ERIC REPORT RESUME

ED 010 025   9-02-66   56   (REV)

THE REPRESENTATIONAL ROLE OF DEMONSTRATIONS IN TEACHING CONCEPTS AND PRINCIPLES IN SCIENCE, STUDIES IN TELEVISED INSTRUCTION, AND DIMENSIONS OF VISUAL REPRESENTATION.

GROPPER, GEORGE L. * AND OTHERS
KTQ36350 METROPOLITAN PITTSBURGH EDUCATIONAL TELEVISION STATION, PA.
NDEA-VIIA-1072
ATA02486 AMERICAN INST. FOR RES. IN BEHAVIORAL SCIENCES

-FEB-66   OEG-7-48-7690-211
EDRS PRICE   MF-$0.27   HC-$6.60   165P.

*SCIENCE INSTRUCTION, *INSTRUCTIONAL IMPROVEMENT, *TELEVISED INSTRUCTION, *DEMONSTRATION PROGRAMS, *CONCEPT TEACHING, TEACHING TECHNIQUES, PERCEPTION, PITTSBURGH, PENNSYLVANIA

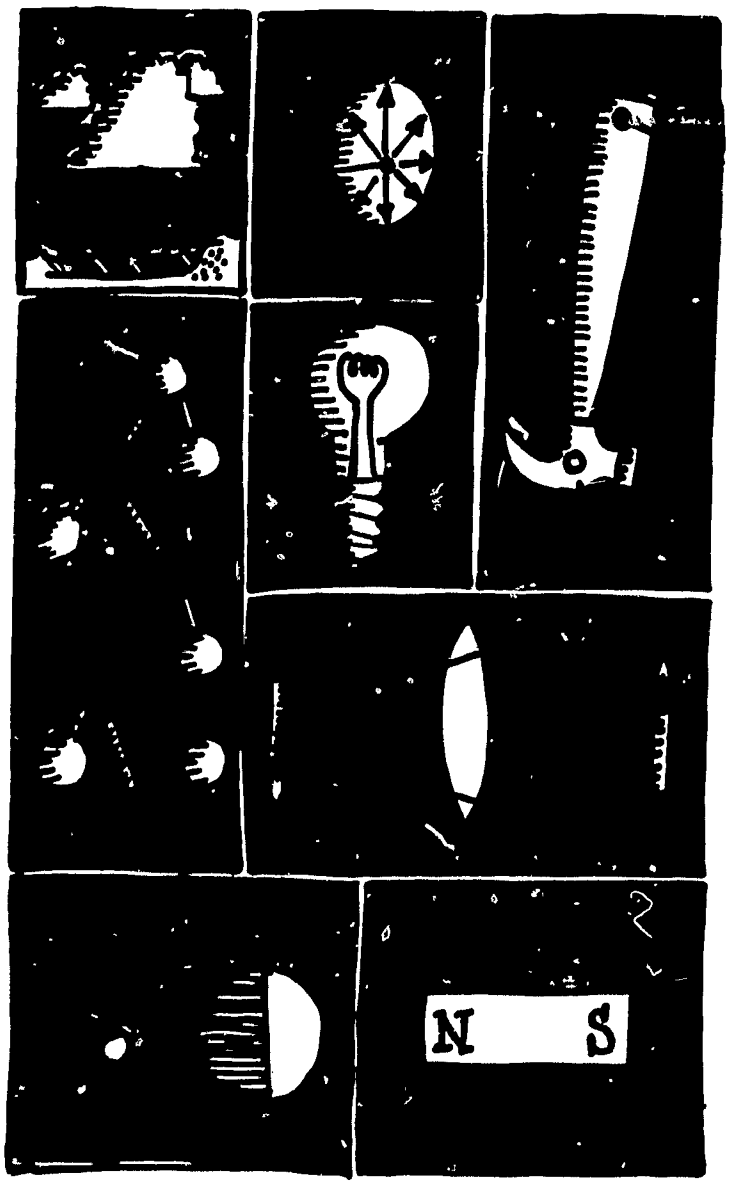
TWO STUDIES CONCERNED WITH THE REPRESENTATIONAL ROLE OF DEMONSTRATIONS IN TEACHING CONCEPTS AND PRINCIPLES OF SCIENCE ARE REPORTED. THE TWO STUDIES WERE PERFORMED WITH DIMENSIONS OF VISUAL TV PRESENTATIONS VARIED IN THE CONTEXT OF PROGRAMED LESSONS. STUDY ONE COMPARES THE EFFECTIVENESS OF REALISTIC (LIVE) WITH NONREALISTIC (ANIMATED) DEMONSTRATIONS UNDER INTUITIVE AND NONINTUITIVE CONDITIONS. TIME-TO-COMPLETE SELF-PLACED VERBAL PROGRAMS, ERRORS ON PROGRAMS AND ACHIEVEMENT TESTS, AND INTEREST AND CREDIBILITY MEASURES YIELDED COMPARATIVE DATA. THE DATA SUGGEST THAT NONINTUITIVE OUTCOMES MAY HAVE LESS CAPACITY FOR CONFIRMING STUDENT PREDICTIONS OF EXPERIMENTAL OUTCOMES THAN INTUITIVE OUTCOMES. DIFFERENCES BETWEEN INTUITIVE AND NONINTUITIVE DEMONSTRATIONS WERE SIGNIFICANTLY AFFECTED BY THE MODE OF PRESENTATION. RESULTS SUGGEST REALISTIC AND UNREALISTIC PRESENTATIONS MAY HAVE THE CAPACITY TO REINFORCE ATTENDING BEHAVIORS. THE CAPACITY APPEARS TO DEPEND ON THE DEGREE OF INTUITIVENESS OF THE PHENOMENA DEMONSTRATED. STUDY TWO COMPARED THE EFFECTS OF DIRECT AND INDIRECT EXAMPLES. THE STUDY WAS CONCERNED WITH THREE PROPERTIES OF THE EXAMPLES--CONVERGENCE OR DIVERGENCE OF STRUCTURAL AND FUNCTIONAL CHARACTERISTICS, THE DEGREE OF INTERNAL SIMILARITY AMONG EXAMPLES WITHIN A SERIES OF EXAMPLES ILLUSTRATING A CONCEPT, AND THE AVAILABILITY OF MEDIATING VERBAL RESPONSES. FEW STATISTICALLY SIGNIFICANT DIFFERENCES WERE OBTAINED. (WN)

1072

Studies in Televised Instruction

Dimensions of Visual Representation

THE REPRESENTATIONAL ROLE OF DEMONSTRATIONS IN TEACHING CONCEPTS AND PRINCIPLES IN SCIENCE



George L. Gropper • Anita J. Czujko • Zita A. Glasgow • Margaret C. Samways

METROPOLITAN PITTSBURGH EDUCATIONAL TELEVISION STATION
and the AMERICAN INSTITUTES FOR RESEARCH

The research reported herein was conducted under the direction of George L. Gropper, Principal Investigator, and was supported by a grant from the U.S. Department of Health, Education, and Welfare Office of Education, Title VII, Project Number 1072, National Defense Education Act of 1958, Grant Number 7-48-7690-211

AIR-D72-2/66-FR

Studies in Televised Instruction

Dimensions of Visual Representation

THE REPRESENTATIONAL ROLE OF DEMONSTRATIONS IN TEACHING CONCEPTS AND PRINCIPLES IN SCIENCE

George L. Gropper
Anita J. Czujko
Zita A. Glasgow
Margaret C. Samways

February 1966

METROPOLITAN PITTSBURGH EDUCATIONAL TELEVISION STATION
and the AMERICAN INSTITUTES FOR RESEARCH

TABLE OF CONTENTS

FOREWORD

The present study was conducted under a grant from the U. S. Office of Education, grant number 7-48-7690-211, title VII-A of the National Defense Education Act of 1958. The proposal title was "An experimental investigation of visual representation in instruction."

Appreciation is due to Dr. Jerry G. Short for his review of the report.

George L. Gropper
Principal Investigator
February 1966

ABSTRACT

When concepts are taught in science, visuals can serve three key functions. They can function as cues, as reinforcement, or as examples. The two studies reported here were concerned with the effect two properties of visuals have on these functions in lessons designed to teach concepts. One property concerns the realism of visuals; the other the literalness with which they represent concepts.

<u>Study 1 - A comparison of live and animated demonstrations.</u>

Two separate lessons, one on Bernoulli's Principle and one on Archimedes' Principle, were programmed for eighth graders. For each lesson, live and animated versions of the visual demonstrations were prepared for television presentation. Each demonstration unit was serially intermixed with a self-paced verbal program covering the same concepts and principles. Dependent measures to contrast the live and animated versions of the visual demonstrations included: time-to-complete the self-paced verbal programs, achievement data based on the visual and verbal program, and questionnaire data concerning the interest value and credibility of demonstration outcomes.

No significant differences in achievement were found between the groups receiving realistic and non-realistic visual presentations. On time-to-complete the self-paced verbal program and on questionnaire items requiring students to indicate their level of interest in doing the experiments they had seen or to predict what the outcomes would be if they did them, there were significant differences between realistic and non-realistic treatment groups. But the direction of the difference depended on the intuitiveness or familiarity of the lesson content. The events illustrating balanced forces needed to understand Archimedes' Principle are highly intuitive. The events illustrating Bernoulli's Principle (e.g., candle flames bending <u>toward</u> moving air) are non-intuitive. While there were sizeable differences on questionnaire items between intuitive and non-intuitive demonstrations, the differences between realistic and non-realistic versions depended on (i.e., interacted with) the intuitiveness of the material. The most consistent interaction obtained appears to support the summary conclusion shown in the following figure:

	live	animated
<u>intuitive</u>	future interest in trying experiments	interest during presentation
<u>non-intuitive</u>	interest during presentation	future interest in trying experiments

Results were interpreted to mean that when the outcomes of experiments are intuitive, seeing them live results in more interest in wanting to try them than when they are seen in animation. Seeing them in animation, however, results in more immediate interest during the presentation. When outcomes are intuitive, it is animation per se that appears to have the capacity to reinforce attending behavior. The converse is true for non-intuitive demonstrations. A live version appears to be more immediately interesting. The live non-intuitive outcome appears to be better able to reinforce attending behavior during the presentation. Non-intuitive outcomes in animation result in greater interest in wanting to try the experiment for oneself later on. Because they are [illegible] less, animated, non-intuitive

outcomes may have a lessened capacity to provide confirmation for responses (student predictions). The general conclusion drawn from this study is that visual demonstrations serve equally well as examples (to facilitate concept acquisition) whether they are live or animated. The capacity of live or animated events to confirm responses (predictions or problem solutions) or to reinforce attending behavior depends on the intuitiveness of the events.

Study 2 - A comparison of direct and indirect examples.

Two separate lessons, one on "heat and molecular movement" and one on "surface tension" were programmed for eighth graders. Two versions of each visual lesson were prepared. In one version all the examples used directly illustrated the concept to be taught (e.g., liquid actually shrinking). In the second version all examples used indirectly illustrated the concept; that is, results or consequences were shown rather than the phenomena themselves (e.g., bristles of a brush clinging together when wet as a result of the tendency of liquids to shrink). The visual lessons were shown on TV and each demonstration unit was serially intermixed with a self-paced verbal program covering the same concepts and principles. Dependent measures used to contrast the effectiveness of the direct and indirect versions included: errors on both visual and verbal programs, time-to-complete the verbal program (that always followed a visual demonstration), and achievement results.

Significant differences in error rates were obtained between treatments, but, since the overall error rates were so low (less than ten per cent) it was concluded that the differences were of negligible practical importance. Generally, other differences obtained were not significant.

To account for these findings an analysis was made of the properties of visual examples that appear to influence their capacity to foster response generalization (concept acquisition). The properties identified included: (a) the convergence or divergence of the superficial, structural properties (physical characteristics) of examples and their functional (conceptual) characteristics; for direct examples they coincide; in indirect examples they diverge and for response generalization to occur to the functional properties, a connection must be established between the structural and functional properties; (this difference between direct and indirect suggests an important role for animation, namely, presenting directly (in animation) what is otherwise unobservable in nature and could only be represented indirectly through observable outcomes or effects); (b) the degree of similarity among examples; for response generalization to occur, students must be able to recognize the relevant similarities within a series of examples; and (c) availability of mediating verbal responses to the visual events; it is likely to be the case that by means of mediating verbal responses that relevant similarities among visual events are more easily recognized and the connection between structural and functional properties established; the more readily available such mediating responses are, the less difference, as between direct and indirect examples, one might expect to find in the case of response generalization.

The series of demonstrations used in this study, both direct and indirect, appear to have possessed a high degree of internal similarity. Mediating verbal responses to the visual examples are likely to have been at high strength. This may account for the negative findings of this study but since no measure of either variable was available, this cannot be stated with confidence. It does suggest, however, that, measures for such variables, although difficult to implement, are likely to be needed for further research on the role of visual examples in teaching concepts and principles.

GENERAL INTRODUCTION

The prospect that pictorial materials might have a unique and effective role to play in education has had a particularly seductive appeal for educators as well as audio-visual specialists. The enthusiastic conviction that a picture is worth a thousand words has however clearly outdistanced the research to demonstrate that it is so. And if it is indeed so, research results have failed to identify systematically how the maxim might be appropriately implemented. To paraphrase a perhaps less ancient saying (rather freely), what has been needed for some time is a little more research and a little less unsupported praise for pictures.

Looking at the research that has been done, it is easy to see, as reviewers Spaulding (1955) and Allen (1960) have pointed out, that the bulk of the research on pictorial illustrations has concerned itself with the preferences of children and adults for various types of pictures. Investigations by Bloomer (1960), Bou (1953), French (1952), Miller (1936), and Rudisill (1952) have been concerned with preferences for: pictures in color vs. in black and white; simple vs, complex drawings; photographs vs. line drawings; realistic vs. non-realistic drawings; and various combinations of the above dimensions. Rarely in studies of this kind is it made explicit what instructional outcomes are expected as a result of variations in these dimensions. Is color supposed to arouse interest or to facilitate understanding? Will particular responses be cued better by a realistic than by a non-realistic presentation? Unless it is made explicit what function pictures, in whichever guise, are expected to accomplish, it is unclear what the consequence of using an unpreferred type of picture rather than a preferred type would be or vice versa.

The implications that seem to underlie preference-research are that some types of pictures will be less successful in arousing interest or in holding attention or, perhaps, as a result of this effect less successful in generating understanding. Studies linking dimensions of pictures with interest, e.g., MacLean and Hazard (1953), or with measures of understanding, e.g., Fonseca and Bryant (1960), Rosenstein and Kanner, 1961, and Spaulding (1956) are few in number. Moreover, these studies as well as others in audio-visual areas, because they also fail to identify specific instructional roles for pictures, have produced results of limited generalizability for pictures.

Barriers to Generalizations about Research Results on Pictorial Presentations

In common with other research areas, generalization of results from research on pictorial presentations is contingent on such sampling considerations as the selection of: subjects, lesson topics, or learning tasks. There is the danger of results being specific to a particular age or reference groups, to a particular lesson or program, or to a particular kind of learning task. There is also the ever-present problem of how to generalize from a controlled laboratory study to more practical applications or from the instructional process in one global field study to another. As the review of such studies by Travers (1964) makes clear, research on pictorial materials has involved both laboratory type and field type studies. Thus, the familiar difficulties in generalizing are felt here too.

The problems of generalization across laboratory and field studies is not, however, simply a matter of precision of experimental control in the one and not in the other. While it is true that the more global, field studies (by definition) represent an amalgam of variables, controlled experiments can be done within their framework. What is required is the careful preparation of instructional materials so that it is possible to specify the precise instructional role each portion of a total lesson or audio-visual presentation is expected to play. Research can then focus on specific roles and on the capacity of specific dimensions of pictorial materials in fulfilling them.

Functions of Pictorial Materials

In response oriented versions of programmed instruction, one requirement in preparing each segment of an instructional sequence is the precise identification of stimuli under whose control responses are to be brought and how such response control is to be produced. Applied to audio-visual presentations the programming approach requires similar identification of the role, or roles, visuals will play in bringing about response control. Based on recent experience in programming science demonstrations, Gropper (1963; 1965a; 1966) has described various functions visuals can fulfill in bringing about response control. The two primary functions they can fulfill are as criterion or as intermediary stimuli. In the former case, they are the stimuli under whose control responses are to be brought. In the latter case, they already possess response control and are used, in an instrumental way, to cue responses so that control can be transferred to still other stimuli, generally verbal stimuli. Within this primary framework, visual or pictorial materials can be used to cue responses, to reinforce responses, or to serve as examples as a means of facilitating response generalization (that is, acquisition of concepts). For these various roles, it is sometimes possible to choose between words or pictures. In his most recent report, Gropper (1966) has suggested some instructional strategy considerations in opting for pictures. These include the facilitation of learning ease: (a) for students of lesser ability (either due to prior experience or age considerations); (b) for all students when material is particularly complex, and (c) for material presented early in the acquisition stage. In any of these situations, the greater ease of learning from pictures may be capitalized upon to meet the response readiness of the learner.

By specifying the functions visuals are to play at each and every segment of an instructional sequence(whether as contexts, or cues, or response options, or confirmation) it is possible to ascertain how well visuals serve those functions. Unlike global, end-of-lesson evaluations, identification of specific, localized functions can provide analytic and perhaps more generalizable answers to traditional research questions explored in audio-visual instruction. Thus, on the issue of, for example, color vs. black and white, an entire lesson in either form would not be compared on a global basis with a comparable lesson in the other form. While this is a legitimate approach to the problem, the results are likely to be relatively undifferentiated (as to why one form should be better than the other) and hence not as generalizable as one might wish. On the other hand, evidence that color stimuli or black and white stimuli serve well as cues or as confirmation at particular points in a lesson can produce more specific, analytic, and generalizable conclusions. By specifying functions visuals are expected to play, even an applied study can begin to approach the tightness of a laboratory study and as a result to make the process of generalizing easier.

Purpose of Present Study

Two studies were performed in which dimensions of visual presentation were varied in the context of programmed lessons. In this manner it was possible to contrast degrees of realism, in one study, and degrees of literalness of examples, in a second study, as to their capacity to fulfill specific functions in instruction.

1

STUDY NO.

AN EXPERIMENTAL EVALUATION OF THE RELATIVE EFFECTIVENESS OF REALISTIC AND NON-REALISTIC SCIENCE DEMONSTRATIONS

METHOD

The purpose of this study is two-fold: (1) to determine whether concepts and principles are learned as well from non-realistically presented examples (science demonstrations) as from the same examples presented realistically; and (2) to determine whether there are differential effects of a <u>confirmation</u> sequence presented either realistically or non-realistically. Stated as hypotheses: (1) there appears to be little theoretical ground to expect differential effects on concept acquisition contingent on the realism or non-realism of a series of demonstration examples; and (2) since the credibility of a realistically presented example is apt to be greater than for a non-realistically presented example, their confirmation value may be expected to differ.

Design of Experiment

<u>Independent variables</u>. - Two lessons were prepared for presentation on television; one covered Archimedes' Principle, the other Bernoulli's Principle. Each of the two lessons was prepared in two versions: a realistic version consisting of live (on TV tape), table-top demonstrations illustrating the concepts and principles to be learned; and a non-realistic version of the same demonstration presented in animation (transcribed to TV tape). Each lesson was segmented into several fixed-paced TV units, and units were serially intermixed with a verbal self-paced unit covering the same material as was covered in the preceding fixed-paced visual unit. This arrangement is summarized in Figure 1, on page 6.

The primary independent variable, as can be seen from the table, is the realism of the presentation. By using two lessons, a second variable was studied, the <u>intuitiveness</u> of the phenomena demonstrated. The relationship of balanced and unbalanced forces to motion (in preliminary explanation of Archimedes' Principle) is in keeping with the prior learning history of eighth grade students. Phenomena covered by Bernoulli's Principle (to be described below) are not. Thus, demonstrations in keeping with experience (intuitive) could be contrasted with those that are in conflict with or counter to experience (non-intuitive). It is recognized, of course, that while the comparison of realistic vs. non-realistic versions, based as they

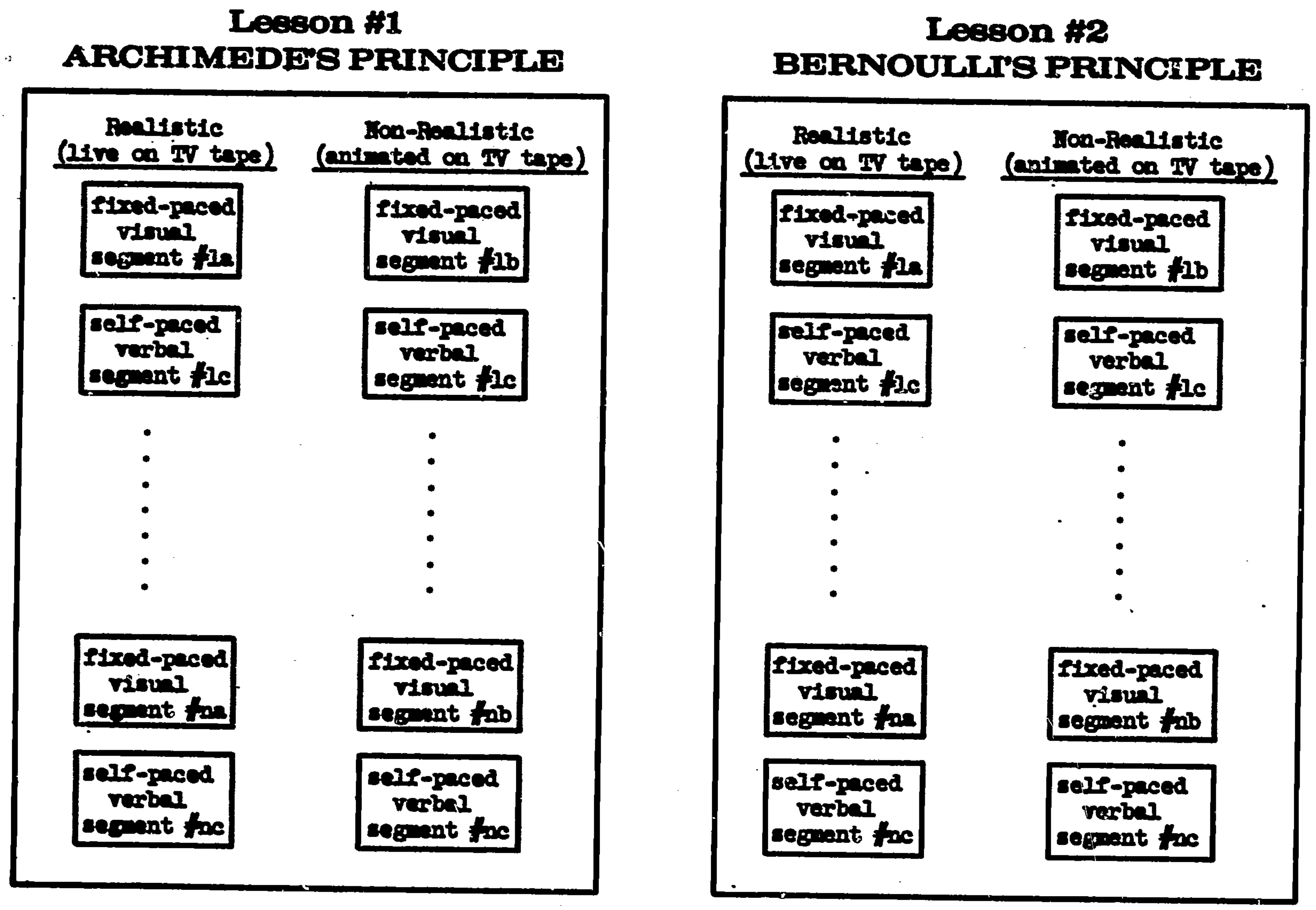

Lesson #1
ARCHIMEDE'S PRINCIPLE
Realistic (live on TV tape)
Non-Realistic (animated on TV tape)
fixed-paced visual segment #1a
fixed-paced visual segment #1b
self-paced verbal segment #1c
self-paced verbal segment #1c
fixed-paced visual segment #na
fixed-paced visual segment #nb
self-paced verbal segment #nc
self-paced verbal segment #nc
Lesson #2
BERNOULLI'S PRINCIPLE
Realistic (live on TV tape)
Non-Realistic (animated on TV tape)
fixed-paced visual segment #1a
fixed-paced visual segment #1b
self-paced verbal segment #1c
self-paced verbal segment #1c
fixed-paced visual segment #na
fixed-paced visual segment #nb
self-paced verbal segment #nc
self-paced verbal segment #nc

Figure 1

are on the same content, permits generalizations to be drawn, the comparison of intuitive vs. non-intuitive does not. The latter comparison is contingent on the particular lesson chosen and hence results are more limited as to their generalizability.

Independent variables and the design of the experiment may be summarized as follows:

Group I	Group II
realistic intuitive demonstration	non-realistic intuitive demonstration
non-realistic non-intuitive demonstration	realistic non-intuitive demonstration

Dependent variables. - Dependent variables consisted of such learning measures as time-to-complete self-paced verbal programs, errors on programs, and achievement tests. They also consisted of scores on attitude scales relating to the interest level and credibility of the demonstrations seen. (All of these measures will be described in more detail below.)

Procedures

The schedule that follows was adhered to by all participating classes, with minor variations in timing to allow for ongoing or previously scheduled activities in the schools.

Week 1 - in the schools:

(1) Administration of pretests.
(2) Administration of a program on "Learning From a Program."

Week 2 - in the schools:

(1) Administration of a preliminary program on "Force and Motion" (concepts necessary to an understanding of the experimental programs).

Week 4 - in the studios of WQED:

(1) Simultaneous administration of two versions of each experimental program on TV tape: (a) balanced forces and Archimedes' Principle; and Bernoulli's Principle.

(2) Administration of the identical self-paced verbal programs on the same topics serially intermixed with portions of the TV presentation.

(3) Administration of an immediate posttest and a questionnaire.

Week 6 - in the schools:

(1) Administration of a retention test (identical with the original test).

Experimental Materials

Instructional materials developed for this study included two pre-experimental programs administered in the schools and two experimental programs administered over closed-circuit TV in the studios of WQED and (simultaneously) in a banquet room of an adjacent hotel.

Pre-experimental materials. - The two programs administered before the conduct of the main experiment were designed to fulfill two different functions. One, entitled "Learning From a Program" was designed, as its title suggests, to familiarize participating subjects with the mechanics of going through a program and of profiting from a program. The program tries to encourage students to produce a response before looking at the confirmation frame or, stated less delicately, not to cheat. This program is reproduced in Appendix A, page 44. The second pre-experimental program deals with concepts of "force" and "motion" both of which are necessary prior concepts for understanding the content of the main experimental programs. Thus, in addition to providing extra familiarization with "programs," the program served to bring participating subjects up to a common level of prior knowledge. The "force and motion" program is reproduced in Appendix A, page 49.

Both preliminary programs, as well as both self-paced verbal programs used in the main experiment, were prepared in the REP style of programming developed by Gropper (1965b). Briefly, this type of program requires the production or construction of responses only after the student has edited lesson material (leaving key sections of lessons unchanged if they are correct or changing them if they are incorrect). Editing responses in turn are required only after recognition responses are made. The sequence recognition, editing, and production is designed to match the response readiness of the learner at different stages of learning. Other features of this style of programming (some of which are held in common with other styles of programming) are: the acquisition of discriminations through the selection of multiple-choice options; the acquisition of generalizations through multiple and varied examples; the use of make-up-a-sentence type production frames in which students may be expected to produce elements of stimulus contexts, responses, or both; and the requirement of long, complex, verbal responses. A fuller description of the rationale for this style of programming is presented in programmed form in the citation made above (Gropper, 1965b).

Main experimental materials. - Two lessons were prepared for study, one on Bernoulli's Principle, the other on balanced forces and their application to Archimedes' Principle. Each lesson consisted of individual segments made up of fixed-paced demonstrations serially intermixed with self-paced verbal materials. Each demonstration segment and the self-paced, verbal segment that followed it covered the same concepts and principles. The demonstration segments, prepared for showing on TV, were designed to teach concepts and principles through discrimination practice with concrete events. Words used during the demonstration only described the events (in concrete terms) and did not explain them. The concept of balanced forces, for example, was acquired by students as they practiced making discriminations about the alternative consequences of attaching an equal or unequal number of weights to a model truck that moved on a fixed platform. Or, in the lesson on Bernoulli's Principle, students practiced making discriminations about alternative effects of moving air or still air on candle flames, paper held in a horizontal position, etc. Not only were the stimulus materials (examples) that were used for concept acquisition concrete, but response options were also concrete, i. e., pictorial options rather than words. Response booklets containing the pictorial options for both programs appear in Appendix A, starting on pages 22 and 26. This style of programming was developed by Gropper (1965a). Both verbal programs are reproduced in their entirety in Appendix A, starting on pages 1 and 12.

The demonstration segments of the two lessons were prepared in two forms. The live version was reproduced on TV tape in the studios of WQED. An animated version using the identical sound track was also prepared. With a kinescope of the taped version at hand, the animated version was designed to reproduce in as non-stylized fashion as possible the same demonstrations (containing as nearly as possible the same amount of complexity of stimulus materials).

Before the demonstrations were recorded on TV tape, they were tried out live with subjects taken from the target population (the eighth grade). They were revised until error rates (on visual answer booklets were low, approximately 10 per cent). Verbal programs were also tried out and revised in similar fashion.

Dependent Measures

The achievement tests and the questionnaire forms used in this study are reproduced in Appendix A, starting on pages 29, 31, and 34. The dependent measure, time-to-complete the self-paced materials was obtained for each verbal segment by proctors who monitored students' work. The ensuing fixed-paced demonstration did not begin until all students completed the self-paced programs.

Subjects

Three eighth grade classes participated in this study, two from a Pittsburgh Parochial School and one from a Pittsburgh City School. Students from each class were assigned at random to each of the two treatment conditions.

RESULTS

Matching Measures

At the completion of the experiment, students who had been assigned at random to experimental treatments were matched for IQ and Work Rate on pre-experimental programs. Only matched cases were selected for the analysis of data, so that the variables IQ and Work Rate could be treated as independent variables, each at two levels. There resulted a 2x2x2 design for data analysis, representing two levels each of IQ and Work Rate and the two experimentally manipulated conditions (live vs. animated presentations). The results of the matching procedure are summarized in Table 1, which is based on seven cases per cell, for a total of 56 cases.

Table 1

Results of Procedures for
Matching Subjects Across Conditions^{+}

		GROUP 1			GROUP 2		
		Animated: Bernoulli's Principle Live: Archimedes' Principle			Live: Bernoulli's Principle Animated: Archimedes' Principle		
		IQ	Pretest	Work Rate^{++}	IQ	Pretest	Work Rate^{++}
HI IQ	Fast	121	10	27	120	9	26
	Slow	121	9	22	120	9	22
LO IQ	Fast	107	7	27	109	6	26
	Slow	108	8	22	109	7	22

$^{+}$results reported as means; $^{++}$time-to-complete in minutes

It shows that there was a separation of approximately 11 IQ points between high and low IQ groups. This difference was statistically significant at the .001 level, as shown in Table 1 in Appendix A, page 56. Table 1, both in the text and in the Appendix also, shows that there was not a significant difference in IQ either between experimental treatments or between Work Rate levels. Similar results can be found in text Table 1 for Work Rate and in Appendix Table 2. Fast and slow levels were significantly different on Work Rate at the .001 level. No significant differences were found for Work Rate between the remaining cells of the design. Table 1 also records

Pretest scores for each of the eight experimental cells. Appendix Table 2 records, as might be expected in advance, a significant difference in Pretest scores between high and low IQ levels. Differences in Pretest scores between other cells were not significant.

