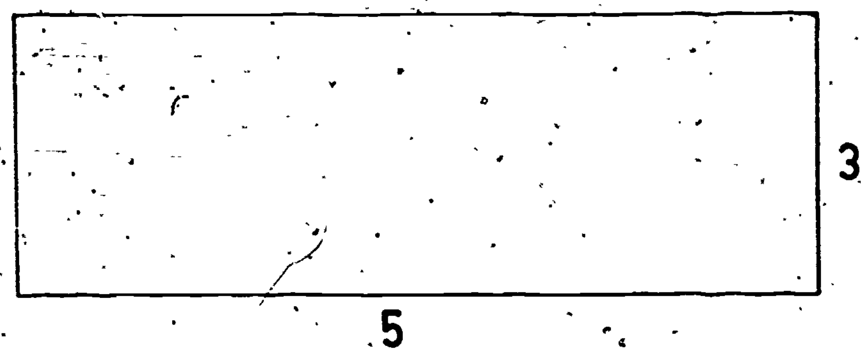
SEX ________

SCHOOL ______________ CLASS ________

DATE ________

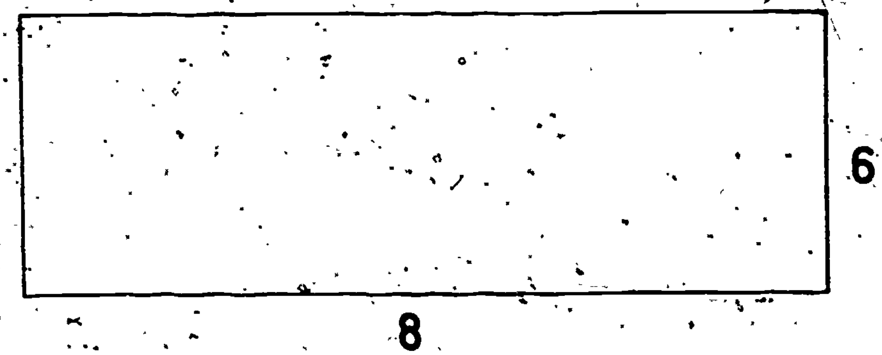
INSTRUCTIONS

Read each question carefully, then write your answer in the space provided. Try to guess the answers to any questions you do not know, but do not waste time on more difficult problems. All answers should be given to the nearest decimal place, and any other calculations may be written on the back of the page. The sign of an answer, where this applies, should be either positive (+) or negative (-).



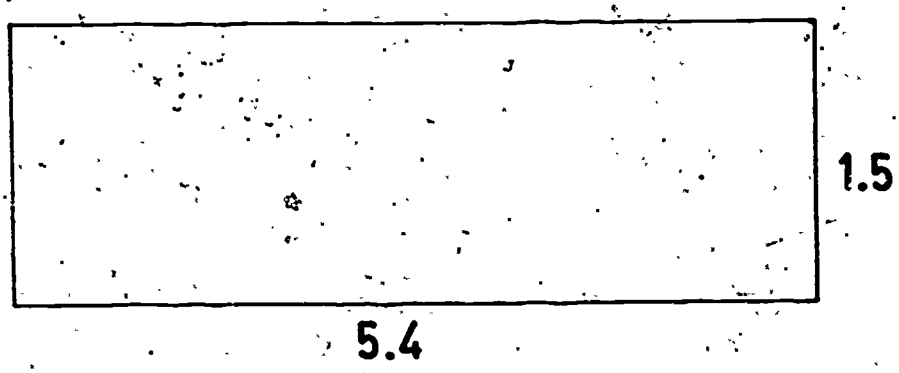
Calculate the area of the rectangle above.

ANSWER ______
(number)



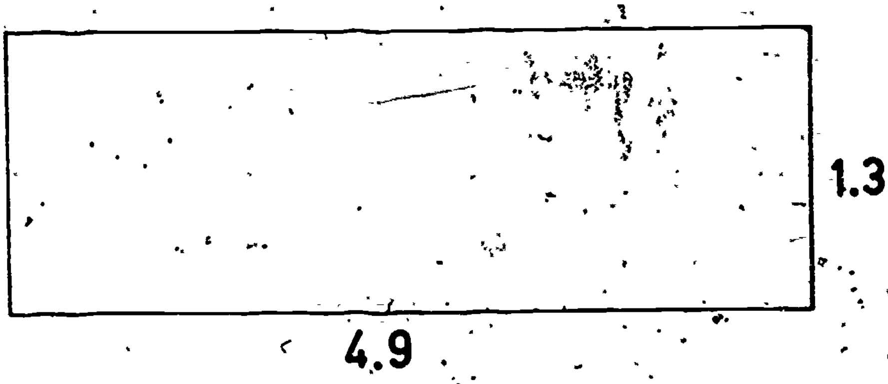
Calculate the area of the rectangle above.

ANSWER ________
(number)



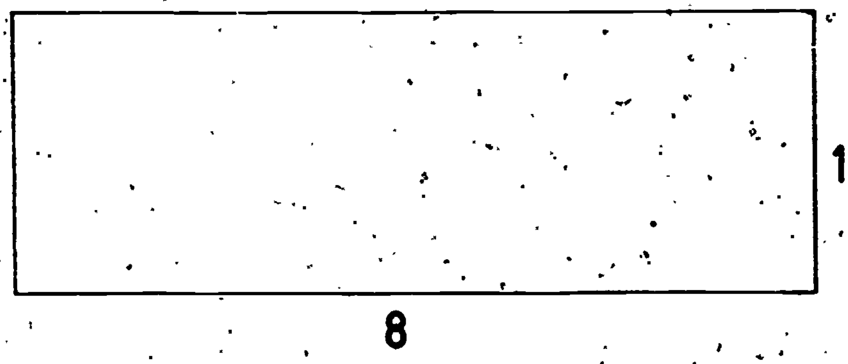
— Calculate the area of the rectangle above.

ANSWER ______
(number)



Calculate the area of the rectangle above.

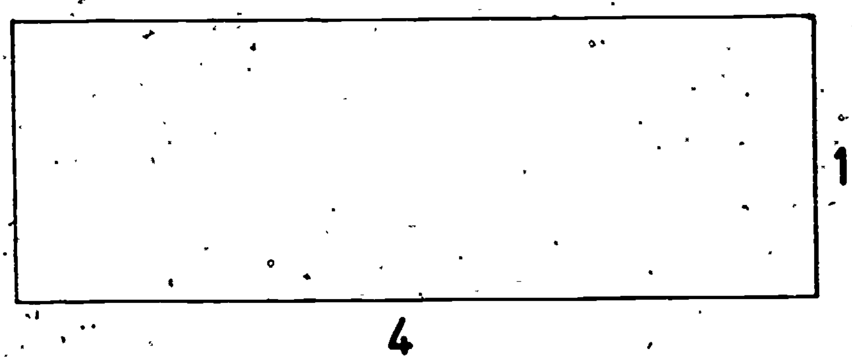
ANSWER ______
(number)



Calculate the area of the rectangle above.

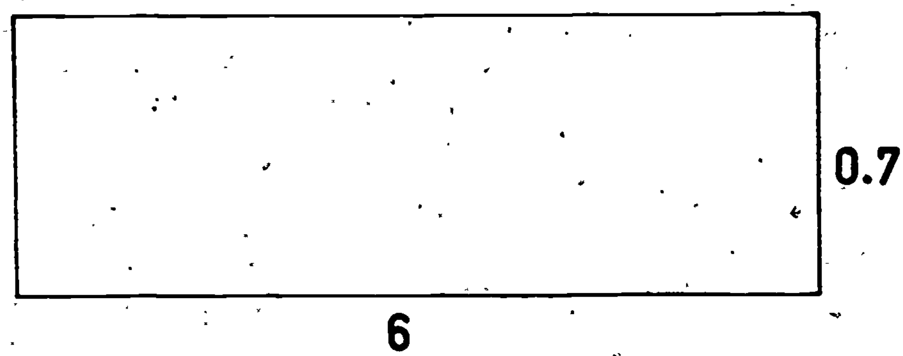
____

ANSWER ______________
(number)



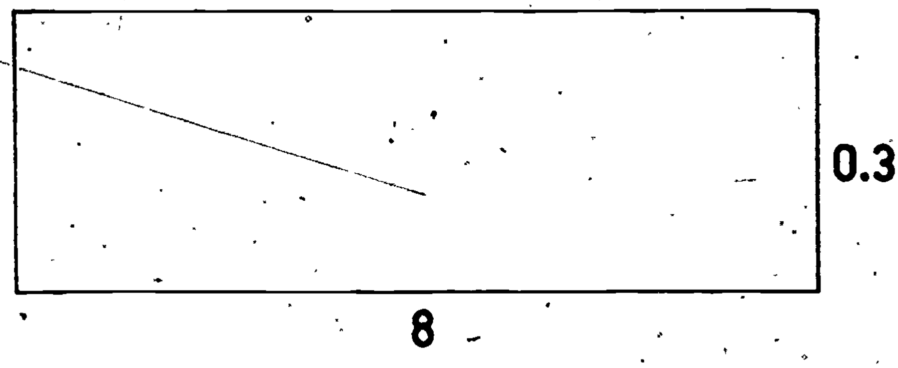
Calculate the area of the rectangle above.

ANSWER ______
(number)



Calculate the area of the rectangle above.

ANSWER ______
(number)



Calculate the area of the rectangle above.

ANSWER ________

(number)

BASIC SKILLS OF GRAPHICAL INTERPRETATION

SUBDIVISION ANALYSIS SET 6/4(B)

NAME ____________ AGE ________

SEX ________

SCHOOL ____________ CLASS ________

DATE ________

INSTRUCTIONS

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Complete the following calculation.

7 × 9 = ____

Complete the following calculation.

$$3 \times 6 = \underline{\qquad}$$

Complete the following calculation.

$4.7 \times 6.6 = \_\_\_$

Complete the following calculation.

$8.2 \times 2.8 =$ ____

Complete the following calculation.

$3 \times 1 = \_\_\_\_$

Complete the following calculation.

$$8 \times 1 = \_\_\_$$

Complete the following calculation.

$4 \times 0.3 = \_\_\_\_$

Complete the following calculation.

$5 \times 0.9 = \_\_\_\_$

THE EFFECTS OF CERTAIN PERSONAL AND SITUATIONAL VARIABLES ON THE ACQUISITION SEQUENCE OF GRAPHICAL INTERPRETATION SKILLS

VOLUME III - APPENDIX

R D LINKE

THE EFFECTS OF CERTAIN PERSONAL AND SITUATIONAL VARIABLES ON THE ACQUISITION SEQUENCE OF GRAPHICAL INTERPRETATION SKILLS

VOLUME III - APPENDIX

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INSTRUCTIONAL AND TESTING MATERIALS USED FOR THE MAJOR VALIDATION STUDIES

SEQUENCE OF PRESENTATION

VALIDATION PROGRAMME	SECTION	NUMBER OF PAGES
I	1	17
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	3	13
II	1	17
	2	17
	3	13
III	1	17
	2	17
	3	13

NOTES

1. The preparation and development of Validation Programme I is described in Chapter VI (Volume I), and subsequent modifications are outlined for Programmes II and III respectively in Chapters VII and VIII (Volume I).

2. The definition and classification code for each element or basic skill is presented in Tables 5/4-5/10 (Chapter V), and a list of the relevant subdivisional conditions is presented for Programmes I and II in Table 6/2 (Chapter VI), and for Programme III in Table 8/1 (Chapter VIII).

3. The presentation sequence of basic and subdivisional skills for each section of the Validation Programmes is outlined in Table 6/1 (Chapter VI).

BASIC SKILLS OF GRAPHICAL INTERPRETATION

PROGRAMME I SECTION 1

NAME ____________ AGE ______ ______
(years) (months)

SEX ______

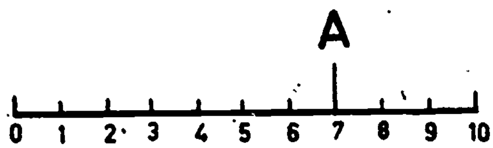
SCHOOL ____________ CLASS ______

DATE ______

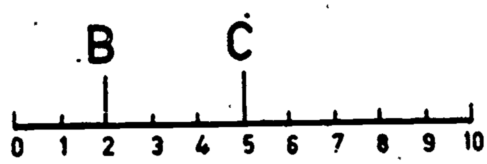
INSTRUCTIONS

As you work through this programme, read each question carefully, then write your answer in the space provided. Any other calculations should be written on the BACK of the page. If you are not sure of the answer to a question, take a guess and go on to the next example.

This is a HORIZONTAL NUMBER LINE with positions marked from 0 to 10.



The position of A on the number line above is 7.



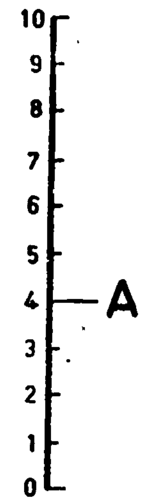
Calculate the position of B on the number line above.

ANSWER B = ____

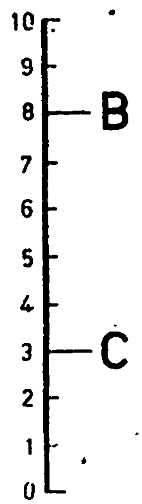
Calculate the position of C on the number line above.

ANSWER C = ____

This is a VERTICAL NUMBER LINE with positions marked from 0 to 10.



The position of A on this number line is 4.



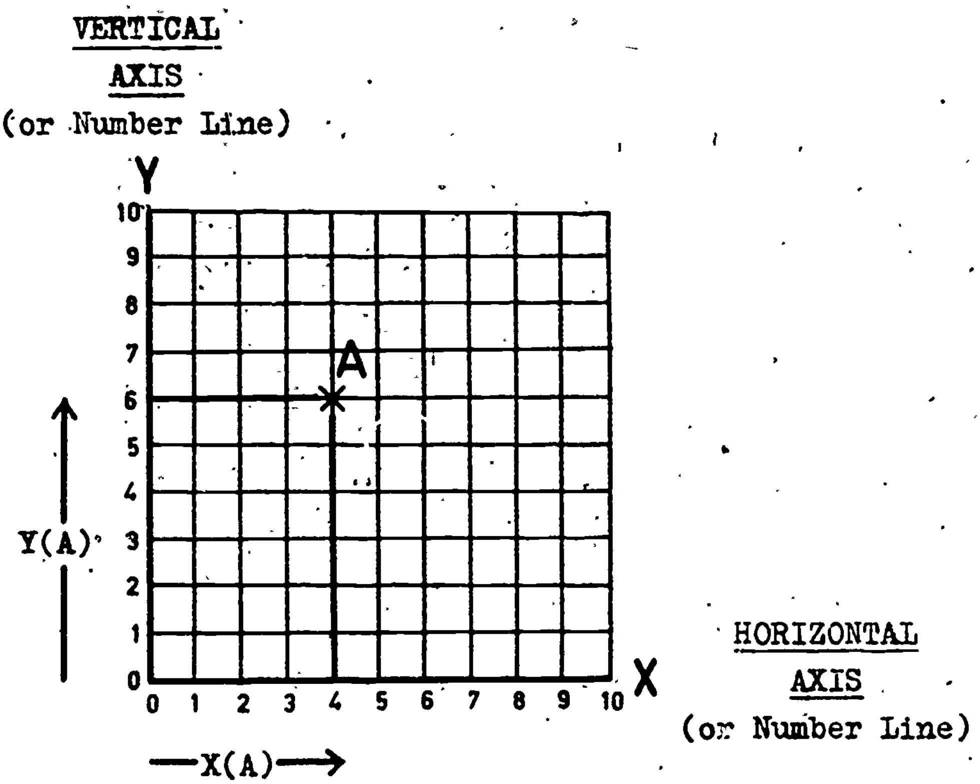
Calculate the position of B.

ANSWER B = ____

Calculate the position of C.

ANSWER C = ____

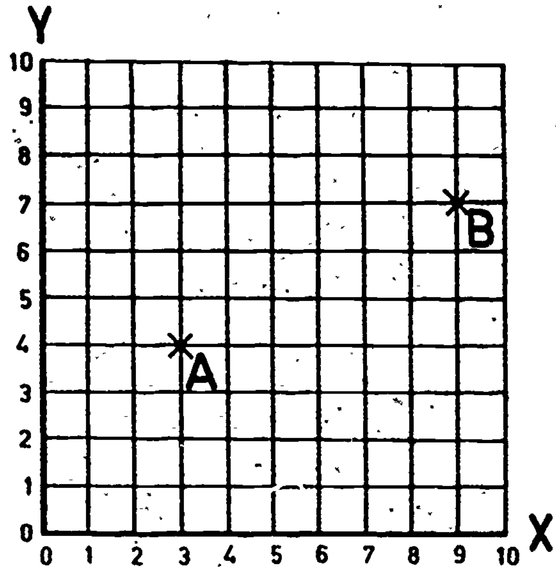
Let us now combine the Horizontal and Vertical number lines to form a GRAPH as shown in the diagram below.



Any point within this graph can now be easily found if we know both its Horizontal position and its Vertical position. These may be calculated in the following way :-

The HORIZONTAL POSITION of a point is its distance from 0 measured along the Horizontal or X axis. This is shown for the point A in the graph above as X(A) = 4.

The VERTICAL POSITION of a point is its distance from 0 measured along the Vertical or Y axis. This is shown for the point A in the graph above as Y(A) = 6.



Calculate the Horizontal position of A.

ANSWER X(A) = ______

Calculate the Horizontal position of B.

ANSWER X(B) = ______

Calculate the Vertical position of A.

ANSWER Y(A) = ______

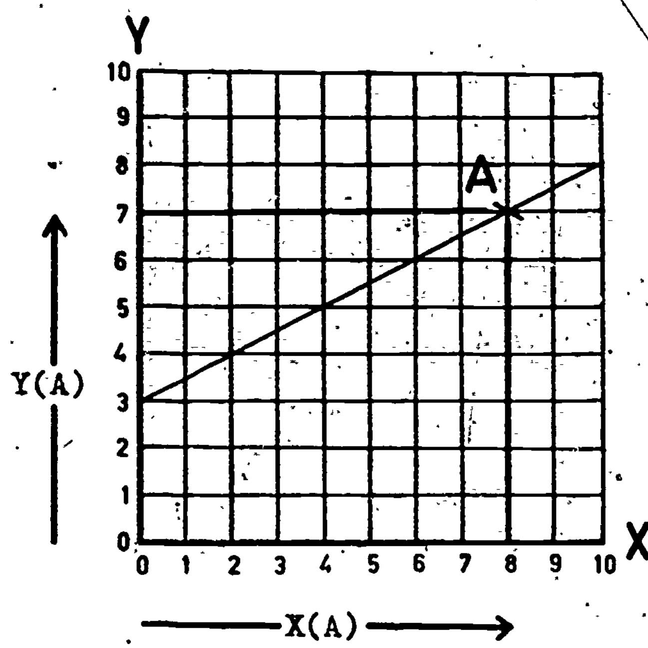
Calculate the Vertical position of B.

ANSWER Y(B) = ______

Now we can find the position of any POINT ON A LINE, using the method described in the example below.

EXAMPLE

Calculate the Horizontal position of A when Y(A) = 7.



METHOD

(1) Find the given position Y(A) = 7 on the Vertical Axis.

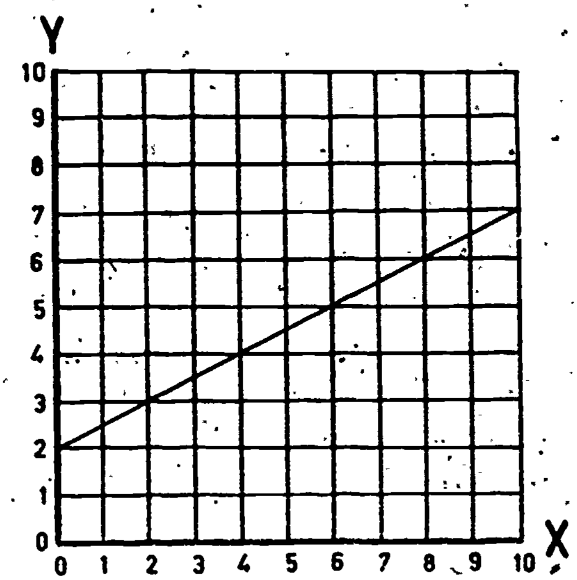
(2) Move across to the line and mark the point A which has the same Vertical position.

(3) Calculate the Horizontal position of this point, as shown on the graph above.

ANSWER

X(A) = 8.

The two points A and B both lie somewhere on the line shown in this graph.



Y(A) = 3.   Y(B) = 6.

Mark the positions A and B on the graph.

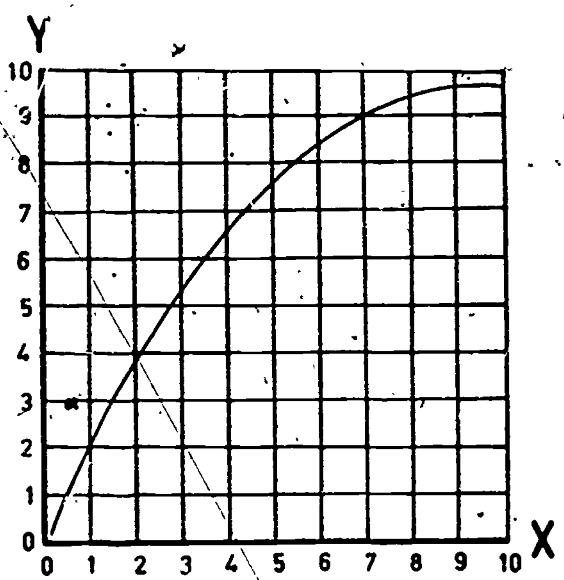
Calculate the Horizontal position of A.

ANSWER   X(A) = ____

Calculate the Horizontal position of B.

ANSWER   X(B) = ____

The two points C and D both lie somewhere on the curve shown in this graph.



Y(C) = 2.   Y(D) = 9.

Mark the positions C and D on the graph.

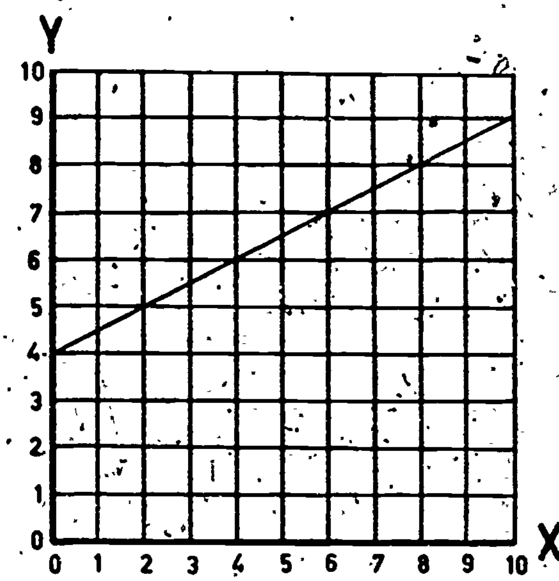
Calculate the Horizontal position of C.

ANSWER   X(C) = ____

Calculate the Horizontal position of D.

ANSWER   X(D) = ____

The two points A and B both lie somewhere on the line shown in this graph.



X(A) = 4. X(B) = 10.

Mark the positions A and B on the graph.

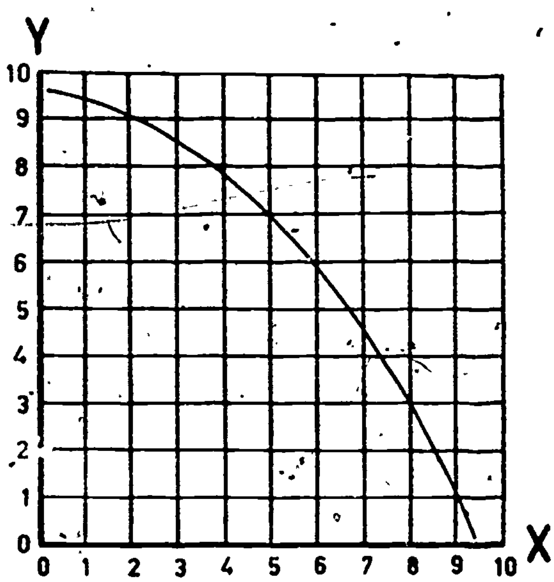
Calculate the Vertical position of A.

ANSWER Y(A) = ____

Calculate the Vertical position of B.

ANSWER Y(B) = ____

The two points C and D both lie somewhere on the curve shown in this graph.



X(C) = 8. X(D) = 5.

Mark the positions C and D on the graph.

Calculate the Vertical position of C.

ANSWER Y(C) = ____

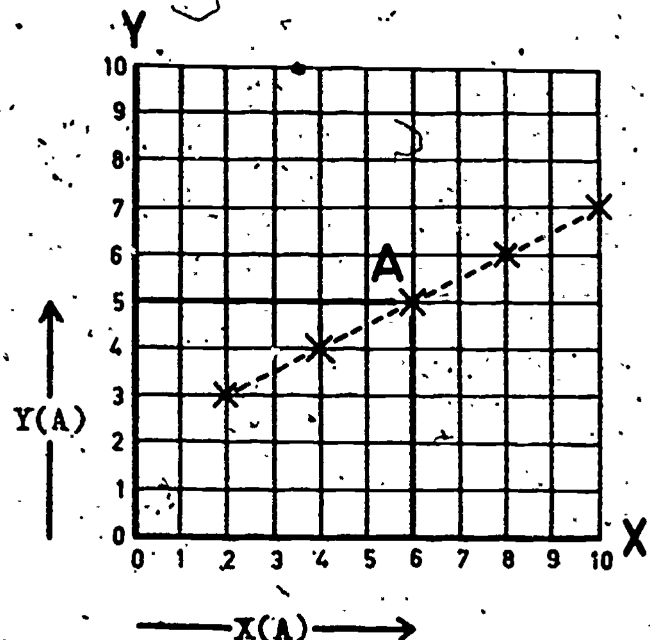
Calculate the Vertical position of D.

ANSWER Y(D) = ____

In order to find a certain POSITION BETWEEN A ROW OF POINTS, use the method described in the following example.

EXAMPLE

Calculate the Horizontal position of A when Y(A) = 5.



METHOD

(1) Rule a line through each of the points, as shown on the graph above.

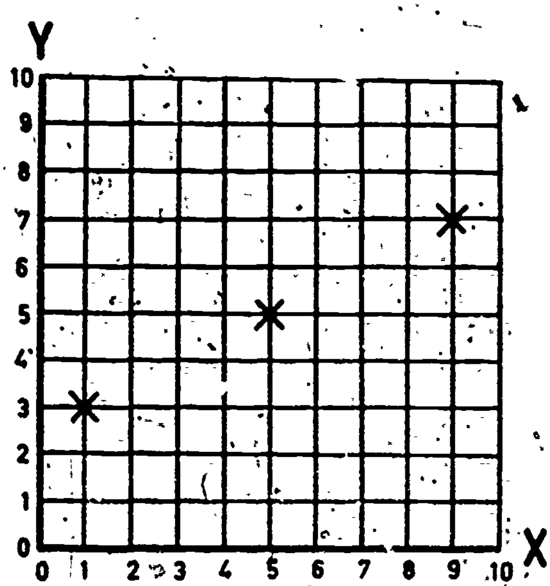
(2) Find the point on this line which has a Vertical position Y(A) = 5.

(3) Calculate the Horizontal position of this point.

ANSWER

X(A) = 6.

The two points A and B both lie somewhere between the row of points shown on this graph.



Calculate the Horizontal position of A when Y(A) = 4.

ANSWER X(A) = ____

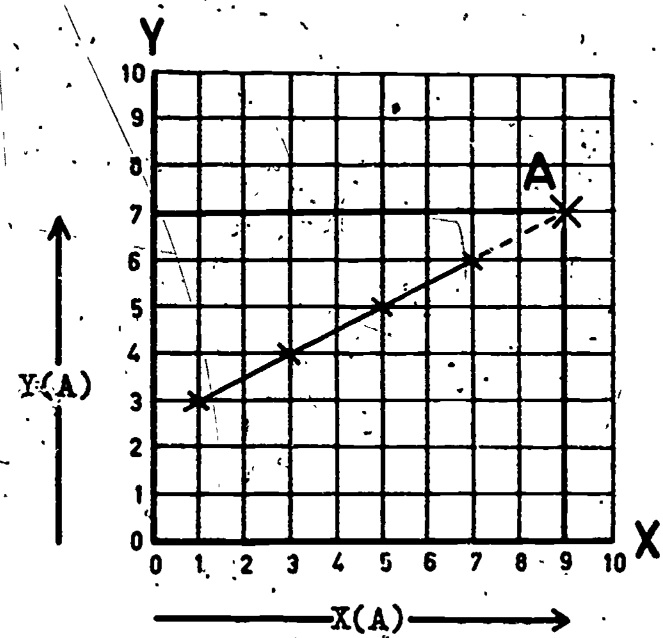
Calculate the Horizontal position of B when Y(B) = 6.

ANSWER X(B) = ____

In order to find a certain <u>POSITION BEYOND A GIVEN LINE OR ROW OF POINTS</u>, follow the instructions described in the example below.

<u>EXAMPLE</u>

Calculate the Horizontal position of <u>A</u> when $Y(A) = \underline{7}$.



<u>METHOD</u>

(1) Rule a line through each of the points (unless a line is given in the problem).

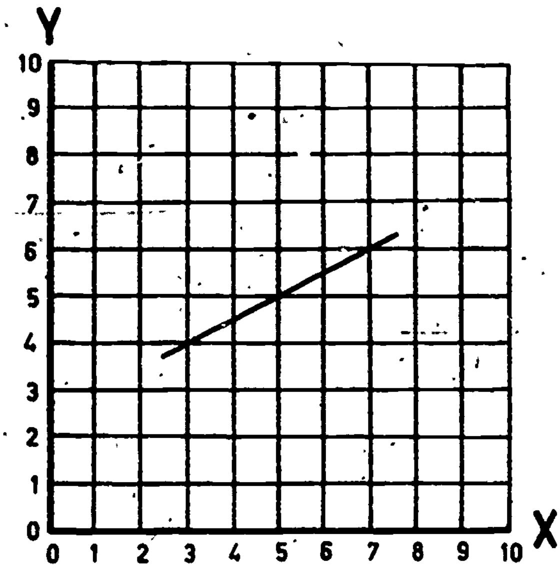
(2) Extend this line, as shown in the graph above, until it reaches the Vertical position $Y(A) = \underline{7}$.

(3) Calculate the Horizontal position of this point.

<u>ANSWER</u>

$\underline{X(A) = 9}$.

The two points **A** and B both lie somewhere beyond the line shown in this graph.

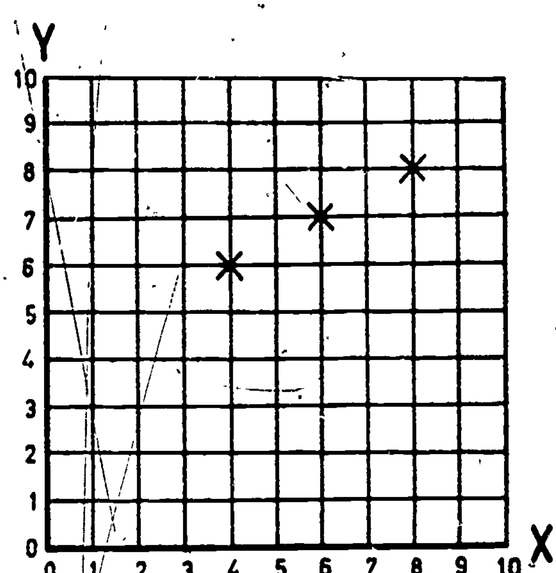


Calculate the Horizontal position of **A** when Y(A) = 3.

ANSWER X(A) = ____

Calculate the Horizontal position of B when Y(B) = 7.

ANSWER X(B) = ____



The two points C and D both lie somewhere beyond the row of points shown in this graph.

Calculate the Horizontal position of C when Y(C) = 5.

ANSWER X(C) = ____

Calculate the Horizontal position of D when Y(D) = 9.

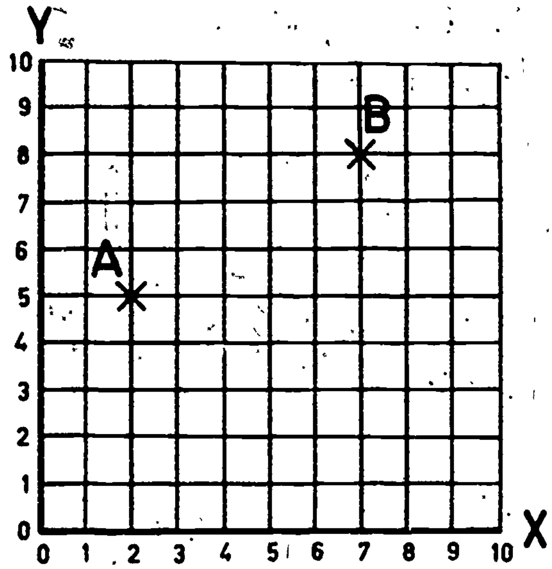
ANSWER X(D) = ____

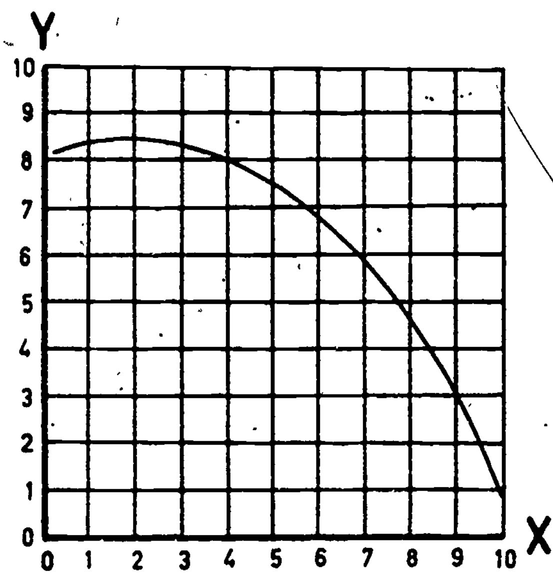
Calculate the Vertical position of A.

ANSWER Y(A) = ____

Calculate the Vertical position of B.

ANSWER Y(B) = ____





The two points C and D both lie somewhere on the curve shown in this graph.

Calculate the Vertical position of C when X(C) = 4.

ANSWER Y(C) = ____

Calculate the Vertical position of D when X(D) = 9.

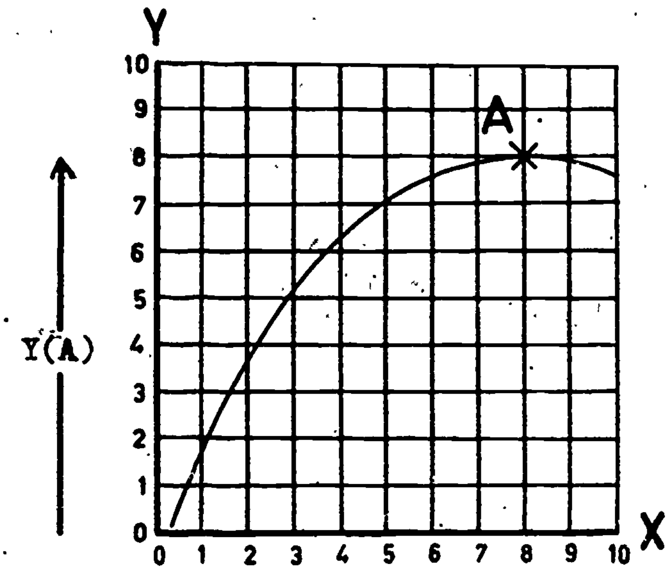
ANSWER Y(D) = ____

The MAXIMUM Value of a curve is equal to the HIGHEST VERTICAL POSITION on the curve.

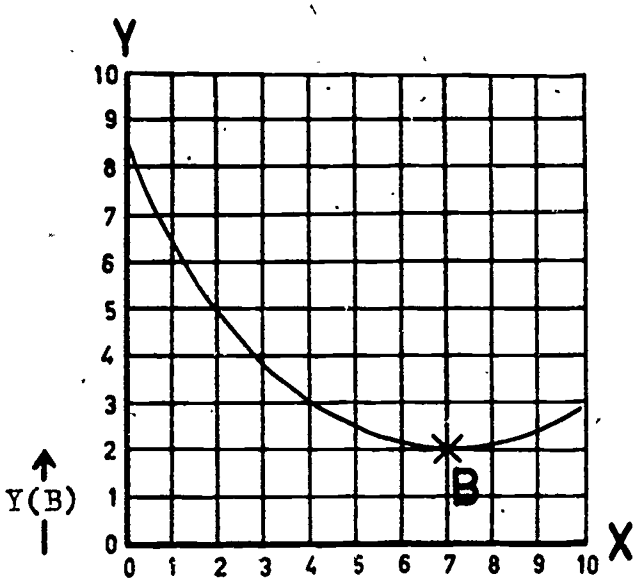
The Maximum Value of this curve

= Y(A)

= 8.



The MINIMUM Value of a curve is equal to the LOWEST VERTICAL POSITION on the curve.



