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ABSTRACT

This is a 1971 reprint of the 1966 syllabus designed to encourage the utilization of such basic concepts as the conservation of energy, the conservation of momentum, and the conservation of charge in related areas rather than in isolation. It is presented in such a way as to show the importance of these ideas as unifying concepts which can be repeatedly applied throughout the course. The basic mathematical skills needed for the course are defined. Mechanics, Wave Phenomena, Electricity, and Atomic and Nuclear Physics are designated as the major areas of study. Topics are listed for each of these areas. Understandings and fundamental concepts and supplementary information are given for each of the topics. (Author/TS)

PHYSICS

A SYLLABUS FOR SECONDARY

HYSICS

LABUS FOR SECONDARY SCHOOLS

PHYSICS

A Secondary School Course With

Major Emphasis on Fundamental

Concepts

This course of study was adopted statewide effective September 1967.

1971 Reprint

The University of the State of New York
The State Education Department
Bureau of Secondary Curriculum Development
Albany, 1966

In the spring of 1963, the State Education Department convened a meeting of an overall Science Advisory Committee for the purpose of initiating revisions in its courses in science. The membership of the committee included representatives from the secondary and collegiate levels, from industry, and from research institutions. The function of this committee was to establish guidelines which would serve to aid the specific syllabus revision committees in their task of updating the various syllabuses in the light of recent developments in society, science, and science education.

Major recommendations of the Science Advisory Committee included: (1) that the present science courses be brought up-to-date in the light of recent developments in the field of science, (2) that a greater emphasis be placed on the understanding and concepts involved in the particular subject matter areas, and (3) that attention be given to coordinating the laboratory with the content aspects of each course.

After the Science Advisory Committee made its recommendations, the Physics Revision Committee met to specify the content of the physics course. The committee included members from different geographic areas of the State who had experience with various approaches to the teaching of physics. The members of the committee were:

William Atherton, Niskayuna High School
John H. Dodge, Irondequoit High School
George Kanstroom, Richmond Hill High School
Robert L. Lehrman, Roslyn High School
Thomas D. Miner, Garden City High School
Dr. Kenneth H. Moore, Rensselaer Polytechnic Institute
Dr. Clifford Swartz, State University at Stoney Brook
Dr. Alexander Taffel, Bronx High School of Science

During the 1963-64 school year four experimental units constituting the basic core of the new physics syllabus were written. These were used, on a trial basis, in twenty

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FOREWORD

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used, on a trial basis, in twenty schools across the State. The results of a testing program and the criticisms of participating teachers were used in preparing the first (1964) revision which was a complete syllabus containing both core and extended areas.

Throughout the development of this course, participating teachers played a vital role in the evaluation and refinement of the Syllabus. An extensive evaluation by participating teachers was an essential part of the program. Examinations which were administered and analyzed supplied further evidence as to the applicability of the materials.

During the years since the inception of this project many people have contributed significantly to its development. Mr. Atherton and Allister W. Crandall, Pulaski High School, prepared the original core units as consultants to the Bureau of Secondary Curriculum Development.

The 1964 edition was prepared by a writing team consisting of John Fitzgibbons, North Syracuse Central School, and Louis Landecker, Bronx High School of Science. Many of the suggestions forwarded to the Department by the New York City Physics Syllabus Committee, consisting of Herman Gewirtz, Chairman of Physical Science, Abraham Lincoln High School; Simon Weissman, Chairman of Physical Science, Midwood High School; Harvey Pollack, Forest Hills High School; and Charles Hellman, Bronx High School of Science; were used in augmenting the original core units. The 1964 edition of the syllabus was reviewed by Dr. Luther Andrews, Professor of Physics at the State University of New York at Albany and a member of the Science Advisory Committee. Hugh Templeton, Chief of the Bureau of Science Education, acted as consultant throughout the project.

The modifications included in the 1965 and final editions were, in large part, recommended by participating teachers and approved by the revision committee.