Dependent Measures

The results of this study are organized and reported under several headings. Each heading will concern either a measure of achievement or a measure obtained from the questionnaire administered after both lessons were presented.

A. Achievement Measures

(1) recall of demonstration outcomes. - At the conclusion of the two lessons (on Bernoulli's Principle and Archimedes' Principle) a questionnaire was distributed to each subject (reproduced in its entirety in Appendix A, starting on page 34). Five questions were asked about each of ten demonstrations. Each of the five questions appeared on a form labeled A, B, C, D, and E. Form B required the subject to indicate what the outcome was for each of ten demonstrations he had seen. The stem was presented in pictorial terms and the options (possible outcomes) were also presented in pictorial form as illustrated in Figure 2 below.

Which way did each of the following experiments turn out? Put an X next to the picture which shows which way it turned out.

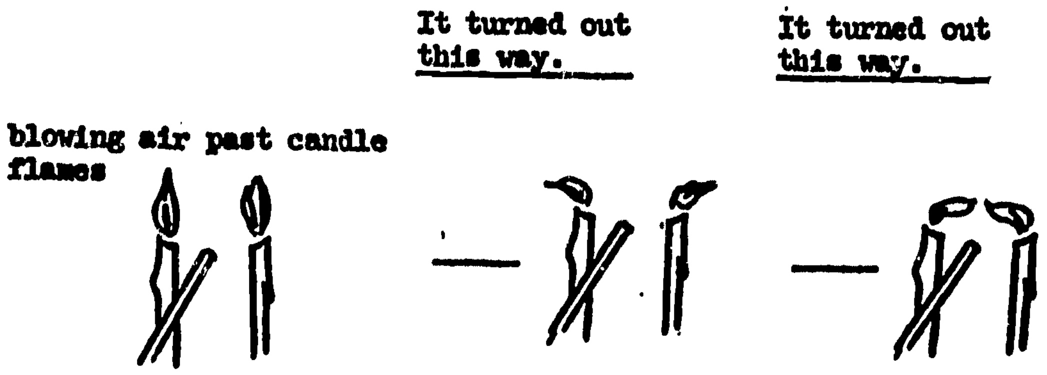


Fig. 2. Sample item from Form B of the questionnaire administered to participating subjects.

Table 2, containing results obtained from Form B, contrasts the realistic and non-realistic versions of the same demonstration. This comparison is made separately for the intuitive and non-intuitive demonstrations. As can be noted in the table, for neither the intuitive nor the non-intuitive demonstrations was there a significant difference between realistic and non-realistic versions in the percentage of correctly recalled outcomes. In general, 95 per cent of all demonstration outcomes were correctly recalled.

Table 2

Percentages of Correctly Recalled Outcomes for
Realistic and Non-Realistic Versions of Demonstrations

		Intuitive Demonstrations		Non-Intuitive Demonstrations	
	all demonstrations	realistic	non-realistic	realistic	non-realistic
correct	95%	92%	94%	97%	99%
incorrect	5%	8%	6%	3%	1%
	100%	100%	100%	100%	100%
# of responses	650	140	185	185	140
		X^2=.2, df=1, .10 > P>.50		X^2=2.3, df=1, .20 > P>.10	

Table 3 regroups the data of Table 2 in order to compare the intuitive and non-intuitive demonstrations. This comparison is made separately for the realistic and non-realistic versions. In both versions, the outcomes of the non-intuitive demonstrations were recalled correctly more often the the outcomes of the intuitive. The differences between intuitive and non-intuitive outcomes, although small, were statistically significant in both analyses as summarized in Table 3, page 14.

Table 3

Percentages of Correctly Recalled Outcomes for Intuitive and Non-Intuitive Demonstrations

	all demonstrations	Realistic Demonstrations		Non-Realistic Demonstrations	
		intuitive	non-intuitive	intuitive	non-intuitive
correct	95%	92%	97%	94%	99%
incorrect	5%	8%	3%	6%	1%
	100%	100%	100%	100%	100%
# of responses	650	140	185	185	140
		X^2=4.1, df=1, .05 > P > .02		X^2=8.1, df=1, P < .01	

(2) achievement test results. - Achievement test results parallel those just described for recall of demonstration outcomes. Although there are differences between means for realistic and non-realistic treatments, as shown in Table 4, for neither the intuitive nor the non-intuitive demonstrations were these differences significant. Complete analysis of variance results for these comparisons are presented in Tables 4 to 7 in Appendix A.

Table 4

Immediate and Delayed Achievement Test Scores for each of Two Lessons Presented both Realistically and Non-Realistically

	Intuitive Archimedes' Principle$^+$				Non-Intuitive Bernoulli's Principle^{++}			
	Immediate Test		Delayed Test		Immediate Test		Delayed Test	
	Mean	S. D.	Mean	S. D.	Mean	S. D.	Mean	S. D.
realistic	15.8	(2.0)	13.9	(2.6)	10.3	(5.0)	7.9	(5.7)
non-realistic	14.3	(3.8)	13.4	(3.6)	12.4	(4.7)	9.7	(5.7)
analysis of differences	F=3.79 df=1/48		F=.4 df=1/48		F=2.7 df=1/48		F=1.7 df=1/48	

$^+$total possible points = 24; $^{++}$total possible points = 22

(3) work rate. - Following an intuitive or a non-intuitive demonstration segment presented either in realistic or non-realistic form, all students went through the identical self-paced verbal program (covering the same concepts illustrated by the demonstrations). Time-to-complete each segment was recorded for every student. The sum of such scores for all segments resulted in a work rate score for each participating subject. The work rate scores of subjects who had watched the realistic demonstration were then compared with those of students who had watched the non-realistic demonstrations. This comparison for both the intuitive and non-intuitive demonstrations is summarized in Table 5.

Table 5

A Comparison of Work Rate Means on Self-Paced Programs for Groups Which Had Previously Watched either a Realistic or Non-Realistic Demonstration (in minutes)

	Intuitive Archimedes' Principle		Non-Intuitive Bernoulli's Principle	
	Mean	S. D.	Mean	S. D.
realistic	34.4	(3.0)	25.1	(2.9)
non-realistic	32.2	(4.0)	30.0	(5.6)
analysis of differences	F=6.03* df=1/48		F=18.7*** df=1/48	

significance levels: * = 5%; *** = .1%

As can be noted in the table, significant differences between treatments resulted. The direction of the differences varied, however, as between the lesson on Archimedes' Principle and the lesson on Bernoulli's Principle. For the "intuitive" lesson on Archimedes' Principle, the animated or non-realistic version of the demonstrations resulted in shorter completion times on the subsequent self-paced verbal program. For the "non-intuitive" lesson on Bernoulli's Principle, the live or realistic version resulted in shorter completion times. The analysis of variance summaries for these comparisons are presented in Tables 8 and 9 in Appendix A.

B. Questionnaire Data

Two item types were employed in the questionnaire administered at the completion of the entire experiment. One type of item was intended to assess the "interest" value of identical demonstrations presented either in realistic or non-realistic versions. The other item type was intended to assess the "credibility" of the demonstration outcomes.

(1) interest in trying demonstrations. - Subjects were instructed to indicate their

ments. The entire questionnaire form (Form A) designed to measure their interest level is reproduced in Appendix A. The beginning portion of the form, including the response options for a sample item, is reproduced in Figure 3.

For each of the experiments which you just saw, put an X in the column which shows whether you would like to try it yourself.

	Would like to try it very much.	Would like to try it.	No interest in trying it.
blowing air past candle flames	____	____	____

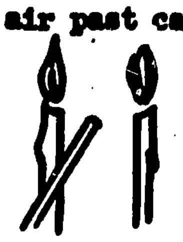


Fig. 3. Sample portion of Form A in the Questionnaire.

A chi-square analysis of the frequencies of endorsements of the three rating categories for all demonstrations resulted in significant chi-square values for both the intuitive and non-intuitive demonstrations (with "very much interested" and "interested" categories combined). Differences between realistic and non-realistic versions varied in direction from intuitive to non-intuitive demonstrations. As noted in Table 6, on page 17, for intuitive demonstrations considerably more interest was expressed in the realistic than in the non-realistic demonstrations. For non-intuitive demonstrations, however, precisely the opposite was found, the magnitude of the difference being considerably smaller. The non-realistic version drew more positive endorsements than did the realistic version.

Table 6

Ratings of Interest Level for
Realistic and Non-Realistic Demonstrations
(in percentages)

	all demonstrations	Intuitive		Non-Intuitive	
		realistic	non-realistic	realistic	non-realistic
very much interested or interested	64%	65%	38%	73%	83%
no interest	36%	35%	62%	27%	17%
	100%	100%	100%	100%	100%
# of responses	734	205	185	185	159
		$X^2=30.1$, df=1, $P < .001$		$X^2=4.2$, df=1, $.05 > P > .02$	

The data of Table 6 were regrouped to permit a comparison of intuitive and non-intuitive demonstrations. This comparison was made separately for realistic and non-realistic versions. As summarized in Table 7, on page 18, it can be noted that for both the realistic and non-realistic versions, more interest was expressed in the non-intuitive than in the intuitive demonstrations. However, this finding was statistically significant only for the non-realistic version.

Table 7

Ratings of Interest Level for Intuitive and Non-Intuitive Demonstrations (in percentages)

	all demonstrations	Realistic		Non-Realistic	
		intuitive	non-intuitive	intuitive	non-intuitive
very much interested or interested	64%	65%	73%	38%	83%
no interest	36%	35%	27%	62%	17%
	100%	100%	100%	100%	100%
# of responses	734	209	185	185	159
		X^2=2.4; df=1, .20 > P > .10		X^2=69.6, df=1, P < .001	

(2) credibility of demonstration outcomes. - Form E of the questionnaire, reproduced in part in Figure 4 below and in its entirety in Appendix A, attempted to get at the reasons for student interest in trying experiments. Options were designed to determine the credibility of demonstration outcomes (and thereby their potential confirmation value).

What reason(s) would you have for trying each of the following experiments yourself?

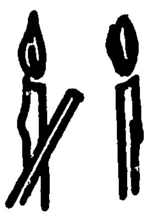
	Just curious to see how it would come out.	To check to see if it would come out the same way.	Don't believe it would come out the same way.
blowing air past candle flames 	___	___	___

Fig. 4. Sample portion of Form E of the Questionnaire.

The data of Table 8 summarize the differences in ratings obtained for realistic and non-realistic versions of the demonstrations. Generally, as shown in the table, non-realistic versions were disbelieved more than their realistic counter-parts. The differences were small and, only for the intuitive demonstrations was the difference significant.

Table 8

Reasons Endorsed for Wanting to Try
Realistic and Non-Realistic Demonstrations
(in percentages)

	all demonstrations	Intuitive		Non-Intuitive	
		realistic	non-realistic	realistic	non-realistic
just curious	33%	37%	32%	33%	28%
to check	54%	63%	64%	44%	45%
don't believe outcome	13%	0%	4%	23%	27%
	100%	100%	100%	100%	100%
# of responses	660	145	185	185	145
		$X^2=8.7$, df=2, $.02 > P > .01$		$X^2=1.2$, df=2, $.50 > P > .30$	

Regrouping the data of Table 8, it is possible to contrast the reasons endorsed for wanting to try either intuitive or non-intuitive demonstrations. As shown in Table 9, on page 20, the outcomes of non-intuitive demonstrations were disbelieved more often than were outcomes of intuitive demonstrations. This finding was significant and held true whether or not the comparison was made for realistic or for non-realistic versions.

Table 9

Reasons Endorsed for Wanting to Try Intuitive and Non-Intuitive Demonstrations (in percentages)

	all demonstrations	Realistic		Non-Realistic	
		intuitive	non-intuitive	intuitive	non-intuitive
just curious	33%	37%	33%	32%	28%
to check	54%	63%	44%	64%	45%
don't believe outcome	13%	0%	23%	4%	27%
	100%	100%	100%	100%	100%
# of responses	660	145	185	185	145
		X^2=39.3, df=2, P<.001		X^2=33.1, df=2, P<.001	

(3) prediction of outcomes if experiments were to be tried by students. - Forms C and D of the questionnaire further attempted to assess the credibility of the experimental outcomes. Form C required subjects to indicate how the experiment would turn out if they tried it. A sample portion of this form is reproduced in Figure 5.

If you tried each of the following experiments yourself, which way do you think they would turn out? Put an X next to the picture which shows which way you think it would turn out if you tried it.

It would turn out this way. It would turn out this way.

blowing air past candle flames

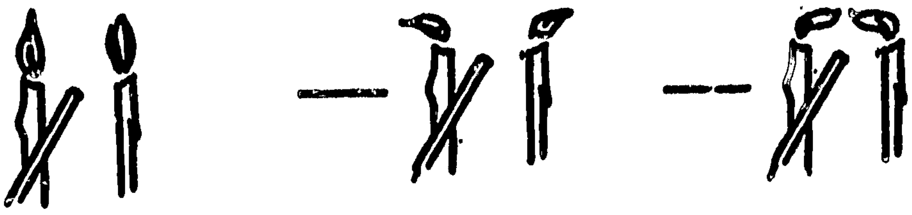
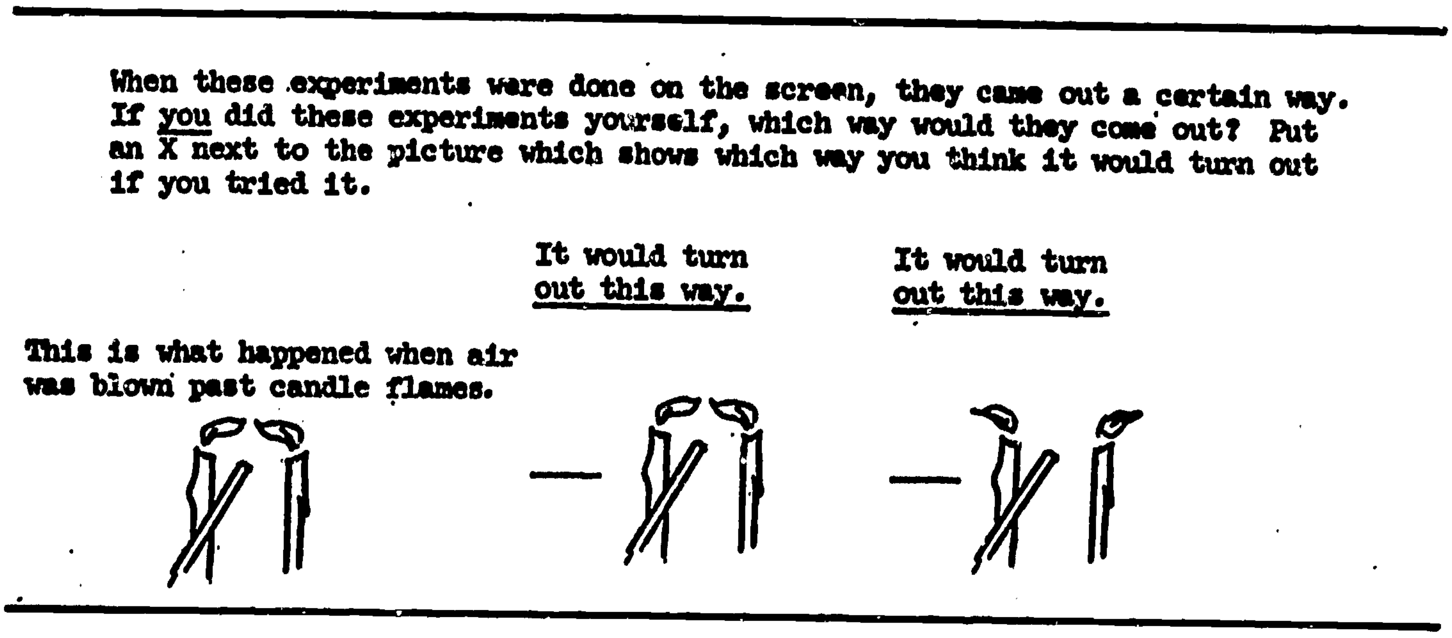


Fig. 5. A sample portion of Form C of the Questionnaire.

Form D went one step further. It indicated how the demonstration turned out on the screen and then asked how the demonstration would turn out if the subject himself tried it. A sample of this form is reproduced in Figure 6.



When these experiments were done on the screen, they came out a certain way. If you did these experiments yourself, which way would they come out? Put an X next to the picture which shows which way you think it would turn out if you tried it.

This is what happened when air was blown past candle flames.

It would turn out this way.

It would turn out this way.

Fig. 6. Sample portion of Form D of the Questionnaire.

Responses on both Forms C and D were categorized as same outcomes or different outcomes (depending on their agreement with the actual outcomes presented on the screen).

The results of Table 10, on page 22, indicate that for intuitive demonstrations, the realistic version led to more predictions (on both Forms C and D) that were in keeping with outcomes presented on the screen. However, the differences are small and only one of them was significant (Form D). For non-intuitive demonstrations, the reverse was true. More predictions based on the non-realistic version were in keeping with demonstrated outcomes. Here, too, only the difference measure obtained was significant (Form C).

Table 10

Predictions of Outcomes for Realistic and Non-Realistic Presentations (in percentages)

		Intuitive		Non-Intuitive	
predictions	all demonstrations	realistic	non-realistic	realistic	non-realistic
FORM C					
same outcome	86%	94%	91%	76%	85%
different outcomes	14%	6%	9%	24%	15%
	100%	100%	100%	100%	100%
# of responses	666	145	182	194	145
		X^2=1.6, df=1, .30 > P > .20		X^2=4.4, df=1, .05 > P > .02	
FORM D					
same outcome	88%	98%	92%	81%	82%
different outcomes	12%	2%	8%	19%	18%
	100%	100%	100%	100%	100%
# of responses	629	130	185	185	129
		X^2=4.1, df=1, .05 > P > .02		X^2=.1, df=1, .80 > P > .70	

The data of Table 10 are regrouped in Table 11 to compare the intuitive and non-intuitive demonstrations. As shown in this latter table, in all four comparisons intuitive outcomes were predicted correctly more often than non-intuitive outcomes. Three of the four comparisons were statistically significant.

Table 11

Predictions of Outcomes for Intuitive and Non-Intuitive Demonstrations (in percentages)

		Realistic		Non-Realistic	
predictions	**all demonstrations**	**intuitive**	**non-intuitive**	**intuitive**	**non-intuitive**
FORM C					
same outcome	86%	94%	76%	91%	85%
different outcomes	14%	6%	24%	9%	15%
	100%	100%	100%	100%	100%
# of responses	666	145	194	182	145
		$X^2=22.1$, df=1, $P<.001$		$X^2=3.1$, df=1, $.10>P>.05$	
FORM D					
same outcome	88%	98%	81%	92%	82%
different outcomes	12%	2%	19%	8%	18%
	100%	100%	100%	100%	100%
# of responses	629	130	185	185	129
		$X^2=20.8$, df=1, $P<.001$		$X^2=8.2$, df=1, $P<.01$	

DISCUSSION

The introduction to this report stressed the need in research on visuals of identifying specific functions assigned to visuals in instruction. It is clear from reading the method section of this report that, in this study, visuals have been assigned several functions. They have served to cue responses and to confirm responses. They have also served as a series of examples to promote response generalization (concept acquisition). The experimental variations involving realism and non-realism have not been specific to any one function. There has not been, for example, a variation in the realism of just confirmation stimuli (with all other functions constant -- that is, all realistic or all non-realistic). The experimental variations in the realism of the presentation have involved all functions. In the non-realistic version, for example, cues, confirmation, and examples were all non-realistic. In the light of this variation in realism for an amalgam of functions, can useful generalizations about realism or non-realism be drawn from the results?

The live (on tape) visual demonstrations used in this study were programmed. This means that visuals were assigned specific functions to fulfill. The program was tried out empirically and revised. The result of this entire procedure was a visual program that produced a low error rate (on response practice items built into the presentation). Within such a tried out program, visual stimuli could be judged to have fulfilled their designated functions adequately, whether as cues, as confirmation, or as examples.

Comparing an animated or non-realistic version of the program with the live or realistic original makes it possible to assess any deterioration in effectiveness (e.g., in error rates) that might result from altering the realistic character of the presentation. While it is true that such a comparison does not attest specifically to the adequacy of non-realistic visuals as cues or of non-realistic visuals as confirmation, etc., it can attest to any change in adequacy of an <u>entire</u> program in which specific functions (in combination) had been previously judged to be adequately fulfilled. Any evidence of deterioration would be a clear indication of the need for a separate, analytic study of the effect of non-realism on each function. However, error rates for the realistic and non-realistic versions of the visual program were negligible and non-significantly different. Achievement data, while also dependent on the self-paced, verbal programs that were taken by groups receiving either the realistic or the non-realistic versions of the visual demonstrations, also indicate that there were no significant differences between the two groups. Recall of demonstration outcomes also yielded no significant differences between realistic and non-realistic versions.

These achievement data suggest no deterioration in effectiveness from the original live visual demonstration as a result of their presentation in animated or non-realistic form. The capacity of visuals in either mode to serve as cues or as examples should come as no particular surprise. Through experience in the classroom, the theater, or at home in front of the television screen, responses to live events are likely to have generalized not only to filmed or taped representations of them but also to animated representations. The effectiveness of non-realistic presentations in generating understanding might more readily be called into question for those who have not yet had experience with filmed or animated representations of real events. This, of course, means the very young, the disadvantaged, or those in other cultures. But, even in our ourn culture, and for age groups that have had experience with "representations" of real events, there might be some question whether non-realistically presented demonstration outcomes would have the capacity to <u>confirm</u> responses.

As Gropper (1963) has suggested, visual events come, after a long series of experiences, to confirm the adequacy of our behavior (that we have tied out shoes properly or shaved well, etc.). Visuals are thus presumed to acquire a generalized confirming property. They also confirm the outcomes of others' behaviors and indeed of inanimate events (e.g., science demonstrations). Whether non-realistic, visual events have the same capacity to confirm is what this study has attempted to assess.

The achievement data suggesting no deterioration in effectiveness of the live, original version as a result of its transformation into an animated version could not provide specific evidence of the confirmation adequacy of of non-realistically presented demonstration outcomes. Achievement data were, as pointed out above, the product of the adequacy of the entire visual presentation in all its functions. Additionally, they were the product not only of the visual presentation but also of the same self-paced, verbal program used in both the realistic and non-realistic treatments. Other data, however, including the questionnaire results, while not providing evidence as to how well the confirmation function was actually fulfilled, are more specifically relevant to the potential value of non-realistic events in providing confirmation.

In questionnaire data and in work rate data for the self-paced, verbal programs, there were differences between the realistic and non-realistic treatment groups. These differences were, however, not simply a function of the realism of the demonstrations. They were in part a function of their intuitiveness. Disbelief was expressed more often for outcomes of the non-intuitive demonstrations. One of the outcomes contrary to prior experience was, for example, candle flames bending toward rather than away from blowing air. Prior experience is more likely to have confirmed that blowing air past a flame is likely to cause it to flicker or that blowing air at an object is likely to cause it to move away from the air. Candle flames moving toward the blowing air is counter to everyday experience. This being the case, non-intuitive visual events may to some extent lose their capacity to confirm student predictions of outcomes. When this does in fact occur, the confirming capacity of the teacher presenting the demonstration may acquire greater importance.

In general, the dimension of intuitiveness appears to have played a more potent role than the dimension of realism. The outcomes of non-intuitive demonstrations were recalled correctly more often than those of intuitive demonstrations. More interest was expressed in wanting to try the non-intuitive experiments. The outcomes of the non-intuitive demonstrations as shown on the screen were disbelieved more often and were more often predicted as likely to be different if students themselves tried them.

Although, in general, students expressed more interest in wanting to try the non-intuitive demonstrations, they were somewhat less likely to want to do so if they had seen it in its realistic version. Interest in wanting to try the intuitive demonstration, on the other hand, was less likely to be expressed if students had seen the non-realistic version.

Worthy of note is the variation in the magnitude of the differences in expressed interest for the intuitive and non-intuitive demonstrations. The differences between them were sizeable and significant (45%) when the non-realistic versions of the two are compared. The differences between them are considerably smaller (only 8%) and not significant when the realistic versions of the two are compared. Interest in wanting to try experiments was roughly comparable for intuitive and non-intuitive experiments when they were presented realistically. When presented non-realistically, interest in the intuitive experiments dropped sharply.

As to obtained data that might account for this pattern of results, the overall differences observed between realistic and non-realistic versions were small. Those differences that are significant suggest that the credibility of non-realistic versions was questioned more often for intuitive than for non-intuitive demonstrations. This would hardly account for the considerably smaller interest expressed in wanting to try non-realistically presented intuitive demonstrations. Generally, non-realistic presentations led to more disbelief, but this appears to affect intuitive demonstrations more. Disbelief about non-intuitive outcomes appears to be held in abeyance somewhat more when they are non-realistic.

Work rate data (on the self-paced verbal programs administered after each visual segment) also reflect an interaction between intuitiveness and realism. Significantly less time was spent on the program when (a) the demonstration was realistic and non-intuitive; and (b) when it was non-realistic and intuitive. This kind of interaction was identical with that found for questionnaire data reflecting disbelief in outcomes. Although there was no rating of the interest level of the demonstrations per se (only a rating of interest in wanting <u>to try</u> the experiment), the combined work rate data and "disbelief" data might suggest <u>greater interest</u> in the presentation itself as an explanation. Students appear to have worked faster on the verbal material following the visual demonstrations they "disbelieved" more. While time-to-complete is traditionally thought of as a measure of learning, it is also plausible that it may reflect interest.

The relationship is likely to be inverse. Thus, while there is no striking evidence in these data that non-realistic presentations cannot confirm acquisition behavior, there is some evidence to suggest, that realistic or non-realistic presentations may have the capacity to reinforce attending behaviors. This capacity appears to depend, however, on the degree of intuitiveness of the material.

CONCLUSION

Overall, the magnitude of the differences obtained between realistic (live) and non-realistic (animated) demonstrations was small compared to the magnitude of the differences obtained between intuitive and non-intuitive demonstrations. Outcomes of non-intuitive demonstrations were recalled correctly more often than those of intuitive demonstrations. The outcomes of non-intuitive demonstrations were also disbelieved more often. Paralleling these findings, it should be noted, more interest was expressed in wanting to try the non-intuitive experiments. These data suggest that non-intuitive outcomes may have had less capacity to confirm student predictions of experimental outcomes than intuitive outcomes.

Differences between intuitive and non-intuitive demonstrations were, however, not unaffected by the mode of presentation. Significant interactions were observed between the intuitiveness of the demonstration and the realism (or non-realism) of the presentation. When both were presented realistically, small and non-significant differences in interest level were observed between intuitive and non-intuitive demonstrations. On the other hand, when both types were presented non-realistically, the interest level (in wanting to try the experiments) in the non-intuitive demonstrations was significantly and substantially greater.

Looking at the intuitive demonstrations alone, students expressed more interest in wanting to try them if they had seen them presented realistically. The converse was true for non-intuitive demonstrations. Students were more apt to want to try them if they had seen the non-realistic version. Other data, however, suggest that interest levels <u>during</u> the presentation may have been the reverse of those just noted (e.g., suggested by time-to-complete data). During the presentation, students, it is interpreted, were more interested in the animated intuitive demonstrations and in the live, non-intuitive demonstrations. These latter types may therefore have been more successful in reinforcing immediate attention. What exactly provided the reinforcement may have been different. In the one instance it was likely to have been the non-intuitive nature of the outcome. In the other case, it may have been the mode of presentation (animation).

The most clear-cut pattern of interaction found in this study is summarized in the figure below.

	live	animated
intuitive	future interest in trying experiments	interest during presentation
non-intuitive	interest during presentation	future interest in trying experiments

The differences between realistic and non-realistic presentations appear to depend on the intuitiveness of the phenomena presented. Thus, it appears that content (degree of intuitiveness of outcomes) as much as, or perhaps more than, the mode of presentation may be relevant for the capacity to confirm student predictions or to reinforce attending behaviors. Since, in this study, there was only one instance each of intuitive and non-intuitive demonstrations, replication is clearly in order. There does appear to be an interaction between realism and intuitiveness, but only with replication can the reliability of the apparent interactions be more clearly ascertained.

2

STUDY NO.

AN EXPERIMENTAL EVALUATION OF THE INSTRUCTIONAL EFFECTIVENESS OF LITERAL AND NON-LITERAL DEMONSTRATIONS

Science demonstrations may be used as a series of examples in order to facilitate response generalization. In teaching concepts and principles, they are often used in precisely this way and, indeed, concept acquisition is contingent on the use of a series of examples, either in a visual or verbal mode. When they are visual, they may be presented either realistically or non-realistically (see Study No. 1 in this report). Another dimension along which visual examples may vary, is the literalness with which they represent the concept to be taught (Gropper, 1963). Examples may literally represent a principle (as when an object is shown to expand when heated). The principle concerning the relationship between heat and expansion may also be non-literally represented. The effect of expansion may be shown rather than expansion itself (as when a heated ball no longer passes through a ring).

The purpose of the present experiment is to assess the effect the literalness of examples may have on the ease with which concepts are acquired.

METHOD

Design of Experiment

Independent variables. - Two lessons were prepared for presentation on television; one covered phenomena having to do with "surface tension," the other "heat and molecular action." Each of the two lessons was prepared in two versions: one version contained examples that directly or literally illustrated the concept being taught; a second version contained non-literal examples that indirectly illustrated the same concepts. Each lesson, in whichever version, was segmented into several fixed-paced TV units, and these units were serially intermixed with a verbal self-paced unit covering the same material as was covered in the preceding fixed-paced visual unit. This arrangement is summarized in Figure 1, on page 32.