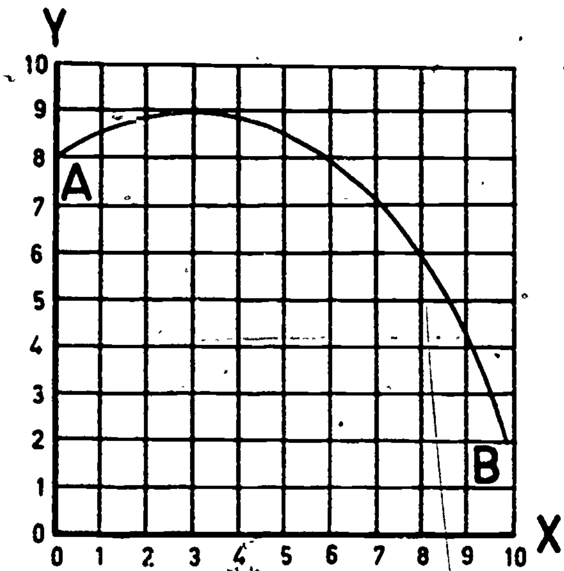
The Minimum Value of this curve

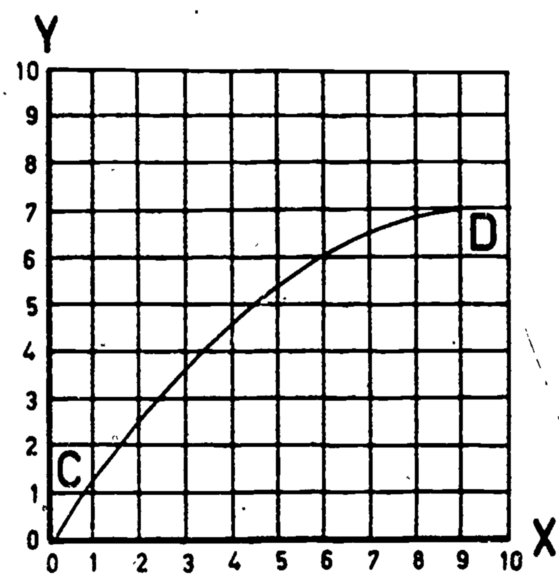
= Y(B)

= 2.

Calculate the Maximum
Value of the curve AB.

ANSWER MAX = ____



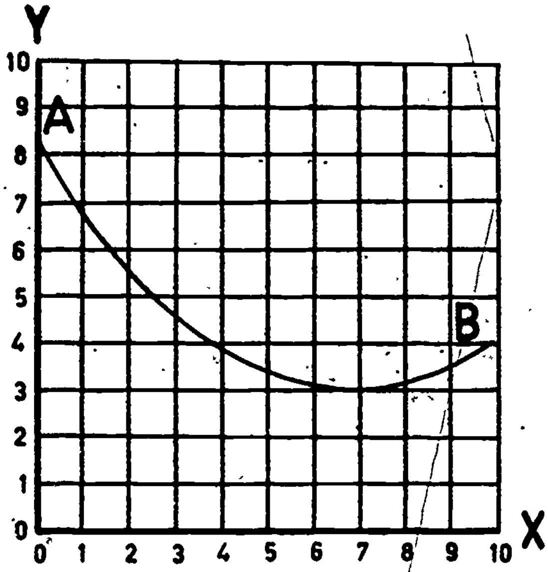


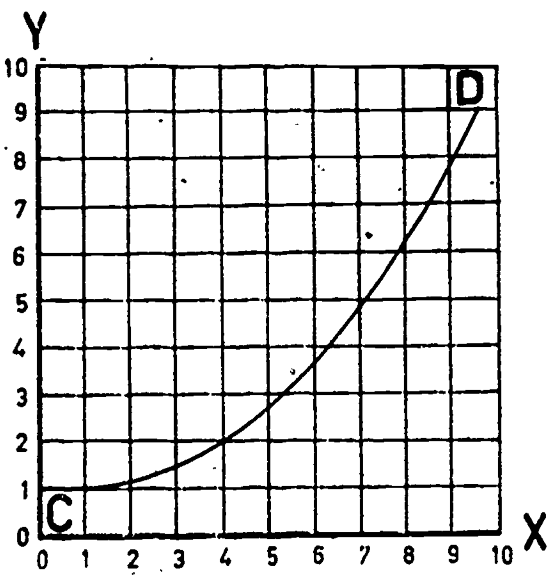
Calculate the Maximum
Value of the curve CD.

ANSWER MAX = ____

Calculate the Minimum
Value of the curve AB.

ANSWER MIN = ____

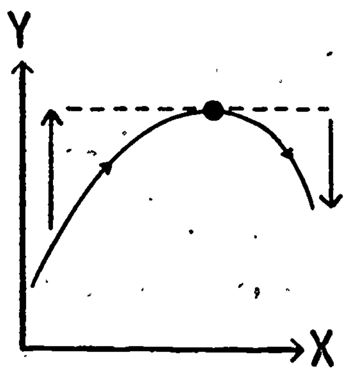




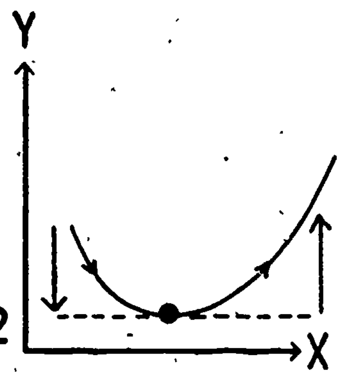
Calculate the Minimum
Value of the curve CD.

ANSWER MIN = ____

The TURNING POINT of a curve is indicated by a Change in Vertical Direction along the curve, as shown in the examples below.

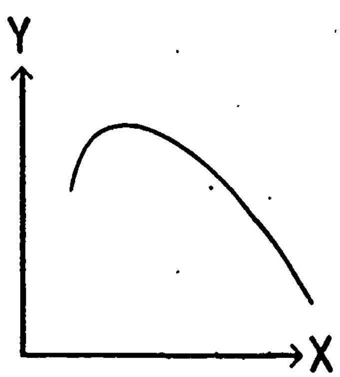


1

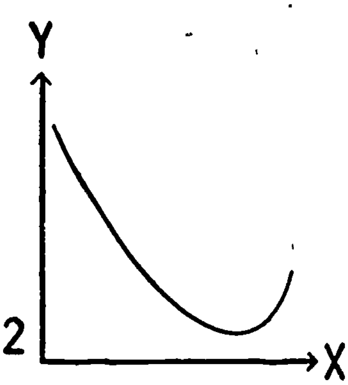


2

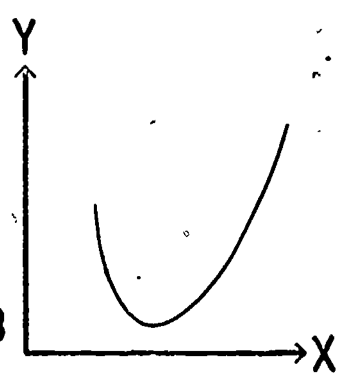
Place a mark (●) at the Turning Point on each of the following curves.



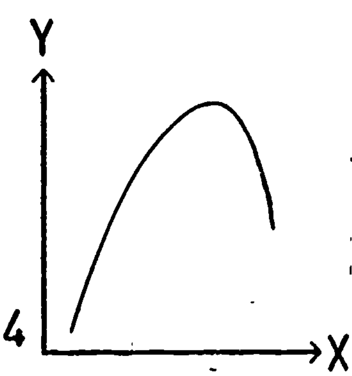
1



2



3

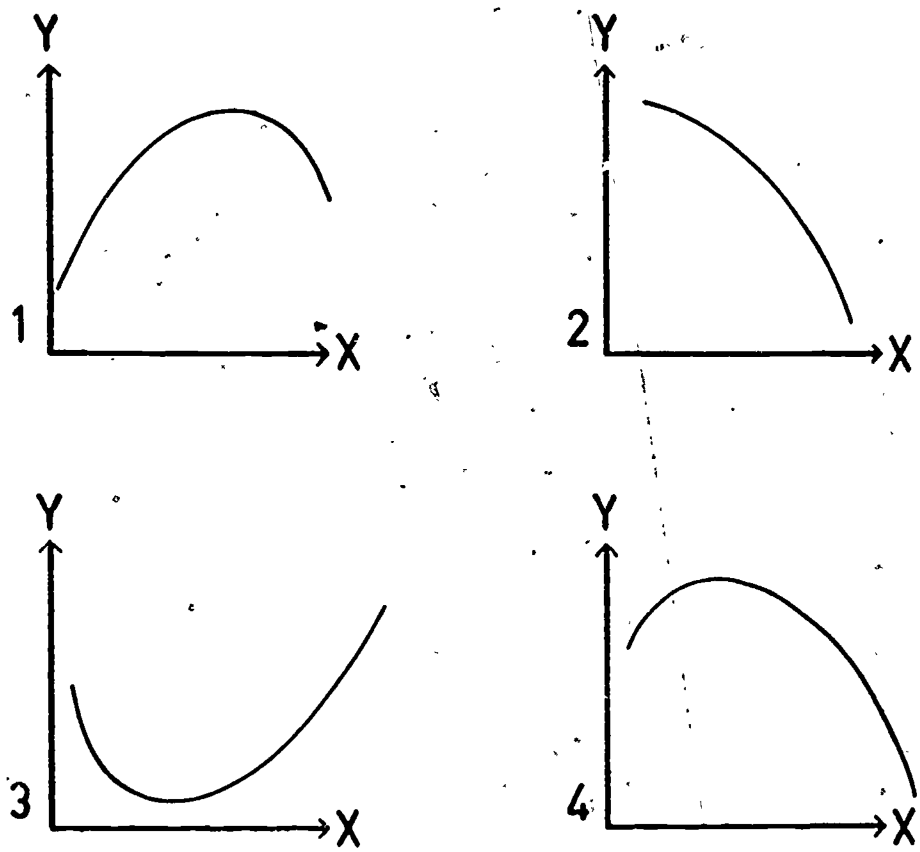


4

If the Turning Point of a curve has the HIGHEST Vertical position on the curve, it is called a <u>MAXIMUM TURNING POINT</u>.

If the Turning Point of a curve has the LOWEST Vertical position on the curve, it is called a <u>MINIMUM TURNING POINT</u>.

Show which of the following curves has a MAXIMUM Turning Point, by writing the number(s) in the space below.



ANSWER ____________

BASIC SKILLS OF GRAPHICAL INTERPRETATION

PROGRAMME I SECTION 2

NAME ____________ AGE ______ ______
(years) (months)

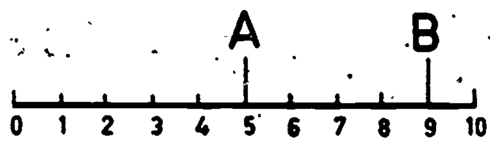
SEX ________

SCHOOL ____________ CLASS ________

DATE ________

INSTRUCTIONS

As you work through this programme, read each question carefully, then write your answer in the space provided. Any other calculations should be written on the BACK of the page. If you are not sure of the answer to a question, take a guess and go on to the next example.



Calculate the position of **A** on the number line above.

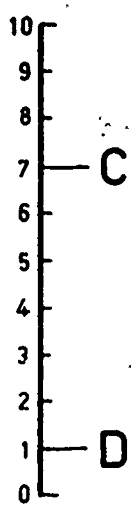
ANSWER **A** = ______

Calculate the position of B on the number line above.

ANSWER B = ______

Calculate the position of C.

ANSWER C = ______



Calculate the position of D.

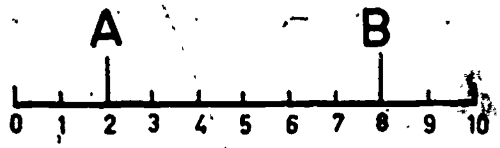
ANSWER D = ______

Complete the following calculations.

10 - 5 = ______ 9 - 2 = ______

The DISPLACEMENT between two points is the CHANGE IN POSITION from one point to the other.

EXAMPLE

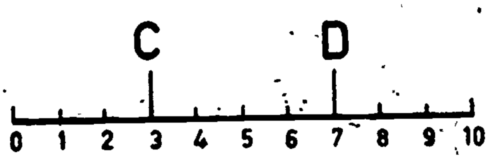


The Displacement from A to B on the number line above (call this AB) = Final Position - First Position

= B - A

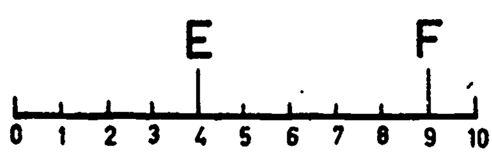
= 8 - 2

= 6



Calculate the Displacement from C to D on the number line above.

ANSWER CD = ____



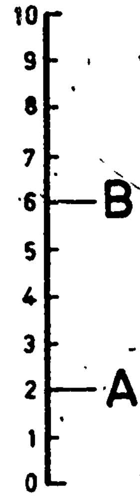
Calculate the Displacement from E to F on the number line above.

ANSWER EF = ____

The same rule can also be used to calculate the Displacement between two points on a Vertical number line.

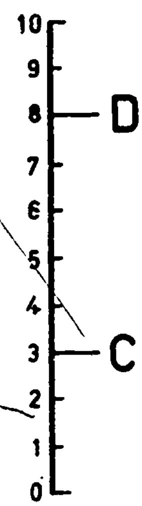
Calculate the Displacement from A to B.

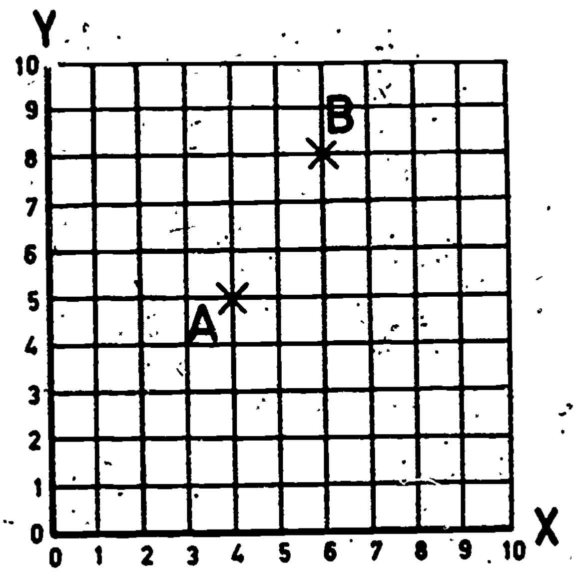
ANSWER AB = ______



Calculate the Displacement from C to D.

ANSWER CD = ______





Calculate the Horizontal position of A.

ANSWER X(A) = ____

Calculate the Horizontal position of B.

ANSWER X(B) = ____

Calculate the Vertical position of A.

ANSWER Y(A) = ____

Calculate the Vertical position of B.

ANSWER Y(B) = ____

The HORIZONTAL DISPLACEMENT between two points on a graph is the CHANGE IN HORIZONTAL POSITION from one point to the other - that is, the change in position measured along the Horizontal or X-axis.

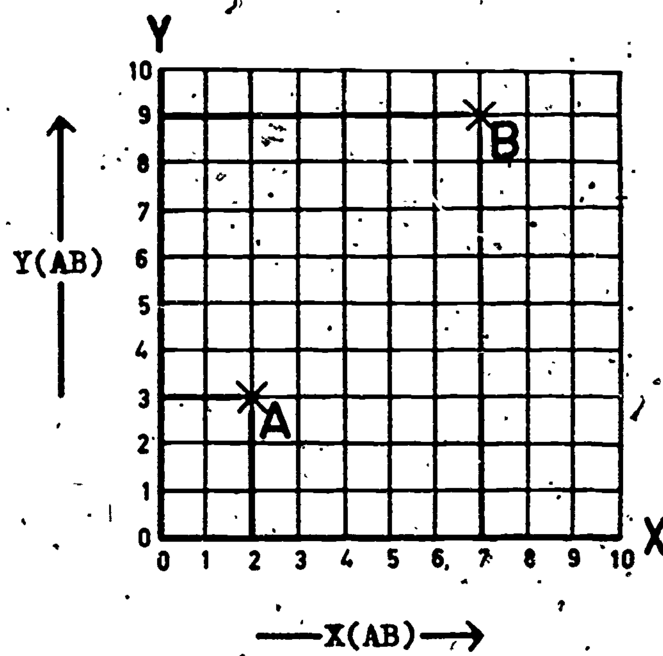
EXAMPLE

The Horizontal Displacement from A to B (called X(AB))

= X(B) - X(A)

= 7 - 2

= 5.



The VERTICAL DISPLACEMENT between two points on a graph is the CHANGE IN VERTICAL POSITION from one point to the other - that is, the change in position measured along the Vertical or Y-axis.

EXAMPLE

The Vertical Displacement from A to B on the graph above (called Y(AB)) = Y(B) - Y(A)

= 9 - 3

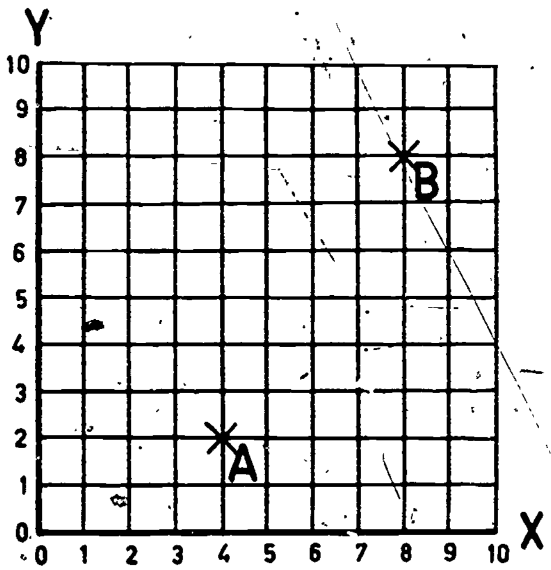
= 6.

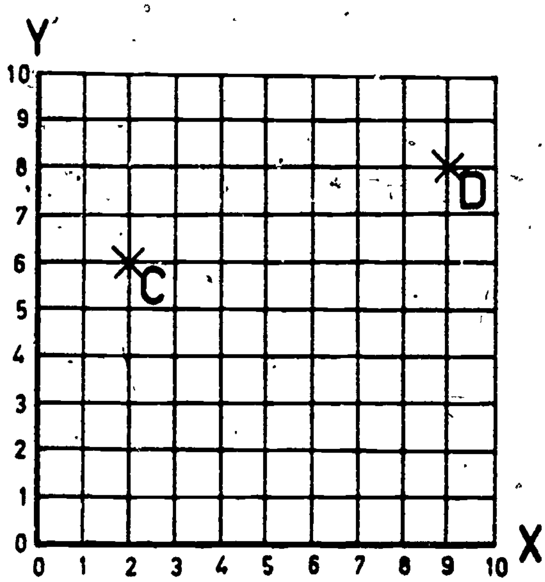
Calculate the Horizontal Displacement from A to B.

ANSWER X(AB) = ______

Calculate the Vertical Displacement from A to B.

ANSWER Y(AB) = ______





Calculate the Horizontal Displacement from C to D.

ANSWER X(CD) = ______

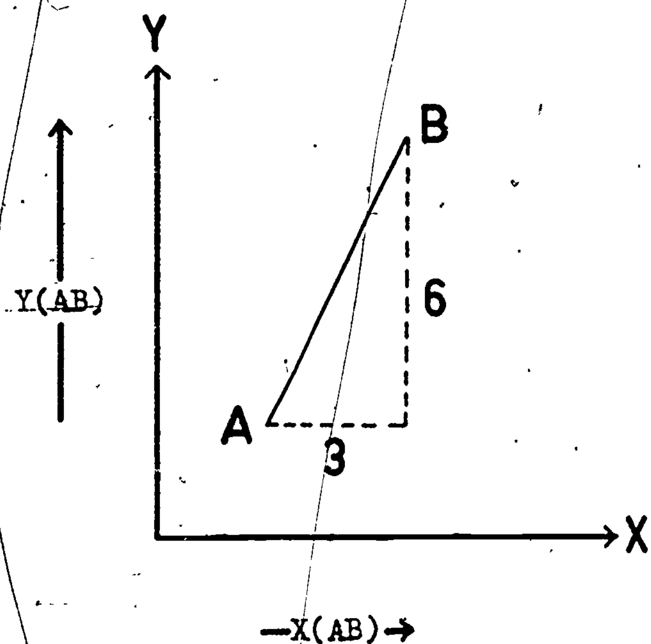
Calculate the Vertical Displacement from C to D.

ANSWER Y(CD) = ______

Complete the following calculations :-

$\frac{9}{3}$ = ______ $\frac{8}{2}$ = ______

The SLOPE OF A STRAIGHT LINE = $\frac{\text{VERTICAL DISPLACEMENT}}{\text{HORIZONTAL DISPLACEMENT}}$



EXAMPLE

The Slope of the line AB. = $\frac{\text{Vertical Displacement from A to B}}{\text{Horizontal Displacement from A to B}}$

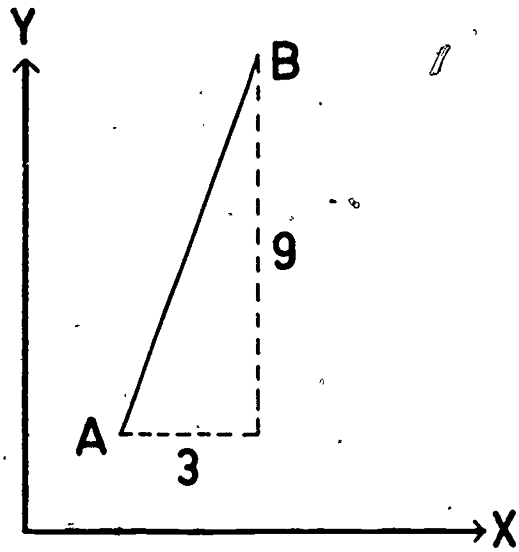
= $\frac{Y(AB)}{X(AB)}$

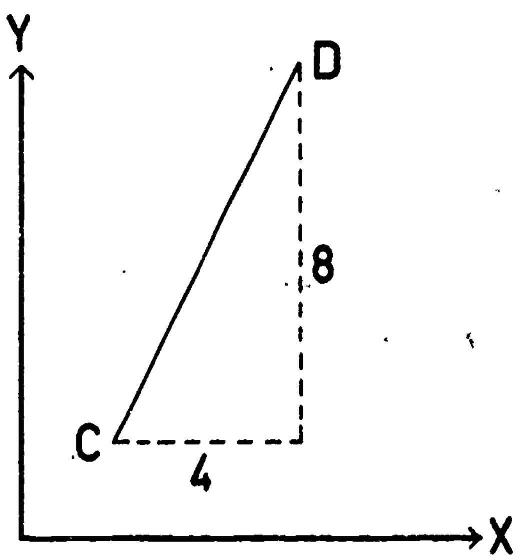
= $\frac{6}{3}$

= 2

Calculate the Slope of the line AB.

ANSWER Slope = ____





Calculate the Slope of the line CD.

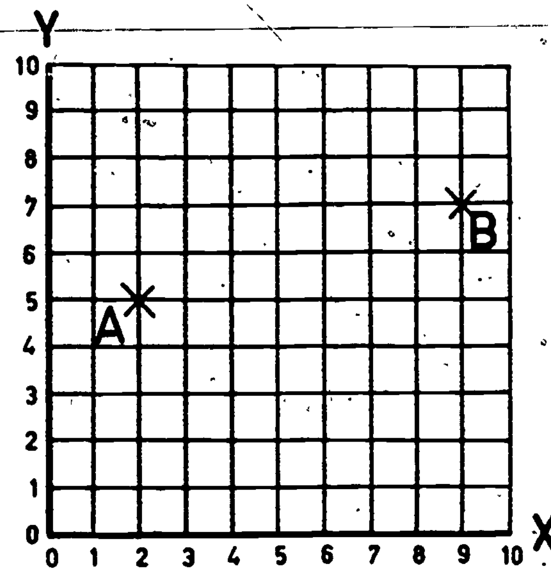
ANSWER Slope = ____

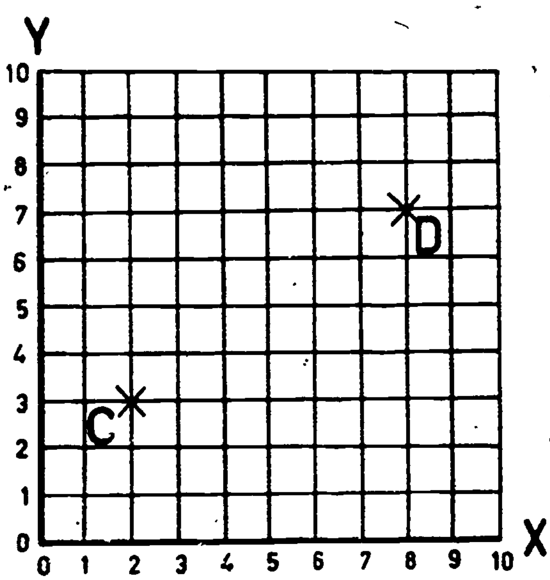
Calculate the Horizontal Displacement from A to B.

ANSWER X(AB) = ____

Calculate the Vertical Displacement from A to B.

ANSWER Y(AB) = ____





Calculate the Horizontal Displacement from C to D.

ANSWER X(CD) = ____

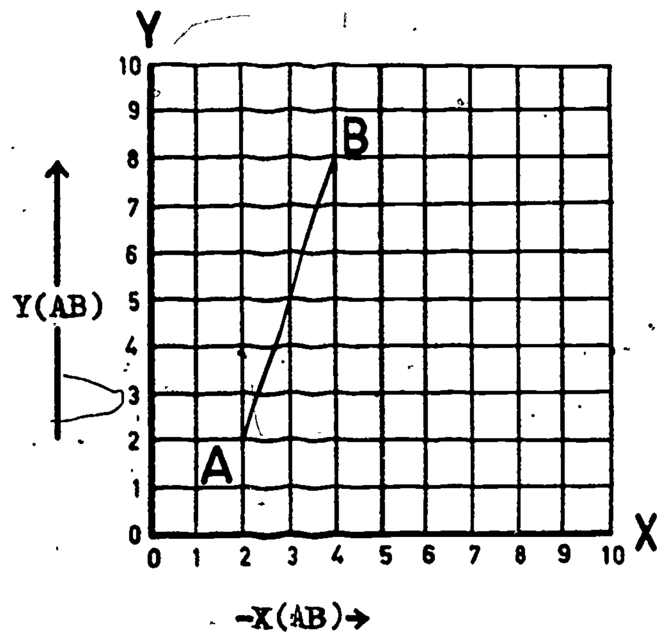
Calculate the Vertical Displacement from C to D.

ANSWER Y(CD) = ____

In order to calculate the SLOPE OF A STRAIGHT LINE from a graph, follow the method described in the example below.

EXAMPLE

Calculate the Slope of the line AB.



METHOD

(1) Calculate the Horizontal Displacement (X(AB) = 2.) and the Vertical Displacement (Y(AB) = 6.) from A to B, as shown on the graph above.

(2) Use these figures to calculate the Slope of the line AB, using the method shown on page 2/7.

ANSWER

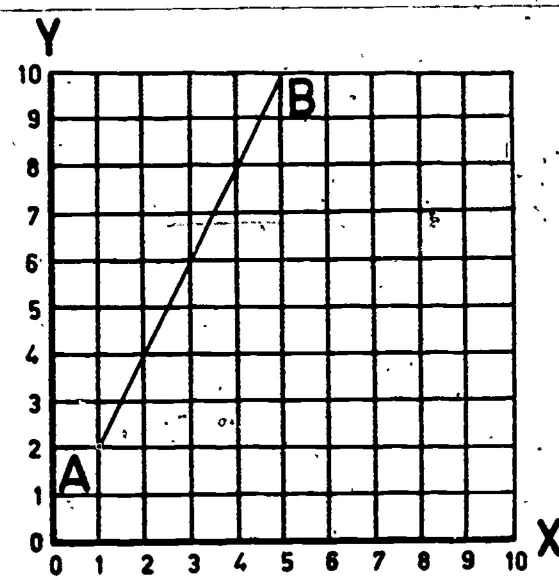
$$\text{Slope of the line } AB = \frac{Y(AB)}{X(AB)}$$

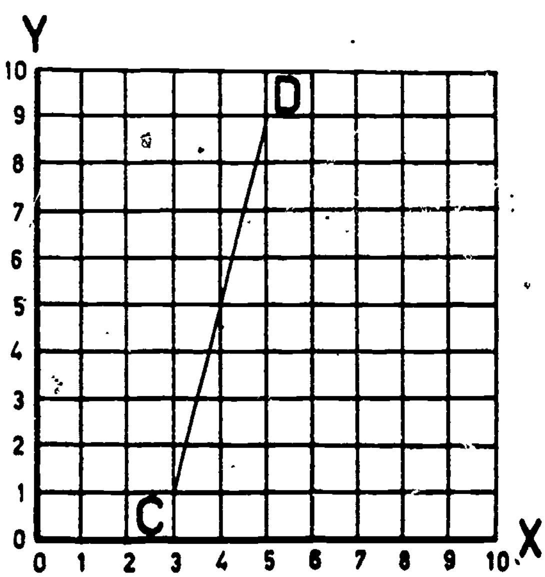
$$= \frac{6}{2}$$

$$= 3.$$

Calculate the Slope of the line AB

ANSWER Slope = ____



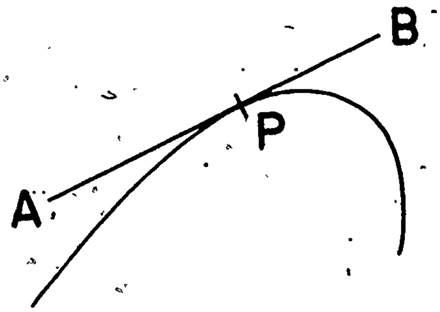


Calculate the Slope of the line CD.

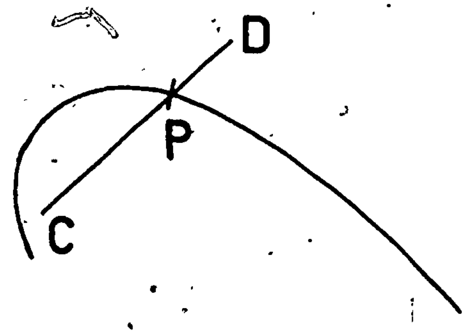
ANSWER Slope = ____

The TANGENT to a curve is a straight line which touches the curve at only one point, as shown in the example below.

EXAMPLE

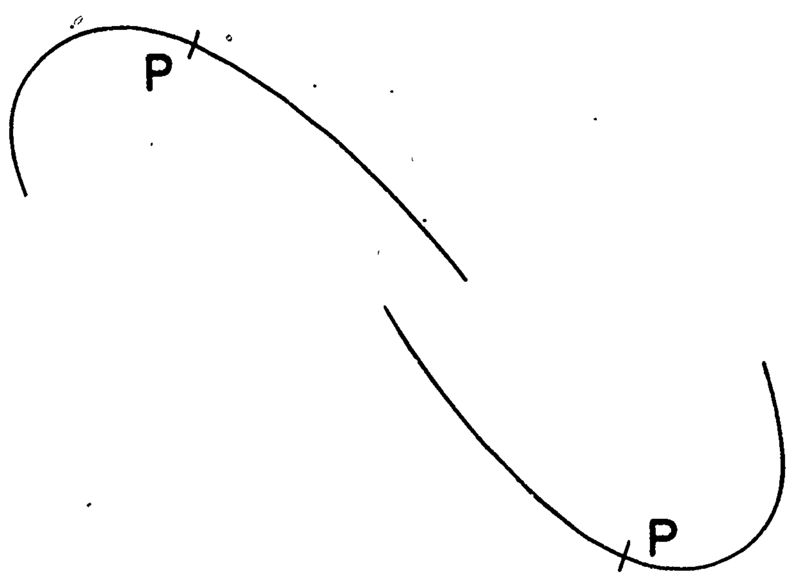


(1) The line AB is a tangent to the curve, touching it at the point P.

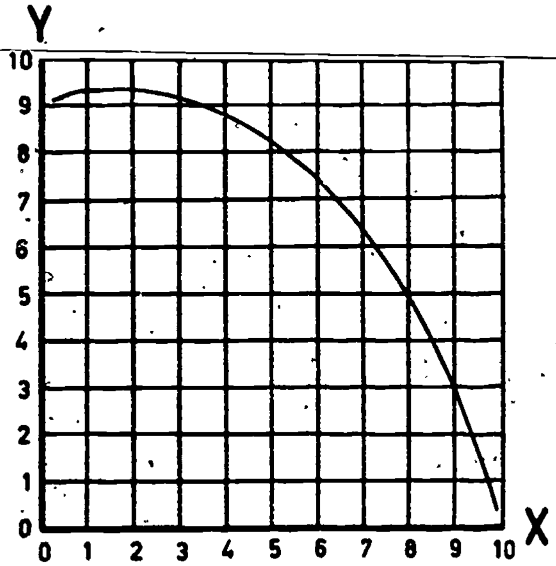


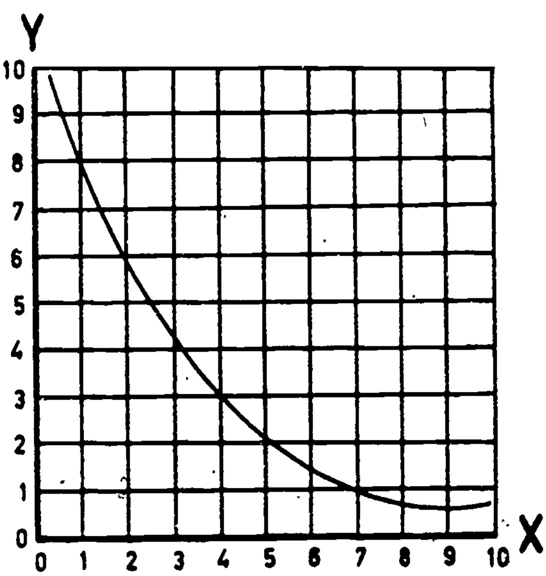
(2) The line CD is not a tangent, since it cuts across the curve at P.

Rule a Tangent to each of the curves below at the point P.



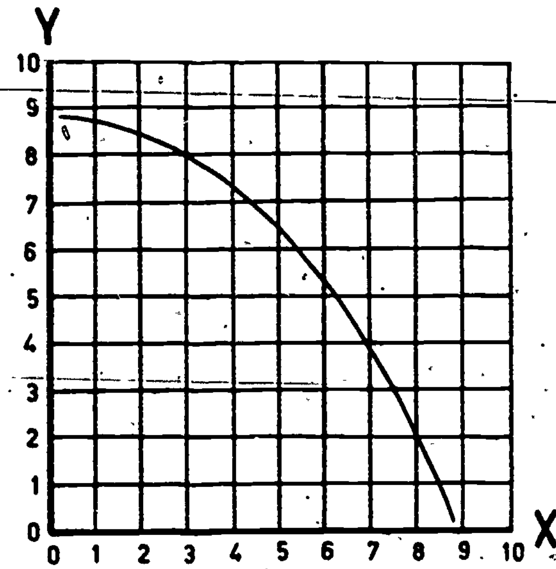
Mark the position of A on the curve, where X(A) = 8.

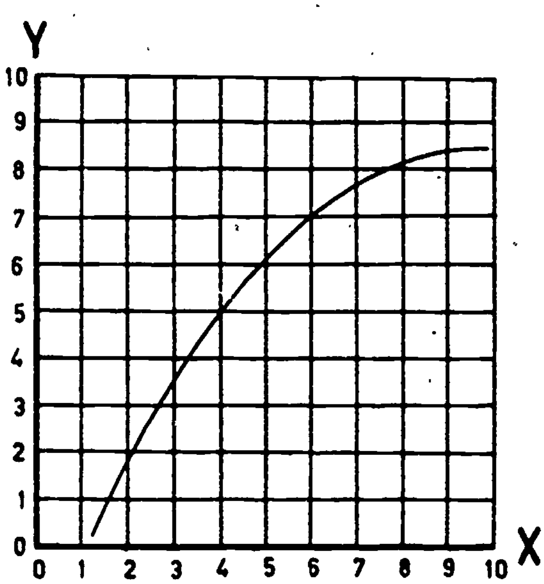




Mark the position of B on the curve, where X(B) = 4.

Rule a Tangent to the curve
at the point A where
X(A) = 3.

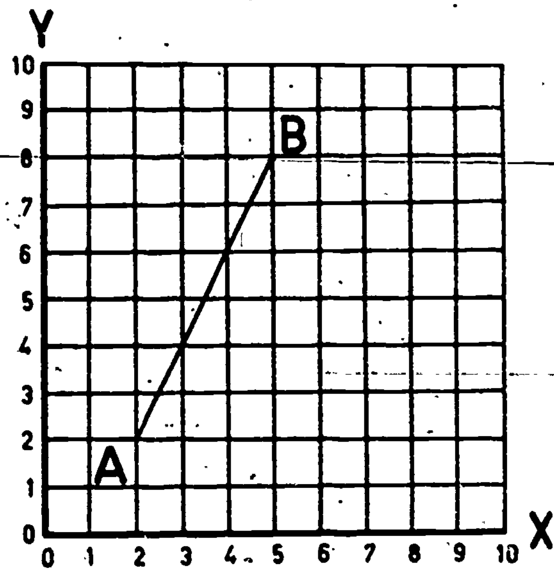


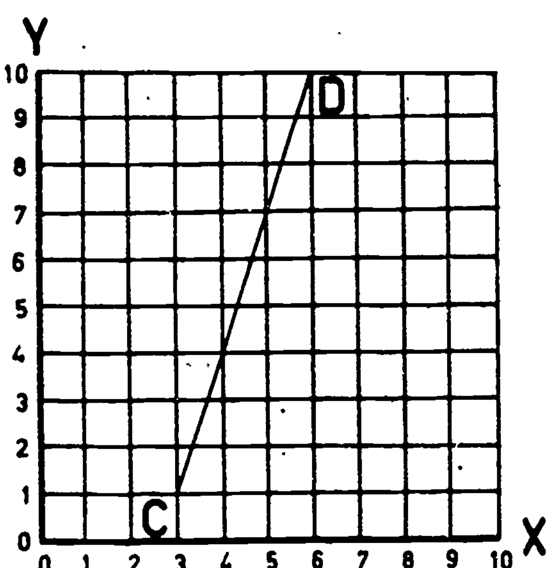


Rule a Tangent to the curve
at the point B where
X(B) = 6.

Calculate the Slope of the line AB.