Sigmund Abeles, Associate in Science Education, coordinated the revision of the syllabus. Robert G. MacGregor, Associate in Science Education, reviewed the manuscript and made valuable suggestions. A review of content accuracy was made by Dr. W. M. Schwarz, Professor fications included in the 1965 and final , in large part, recommended by participating approved by the revision committee.

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Gordon E. Van Hooft, *Chief*
Bureau of Secondary
Curriculum Development

H. George Murphy
Director, Division of School Supervision

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Aims and Content of the Physics Course

This course presents a modern view of physics with major emphasis placed on the fundamental concepts underlying this basic science. The syllabus is designed to encourage the utilization of such basic concepts as the conservation of energy, the conservation of momentum, and the conservation of charge in related areas rather than in isolation. This approach tends to foster an appreciation for the unity of physics. As a result, the syllabus is presented in such a way as to show the importance of these ideas as unifying concepts which can be repeatedly applied throughout the course.

The objectives of the course in physics should extend beyond a minimal comprehension of the basic facts and principles outlined in this syllabus. The appreciation of scientific method, the ability and willingness to change beliefs and opinions after careful weighing of new evidence, and the development of the habit of critical thinking are the intangible but most important outcomes of the study of this science. These methods of thought and action will remain long after many specific details of subject matter are forgotten.

The tremendous scientific advances within the past 25 years have created a critical shortage of skilled technicians, scientists, and engineers. At all levels of ability, there is an increasing demand for workers with more training and understanding of our physical world. The maintenance of our standard of living and our national security depend in large part upon an increasing supply of scientifically trained personnel. Of equal and perhaps even greater importance is the need for a continuing supply of well-informed citizens capable of making sound decisions on the many new issues and problems that face us.

State Diploma Credit

This course may be used as one unit of the Group II major science sequence or for Group III credit as an elective toward a State Diploma

Sequence and Schedulin

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Introduction

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Sequence and Scheduling

One of the major problems in constructing a syllabus for a one-year course in physics is to provide a broad general understanding of the fundamental principles of the basic area of physics and, at the same time, to achieve an extension of understanding in at least some of these areas. Limitation of time precludes this extension in all areas, while teacher training and preference dictate the areas of choice in a particular school.

In an attempt to introduce some degree of flexibility in the course, and at the same time provide for an adequate coverage of basic areas, the content of the proposed syllabus has been kept to a minimum. It consists of a basic core section and four optional extended areas.

The minimum requirements of the course include the basic core, and any _two_ *of the four extended areas.*

The order of presentation used in the syllabus indicates one of several possible teaching sequences. Any sequence that presents a logical development of physical principles may be followed.

The successful completion of physics usually requires slightly more maturity and understanding of mathematical concepts than does chemistry. It is, therefore, recommended that physics be placed at the top of the science sequence. While chemistry is not a prerequisite, if students are to take both chemistry and physics, normally they should be studied in that order. However, an exception may be made in the case of boys and girls with above-average ability in mathematics and science who are comtemplating careers in engineering, mathematics, or science. If these pupils elect physics in grade 11, they may be better prepared to compete for scholarships since many of the examinations for scholarships are given early in the 12th year. This plan also makes it possible for schools to offer an elective course in advanced physics in the 12th year or a college-level course for advanced standing. A second year in physics, however, is not recommended at the expense of a Regents course in chemistry.

The minimum time required for this course is six 45-minute periods per week, although seven periods are recommended. This time allotment should include a double laboratory period each week.

Teachers are encouraged to set their own time allotments based on student interest and achievement and their own teaching experience.

The guide below may help to establish a basic frame of reference for the course:

	Core Area	Extended Area
Mechanics	10 weeks	2 weeks
Waves	7 weeks	1 week
Electricity	8 weeks	1 week
Atomic and Nuclear Physics	4 weeks	1 week

Prerequisites

Ninth year mathematics - course 1 (algebra) is a prerequisite for physics. It is strongly recommended that pupils successfully complete Mathematics 10 before being enrolled in the physics course. Application of mathematical skills is stressed frequently in this syllabus. Some of this material will have been developed previously in courses in mathematics and science, and may be omitted or covered in brief review. Other topics, such as vectors, that may not have been studied previously may be undertaken as a unit at the beginning of the course, or may be introduced with

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ourse, or may be introduced with associated material at the discretion of the teacher.