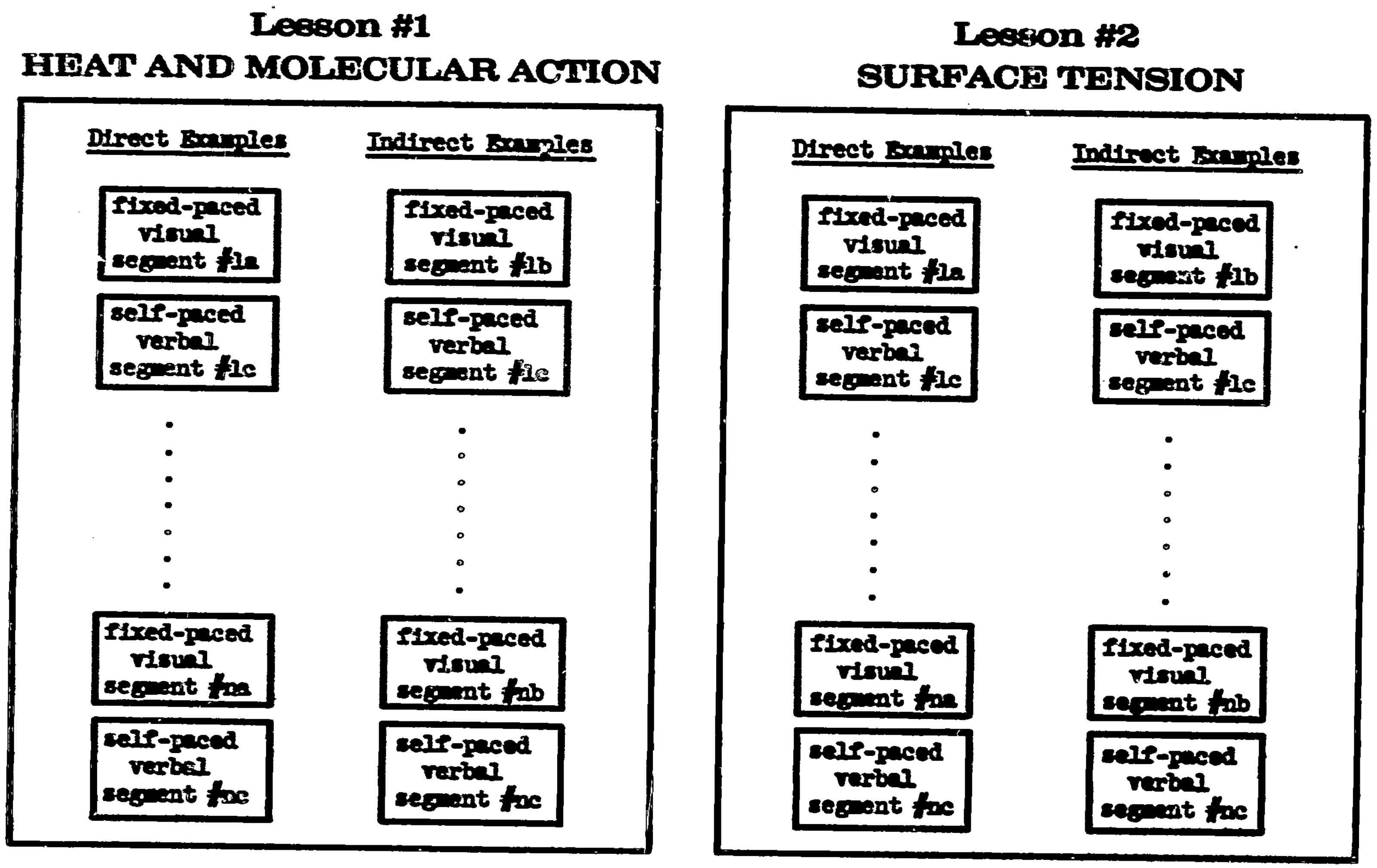

Lesson #1
HEAT AND MOLECULAR ACTION
Direct Examples
Indirect Examples
fixed-paced visual segment #1a
self-paced verbal segment #1c
fixed-paced visual segment #na
self-paced verbal segment #nc
fixed-paced visual segment #1b
self-paced verbal segment #1c
fixed-paced visual segment #nb
self-paced verbal segment #nc
Lesson #2
SURFACE TENSION
Direct Examples
Indirect Examples
fixed-paced visual segment #1a
self-paced verbal segment #1c
fixed-paced visual segment #na
self-paced verbal segment #nc
fixed-paced visual segment #1b
self-paced verbal segment #1c
fixed-paced visual segment #nb
self-paced verbal segment #nc

Figure 1

As can be seen from an inspection of the table, the independent variable studied is the directness or indirectness of the visual examples. The use of two lessons merely serves to provide replication.

The design of the experiment may be summarized as follows:

Group I		Group II	
Lesson 1:	direct version	Lesson 1:	indirect version
Lesson 2:	indirect version	Lesson 2:	direct version

Dependent variables. - Dependent variables consisted of such learning measures as time-to-complete the self-paced verbal program, errors on the program, and achievement test scores.

Procedures

The schedule below indicates the time intervals between the administration of the several instructional and evaluation materials used in this study. All participating classes adhered to the schedule with minor variations occurring for those schools previously committed to other school activities.

Week 1 - in the schools:

(1) Administration of pretests.
(2) Administration of a program on "Learning From a Program."

Week 2 - in the schools:

(1) Administration of a self-paced preliminary program on "Atoms and Molecules" (concepts necessary to an understanding of the experimental programs).

Week 4 - in the studios of WQED:

(1) Simultaneous administration of the direct and indirect versions of each of the two experimental programs (on "heat" and on "surface tension").

(2) Administration of an identical self-paced verbal program to both experimental groups; verbal programs covered the same concepts illustrated by the televised demonstrations and were serially intermixed with the demonstrations.

(3) Administration of an immediate posttest.

Week 7 - in the schools:

(1) Administration of a retention test (identical with the original test).

Experimental Materials

As can be noted in the above schedule, the instructional materials for this study included two pre-experimental self-paced programs administered in the schools and two experimental programs administered over closed-circuit TV in the studios of WQED and (simultaneously) in a banquet room of an adjacent hotel.

Pre-experimental materials. - The two programs administered before the conduct of the main experiment were designed to fulfill two differenc functions. One, entitled "Learning From a Program" was designed, as its title suggests, to familiarize subjects with the mechanics of going through a program and of profiting from the program. The program is reproduced in its entirety in Appendix A, page 44. The second pre-experimental program dealing with "atoms and molecules" is reproduced in Appendix B, page 31. Its primary purpose was, in addition to providing additional familiarization with "programs," to bring participating subjects up to a common level of prior knowledge, knowledge judged to be necessary for successful work in the main experimental programs. Both preliminary or pre-experimental programs, as well as both self-paced verbal programs used in the main experiment, were prepared in the REP style of programming developed by Gropper (1965b). A brief rationale for this style appears in Study No. 1, beginning on page 8.

Main experimental materials. - The visual portions of the lessons on "heat" and on "surface tension" were programmed in the style developed by Gropper (1965b). This is described in Study No. 1, page 9. Briefly, the programming approach used calls for discrimination practice with concrete events (and minimal use of language) as a means of teaching concepts and principles. When language is used, it is concrete and describes rather than explains what is occurring. The explanation (the principle) is acquired inductively through discrimination practice based on a series of visual (concrete) examples.

The visual, demonstration segments of each of the two lessons were prepared in two versions. In one version, examples were direct. In the other, they were indirect. The differences between the two can be illustrated by describing demonstrations used in the lesson on surface tension. The fact that "liquids tend to shrink" was demonstrated in the direct version by: a wet spot on a smooth surface becoming smaller and occupying less area; soap film in a funnel getting smaller, etc. The same tendency of liquids to shrink was illustrated in the indirect version by its effects. When dipped in water and then removed, the bristles of a paint brush or the fibres of a fur piece cling more tightly to each other (as a result of the tendency of liquids to shrink). While in the literal version the fact or principle was directly illustrated, in the non-literal version it was illustrated by consequences it had for other phenomena. One important feature of the visual program was the animation of phenomenon, invisible in nature, as direct examples. Moving molecules was one such an instance.

Before the demonstrations were recorded on TV tape, they were tried out live with subjects drawn from the target population (the eighth grade). They were revised until relatively low error rates (on problems posed in visual work books) were low, approximately 10-15 per cent. (See Appendix B for copies of the answer books.)

Verbal, self-paced programs were similarly tried out and revised. These programs, reproduced in Appendix B, pages 1 and 12, were serially intermixed with and were identical for both the direct and indirect visual demonstrations.

Dependent Measures

The achievement tests used to assess student knowledge before, immediately after, and three weeks after the administration of the experimental lessons are reproduced in Appendix B, pages 28-30. Time-to-complete the self-paced materials that followed each visual demonstration was also recorded.

Subjects

Three eighth grade classes drawn from City and Parochial schools participated in the study. Students from each class were assigned at random to each of the two treatment conditions.

RESULTS

Matching Measures

At the completion of the experiment, students who had been assigned at random to experimental treatments were matched for IQ and Work Rate on pre-experimental programs. Only matched cases were selected for the analysis of data, so that the variables IQ and Work Rate could be treated as independent variables, each at two levels. There resulted a 2x2x2 design for data analysis, representing two levels each of IQ and Work Rate and the two experimentally manipulated conditions (direct vs. indirect examples). The results of the matching procedure are summarized in Table 1, which is based on eight cases per cell, for a total of 64 cases.

Table 1

Results of Procedures for
Matching Subjects Across Conditions$^+$

		GROUP 1 Direct: Heat Indirect: Surface Tension			GROUP 2 Indirect: Heat Direct: Surface Tension		
		IQ	Pretest	Work Rate^{++}	IQ	Pretest	Work Rate^{++}
HI IQ	Fast	128	5.1	31	126	5.0	31
	Slow	126	3.6	40	129	5.5	41
LO IQ	Fast	115	2.9	31	115	3.4	32
	Slow	113	4.6	39	115	3.8	39

$^+$results reported as means; $^{++}$time-to-complete in minutes

The table shows that there was a separation of approximately 12 IQ points between high and low IQ groups. This difference was statistically significant at the .001 level, as shown in Table 1 in Appendix B. Table 1, both in the text and in the Appendix also, shows that there was not a significant difference in IQ either between experimental treatments or between Work Rate levels. Similar results for Work Rate can be found in text Table 1 and in Appendix B, Table 2. Fast and slow levels were significantly different on Work Rate at the .001 level. No significant differences were found for Work Rate between the remaining cells of the design. Table 1 also records Pretest scores for each of the eight experimental cells. Appendix B, Table 2, records no significant differences between cells on Pretest scores.

Dependent Measures

The results of all comparisons between groups receiving direct and indirect examples are summarized in Table 2.

Table 2

Summary Comparison of Means on Dependent Measures for Groups Receiving Direct and Indirect Versions of Visual Lessons

	HEAT				SURFACE TENSION			
	Direct		Indirect		Direct		Indirect	
	Mean	(S.D.)	Mean	(S.D.)	Mean	(S.D.)	Mean	(S.D.)
# of correct responses on visual program[+]	11.6	(0.6)	11.5	(0.7)	*10.8	(1.3)	11.4	(1.1)
# of errors on verbal program[++]	**4.1	(3.9)	2.1	(2.6)	*2.1	(2.9)	3.8	(3.8)
time-to-complete verbal program (in minutes	31.7	(4.8)	33.7	(8.2)	19.7	(4.0)	18.8	(3.1)
immediate posttest[+++]	15.5	(2.7)	15.6	(3.1)	9.3	(2.8)	9.0	(3.3)
retention test[+++]	13.5	(4.0)	13.6	(.39)	5.9	(2.8)	6.3	(2.9)

[+] total number of responses possible on visual "heat" program - 12; on visual "surface tension" program - 13

[++] total number of responses possible on "heat" program - 74; on "surface tension" program - 61

[+++] total number of points possible on "heat" test - 22; on "surface tension" test - 16

*significance at the .05 level; **significance at the .01 level

The significant differences are underlined and starred; the variance analyses for all comparisons appear in Appendix B.

Although there were statistically significant differences in errors on the verbal program, the direction was reversed on the two different programs. More important, however, was the fact that on neither program did the error rate approach 10 per cent. Thus, as can be noted in the table, few statistically significant differences were obtained. Of those obtained, all were of negligible magnitude and appear to be of little practical importance.

DISCUSSION

In Study No. 1, it was suggested that for the acquisition of concepts the mode of lesson presentation (realistic or non-realistic) was not nearly so important as other characteristics of its content. The intuitiveness or familiarity of lesson content appeared to be more crucial. Here, too, other content considerations may be as important in influencing the ease of concept acquisition as the directness or indirectness of examples.

By concept acquisition we mean that the learner acquires a generalized response to a <u>class</u> of objects or events. Concepts, such as "liquids shrink" or "molecules move faster when heat is applied to objects" are the kinds of response generalizations required of students watching a series of science demonstrations. For such generalization to occur, the learner must be able to recognize and respond to the similarities among the objects or events. Acquiring the concepts on the basis of <u>visual</u> examples is likely to require some form of verbal mediation, particularly if this kind of visual lesson is to facilitate transfer to verbal lessons that follow it (Gropper, 1965a). It is to the essential similarities of the visual example that mediating verbal responses have to be made if response generalization is to occur.

As Gropper (1963) has pointed out, most visual examples can bear either a structural and/or functional similarity to one another. To illustrate: all examples illustrating the expansion that follows the application of heat, are functionally or conceptually similar. They all illustrate the relationship between heat and expansion. Structurally, that is, in terms of the physical events presented, they may be highly dissimilar, e.g., water <u>rising</u> in a tube, a balloon filled with air <u>inflating</u>, cracks in railroad tracks <u>widening</u>, a ball no longer <u>passing through</u> a ring, a thermostat <u>bending</u>, etc. These structural characteristics of events are highly visible and are dissimilar. Despite their relevance to the concept to be learned, their dissimilarity may interfere with response generalization to the less superficial and critical functional or conceptual features (the <u>expansion</u> of the matter involved). The greater the dissimilarity among the superficial, structural events or attributes of objects, the more likely is interference with response generalization to the functional characteristics to occur.

The highest degree of similarity is, of course, identity. This, too, creates problems, for we wish responses to generalize to all members of a class. Solids, liquids, gases -- in all shapes, sizes, colors, etc., expand when heated. With insufficient variation in these attributes, generalization is likely to be limited. The problem thus arises in using visual examples of arriving at a proper balance: how to achieve sufficient variation and at the same time sufficient similarity. It is in the reconciliation of this problem that words, as mediators, can play one of their most effective roles in audio-visual instruction.

In direct examples, structural and functional (conceptual) properties coincide. Expanding objects directly illustrate the principle that heat leads to expansion; submerged objects result in reduced scale readings directly illustrating the principle that there is an "apparent" loss of weight when objects are weighed in water; rubber balls or sponges spring back to shape when stresses are removed, directly illustrating what happens to perfectly elastic bodies when stresses are removed; etc. Since structural and functional properties do not diverge, there is no barrier to response generalization to the functional or conceptual properties. This is not to say, however, that within a series direct examples will not be dissimilar. The depressed rubber ball or a squashed sponge or a stretched metal coil all will return to their original shape. But there are physical differences among them which may obscure the fact that all are variations of a single concept, i.e., that they return to their original shape. So that all are recognized as instances of a class, the essential relevant similarities may have to be pointed out (in words). Only then is response generalization likely to occur.

In indirect examples structural and functional properties diverge from one another. Water may rise in a tube after it is heated, a ball no longer passes through a ring, and a balloon inflates when air expands. Or, as in this study, the hairs of a brush may cling together as a result of being dipped in water. The student thus sees the result of water shrinking, rather than seeing the actual shrinking. For indirect examples to lead to efficient response generalization, two things are required: (a) the connection between structural and functional properties must be recognized; and (b) as is also the case for direct examples, similarity among examples must obtain. Even though they are indirect, examples can be highly similar. When this is so, the only barrier to response generalization is establishing the connection between structural and functional properties. Words can serve a mediating role in this regard.

Although there is no immediate evidence available in this study bearing on the problem, it is perhaps important that if examples are direct, all examples be direct; if indirect, that all be indirect. Such was the case in the present study. Within a series of examples, all direct or all indirect, it is also probably important that the relevant features that are similar be highly visible (i.e., easily responded to) so that generalization can occur.

A review of the examples used in the present study indicates that the direct version of the lesson contained examples that were similar to one another. The indirect version also contained examples that were similar to one another. Thus, although there was no measure of similarity and it is likely to be a difficult measurement problem to achieve one, both versions may be said to have had a fairly high degree of internal similarity. The two versions were different then only with respect to the need for a connection to be made between structural and functional properties in the indirect version.

Based on the foregoing analysis, one might expect concept acquisition to have been more difficult for the indirect version. In this version the connection between structural and functional properties had to be established. In the direct version, the connection was already established. However, in this study differences were not observed between the two versions.

Under what kinds of circumstances might one expect direct and indirect examples to be equally effective? This would seem likely to occur: (1) when there is an approximately equal degree of internal similarity within the series of direct and within the series of indirect examples; and (2) when, in the indirect version, students have available the verbal responses needed to mediate the connection between the effects they see and the concept the effects indirectly represents. In the present study, there was no measure of internal similarity and, indeed, measuring it represents, it would seem, a particularly difficult scaling problem. Future research on visual examples will, it seems clear, have to come to grips with this problem. As to the second point, concerning availability of mediating verbal responses, this too was not assessed quantitatively. If a judgment were to be made, it would be that by virture of the particular events chosen to illustrate both heat and surface tension concepts, mediating verbal responses of relatively high strength were probably available. This fact may have accounted for the results obtained.

CONCLUSION

The discussion of direct and indirect examples used to teach concepts in this study has centered on three properties of examples: (a) the convergence or divergence of structural and functional characteristics of examples; (b) the degree of internal similarity among examples within a series of examples illustrating a concept; and (c) the availability of mediating verbal responses.

In direct examples, there is a high degree of convergence between the structural or physical properties of examples and their functional or conceptual properties. This means that the physical events directly illustrate the concept (e.g., expanding objects directly illustrate the relationship between heat and expansion). In indirect examples, there is a divergence between the two sets of characteristics. The heated ball no longer passing through a ring indirectly represents the concept of expansion (expansion itself is not shown). Because of this divergence of structural and functional characteristics in indirect examples, we might expect response generalization (to the functional characteristics) to occur less readily than in a situation employing direct examples where the two sets of characteristics coincide. The latter instance highlights the practical value that animation may have in being able to present directly what would otherwise have to be represented indirectly (e.g., increased molecular movement in animation rather than the external consequences of it). In the case of indirect examples, however, the availability of verbal responses to mediate the connection between structural and functional characteristics of examples may render indirect examples as "easy" as direct ones.

Achievement data, based on lesson materials used in this study, revealed no differences between lesson versions using direct and indirect examples. It was suggested in explanation that perhaps other properties of examples may play an equally important role than directness/indirectness. The series of direct examples used in the study possessed a high degree of internal similarity. The same was true for the indirect examples. Because response generalization depends on the ability to respond to the relevant, critical features of a class of events, similarity among such features facilitates its occurrence. The degree of example similarity was not measured in this study, and accordingly no quantitative comparison is possible. Thus whether the series of direct and the series of indirect examples bore equal degrees of internal similarity remains quantitatively unknown. They were, however, both judged to possess a higher degree of internal similarity. A more crucial test of the relative effectiveness of using direct or indirect examples would appear to depend on the availability of quantitative measures of internal similarity. Similar considerations merit attention in the case of the availability of mediating, verbal responses.

Audio-visual research on and practical efforts to foster concept acquisition, it seems clear, must concern itself with properties of visual examples, that influence response generalization. It is suggested that these include: (a) the degree of similarity among examples; (b) the directness or indirectness of examples and (c) the degree of availability of mediating verbal responses. Some of these may be capable of quantitative treatment (e.g., perceived similarity). Others may be more profitably studied through logical analysis (e.g., the relationship between concept and example used to illustrate it). In either case, needed information will be gathered about variables affecting an important role visuals play in instruction: examples serving to facilitate concept acquisition.

REFERENCES

Allen, W. H. Audio-visual communication. In, C. W. Harris (Ed.) Encyclopedia of educational research. New York: MacMillan, 1960. Pp. 115-137. (3rd edition)

Bloomer, R. H. Children's preferences and responses as related to styles and themes of illustration. Elementary School Journal, 1960, 60, 334-340.

Bou, I. R. & Lopez, D. C. Preferences in colors and illustrations of elementary school children in Puerto Rico. Journal of Educational Psychology, 1953, 44, 490-496.

Fonsesca, L. & Bryant, K. Comprehension of pictorial symbols: An experiment in rural Brazil. Madison: University of Wisconsin, Department of Agricultural Journalism, 1960.

French, J. E. Children's preferences for pictures of varied complexity of pictorial pattern. Elementary School Journal, 1952, 53, 90-95.

Gropper, G. L. Why is a picture worth a thousand words? Audio-Visual Communication Review, 1963, 11, 75-95.

Gropper, G. L. Controlling student responses during visual presentations - Report #2. Studies in televised instruction: The role of visuals in verbal learning. Study No. 1. - An investigation of response control during visual presentations. Study No. 2 - Integrating visual and verbal presentations. Pittsburgh: American Institutes for Research, 1965. (a)

Gropper, G. L. A description of the REP style program and its rationale. Presented at the NSPI convention held in Philadelphia, Pennsylvania, 1965. (b)

Gropper, G. L. Learning from visuals - some behavioral considerations. Audio-Visual Communication Review, 1966. (In Press)

MacLean, M. & Hazard, W. R. Women's interest in news pictures: The Badger Village study. Journalism Quarterly, 1953, 30, 139-162.

Miller, W. A. What children see in pictures. Elementary School Journal, 1938, 39, 280-288.

Rosenstein, A. J. & Kanner, J. H. Television and army training: Color vs. black and white. Audio-Visual Communication Review, 1961, 9, 44-49.

Rudisill, Mabel. Children's preferences for color versus other qualities in illustrations. Elementary School Journal, 1952, 52, 444-451

Spaulding. S. Research on pictorial illustration. Audio-Visual Communication Review, 1955, 3, 34-45.

Spaulding, S. Communication potential of pictorial illustrations. Audio-Visual Communication Review, 1956, 4, 31-46.

Travers, R. M. W. (Ed.) Research and theory related to audiovisual information transmission. Salt Lake City: University of Utah, Bureau of Educational Research, July 1964.

APPENDIX A

Archimedes' Principle and Bernoulli's Principle

(Study No. 1)

ARCHIMEDES' PRINCIPLE*

1.

A wagon moves toward the left when you push it toward the

left	right
X	

You would make the wagon move in the opposite direction if you applied a force toward the

left	right
	X

2.

If you push a box toward the NORTH, while someone else pushes a box toward the SOUTH, the two forces applied to the box are

in the same direction	in opposite directions
	X

3.

One boy applies a force to the East while another boy applies a force to the West.

EDIT THIS SENTENCE

The forces are applied in the same direction.

If correct, copy the underlined words.

____

If incorrect, change the underlined words.

THE FORCES ARE APPLIED IN OPPOSITE DIRECTIONS.

4.

If you push a wagon with a 15-lb. force and someone else pushes the wagon with a 15-lb. force, the two forces applied to the wagon are

not equally strong	equally strong
	X

5.

For each of the following examples, write E if the forces are equally strong. Write N if the forces are not equally strong.

A 14-lb. force & a 36-lb. force	A 22-lb. force & a 22-lb. force
N	E

A 92-lb. force & a 67-lb. force
N

6.

Make up a sentence using the words below. You may use any other words in addition to the words below, but make sure your sentence includes all of the words below.

a 35-lb. force
a 21-lb. force
equally strong

A 35-LB. FORCE AND A 21-LB. FORCE ARE NOT EQUALLY STRONG.

---

*The frames reproduced here are those which were presented to the subjects as confirmation frames after they had made their own responses. X's are used to indicate the correct multiple choice responses.

7.

EDIT THIS SENTENCE

A 300-lb. UPWARD force and a 200-lb. DOWNWARD force are in the same direction and are equally strong.

If correct, copy the underlined words.

____

If incorrect, change the underlined words.

IN OPPOSITE DIRECTIONS AND ARE NOT EQUALLY STRONG.

8.

Make up a sentence using the words below. You may use any other words in addition to the words below, but make sure your sentence includes all of the words below.

5-lb. downward force
9-lb. downward force
direction
strong

A 5-LB. DOWNWARD FORCE AND A 9-LB. DOWNWARD FORCE ARE IN THE SAME DIRECTION, BUT ARE NOT EQUALLY STRONG.

9.

When two forces are in opposite directions and are also equally strong, we say that the forces are balanced.

Which of the following is an example of balanced forces?

One boy applies a 34-lb. force to the left and another boy applies a 41-lb. force to the right.	One boy applies a 26-lb. force to the left and another boy applies a 26-lb. force to the right.
	X

10.

Which of the following is an example of balanced forces?

a 49-lb. upward force and a 16-lb. downward force	a 21-lb. upward force and a 21-lb. downward force
	X

11.

A force toward the North and a force toward the South are applied to a wagon. The two forces are balanced if they are

equally strong	not equally strong
X	

12.

In order to be called balanced, two forces have to be both equally strong and also in opposite directions.

Two 59-lb. forces applied to a box are balanced if

one force is toward the left and the other is toward the right	both forces are toward the left
X	

13.

Which of the following is an example of balanced forces?

two 300-lb. upward forces	a 700-lb. upward force and a 700-lb. downward force
	X

14.

Two 400-lb. forces are applied to a boat.

These two forces are balanced only if they are

in the same direction	in opposite directions
	X

15.

A 38-lb. force to the left and a 38-lb. force to the right are applied to a wagon.

The forces are

only equally strong	only in opposite directions	equally strong and also in opposite directions
		X

Therefore, we say that the forces are

balanced	not balanced
X	

16.

When two forces are equally strong and also in opposite directions, we say that the forces are

balanced	unbalanced
X	

17.

Two people are applying balanced forces to a wagon. If we know that one person applies a 19-lb. force toward the left, we know that the other person applies a

25-lb. force to the right	19-lb. force to the right	19-lb. force to the left	25-lb. force to the left
	X		

18.

Two balanced forces are applied to a ball. If we know that one of the forces is 2 lbs. toward the right, we know that the other force is 2 lbs. toward the LEFT.

19.

A 3-lb. force to the South is applied to a table. Tell how you would apply a force so that balanced forces would be applied to the table.

APPLY A 3-LB. FORCE TO THE NORTH.

20.

In order for us to say that two forces are balanced, the forces

only have to be in opposite directions	only have to be equally strong	have to be both in opposite directions and also be equally strong
		X

21.

EDIT THIS SENTENCE

A 37-lb. upward force and a 37-lb. downward force applied to a table are not balanced forces.

If correct, copy the underlined words.

If incorrect, change only the underlined words.

BALANCED FORCES

22.

Make up a sentence using the words below.

two forces
balanced
5 lbs.
to the West

TWO FORCES ARE BALANCED IF ONE IS 5 LBS. TO THE WEST AND THE OTHER IS 5 LBS. TO THE EAST.

23.

Make up a sentence using the words below.

balanced forces
strong
directions

BALANCED FORCES ARE EQUALLY STRONG AND IN OPPOSITE DIRECTIONS.

24.

When two forces are not balanced, we say that the forces are unbalanced.

For each example below, write B if the forces are balanced. Write U if the forces are unbalanced.

Two opposite forces are applied. One is 16 lbs. and the other is 13 lbs.	A 23-lb. force is applied toward the left and a 23-lb. force is applied toward the right.
U	B

25.

A 17-lb. force is applied toward the East and a 28-lb. force is applied toward the West.

The forces are

equally strong	not equally strong
	X

Therefore, we say the forces are

balanced	unbalanced
	X

26.

Two 39-lb. forces are both applied toward the South.

The forces are

in opposite directions	in the same direction
	X

Therefore, we say that the two forces are

balanced	unbalanced
	X

27.

For each example below, write B if the forces are balanced. Write U if the forces are unbalanced.

Two 36-lb. forces are applied toward the East.	A 49-lb. force to the South and a 49-lb. force to the North are applied.
U	B

28.

A 14-lb. force to the East and a 25-lb. force to the East are applied to a box.

The forces are

not equally strong and ALSO in the same direction	not equally strong ONLY	in the same direction ONLY
X		

Therefore, we say that the forces are

balanced	unbalanced
	X

29.

EDIT THIS SENTENCE

A 37-lb. upward force and a 45-lb. downward force applied to a table are <u>unbalanced forces</u>.

If correct, copy the underlined words.

UNBALANCED FORCES

If incorrect, change only the underlined words.

30.

For each example below, write B if the forces are <u>balanced</u>. Write U if the forces are <u>unbalanced</u>.

Two 80-lb. forces are applied toward the left.	A 30-lb. force is applied toward the left and a 30-lb. force is applied toward the right.
U	B
A 67-lb. force and a 45-lb. force are applied toward the right.	A 49-lb. force is applied toward the right and a 43-lb. force is applied toward the left.
U	U

31.

For each example below, write B if the forces are <u>balanced</u>. Write U if the forces are <u>unbalanced</u>.

Two equally strong forces are applied in the same direction.	Two equally strong forces are applied in opposite directions.
U	B
Two forces are in the same direction and are <u>not</u> equally strong.	Two forces are in opposite directions and are <u>not</u> equally strong.
U	U

32.

Make up a sentence using the words below.

two 700-lb. forces
direction
unbalanced

TWO 700-LB. FORCES APPLIED IN THE SAME DIRECTION ARE UNBALANCED.

33.

Make up a sentence using the words below.

two forces	TWO FORCES IN
opposite directions	OPPOSITE DIRECTIONS
unbalanced if	ARE UNBALANCED IF
stronger	ONE FORCE IS STRONGER.

34.

A 60-lb. force to the NORTH and a 60-lb. force to the SOUTH are applied to a boat. We say that the two forces are BALANCED because they are EQUALLY STRONG AND IN OPPOSITE DIRECTIONS.

35.

Two boys are applying BALANCED forces to a bicycle.

Make up an example of two forces which the boys might be applying to the bicycle, using a specific number of lbs. and a specific direction for each of the two forces.

ONE BOY APPLIES A 35-LB. FORCE TO THE LEFT AND THE OTHER APPLIES A 35-LB. FORCE TO THE RIGHT.

36.

A wagon will remain at rest, even when two boys are pushing it, if the boys are applying balanced forces.

However, if the boys apply forces which are unbalanced, the wagon will

start to move	remain at rest
X	

37.

Two boys both push a table toward the left. One boy applies a 16-lb. force and the other boy applies a 23-lb. force. The table will

remain at rest	start to move
	X

The reason for this is that the forces are

balanced	unbalanced
	X

38.

When two boys on the same side of a wagon pull equally hard in the same direction, the wagon

starts to move	remains at rest
X	

The reason for this is that the forces are

balanced	unbalanced
	X

39.

Two people are pushing on opposite sides of a swinging door. If one person pushes harder than the other, the door will

remain at rest	open
	X

The reason is that the forces are

balanced	unbalanced
	X

40.

A car parked on a hill will start to move whenever the forces applied to it are

balanced	unbalanced
	X

41.

A 40-lb. force to the left and a 40-lb. force to the right are applied to a wagon. The wagon

starts to move	remains at rest
	X

The reason for this is that the forces are

balanced	unbalanced
X	

42.

When two boys push a box equally hard in opposite directions, the box

remains at rest	starts to move
X	

The reason is that the forces are

balanced	unbalanced
X	

43.

When two forces are applied to a wagon but the wagon remains at rest, we know that the two forces are

balanced	unbalanced
X	

44.

Two boys playing tug-of-war are applying unbalanced forces to a box. The box will

remain at rest	start to move
	X

45.

When two balanced forces are applied to an object, the object

starts to move	remains at rest
	X

46.