ANSWER Slope = ____

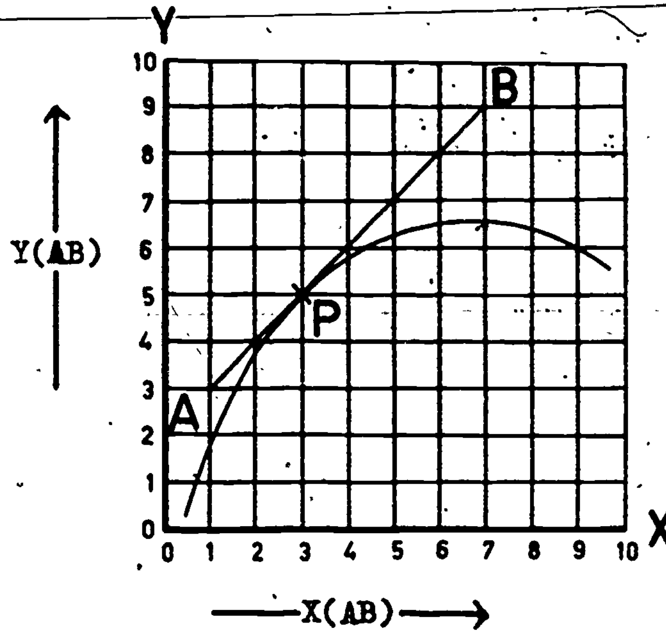




Calculate the Slope of the line CD.

ANSWER Slope = ____

The Tangent to a curve has the same slope as the curve at the point of contact. This means that we can now calculate the SLOPE OF A CURVE at any point, using the method described in the example below.



EXAMPLE

Calculate the Slope of the curve at the point P where X(P) = 3.

METHOD

(1) Mark the point P on the curve where X(P) = 3.

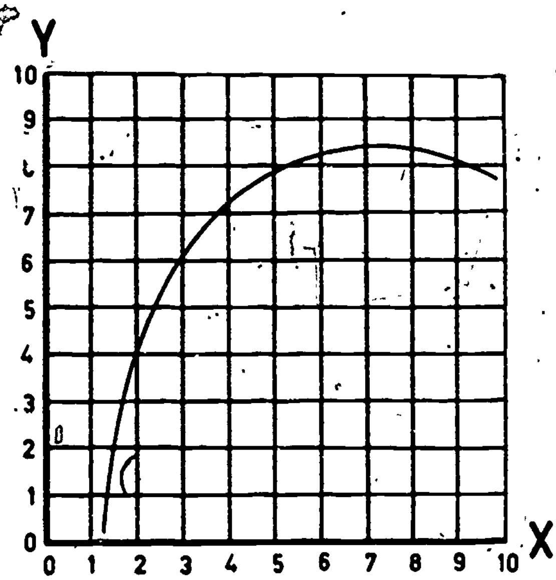
(2) Rule a Tangent to the curve at this point, so that the ends of the Tangent are whole numbers (marked A and B on the graph above)

(3) Calculate the Slope of the Tangent AB using the method shown on page 2/10.

(4) This is the Slope of the curve at the point P.

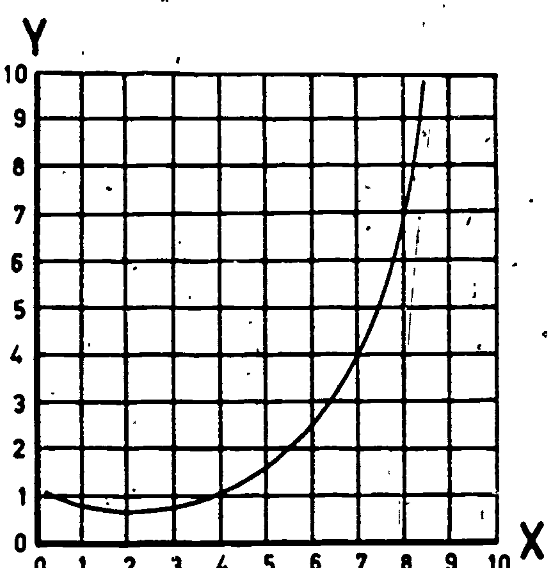
ANSWER

$$\text{Slope} = \frac{Y(AB)}{X(AB)} = \frac{9-3}{7-1} = \frac{6}{6} = \underline{1}$$



Calculate the Slope of the curve at the point A where X(A) = 2.

ANSWER Slope = ____



Calculate the Slope of the curve at the point B where X(B) = 7.

ANSWER Slope = ____

BASIC SKILLS OF GRAPHICAL INTERPRETATION

PROGRAMME I SECTION 3

NAME ______________ AGE ______ ______
(years) (months)

SEX ______

SCHOOL ______________ CLASS ______

DATE ______

INSTRUCTIONS

As you work through this programme, read each question carefully, then write your answer in the space provided. Any other calculations should be written on the BACK of the page. If you are not sure of the answer to a question, take a guess and go on to the next example.

Complete the following calculations :-

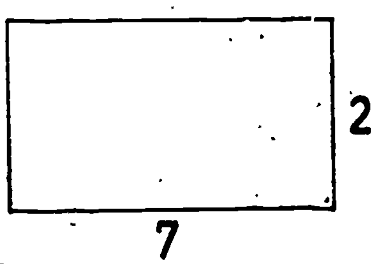
4 x 2 = ____ 5 x 3 = ____

37 x 4 = ____ 29 x 5 = ____

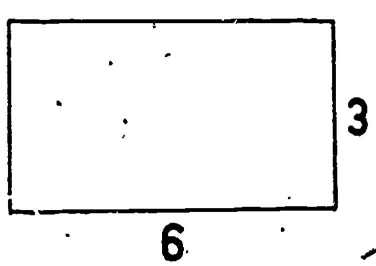
Now we can use the following formula to calculate the AREA of any rectangle or square.

AREA = LENGTH x HEIGHT

Use this formula to calculate the Area of the following figures.



ANSWER Area = ____



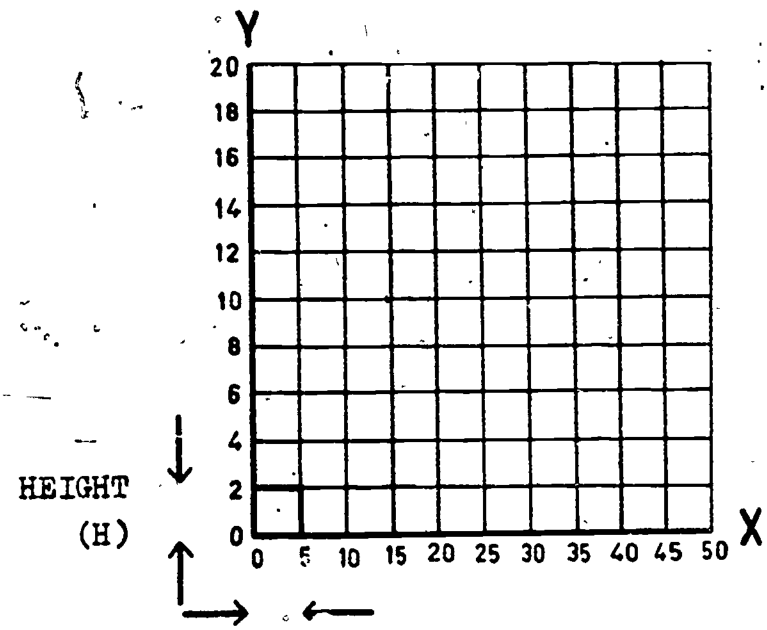
ANSWER Area = ____

The same formula can also be used to calculate the AREA OF A GRAPH, or of any square section of a graph.

Now each graph is made up of many small blocks, each of the same size, and the AREA OF EACH BLOCK is given by the formula Area = Length x Height , as shown on page 3/1.

EXAMPLE

Calculate the Area of a single block on this graph.



The LENGTH (L) of each block is shown on the Horizontal Axis, and the HEIGHT (H) is shown on the Vertical Axis.

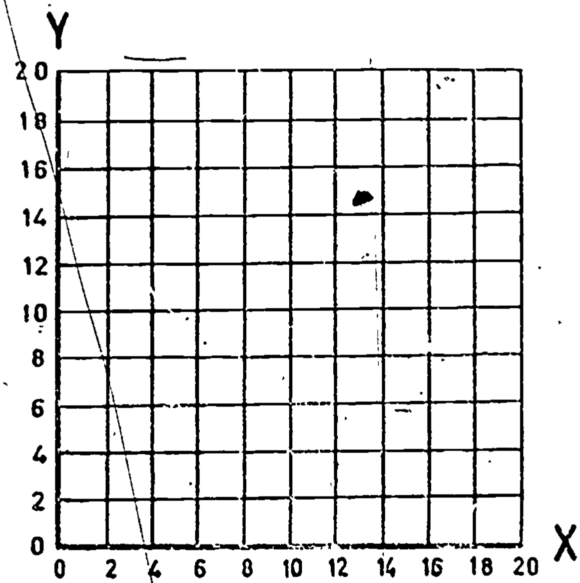
In this example, the Area of a single block on the graph above = LENGTH (L) x HEIGHT (H)

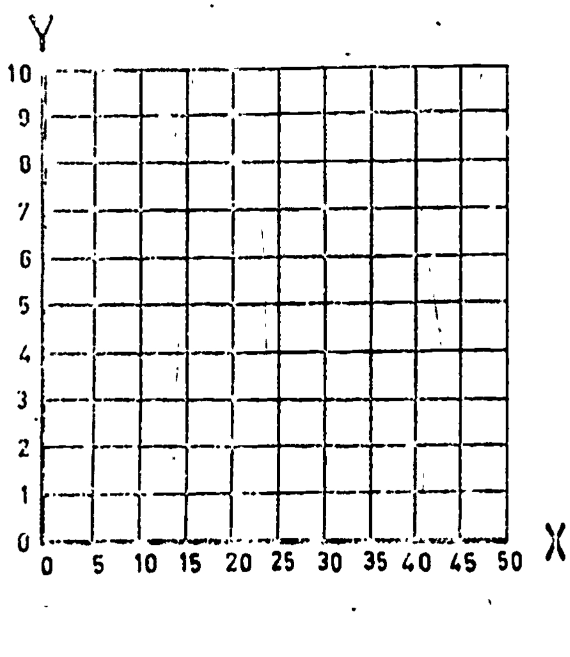
= 5 x 2

= 10 units.

Calculate the Area of a single block on this graph.

<u>ANSWER</u> Area = ______





Calculate the Area of a single block on this graph.

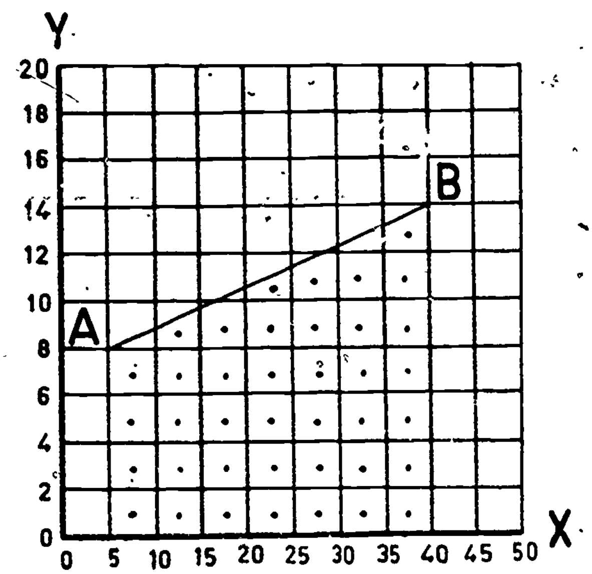
<u>ANSWER</u> Area = ______

Now we can calculate the <u>AREA OF ANY SECTION OF A GRAPH</u>, by counting the number of blocks in the section and using the following formula :-

The <u>TOTAL AREA</u> of any Section	=	Area of a single Block.	x	Total Number of Blocks in the Section.

<u>EXAMPLE</u>

Calculate the Area below the line <u>AB</u> on this graph.



<u>METHOD</u>

(1) Calculate the Area of a single block on the graph.

(2) Count the total number of blocks in the section - each block to be counted is marked with a dot (•) on the graph above.

(3) Calculate the Total Area of this section, using the formula shown above.

(Example continued on page 3/5)

EXAMPLE (Continued from page 3/4)

Some of the blocks in the section to be counted from the graph on page 3/4 are cut by the line AB. In such a case, we use the following rules for counting :-

(a) If less than half of the block is included in the area we wish to calculate, then do not count that block.

(b) If half or more of the block is included in the area we wish to calculate, then count the whole block.

In this example, each block to be counted in the section is marked with a dot (•) on the graph (page 3/4).

ANSWER

The Area of a single block (as shown on page 3/2) = 5 x 2

= 10 units.

The Total number of blocks = 39.

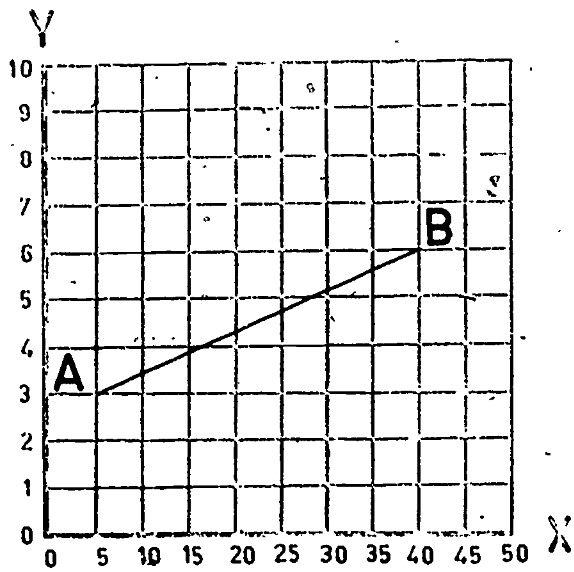
The Total Area of the section below AB = Area of a single block x Total number of blocks in the section

= 10 x 39

= 390 units.

Calculate the Area of a single block on this graph.

ANSWER Area = ____



(1) Mark with a dot each block you would count to calculate the area below the line AB on the graph above.

(2) Count the number of blocks you have marked.

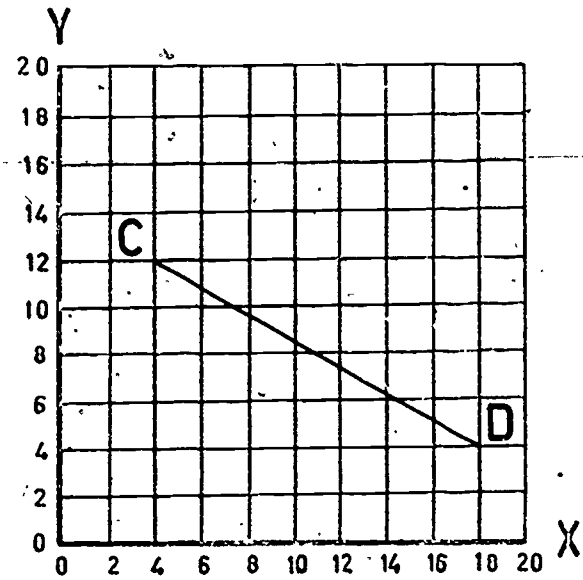
ANSWER ____

(3) Calculate the Area of the section below the line AB on the graph above.

ANSWER Area = ____

Calculate the Area of a single block on this graph.

ANSWER Area = ______



(1) Mark with a dot each block you would count to calculate the area below the line CD on the graph above.

(2) Count the number of blocks you have marked.

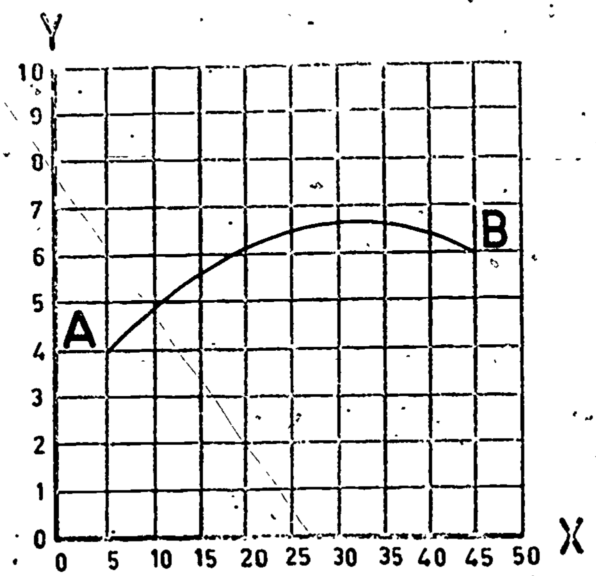
ANSWER ______

(3) Calculate the Area of the section below the line CD on the graph above.

ANSWER Area = ______

Calculate the Area of a single block on this graph.

ANSWER Area = ____



(1) Mark with a dot each block you would count to calculate the area below the curve AB on the graph above.

(2) Count the number of blocks you have marked.

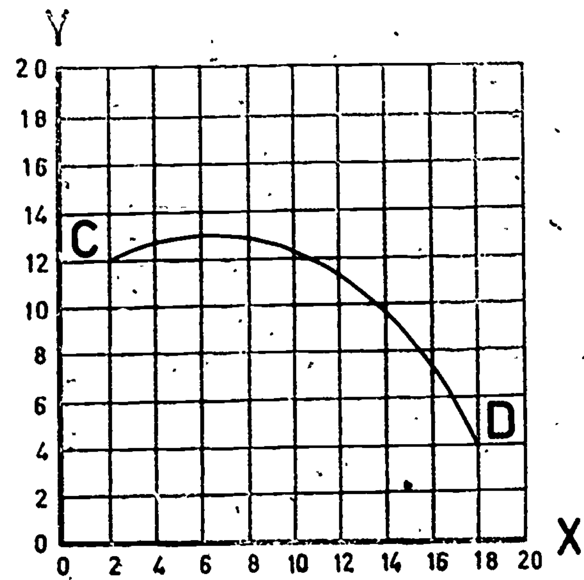
ANSWER ____

(3) Calculate the Area of the section below the curve AB on the graph above.

ANSWER Area = ____

Calculate the Area of a single block on this graph.

ANSWER Area = ____



(1) Mark with a dot each block you would count to calculate the area below the curve CD on the graph above.

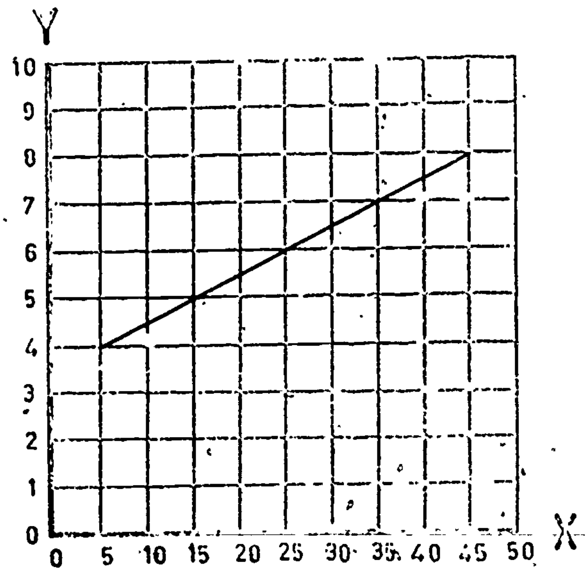
(2) Count the number of blocks you have marked.

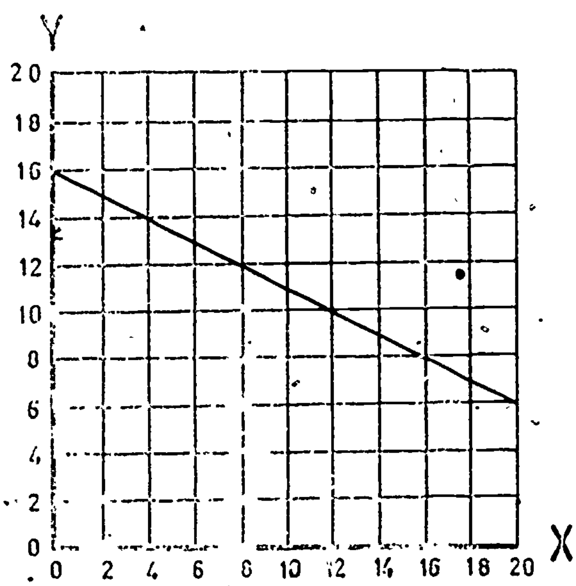
ANSWER ____

(3) Calculate the Area of the section below the curve CD on the graph above.

ANSWER Area = ____

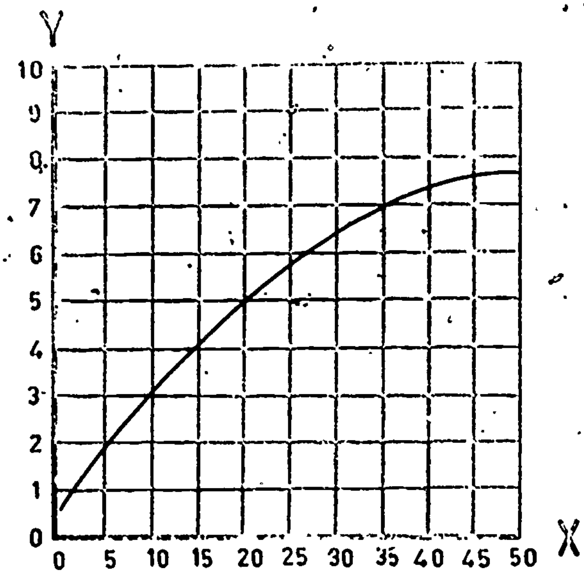
Mark the position of A on the line, where X(A) = 25.

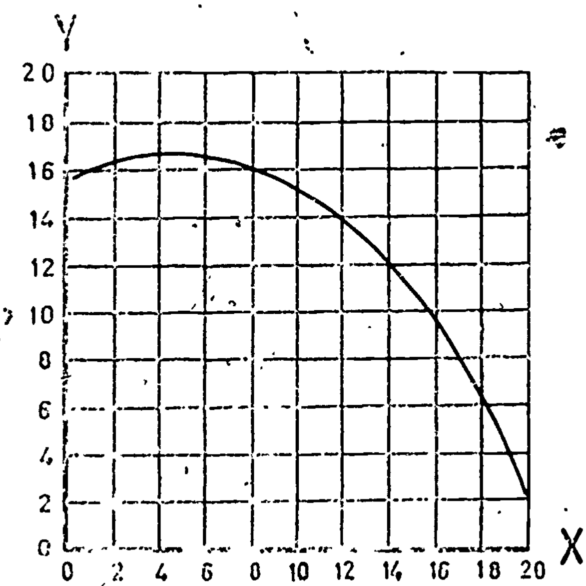




Mark the position of B on the line, where X(B) = 16.

Mark the position of A on the curve, where X(A) = 35.

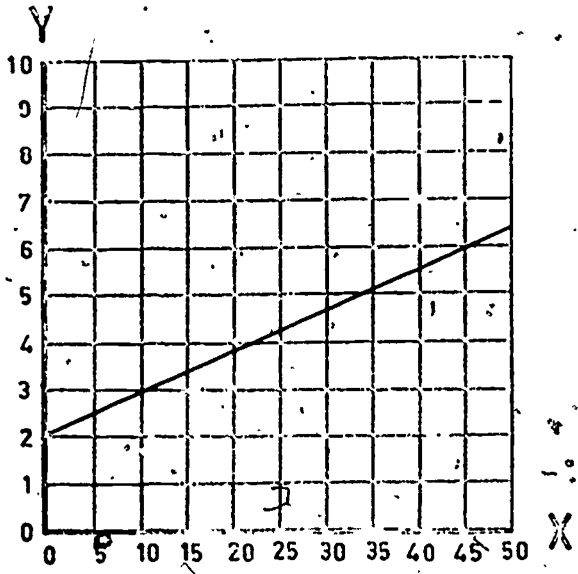


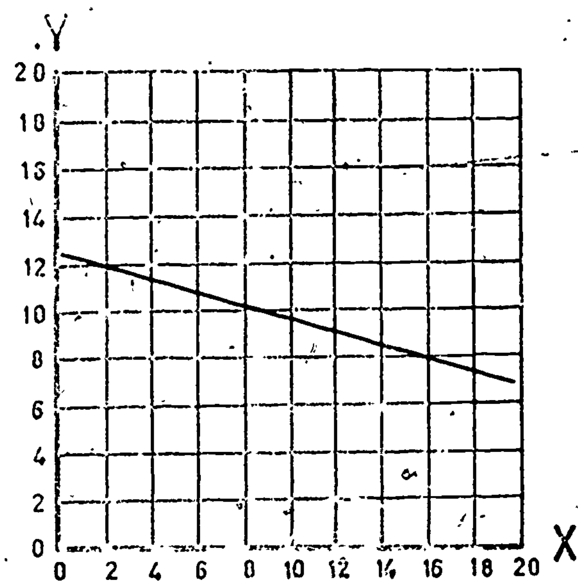


Mark the position of B on the curve, where X(B) = 12.

Calculate the Area below the line in this graph from **A** to B, where X(A) = 10 and X(B) = 45.

ANSWER Area = ____



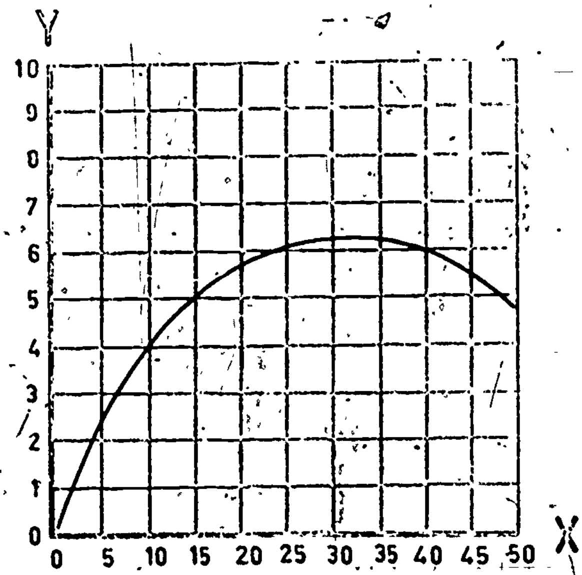


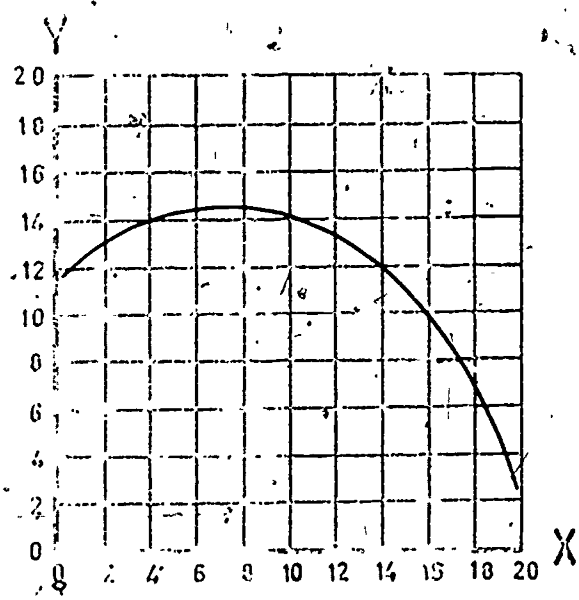
Calculate the Area below the line in this graph from C to D, where X(C) = 2 and X(D) = 16.

ANSWER Area = ____

Calculate the Area below the curve in this graph from A to B, where X(A) = 15 and X(B) = 40.

ANSWER Area = ______





Calculate the Area below the curve in this graph from C to D, where X(C) = 4 and X(D) = 14.

ANSWER Area = ______

BASIC SKILLS OF GRAPHICAL INTERPRETATION

PROGRAMME II SECTION 1

NAME ______ AGE ______ ______
(years) (months)

SEX ______

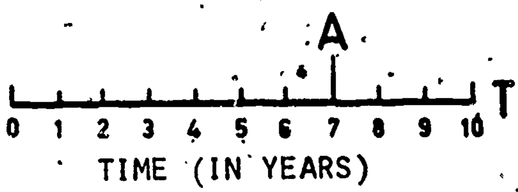
SCHOOL ______ CLASS ______

DATE ______

INSTRUCTIONS

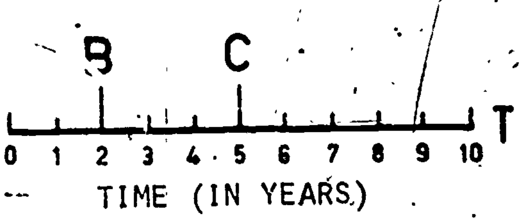
As you work through this programme, read each question carefully, then write your answer in the space provided. Any other calculations should be written on the BACK of the page. If you are not sure of the answer to a question, take a guess and go on to the next example.

This is a TIME SCALE measured in years from 0 to 10.



The time at position A on the scale above is 7 years.

This is written as T(A) = 7 years.



Calculate the time at position B on the scale above.

ANSWER T(B) = ____ years.

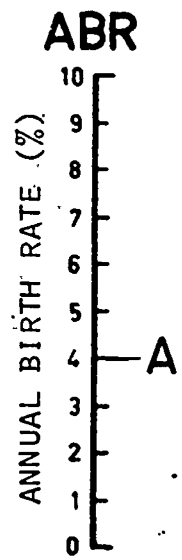
Calculate the time at position C on the scale above.

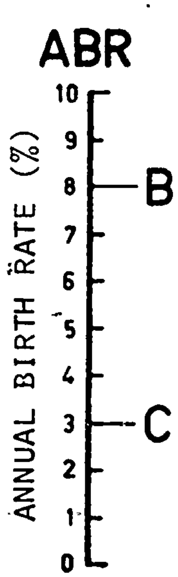
ANSWER T(C) = ____ years.

This scale shows the **ANNUAL BIRTH RATE** (that is, the number of births per year for each hundred people) in a large city, and is measured in percent (%) from 0 to 10.

The Annual Birth Rate at position A on this scale is 4 %.

This is written as ABR(A) = 4 %.





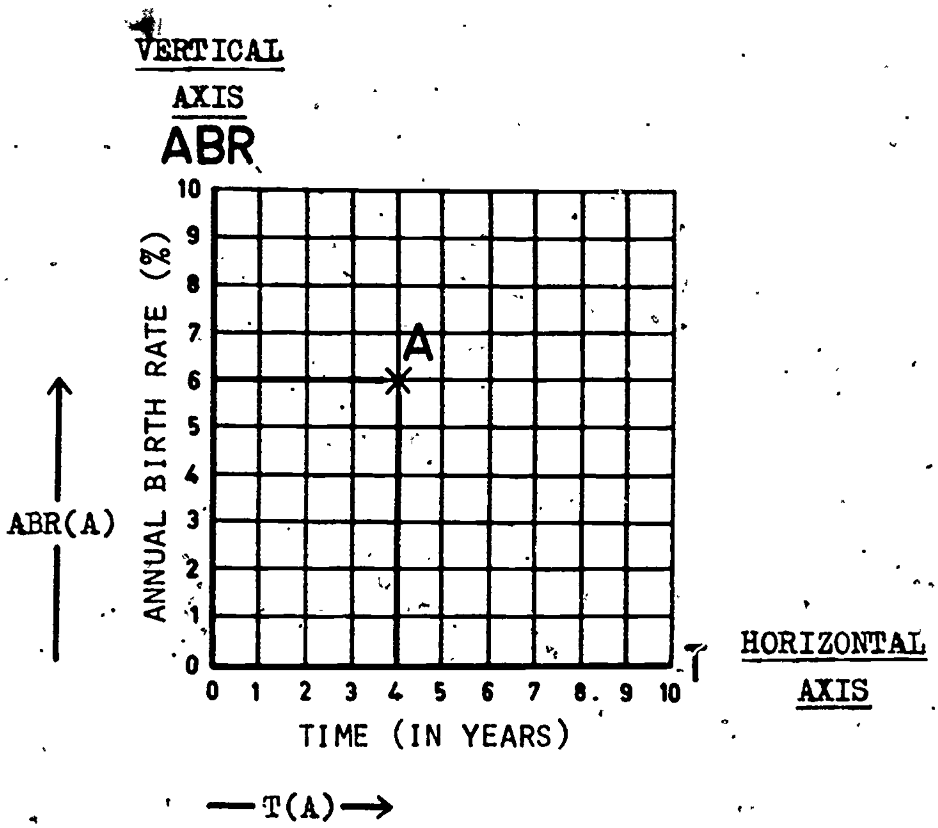
Calculate the Annual Birth Rate at B.

ANSWER ABR(B) = ______ %.

Calculate the Annual Birth Rate at C.

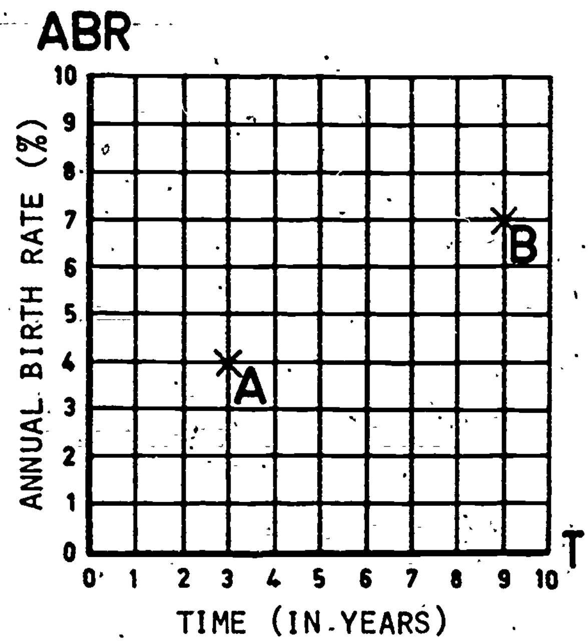
ANSWER ABR(C) = ______ %.

Let us now combine these two scales to form a GRAPH, as shown in the diagram below.



The TIME at any point on this graph is shown by its distance from 0 measured along the Horizontal or T axis. The time at position A on the graph above is shown as T(A) = 4 years.

The ANNUAL BIRTH RATE at any point on the graph is given by its distance from 0 measured along the Vertical or ABR axis. The Annual Birth Rate at A on the graph above is shown as ABR(A) = 6 %.



Calculate the Time at position A.

ANSWER T(A) = ______ years.

Calculate the Time at position B.

ANSWER T(B) = ______ years.

Calculate the Annual Birth Rate at A.

ANSWER ABR(A) = ______ %.

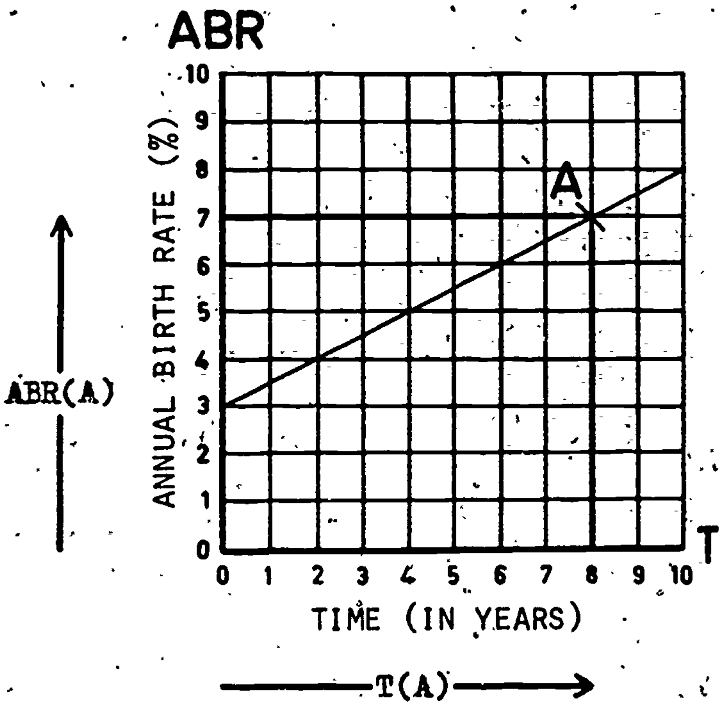
Calculate the Annual Birth Rate at B.

ANSWER ABR(B) = ______ %.

Now we can find the Time or Annual Birth Rate at any POINT ON A LINE, using the method described in the example below.

EXAMPLE

Calculate the Time at position **A** when ABR(A) = 7 %.



METHOD

(1) Find the given position ABR(A) = 7 % on the Vertical axis.

(2) Move across to the line and mark the point A on the same level.

(3) Calculate the Time at this point, as shown on the graph above.

ANSWER

T(A) = 8 years.

The two points A and B both lie somewhere on the line shown in this graph.

ABR(A) = 3 %. ABR(B) = 6 %.

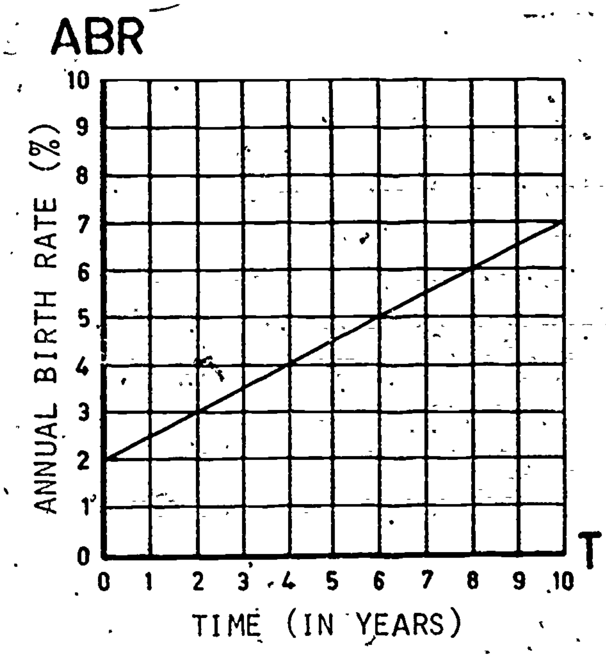
Mark the positions A and B on the graph.