Laboratory

A physics laboratory "exercise" is defined as the laboratory work done by the pupil during one school period. In addition, a satisfactory report of this work is required. The minimum laboratory requirement can be met by performing 30 individual exercises requiring 30 laboratory periods. However, many of the experiences recommended for laboratory work in the physics course require two or more periods for completion. Therefore, the minimum requirement may also be met by 30 periods involving a smaller number of experiments. This is not intended to permit the student to spread what is ordinarily a one-period exercise over two or more periods.

Organization of the Syllabus

The material in the syllabus is organized under three major headings:

Topics. This column contains the topical outline. Topics preceded by an asterisk * must be treated quantitatively. Topics included in the extended areas are enclosed in boxes in all three columns. A boxed asterisk $\boxed{*}$ indicates that the topic is to be treated qualitatively in the core and quantitatively in the extended area.

Understandings and Fundamental Concepts. This column outlines the basic concepts of the course.* Those concepts which are boxed are required for the extended areas only.

Supplementary Information. This column includes some additional information and explanation of the basic concepts. *Statements which delimit the material subject to examination, and specific suggestions to teachers are printed in italics in this column.*

**Only the concepts in this column are subject to testing in parts I and II of the Regents examination.*

The Relation of the Physics Syllabus to the Regents Examination.

The Regents examination in physics will have two major parts. Part I will consist of questions based only on the basic core, and part II questions will consist of items from the basic core and the extended areas. Since there are four extended areas, there will be four part II questions. The Regents examination will be constructed so that part I will account for 70% of the score and part II for 30%. *All students taking the examination should answer all of the questions in part I and two of the four alternative extended areas on part II.*

System of Units

In recent years the MKSA system (meter, kilogram, second, ampere) has found increased use in many science courses, particularly in physics. As a result this syllabus makes use of it. The meter, the kilogram, t degree Kelvin. These Systéme International Eleventh General Confe in October, 1960.*

Regents examinati the five fundamental u the appropriate derive volt, etc.) as defined syllabus. While exami to these units, the us FPS) in class and labo

Changes in Syllabus

Corrections or ch necessary will be brou principals by means of Department.

* The sixth fundamental unit in SI is the candela (cd), a unit of luminous intensity.

There is little value in having students remember the exact definitions of the fundam be aware of their arbitrary nature.

R. D. Huntoon, director of the Institute for Basic Standards of the National Bureau o March 1966 issue of *The Physics Teacher*, " within the next few decades the number of an independent basis may possibly decrease to three, but we shall probably continue t quantities as the base of our system."

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KSA system (meter, kilogram, increased use in many science hysics. As a result this syllabus makes use of it. The fundamental units used are the meter, the kilogram, the second, the ampere, and the degree Kelvin. These are five of the six units in the Systéme International des Unités (S.I.) adopted at the Eleventh General Conference on Weights and Measures in October, 1960.*

Regents examination questions will be in terms of the five fundamental units mentioned above and the appropriate derived units (e.g., newton, joule, volt, etc.) as defined at appropriate points in the syllabus. While examination questions will be confined to these units, the use of other systems (e.g., CGS and FPS) in class and laboratory is encouraged.

Changes in Syllabus

Corrections or changes in the syllabus that become necessary will be brought to the attention of school principals by means of supervisory letters from the Department.

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of the Institute for Basic Standards of the National Bureau of Standards, states in the *Physics Teacher,* " within the next few decades the number of units that are established on possibly decrease to three, but we shall probably continue to consider the six SI physical f our system."

Several mathematical skills and related concepts are continually used throughout the physics syllabus. A consistent emphasis on these basic skills and concepts is recommended.