When two equally strong forces are applied to an object in opposite directions, the object

remains at rest because the forces are unbalanced	starts to move because the forces are unbalanced

remains at rest because the forces are balanced	starts to move because the forces are balanced.
X	

47.

Make up a sentence using the words below.

start to move	A CHAIR WILL NOT START
chair	TO MOVE IF BALANCED
balanced forces	FORCES ARE APPLIED.

48.

No matter what is happening to a 4-lb. object, the downward force of gravity applied to it is always 4 lbs.

The downward force of gravity applied to a 9-lb. ball is 9 lbs.

when the ball is falling and also when it is on the ground	only when the ball is falling
X	

49.

When you hold a 17-lb. stone in your hand, the stone feels heavy because the force of gravity pulling it down

is not 17 lbs. anymore	is 17 lbs. even though the stone isn't falling
	X

50.

Under each of the examples below, write the number of lbs. with which the force of gravity is pulling the object down.

a 2-lb. ball which is thrown up in the air	a 500-lb. boat which is floating in water
2 LBS.	500 LBS.

a 45-lb. box which is at rest on the ground

45 LBS.

51.

Make up a sentence using the words below.

gravity applies	GRAVITY APPLIES A
downward force of	DOWNWARD FORCE OF
lbs.	3 LBS. TO A 3-LB.
to a 3-lb. ball in water	BALL IN WATER.

52.

When a ping-pong ball floats in water, the water applies an upward force to the ball. The ball doesn't sink, even though the downward force of gravity is applied to it, because

the water applies an upward force to the ball	gravity applies an upward force to the ball
X	

53.

When you let go of a sponge under water, the sponge rises to the top of the water. This upward movement is evidence that

the water applies an upward force to the sponge	the water applies a downward force to the sponge
X	

gravity applies an upward force to the sponge

54.

When you fall, you move downward because the force of gravity applied to you is in

an upward direction	a downward direction
___	X

However, you can swim in water without sinking because

the downward force of gravity is no longer applied to you	the water applies an upward force to you
___	X

55.

When you drop a stone in air, it falls quickly.

When you drop a stone in water, it falls more slowly because

gravity applies a smaller downward force to stones in water	the upward force of the water slows down the stone
___	X

56.

When an object is in water,

the downward force of gravity is applied but the water applies NO upward force	the water applies an upward force but the downward force of gravity is NOT applied
___	___

the downward force of gravity and the upward force of the water are BOTH applied

X

57.

Make up a sentence using the words below.

gravity applies
water applies
downward force
upward force
to a boat

GRAVITY APPLIES A DOWNWARD FORCE AND WATER APPLIES AN UPWARD FORCE TO A BOAT.

58.

Name the forces applied to a fish in water and name the DIRECTION of each force.

UPWARD FORCE OF THE WATER
DOWNWARD FORCE OF GRAVITY

59.

When a ball is in water, gravity applies a force to the ball and the water also applies a force to the ball.

These two forces are

in the same direction	in opposite directions
___	X

60.

When a piece of wood is in water, the two forces applied to it are

in the same direction	in opposite directions
___	X

61.

Gravity applies a 500-lb. force to a boat that weighs 500 lbs. The water applies an upward force to the boat of 500 lbs.

These two forces are in opposite directions and are also

equally strong	not equally strong
X	

Therefore, the two forces are

balanced	unbalanced
X	

62.

When a 600-lb. box is in water, gravity applies a force to the box and the water also applies a force to the box.

These two forces are balanced if the force of the water is

300 lbs.	600 lbs.	900 lbs.
	X	

63.

When a 2-lb. toy boat is in water, the force of gravity applies a downward force and the water applies an upward force to the boat.

EDIT THIS SENTENCE

If the upward force of the water is LESS THAN 2 lbs., balanced forces are applied to the boat.

If correct, copy the underlined words.

If incorrect, change only the underlined words.

UNBALANCED FORCES

64.

When a 6-lb. beach ball floats in water, two balanced forces are applied to the ball.

Tell the STRENGTH and DIRECTION of the two balanced forces applied to the ball.

6 LB. UPWARD FORCE, 6 LB. DOWNWARD FORCE

65.

An ice cube falls when you let go of it because

an upward force is applied to it	the downward force of gravity is applied to it
	X

In order to keep the ice cube from falling, you must

apply an upward force to it	apply a downward force to it
X	

66.

An ice cube floats in a glass of water instead of sinking to the bottom of the glass because the downward force of gravity and the upward force of the water are

balanced	unbalanced
X	

67.

A raft floats on the lake instead of sinking because the forces applied to the raft are

balanced	unbalanced
X	

68.

An object sinks when you put it in water only if the forces applied to the object are

balanced	unbalanced
	X

69.

While an old shoe is sinking in water, we know that the forces applied to the shoe are

balanced	unbalanced
	X

When you let go of a beach ball under water, it rises to the top of the water.

The ball moves upward because the forces applied to it are

unbalanced	balanced
X	

70.

When a boat is in water and the forces applied to the boat are balanced, the boat

sinks	floats
	X

71.

Because unbalanced forces are applied to a stone in water, the stone

floats	sinks
	X

72.

EDIT THIS SENTENCE

A beach ball floats in water because the force of gravity and the force of the water are unbalanced.

If correct, copy the underlined word.

____

If incorrect, change only the underlined word.

BALANCED

73.

EDIT THIS SENTENCE

An object SINKS in water because the force of gravity and the force of the water are balanced.

If correct, copy the underlined word.

____

If incorrect, change only the underlined word.

UNBALANCED

74.

Make up a sentence using the words below. You may use any other words in addition to the words below, but make sure your sentence includes all of the words below.

sponge	A SPONGE FLOATS IN WATER
floats in water	BECAUSE THE FORCES APPLIED
because	TO IT ARE BALANCED.
forces	

75.

A 900-lb. whale floats in water because the forces applied to it are balanced. Tell the strength of the two balanced forces applied to the whale. 900 LBS.

Name the directions of the two balanced forces applied to the whale.

UPWARD AND DOWNWARD

BERNOULLI'S PRINCIPLE*

1.

During a hurricane, air is

moving	still
X	

But, on a calm day, the air is

moving	still
	X

2.

An empty bottle contains air.

The air inside a bottle is an example of

moving air	still air
	X

3.

When we turn on an electric fan we feel a breeze.

This is an example of

moving air	still air
X	

4.

Put an S below the example of still air.

Put an M below the example of moving air.

Curtains fluttering in an open window.	The air inside an automobile tire.
M	S

5.

You can feel moving air applying a force when you

extend your arm from a moving car	sit inside a parked car with the windows closed
X	

6.

You can see moving air applying a force when

a man's hat blows off his head	the branches of a tree bend in the breeze
both	neither
X	

7.

When you put your hand on the nozzle of a vacuum cleaner you feel a pull.

EDIT THIS SENTENCE

The reason is moving air applies a force to your hand.

If correct, copy the underlined words.

MOVING AIR APPLIES A FORCE

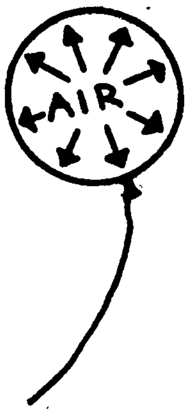
If incorrect, change the underlined part and make it correct.

---

*The frames reproduced here are those which were presented to the subjects as confirmation frames after they had made their own responses. X's are used to indicate the correct multiple choice responses.

8.

The air inside a balloon is not moving. Nevertheless, the balloon holds its shape because the still air is applying



a force to the outside ____

a force to the inside X

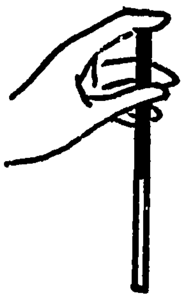
9.

We know that moving air applies a force.

It is sometimes surprising to learn that still air

also applies a force	never applies a force
X	

10.



You can sip pop through a straw and put your finger on the top of the straw. The pop will not spill out because

your finger is applying a force to the pop	the still air on the bottom is applying an upward force to the pop
	X

11.

Make up a sentence about the picture using these words.

the water does not spill

applying a force

to the water

THE WATER DOES NOT SPILL BECAUSE STILL AIR IS APPLYING AN UPWARD FORCE TO THE WATER.

12.

A force can be applied by air. Complete this sentence.

The air can be either MOVING AIR OR STILL AIR.

13.

A boy is pushing one side of a wagon with a force of 30 lbs. A boy is also pushing the other side with a force of 30 lbs.

The wagon will not move because the forces are

unequal	equal
	X

14.

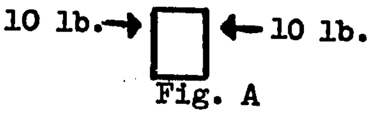


Fig. A

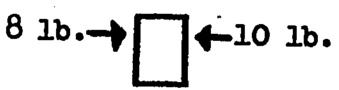


Fig. B

In Fig. A, the box will not move because the forces are

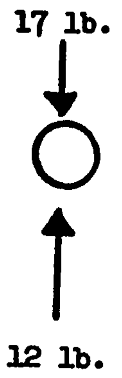
equal	unequal
X	

In Fig. B, the box will move because the 10-lb. force is

weaker	stronger
	X

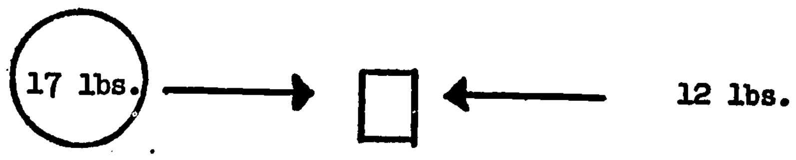
15.

Below, the ball will be pushed



up by the 12 lb. force	down by the 17 lb. force
	X

16.



Circle the stronger force in the above picture.

The stronger force will move the box to the

right	left
X	

17.

EDIT THIS SENTENCE

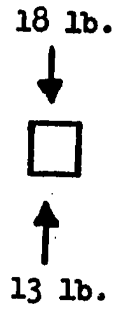
The box will be pushed to the <u>LEFT</u> because the 15-lb. force is <u>weaker</u>.

If correct, copy the underlined words.

If incorrect, change the underlined words.

RIGHT STRONGER or, RIGHT BECAUSE THE 10-LB. FORCE IS WEAKER.

18.



Complete this sentence.

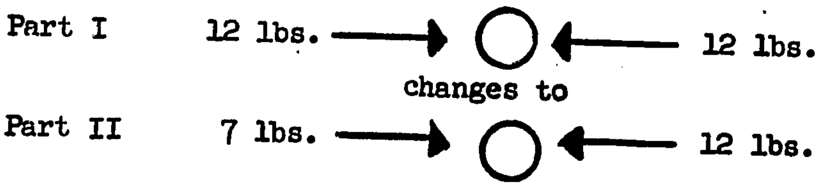
The box will be pushed DOWN because THE 18-LB. FORCE IS STRONGER (THAN THE 13-LB. FORCE).

19.

A group of boys are playing tug-of-war. There are three boys on each side. If one boy lets go of the rope, the amount of force on his side of the rope will become

stronger	weaker
	X

20.



In Part I, the ball will not move because the forces are equal. In Part II, the force on the left has become weaker. The force on the right will

move the ball	do nothing
X	

21.

If two boys are pushing opposite sides of a box with equal forces, the box will not move.

Complete the following sentence.

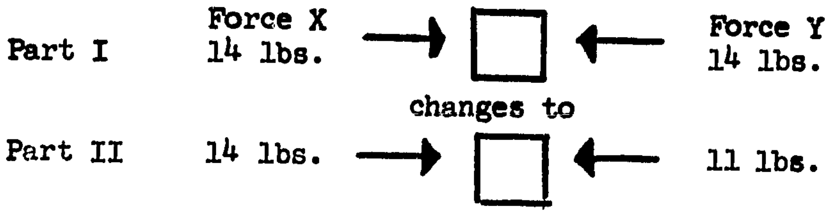
If one boy should weaken the force on his side, the other boy will be able to MOVE THE BOX.

22.

Forces A and B are equal. If force A becomes weaker, force B will be

stronger than A	weaker than A
X	

23.



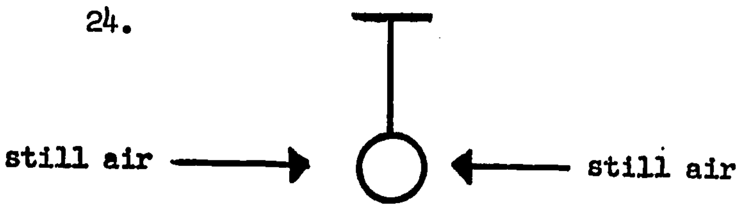
Using the words "BECOMES WEAKER" and "STRONGER," explain what happens to the forces when Part I changes to Part II.

FORCE Y BECOMES WEAKER; THEREFORE, FORCE X IS STRONGER.

What will happen to the box in Part II?

THE BOX WILL MOVE TOWARD THE RIGHT.

24.



In the picture, the air is still.

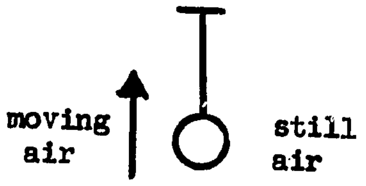
The ball hanging from the ceiling by a rope will not move because the forces are

equal	unequal
X	

25.

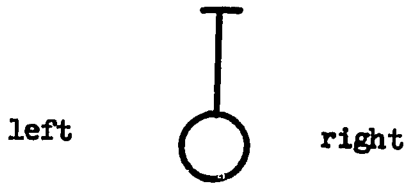
The air on one side is still but on the other side the air is moving past the ball.

The forces are



equal	not equal
	X

26.



If we blow air past the left side of the ball, the ball will move toward the left.

If we blow air past the right side of the ball, the ball will move toward the

right	left
X	

27.

When air moves past one side of an object, the moving air applies a weaker force. Thus, the still air on the other side applies a

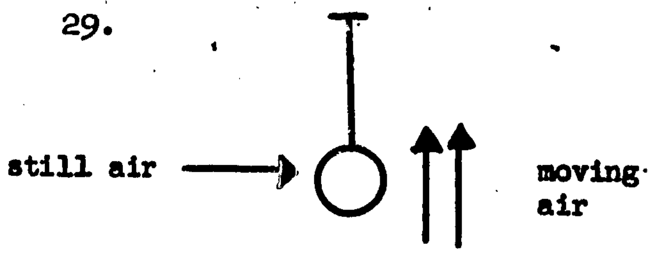
stronger force	weaker force
X	

28.

When air is moving past one side of an object, it applies less force. Thus, the still air on the other side applies

less force	more force
	X

29.



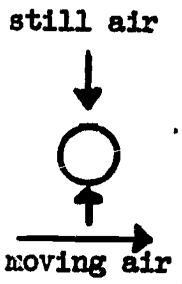
In the picture, air is moving past one side. On the other side, a stronger force is applied by the

moving air	still air
	X

The stronger force will move the ball toward the

left	right
	X

30.



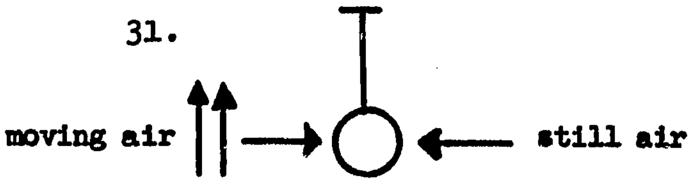
A stronger force is applied by

still air	moving air
X	

The stronger force will move the ball

up	down
	X

31.



Make up one sentence about the picture using these words.

the ball will move toward
still air applies
force

THE BALL WILL MOVE TOWARD THE LEFT BECAUSE STILL AIR APPLIES A STRONGER FORCE.

32.

A stronger force is applied by still air, but a weaker force is applied by

still air	moving air
	X

33.

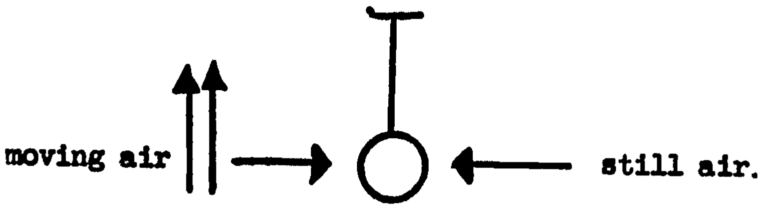
A force is applied by both still air and moving air. Still air applies a

stronger force	weaker force
X	

While moving air applies a

stronger force	weaker force
	X

34.



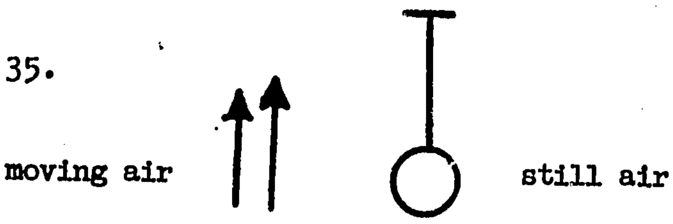
Here, the air moving past the ball applies a

weaker force than still air	stronger force than still air
X	

The ball will move to the

left	right
X	

35.



Make up one sentence using these words.

the ball will move toward

because air moving past the

still air

THE BALL WILL MOVE TOWARD THE LEFT BECAUSE AIR MOVING PAST THE BALL APPLIES LESS FORCE THAN STILL AIR.

36.

EDIT THIS SENTENCE

Still air applies a weaker force than air moving past an object.

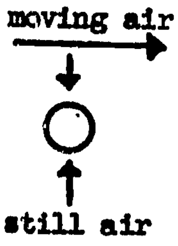
If correct, copy the underlined words.

____

If incorrect, change the underlined words.

MOVING AIR

37.



Complete this sentence.

The ball will move UP because STILL AIR APPLIES A STRONGER FORCE THAN THE AIR MOVING PAST THE TOP.

38.

EDIT THIS SENTENCE

If we blow air past one side of an object, the still air on the other side will push the object toward the moving air.

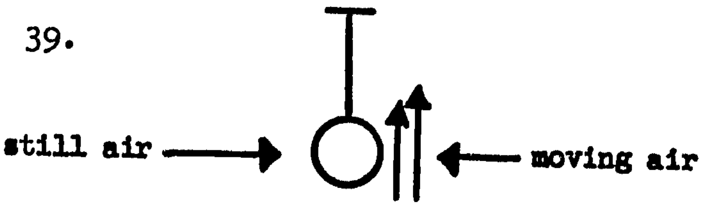
If correct, copy the underlined words.

THE STILL AIR ON THE OTHER SIDE WILL PUSH THE OBJECT TOWARD THE MOVING AIR.

If incorrect, change the underlined words.

____

39.



The weaker force is on the

left	right
	X

The ball will move toward the

left	right
	X

40.

If you want the paper to move up, past which side would you blow air?

X past the top

____ past the bottom

41.

The faster air moves, the less force it applies. Thus, as air moves faster the amount of force it applies becomes

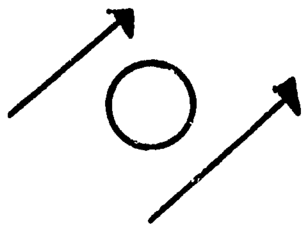
stronger	weaker
	X

42.

Air moving at 17 miles per hour applies less force than air moving at 12 miles per hour.

In the picture, put an X under the amount which is applying the smaller force.

15 miles per hour

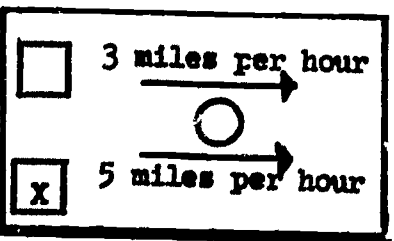


30 miles per hour

X

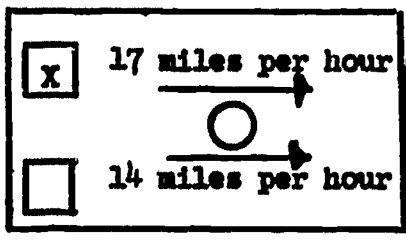
43.

In each example, put an X in the box where the air is applying a smaller force.



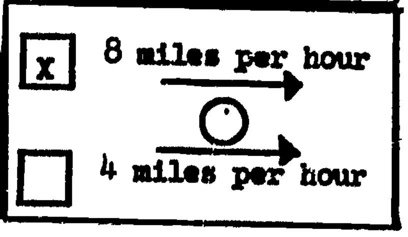
☐ 3 miles per hour

☒ 5 miles per hour



☒ 17 miles per hour

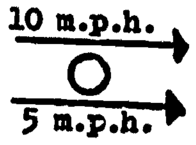
☐ 14 miles per hour



☒ 8 miles per hour

☐ 4 miles per hour

44.



The slower air moves the more force it applies. Thus, a stronger force is being applied by the air moving at

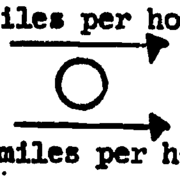
10 m.p.h. ______

5 m.p.h. X

45.

Put an X in front of the stronger force.

X 6 miles per hour



______ 13 miles per hour

The stronger force will move the ball

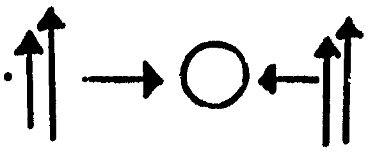
down X

up ______

46.

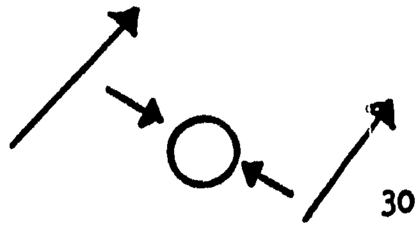
In the picture below, which force will move the ball?

3 m.p.h. X



7 m.p.h. ______

47.



EDIT THIS SENTENCE

Above, the air moving at 30 miles per hour is moving faster but it applies less force.

If correct, copy the underlined words.

IS MOVING FASTER BUT IT APPLIES LESS FORCE

If incorrect, change the underlined words.

______

48.

Make up one sentence using these words.

slower
air
stronger force

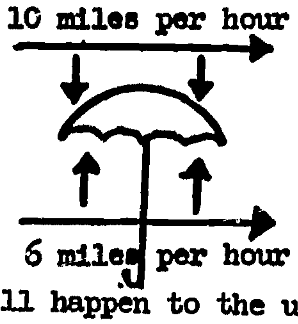
THE SLOWER AIR MOVES THE STRONGER THE FORCE IT APPLIES.

49.

Make up one sentence using these words.

air THE FASTER AIR MOVES THE
faster WEAKER THE FORCE IT
force APPLIES.

50.



What will happen to the umbrella? Explain why. THE UMBRELLA WILL BE PUSHED UP BECAUSE THE SLOWER MOVING AIR IS APPLYING A STRONGER UPWARD FORCE.

51.

When an airplane is in flight, air is moving past it.

The airplane stays up because air is applying a

stronger force on the bottom	stronger force on the top
X	

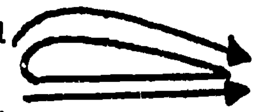
52.

If a stronger force is on the bottom of an airplane, then a weaker force is applied by the air moving past the

top of an airplane	bottom of an airplane
X	

53.

An airplane wing is shaped like this.

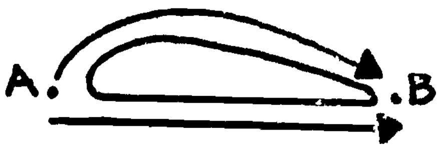


Compare the distance along the top to the distance along the bottom.

The air moving over the top must travel a

shorter distance	farther distance
	X

54.

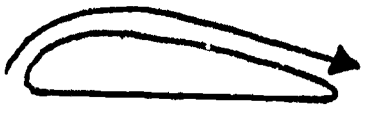


Starting at A, the air moving past the curved top of an airplane wing and the air moving past the bottom will arrive at B at the same time.

To arrive at B at the same time as the air on the bottom, the air on the top must move both farther and

faster	slower
X	

55.



Because the top of an airplane wing is curved, the air moving past the top must move farther and

faster	slower
X	

56.

The faster air moves, the less force it applies.

Thus, the faster air moving past the top of an airplane wing applies a

stronger force to the top of the wing	weaker force to the top of the wing
___	___
___	X

The slower air moving past the bottom of the wing applies a

weaker force to the bottom of the wing	stronger force to the bottom of the wing
___	___
___	X

57.

Air moving past the top of an airplane wing

moves faster and is weaker	moves slower and is stronger
___	___
X	___

58.

EDIT THIS SENTENCE

A stonger force is applied by the faster air moving past the top of an airplane.

If correct, copy the underlined words.

___

If incorrect, change the underlined words.

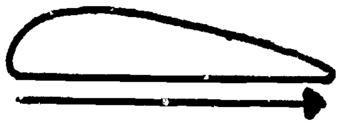
A WEAKER FORCE

59.

Make up a sentence using these words.

top of an airplane wing moves faster force	THE AIR MOVING OVER THE TOP OF AN AIRPLANE WING MOVES FASTER AND APPLIES LESS FORCE.

60.



On the bottom of an airplane wing, the air travels a shorter distance and moves

faster	slower
___	___
___	X

The air on the bottom applies a

stronger force	weaker force
___	___
X	___

The airplane stays up because the force applied to the wing is stronger at the

bottom	top
___	___
X	___

61.

EDIT THIS SENTENCE

The air going past the airplane wing moves slower and applies a weaker force to the bottom of the wing.

If correct, copy the underlined words.

___

If incorrect, change the underlined words.

STRONGER FORCE

62.

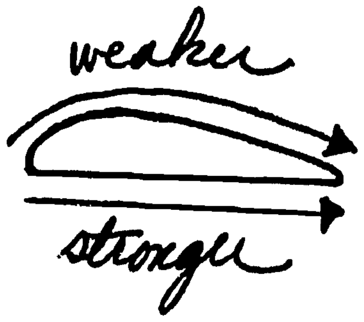
Make up one sentence using these words.

air moves bottom of the wing force to	ON THE BOTTOM OF AN AIRPLANE WING AIR MOVES SLOWER AND APPLIES MORE FORCE TO THE BOTTOM.

63.

Write weaker on the side where air applies less force to the wing.

Write stronger on the side where air applies more force to the wing.



64.

EDIT THIS SENTENCE

An airplane rises because the slower moving air beneath the wing pushes it up.

If correct, copy the underlined words.

THE SLOWER MOVING AIR BENEATH THE WING PUSHES IT UP.

If incorrect, change the underlined words.

____

65.

Complete this sentence.

On an airplane wing the stronger force is on the BOTTOM because THE AIR ON THE BOTTOM IS MOVING SLOWER THAN THE AIR ON THE TOP.

66.

Complete this sentence.

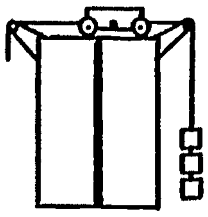
An airplane stays up in the air because THE SLOW MOVING AIR ON THE BOTTOM APPLIES A STRONGER FORCE.