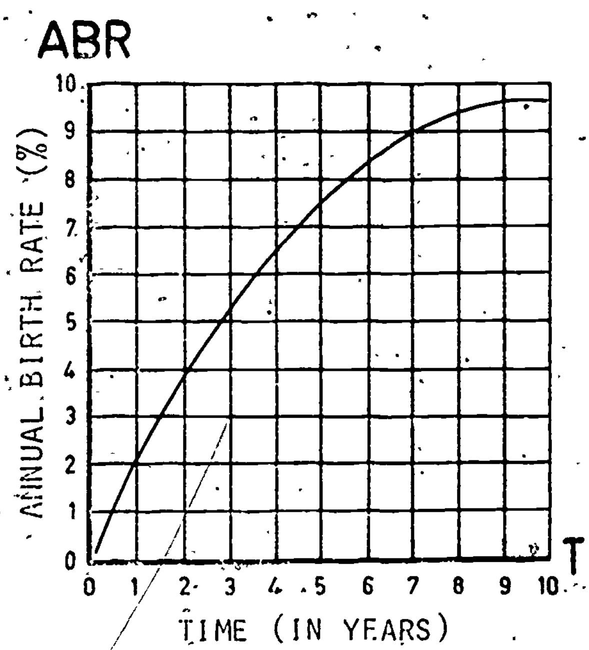
Calculate the Time at A.

ANSWER T(A) = ______ years.

Calculate the Time at B.

ANSWER T(B) = ______ years.





The two points C and D both lie somewhere on the curve shown in this graph.

ABR(C) = 2 %. ABR(D) = 9 %.

Mark the positions C and D on the graph.

Calculate the Time at C.

ANSWER T(C) = ______ years.

Calculate the Time at D.

ANSWER T(D) = ______ years.

The two points A and B both lie somewhere on the line shown in this graph.

T(A) = 4 yrs. T(B) = 10 yrs.

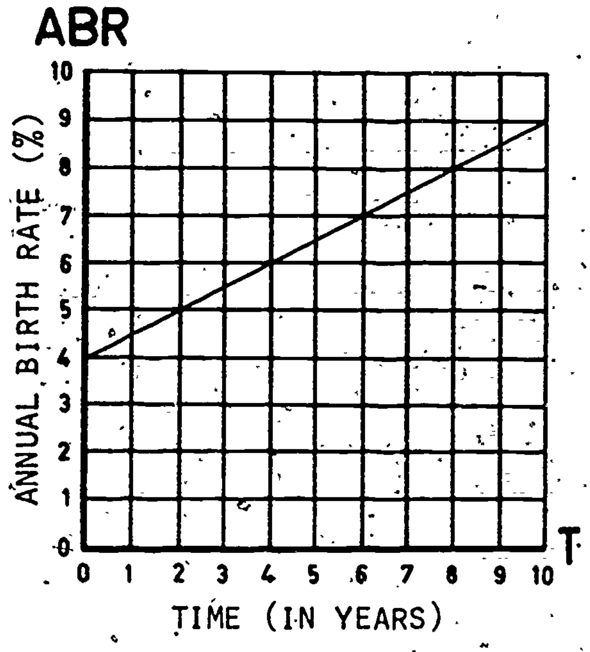
Mark the positions A and B on the graph.

Calculate the Annual Birth Rate at A.

ANSWER ABR(A) = ______ %.

Calculate the Annual Birth Rate at B.

ANSWER ABR(B) = ______ %.



The two points C and D both lie somewhere on the curve shown in this graph.

T(C) = 8 yrs. T(D) = 5 yrs.

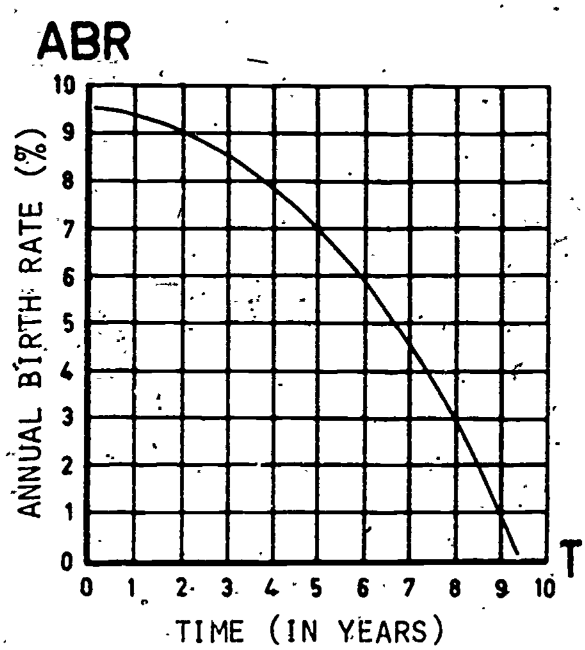
Mark the positions C and D on the graph.

Calculate the Annual Birth Rate at C.

ANSWER ABR(C) = ______ %.

Calculate the Annual Birth Rate at D.

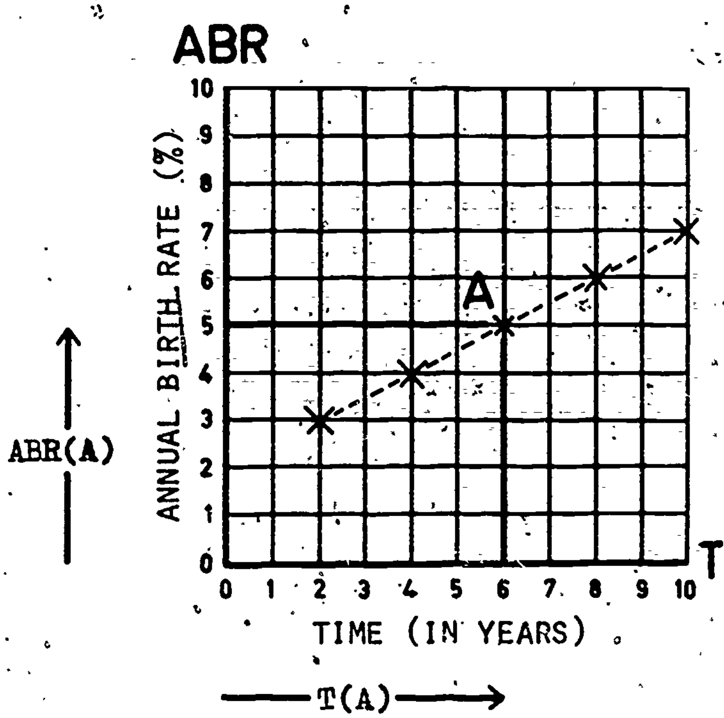
ANSWER ABR(D) = ______ %.



The following method may be used to find the Time or Annual Birth Rate at any position between a row of points on a graph.

EXAMPLE

Calculate the Time at position A when ABR(A) = 5 %.



METHOD

(1) Rule a line through each of the points, as shown on the graph above.

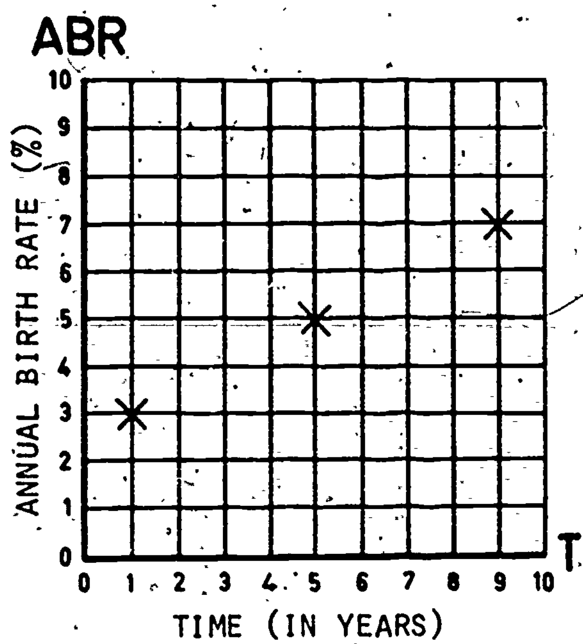
(2) Find the point A on this line, where the Annual Birth Rate (ABR) = 5 %.

(3) Calculate the Time at this position.

ANSWER

T(A) = 6 years.

The two points A and B both lie somewhere between the row of points shown on this graph.



Calculate the Time at A when ABR(A) = 4 %.

ANSWER T(A) = ______ years.

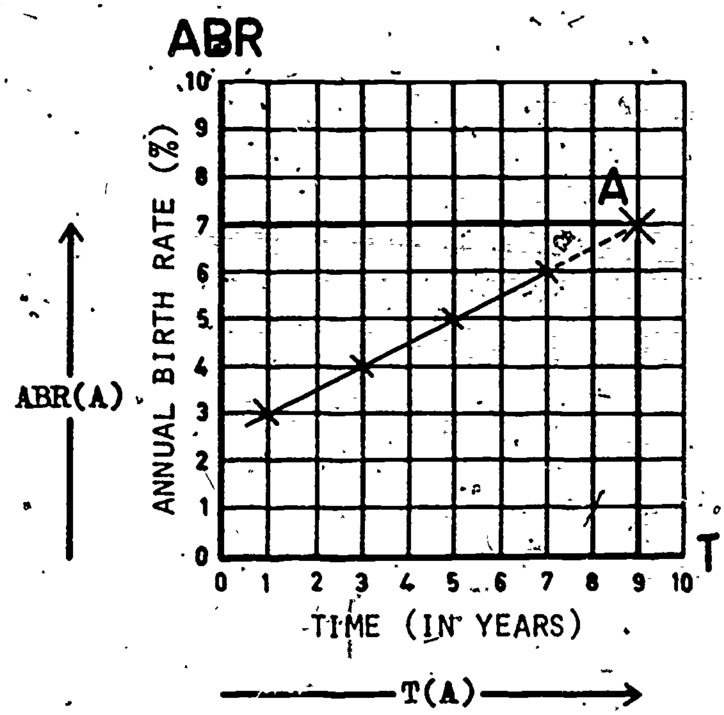
Calculate the Time at B when ABR(B) = 6 %.

ANSWER T(B) = ______ years.

In order to find the Time or Annual Birth Rate at any position beyond a given line or row of points, follow the instructions described in the example below.

EXAMPLE

Calculate the Time at position A when ABR(A) = 7 %.



METHOD

(1) Rule a line through each of the points (unless a line is given in the problem).

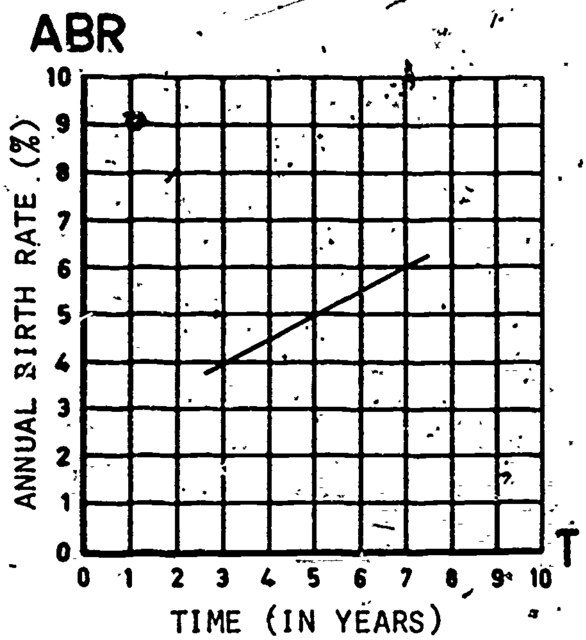
(2) Extend this line, as shown in the graph above, until it reaches the Vertical Position ABR(A) = 7 %.

(3) Calculate the Time at this position.

ANSWER

T(A) = 9 years.

The two points A and B both lie somewhere beyond the line shown in this graph.

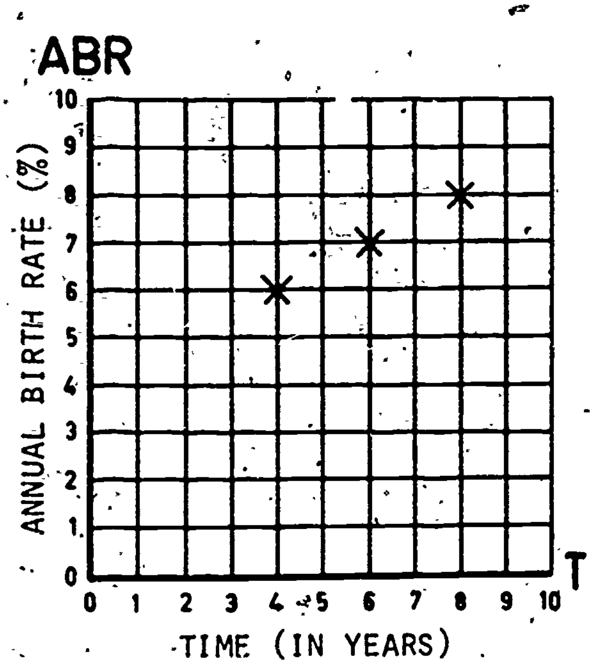


Calculate the Time at A when ABR(A) = 3 %.

ANSWER T(A) = ______ years.

Calculate the Time at B when ABR(B) = 7 %.

ANSWER T(B) = ______ years.



The two points C and D both lie somewhere beyond the row of points shown in this graph.

Calculate the Time at C when ABR(C) = 5 %.

ANSWER T(C) = ______ years.

Calculate the Time at D when ABR(D) = 9 %.

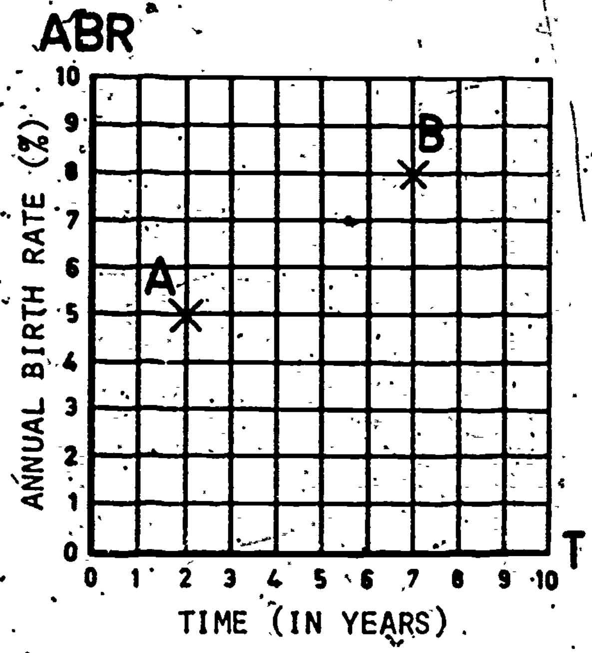
ANSWER T(D) = ______ years.

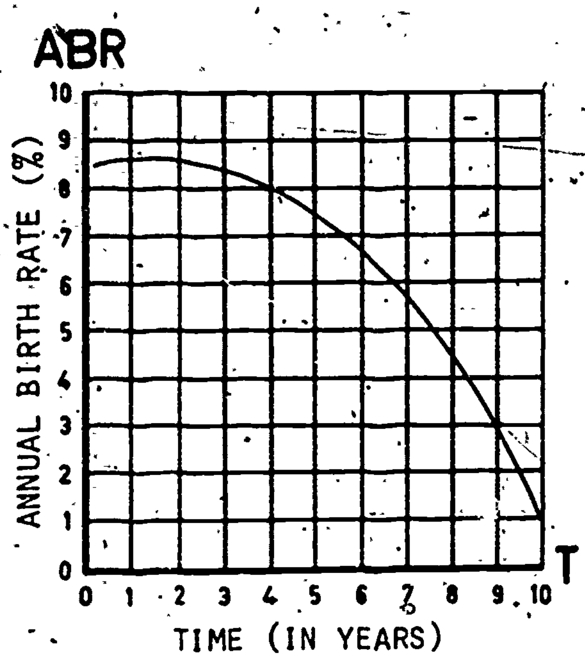
Calculate the Annual Birth Rate at A.

ANSWER ABR(A) = ______ %.

Calculate the Annual Birth Rate at B.

ANSWER ABR(B) = ______ %.





The two points C and D both lie somewhere on the curve shown in this graph.

Calculate the Annual Birth Rate at C when T(C) = 4 years.

ANSWER ABR(C) = ______ %.

Calculate the Annual Birth Rate at D when T(D) = 9 years.

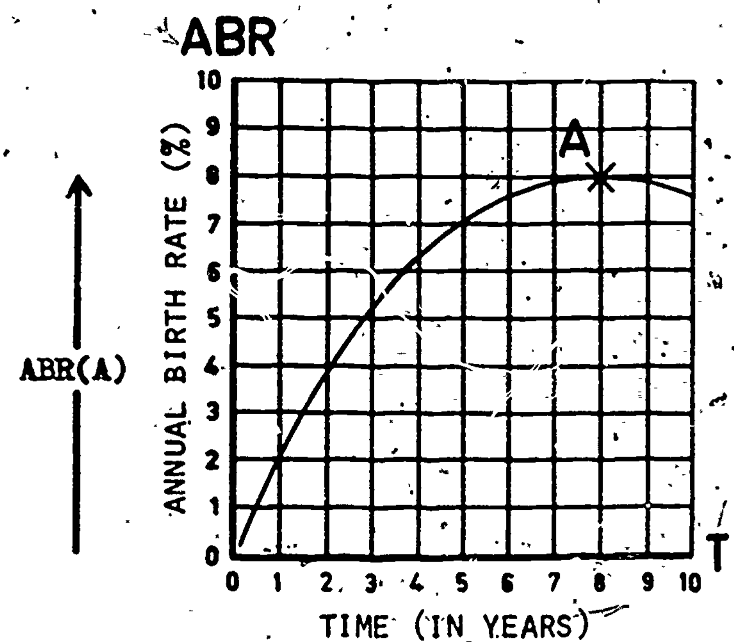
ANSWER ABR(D) = ______ %.

The MAXIMUM Value of a curve is equal to the HIGHEST VERTICAL POSITION on the curve.

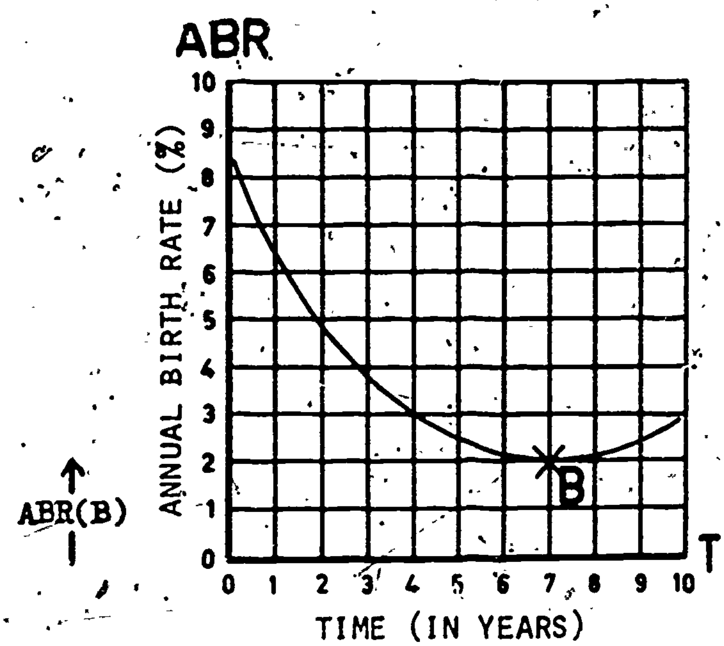
The Maximum Annual Birth Rate shown on this curve

= ABR(A)

= 8 %.



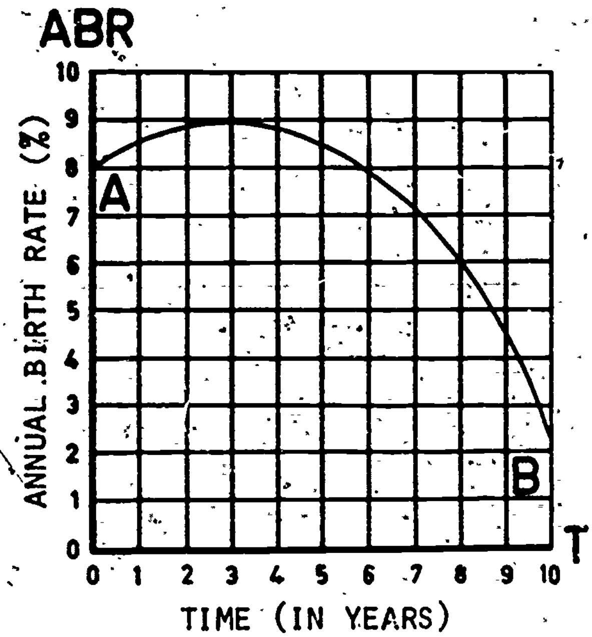
The MINIMUM Value of a curve is equal to the LOWEST VERTICAL POSITION on the curve.



The Minimum Annual Birth Rate shown on this curve

= ABR(B)

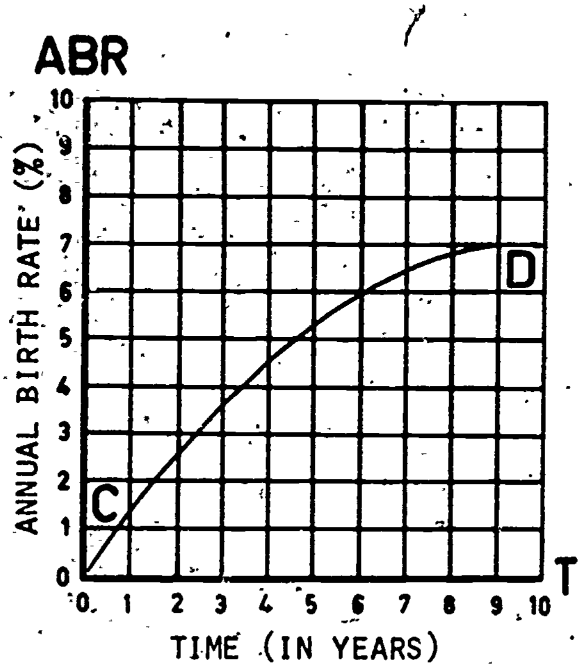
= 2 %.



Calculate the Maximum Annual Birth Rate on the curve AB.

ANSWER

Max.ABR = ______ %.



Calculate the Maximum Annual Birth Rate on the curve CD.

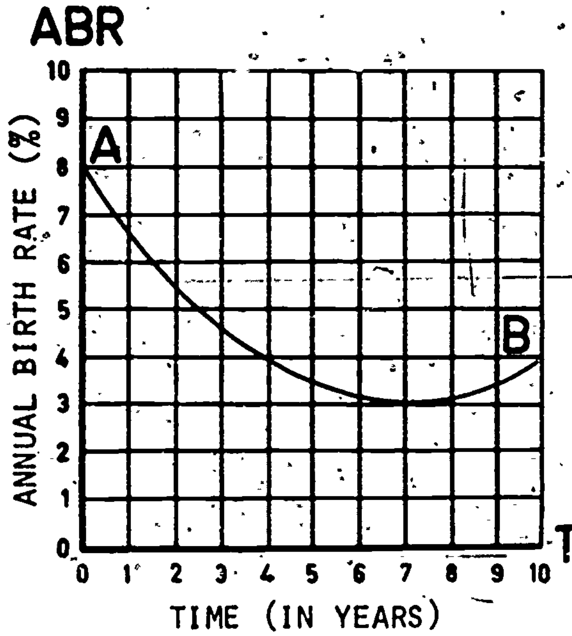
ANSWER

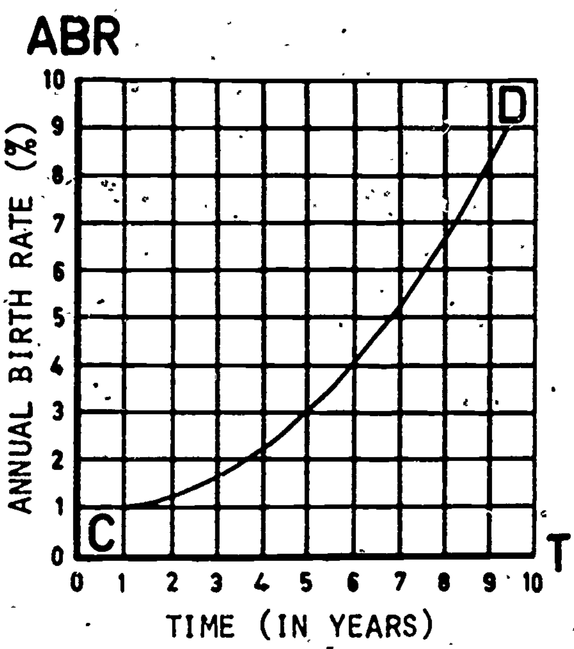
Max.ABR = ______ %.

Calculate the Minimum Annual Birth Rate on the curve AB.

ANSWER

Min.ABR = ______ %.



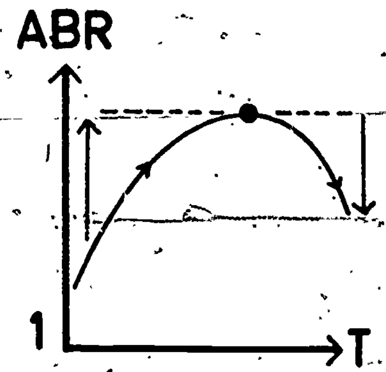


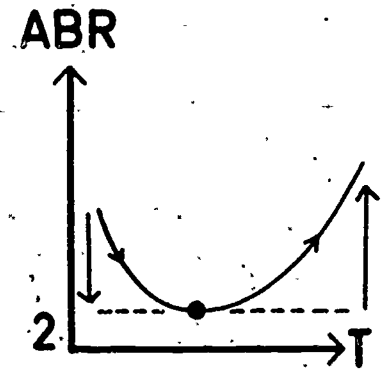
Calculate the Minimum Annual Birth Rate on the curve CD.

ANSWER

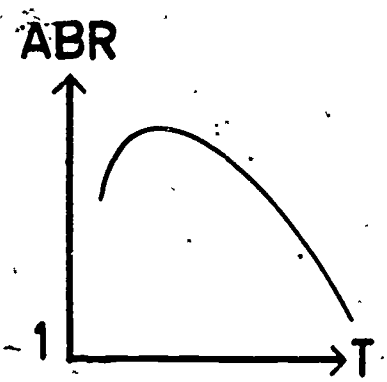
Min.ABR = ______ %.

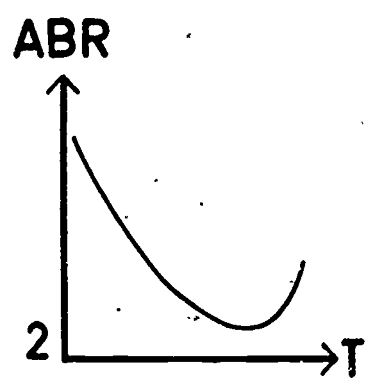
The TURNING POINT of a curve is indicated by a Change in Vertical Direction along the curve, as shown in the two examples below.

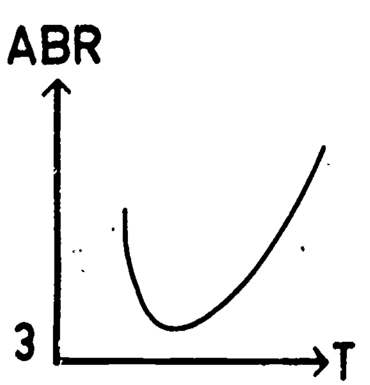


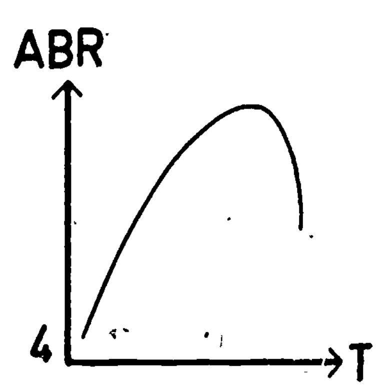


Place a mark (●) at the Turning Point on each of the following curves.





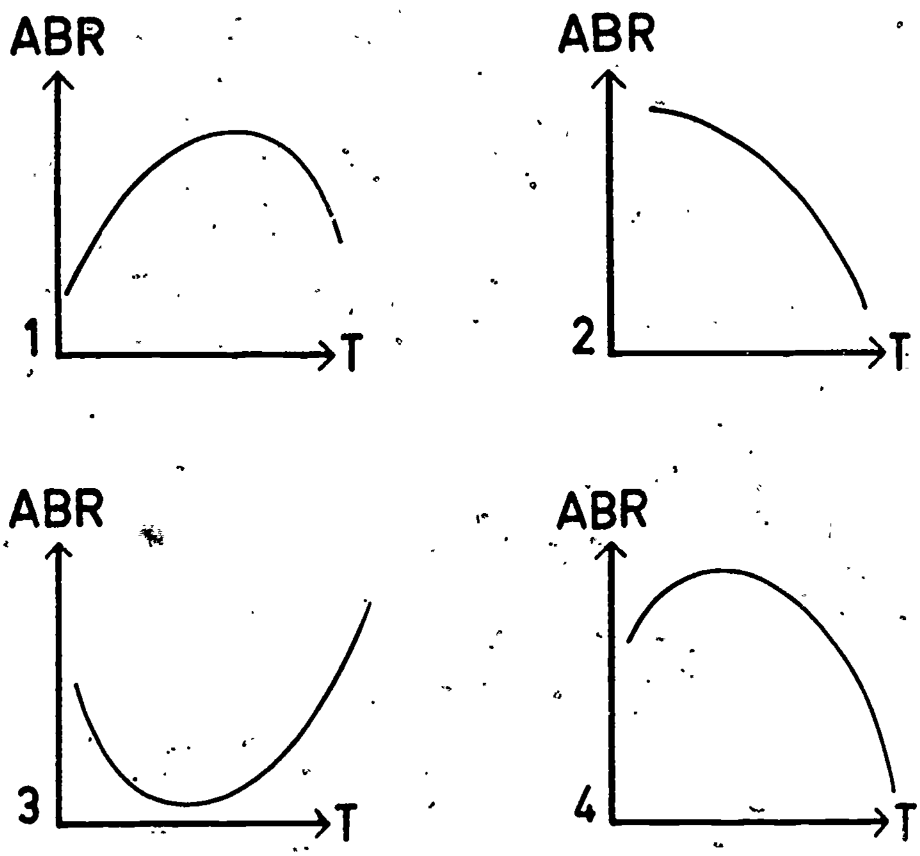




If the Turning Point of a curve has the HIGHEST Vertical position on the curve, it is called a <u>MAXIMUM TURNING POINT</u>.

If the Turning Point of a curve has the LOWEST Vertical position on the curve, it is called a <u>MINIMUM TURNING POINT</u>.

Show which of the following curves has a MAXIMUM Turning Point, by writing the number(s) in the space below.



<u>ANSWER</u> ______________________

BASIC SKILLS OF GRAPHICAL INTERPRETATION

PROGRAMME II SECTION 2

NAME ______________________ AGE ________ ________
(years) (months)

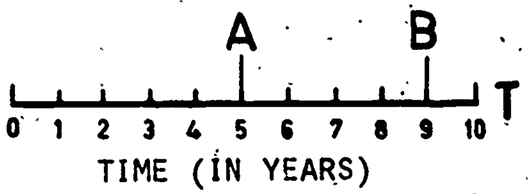
SEX ____________

SCHOOL ____________________ CLASS ______________

DATE ____________

INSTRUCTIONS

As you work through this programme, read each question carefully, then write your answer in the space provided. Any other calculations should be written on the BACK of the page. If you are not sure of the answer to a question, take a guess and go on to the next example.

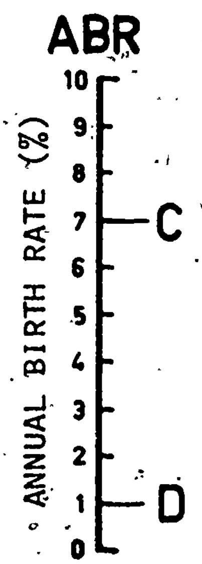


Calculate the Time at position A on the scale above.

ANSWER T(A) = _____ years.

Calculate the Time at position B on the scale above.

ANSWER T(B) = _____ years.



Calculate the Annual Birth Rate at C.

ANSWER ABR(C) = _____ %.

Calculate the Annual Birth Rate at D.

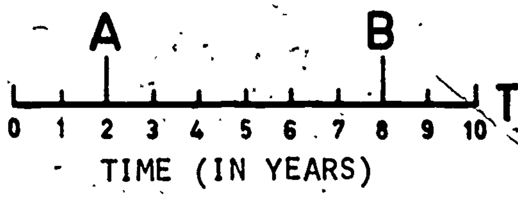
ANSWER ABR(D) = _____ %.

Complete the following calculations.

10 - 5 = _____ 9 - 2 = _____

The CHANGE IN TIME between two points on a Time scale is measured by the change in position on the scale from one point to the other.

EXAMPLE



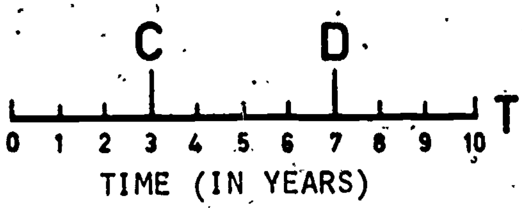
The Change in Time from A to B on the scale above (called T(AB))

= Final Position - First Position

= T(B) - T(A)

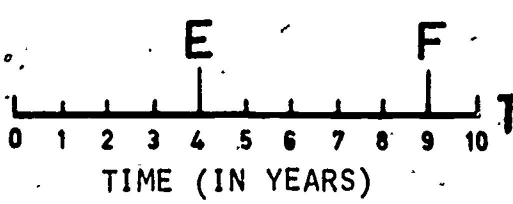
= 8 - 2 years

= 6 years



Calculate the Change in Time from C to D on the scale above.

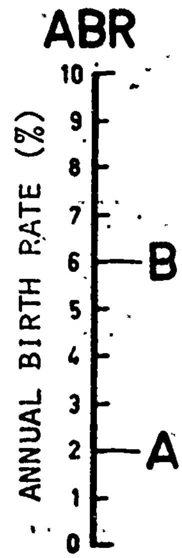
ANSWER T(CD) = ______ years.



Calculate the Change in Time from E to F on the scale above.

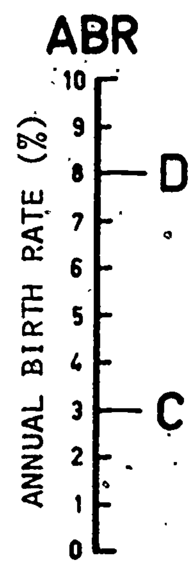
ANSWER T(EF) = ______ years.

The same rule can also be used to calculate the CHANGE IN ANNUAL BIRTH RATE between two points on a Vertical scale.



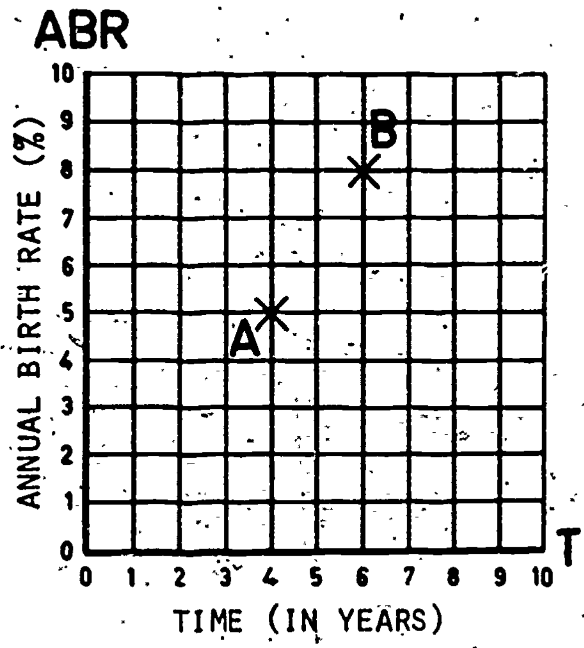
Calculate the Change in Annual Birth Rate from A to B.

ANSWER ABR(AB) = ______ %.



Calculate the Change in Annual Birth Rate from C to D.

ANSWER ABR(CD) = ______ %.



Calculate the Time at position A.

ANSWER T(A) = ______ years.

Calculate the Time at position B.

ANSWER T(B) = ______ years.

Calculate the Annual Birth Rate at A.

ANSWER ABR(A) = ______ %.

Calculate the Annual Birth Rate at B.

ANSWER ABR(B) = ______ %.

The Change in Time between two points on a GRAPH is equal to the Change in Position from one point to the other, measured along the Horizontal (T) axis.