Measurement

Measurement is a comparison of an unknown quantity with a known quantity. All physical measurements are subject to errors.

Errors may be due to the method used, environmental fluctuation, instrumental limitations, and personal error. Systematic errors tend to be in one direction. Random errors tend to fluctuate in both directions. The random error may be reduced by increasing the number of observations.

Significant figures

Significant figures are digits which indicate the reasonably certain number of digits in a measured quantity. In mathematical operations involving significant figures, the answer should not contain more significant figures than the least number of significant figures in the original quantities.

A significant figure is one which is known to be reasonably reliable. In expressing the results [illegible] a measurement, one estimated figure is considered [illegible]nificant; for example, in measuring temperature, if the thermometer is calibrated in degrees, the reading may be <u>estimated</u> to the tenth of a degree. In this case, in the

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reading 20.3°, the figure "3" is considered significant.

Zeros which appear in front of a number are not significant figures. The number 0.083 contains two significant figures.

Zeros which appear between numbers are always significant. The number 803 contains three significant figures.

Zeros which appear after a number are significant only (1) if followed by a decimal point, or (2) if to the right of a decimal point. The number 1800 contains two significant figures, but the numbers 1800. and 18.00 contain four significant figures.

For whole numbers ending in two or more zeros there is no way of indicating that some, but not all, of the zeros are significant; for example, the number 186,000 would indicate three significant figures if no decimal point is expressed, and six significant figures if the decimal point is expressed. There is no way of indicating its accuracy to four or five significant figures except by the use of standard notation.

The following rules will assist pupils when rounding off a number:

When the number dropped is less than 5, the preceding number remains unchanged; for example, 5.3634 to three significant figures becomes 5.36.

When the number dropped is 5 or more, the preceding number is increased by 1; for example, 2.4179 to three significant figures becomes 2.42.

When adding or subtracting, the answer should be rounded off to contain the least accurately known figure as the final one; for example,

Add	Subtract
32.6	531.46
431.33	86.3
6144.212	445.16 = 445.2
6608.142 ≈ 6608.1	

When multiplying or dividing, the answer should be rounded off to contain only as many significant figures as are contained in the least accurate number; for example,

Multiply	Divide
1.36	$5.1 \div 2.13$
4.2	
272	2.39 = 2.4
544	2.13/ 5.1000
5.712 = 5.7	4.26
	840
	639
	2010

When adding, subtracting, multiplying, or dividing, numbers may be rounded off to one more than the number of significant figures to be carried in the answer <u>before</u> the manipulation is carried out; for example,
$2.7468 \times 3.2 = 2.75 \times 3.2 = 8.8$

Standard notation (scientific or exponential notation)

Standard notation should be used to indicate the number of significant figures and to facilitate mathematical operations with large and small numbers.

Any number can be expressed in the form $A \times 10^n$, where A is any number with one digit to the left of the decimal point and n is an integer. All of the digits

in A are signifi
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example 186,000

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$2.2 \times 10^4 \times 3.01$
$2.2 \times 10^{-4} \times 3.0$
$6.0 \times 10^3 \times 3.01$
$6.0 \times 10^5 \div 3.0$
$6.0 \times 10^5 \div 3.0$
$3.0 \times 10^2 \div 6.0$

Addition an
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Subtract

531.46
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445.16 = 445.2

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Divide

$5.1 \div 2.13$

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        2.39     = 2.4
2.13/ 5.1000
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in A are significant. The value of n is determined by counting the number of places the decimal was moved. If the decimal was moved to the left, n is positive. If it was moved to the right, n is negative. For example 186,000 becomes 1.86×10^5, and 0.0000520 becomes 5.20×10^{-5}. In standard notation it is possible to indicate any desired number of significant figures. For example, if the figure 186,000 were known to four significant figures, it would be written 1.860×10^5.