Visual Answer Booklet

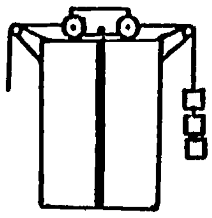
ARCHIMEDES' PRINCIPLE

Page 1

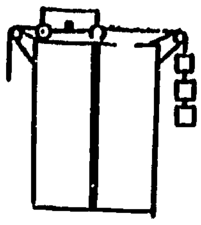
☐



☐

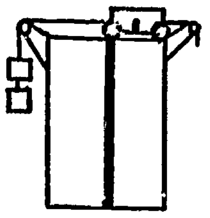


☐

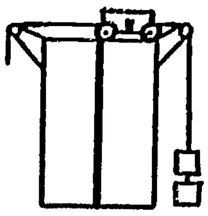


Page 2

☐

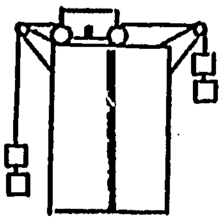


☐

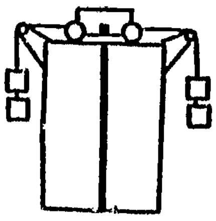


Page 3

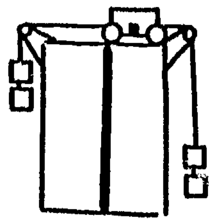
☐



☐

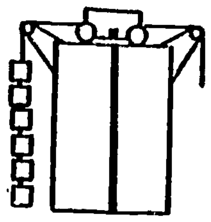


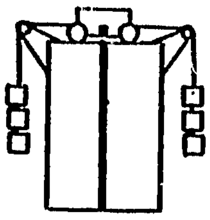
☐

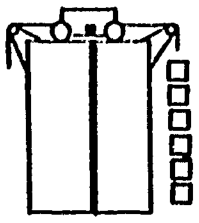


Visual Answer Booklet - Archimedes' Principle

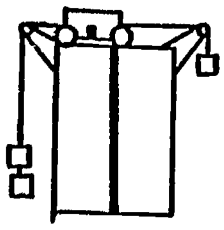
Page 4

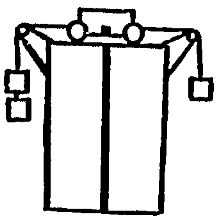
☐


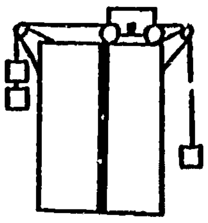
☐


☐


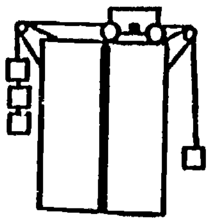
Page 5

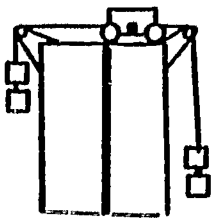
☐


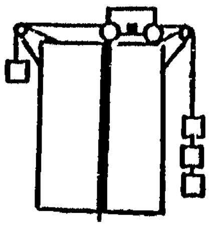
☐


☐


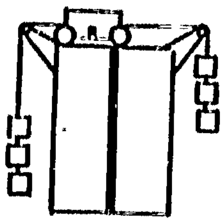
Page 6

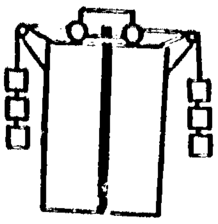
☐


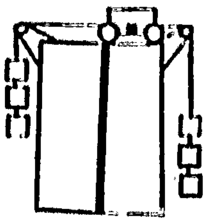
☐


☐


Page 7

☐


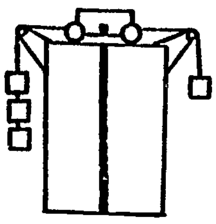
☐


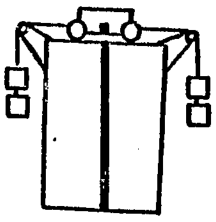
☐


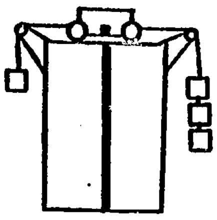
Visual Answer Booklet - Archimedes' Principle

Page 8

☐ ☐ ☐

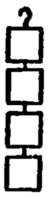






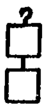
Page 9

☐ ☐ ☐



Page 10

☐ ☐ ☐



NO BLOCKS
AT ALL

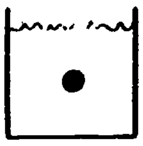
Page 11

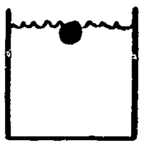
☐ ☐ ☐

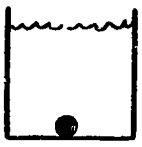
Visual Answer Booklet - Archimedes' Principle

Page 12

☐ ☐ ☐

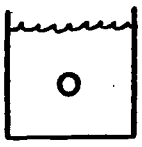


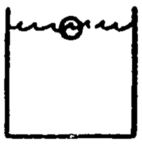


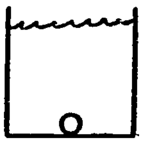


Page 13

☐ ☐ ☐



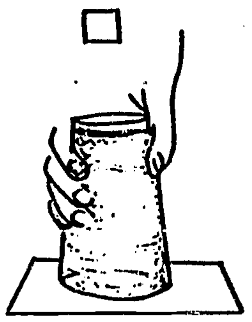




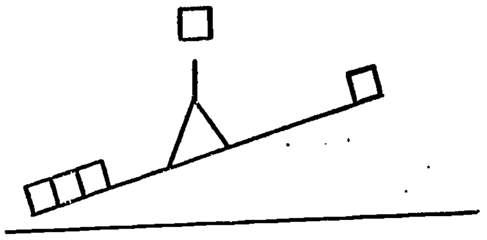
Visual Answer Booklet

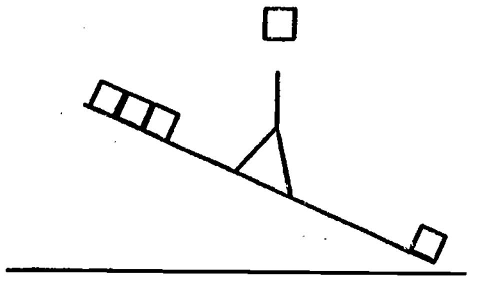
BERNOULLI'S PRINCIPLE

PAGE 1

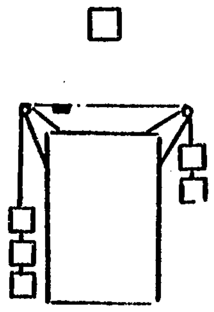


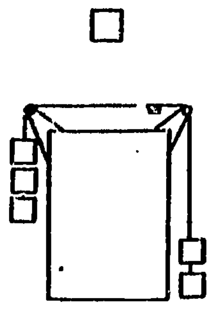
PAGE 2





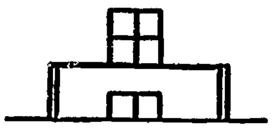
PAGE 3

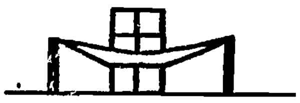




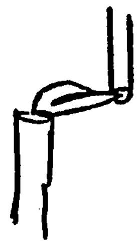
Visual Answer Booklet - Bernoulli's Principle

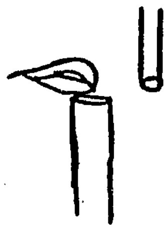
PAGE 4

☐


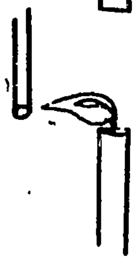
☐


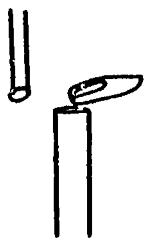
PAGE 5

☐


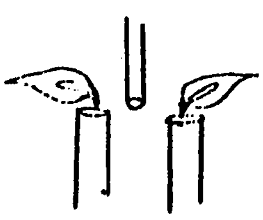
☐


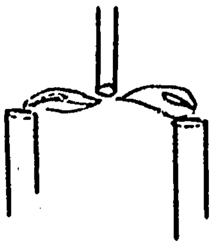
PAGE 5A

☐


☐


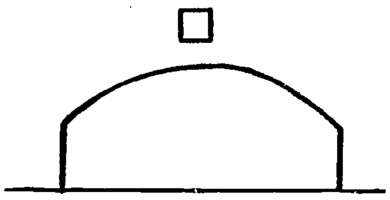
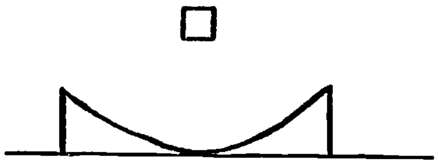
PAGE 5B

☐


☐


<u>Visual Answer Booklet</u> - Bernoulli's Principle

PAGE 6

PAGE 7

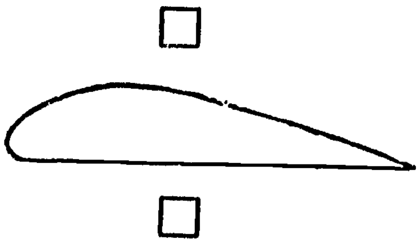
Make up <u>one</u> sentence using these words:

FASTER AIR FORCE

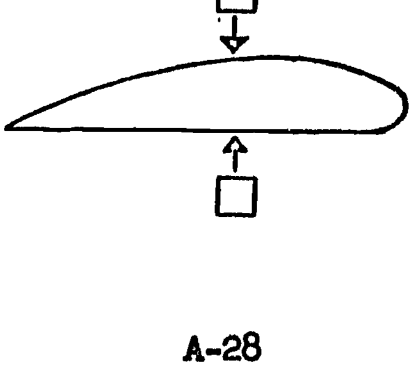
____

______________________________.

PAGE 8



PAGE 9



ARCHIMEDES' PRINCIPLE

Part I - Fill-ins

1. A 500-lb. rowboat floats in water because the forces applied to it are ________________.

   The upward force of the water applied to the rowboat is

   ____ stronger than 500 lbs.

   ____ equal to 500 lbs.

   ____ less than 500 lbs.

2. An anchor sinks in water because the forces applied to it are ________________.

3. In order for two forces to be balanced, what must be true about the strength and the direction of the two forces?

   ____

   ____

4. We say that two forces are unbalanced if the two forces are

   ____

   ____

5. Tell what happens when balanced forces are applied to a baseball at rest on the ground.

   ____

   ____

6. Two boys are pulling a rope. One boy applies a 16-lb. force to the left. If the two boys apply balanced forces, what force does the other boy apply?

   ____

Achievement Tests - Archimedes' Principle

7. When a 58-lb. piece of wood floats in water, two forces are applied to it. Tell the strength and direction of these two forces.

____

____

8. In a tug of war, if unbalanced forces are applied to the rope, what will happen?

____

____

Part II

There are five examples below of different combinations of forces applied to objects. For each combination, check whether the forces are balanced or unbalanced and also whether the object to which the forces are applied will move.

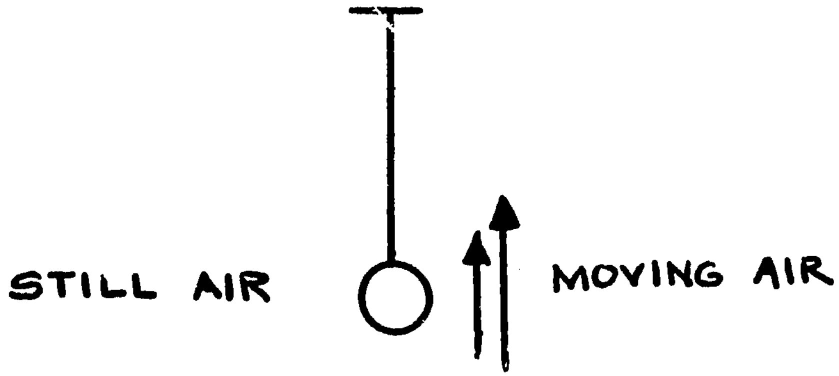
The forces are:			The object will:	
balanced	unbalanced		move	not move
____	____	1. two 47-lb. forces applied in the same direction	____	____
____	____	2. two 10-lb. forces, one applied upward the other applied down	____	____
____	____	3. two unequal forces applied, both applied in a right-hand direction	____	____
____	____	4. two unequal forces applied in opposite directions	____	____
____	____	5. a 5-lb. force applied toward the East and a 5-lb. force applied to the West	____	____

Achievement Tests

BERNOULLI'S PRINCIPLE

Part I - Fill-ins

1. A ping pong ball is hanging by a string, as in the example below.



a. If we blow air past the right-hand side of the ping pong ball, in which direction will the ping pong ball move?

____

b. Why does it move in that direction?

____

____

2. Why is an airplane supported in the air? ____________________

____

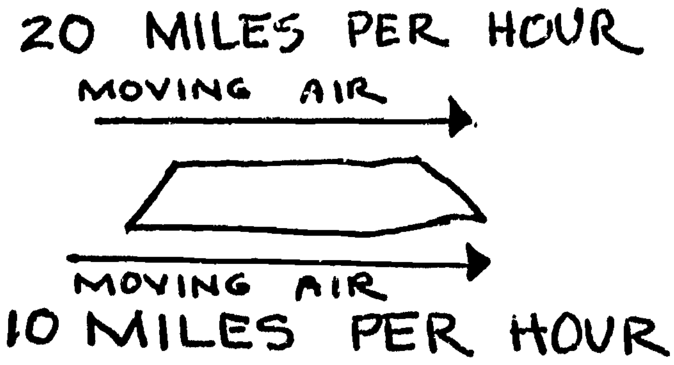
____

3. In the example below, what will happen to the paper? ____________________

____

Explain why. ____________________

____



Achievement Tests - Bernoulli's Principle

4. Draw an airplane wing.

a. When the airplane is moving air applies a stronger force to one part. To which part of the airplane wing does air apply the stronger force?

____

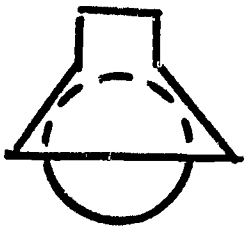
b. Why is the force stronger there? ______________________________

____

5. If you put a ping pong ball in a funnel and turn it upside down, it would fall out. If you wanted to keep the ball from falling out while the funnel was upside down, past which side would you blow air? Put an X in front of the correct answer in the picture below.

____ past the top

____ past the left



____ past the right

____ past the bottom

Explain why you chose that answer. ______________________________

____

6. When there is an increase in the speed of air, what happens to the force it applies? ______________________________

Achievement Tests - Bernoulli's Principle

Part II - Multiple Choice

1. The smallest force is applied by

    _____ air moving past an object at 10 miles per hour.

    _____ air moving past an object at 15 miles per hour.

    _____ air which is not moving.

2. During a hurricane the air is moving past the top of the house but the air inside is still. What will happen?

    _____ The still air will pull the roof down.

    _____ The still air will push the roof up.

    _____ The moving air will push the roof down.

    _____ The moving air will lift the roof up.

3. When a convertible automobile is moving along a highway, the roof may be pushed up because

    _____ the moving air is applying a stronger force.

    _____ the still air is applying a weaker force.

    _____ the still air is applying a stronger force.

    _____ none of the above.

4. If air starts to move past the right-hand side of an object, what will happen?

    _____ The force becomes weaker on the right-hand side.

    _____ The force becomes stronger on the right-hand side.

    _____ The force becomes weaker on the left-hand side.

    _____ The force stays the same.

    _____ None of the above.

5. One of the reasons an airplane flies is

    _____ the force applied to the bottom is weaker.

    _____ the force applied to the top is weaker.

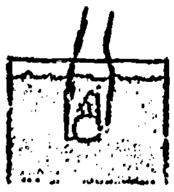
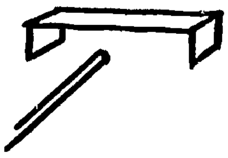
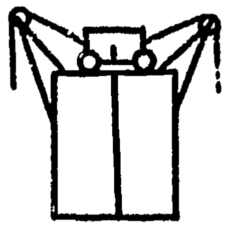
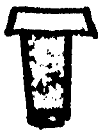
    _____ the force applied to the top is stronger.

    _____ the forces are equal.

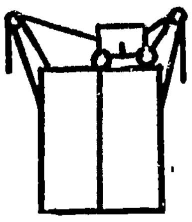
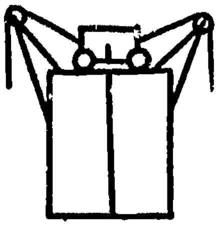
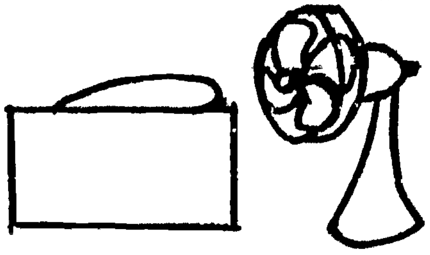
    _____ none of the above.

AN ATTITUDE SCALE

A. For each of the experiments which you just saw, put an X in the column which shows whether you would like to try it yourself.

	Would like to try it very much.	Would like to try it.	No interest in trying it.
1. blowing air past candle flames 	____	____	____
2. release ping pong ball in middle of tank 	____	____	____
3. blowing air under paper 	____	____	____
4. putting different numbers of blocks on each side so that the car will move 	____	____	____
5. turning glass of water upside down 	____	____	____

An Attitude Scale

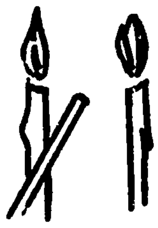
	Would like to try it very much.	Would like to try it.	No interest in trying it.
6. finding out how to distribute the blocks to make the car move to the right 	____	____	____
7. blowing air past top of paper 	____	____	____
8. putting the right number of blocks on each side so car doesn't move 	____	____	____
9. blowing air past an airplane wing 	____	____	____
10. release heavy ball at top of water 	____	____	____

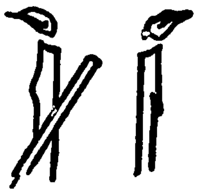
An Attitude Scale

B. Which way did each of the following experiments turn out? Put an X next to the picture which shows which way it turned out.

It turned out this way.
It turned out this way.
It turned out this way.

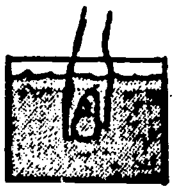
1. blowing air past candle flames

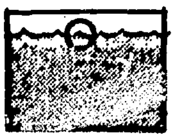


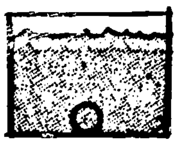
____ 

____ 

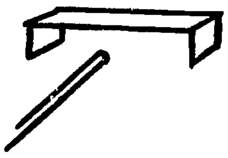
2. release ping pong ball in middle of tank

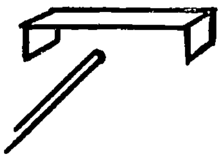


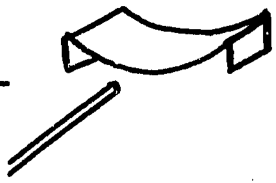
____ 

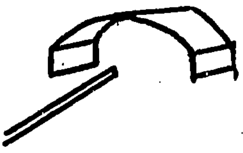
____ 

3. blowing air under paper

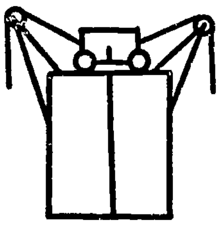


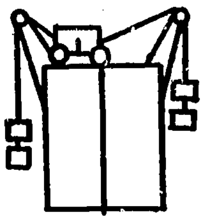
____ 

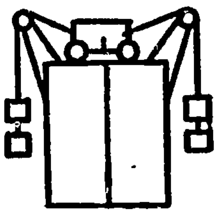
____ 

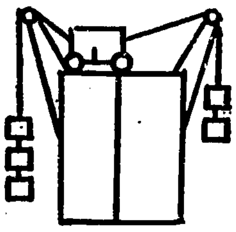
____ 

4. putting different numbers of blocks on each side so that the car will move

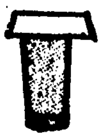


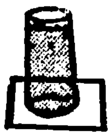
____ 

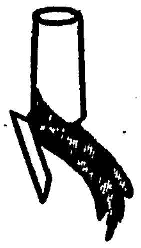
____ 

____ 

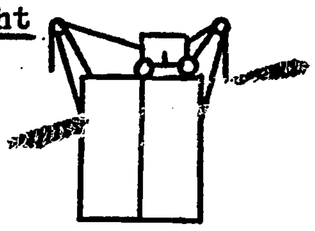
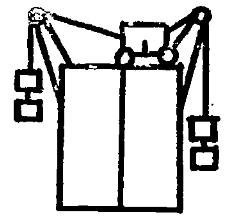
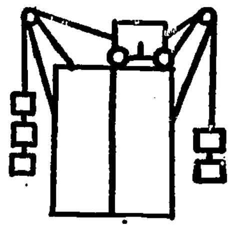
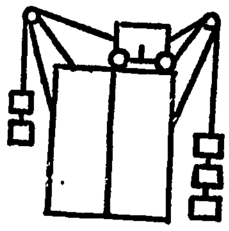
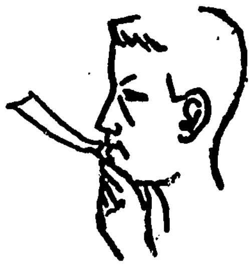
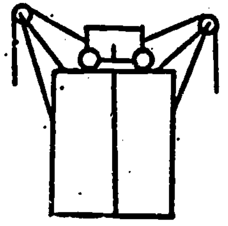
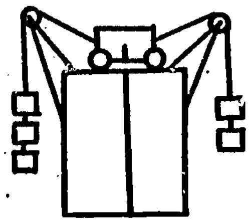
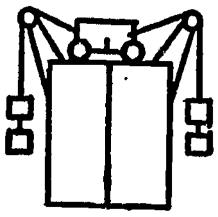
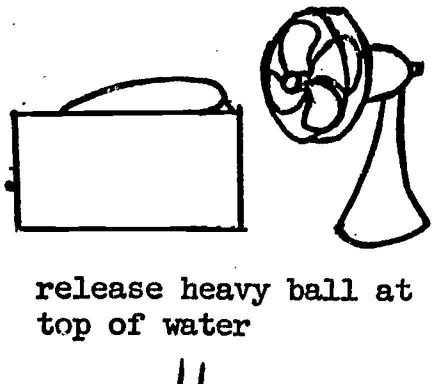
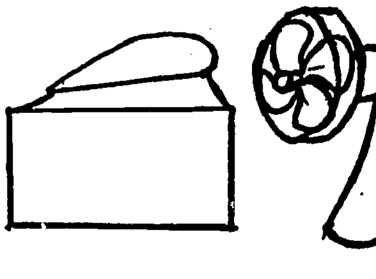
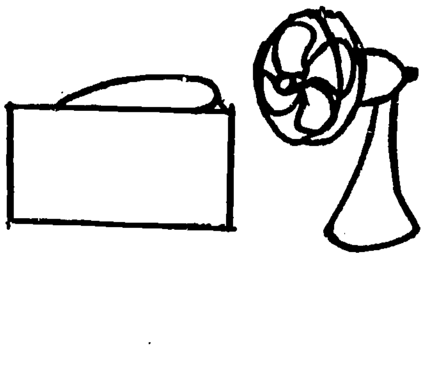
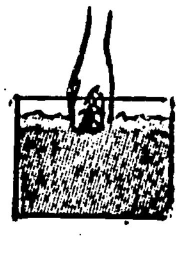
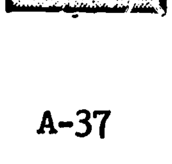
5. turning glass of water upside down



____ 

____ 

An Attitude Scale

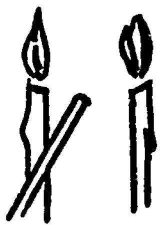
	It turned out this way.	It turned out this way.	It turned out this way.
6. finding out how to distribute the blocks to make the car move to the right 	___ 	___ 	___ 
7. blowing air past top of paper 	___ 	___ 	
8. putting the right number of blocks on each side so car doesn't move 	___ 	___ 	
9. blowing air past an airplane wing 	___ 	___ 	
10. release heavy ball at top of water 	___ 	___ 	

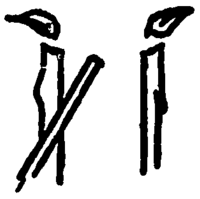
An Attitude Scale

C. If you tried each of the following experiments yourself, which way do you think they would turn out? Put an X next to the picture which shows which way you think it would turn out if you tried it.

It would turn out this way. | It would turn out this way. | It would turn out this way.

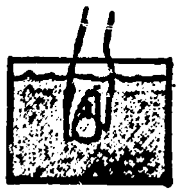
1. blowing air past candle flames

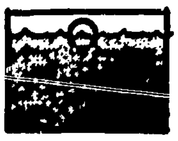


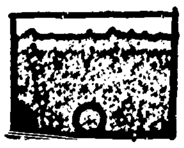
___ 

___ 

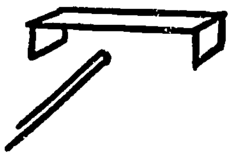
2. release ping pong ball in middle of tank

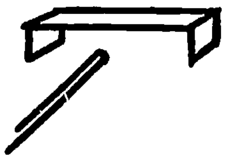


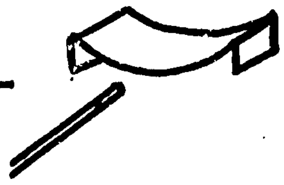
___ 

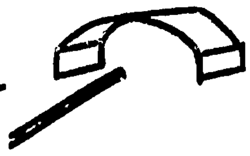
___ 

3. blowing air under paper

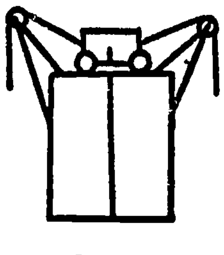


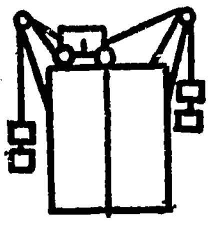
___ 

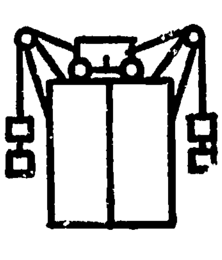
___ 

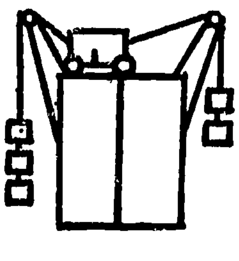
___ 

4. putting different numbers of blocks on each side so that the car will move

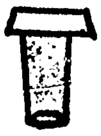


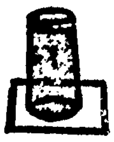
___ 

___ 

___ 

5. turning glass of water upside down



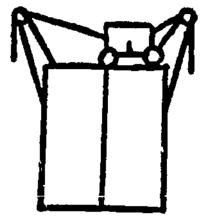
___ 

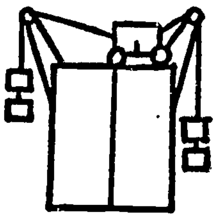
___ 

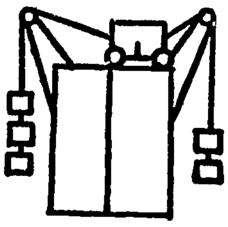
An Attitude Scale

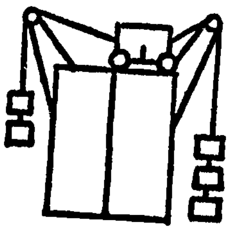
It would turn out this way.
It would turn out this way.
It would turn out this way.

6. finding out how to distribute the blocks to make the car move to the right



____ 

____ 

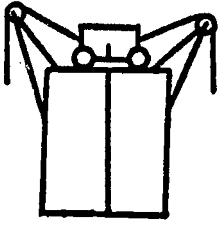
____ 

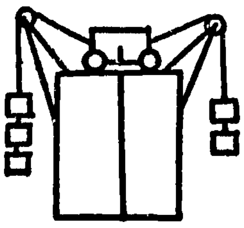
7. blowing air past top of paper

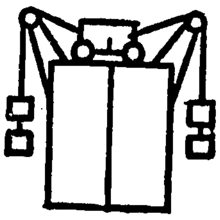
____ 

____ 

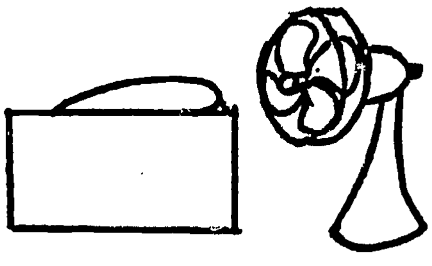
8. putting the right number of blocks on each side so car doesn't move

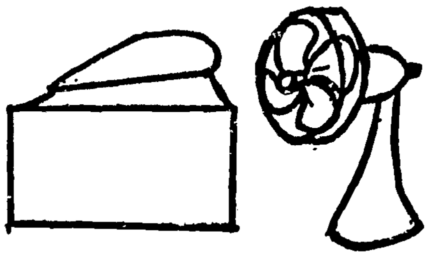


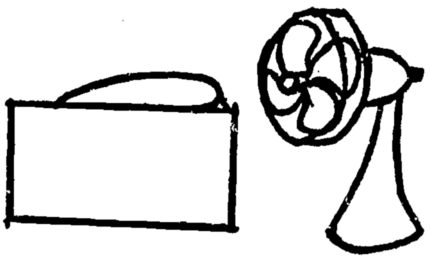
____ 

____ 

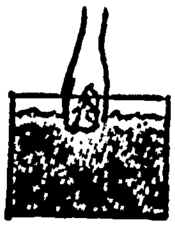
9. blowing air past an airplane wing

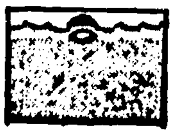


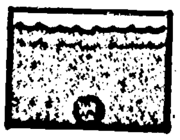
____ 

____ 

10. release heavy ball at top of water



____ 

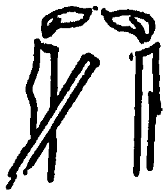
____ 

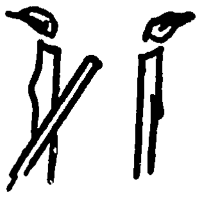
An Attitude Scale

D. When these experiments were done on the screen, they came out a certain way. If you did these experiments yourself, which way would they come out? Put an X next to the picture which shows which way you think it would turn out if you tried it.

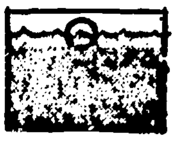
It would turn out this way. It would turn out this way. It would turn out this way.

1. This is what happened when air was blown past candle flames.

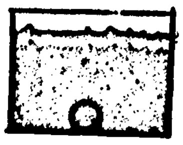
— 

— 

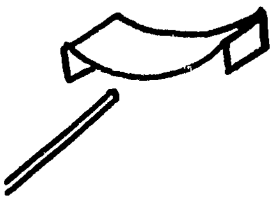
2. This is what happened when the ping pong ball was released in middle of tank.

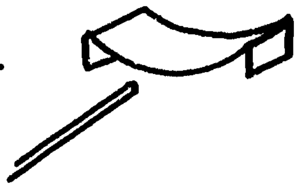


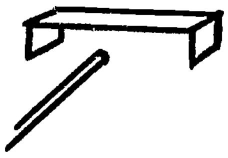
— 

— 

3. This is what happened when air was blown under paper.

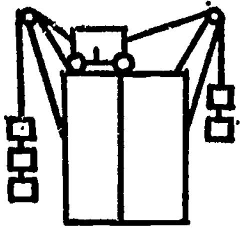


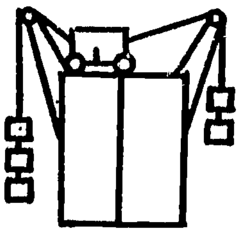
— 

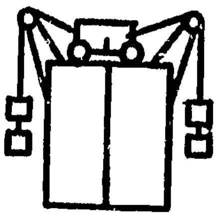
— 

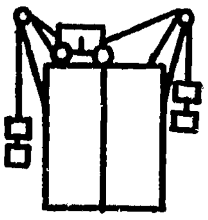
— 

4. This is what happened when different numbers of blocks were put on each side so that the car would move.

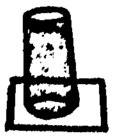


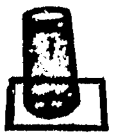
— 

— 

— 

5. This is what happened when a glass of water was turned upside down.



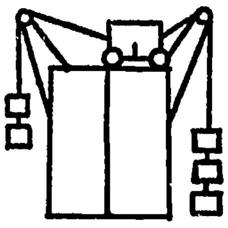
— 

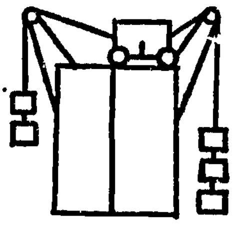
— 

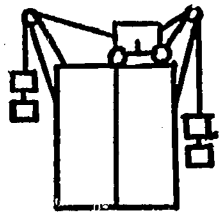
An Attitude Scale

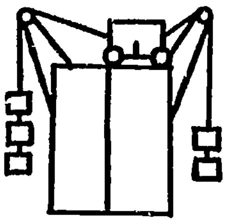
It would turn out this way. It would turn out this way. It would turn out this way.

6. This is what happened when we found out how to distribute the blocks to make the car move to the right.

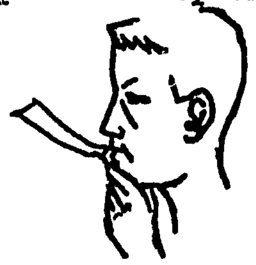


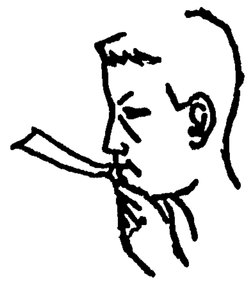
___ 

___ 

___ 

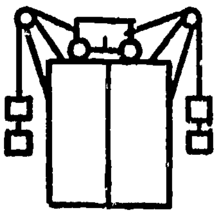
7. This is what happened when air was blown past the top of paper.

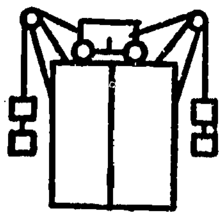


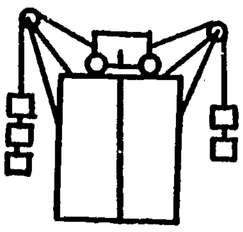
___ 

___ 

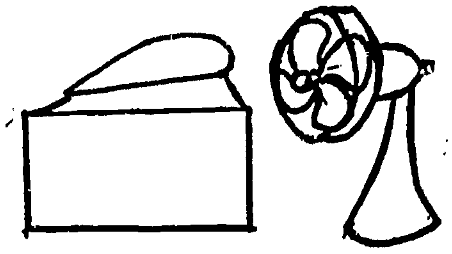
8. This is what happened when the right number of blocks were put on each side so the car didn't move.