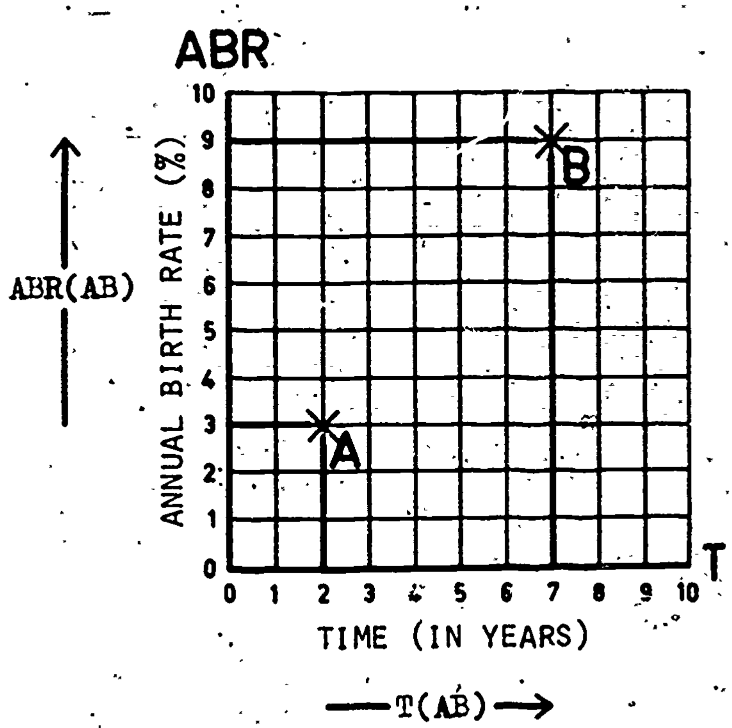
EXAMPLE

The Change in Time from A to B. (marked T(AB))

= T(B) - T(A)

= 7 - 2 years

= 5 years.



The Change in Annual Birth Rate between two points on a Graph is equal to the Change in Position from one point to the other, measured along the Vertical (ABR) axis.

EXAMPLE

The Change in Annual Birth Rate from A to B on the graph above (marked ABR(AB)).

= ABR(B) - ABR(A)

= 9 - 3 %

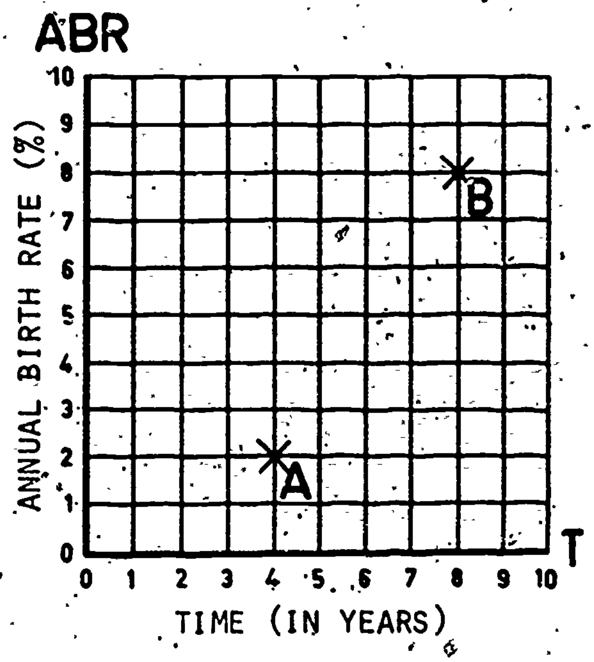
= 6 %.

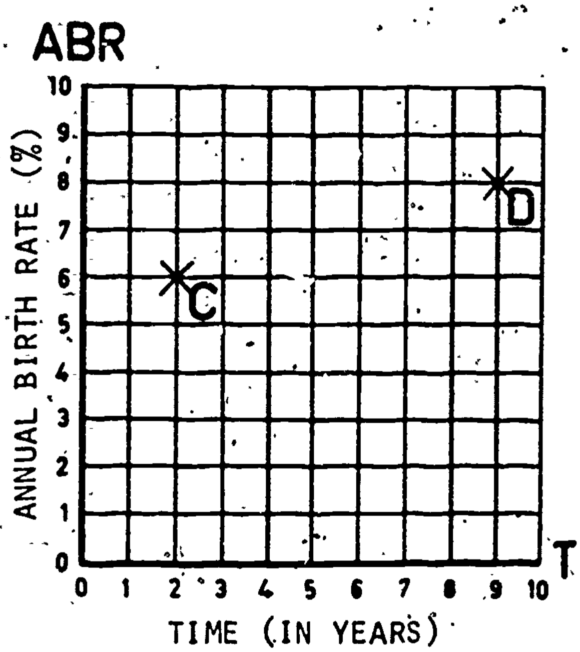
Calculate the Change in Time from A to B.

ANSWER T(AB) = _____ yrs.

Calculate the Change in Annual Birth Rate from A to B.

ANSWER ABR(AB) = _____ %.





Calculate the Change in Time from C to D.

ANSWER T(CD) = _____ yrs.

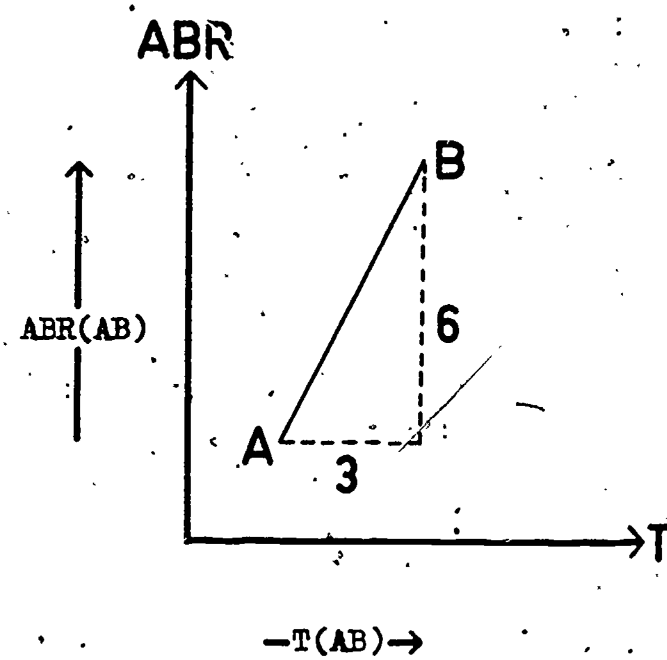
Calculate the Change in Annual Birth Rate from C to D.

ANSWER ABR(CD) = _____ %.

Complete the following calculations :-

$\frac{9}{3}$ = ____ $\frac{8}{2}$ = ____

The RATE OF CHANGE in Annual Birth Rate (measured in % per year) between two points on a graph is equal to the SLOPE of the line joining these points. This may be calculated as shown in the example below.



EXAMPLE

The Rate of Change in Annual Birth Rate from A to B.

= Slope of line AB.

$= \frac{\text{Change in Annual Birth Rate from A to B (\%)}}{\text{Change in Time from A to B (years)}}$

$= \frac{ABR(AB)}{T(AB)}$

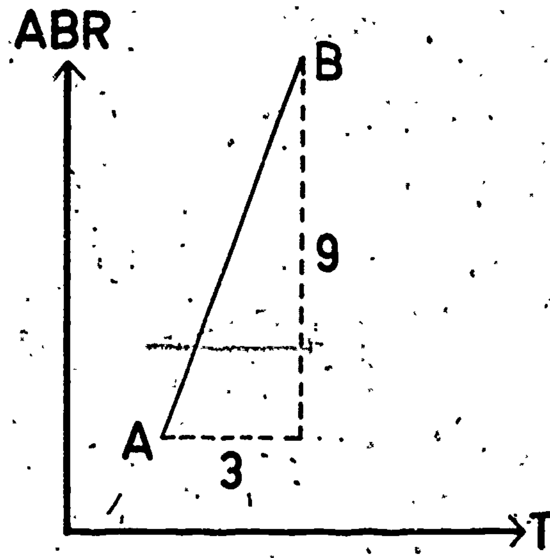
$= \frac{6}{3}$ % per year.

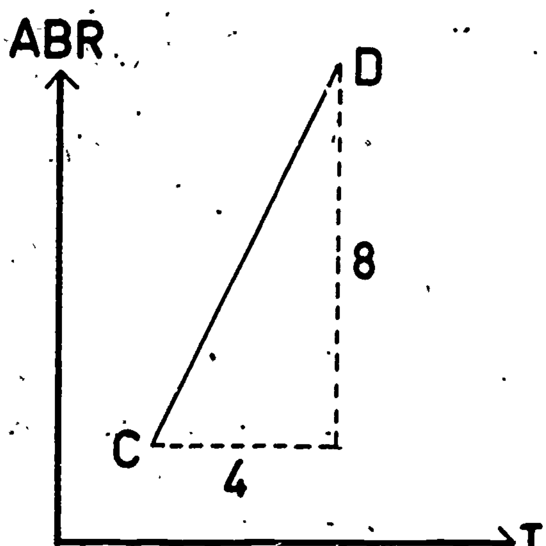
= 2 % per year.

Calculate the Rate of Change in Annual Birth Rate from A to B.

ANSWER

Rate = ______ % per year.





Calculate the Rate of Change in Annual Birth Rate from C to D.

ANSWER

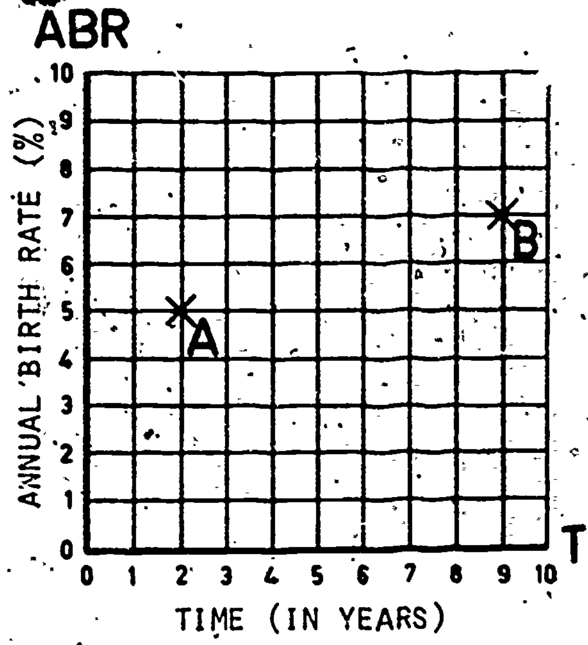
Rate = ______ % per year.

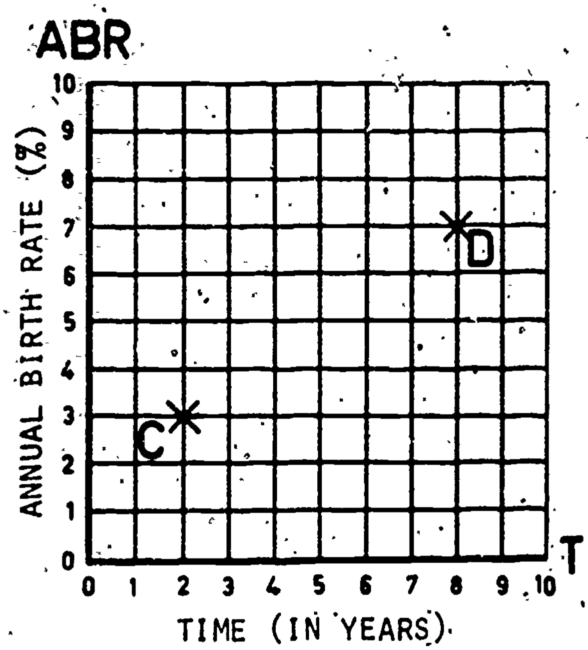
Calculate the Change in Time from A to B.

ANSWER T(AB) = ______ yrs.

Calculate the Change in Annual Birth Rate from A to B.

ANSWER ABR(AB) = ______ %.





Calculate the Change in Time from C to D.

ANSWER T(CD) = ______ yrs.

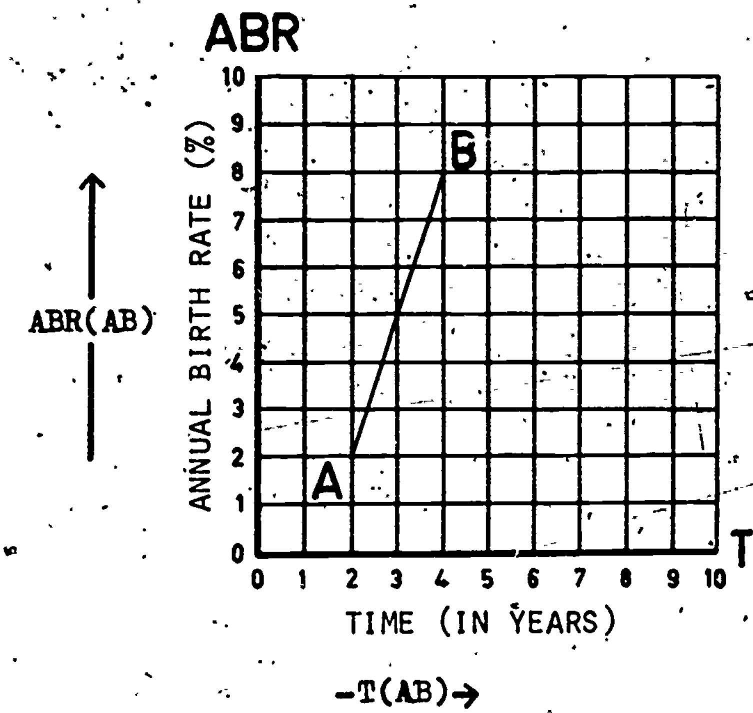
Calculate the Change in Annual Birth Rate from C to D.

ANSWER ABR(CD) = ______ %.

In order to calculate the RATE OF CHANGE in Annual Birth Rate from a GRAPH, follow the method described in the example below.

EXAMPLE

Calculate the Rate of Change in Annual Birth Rate from A to B.



METHOD

(1) Calculate the Change in Time (T(AB) = 2 years) and the Change in Annual Birth Rate (ABR(AB) = 6 %) from A to B, as shown on the graph above.

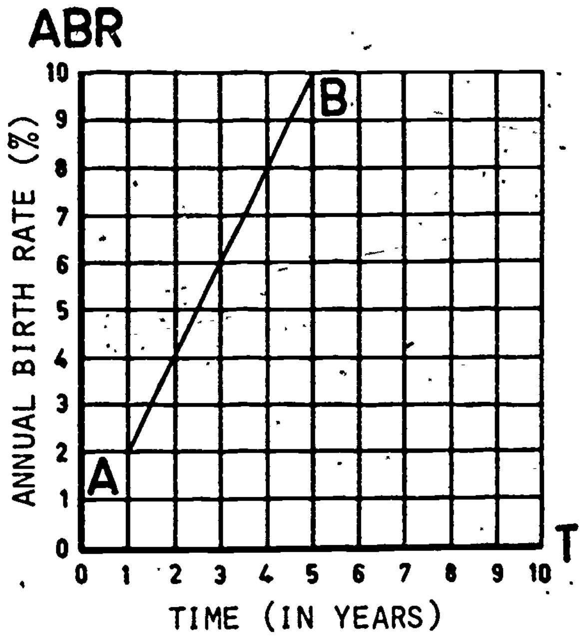
(2) Use these figures to calculate the Rate of Change in Annual Birth Rate, using the method shown on page 2/7.

ANSWER

Rate of Change in ABR from A to B. $= \frac{ABR(AB)}{T(AB)}$

$= \frac{6}{2}$ % per year

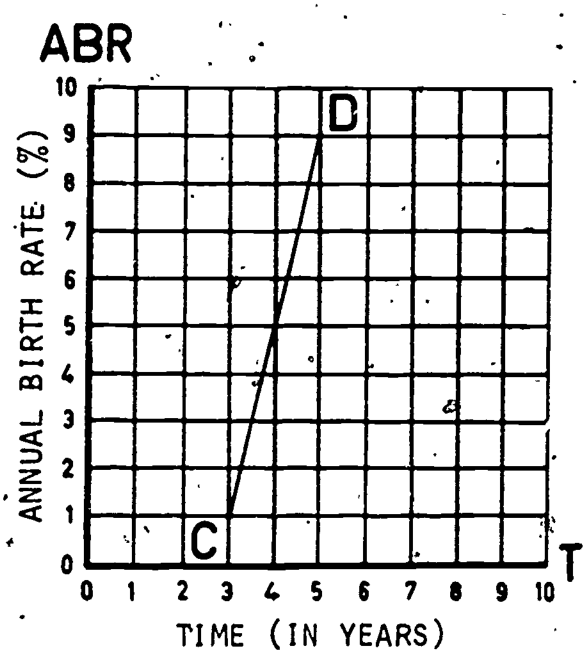
$=$ 3 % per year.



Calculate the Rate of Change in Annual Birth Rate from A to B.

ANSWER

Rate = ______ % per year.



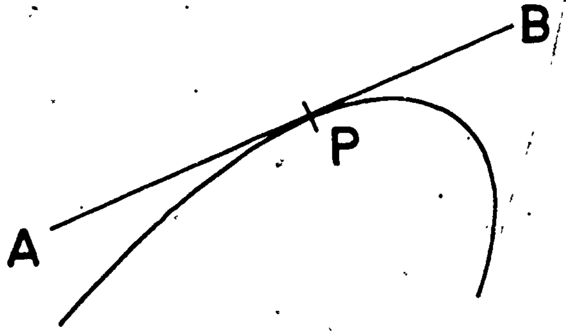
Calculate the Rate of Change in Annual Birth Rate from C to D.

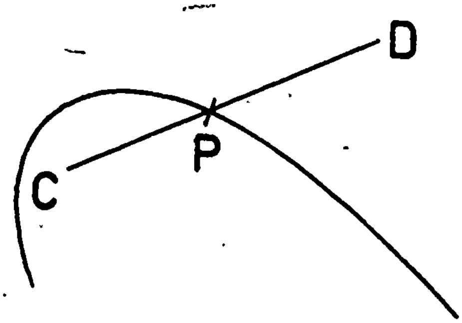
ANSWER

Rate = ______ % per year.

The TANGENT to a curve is a straight line which touches the curve at only one point, as shown in the example below.

EXAMPLE

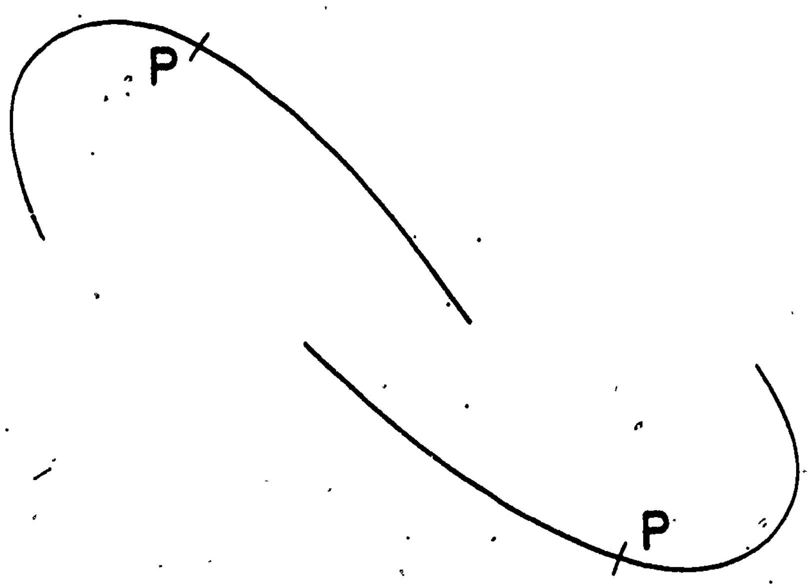


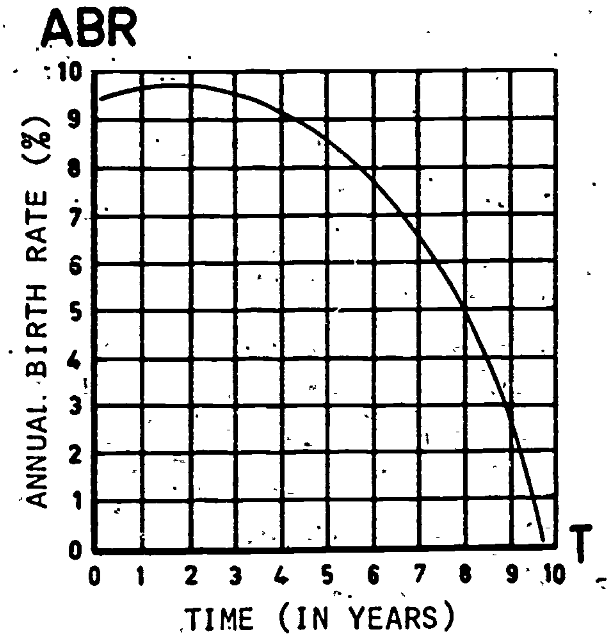


(1) The line AB is a Tangent to the curve, touching it at the point P.

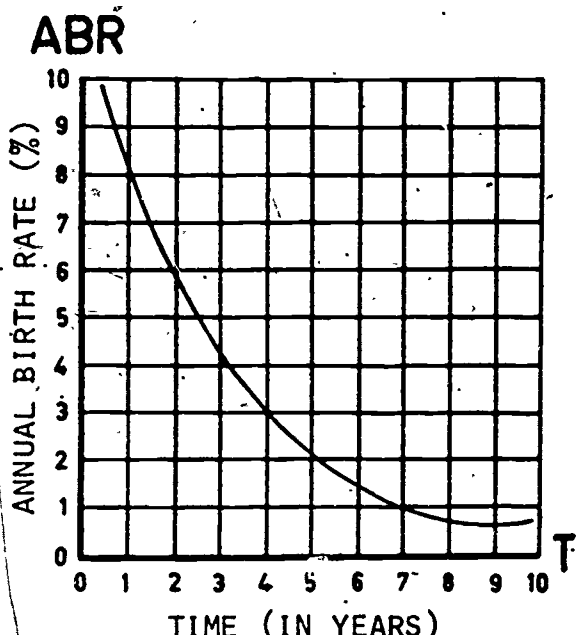
(2) The line CD is not a tangent, since it cuts across the curve at P.

Rule a Tangent to each of the curves below at the point P.



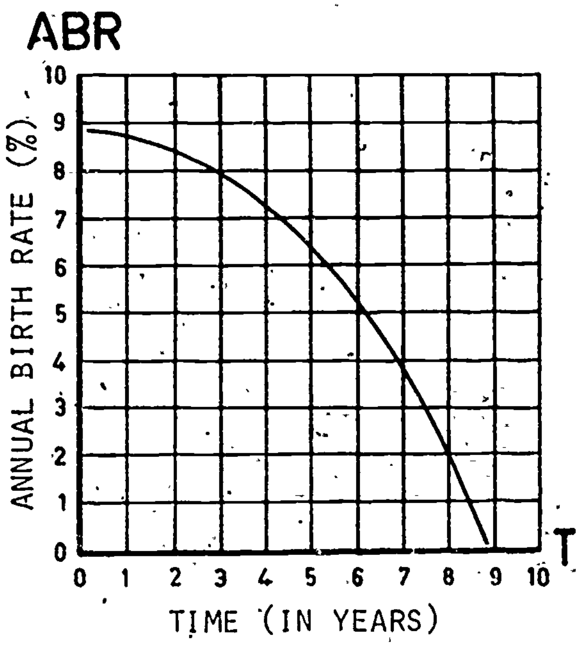


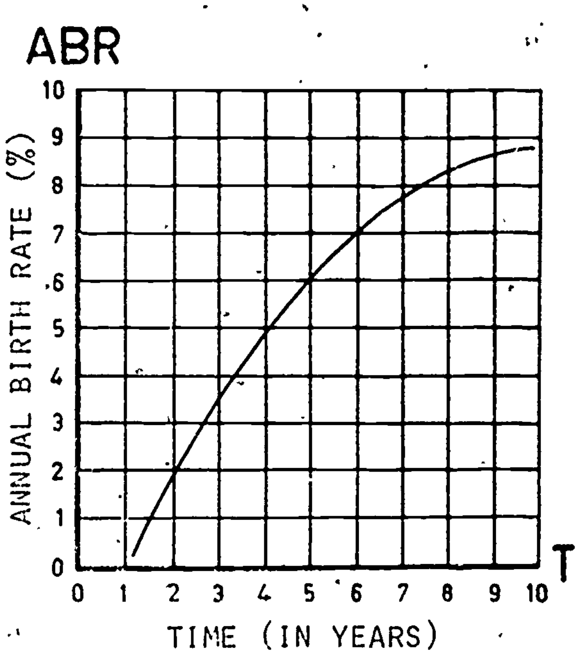
Mark the position of A on the curve, where T(A) = 8 years.



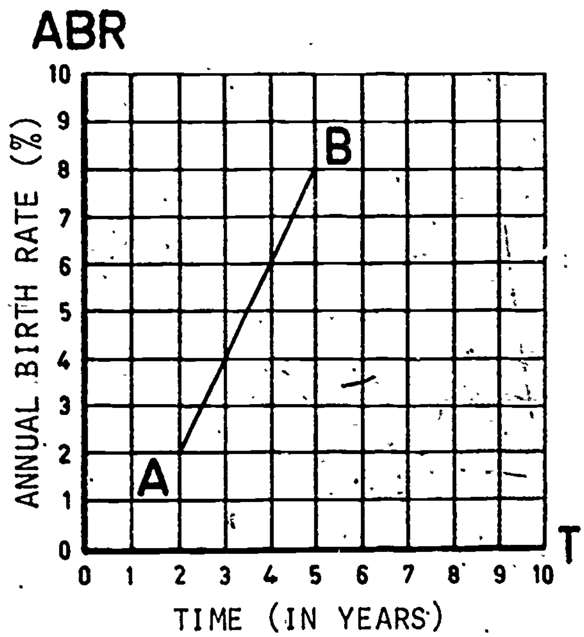
Mark the position of B on the curve, where T(B) = 4 years.

Rule a Tangent to the curve at the point A where T(A) = 3 years.





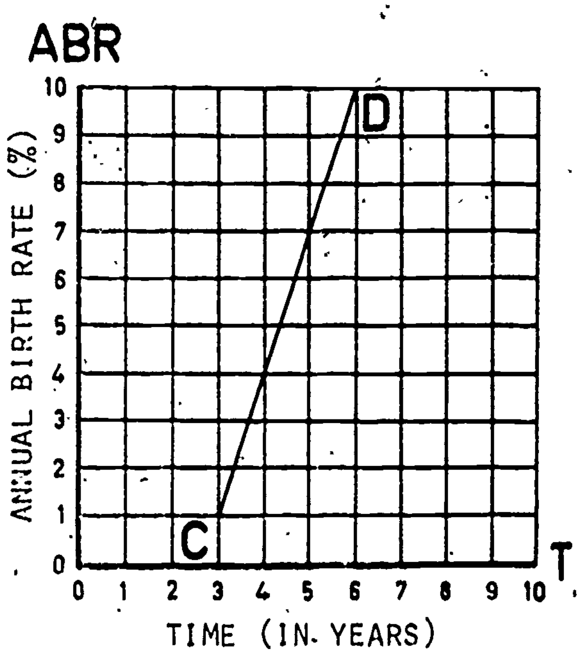
Rule a Tangent to the curve at the point B where T(B) = 6 years.



Calculate the Rate of Change in Annual Birth Rate from A to B.

ANSWER

Rate = _____ % per year.

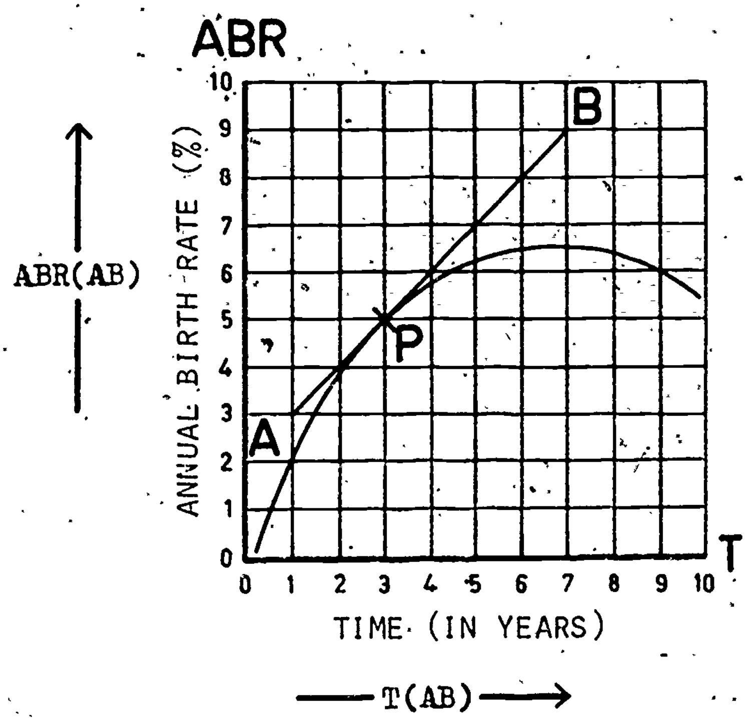


Calculate the Rate of Change in Annual Birth Rate from C to D.

ANSWER

Rate = _____ % per year.

The Tangent to a curve has the same slope as the curve at the point of contact. This means that we can now calculate the Rate of Change in ABR at any point on a CURVE, since this is equal to the Slope of the Tangent at that point.



EXAMPLE

Calculate the Rate of Change in ABR at the point P where T(P) = 3 yrs.

METHOD

(1) Mark the point P on the curve where T(P) = 3 years.

(2) Rule a Tangent to the curve at this point, so that the ends of the Tangent are whole numbers (marked A and B on the graph above)

(3) Calculate the Slope of the Tangent AB using the method shown on page 2/10.

(4) This is equal to the Rate of Change in Annual Birth Rate (ABR) at P, the point of contact on the curve.

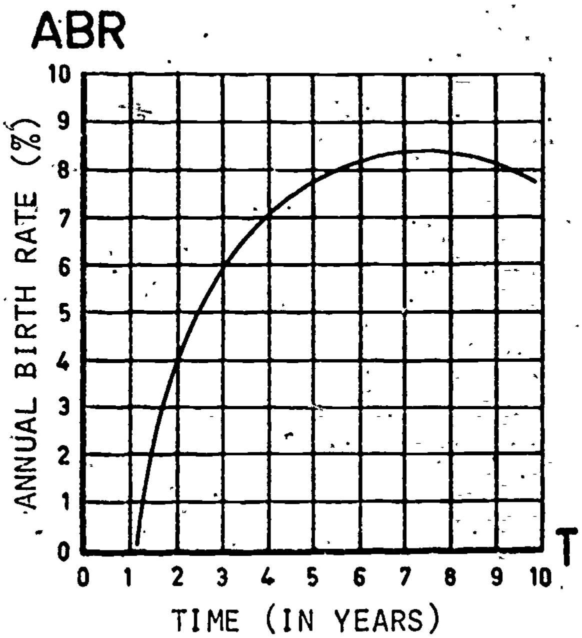
ANSWER

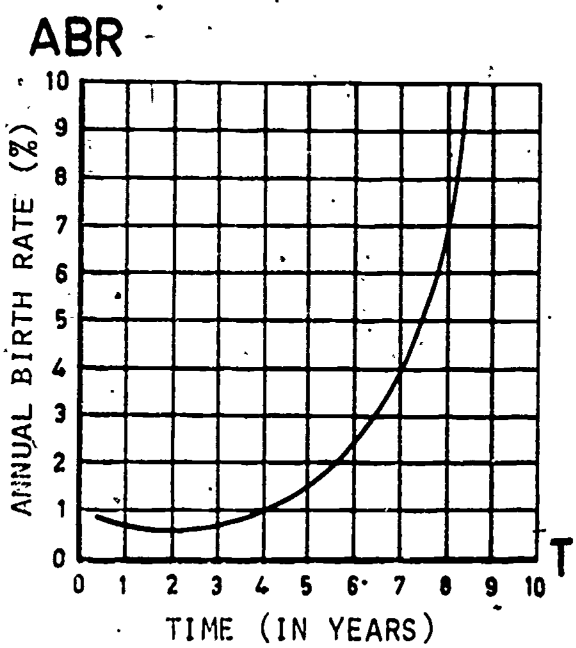
$$\text{Rate} = \frac{\text{ABR(AB)}}{\text{T(AB)}} = \frac{9 - 3}{7 - 1} = \frac{6}{6} = 1 \text{ \% per year.}$$

Calculate the Rate of Change in Annual Birth Rate at the point **A** where T(A) = 2 years.

ANSWER

Rate = _____ % per year.





Calculate the Rate of Change in Annual Birth Rate at the point B where T(B) = 7 years.

ANSWER

Rate = _____ % per year.

BASIC SKILLS OF GRAPHICAL INTERPRETATION

PROGRAMME II SECTION 3

NAME ________ AGE ______ ______
(years) (months)

SEX ________

SCHOOL ________ CLASS ________

DATE ________

INSTRUCTIONS

As you work through this programme, read each question carefully, then write your answer in the space provided. Any other calculations should be written on the BACK of the page. If you are not sure of the answer to a question, take a guess and go on to the next example.

Complete the following calculations :-

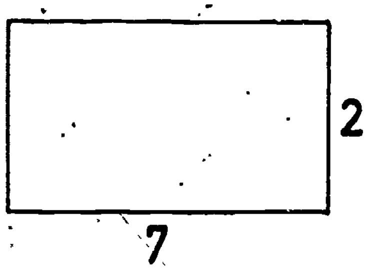
4 x 2 = ____ 5 x 3 = ____

37 x 4 = ____ 29 x 5 = ____

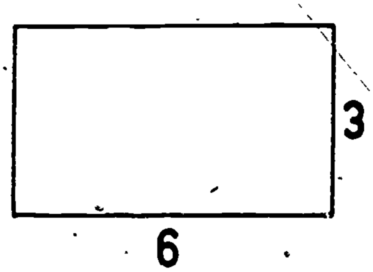
Now we can use the following formula to calculate the AREA of any Rectangle or Square.

AREA = LENGTH x HEIGHT

Use this formula to calculate the Area of the following figures.



ANSWER Area = ____

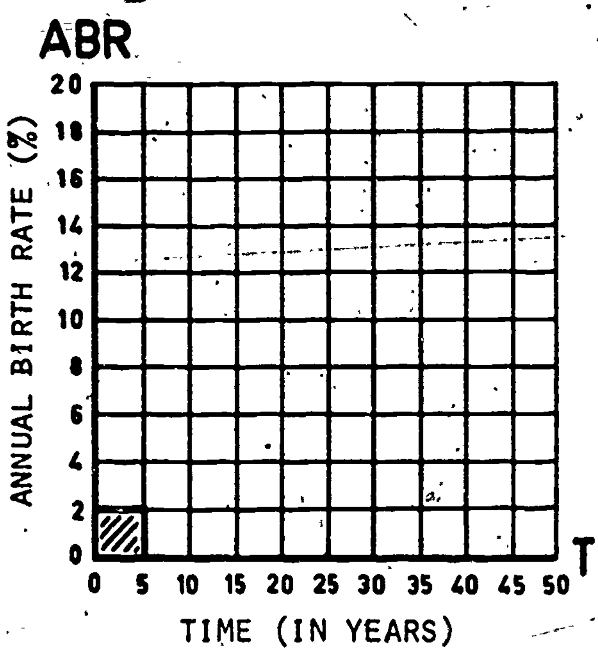


ANSWER Area = ____

The same formula can also be used to calculate the AREA OF A GRAPH, which represents the TOTAL NUMBER OF BIRTHS (per 100 people) over a given period of time.

Now each graph is made up of many small Blocks, each of the same size, and the Area of each Block is given by the formula Area = Length x Height as shown on page 3/1.

The Length of each block is shown on the Horizontal (Time) axis, and the Height is shown on the Vertical (ABR) axis.



EXAMPLE

The Total Number of Births represented by a Single Block on the graph above

= Area of a Single Block

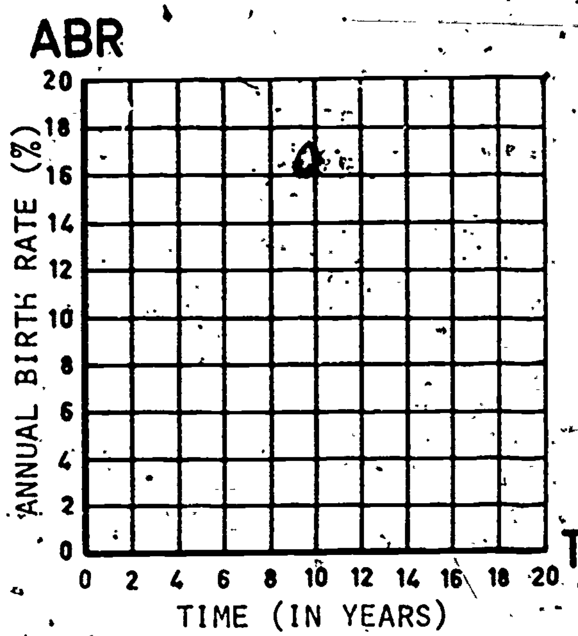
= Length x Height

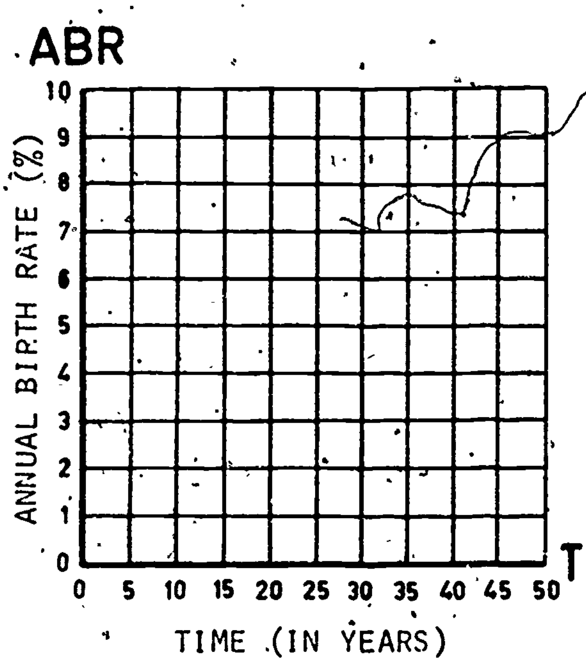
= 5 (years) x 2 (%)

= 10 %. (This represents the Total Number of Births at 2 % per year over a period of 5 years.)

Calculate the Total Number of Births represented by a Single Block on this graph.

ANSWER Total = ______ %.