Multiplication and division in standard notation: To multiply or divide numbers in standard notation, multiply or divide the significant figure factors to obtain the new value of A, retaining the correct number of significant figures (opposite col.), and add or subtract the powers of 10 to obtain the new value of n. Adjust the decimal point if the new A has more or less than one non-zero digit to the left of the decimal point. Examples:

$2.2 \times 10^4 \times 3.01 \times 10^2 = 6.6 \times 10^6$

$2.2 \times 10^{-4} \times 3.01 \times 10^2 = 6.6 \times 10^{-2}$

$6.0 \times 10^3 \times 3.01 \times 10^4 = 18 \times 10^7 = 1.8 \times 10^8$

$6.0 \times 10^5 \div 3.0 \times 10^2 = 2.0 \times 10^3$

$6.0 \times 10^5 \div 3.0 \times 10^{-2} = 2.0 \times 10^7$

$3.0 \times 10^2 \div 6.0 \times 10^5 = 0.50 \times 10^{-3} = 5.0 \times 10^{-4}$

Addition and Subtraction in Standard Notation: Numbers expressed in standard notation can be added or subtracted only if the powers of 10 are the same; for example, $5 \times 10^3 + 2 \times 10^3 = (5 + 2) \times 10^3 = 7 \times 10^3$. If the numbers to be added or subtracted have different powers of 10, then the powers must be equalized. For example,

$2 \times 10^2 + 3 \times 10^3 = 2 \times 10^2 + 30 \times 10^2 = 32 \times 10^2 = 3.2 \times 10^3$.

Manipulation of Units

In mathematical manipulations, units behave like algebraic quantities. In any physical equation the units on each side must be equivalent.

Mathematical Functions

Graphs may be used to illustrate mathematical functions. Students should be able to recognize, interpret, and use mathematical expressions and graphs representing: (1) direction linear relations, $y = kx$; (2) direct second degree relations, $y = kx^2$; (3) inverse first degree relations, $y = \frac{k}{x}$; and (4) inverse square relations, $y = \frac{k}{x^2}$.

A proportionality represents a ratio, and can be

$0^3 = 2 \times 10^2 + 30 \times 10^2 = 32 \times 10^2 =$

Units

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$\frac{k}{x}$; and (4) inverse square relations, $y = \frac{k}{x^2}$.

onality represents a ratio, and can be written as an equation by inserting the proper proportionality constant.

Care should be taken to associate the proper units with the proportionality constant.

Graphs

Graphs should be used to illustrate physical relationships. A line representing the relationship should be smooth and probably will not pass through all measured points. Points should be circled to indicate their uncertainty.

Vectors

The ability to add and subtract vectors should be developed.

The Slide Rule

The use of slide rules should be encouraged.

TOPICAL OUTLINE

MECHANICS

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TOPICAL OUTLINE

MECHANICS

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TOPICAL OUTLINE (continued)

ATOMIC AND NUCLEAR PHYSICS

boxed are required of those selecting Atomic and Nuclear Physics as an extended area.

Topics	Understandings and Fundamental Concepts	
I. Kinematics	Kinematics deals with the mathematical methods of describing motion without regard to the forces which produce it.	
A. Linear motion	The motion of a body may be described in terms of its velocity and acceleration.	*Minimum re* *accelerati* *or finally* Motion is
1. Distance and displacement	Distance is a scalar quantity that represents the length of a path from one point to another.	The distin stressed.
	Displacement is a vector quantity that represents the length and direction of a straight line path from one point to another between which motion of an object has taken place.	Whenever n or scalar Total disp
a. The meter	The meter is the MKS unit of length. It is a fundamental unit.	The concep The meter in a vacuu of krypton
*2. Velocity and speed	Velocity is a vector quantity which represents the time-rate of change of displacement.	*Minimum qu* *recognize,* *versus tim*
	Speed is a scalar quantity that represents the magnitude of the velocity.	

MECHANICS

Understandings and Fundamental Concepts / **Supplementary Information**

Kinematics deals with the mathematical methods of describing motion without regard to the forces which produce it.

The motion of a body may be described in terms of its velocity and acceleration.