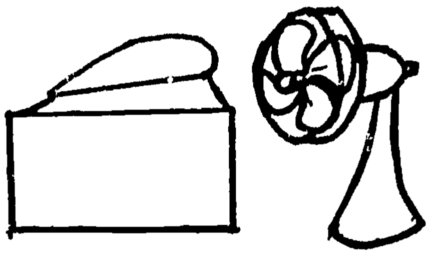


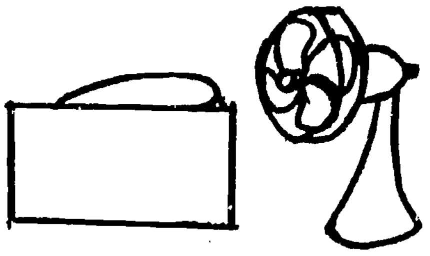
___ 

___ 

9. This is what happened when air was blown past an airplane wing.



___ 

___ 

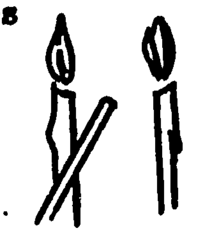
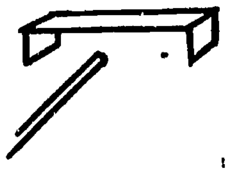
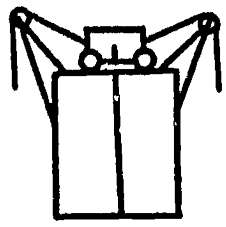
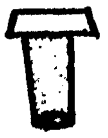
10. This is what happened when the heavy ball was released at top of water.

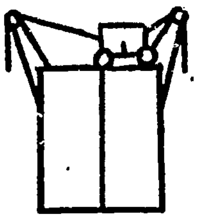
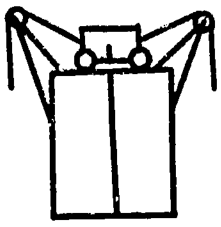
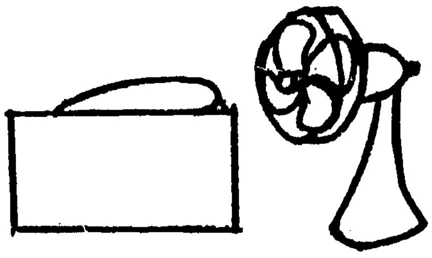
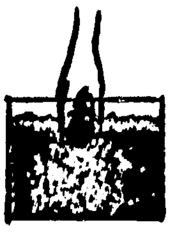
___ 

___ 

An Attitude Scale

E. What reason(s) would you have for trying each of the following experiments yourself?

	Just curious to see how it would come out.	To check to see if it would come out the same way.	Don't believe it would come out the same way.
1. blowing air past candle flames 	___	___	___
2. release ping pong ball in middle of tank 	___	___	___
3. blowing air under paper 	___	___	___
4. putting different numbers of blocks on each side so that the car will move 	___	___	___
5. turning glass of water upside down 	___	___	___

An Attitude Scale	Just curious to see how it would come out.	To check to see if it would come out the same way.	Don't believe would come out the same way.
6. finding out how to distribute the blocks to make the car move to the right 	___	___	___
7. blowing air past top of paper 	___	___	___
8. putting the right number of blocks on each side so car doesn't move 	___	___	___
9. blowing air past an airplane wing 	___	___	___
10. release heavy ball at top of water 	___	___	___

F. In a sentence or two, tell which experiments you preferred seeing and why, the live experiments or the experiments done in animation.

LEARNING FROM A PROGRAM*

1.

This is a new kind of lesson, called a "program." A program does NOT try to find out what you already know. Place an X in one of the two boxes below.

A program is a test.	A program is not a test.
____	____
____	____

2.

A nice thing about a program is that everyone in the class doesn't have to finish at the same time. This means that in a program you work

at the same speed as everyone else	at your own best speed
____	____
____	____

3.

John likes to work a little slower than Mary. They both learn well from a program because in a program they work

at their own speed	at the same speed as the rest of the class
____	____
____	____

4.

EDIT THIS SENTENCE

When he worked on a program, Bob worked at the same speed as everybody else in the class.

If the underlined part of the sentence is correct, COPY it.

____

If the underlined part is incorrect, CHANGE it.

____

5.

Make up a sentence.
Use all the words listed below. Add any extra words you need to make a complete sentence. Write your sentence below.

program ________________________________
speed ________________________________
class ________________________________

6.

It doesn't make any difference how fast or slow you work as long as you work accurately. You must remember to

answer without reading the page carefully	read the page carefully and answer accurately
____	____
____	____

7.

Programs help you by telling you things before asking you questions about them. You learn by

answering the questions without reading carefully	reading carefully then answering the questions
____	____
____	____

8.

EDIT THIS SENTENCE

Peter nearly always got his answers right in the program because he read the page carefully first.

If the underlined part of the sentence is correct, COPY it.

____

If the underlined part is incorrect, CHANGE it.

____

---

*The frames reproduced here are those which were presented to the subjects as confirmation frames after they had made their own responses. X's are used to indicate the correct multiple choice responses. The first nine frames did not have confirmation frames.

9.

It's easy to get correct answers in a program as long as you answer accurately. Katie was careless and inaccurate in writing her answers, so therefore she didn't ______________________________.

10.

Make up a sentence which includes all the words listed below. Write your complete sentence below.

correct answers ____________________

read carelessly ____________________

____

10a.

CHECKING PAGE

This is a checking page. Programs usually have checking pages like this one.

The sentence you just wrote doesn't have to be exactly like the one below, but it should mean the same.

YOU CAN'T GET THE CORRECT ANSWERS IF YOU READ THE PAGE CARELESSLY.

11.

You're supposed to learn algebra.
If you simply copy somebody's answer on one problem, later on

you will be able to solve other problems by yourself	you won't be able to solve other problems by yourself
____	____
____	X

12.

It is easy to get the right answers if you are told the answer first. But you always learn better if you figure things out for yourself.
You learn well from a program because

you can look up the answers	you get practice in figuring out the answers for yourself
____	____
____	X

13.

Teachers have discovered that students remember what is in a lesson if they find out whether their answer is correct right after they have figured it out. They forget if they look at the answer

without trying to figure it out	after they have figured it out
____	____
X	____

14.

If you figure things out for yourself instead of copying the answer you

forget quicker	remember better
____	____
____	X

15.

A program is not a test, but after you have finished the program you usually take a test. The way to remember things in a program and to pass the test afterwards is to

just copy the answers	figure the answers out for yourself
____	____
____	X

16.

The checking page is for checking your answer after you have figured it out. It tells you if your answer was correct. You should look at the checking page

before you figure out the answer	after you figure out the answer
	X

17.

You remember lessons better if you

figure answers out for yourself	copy answers
X	

Therefore, in a program it is important to

look at the checking page first and then write your answer	write your answer first and then look at the checking page
	X

18.

The way to learn how to solve problems by yourself is to

get practice in solving them	just look up the answers
X	

19.

Being able to look answers up on the checking page is important, but it only helps you to remember if you

merely copy the answers from the checking page	practice figuring out the answers first and then check them
	X

20.

You can get the right answers on a program just by copying them. If you do copy, later on

you will be able to do new problems by yourself	you won't be able to do new problems by yourself
	X

21.

EDIT THIS SENTENCE

A reason people remember so well what they learn from programs is that they can copy the answer from the checking page without first trying to figure it out for themselves.

If the underlined part of the sentence is correct, COPY it.

____

If the underlined part is incorrect, CHANGE it.

FIGURE THE ANSWER OUT FOR THEMSELVES FIRST AND THEN LOOK AT THE CHECKING PAGE TO SEE IF IT'S RIGHT

22.

Complete this sentence.
You are more likely to forget what's in a program if YOU SIMPLY COPY THE ANSWERS FROM THE CHECKING PAGE.

23.

It is important to figure out answers for yourself in a program because it helps you REMEMBER (or, UNDERSTAND, LEARN) better.

24.

The physics teacher told the class they were going to take a program. The program would tell them things and then ask questions. There would be no grade given for the work, because a program

is not a test	is a test
X	

25.

You can learn new subjects by answering questions in a program like this one. A program is supposed

to teach you something new	to test you to see what you already know
X	

26.

EDIT THIS SENTENCE

Although you answer questions in a program, a program is just like a test.

If the underlined part of the sentence is correct, COPY it.

____

If the underlined part is incorrect, CHANGE it.

NOT LIKE A TEST

27.

Make up a sentence which includes all the words listed below. Write your complete sentence below.

program A PROGRAM IS NOT A TEST.

test

28.

Complete this sentence.

Even though you answer questions in a program, you don't get grades because a program IS SUPPOSED TO TEACH YOU SOMETHING AND NOT TO TEST YOU.

29.

Jim and Dave both worked on a program. They both got the right answers in the program, but Dave had merely copied his answers each time. Later on, when they were given a test, Jim remembered better and got a better test score. Why?
JIM REMEMBERED BETTER BECAUSE WHILE WORKING ON THE PROGRAM HE FIGURED THE ANSWERS OUT FOR HIMSELF AND THEN CHECKED THEM AFTERWARDS.

30.

When a teacher has you figure answers out on a test, it's because the teacher wants to

find out what you have already learned	teach you something new
X	

When a teacher has you figure answers out in a program, it's because the teacher wants to

find out what you have already learned	teach you something new
	X

31.

What is the difference between a program and a test? A PROGRAM IS MEANT TO TEACH YOU SOMETHING, AND NOT TO FIND OUT WHAT YOU ALREADY KNOW.

32.

You will be surprised how much this program has taught you already. Mark the statements below as "T" (true) or "F" (false).

A program is a test. F

You can get your answers correct in a program if you read carefully. T

You all have to work at the same speed in a program. F

It is not important to work accurately. F

After you have given your answer, the program has a checking page, which tells you if your answer was correct. T

33.

After you finish a program, you sometimes are given a test to find out what you have learned. What is the best way to work on the program in order to get the best mark on the test given afterwards?

IT'S BEST TO TRY TO FIGURE OUT PROBLEMS FIRST AND THEN CHECK TO SEE IF THE ANSWERS ARE RIGHT.

34.

Write a few sentences describing what you have learned about programs.

A PROGRAM IS MEANT TO TEACH YOU SOMETHING, NOT TO TEST YOU.

YOU MUST READ CAREFULLY BEFORE YOU ANSWER.

AS LONG AS YOU WORK ACCURATELY YOU CAN WORK AT YOUR OWN SPEED.

YOU CAN REMEMBER THINGS BETTER IF YOU LOOK AT THE CHECKING PAGE AFTER YOU HAVE WRITTEN YOUR ANSWER.

35.

The main reason I remembered as many things as I did about a "program" is that I TRIED TO FIGURE ANSWERS OUT FIRST AND THEN CHECKED TO SEE IF THEY WERE RIGHT.

FORCE PROGRAM*

1.

We say that an object is "at rest" when it isn't moving. An automobile is at rest when it is

parked	speeding
X	

2.

A ball is at rest when it is

lying on a table	rolling off the table
X	

3.

Unless you push a book which is lying still on a table, the book will

remain at rest	start to move
X	

4.

We use the words "apply a force" whenever someone pushes or pulls an object. If a man applies a force to a ball, the ball will

remain at rest	start to move
	X

5.

If a man doesn't apply a force to a box, the box will

remain at rest	start to move
X	

6.

A man can make a wagon start to move if he applies a force to it. He can apply a force to the wagon by

getting in back and pushing it	getting in front and pulling it	either way
		X

7.

EDIT THIS SENTENCE

When a man pushes a box, he is applying a force to the box.

If the underlined part of the sentence is correct, copy the underlined words.

APPLYING A FORCE TO THE BOX

If the underlined part of the sentence is incorrect, change the underlined words.

8.

Make up one correct sentence out of all of these words. They can be in any order you want. You can change the tenses of the verbs if you want. You can add any words you want to make a complete sentence.

apply a force to

by pushing or pulling

YOU APPLY A FORCE TO AN OBJECT BY PUSHING OR PULLING IT.

---

*The frames reproduced here are those which were presented to the subjects as confirmation frames after they had made their own responses. X's are used to indicate the correct multiple choice responses.

9.

EDIT THIS SENTENCE

When a man applies a force to a cart, the cart will remain at rest.

If the underlined part of the sentence is correct, copy the underlined words.

____

If incorrect, change the underlined words.

NOT REMAIN AT REST or START TO MOVE

10.

Make up one sentence using all these words and any other words you need.

baby carriage
apply a force to
start to move

WHEN YOU APPLY A FORCE TO A BABY CARRIAGE, IT WILL START TO MOVE or THE BABY CARRIAGE STARTED TO MOVE WHEN THE MAN APPLIED A FORCE TO IT.

11.

Make up one sentence out of these words.

apply a force
remain at rest

IF YOU APPLY A FORCE TO AN OBJECT, IT WILL NOT REMAIN AT REST or, UNLESS YOU APPLY A FORCE TO AN OBJECT, IT WILL REMAIN AT REST.

12.

When a sailboat stays perfectly still in the middle of a lake, it's because NO FORCE IS BEING APPLIED TO IT.

13.

If you push something in a forward direction, the direction of the push is said to be

forward	backward
X	

Since a push is one kind of force, we can also say that the direction of the force is

forward	backward
X	

14.

If you pull a bucket up to the roof with a rope, the force pulling on the bucket is

in a right-hand direction	in a left-hand direction	in an upward direction	in a downward direction
		X	

15.

When you throw a ball up in the air, you are applying a force to the ball in

an upward direction	a downward direction
X	

16.

When you push a box toward the door, you are applying a force to the box

in a direction toward the door	in a direction away from the door
X	

17.

You apply a force to a box; if you apply a force in a right-hand direction, the box will move in a

right-hand direction	left-hand direction
X	

18.

An example of a force and movement being in the same direction is when you push clothes down in a hamper and the clothes

move up	move down
	X

19.

If you push a box toward the left, the box will move to the left. The force you apply and the movement of the box are

in the same direction	in opposite directions
X	

20.

EDIT THIS SENTENCE

If you push an object forward and the object moves forward, we would say that the force and the movement are <u>in the opposite direction</u>.

If the underlined words are correct, copy them.

____

If incorrect, correct them.

IN THE SAME DIRECTION

21.

If a wagon moves because you have applied a force to it, the <u>direction</u> in which the wagon moves and the <u>direction</u> of the force you applied to it are

the same	opposite
X	

22.

EDIT THIS SENTENCE

If an object moves because a force is applied to it, <u>the object will move in the same direction as the force which is applied to it</u>.

If the underlined part of the sentence is correct, copy the underlined words.

THE OBJECT WILL MOVE IN THE SAME DIRECTION AS THE FORCE WHICH IS APPLIED TO IT

If incorrect, change the underlined words.

____

23.

Make up one sentence out of these words.

a cart will move in the same direction as	A CART WILL MOVE IN THE SAME DIRECTION AS THE FORCE APPLIED TO IT.

24.

A wagon will start to move toward the east only if THE FORCE APPLIED IS TOWARD THE EAST.

25.

Make up your own example of when the direction of a force and the direction of the movement are the same.

A MAN PUSHES AN OBJECT TOWARD THE RIGHT-HAND SIDE OF A ROOM AND THE OBJECT MOVES TOWARD THE RIGHT-HAND SIDE OF THE ROOM.

26.

One man can't push a stalled car by himself. Five men can push it, because the force they apply to the car is

strong enough	too weak
X	

27.

A large boulder is NOT likely to be moved when the force applied to it is

weak	strong	very strong
X		

28.

When the force applied to an object is too weak, the object will

start to move	remain at rest
	X

29.

EDIT THIS SENTENCE

When the force applied to an object is strong enough, the object will start to move.

If the sentence is correct, copy the underlined words.

WHEN THE FORCE APPLIED TO AN OBJECT IS STRONG ENOUGH, THE OBJECT WILL START TO MOVE.

If the sentence is incorrect, change the underlined words.

30.

Make up one sentence out of these words.

force IF THE FORCE WE APPLY TO AN
too weak OBJECT IS TOO WEAK, THE OBJECT
move WILL NOT MOVE.

31.

The strength of forces is measured in lbs. The strongest force is the

10-lb. force	3-lb. force	5-lb. force
X		

32.

Compare a 200-lb. force and a 100-lb. force. The 200-lb. force is

stronger	weaker
X	

33.

A 100-lb. force is LESS likely to make a stalled car move than a 200-lb. force because the 100-lb. force is

weaker	stronger
X	

34.

We talk about how STRONG a force is. We DON'T talk about how much a force weighs. Therefore, if a man applies a 30-lb. force, the 30 lbs. tells us

how strong the force is	how much the force weighs
X	

35.

A man's weight is measured in lbs. The STRENGTH of forces is ALSO measured in LBS. If a 10-lb. force is applied to a box, 10 lbs. tells us the

strength of the force	weight of the force
X	

36.

When we talk about a force of 15 lbs. or 25 lbs., the number of lbs. tells us

how much the force weighs	how strong the force is
	X

37.

Compare a 30-lb. force and a 10-lb. force. The 30-lb. force

weighs more	is stronger
	X

38.

A boy was just barely able to make a wagon move when he applied a force of 45 lbs. to it.

EDIT THIS SENTENCE

If the boy had applied less force, the wagon wouldn't move because the force would not be strong enough.

If correct, copy the underlined words.

THE WAGON WOULDN'T MOVE BECAUSE THE FORCE WOULD NOT BE STRONG ENOUGH.

If incorrect, make it correct.

______________________________.

39.

A man pushed a cart with a force of 25 lbs.

EDIT THIS SENTENCE

The number of lbs. tells us how much the force weighs.

If the underlined part of the sentence is correct, copy the underlined words.

____

If incorrect, change the underlined words.

HOW STRONG THE FORCE IS

40.

Make up one sentence out of these words.

we measure	WE MEASURE THE STRENGTH
of a force	OF A FORCE IN LBS.
in lbs.	

41.

Construct a sentence out of these words.

remain at rest	AN OBJECT WILL REMAIN AT
force	REST IF THE FORCE APPLIED
strong	TO IT IS NOT STRONG ENOUGH.

42.

Make up your own example of a situation where something doesn't move because the force applied to it isn't strong enough.

IF A BOY TRIES TO LIFT A CAR, THE CAR DOESN'T MOVE BECAUSE THE BOY ISN'T STRONG ENOUGH.

43.

A 3-lb. book on a desk applies a 3-lb. downward force to the desk. A 10-lb. box on the desk applies a downward force to the desk of

3 lbs.	10 lbs.
	X

44.

A 180-lb. man standing on the floor applies

a downward force of 180 lbs. to the floor	an upward force of 180 lbs. to the floor
X	

45.

The more an object weighs,

the stronger the downward force it applies	the weaker the downward force it applies
X	

46.

Compare a 2000-lb. and a 3000-lb. automobile. The downward force applied to the road by the 3000-lb. car is

stronger	weaker
X	

47.

The strength of a downward force which an object applies to a table depends on the

weight of the object	weight of the table
X	

48.

We want to put one box on a table, but the table is in danger of breaking. It would be better to select the

200-lb. box	250-lb. box
X	

because it will apply a

weaker downward force to the table	stronger downward force to the table
X	

49.

A pile of books is lying on a table. If we know how much the books weigh, we also know

the strength of the downward force applied to the table	the weight of the downward force which is applied to the table
X	

50.

A 15-lb. box is resting on the floor.

The box weighs 15 lbs.	The strength of the downward force on the floor is 15 lbs.

both	neither
X	

51.

A 95-lb. boy lying on a bed applies a downward force to the bed of

less than 95 lbs.	exactly 95 lbs.	more than 95 lbs.
	X	

52.

EDIT THIS SENTENCE

A 30-lb. bag of sand applies a downward force of less than 30 lbs. to the ground.

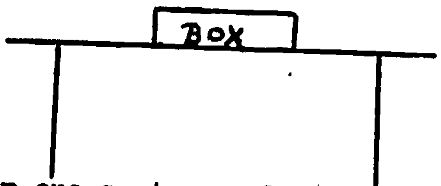
If the underlined part of the sentence is correct, copy the underlined words.

____

If incorrect, change the underlined words.

A DOWNWARD FORCE OF EXACTLY 30 LBS. TO THE GROUND

53.



Make up one sentence about this picture using these words.

downward force
applied by the
depends on
weighs

THE STRENGTH OF THE DOWNWARD FORCE APPLIED BY THE BOX TO THE TABLE DEPENDS ON HOW MUCH THE BOX WEIGHS.

54.

An object lying on a table applies a downward force to the table. The strength of the force is equal to THE WEIGHT OF THE OBJECT.

55.

Complete this sentence.

An object at rest will start to move only if YOU APPLY A FORCE TO IT.

56.

How can you apply a force to objects? BY PULLING THEM OR PUSHING THEM.

57.

The direction in which an object moves depends on THE DIRECTION OF THE FORCE APPLIED TO IT.

58.

An object will remain at rest unless the force you apply to it is STRONG ENOUGH.

59.

How much downward force does an object apply to the surface on which it's lying? A FORCE EQUAL TO ITS WEIGHT.

60.

When a 30-lb. object is on the ground, what does the object do to the ground? APPLIES A DOWNWARD FORCE OF 30 LBS. TO THE GROUND.

61.

When you lift an object off the ground what are you doing to the object? APPLYING A FORCE TO IT.

ADDITIONAL RESULTS

Table 1

Summary of Analysis of Variance
for the Matching of Ss for:
Otis IQ

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	.28571	.28571	.01
2	1	2162.57156	2162.57156	54.06***
3	1	.28571	.28571	.01
12	1	10.28571	10.28571	.26
13	1	.28571	.28571	.01
23	1	.28571	.28571	.01
123	1	.28528	.28528	.01
WITHIN REPLICATES	48	1925.42836	40.11309	
TOTAL	55	4099.71375		

Table 2

Summary of Analysis of Variance
for the Matching of Ss for:
Work Rate

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	4.01786	4.01786	.80
2	1	.01786	.01786	.00
3	1	270.16072	270.16072	54.03***
12	1	.87500	.87500	.17
13	1	1.44643	1.44643	.29
23	1	.44643	.44643	.09
123	1	.01782	.01782	.00
WITHIN REPLICATES	48	239.99998	5.00000	
TOTAL	55	516.98208		

Significance levels: * = .05; ** = .01; *** = .001.

Table 3

Summary of Analysis of Variance for the Matching of Ss for: Pretest Scores

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	7.87500	7.87500	.60
2	1	75.44643	75.44643	5.81*
3	1	3.01786	3.01786	.23
12	1	.44643	.44643	.03
13	1	1.44643	1.44643	.11
23	1	7.87500	7.87500	.61
123	1	.87495	.87495	.07
WITHIN REPLICATES	48	619.99993	12.91667	
TOTAL	55	716.98202		

Table 4

Summary of Analysis of Variance: Posttest - Archimedes' Principle

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	31.50000	31.50000	3.78
2	1	48.28571	48.28571	5.79*
3	1	2.57143	2.57143	.31
12	1	31.50000	31.50000	3.78
13	1	.07143	.07143	.01
23	1	7.14286	7.14286	.86
123	1	12.07143	12.07143	1.45
WITHIN REPLICATES	48	400.57137	8.34524	
TOTAL	55	533.71423		

Table 5

Summary of Analysis of Variance: Retention Test - Archimedes' Principle

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	3.50000	3.50000	.38
2	1	68.64286	68.64286	7.55**
3	1	.07143	.07143	.01
12	1	3.50000	3.50000	.38
13	1	1.78571	1.78571	.20
23	1	8.64286	8.64286	.95
123	1	5.78569	5.78569	.64
WITHIN REPLICATES	48	439.42852	9.15476	
TOTAL	55	531.35706		

Table 6

Summary of Analysis of Variance: Posttest - Bernoulli's Principle

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	58.01786	58.01786	2.73
2	1	95.16071	95.16071	4.47*
3	1	62.16071	62.16071	2.92
12	1	.44643	.44643	.02
13	1	7.87500	7.87500	.37
23	1	.44643	.44643	.02
123	1	85.01782	85.01782	4.00
WITHIN REPLICATES	48	1019.42847	21.23809	
TOTAL	55	1328.55342		

Table 7

Summary of Analysis of Variance: Retention Test - Bernoulli's Principle

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	44.64286	44.64286	1.70
2	1	265.78571	265.78571	10.10**
3	1	73.14285	73.14285	2.78
12	1	12.07143	12.07143	.46
13	1	4.57143	4.57143	.17
23	1	4.57143	4.57143	.17
123	1	151.14281	151.14281	5.74*
WITHIN REPLICATES	48	1248.28551	26.00595	
TOTAL	55	1804.21402		

Table 8

Summary of Analysis of Variance: Work Rate - Archimedes' Principle

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	66.44642	66.44642	6.05*
2	1	6.44643	6.44643	.59
3	1	111.44642	111.44642	10.14**
12	1	.87500	.87500	.08
13	1	.44643	.44643	.04
23	1	15.01785	15.01785	1.37
123	1	.01785	.01785	.00
WITHIN REPLICATES	48	529.14281	11.02381	
TOTAL	55	729.83920		

Table 9

Summary of Analysis of Variance: Work Rate - Bernoulli's Principle

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	335.16071	335.16071	18.77***
2	1	33.01785	33.01785	1.85
3	1	75.44643	75.44643	4.22*
12	1	62.16072	62.16072	3.48
13	1	2.16072	2.16072	.12
23	1	1.44643	1.44643	.08
123	1	30.01775	30.01775	1.68
WITHIN REPLICATES	48	858.57130	17.88690	
TOTAL	55	1397.98189		

APPENDIX B

Heat and Surface Tension

(Study No. 2)

HEAT*

1.

As an object gets hotter, its molecules start to move faster.

When you heat a pan of water on the stove, the speed of the water molecules starts to

increase	decrease
X	

2.

When you toast a marshmallow in a fire, the molecules of the marshmallow will start moving

slower	faster
	X

However, when you blow on the marshmallow and make it cooler, the molecules start to move

slower	faster
X	

3.

Since, when an object is heated, the molecules move

faster	slower
X	

you know that when something feels very hot, the molecules are

very far apart	moving very fast
	X

4.

The temperature of an object is related to the speed of its molecules.

How hot a cup of coffee feels depends on

how fast the molecules of coffee are moving	how big the molecules of coffee are
X	

5.

How warm the air outside feels depends on

how close together the molecules of air are	how fast molecules of air are moving
	X

6.

Make up a sentence using all of the words below. Add any other words that you need.

molecules MOLECULES DO NOT MOVE FASTER
move fast WHEN THEY ARE COOLED.
cooled

7.

Every object is made of molecules which are always moving.

EDIT THIS SENTENCE

As its molecules start to move faster, an object starts to feel cooler.

If the underlined part of the sentence is correct, COPY it.

____

If the underlined part is incorrect, CHANGE it.

WARMER

---

*The frames reproduced here are those which were presented to the subjects as confirmation frames after they had made their own responses. X's are used to indicate the correct multiple choice responses.

8.

The way to get the molecules of an object to move more slowly is to COOL IT.

9.

The speed of the molecules in an object depends on HOW MUCH THE OBJECT IS HEATED.

10.

An object starts to feel hotter when its molecules start to MOVE FASTER.

11.

Make up a sentence using all of the words below.

temperature of an object

molecules

THE TEMPERATURE OF AN OBJECT GOES UP AS THE MOLECULES MOVE FASTER.

12.

A slow-moving molecule which comes near another slow-moving molecule will not increase the speed of the slow-moving molecule.

However, a fast-moving molecule that comes near to a slow-moving molecule makes the slow-moving molecule move

no faster than before	faster than before
	X

13.

After a fast-moving air molecule has approached a slow-moving air molecule, the slow-moving molecule will move at

the same speed as before	a faster speed than before
	X

14.

If a slow-moving molecule is approached by a fast-moving molecule, the slow-moving molecule will move

faster than before	no faster than before
X	

But, when it is approached by another slow-moving molecule, the slow-moving molecule will move

faster than before	no faster than before
	X

15.

When a slow-moving gold molecule comes near another slow-moving gold molecule, the speed of the second molecule will

stay the same as before	increase
X	

16.

A slow-moving molecule can be speeded up only when it is approached by

another slow-moving molecule	a fast-moving molecule
	X

17.

A slow-moving molecule starts to move faster than before if it is approached by

a fast-moving molecule	another slow-moving molecule
X	

A slow-moving molecule continues to move slowly when it is approached by

a fast-moving molecule	another slow-moving molecule
	X

18.

Draw lines connecting each sentence on the left side with the sentence on the right side which tells what happens.

1.	a.
A slow-moving molecule is approached by another slow-moving molecule.	The slow-moving molecule starts to move faster.
2.	b.
A slow-moving molecule is approached by a fast-moving molecule.	The slow-moving molecule continues to move at the same speed.

19.

EDIT THIS SENTENCE

A slow-moving molecule starts to move faster if it is approached by <u>another slow-moving molecule</u>.

If the underlined part of the sentence is correct, COPY it.

____

If the underlined part is incorrect, CHANGE it.

A FAST-MOVING MOLECULE

20.

Make up a sentence using <u>all</u> of the words below.

a slow-moving molecule
approached by
continues to move slowly

A SLOW-MOVING MOLECULE APPROACHED BY A SLOW-MOVING MOLECULE CONTINUES TO MOVE SLOWLY.

21.

What happens to a slow-moving sugar molecule when a fast-moving sugar molecule comes close to it?

IT STARTS TO MOVE FASTER.

22.

A slow-moving molecule will start moving faster than before when a fast-moving molecule

stays far away	comes near it
	X

23.

In order to make a slow-moving molecule move faster than before, a fast-moving molecule has to

<u>approach</u> the slow-moving molecule	<u>move away from</u> the slow-moving molecule
X	

24.

A fast-moving molecule makes a slow-moving molecule move faster.

EDIT THIS SENTENCE

A slow-moving molecule will move faster whether or not the fast-moving molecule comes near it.

If the underlined part of the sentence is correct, COPY it.

____

If the underlined part is incorrect, CHANGE it.

ONLY WHEN A FAST-MOVING MOLECULE COMES NEAR IT.

25.

A slow-moving molecule starts to move faster only if A FAST-MOVING MOLECULE COMES NEAR IT.

26.

At Jim's party, 20 people were crowded into a small room.

At Bob's party, 20 people were spread out in a large room.

People bumped into each other more often at

Jim's party	Bob's party
X	

27.

Five hundred cars are crowded together on a section of the highway.

In one hour's time,

many cars come near each other	only a few cars come near each other
X	

However, if the 500 cars are spread far apart on the highway, the cars come near each other

many times	only a few times
	X

28.

Many boys are playing tag on a small playground. Because the boys are spaced close together, the boys move near one another

very often	not very often
X	

Molecules that are packed closely together also move near each other

very often	not very often
X	

29.

A bottle of water contains more molecules than a bottle filled with air. Therefore, we know that the water molecules are spaced

closer together than air molecules	farther apart than air molecules
X	

and therefore we also know that, compared to the air molecules, the water molecules come near each other

more frequently	less frequently
X	

30.

Because copper molecules are closely packed, they come near each other

very often	not very often
X	

Water molecules, however, are more widely spaced. Therefore, water molecules approach each other

very often	not very often
	X

31.

The molecules that make up a metal knife are packed tightly together. In one second, the molecules come near each other

only a few times	many times
	X

32.

Molecules of water are spaced farther apart than molecules of metal.

Therefore, in a glass of water, the molecules approach each other

more often	not as often
	X

33.

Write 1 under the substance whose molecules approach each other most often.

Write 3 under the substance whose molecules approach each other least often.