Calculate the Total Number of Births represented by a Single Block on this graph.

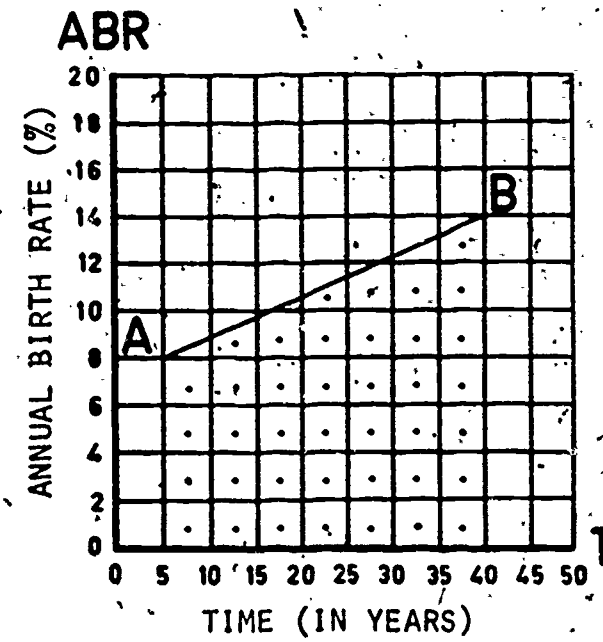
ANSWER Total = ______ %.

Now we can calculate the Total Number of Births represented in ANY SECTION OF THE GRAPH, by counting the number of blocks in the section and using the following formula.

Total N°. of Births represented in any section of the graph	=	Number of Births represented by a single block	x	Total number of blocks in the section.

EXAMPLE

Calculate the Total Number of Births represented on this graph in the time from A to B.



METHOD

(1) Calculate the number of Births represented by a single block on the graph.

(2) Count the Total number of blocks in the section below the line from A to B - each block to be counted is marked with a dot (•) on the graph above.

(3) Calculate the Total Number of Births (per 100 people) represented in this section of the graph, using the formula shown above.

(Example continued on page 3/5)

EXAMPLE (Continued from page 3/4)

Some of the blocks in the section to be counted from the graph on page 3/4 are cut by the line AB. In such a case, we use the following RULES FOR COUNTING :-

(a) If less than half of the block is included in the area we wish to calculate, then do not count that block.

(b) If half or more of the block is included in the area we wish to calculate, then count the whole block.

In this example, each block to be counted in the section is marked with a dot (•) on the graph (page 3/4).

ANSWER

The Number of Births represented by a Single Block (as shown on page 3/2) = 5 x 2 %

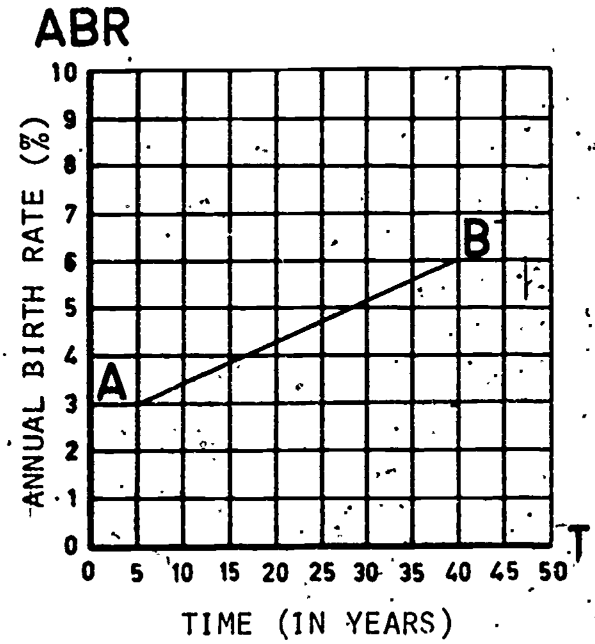
= 10 %.

The Total number of blocks = 39

The Total Number of Births in the time from A to B	=	Number of Births represented by a single block	x	Total Number of blocks in this section
	=	10 (%)	x	39
	=	390 %.		

Calculate the Number of Births represented by a Single Block on this graph.

ANSWER
No. of Births = ______ %.



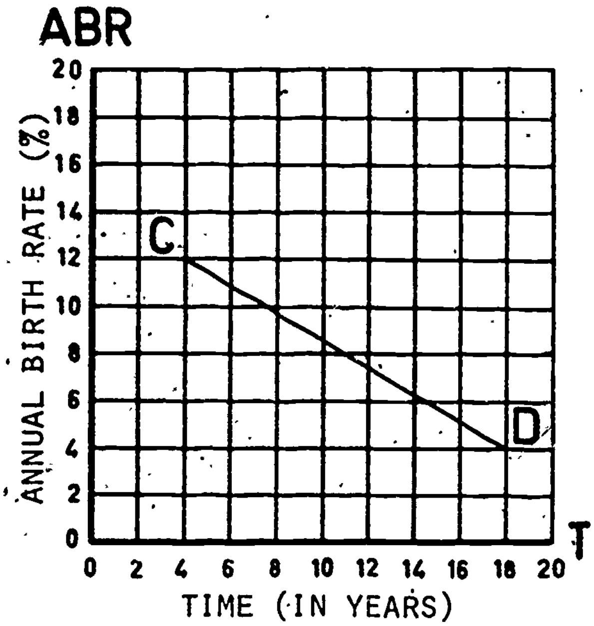
(1) Mark with a dot each block you would count to calculate the total number of births represented in the time from A to B on the graph above.

(2) Count the number of blocks you have marked.

ANSWER ______

(3) Calculate the Total Number of Births represented in the time from A to B on the graph above.

ANSWER Total = ______ %.



Calculate the Number of Births represented by a Single Block on this graph.

ANSWER

N°. of Births = ____ %.

(1) Mark with a dot each block you would count to calculate the total number of births represented in the time from C to D on the graph above.

(2) Count the number of blocks you have marked.

ANSWER ____

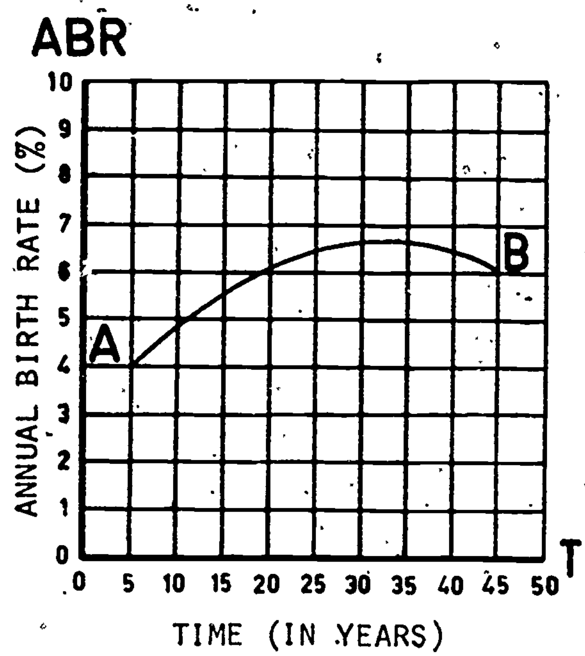
(3) Calculate the Total Number of Births represented in the time from C to D on the graph above.

ANSWER Total = ____ %.

Calculate the Number of Births represented by a Single Block on this graph.

ANSWER

No. of Births = ____ %.



(1) Mark with a dot each block you would count to calculate the total number of births represented in the time from A to B on the graph above.

(2) Count the number of blocks you have marked.

ANSWER ____

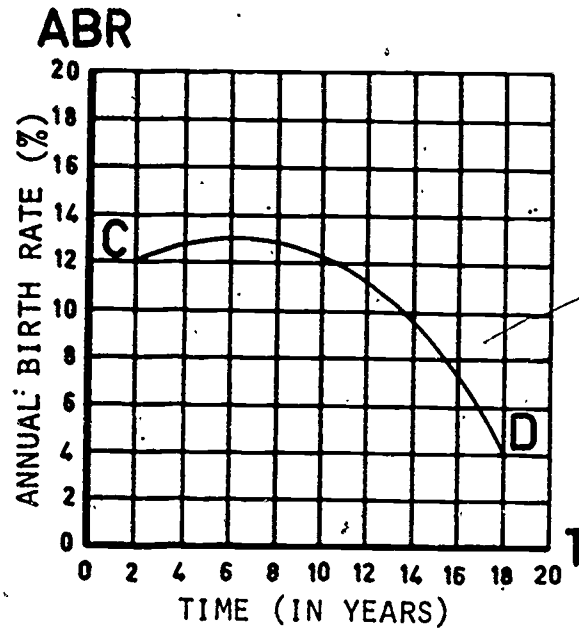
(3) Calculate the Total Number of Births represented in the time from A to B on the graph above.

ANSWER Total = ____ %.

Calculate the Number of Births represented by a Single Block on this graph.

ANSWER

N^o^. of Births = ______ %.



(1) Mark with a dot each block you would count to calculate the total number of births represented in the time from C to D on the graph above.

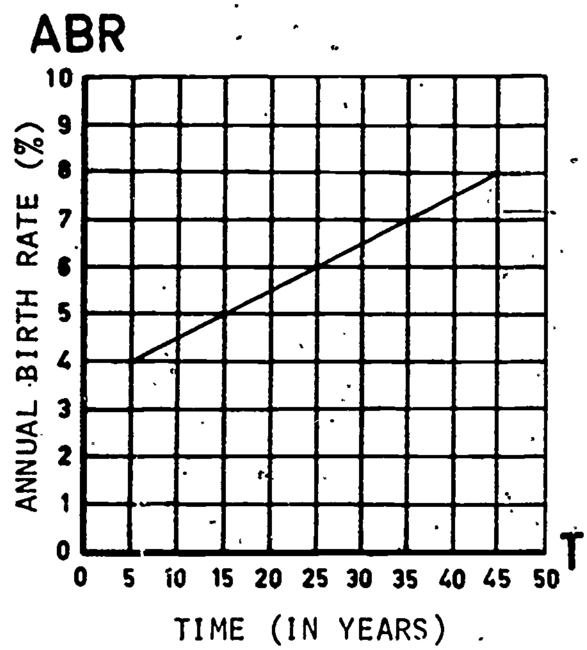
(2) Count the number of blocks you have marked.

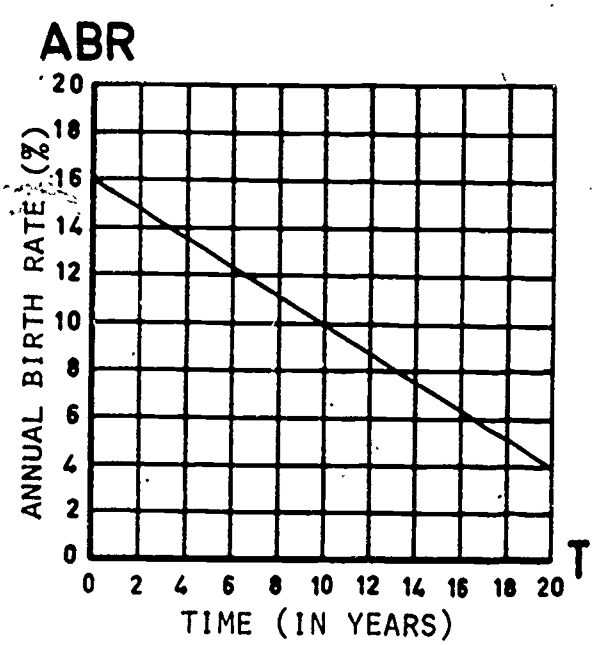
ANSWER ______

(3) Calculate the Total Number of Births represented in the time from C to D on the graph above.

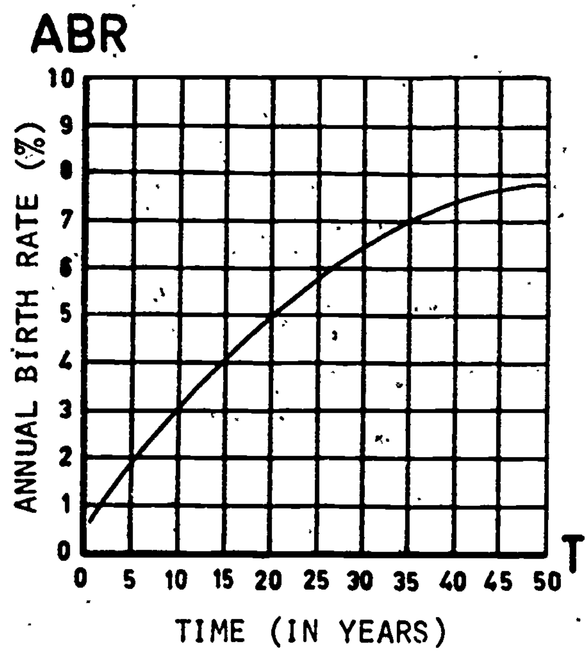
ANSWER Total = ______ %

Mark the position of A on the line, where T(A) = 25 years.

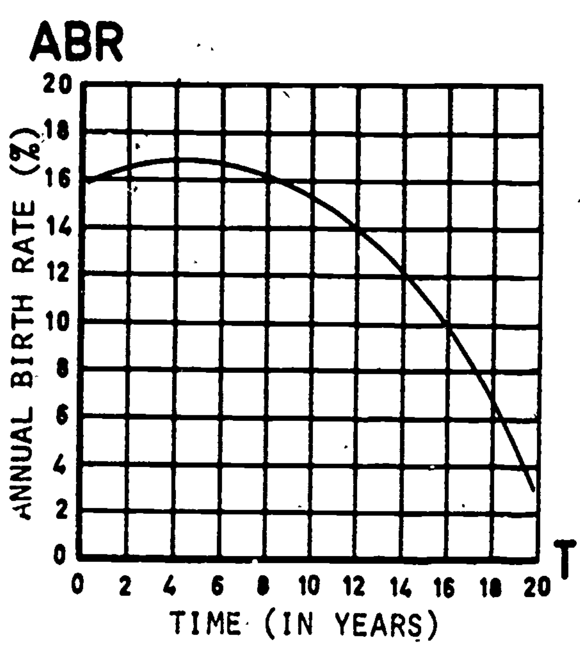




Mark the position of B on the line, where T(B) = 16 years.



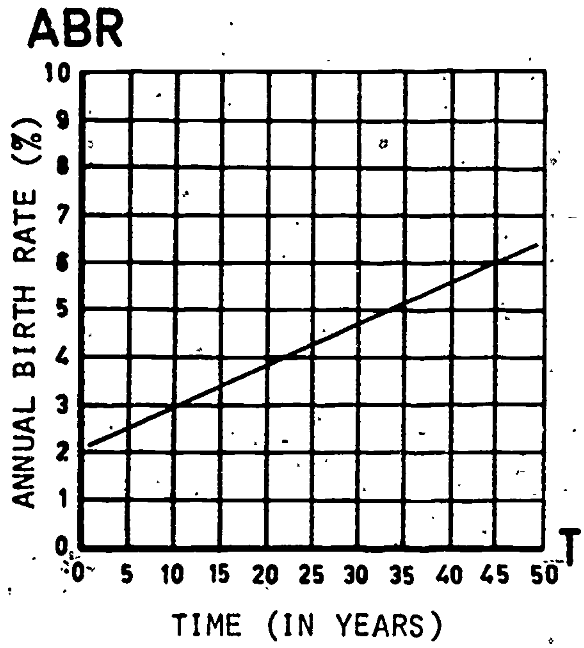
Mark the position of A on the curve, where T(A) = 35 years.

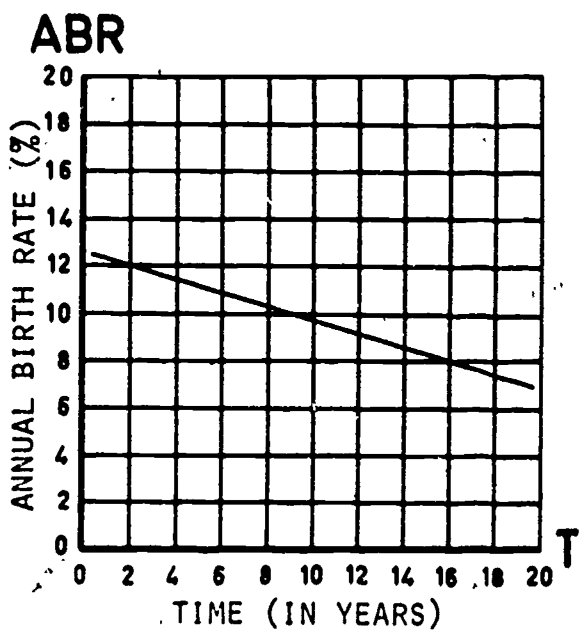


Mark the position of B on the curve, where T(B) = 12 years.

Calculate the Total Number of Births represented in this graph from A to B, where T(A) = 10 years and T(B) = 45 years.

ANSWER Total = ______ %.



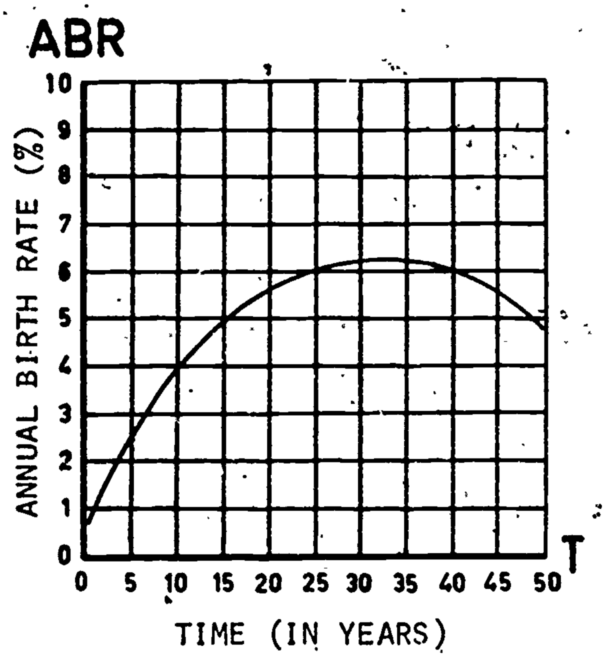


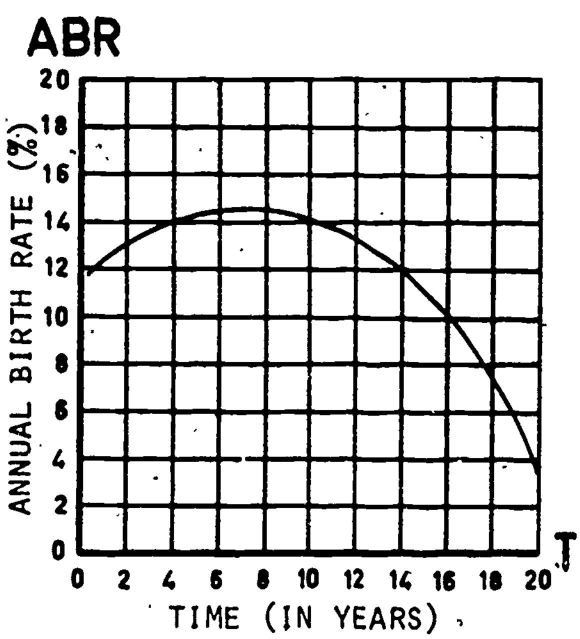
Calculate the Total Number of Births represented in this graph from C to D, where T(C) = 2 years and T(D) = 16 years.

ANSWER Total = ______ %.

Calculate the Total Number of Births represented in this graph from A to B, where T(A) = 15 years and T(B) = 40 years.

ANSWER Total = ____ %.





Calculate the Total Number of Births represented in this graph from C to D, where T(C) = 4 years and T(D) = 14 years.

ANSWER Total = ____ %.

BASIC SKILLS OF GRAPHICAL INTERPRETATION

PROGRAMME III SECTION 1

NAME ______________ AGE ______ ______
(years) (months)

SEX ______

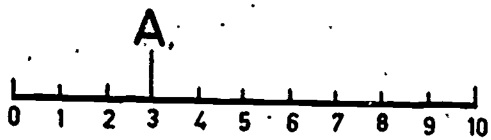
SCHOOL ______________ CLASS ______

DATE ______

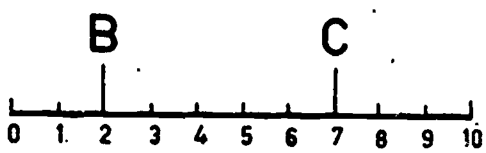
INSTRUCTIONS

As you work through this programme, read each question carefully, then write your answer in the space provided. Any other calculations should be written on the BACK of the page. If you are not sure of the answer to a question, take a guess and go on to the next example. Every answer should be given to the nearest decimal place.

This is a HORIZONTAL NUMBER LINE with positions marked from 0 to 10.



The position of A on the number line above is 3.0



Calculate the position of B on the number line above.

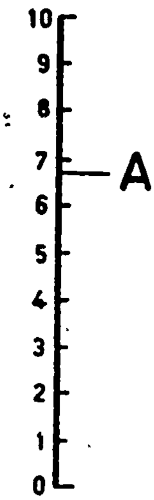
ANSWER B = ______

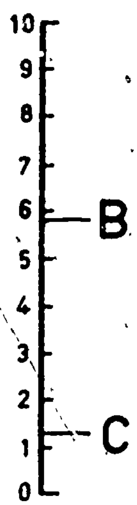
Calculate the position of C on the number line above.

ANSWER C = ______

This is a VERTICAL NUMBER LINE with positions marked from 0 to 10.

The position of A on this number line is 6.7





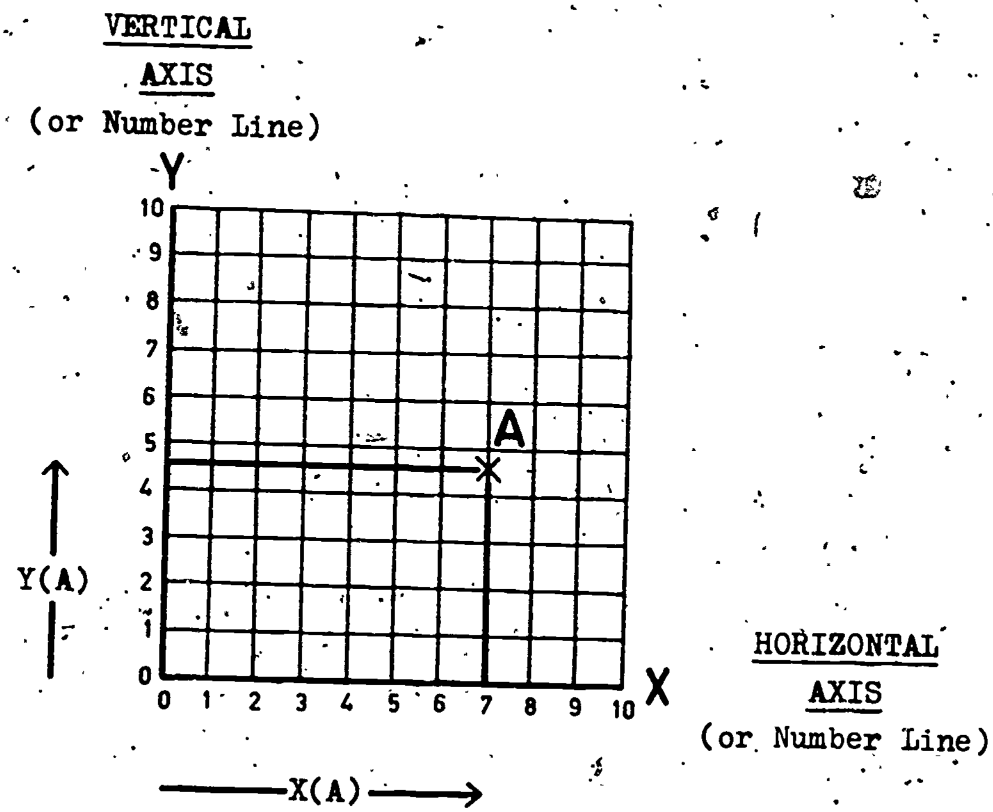
Calculate the position of B.

ANSWER B = ______

Calculate the position of C.

ANSWER C = ______

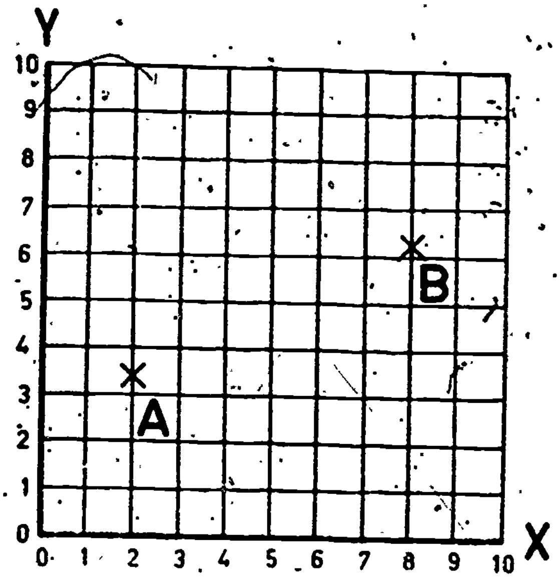
Let us now combine the Horizontal and Vertical number lines to form a GRAPH as shown in the diagram below.



Any point within this graph can now be easily found if we know both its Horizontal position and its Vertical position. These may be calculated in the following way :-

The HORIZONTAL POSITION of a point is its distance from 0 measured along the Horizontal or X axis. This is shown for the point A in the graph above as X(A) = 7.0

The VERTICAL POSITION of a point is its distance from 0 measured along the Vertical or Y axis. This is shown for the point A in the graph above as Y(A) = 4.6



Calculate the Horizontal position of A.

ANSWER X(A) = ______

Calculate the Horizontal position of B.

ANSWER X(B) = ______

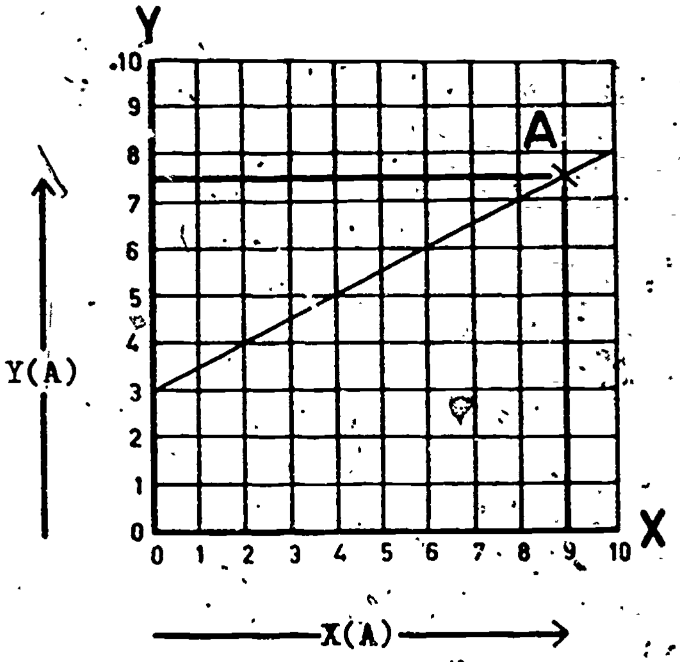
Calculate the Vertical position of A.

ANSWER Y(A) = ______

Calculate the Vertical position of B.

ANSWER Y(B) = ______

Now we can find the position of any POINT ON A LINE, using the method described in the example below.



EXAMPLE

Calculate the Horizontal position of A when Y(A) = 7.5

METHOD

(1) Find the given position Y(A) = 7.5 on the Vertical Axis.

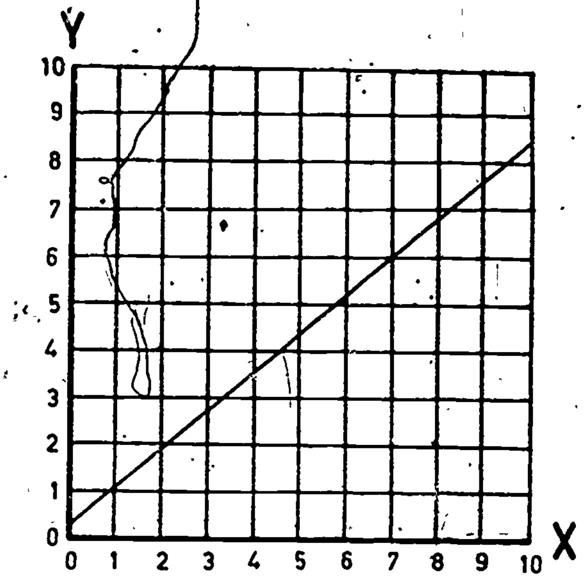
(2) Move across to the line and mark the point A which has the same Vertical position.

(3) Calculate the Horizontal position of this point, as shown on the graph above.

ANSWER

X(A) = 9.0

The two points A and B both lie somewhere on the line shown in this graph.



Y(A) = 3.6   Y(B) = 5.2

Mark the positions A and B on the graph.

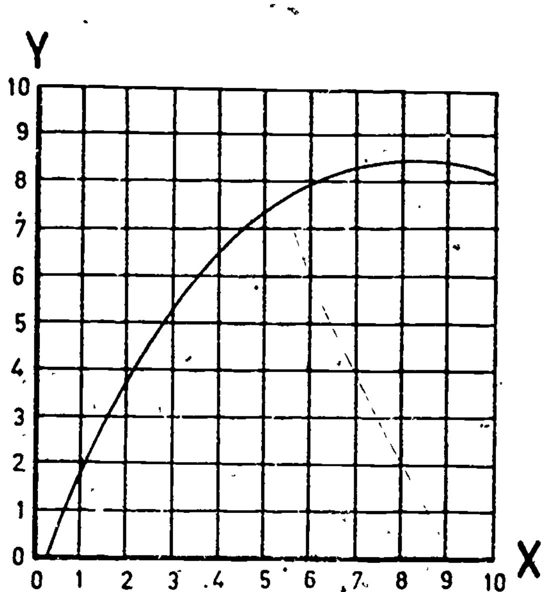
Calculate the Horizontal position of A.

ANSWER X(A) = ______

Calculate the Horizontal position of B.

ANSWER X(B) = ______

The two points C and D both lie somewhere on the curve shown in this graph.



Y(C) = 1.8   Y(D) = 7.3

Mark the positions C and D on the graph.

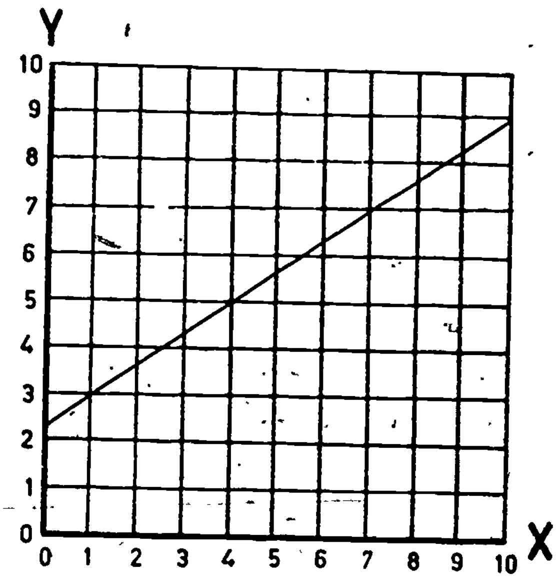
Calculate the Horizontal position of C.

ANSWER X(C) = ______

Calculate the Horizontal position of D.

ANSWER X(D) = ______

The two points A and B both lie somewhere on the line shown in this graph.



X(A) = 3.0   X(B) = 9.0

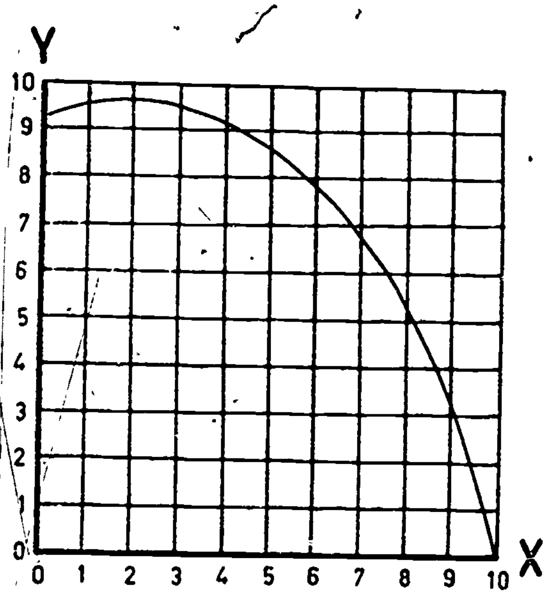
Mark the positions A and B on the graph.

Calculate the Vertical position of A.

ANSWER Y(A) = ____

Calculate the Vertical position of B.

ANSWER Y(B) = ____



The two points C and D both lie somewhere on the curve shown in this graph.

X(C) = 2.0   X(D) = 8.0

Mark the positions C and D on the graph.

Calculate the Vertical position of C.

ANSWER Y(C) = ____

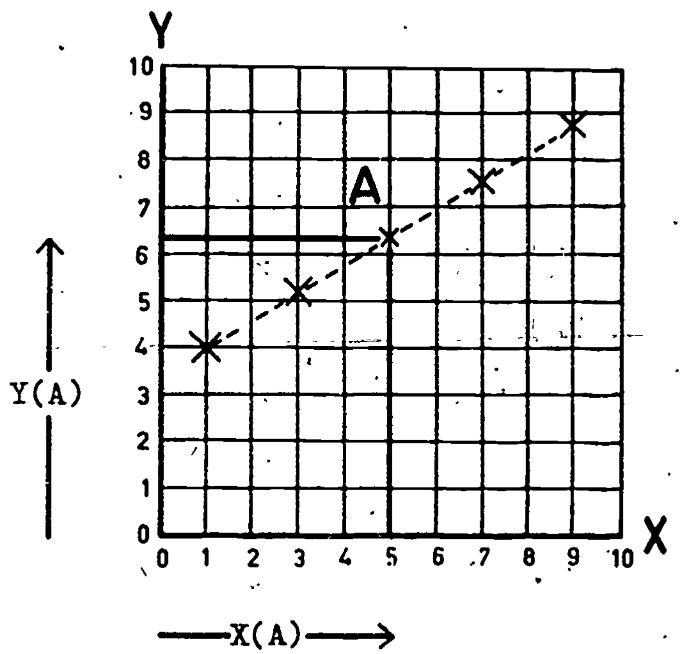
Calculate the Vertical position of D.

ANSWER Y(D) = ____

In order to find a certain POSITION BETWEEN A ROW OF POINTS, use the method described in the following example.

EXAMPLE

Calculate the Horizontal position of A when Y(A) = 6.4



METHOD

(1) Rule a line through each of the points, as shown on the graph above.

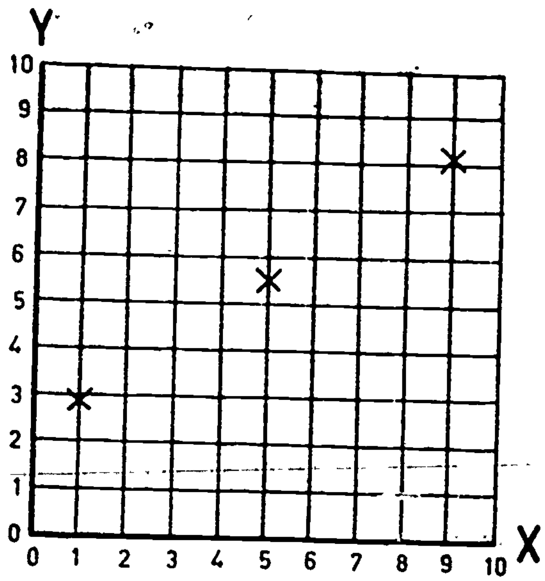
(2) Find the point on this line which has a Vertical position Y(A) = 6.4

(3) Calculate the Horizontal position of this point.

ANSWER

X(A) = 5.0

The two points A and B both lie somewhere between the row of points shown on this graph.



Calculate the Horizontal position of A when Y(A) = 4.2

ANSWER X(A) = ____

Calculate the Horizontal position of B when Y(B) = 6.8

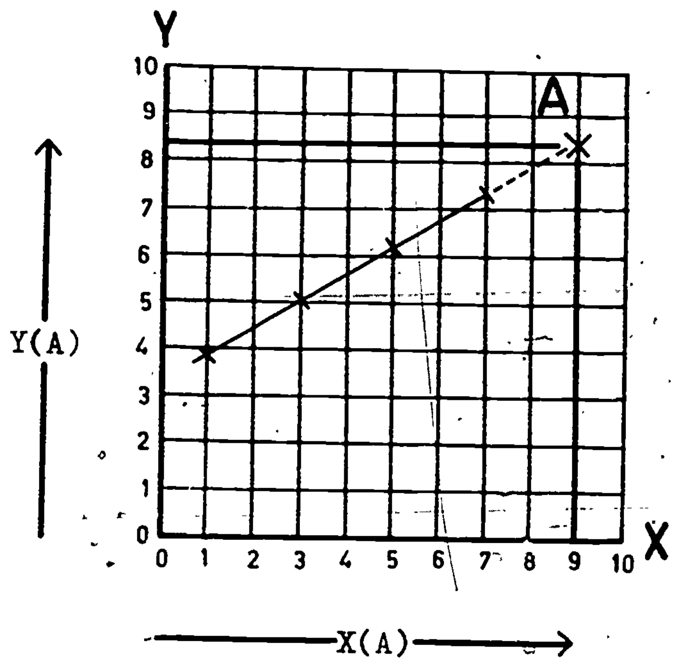
ANSWER X(B) = ____

CHECK All answers should be given to the nearest decimal place.

In order to find a certain POSITION BEYOND A GIVEN LINE OR ROW OF POINTS, follow the instructions described in the example below.