Minimum requirements are limited to motion with constant acceleration in a linear path, and to bodies initially or finally at rest.

Motion is relative to a given frame of reference.

Distance is a scalar quantity that represents the length of a path from one point to another.

The distinction between scalars and vectors should be stressed.

Displacement is a vector quantity that represents the length and direction of a straight line path from one point to another between which motion of an object has taken place.

Whenever new quantities are introduced their vector or scalar nature should be stressed.

Total displacement is a vector sum.

The meter is the MKS unit of length. It is a fundamental unit.

The concept of fundamental units should be introduced.

The meter is now defined as 1,650,763.73 wavelengths in a vacuum of the orange-red line in the spectrum of krypton 86.

Velocity is a vector quantity which represents the time-rate of change of displacement.

Minimum quantitative requirements are the ability to recognize, interpret, and use graphs of distance versus time and to apply the related equations.

Speed is a scalar quantity that represents the magnitude of the velocity.

Topics	Understandings and Fundamental Concepts	
		The relation o developed grap should be plot Show that $\frac{s}{t}$ = speed). If the speed i the distance-t instantaneous Mathematical f equations may the fundamenta physics.
a. The second	The second is the MKS unit of time. It is a fundamental unit.	The second is of the cesium 6 parts in 10^{1} times more acc formerly in us International October 8, 196
*3. Acceleration	Acceleration is a vector quantity that represents the time-rate of change in velocity.	*Minimum quanti recognize, int time, and to a* The relation o graphically. Show that the when the accel

The relation of position versus time should be developed graphically. The independent variable (time) should be plotted on the horizontal axis.

Show that $\frac{s}{t} = v = \bar{v}$, if the slope is constant (constant speed).

If the speed is changing, the slope of the tangent to the distance-time curve at any point represents the instantaneous speed at that point.

Mathematical functions such as first and second degree equations may be introduced as a means of emphasizing the fundamental relationship between mathematics and physics.

The second is the MKS unit of time. It is a fundamental unit.

The second is now defined as 9,192,631,770 vibrations of the cesium atom. This measurement is accurate to 6 parts in 10^{12} or 1 second in 5000 years and is 200 times more accurate than the astronomical definition formerly in use. This value was adopted by the International Committee on Weights and Measures on October 8, 1964 at 1725 hr. Paris time.

Acceleration is a vector quantity that represents the time-rate of change in velocity.

Minimum quantitative requirements are the ability to recognize, interpret, and use graphs of speed versus time, and to apply the related equations.

The relation of speed to time should be developed graphically.

Show that the slope of the speed-time curve = $\frac{\Delta v}{\Delta t} = a$, when the acceleration is constant.

Topics	Understandings and Fundamental Concepts	
*4. Distance traveled by a uniformly accelerating object	The distance traveled by a uniformly accelerating object is equal to the product of the average speed and the elapsed time.	*Minimum qua applicatior*
	The distance traveled by an object accelerating uniformly from rest is proportional to the square of the time.	The distanc speed-time
*5. Freely-falling objects	Freely-falling objects may be considered as examples of objects with constant acceleration.	*The minimum to solve pr with initia*
		Actual cond
II. Force	A force is a vector quantity that may be defined as a push or pull.	A more rigo in conside
	Forces may act upon an object through space.	Forces may magnetic,
		The region of the forc the concept
*A. Composition of forces	The resultant of two or more concurrent forces acting on a body is the single force producing the same effect. The resultant may be found by the vector addition of the individual forces.	Determinati graphical
		Minimum qua solutions angle.
		Minimum qua solutions of 0° or l