Write 2 under the remaining substance.

gold molecules, spaced very close together	alcohol molecules, spaced moderately far apart
1	2

oxygen molecules, spaced very far apart

3

34.

The molecules in a silver fork are spaced close together.

EDIT THIS SENTENCE

The silver molecules do not approach each other very frequently.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

APPROACH EACH OTHER VERY FREQUENTLY.

35.

EDIT THIS SENTENCE

The molecules that make up an object do not come near each other frequently if the molecules are closely spaced.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

IF THE MOLECULES ARE WIDELY SPACED

36.

Make up a sentence using all of the words below.

frequently
molecules
spaced

MOLECULES COME NEAR EACH OTHER FREQUENTLY WHEN THEY ARE CLOSELY SPACED.

37.

A flask of oxygen gas contains molecules that are very far apart. As the molecules move around in the flask, what happens to the molecules?

THEY APPROACH EACH OTHER VERY INFREQUENTLY.

38.

How frequently the molecules that make up an object come near each other depends on HOW CLOSELY PACKED THE MOLECULES ARE.

39.

When heat travels through an object, we say that heat is conducted.

When a pot is on the stove, we say heat is conducted if

heat goes through the pot and the handle gets hot	heat stays only in the bottom of the pot near the flame
X	

40.

A short time after you heat one end of a silver wire,

the rest of the wire also gets hot	only the wire near the heat gets hot
X	

Therefore,

heat travels quickly through silver	heat does not travel through silver
X	

41.

We say that a bar of gold conducts heat because, when you apply a flame to one end of the bar,

heat stays in the end near the flame	heat spreads through the bar
	X

42.

A metal spoon is a good conductor of heat. If you apply a flame to one part of a spoon,

only that part gets hot	all of the spoon gets hot
	X

However, if heat is applied to one part of a tube of water, which is a poor conductor of heat,

only the heated part gets hot	all of the water gets hot
X	

43.

When heat spreads quickly through an object, we say the object is a good conductor of heat.

Because heat travels slowly through water, water is a

good conductor of heat	poor conductor of heat
	X

44.

Heat travels very slowly through alcohol. Therefore, we say alcohol is a

poor conductor	good conductor
X	

However, heat goes through a metal bar from one part to another very quickly because metal is a

poor conductor	good conductor
	X

45.

EDIT THIS SENTENCE

When one part of a tube of air is heated, the rest of the air stays cool. Therefore, we say that air is a good conductor of heat.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

IS NOT A GOOD CONDUCTOR OF HEAT

46.

EDIT THIS SENTENCE

We say heat is conducted when you heat one part of an object and the rest of the object stays cool.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

GETS HOT

47.

Make up a sentence using all of the words below.

heat is conducted
travels
from one end

HEAT IS CONDUCTED WHEN HEAT TRAVELS FROM ONE END OF AN OBJECT TO THE OTHER END.

48.

Heat travels very slowly through a piece of asbestos. Therefore, we say that asbestos is A POOR CONDUCTOR OF HEAT.

49.

What do we mean by conduction?
HEAT TRAVELS THROUGH AN OBJECT.

50.

Give an example of an object which is a poor conductor of heat, and tell what happens to the object when you apply heat to part of it.

Your example can be any object which is a poor conductor of heat, for instance, asbestos, air, etc. When you apply heat to part of it, ONLY THE HEATED PART GETS HOT.

51.

When heat is applied to the left side of a metal bar, the molecules at the left side start to move faster. Therefore, the left side

starts to feel hotter	continues to feel the same as before
X	

The right side of the bar will start to feel hotter, also, when the molecules at the right side

start to move faster than before	continue to move the same as before
X	

52.

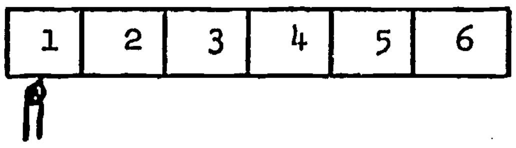
When heat is applied to one part of a metal object, the molecules of that part start to move

faster	slower
X	

They approach the slow-moving molecules next to them and make them

start to move faster	stay the same speed as before
X	

53.



The fast-moving molecules in Area #1 approach the molecules in Area #2.

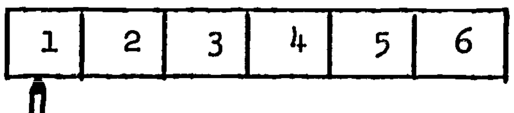
The molecules in Area #2

start to move faster	stay the same speed as before
X	

Therefore, Area #2 feels

the same as before	hotter than before
	X

54.



After the fast-moving molecules in Area #1 make the molecules in Area #2 start to move faster, the fast-moving molecules in Area #2

have no effect on Area #3 molecules	approach the molecules in Area #3 and make them move faster
	X

Therefore, Area #3 feels

the same as before	hotter than before
	X

55.

EDIT THIS SENTENCE

When part of an object is heated, the heated molecules do not increase the speeds of the molecules nearby.

If the underlined part of the sentence is correct, COPY it.

____

If the underlined part is incorrect, CHANGE it.

THE HEATED MOLECULES DO INCREASE THE SPEEDS OF THE MOLECULES NEARBY.

56.

The molecules at one end of a metal wire do not move all the way to the other end of the wire, but they can still change the speeds of the molecules at the other end of the wire. Explain how.

THE MOLECULES AT THE HEATED PART MOVE FASTER AND MAKE THE MOLECULES NEXT TO THEM MOVE FASTER, AND THEY MAKE THE MOLECULES NEXT TO THEM MOVE FASTER, AND SO ON, UNTIL ALL THE MOLECULES MOVE FASTER.

57.

The bottom of a metal pan is heated on the stove. At first only the molecules of the bottom start to move faster, but then the fast-moving molecules

do not affect any other molecules	make the slow-moving molecules next to them move faster
	X

When fast-moving molecules make slow-moving molecules move faster,

heat travels through the pan	heat stays only in the bottom of the pan
X	

58.

The top of a metal pole is heated. The molecules at the top start to move faster.

When the fast-moving molecules at the top make the molecules next to them move faster,

heat stays only in the top of the pole	heat is conducted through the pole
	X

59.

If heat is applied to the left side of a metal bar, the right side gets hot in a little while because

the heated molecules make the others move faster	the heated molecules move to the other side
X	

60.

Heat is conducted through a brass handle because

fast-moving molecules move to the cool parts	fast-moving molecules make slow-moving molecules move faster
	X

61.

Make up a sentence using all of the words below.

heat is conducted
fast-moving molecules
near the heat
slow-moving molecules

HEAT IS CONDUCTED WHEN FAST-MOVING MOLECULES NEAR THE HEAT MOVE FASTER AND THEN MAKE THE SLOW-MOVING MOLECULES MOVE FASTER.

62.

A flame is applied to one end of a metal spoon. Explain fully how heat gets conducted through the spoon.

HEAT MAKES THE MOLECULES NEAR THE FLAME MOVE FASTER, AND THESE MOLECULES MAKE THE SLOW-MOVING MOLECULES MOVE FASTER.

63.

Because copper molecules are spaced close together, a fast-moving copper molecule can come near

many slow-moving copper molecules	only a few slow-moving copper molecules
X	

Therefore, a fast-moving copper molecule would be able to increase the speeds of

many slow-moving copper molecules	only a few slow-moving copper molecules
X	

64.

Because air molecules are spaced very far from each other, a fast-moving air molecule can approach

many slow-moving air molecules	only a few slow-moving air molecules
	X

Therefore, a fast-moving air molecule could speed up

many slow-moving air molecules	only a few slow-moving air molecules
	X

65.

When we heat one end of a bar of aluminum, the molecules at that end move faster right away.

Since the molecules of aluminum are very close together, the fast-moving molecules make the slow-moving molecules move faster

in a short time	after a long time
X	

66.

Water molecules are not as close together as molecules of metal. Therefore, when heat is conducted, fast-moving molecules make slow-moving molecules move faster

more quickly in water	less quickly in water
	X

67.

Write Q under the substance in which the faster movement of molecules caused by heating spreads quickly.

Write S under the substance in which the faster movement of molecules caused by heating spreads slowly.

oxygen gas that has molecules which are far apart	aluminum that has molecules which are close together
S	Q

68.

Write 1 under the substance in which the faster movement of the molecules caused by heating spread fastest.

Write 3 under the substance in which the faster movement of the molecules spreads slowest.

Write 2 under the other substance.

milk molecules which are far apart	air molecules which are very far apart	lead molecules which are very close together
2	3	1

69.

Heat is conducted when fast-moving molecules make slow-moving molecules move faster. Therefore, heat is conducted slowly through oxygen gas because oxygen molecules are

close together	far apart
	X

Heat is conducted quickly through copper because copper molecules are

closely spaced	widely spaced
X	

70.

Silver conducts heat fastest because silver molecules are very

close together	far apart
X	

Air conducts heat slowest because air molecules are very

close together	far apart
	X

71.

EDIT THIS SENTENCE

An object conducts heat quickly if it has widely-spaced molecules.

If the underlined part of the sentence is correct, COPY it.

____

If the underlined part is incorrect, CHANGE it.

CLOSELY-SPACED MOLECULES

72.

EDIT THIS SENTENCE

An object with widely-spaced molecules conducts heat slowly because the faster movement caused by heat spreads quickly.

If the underlined part of the sentence is correct, COPY it.

____

If the underlined part is incorrect, CHANGE it.

THE FASTER MOVEMENT CAUSED BY HEAT SPREADS SLOWLY.

73.

Why does an object with closely-spaced molecules conduct heat fastest?

THE FASTER MOVEMENT FROM HEATING SPREADS QUICKLY.

74.

How fast an object conducts heat depends on HOW CLOSE THE MOLECULES ARE.

SURFACE TENSION*

1.

If we place a needle in the center of water, it will

sink	float
X	

But, if we place a needle on the surface of water, it will

sink	float
	X

2.

A razor blade will float if it is placed

on the surface of the water	in the center of the water
X	

A razor blade will sink if it is placed

on the surface of water	in the center of water
	X

3.

EDIT THIS SENTENCE

A needle floats on water when it is placed beneath the surface.

If the underlined part of the sentence is correct, COPY it.

____

If the underlined part is incorrect, CHANGE it.

ON THE SURFACE

4.

Make up a sentence using all of the words below. Add any other words that you need.

razor blade A RAZOR BLADE SINKS IN
center of water THE CENTER OF WATER, BUT
surface of water FLOATS ON THE SURFACE
OF WATER.

5.

At the top of all liquids there is a thin film called the surface film.

If we place a razor blade on water, the surface film

supports it	lets it sink
X	

6.

Although a needle is heavier than water, it floats because there is a surface film holding it up at the

top of the liquid	bottom of the liquid
X	

7.

A bug can "skate" across the top of water because it is

supported by a surface film	pulled down by the surface film
X	

---

*The frames reproduced here are those which were presented to the subjects as confirmation frames after they had made their own responses. X's are used to indicate the correct multiple choice responses.

8.

EDIT THIS SENTENCE

A hairpin floating on top of water is not supported by the surface film.

If the underlined part of the sentence is correct, COPY it.

____

If the underlined part is incorrect, CHANGE it.

IS SUPPORTED BY THE SURFACE FILM.

9.

Complete this sentence.

A razor blade does not sink because IT IS SUPPORTED BY A SURFACE FILM.

10.

When you stand on a trampoline, the trampoline

bends	remains stiff
X	

When you jump off the trampoline, the trampoline

gets straight again	still remains bent
X	

11.

The surface film acts like a trampoline. When you place a razor blade on it, the surface

bends	remains stiff
X	

When you remove the blade, the surface

gets straight again	still remains bent
X	

12.

Because the surface film bends, we could describe it as acting like a

sheet of rubber	sheet of steel
X	

That is, the surface film supports things because it bends and

breaks easily	does not break
	X

13.

A paper clip floats on top of the water because there is a surface film which

bends but does not break	bends and breaks easily
X	

14.

EDIT THIS SENTENCE

When you touch mercury with a pin and then release the pin, the surface gets straight again because the surface film bends and breaks easily.

If the underlined part of the sentence is correct, COPY it.

____

If the underlined part is incorrect, CHANGE it.

SURFACE FILM BENDS AND DOES NOT BREAK EASILY.

15.

Make up a sentence using all of the words below.

razor blade A RAZOR BLADE FLOATS ON WATER
floats BECAUSE THE SURFACE FILM BENDS
break easily BUT DOES NOT BREAK EASILY.

16.

What will happen to a paper clip if we put it on top of a liquid? Explain why.

THE PAPER CLIP WILL FLOAT BECAUSE IT IS SUPPORTED BY A SURFACE FILM WHICH BENDS BUT DOES NOT BREAK.

17.

A child blows a soap bubble.

When the child stops blowing, the air escapes and the bubble

stays the same	gets smaller
	X

18.

When you stretch a rubber band it

gets bigger	stays the same	shrinks
X		

But, when you let go of a rubber band it

gets bigger	stays the same	shrinks
		X

19.

Just like when you let go of a rubber band, or when you let air out of a bubble, the surface film of a liquid tends to

shrink	stay the same	spread out
X		

20.

The surface film of a liquid does not stay the same size, rather it tends to

shrink	spread out
X	

21.

If you smear water on a table top, the film of water you leave on the table will

shrink	spread out
X	

22.

When there is a thin film of water on a waxed automobile hood, the part which dries first is the

outer edge of the film	center of the film
X	

23.

When there is a film of water on an automobile hood, the outer edge of the film dries first because the film of water

shrinks and gets smaller	spreads out and gets bigger
X	

24.

If you wet an area with water, the water shrinks and gets smaller because the surface film pulls the water

in toward the center	out toward the edges
X	

25.

EDIT THIS SENTENCE

When you wash a blackboard, the film of water on the board tends to get bigger.

If the underlined part of the sentence is correct, COPY it.

____

If the underlined part is incorrect, CHANGE it.

GET SMALLER (SHRINK).

26.

The surface film on top of the water in a glass acts the same as the film of water on a blackboard.

EDIT THIS SENTENCE

When water is in a glass, the surface film on the top of the water does NOT get smaller.

If the underlined part of the sentence is correct, COPY it.

____

If the underlined part is incorrect, CHANGE it.

THE SURFACE FILM ON THE TOP OF THE WATER DOES GET SMALLER.

27.

Make up a sentence using all of the words below.

surface film

stay the same size

shrinks

THE SURFACE FILM OF A LIQUID DOES NOT STAY THE SAME SIZE, BUT SHRINKS.

28.

If you spread a film of water on the roof of a car, what will happen to the film of water?

THE WATER SHRINKS AND GETS SMALLER.

29.

If you wet a 10-inch circular area with water, the circle of water would become a

12-inch circle of water	8-inch circle of water
	X

Explain why you chose that answer.

LIQUID TENDS TO SHRINK.

30.

A magnet pulls particles of steel toward it because the magnet

attracts steel	repels steel
X	

31.

Just like a magnet, water molecules are pulled together because they

attract each other	repel each other
X	

32.

If two water molecules attract each other they will

move together	move apart
X	

33.

The molecules in a liquid attract each other. Therefore, they

cling together	move apart
X	

34.

The molecules in a liquid cling together because they

attract each other	repel each other
X	

35.

EDIT THIS SENTENCE

Because liquid molecules attract each other, they tend to move apart.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

MOVE TOGETHER (CLING TOGETHER).

36.

Make up a sentence using all of the words below.

because water molecules attract move apart	BECAUSE WATER MOLECULES ATTRACT EACH OTHER, THEY DO NOT MOVE APART.

37.

A molecule in the center of a glass of milk has molecules

only above it	only below it	all around it
		X

38.

A molecule on the surface of a glass of milk has no liquid molecules

below it	beside it	above it
		X

But, it does have liquid molecules

on all sides	on all sides except the top
	X

39.

A molecule in the center of a liquid is attracted by the molecules

all around	only from the top
X	

40.

Because there are no liquid molecules above it, a molecule on the surface of water is attracted in all directions but

not down	not up	not sidewards
	X	

41.

A molecule on the surface of a liquid is only attracted sidewards and downwards because there are no liquid molecules

below it	above it
	X

42.

Put X's below all the answers that tell in how many directions a molecule on the surface of a liquid is attracted by the other molecules.

sidewards	upwards	downwards
X		X

43.

EDIT THIS SENTENCE

The molecules at the surface of a liquid are being attracted in all directions.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

SIDEWARDS AND DOWNWARDS BUT NOT UP

44.

Make up a sentence using all of the words below.

surface molecules SURFACE MOLECULES ARE
attracted ATTRACTED SIDEWARD AND
upward direction DOWNWARD BUT NOT IN AN
UPWARD DIRECTION.

45.

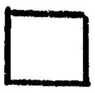
Complete this sentence.

Liquid molecules at the surface are not attracted upward because THERE ARE NO LIQUID MOLECULES ABOVE THEM.

46.

When rain falls it takes the shape of a sphere.

Put an X below the shape that is most like dripping water.



		X

47.

We speak of rain "drops" because liquids tend to form

cubes	cones	spheres
		X

48.

When a liquid shrinks it covers a

bigger area	smaller area
	X

49.

When liquids shrink, they cover a very small area.

Liquids form drops because the shape with the smallest area is a

rectangle	sphere	triangle
	X	

50.

If you spilled mercury, it forms tiny spheres. That is, the mercury takes the shape with the

largest area	smallest area
	X

51.

EDIT THIS SENTENCE

When water drips from a tap it forms spheres because a sphere covers the largest area.

If the underlined part of the sentence is correct, COPY it.

____

If the underlined part is incorrect, CHANGE it.

A SPHERE COVERS THE SMALLEST AREA

52.

Complete this sentence.

When liquids shrink they form a sphere because A SPHERE COVERS THE SMALLEST AREA.

53.

When water is in a glass it has a surface film. Liquids also have a surface film when they

form a sphere	are spilled on the floor	both
		X

54.

When water is in a glass, the molecules at the surface are being attracted

sidewards and downwards	in all directions
X	

When water forms a sphere, the molecules at the surface are still being attracted

sidewards and downwards	in all directions
X	

55.

When water is spilled on the floor, the sideward and downward attraction of the surface molecules causes the water to

spread out and cover the biggest possible area	shrink and cover the smallest possible area
	X

56.

The surface film of a liquid always

shrinks to the smallest possible area	spreads the liquid out
X	

This happens because

there is a sideward and downward attraction on the surface molecules	there is no attraction on the surface molecules
X	

57.

EDIT THIS SENTENCE

When you spill a drop of milk, the sideward and downward attraction of surface molecules causes the milk to spread out to the biggest possible area.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

SHRINK TO THE SMALLEST POSSIBLE AREA

58.

EDIT THIS SENTENCE

Water on a waxed table forms spheres because the molecules in the surface film are attracted upwards and downwards.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

SIDEWARDS AND DOWNWARDS

59.

Because the molecules at the surface of a liquid are being pulled sideward and downward, what happens to the liquid?

IT SHRINKS TO THE SMALLEST POSSIBLE AREA. (IT FORMS A SPHERE.)

60.

Make up a sentence using all of the words below.

surface film
spread out
attraction of molecules

THE SURFACE FILM DOES NOT SPREAD OUT BECAUSE OF THE SIDEWARD AND DOWNWARD ATTRACTION OF THE MOLECULES.

61.

When you get out of a swimming pool, the water beads on your skin.

Explain what happens to the molecules when water takes that shape.

BECAUSE THE SURFACE MOLECULES ARE ATTRACTED SIDEWARDS AND DOWNWARDS, THE WATER SHRINKS TO THE SMALLEST POSSIBLE SPHERE.

Visual Answer Booklet

HEAT - DIRECT

1.

Answer A	Answer B
Fast-moving molecules	Slow-moving molecules
______ ______	______ ______

2.

Answer A	Answer B
Fast-moving molecules	Slow-moving molecules
______ ______	______ ______

3.

Answer A	Answer B
Molecule continues to move slowly*	Molecule starts to move faster*
______ ______	______ ______

4.

Answer A	Answer B
Molecule continues to move slowly*	Molecule starts to move faster*
______ ______	______ ______

5.

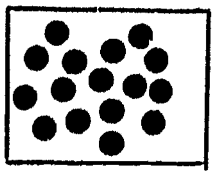
Answer A	Answer B
Molecules far apart*	Molecules close together*
______ ______	______ ______

6.

Answer A

______

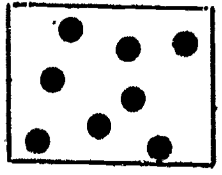
______



Answer B

______

______

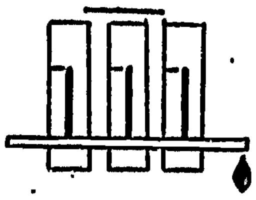


7.

Answer A

______

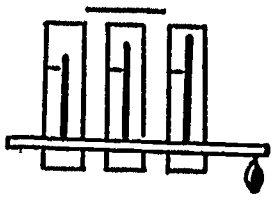
______



Answer B

______

______

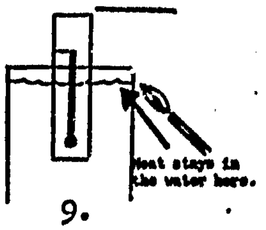


8.

Answer A

______

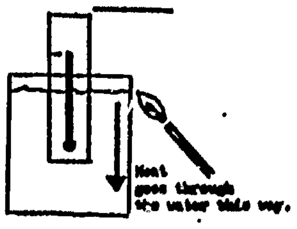
______



Answer B

______

______

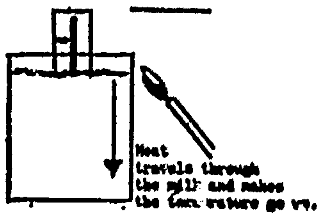


9.

Answer A

______

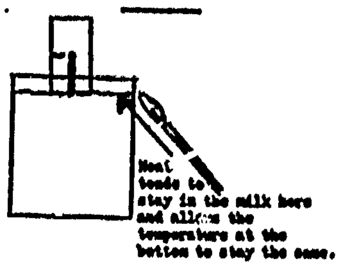
______



Answer B

______

______



10.

Answer A	Answer B
Molecules all move fast at once*	At first only molecules near heat move fast, then it spreads*
______ ______	______

11.

Answer A	Answer B
Fast movement spreads slowly*	Fast movement spreads quickly*
______ ______	______ ______

12.

Answer A	Answer B
Slow-moving molecules spaced close together*	Slow-moving molecules spaced far apart*
______ ______	______ ______

*Students saw only "Answer A" and "Answer B" in their booklets. The phrases are descriptive of what they saw on the screen.

Visual Answer Booklet

HEAT - INDIRECT

1.
Answer A Slow pinging
Answer B Fast pinging

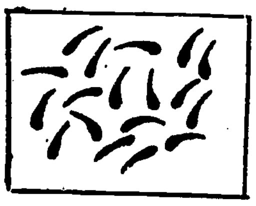
2.
Answer A Fast pinging
Answer B Slow pinging

3.
Answer A Molecule continues to move slowly*
Answer B Molecule starts to move faster*

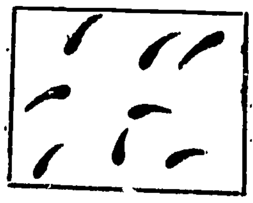
4.
Answer A Molecule continues to move slowly*
Answer B Molecule starts to move faster*

5.
Answer A Molecules far apart*
Answer B Molecules close together*

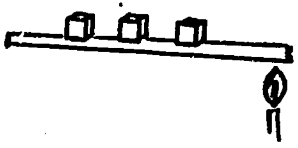
6.
Answer A



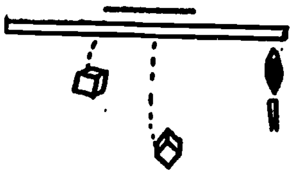
Answer B



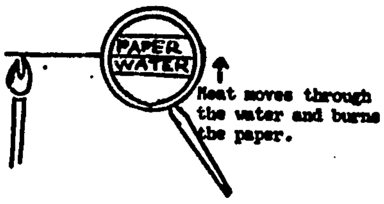
7.
Answer A



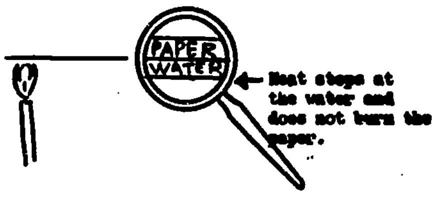
Answer B



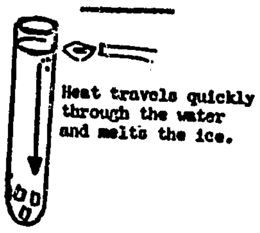
8.
Answer A



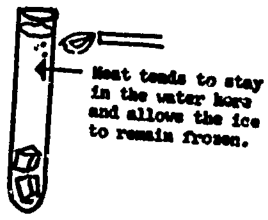
Answer B



9.
Answer A



Answer B



10.
Answer A Molecules all move fast at once*
Answer B At first only molecules near heat move fast, then it spreads*

11.
Answer A Fast movement spreads slowly*
Answer B Fast movement spreads quickly*

12.
Answer A Slow-moving molecules spaced far apart*
Answer B Slow-moving molecules spaced close together*

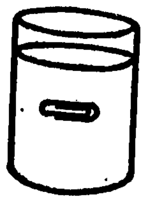
---

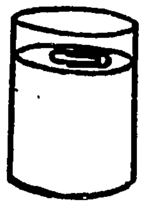
*Students saw only "Answer A" and "Answer B" in their booklets. The phrases are descriptive of what they saw on the screen.

Visual Answer Booklet

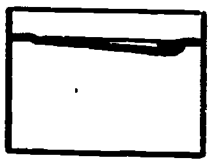
SURFACE TENSION - DIRECT

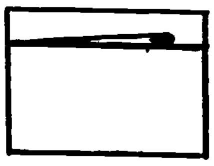
Page 1


☐

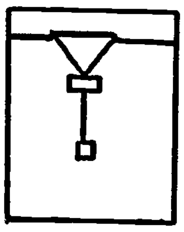

☐

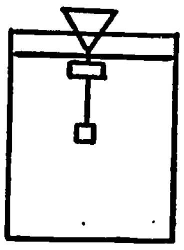
Page 2


☐

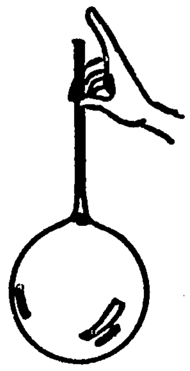

☐

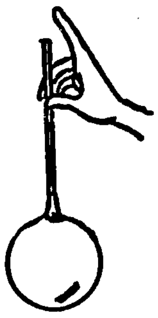
Page 3

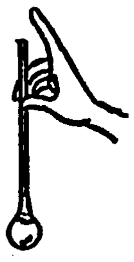

☐


☐

Page 4

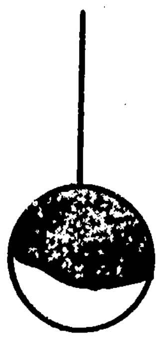
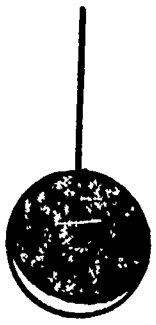
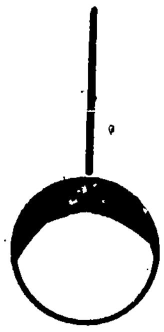

☐


☐


☐

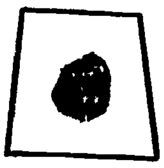
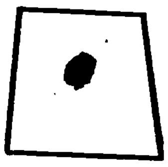
Visual Answer Booklet - Surface Tension (Direct)

Page 5

☐ ☐ ☐

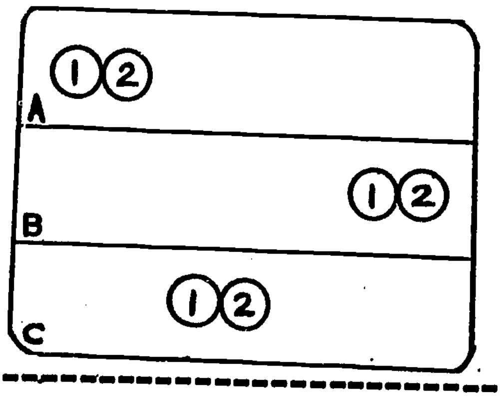
Page 6

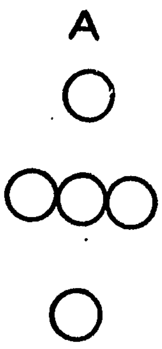
☐ ☐ ☐

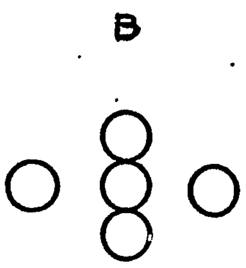
Page 7

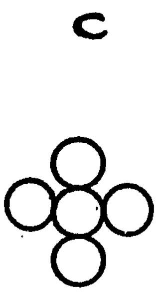
☐ ☐ ☐



Page 8





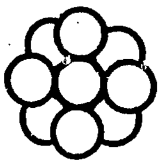


☐ ☐ ☐

Visual Answer Booklet - Surface Tension (Direct)

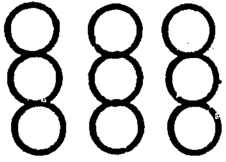
Page 9

A



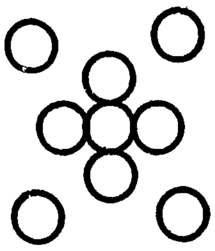
☐

B



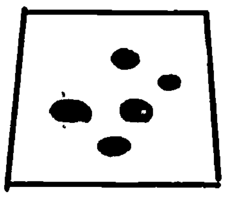
☐

C

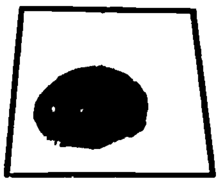


☐

Page 10

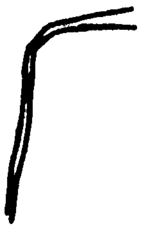


☐



☐

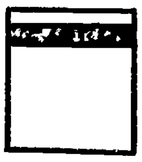
Page 11



☐

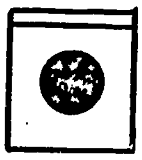
☐

Page 12



☐

☐



☐

Visual Answer Booklet

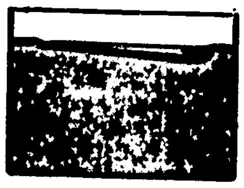
SURFACE TENSION - INDIRECT

Page 1

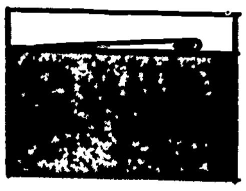
☐

☐

Page 2

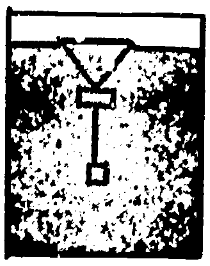


☐

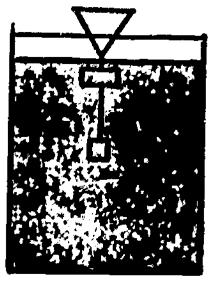


☐

Page 3



☐



☐

Page 4

☐

☐

Visual Answer Booklet - Surface Tension (Indirect)

Page 5

spread out

☐

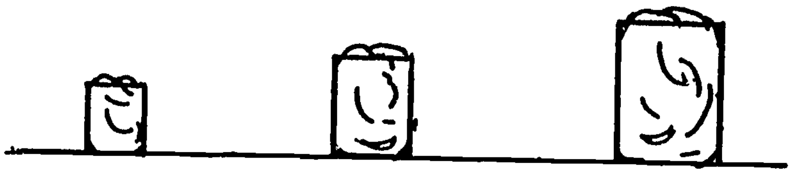
stay the same

☐

shrink

☐

Page 6



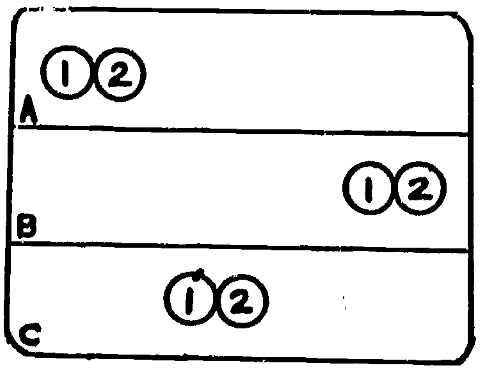
☐ ☐ ☐

Page 7

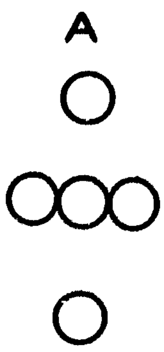
☐

☐

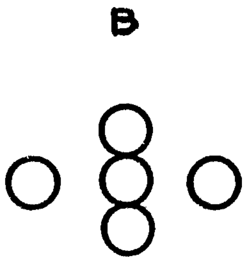
☐



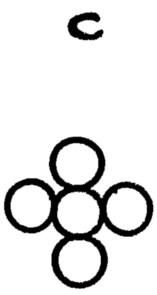
Page 8



☐



☐

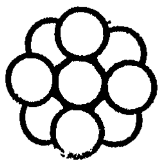


☐

Visual Answer Booklet - Surface Tension (Indirect)

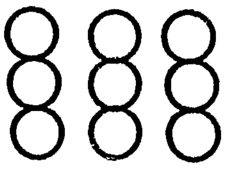
Page 9

A



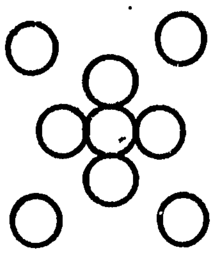
☐

B



☐

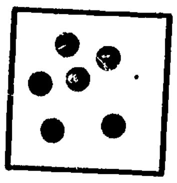
C



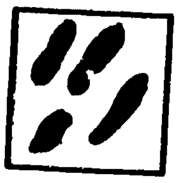
☐

Page 10

☐



☐



☐

Page 11

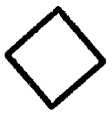
☐

☐

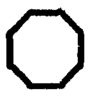
☐

Page 12

☐



☐



☐

Achievement Test

HEAT

)

PART I

1. The left side of a metal bar is heated. Explain how heat is conducted through the metal bar so that the right side also becomes hot.