EXAMPLE

Calculate the Horizontal position of **A** when Y(A) = 8.4



METHOD

(1) Rule a line through each of the points (unless a line is given in the problem).

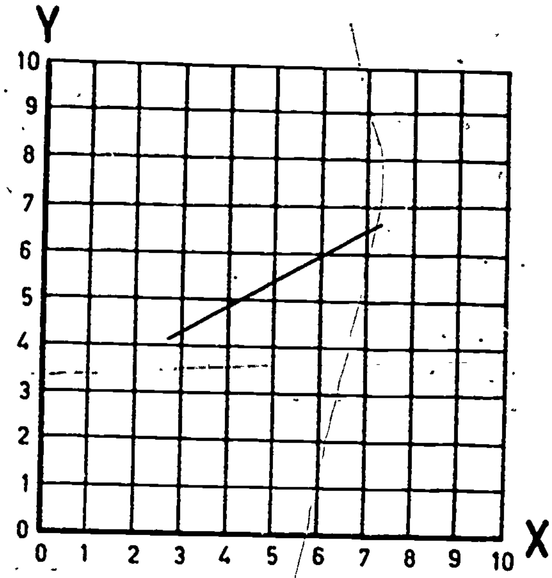
(2) Extend this line, as shown in the graph above, until it reaches the Vertical position Y(A) = 8.4

(3) Calculate the Horizontal position of this point.

ANSWER

X(A) = 9.0

The two points A and B both lie somewhere beyond the line shown in this graph.

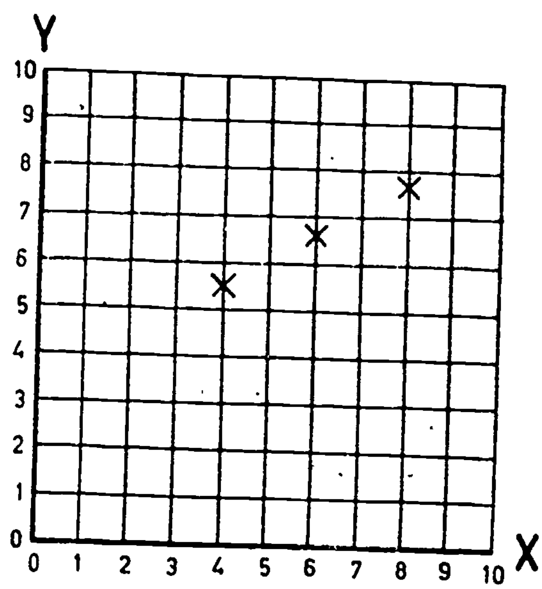


Calculate the Horizontal position of A when Y(A) = 3.3

ANSWER X(A) = ____

Calculate the Horizontal position of B when Y(B) = 7.6

ANSWER X(B) = ____



The two points C and D both lie somewhere beyond the row of points shown in this graph.

Calculate the Horizontal position of C when Y(C) = 4.5

ANSWER X(C) = ____

Calculate the Horizontal position of D when Y(D) = 8.8

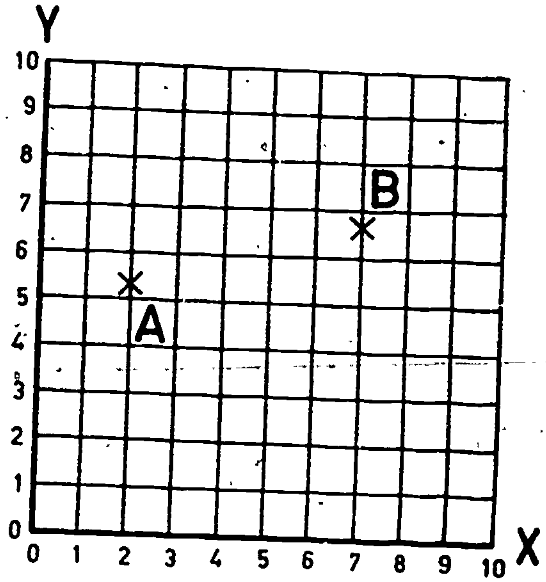
ANSWER X(D) = ____

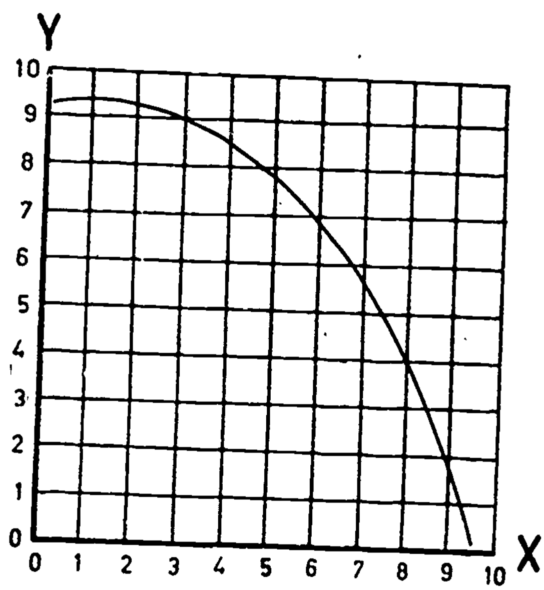
Calculate the Vertical position of A.

ANSWER Y(A) = ____

Calculate the Vertical position of B.

ANSWER Y(B) = ____





The two points C and D both lie somewhere on the curve shown in this graph.

Calculate the Vertical position of C when X(C) = 4.0

ANSWER Y(C) = ____

Calculate the Vertical position of D when X(D) = 9.0

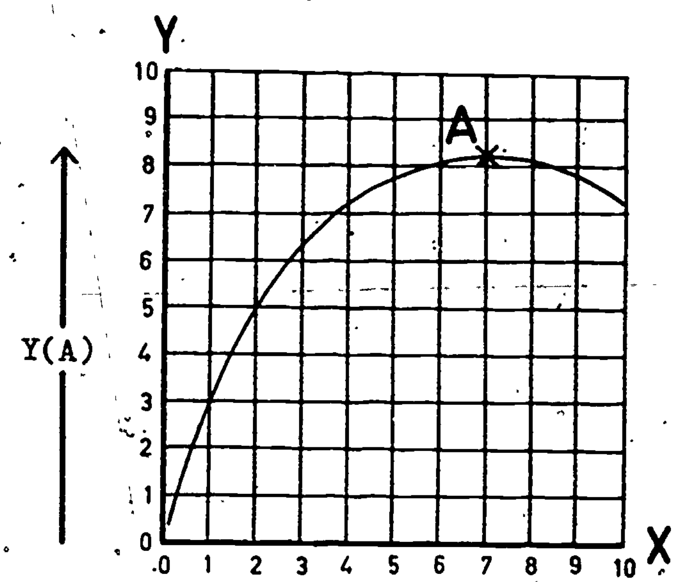
ANSWER Y(D) = ____

The MAXIMUM Value of a curve is equal to the HIGHEST VERTICAL POSITION on the curve.

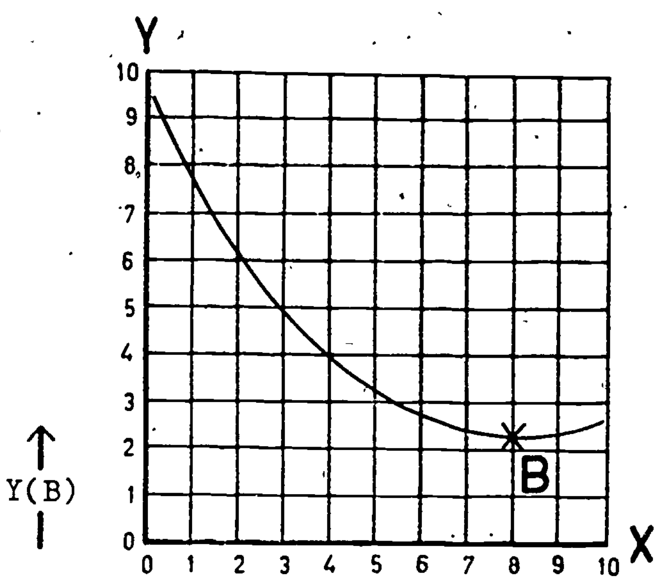
The Maximum Value of this curve

= Y(A)

= 8.2



The MINIMUM Value of a curve is equal to the LOWEST VERTICAL POSITION on the curve.



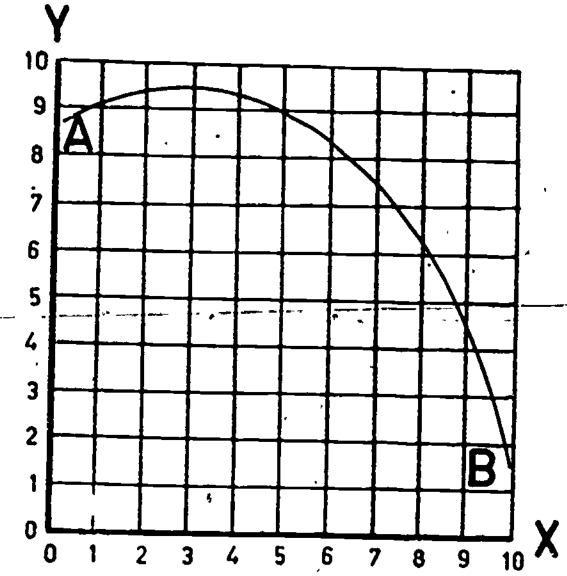
The Minimum Value of this curve

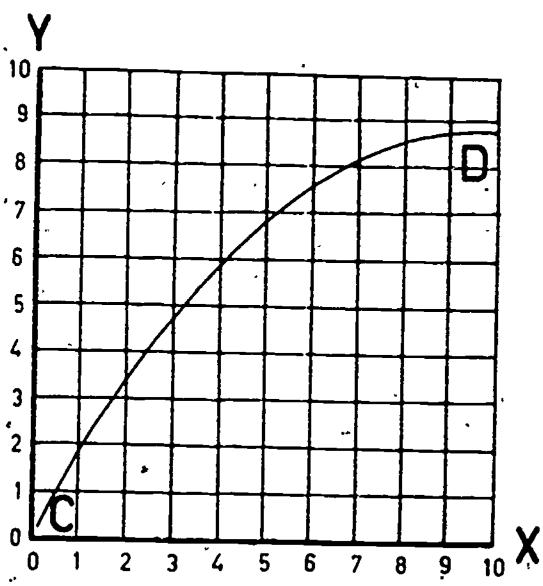
= Y(B)

= 2.3

Calculate the Maximum
Value of the curve AB.

ANSWER MAX = ______



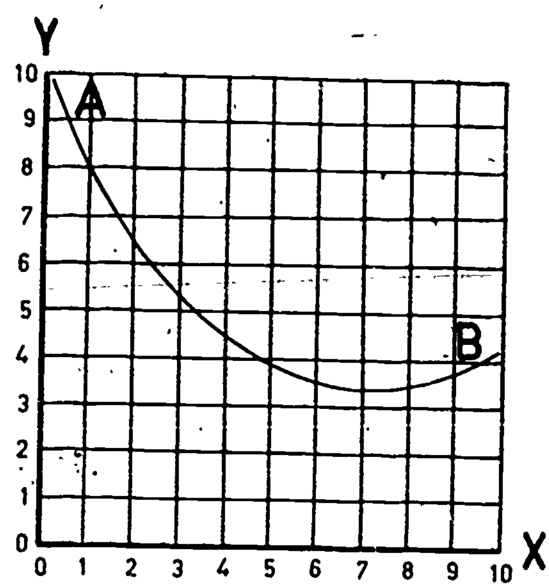


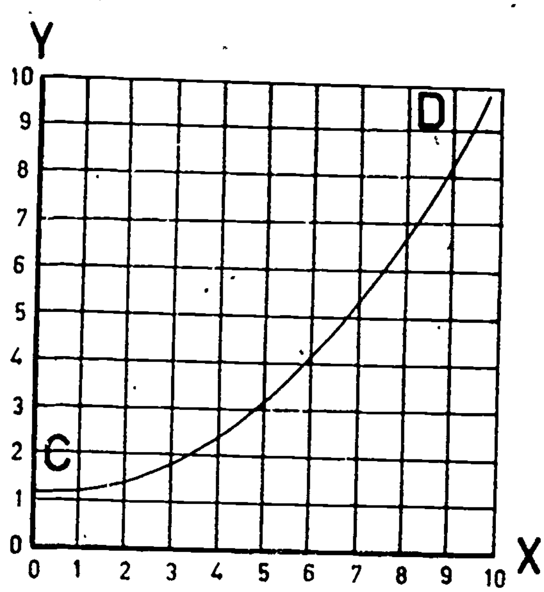
Calculate the Maximum
Value of the curve CD.

ANSWER MAX = ______

Calculate the Minimum Value of the curve AB.

ANSWER MIN = ______

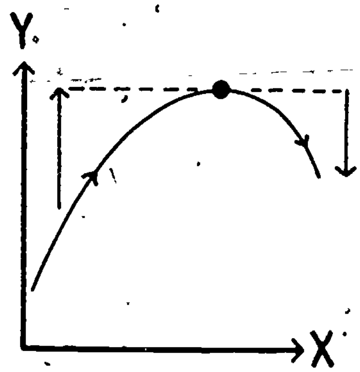




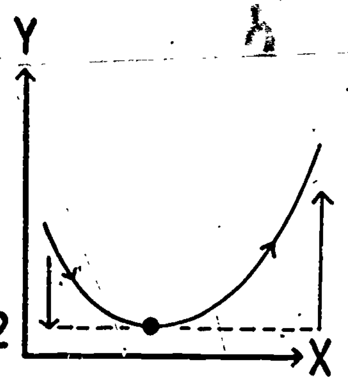
Calculate the Minimum Value of the curve CD.

ANSWER MIN = ______

The TURNING POINT of a curve is indicated by a Change in Vertical Direction along the curve, as shown in the examples below.

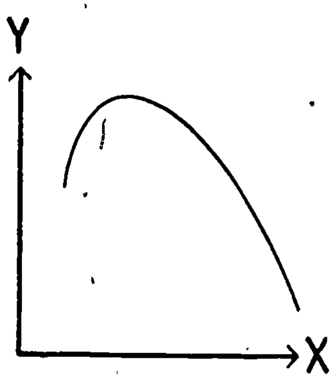


1

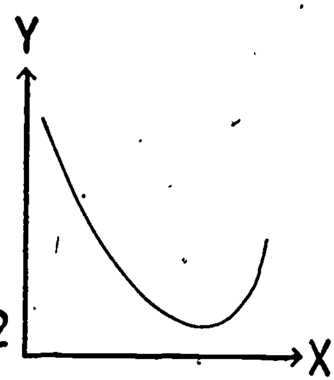


2

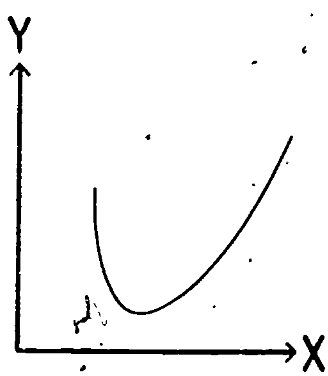
Place a mark (●) at the Turning Point on each of the following curves.



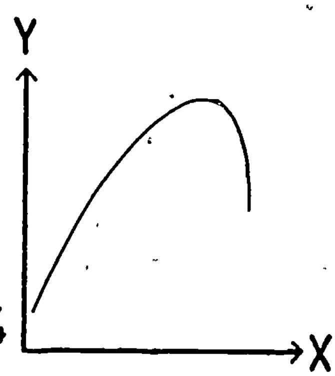
1



2



3

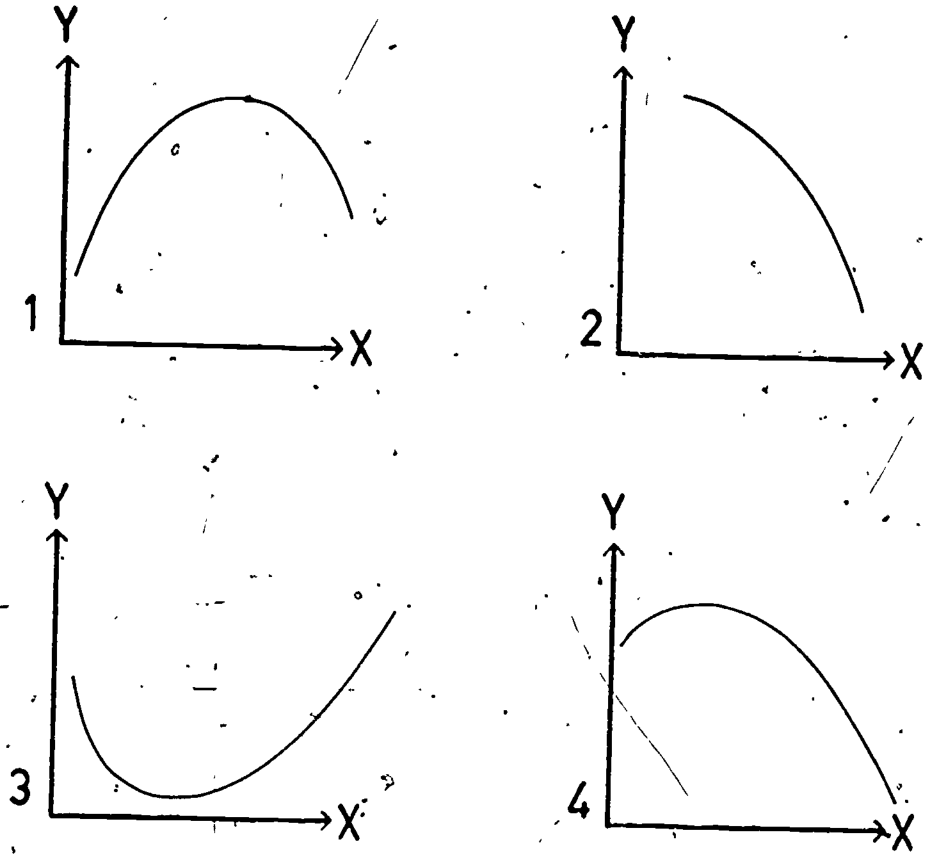


4

If the Turning Point of a curve has the HIGHEST Vertical position on the curve, it is called a MAXIMUM TURNING POINT.

If the Turning Point of a curve has the LOWEST Vertical position on the curve, it is called a MINIMUM TURNING POINT.

Show which of the following curves has a MAXIMUM Turning Point, by writing the number(s) in the space below.



ANSWER ____________________

BASIC SKILLS OF GRAPHICAL INTERPRETATION

PROGRAMME III SECTION 2

NAME ______________ AGE ________ ________
(years) (months)

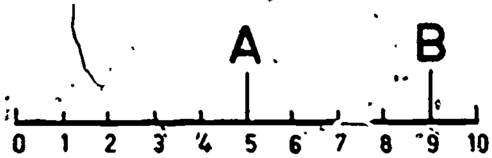
SEX ________

SCHOOL ______________ CLASS ________

DATE ________

INSTRUCTIONS

As you work through this programme, read each question carefully, then write your answer in the space provided. Any other calculations should be written on the BACK of the page. If you are not sure of the answer to a question, take a guess and go on to the next example. Every answer should be given to the nearest decimal place.

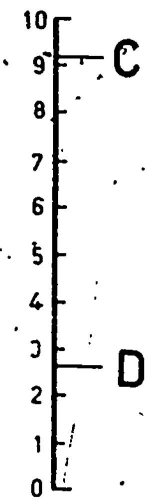


Calculate the position of A on the number line above.

ANSWER A = ____

Calculate the position of B on the number line above.

ANSWER B = ____



Calculate the position of C.

ANSWER C = ____

Calculate the position of D.

ANSWER D = ____

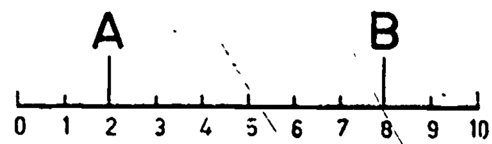
Complete the following calculations :-

10 - 5 = ____ 9 - 2 = ____

9.7 - 5.4 = ____ 6.3 - 3.1 = ____

The DISPLACEMENT between two points is the CHANGE IN POSITION from one point to the other.

EXAMPLE



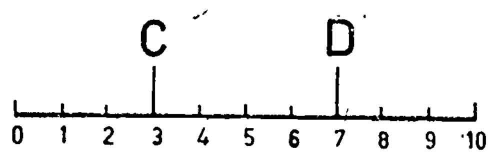
The Displacement from A to B on the number line above (call this AB)

= Final Position - First Position

= B - A

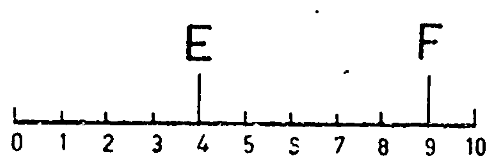
= 8.0 - 2.0

= 6.0



Calculate the Displacement from C to D on the number line above.

ANSWER CD = ______

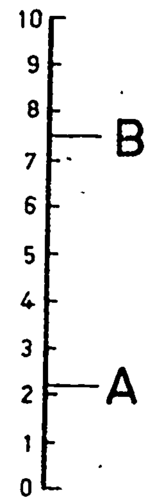


Calculate the Displacement from E to F on the number line above.

ANSWER EF = ______

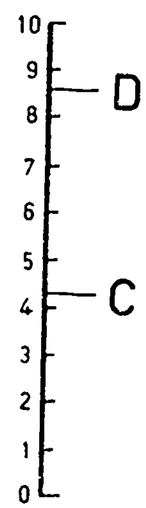
The same rule can also be used to calculate the Displacement between two points on a Vertical number line.

Calculate the Displacement from A to B.

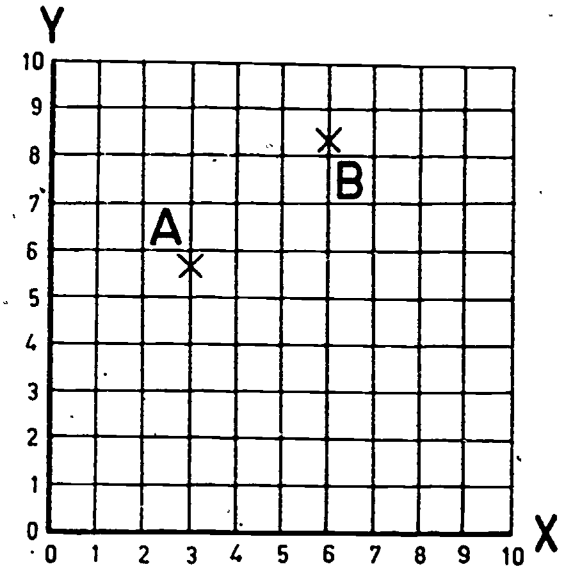


ANSWER AB = ______

Calculate the Displacement from C to D.



ANSWER CD = ______



Calculate the Horizontal position of A.

ANSWER X(A) = ______

Calculate the Horizontal position of B.

ANSWER X(B) = ______

Calculate the Vertical position of A.

ANSWER Y(A) = ______

Calculate the Vertical position of B.

ANSWER Y(B) = ______

The HORIZONTAL DISPLACEMENT between two points on a graph is the CHANGE IN HORIZONTAL POSITION from one point to the other - that is, the change in position measured along the Horizontal or X-axis.

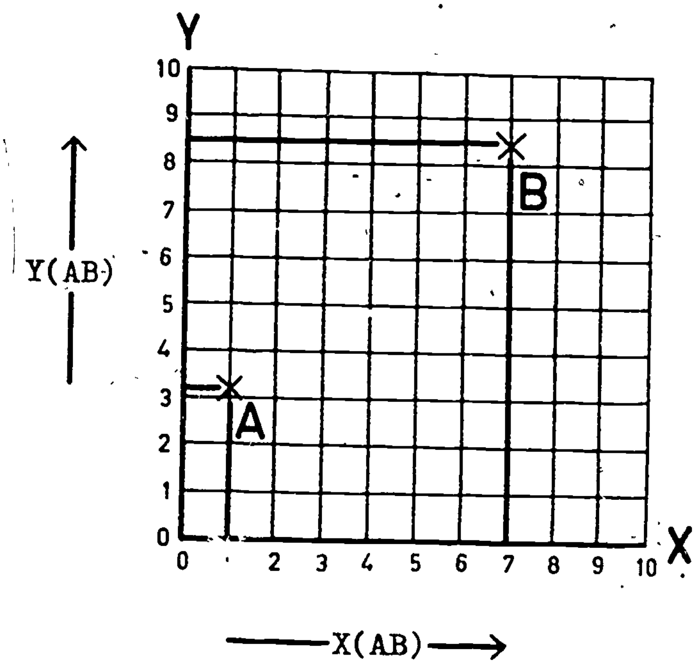
EXAMPLE

The Horizontal Displacement from A to B (called X(AB))

= X(B) - X(A)

= 7.0 - 1.0

= 6.0



The VERTICAL DISPLACEMENT between two points on a graph is the CHANGE IN VERTICAL POSITION from one point to the other - that is, the change in position measured along the Vertical or Y-axis.

EXAMPLE

The Vertical Displacement from A to B on the graph above (called Y(AB))

= Y(B) - Y(A)

= 8.5 - 3.2

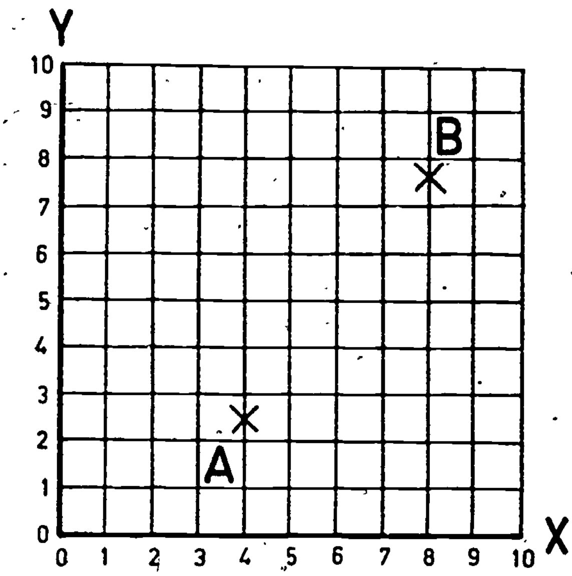
= 5.3

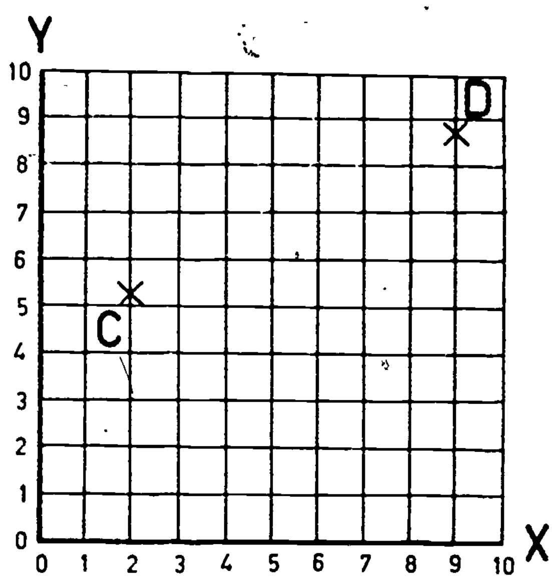
Calculate the Horizontal Displacement from A to B.

ANSWER X(AB) = _____

Calculate the Vertical Displacement from A to B.

ANSWER Y(AB) = _____





Calculate the Horizontal Displacement from C to D.

ANSWER X(CD) = _____

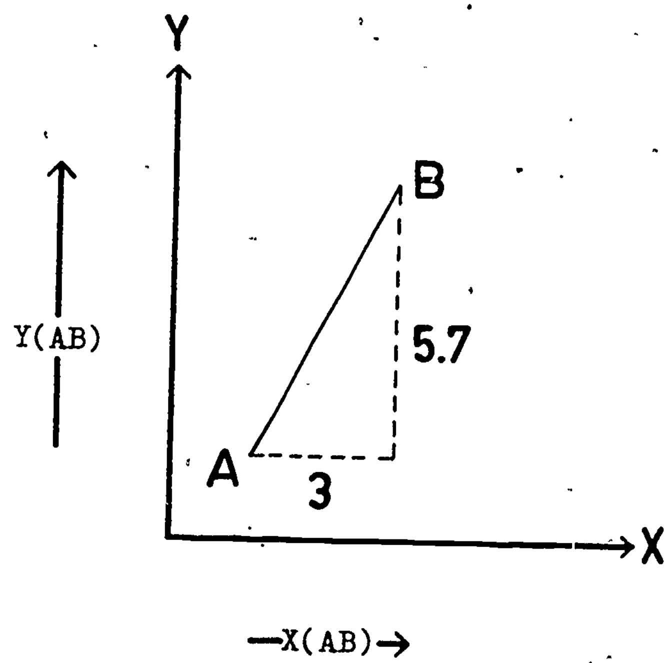
Calculate the Vertical Displacement from C to D.

ANSWER Y(CD) = _____

Complete the following calculations :-

$\frac{8.4}{3}$ = ______ $\frac{9.6}{2}$ = ______

The <u>SLOPE OF A STRAIGHT LINE</u> = $\frac{\text{VERTICAL DISPLACEMENT}}{\text{HORIZONTAL DISPLACEMENT}}$



<u>EXAMPLE</u>

The Slope of the line <u>AB</u>. = $\frac{\text{Vertical Displacement from A to B}}{\text{Horizontal Displacement from A to B}}$

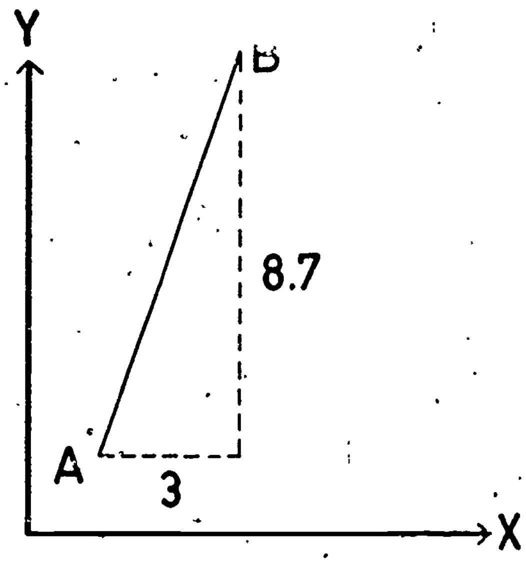
$= \frac{Y(AB)}{X(AB)}$

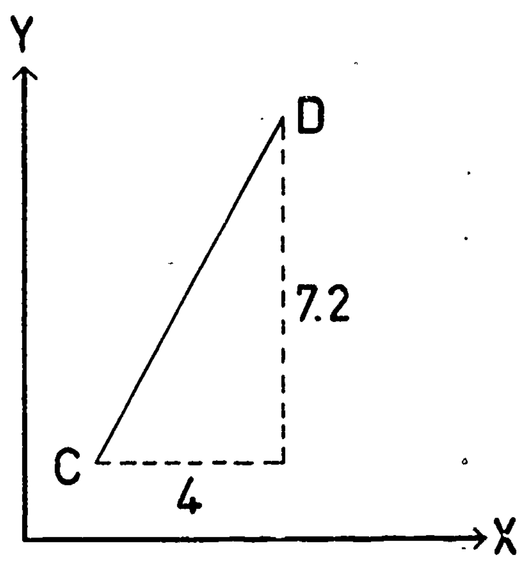
$= \frac{5.7}{3}$

= <u>1.9</u>

Calculate the Slope of the line AB.

ANSWER Slope = ____





Calculate the Slope of the line CD.

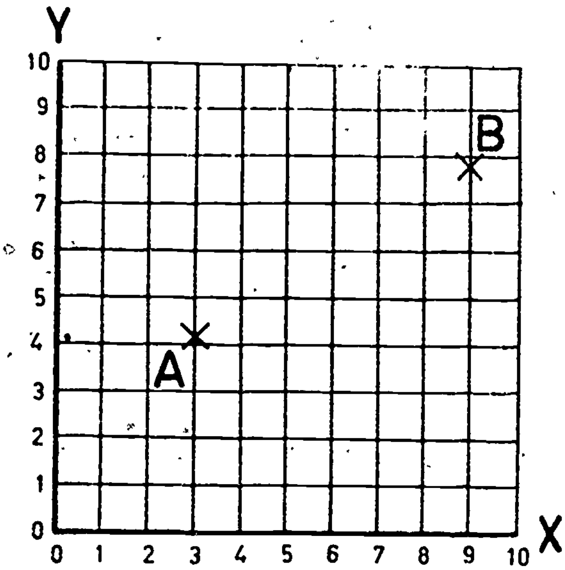
ANSWER Slope = ____

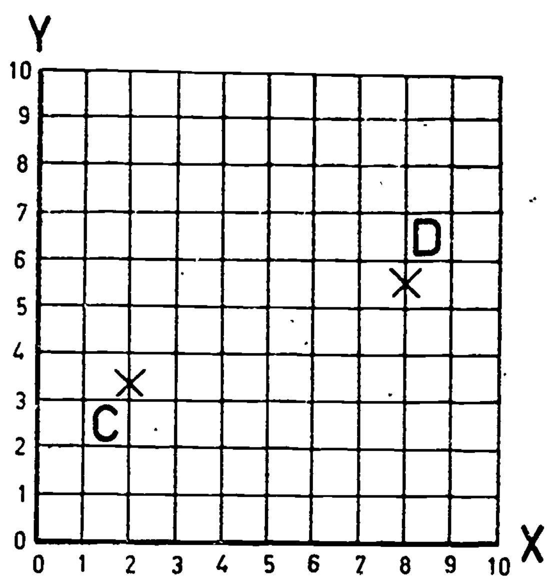
Calculate the Horizontal Displacement from A to B.

ANSWER X(AB) = ____

Calculate the Vertical Displacement from A to B.

ANSWER Y(AB) = ____





Calculate the Horizontal Displacement from C to D.

ANSWER X(CD) = ____

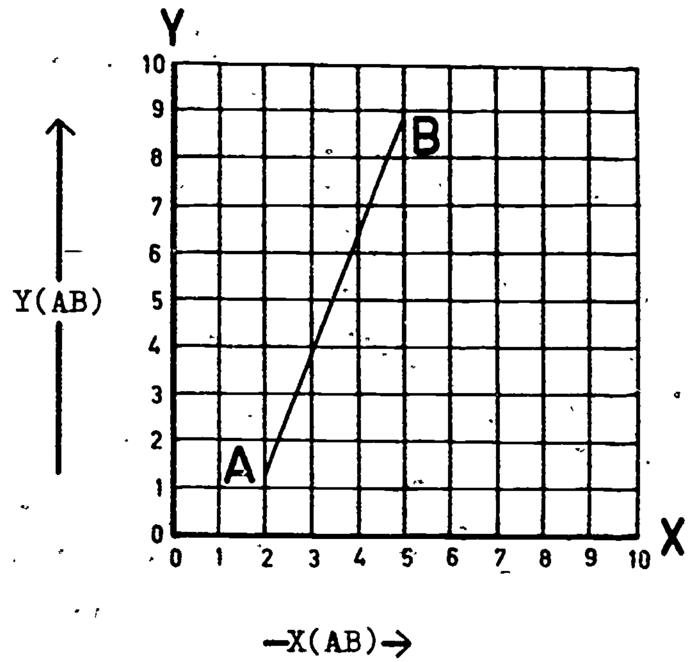
Calculate the Vertical Displacement from C to D.

ANSWER Y(CD) = ____

In order to calculate the SLOPE OF A STRAIGHT LINE from a graph, follow the method described in the example below.

EXAMPLE

Calculate the slope of the line AB.



METHOD

(1) Calculate the Horizontal Displacement (X(AB) = 3.0) and the Vertical Displacement (Y(AB) = 7.5) from A to B, as shown on the graph above.

(2) Use these figures to calculate the Slope of the line AB, using the method shown on page 2/7.

ANSWER

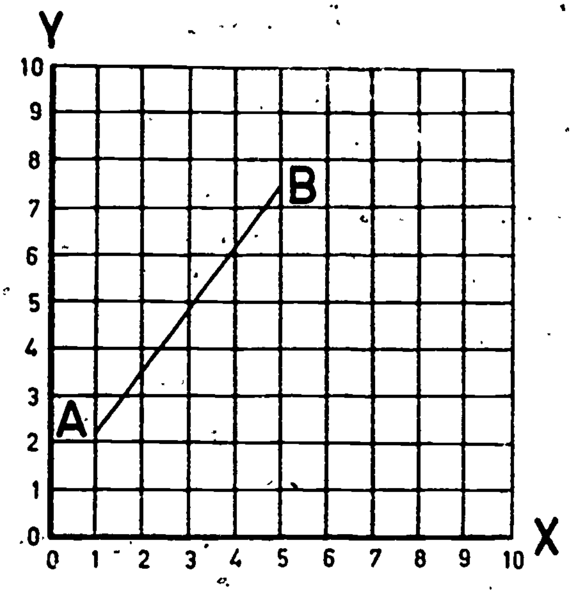
$$\text{Slope of the line AB} = \frac{Y(AB)}{X(AB)}$$

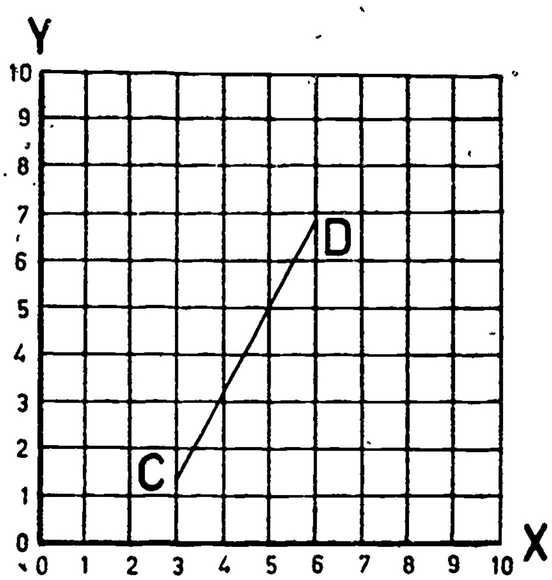
$$= \frac{7.5}{3.0}$$

$$= 2.5$$

Calculate the Slope of the line AB.

ANSWER Slope = ____



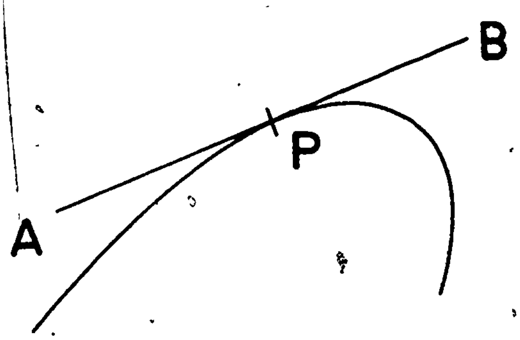


Calculate the Slope of the line CD.

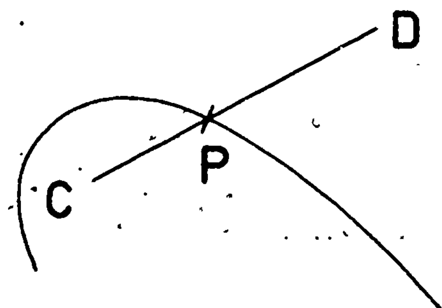
ANSWER Slope = ____

The TANGENT to a curve is a straight line which touches the curve at only one point, as shown in the example below.

EXAMPLE

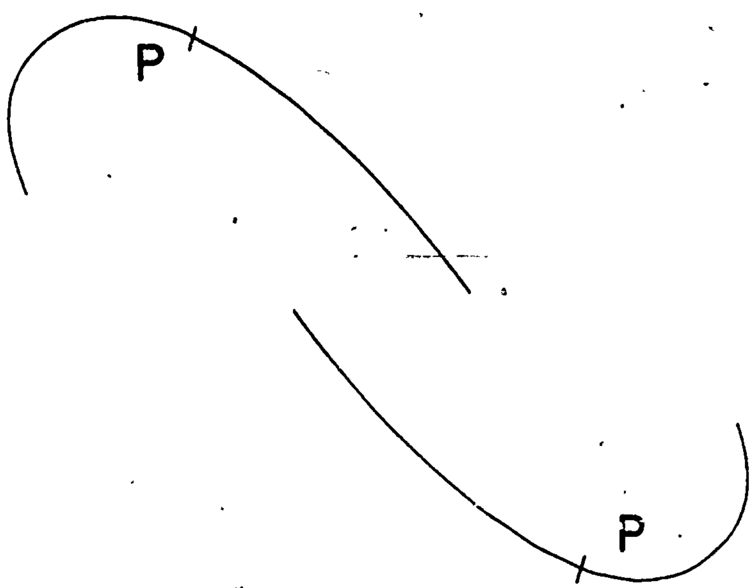


(1) The line AB is a Tangent to the curve, touching it at the point P.

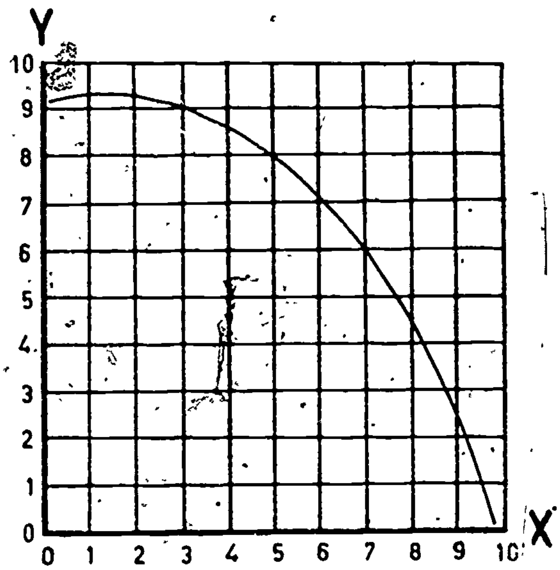


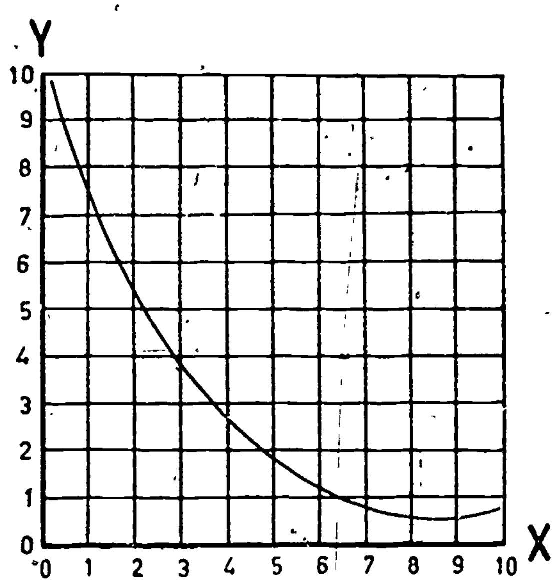
(2) The line CD is not a Tangent, since it cuts across the curve at P.

Rule a Tangent to each of the curves below at the point P.



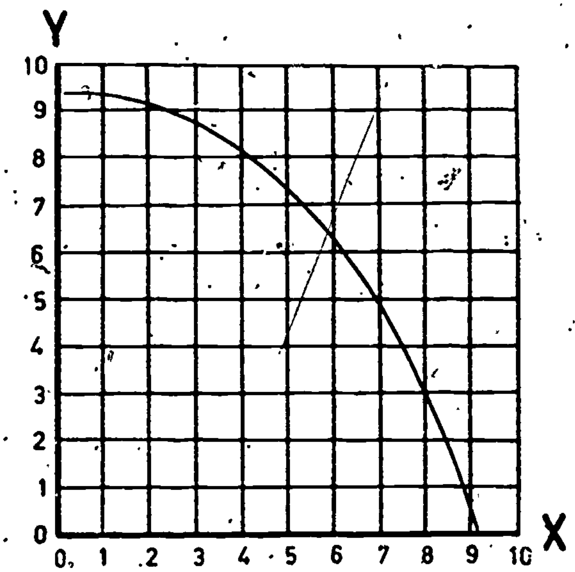
Mark the position of A on the curve, where X(A) = 8.0

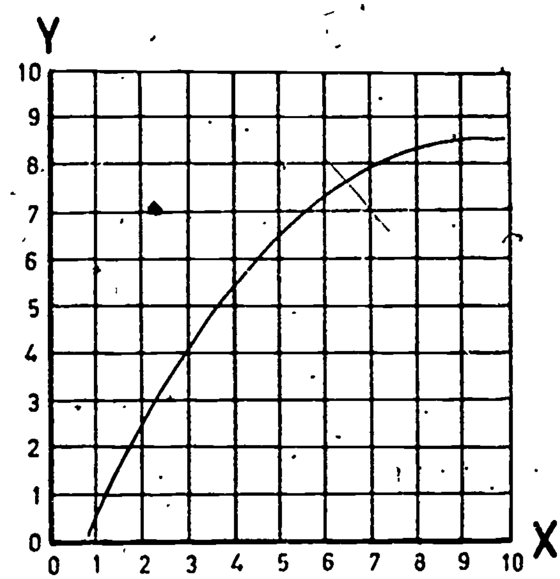




Mark the position of B on the curve, where X(B) = 4.0

Rule a Tangent to the curve at the point A where X(A) = 3.0

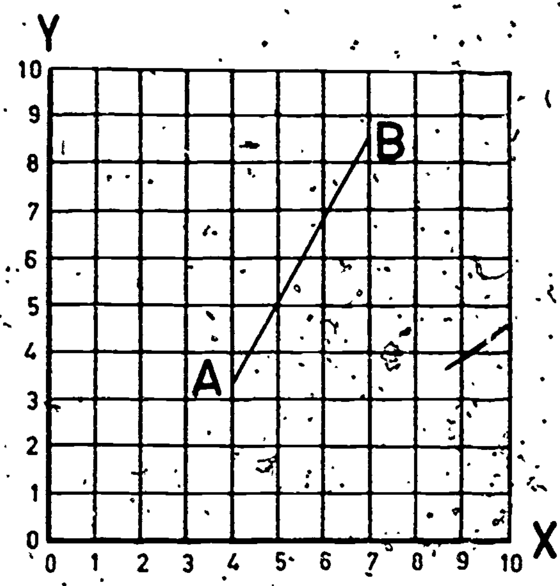


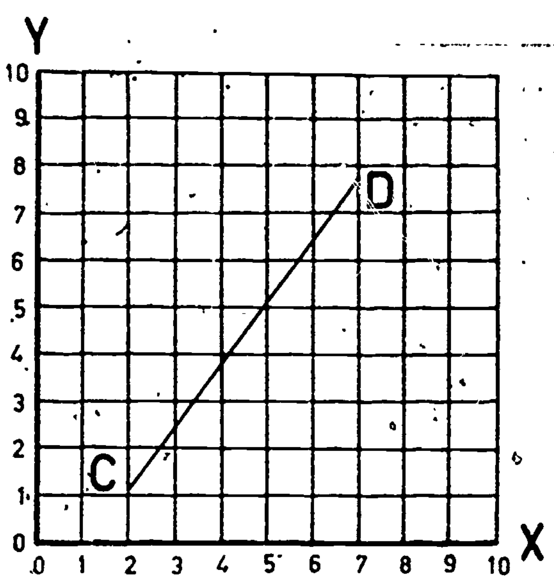


Rule a Tangent to the curve at the point B where X(B) = 6.0

Calculate the Slope of the line AB.

ANSWER Slope = ______

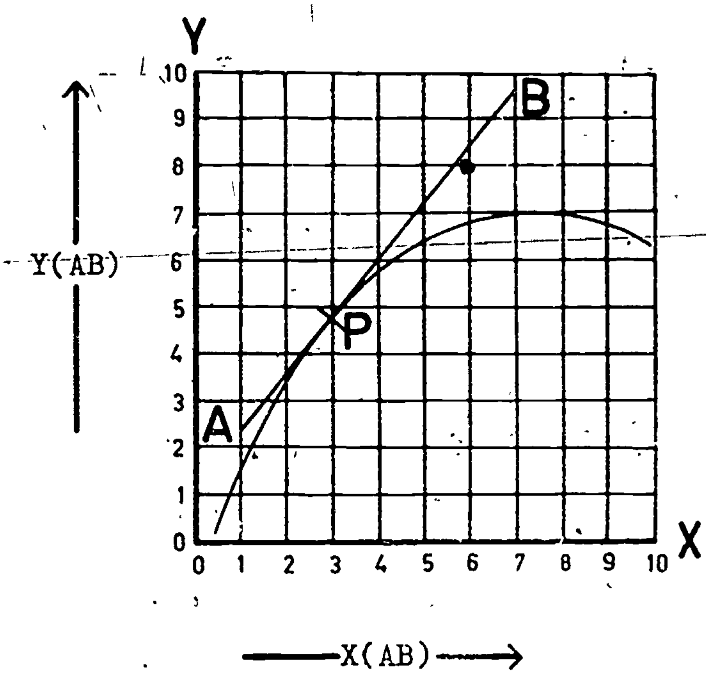




Calculate the Slope of the line CD.

ANSWER Slope = ______

The Tangent to a curve has the same slope as the curve at the point of contact. This means that we can now calculate the SLOPE OF A CURVE at any point, using the method described in the example below.



EXAMPLE

Calculate the Slope of the curve at the point P where X(P) = 3.0

METHOD

(1) Mark the point P on the curve where X(P) = 3.0

(2) Rule a Tangent to the curve at this point, so that the Horizontal position at each end of the Tangent is a whole number (as for points A and B on the graph above).

(3) Calculate the Slope of the Tangent AB using the method shown on page 2/10.

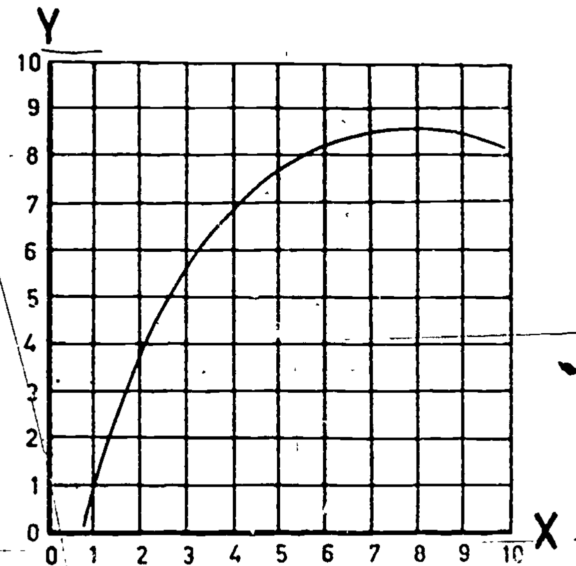
(4) This is the slope of the curve at the point P.

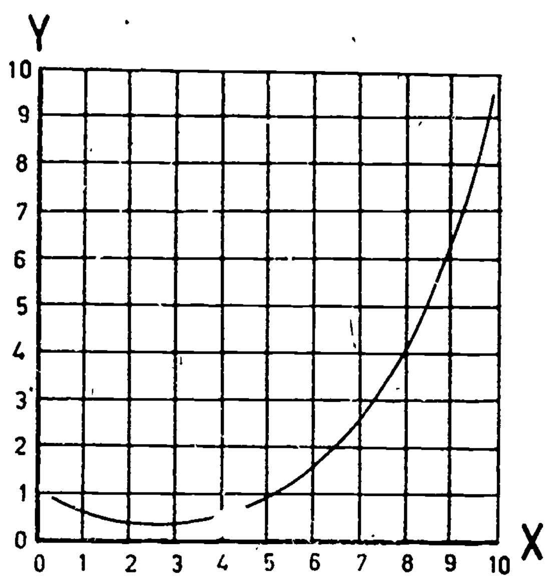
ANSWER

$$\text{Slope} = \frac{Y(AB)}{X(AB)} = \frac{9.6 - 2.4}{7.0 - 1.0} = \frac{7.2}{6.0} = \underline{1.2}$$

Calculate the Slope of the curve at the point A where X(A) = 2.0

ANSWER Slope = ______





Calculate the Slope of the curve at the point B where X(B) = 7.0

ANSWER Slope = ______

BASIC SKILLS OF GRAPHICAL INTERPRETATION

PROGRAMME III SECTION 3

NAME ______________ AGE ______ ______

(years) (months)

SEX ______

SCHOOL ______________ CLASS ______________

DATE ______

INSTRUCTIONS

As you work through this programme, read each question carefully, then write your answer in the space provided. Any other calculations should be written on the BACK of the page. If you are not sure of the answer to a question, take a guess and go on to the next example. Every answer should be given to the nearest decimal place.

Complete the following calculations :-

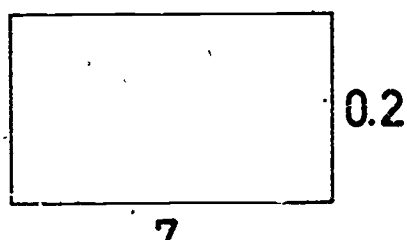
8 x 0.2 = ______ 3 x 0.5 = ______

37 x 0.4 = ______ 29 x 0.5 = ______

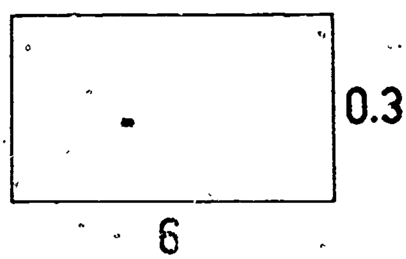
Now we can use the following formula to calculate the <u>AREA</u> of any <u>Rectangle</u> or <u>Square</u>.

<u>AREA</u> = <u>LENGTH</u> x <u>HEIGHT</u>

Use this formula to calculate the Area of the following figures.



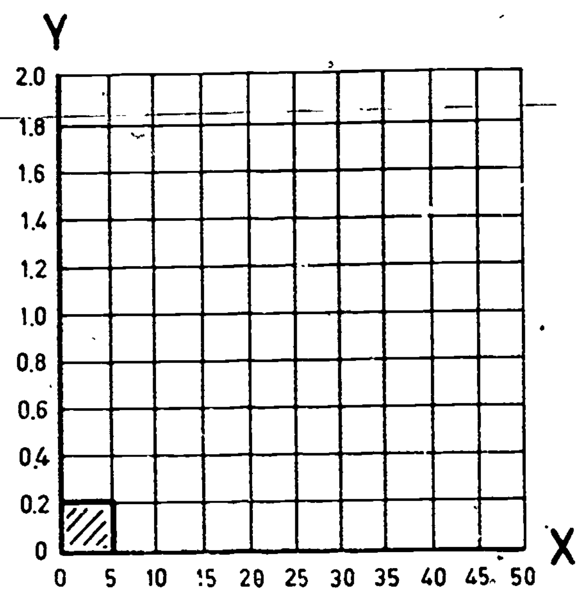
<u>ANSWER</u> Area = ______



<u>ANSWER</u> Area = ______

The same formula can also be used to calculate the AREA OF A GRAPH, or of any square section of a graph.

Now each graph is made up of many small Blocks, each of the same size, and the AREA OF EACH BLOCK is given by the formula Area = Length x Height , as shown on page 3/1.



EXAMPLE

Calculate the Area of a single Block on this graph.

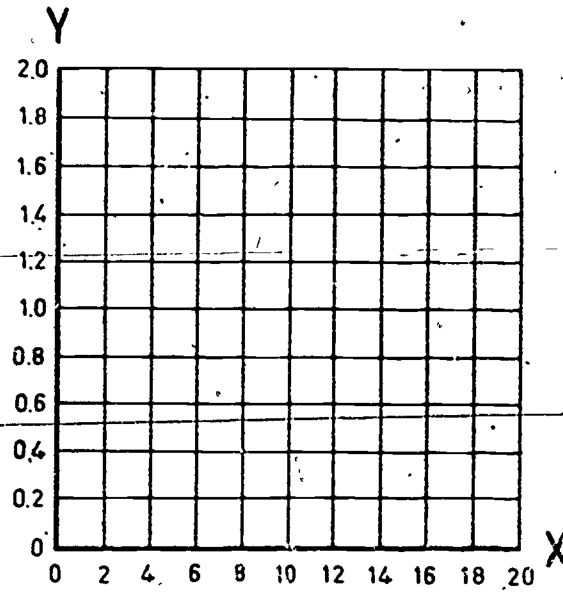
The LENGTH of each block is shown on the Horizontal Axis, and the HEIGHT is shown on the Vertical Axis.

In this example, the Area of a single Block on the graph = Length x Height

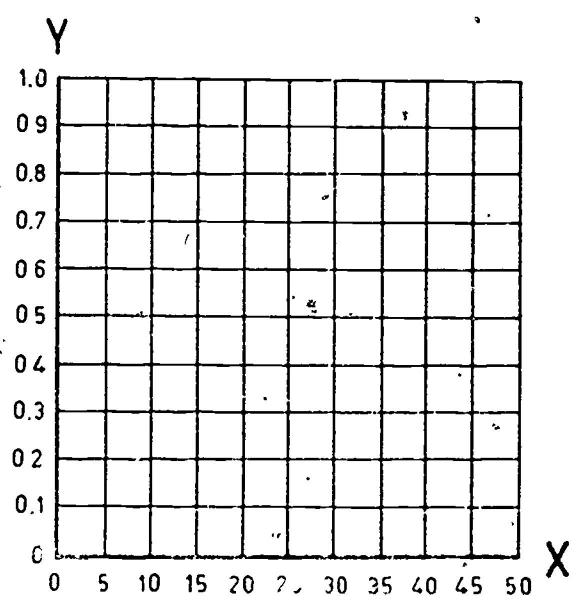
= 5 x 0.2

= 1.0

Calculate the Area of a single Block on this graph.



ANSWER Area = ______

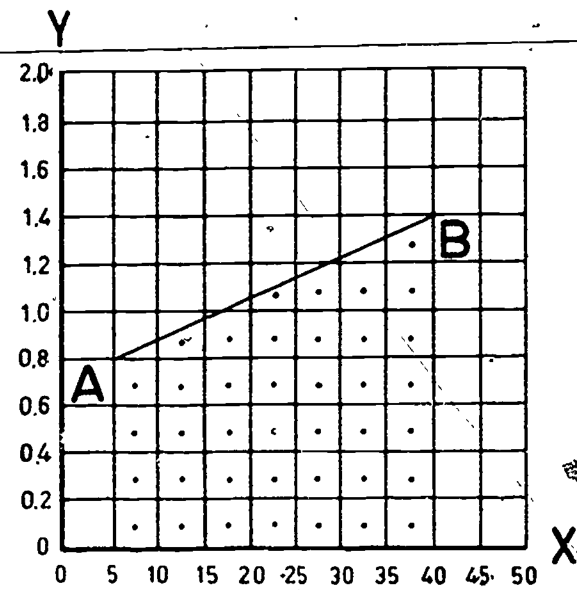


Calculate the Area of a single Block on this graph.

ANSWER Area = ______

Now we can calculate the <u>AREA OF ANY SECTION OF A GRAPH</u>, by counting the number of blocks in the section and using the following formula :-

The <u>TOTAL AREA</u> of any Section = Area of a single Block. x Total Number of Blocks in the Section.



<u>EXAMPLE</u>

Calculate the Area below the line <u>AB</u> on this graph.

<u>METHOD</u>

(1) Calculate the Area of a single Block on the graph.

(2) Count the total number of Blocks in the section - each block to be counted is marked with a dot (·) on the graph above.

(3) Calculate the Total Area of this section, using the formula shown above.

(example continued on page 3/5)

EXAMPLE (Continued from page 3/4)

Some of the blocks in the section to be counted from the graph on page 3/4 are cut by the line AB. In such a case, we use the following RULES FOR COUNTING :-

(a) If less than half of the block is included in the area we wish to calculate, then do not count that block.

(b) If half or more of the block is included in the area we wish to calculate, then count the whole block.

In this example, each block to be counted in the section is marked with a dot (•) on the graph (page 3/4).

ANSWER

The Area of a single block (as shown on page 3/2) = 5 x 0.2

= 1.0

The Total number of blocks in the section = 39.

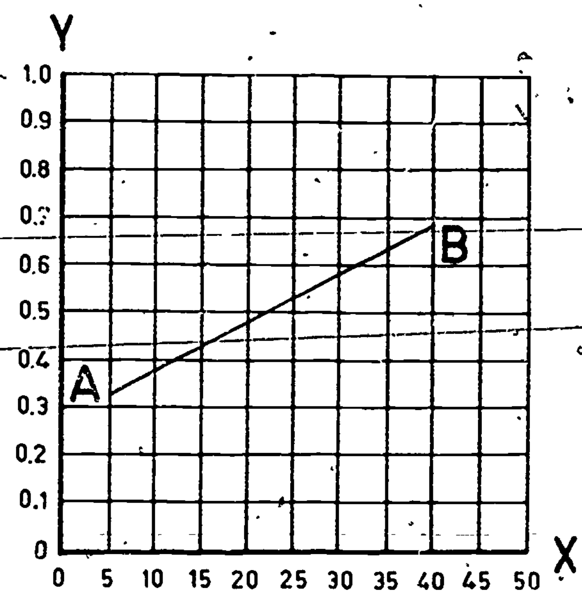
The Total Area of the section below AB = Area of a single block x Total number of blocks in the section

= 1.0 x 39

= 39.0

Calculate the Area of a single block on this graph.

ANSWER Area =



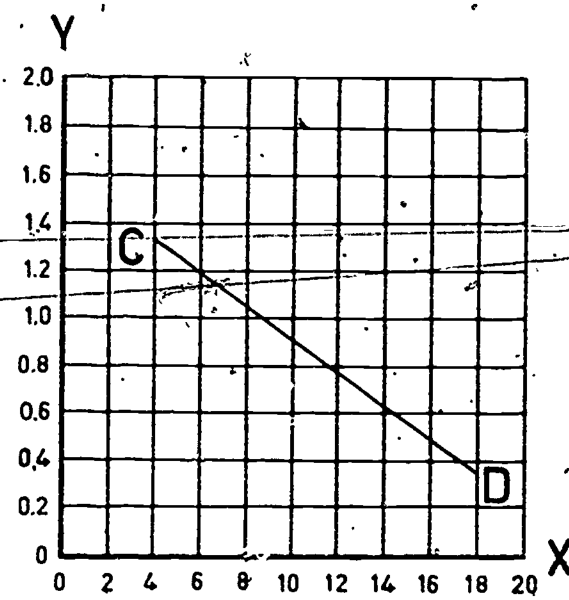
(1) Mark with a dot each block you would count to calculate the Area below the line AB on the graph above.

(2) Count the number of blocks you have marked.

ANSWER ______

(3) Calculate the Area of the section below the line AB on the graph above.

ANSWER Area = ______



Calculate the Area of a single block on this graph.

ANSWER Area = ______

(1) Mark with a dot each block you would count to calculate the area below the line CD on the graph above.

(2) Count the number of blocks you have marked.

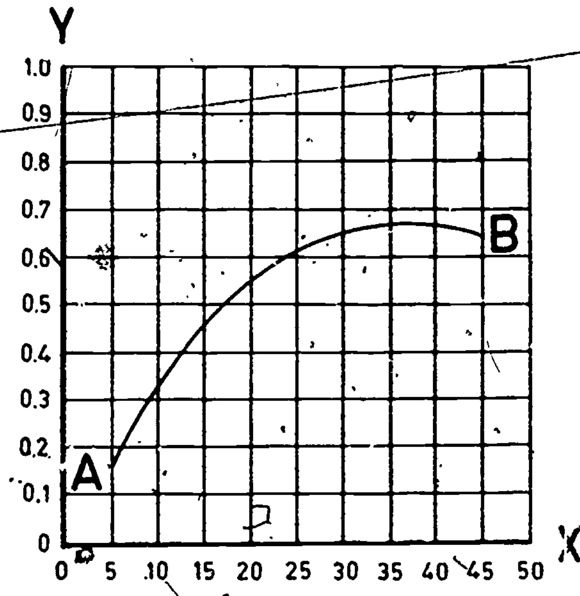
ANSWER ______

(3) Calculate the Area of the section below the line CD on the graph above.

ANSWER Area = ______

Calculate the Area of a single block on this graph.

ANSWER Area = ______



(1) Mark with a dot each block you would count to calculate the area below the curve AB on the graph above.

(2) Count the number of blocks you have marked.

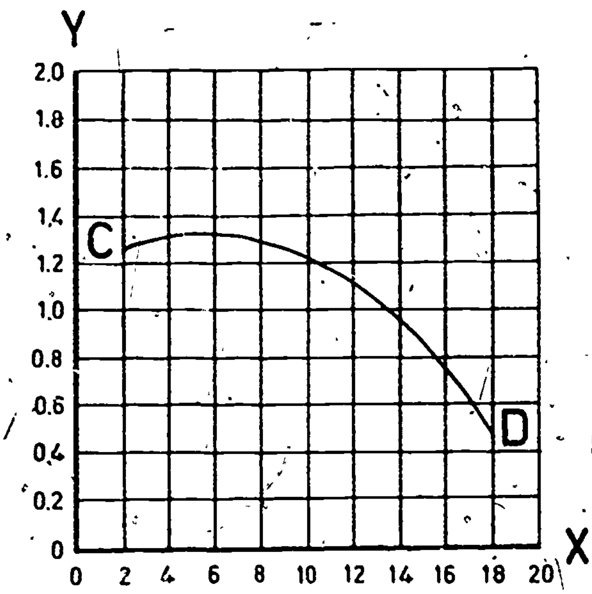
ANSWER ______

(3) Calculate the Area of the section below the curve AB on the graph above.

ANSWER Area = ______

Calculate the Area of a single block on this graph.

ANSWER Area = ______



(1) Mark with a dot each block you would count to calculate the area below the curve CD on the graph above.

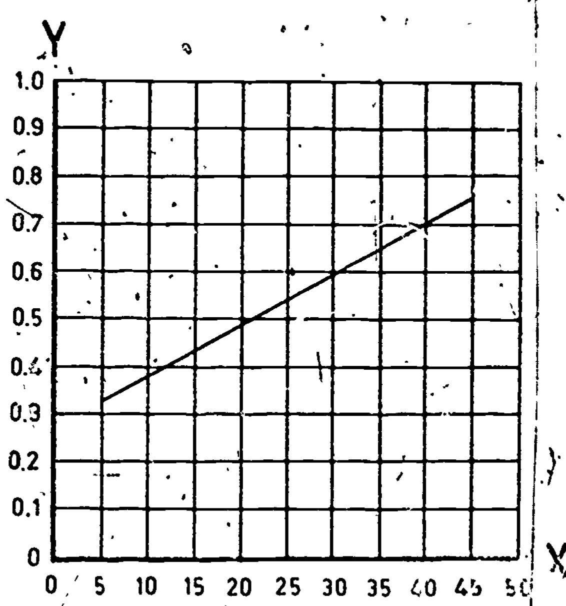
(2) Count the number of blocks you have marked.

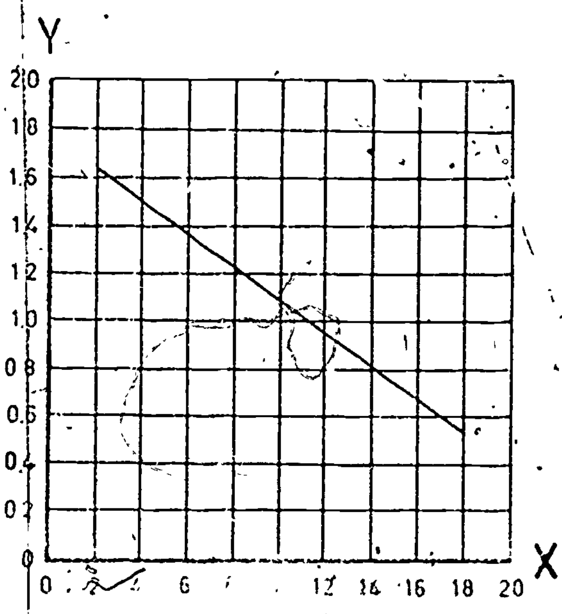
ANSWER ______

(3) Calculate the Area of the section below the curve CD on the graph above.

ANSWER Area = ______

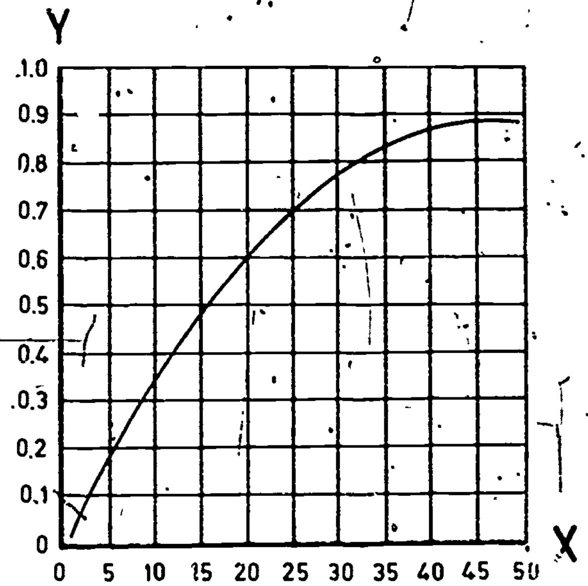
Mark the position of A on the line, where X(A) = 25

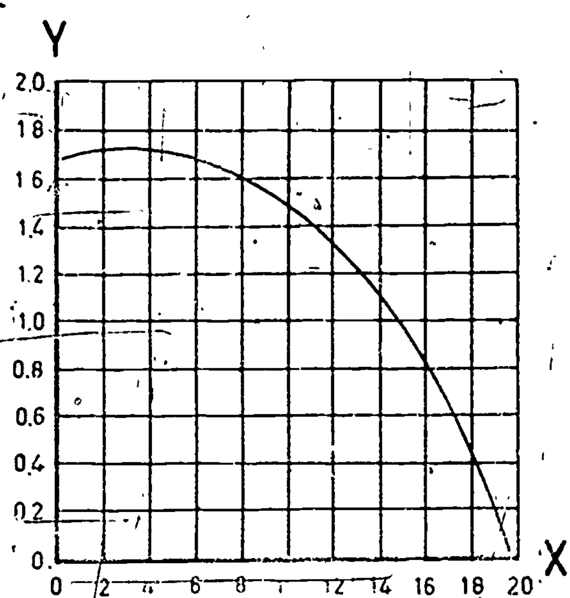




Mark the position of B on the line, where X(B) = 16

Mark the position of A on the curve, where X(A) = 35

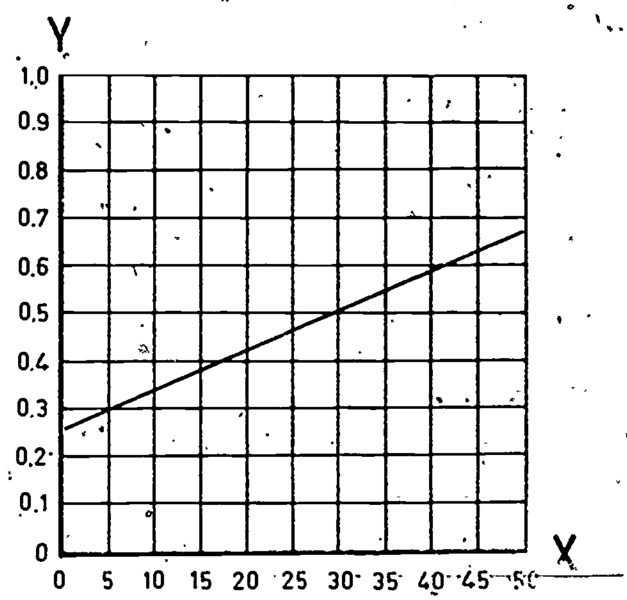


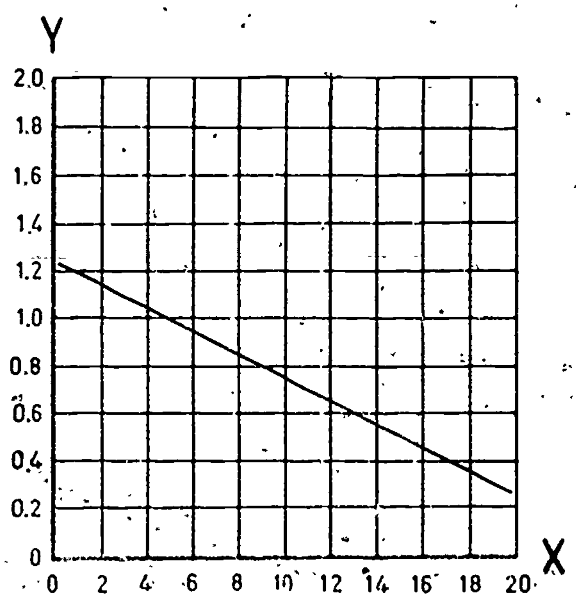


Mark the position of B on the curve, where X(B) = 12

Calculate the Area below the line in this graph from A to B where X(A) = 10 and X(B) = 45

ANSWER Area = ______



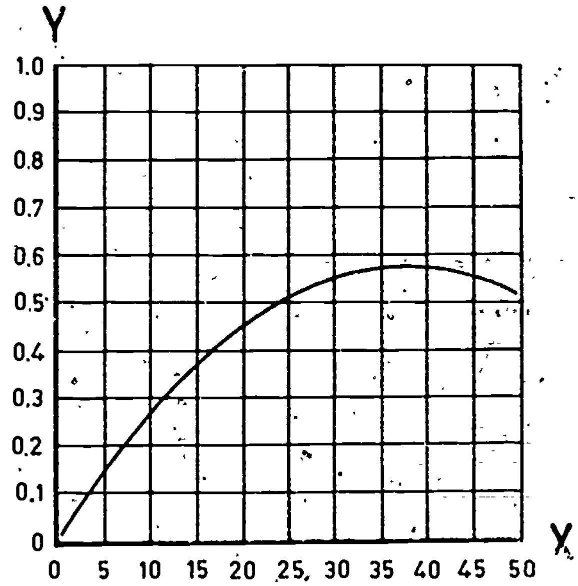


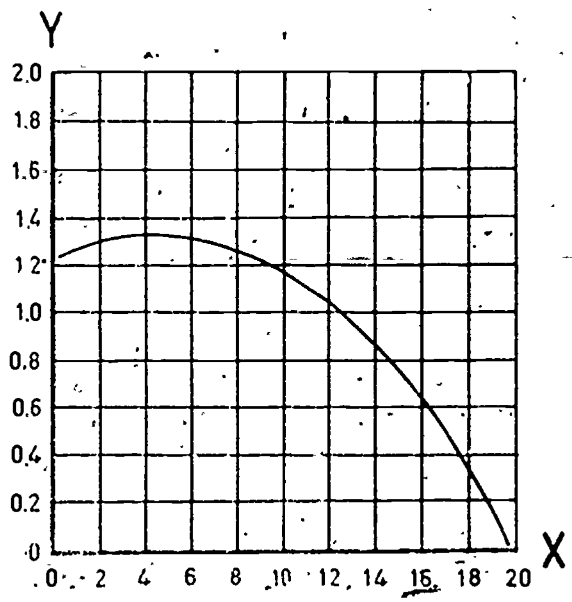
Calculate the Area below the line in this graph from C to D where X(C) = 2 and X(D) = 16

ANSWER Area = ______

Calculate the Area below the curve in this graph from A to B where X(A) = 15 and X(B) = 40

ANSWER Area = ______





Calculate the Area below the curve in this graph from C to D where X(C) = 4 and X(D) = 14

ANSWER Area = ______