2. Different substances conduct heat differently. Some substances conduct heat easily and quickly. Others conduct heat slowly or not at all. What determines how easily heat is conducted?

3. Describe two conditions which are necessary if the movement of one molecule is to change the movement of another molecule.

4. Describe two conditions under which the movement of one molecule will not change the movement of another molecule.

5. What effect does cooling an object have on the molecules that make up the object?

Achievement Test - Heat

PART II

1.

a. Circle the substance which conducts heat the slowest.

metal water air

b. Why does that substance conduct heat the slowest?

____

____

2.

a. When one part of the substance is heated, the molecules at that part change speeds. Circle the substance in which the change in speed spreads slowest from molecule to molecule.

metal water air

b. Why does it spread slowest in that substance?

____

____

3.

Circle the substance in which molecules approach each other most often.

metal water air

b. Why do molecules approach each other most often in that substance?

____

____

Achievement Test

SURFACE TENSION

1.

a. Some objects which are heavier than water can, nevertheless, still float on top of the water. How is this possible?

b. When the same objects are placed below the top of the water, they sink. What difference is there between the top of the water and the middle of the water?

c. Using the word "molecules" in your answer explain why there is a difference between the top and middle of the water.

2. When it rains, in what shape does rain come down? Explain why the rain takes on this shape.

3. After you spill some pop on your clothes, the wet spot begins to dry. Describe which part of the spot dries first and explain why it dries first.

4. What causes a surface film to be formed in a glass of soda pop?

5. Describe the ways in which surface films act.

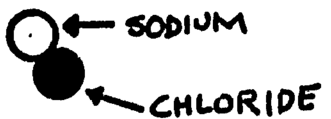
ATOMS AND MOLECULES*

1.

All substances like iron, wood, water, air, aluminum, etc. can be broken down into tiny pieces which we call "atoms." Atoms are

the smallest pieces	the largest pieces
X	

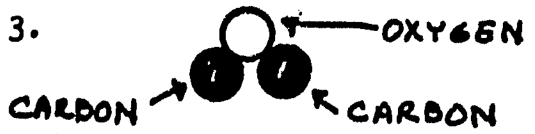
2.



The picture shows the atoms that make up salt. Salt is made up of

one kind of atom	two kinds of atoms
	X

3.



Carbon dioxide is made up of

(a)

1 atom	2 atoms	3 atoms
		X

(b)

oxygen atom	carbon atoms	oxygen and carbon atoms
		X

(c)

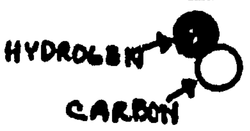
one kind	two kinds
	X

(d)

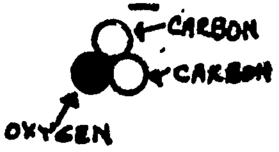
one carbon atom	two carbon atoms
	X

4.

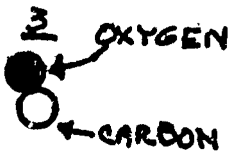
1



2



3



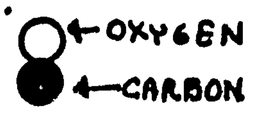
Which examples have the same <u>number</u> of atoms?

1 & 2	1 & 3	2 & 3
	X	

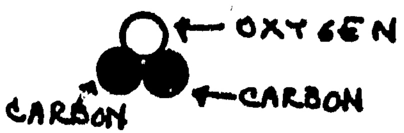
Which examples have the same <u>kinds</u> of atoms?

1 & 2	1 & 3	2 & 3
		X

5.



CARBON MONOXIDE



CARBON DIOXIDE

The two gases carbon monoxide and carbon dioxide are <u>different</u> because they have

different kinds of atoms	different number of atoms
	X

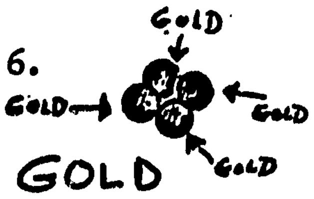
They are <u>similar</u> because they have the

same kinds of atoms	same number of atoms
X	

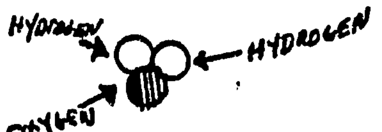
---

*The frames reproduced here are those which were presented to the subjects as confirmation frames after they had made their own responses. X's are used to indicate the correct multiple choice responses.

6.



GOLD



WATER

EDIT THIS SENTENCE

Substances are made up of only one kind of atom.

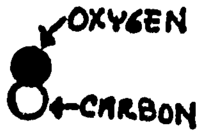
If the underlined part of the sentence is correct, COPY it.

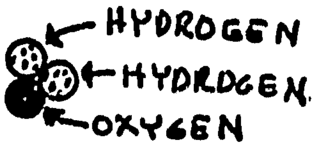
____

If the underlined part is incorrect, CHANGE it.

SUBSTANCES ARE MADE UP OF DIFFERENT KINDS OF ATOMS.

7.





CARBON DIOXIDE WATER

EDIT THIS SENTENCE

Substances are made up of the same number of atoms.

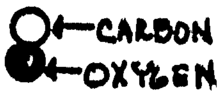
If the underlined part of the sentence is correct, COPY it.

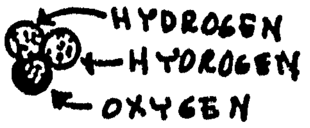
____

If the underlined part is incorrect, CHANGE it.

SUBSTANCES ARE MADE UP OF DIFFERENT NUMBERS OF ATOMS.

8.





CARBON DIOXIDE WATER

There is a difference between carbon dioxide and water. Make up a sentence using the words below telling what the difference is.

number	CARBON DIOXIDE AND WATER ARE
kinds	DIFFERENT BECAUSE THEY ARE MADE
atoms	UP OF A DIFFERENT NUMBER OF ATOMS
	AND OF DIFFERENT KINDS OF ATOMS.

9.

Atoms join together and form tiny clumps, called molecules.

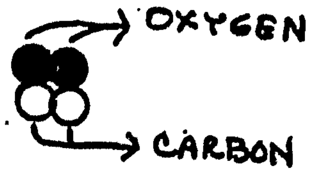
An atom is part of a molecule	A molecule is part of an atom
X	

10.

Since atoms joined together make up molecules, we can say that

a molecule contains one or more atoms	an atom contains one or more molecules
X	

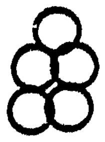
11.



The molecule in this picture is

the whole clump of circles	a smaller circle
X	

12.



If the big clump is a molecule, the small circles are ATOMS.

13.

This picture shows the smallest particles in a drop of water. The atoms are the

small circles	groups of circles
X	

The molecules are the

clumps of circles labelled "water"	smaller circles labelled "hydrogen" and "oxygen"
X	

14.

EDIT THIS SENTENCE

A molecule contains one or more atoms.

If the underlined part of the sentence is correct, COPY it.

A MOLECULE CONTAINS ONE OR MORE ATOMS.

If the underlined part is incorrect, CHANGE it.

15.

Atoms of chloride joined with atoms of sodium make salt. However, atoms of chloride joined with atoms of hydrogen make a gas. Salt and the gas are different because they are made up of

the same atoms joined together	different atoms joined together
	X

16.

Some things, called elements, are made of only one kind of atom. Gold is an element; it is made up of

one kind of atom	different kinds of atoms
X	

Therefore, gold is made up of

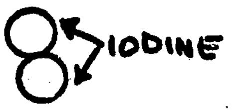
only gold atoms	gold atoms and other kinds of atoms
X	

17.

Iron is an element. If we broke iron into its smallest pieces, we would find many atoms but they would be

different kinds of atoms	just iron atoms
	X

18. **Molecule of Rust** **Molecule of Iodine**



Study these pictures of molecules. You can tell that

rust is an element	iodine is an element
	X

19.

Because salt can be broken down into two kinds of atoms, we know it is

not an element	an element
X	

20.

Water is made up of hydrogen atoms and oxygen atoms. Water is

an element	not an element
	X

21.

EDIT THIS SENTENCE

An element is something made up of different kinds of atoms.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

AN ELEMENT IS SOMETHING MADE UP OF ONLY ONE KIND OF ATOM.

22.

Make up a sentence. Include all the words below, and add any other words that you need.

element
different kinds of

AN ELEMENT IS
NOT MADE UP OF
DIFFERENT KINDS
OF ATOMS.

23.

In an element, the atoms in each molecule are of

only one kind	different kinds
X	

24.

A molecule of various substances can contain one atom or several atoms. Often the atoms are of a different kind. When the atoms are of the same kind we know the material is

not an element	an element
	X

25.

Make up a sentence, using all the words below.

molecule
silver

A MOLECULE OF SILVER
CONTAINS ONLY ONE ATOM.

26.

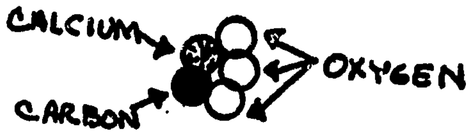
Since silver is an element, it contains

different kinds of atoms	only one kind of atom
	X

Thus, the molecules in silver contain

different kinds of atoms	only a silver atom
	X

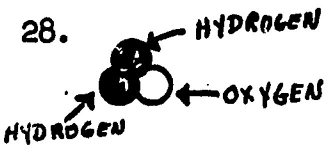
27.



The picture shows a molecule of chalk. By looking at the different kinds of atoms in the molecule we can tell that chalk

is an element	is not an element
	X

28.



Molecule of Water

Molecule of Water

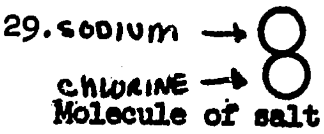
Each molecule of water has

the same number of hydrogen atoms as the other molecule	the same number of oxygen atoms as the other molecule	both answers are correct
		X

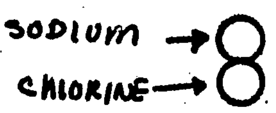
Both molecules of water have

2 hydrogen atoms	1 oxygen atom	both answers are correct
		X

29.



Molecule of salt



Molecule of salt

These two molecules of salt are the same because they both

contain the same kinds of atoms ____ ____

have the same number of each kind of atom in the molecules ____ ____

both answers are correct ____ X

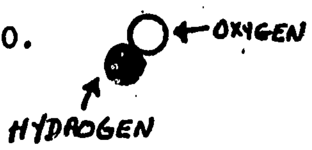
If a hydrogen atom were added to one of the molecules, the two molecules would be different because they would have

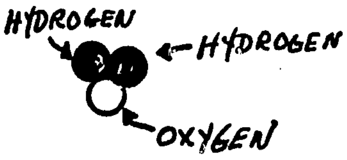
a different number of atoms ____ ____

different kinds of atoms ____ ____

both a different number & different kinds of atoms ____ X

30.





These two molecules are similar because they are made up of

the same kind of atoms ____ X

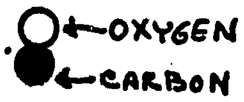
the same number of atoms ____ ____

These two molecules are different because they are made up of

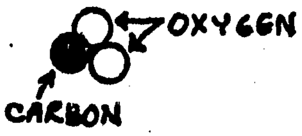
different kinds of atoms ____ ____

a different number of the same kind of atom ____ X

31.



Carbon monoxide molecule



Carbon dioxide molecule

Look at the kinds and numbers of atoms in these two molecules. Carbon monoxide and carbon dioxide are different because their molecules are made up of

different kinds of atoms ____ ____

different numbers of the same kinds of atoms ____ X

32.

EDIT THIS SENTENCE

What a thing is depends on the kinds of atoms it contains and the number of each kind of atom in the molecule.

If the underlined part of the sentence is correct, COPY it.

KINDS OF ATOMS NUMBER OF EACH KIND OF ATOM IN THE MOLECULE

If the underlined part is incorrect, CHANGE it.

____

33.

Complete the sentence below using the words on the left to help you.

Flour and butter molecules could be different for either of two reasons; either because

kinds of atoms

number of each kind of atom

THEY CONTAIN DIFFERENT KINDS OF ATOMS or because THEY CONTAIN A DIFFERENT NUMBER OF THE SAME KINDS OF ATOMS.

34.

The reason that water and peroxide are different is because THEY CONTAIN THE SAME KINDS OF ATOMS, BUT THE NUMBER OF ATOMS IN THEIR MOLECULES ARE DIFFERENT.

35.

Although we cannot see them, scientists have found that the tiny molecules are always moving. Even in solid objects, the molecules are always

moving	staying still
X	

36.

It is easy to imagine the molecule in water moving, but it is also true that the molecules in a block of wood are also

staying still	moving
	X

37.

The molecules that make up the air are

still	moving
	X

38.

Molecules move in all substances. Molecules are always moving in

wood	air	tea	all of these things
			X

39.

Leather and silver are different substances. However, the molecules move in

neither of these substances	both of these substances
	X

40.

EDIT THIS SENTENCE

Molecules are always moving only in some substances.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

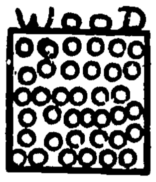
IN ALL SUBSTANCES

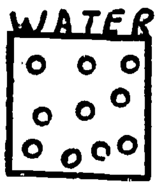
41.

Make up a sentence, using all the words below.

molecules	MOLECULES ARE ALWAYS
always	MOVING IN ALL
substances	SUBSTANCES.

42.

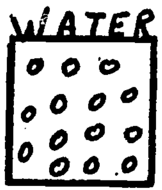


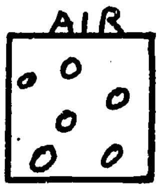


Molecules are arranged differently in different types of materials. Comparing molecules in wood and water, you can see that in wood the molecules are

closer together	farther apart
X	

43.

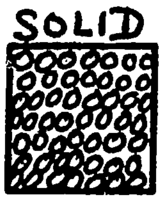


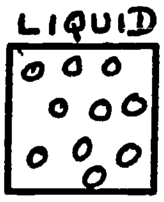


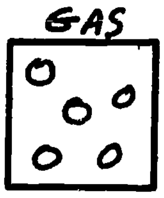
Comparing water molecules with air molecules, air molecules are

farther apart	closer together
X	

44.







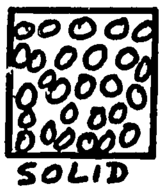
Mark the words below 1, 2, 3 in order of the closeness together of the molecules.

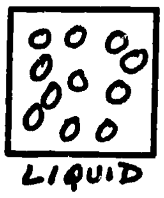
2 - liquid

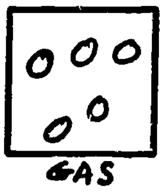
3 - gas

1 - solid

45.







In solids, the molecules are usually

close together	moderately far apart	very far apart
X		

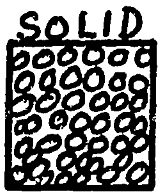
In liquids, the molecules are usually

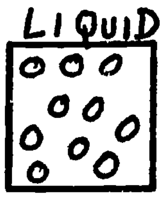
close together	moderately far apart	very far apart
	X	

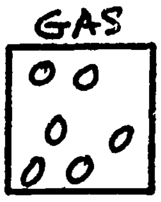
In gases, the molecules are usually

close together	moderately far apart	very far apart
		X

46.







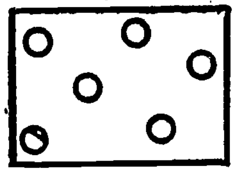
In solids, the molecules are usually CLOSE TOGETHER.

In liquids, the molecules are usually MODERATELY FAR APART (NOT SO CLOSE TOGETHER).

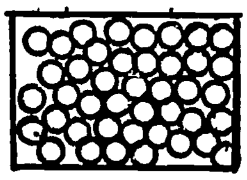
In gases, the molecules are usually FAR APART.

47.

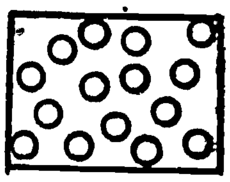
Look at the drawings below. Then, depending on how close together the molecules are, write in below the appropriate drawings with the words solid, liquid, or gas.



GAS



SOLID



LIQUID

48.

EDIT THIS SENTENCE

The more solid a substance is, the further apart are the molecules.

If the underlined part of the sentence is correct, COPY it.

____

If the underlined part is incorrect, CHANGE it.

THE CLOSER TOGETHER ARE THE MOLECULES

49.

Complete the table below by putting check marks in the correct squares.

	Molecules very far apart	Molecules moderately far apart	Molecules close together
Solids			✓
Liquids		✓	
Gases	✓		

50.

Describe the molecules in:

gas - MOLECULES ARE FURTHEST APART

liquid - MOLECULES ARE MODERATELY FAR APART

solid - MOLECULES ARE CLOSE TOGETHER

51.

Describe the molecules in:

solid iron - SINCE IRON IS A SOLID, THE MOLECULES ARE CLOSE TOGETHER.

milk - SINCE MILK IS A LIQUID, THE MOLECULES ARE MODERATELY FAR APART.

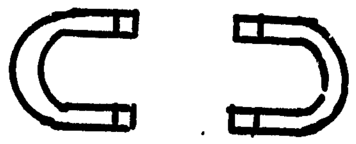
iodine gas - SINCE IODINE GAS IS A GAS, THE MOLECULES ARE VERY FAR APART.

52.

The moving molecules are like children playing tag in a playground, always pushing and pulling at each other. The closer together they are, the more strongly they

push and pull each other	stay still
X	

53.



Magnets can pull towards each other or away. The closer they are together, the more strongly they push or pull. Similarly, the closer molecules are together, the

more strongly they push and pull	less strongly they push and pull
X	

54.

Since molecules in solids are

closest together	furthest apart
X	

molecules in solids

push and pull each other the least	push and pull each other the most
	X

55.

The farther apart molecules are

the less strongly they push and pull	the more strongly they push and pull
X	

Gas molecules push and pull

more strongly than liquid molecules	less strongly than liquid molecules
	X

56.

Complete the table below by putting check marks in the correct squares.

	Molecules push and pull each other the most	Molecules push and pull each other a moderate amount	Molecules push and pull each other the least
Solids	✓		
Liquids		✓	
Gases			✓

57.

EDIT THIS SENTENCE

When molecules are closest together, they push and pull the least.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

THEY PUSH AND PULL THE MOST

58.

Make up a sentence, using all the words below.

molecules	WHEN MOLECULES ARE
furthest apart	FURTHEST APART, THEY
push and pull	PUSH AND PULL THE LEAST.

59.

Compare the pulling of molecules in hydrogen chloride and in ammonium sulfide.

THE MOLECULES IN AMMONIUM SULFIDE ARE CLOSER TOGETHER AND THEREFORE PUSH AND PULL MORE.

60.

When molecules are close together, the spaces between them are small. The spaces between molecules are smallest in a

solid	liquid	gas
X		

61.

You will remember that the molecules push and pull most when they are closest together. This also means that the molecules push and pull most when the spaces between them are

largest	smallest
	X

62.

Liquid oxygen is used in rockets. Gaseous oxygen is a gas. Compare the spaces between liquid oxygen molecules and gaseous oxygen molecules. The spaces between gaseous oxygen molecules are

larger	the same	smaller
X		

The molecules push and pull each other more in

gaseous oxygen	liquid oxygen
	X

63.

EDIT THIS SENTENCE

The amount of push and pull among molecules depends on the amount of space between the molecules.

If the underlined part of the sentence is correct, COPY it.

AMOUNT OF SPACE BETWEEN THE MOLECULES

If the underlined part is incorrect, CHANGE it.

64.

Make up a sentence, using all the words below.

pushing and pulling
molecules
depends on

THE AMOUNT OF PUSHING AND PULLING AMONG MOLECULES DEPENDS ON THE AMOUNT OF SPACE BETWEEN THEM.

65.

Molecules do most pushing and pulling in a

gas	liquid	solid
		X

This is because in this substance the spaces between the molecules are

smallest	largest
X	

66.

EDIT THIS SENTENCE

The closer the molecules are to each other the less they push and pull each other.

If the underlined part of the sentence is correct, COPY it.

____

If the underlined part is incorrect, CHANGE it.

MORE

67.

Hot steam is a gas. Below, explain why the molecules push and pull each other less in steam than in water.

THE MOLECULES IN STEAM ARE FURTHER APART or THE SPACES BETWEEN STEAM MOLECULES ARE LARGER.

68.

Let's see what you remember.
An element contains

different kinds of atoms	only one kind of atom
	X

In elements and all other materials, one or more atoms form

molecules	fragments
X	

69.

What makes things different is

only the kinds of atoms they contain	only the numbers of each kind of atom in the molecules

both answers can be correct
X

70.

Molecules are always

moving	still
X	

71.

Molecules are usually closest together in

solids	liquids	gases
X		

The spaces between molecules are usually largest in

solids	liquids	gases
		X

72.

Molecules push and pull each other most when

they are closest together	the spaces between are the largest
X	

73.

Below, write what you know about what decides the amount of pushing and pulling among molecules.

1. THE AMOUNT OF PUSHING AND PULLING AMONG MOLECULES DEPENDS ON THE AMOUNT OF SPACE BETWEEN THEM.
2. THE AMOUNT OF PUSHING AND PULLING AMONG MOLECULES DEPENDS ON HOW CLOSE THEY ARE TOGETHER.

74.

Compare how the molecules of water push and pull each other: (1) at the surface of a pool of water and (2) in the middle of a pool of water.

1. AT THE SURFACE THEY PUSH AND PULL ONLY SIDEWAYS AND DOWNWARDS.
2. IN THE MIDDLE OF THE POOL, THEY PUSH AND PULL IN ALL DIRECTIONS.

ADDITIONAL RESULTS

Table 1

Summary of Analysis of Variance
for the Matching of Ss for:
Work Rate

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	.39063	.39063	.05
2	1	3.51563	3.51563	.49
3	1	1080.76563	1080.76563	151.30***
12	1	.39063	.39063	.05
13	1	.01563	.01563	.00
23	1	15.01563	15.01563	2.10
123	1	4.51563	4.51563	.63
WITHIN REPLICATES	56	403.37500	7.20313	
TOTAL	63	1507.98438		

Table 2

Summary of Analysis of Variance
for the Matching of Ss for:
Otis IQ

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	14.06250	14.06250	.51
2	1	2475.06250	2475.06250	89.10***
3	1	1.56250	1.56250	.06
12	1	.25000	.25000	.01
13	1	49.00000	49.00000	1.76
23	1	4.00000	4.00000	.14
123	1	3.06250	3.06250	.11
WITHIN REPLICATES	56	1530.75000	27.33482	
TOTAL	63	4077.75000		

Significance levels: * = .05; ** = .01; *** = .001

Table 3

Summary of Analysis of Variance
for the Matching of Ss for:
Pretest Scores - Heat

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	1.56250	1.56250	.20
2	1	20.25000	20.25000	2.63
3	1	1.56250	1.56250	.20
12	1	5.06250	5.06250	.66
13	1	.25000	.25000	.03
23	1	10.56250	10.56250	1.37
123	1	12.25000	12.25000	1.59
WITHIN REPLICATES	56	438.50000	7.83036	
TOTAL	63	490.00000		

Table 4

Summary of Analysis of Variance
for the Matching of Ss for:
Pretest Scores - Surface Tension

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	.06250	.06250	.19
2	1	2.25000	2.25000	7.24**
3	1	.06250	.06250	.19
12	1	.56250	.56250	1.80
13	1	1.00000	1.00000	3.22
23	1	.06250	.06250	.19
123	1	2.25000	2.25000	7.24**
WITHIN REPLICATES	56	17.50000	.31250	
TOTAL	63	23.75000		

Table 5

Summary of Analysis of Variance: Errors - Heat

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	58.14063	58.14063	7.56**
2	1	172.26563	172.26563	22.39***
3	1	.76563	.76563	.10
12	1	3.51563	3.51563	.46
13	1	54.39063	54.39063	7.07**
23	1	2.64063	2.64063	.34
123	1	13.14063	13.14063	1.71
WITHIN REPLICATES	56	439.37500	7.84598	
TOTAL	63	744.23438		

Table 6

Summary of Analysis of Variance: Errors - Surface Tension

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	45.56250	45.56250	5.47*
2	1	121.00000	121.00000	14.52***
3	1	4.00000	4.00000	.48
12	1	9.00000	9.00000	1.08
13	1	56.25000	56.25000	6.75*
23	1	.56250	.56250	.07
123	1	45.56250	45.56250	5.47*
WITHIN REPLICATES	56	464.00000	8.28571	
TOTAL	63	745.93750		

Table 7

Summary of Analysis of Variance: Visual Booklet - Heat

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	.25000	.25000	.70
2	1	3.06250	3.06250	8.51**
3	1	.06250	.06250	.17
12	1	.06250	.06250	.17
13	1	.06250	.06250	.17
23	1	.25000	.25000	.70
123	1	.00000	.00000	.00
WITHIN REPLICATES	56	20.00000	.35714	
TOTAL	63	23.75000		

Table 8

Summary of Analysis of Variance: Visual Booklet - Surface Tension

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	5.64063	5.64063	4.06*
2	1	4.51563	4.51563	3.25
3	1	1.26563	1.26563	.91
12	1	.76563	.76563	.55
13	1	.39063	.39063	.28
23	1	4.51563	4.51563	3.25
123	1	.01563	.01563	.01
WITHIN REPLICATES	56	77.12500	1.37723	
TOTAL	63	94.23438		

Table 9

Summary of Analysis of Variance:
Time - Heat

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	64.00000	64.00000	1.66
2	1	45.56250	45.56250	1.18
3	1	529.00000	529.00000	13.75***
12	1	64.00000	64.00000	1.66
13	1	14.06250	14.06250	.37
23	1	1.00000	1.00000	.03
123	1	14.06250	14.06250	.36
WITHIN REPLICATES	56	2145.25000	38.30804	
TOTAL	63	2876.93750		

Table 10

Summary of Analysis of Variance:
Time - Surface Tension

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	13.14063	13.14063	1.30
2	1	8.26563	8.26563	.82
3	1	172.26563	172.26563	17.05***
12	1	5.64063	5.64063	.56
13	1	6.89063	6.89063	.68
23	1	15.01563	15.01563	1.49
123	1	.76563	.76563	.08
WITHIN REPLICATES	56	564.37500	10.07813	
TOTAL	63	786.35938		

Table 11

Summary of Analysis of Variance:
Posttest - Heat

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	.14063	.14063	.02
2	1	54.39063	54.39063	8.16**
3	1	.39063	.39063	.06
12	1	26.26563	26.26563	3.94
13	1	34.51563	34.51563	5.18*
23	1	21.39063	21.39063	3.21
123	1	.76563	.76563	.11
WITHIN REPLICATES	56	382.12500	6.82366	
TOTAL	63	519.98438		

Table 12

Summary of Analysis of Variance:
Posttest - Surface Tension

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	1.26563	1.26563	.16
2	1	147.01563	147.01563	19.11***
3	1	1.26563	1.26563	.16
12	1	.39063	.39063	.05
13	1	4.51563	4.51563	.59
23	1	3.51563	3.51563	.46
123	1	4.51563	4.51563	.59
WITHIN REPLICATES	56	418.62500	7.47545	
TOTAL	63	581.10938		

Table 13

Summary of Analysis of Variance: Retention Test - Heat

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	.14063	.14063	.01
2	1	70.14063	70.14063	5.05*
3	1	28.89063	28.89063	2.08
12	1	4.51563	4.51563	.32
13	1	26.26563	26.26563	1.89
23	1	47.26563	47.26563	3.40
123	1	2.64063	2.64063	.19
WITHIN REPLICATES	56	776.12500	13.85938	
TOTAL	63	955.98438		

Table 14

Summary of Analysis of Variance: Retention Test - Surface Tension

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES	F
1	1	2.64063	2.64063	.40
2	1	102.51563	102.51563	15.38***
3	1	1.26563	1.26563	.19
12	1	.14063	.14063	.02
13	1	2.64063	2.64063	.40
23	1	19.14063	19.14063	2.87
123	1	3.51563	3.51563	.53
WITHIN REPLICATES	56	370.37500	6.61384	
TOTAL	63	502.23438		