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Understandings and Fundamental Concepts	Supplementary Information
The distance traveled by a uniformly accelerating object is equal to the product of the average speed and the elapsed time.	*Minimum quantitative requirements are limited to applications of the relationships* $s = \bar{v}t$ *and* $s = \frac{1}{2}at^2$.
The distance traveled by an object accelerating uniformly from rest is proportional to the square of the time.	The distance can be determined from the area under the speed-time curve.
Freely-falling objects may be considered as examples of objects with constant acceleration.	*The minimum quantitative requirement is the ability to solve problems with constant g, no friction, and with initial or final velocity equal to zero.* Actual conditions should be discussed.
A force is a vector quantity that may be defined as a push or pull.	A more rigorous definition of force will be developed in considering Newton's second law of motion.
Forces may act upon an object through space.	Forces may be classified as gravitational, electromagnetic, nuclear, and weak interactions. The region in which a force acts is known as the "field" of the force. The field concept may be introduced when the concept of a gravitational field is developed.
The resultant of two or more concurrent forces acting on a body is the single force producing the same effect. The resultant may be found by the vector addition of the individual forces.	Determination of vector sums should include both graphical and numerical solutions. *Minimum quantitative requirements for graphical solutions will be limited to two forces acting at any angle.* *Minimum quantitative requirements for numerical solutions will be limited to forces acting at angles of 0° or 180°, or two forces acting at an angle of 90°.*

Topics	Understandings and Fundamental Concepts	
*B. Resolution of forces	A single force may be resolved into an unlimited number of components.	*Min num at com you*
III. Dynamics	Dynamics deals with the relation between the forces acting on an object and the resulting change in motion.	
A. Mass, force, and acceleration - the inertial and gravitational properties of objects.		
1. First law of motion	An object remains at rest or in uniform motion unless acted upon by an unbalanced force.	Thi or cas
*2. Second law of motion, inertial mass	An unbalanced force acting on an object causes an acceleration which is directly proportional to the force, and in the direction of the force.	The for
	The inertial mass of an object is proportional to the ratio of the force on an object to the acceleration that the force gives the object. Inertial mass is a scalar quantity.	*Min app*
a. The kilogram	The kilogram is the MKS unit of mass. It is a fundamental unit.	The na The no

Understandings and Fundamental Concepts	Supplementary Information
A single force may be resolved into an unlimited number of components.	*Minimum quantitative requirements for graphical and numerical solutions will be limited to two components at right angles to each other. Include right angle components which are not horizontal and vertical in your discussion.*
Dynamics deals with the relation between the forces acting on an object and the resulting change in motion.	
An object remains at rest or in uniform motion unless acted upon by an unbalanced force.	This may be presented as Newton's first law of motion, or the first law may be presented later as a special case of the second law, when F = 0.
An unbalanced force acting on an object causes an acceleration which is directly proportional to the force, and in the direction of the force.	The unbalanced force is the vector sum of all the forces acting on the object.
The inertial mass of an object is proportional to the ratio of the force on an object to the acceleration that the force gives the object. Inertial mass is a scalar quantity.	*Minimum quantitative requirements are limited to application of the relationship, $F = ma$.*
The kilogram is the MKS unit of mass. It is a fundamental unit.	The kilogram is defined as the mass of the international kilogram at Sèvres, France. The kilogram should be used only as a unit of mass and not as a unit of force.

Topics	Understandings and Fundamental Concepts	
b. The newton	The newton is that force which will impart to a mass of one kilogram an acceleration of one meter per second per second. It is a derived unit.	
3. Newton's law of gravitation	Any two objects whose dimensions are small in comparison to the distance between them, attract each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.	*Minimum qu* *applicatio* $F_g \propto \frac{m}{r}$ *universal g*
		At this po develop the field asso relate to and not to by gravita mass. Gra mass; and
		The concep *will* *not* *b*
		The relati distance i law to be fields, an desirable. spherical be emphasi
*4. Weight	The weight of an object is the net gravitational force acting on the object.	The magnit the locati Thus weigh
	The weight of an object is directly proportional to its mass.	The accele one locati to its mas

The newton is that force which will impart to a mass of one kilogram an acceleration of one meter per second per second. It is a derived unit.

Any two objects whose dimensions are small in comparison to the distance between them, attract each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

Minimum quantitative requirements are limited to applications of the relationships

$$F_g \propto \frac{m_1 m_2}{r^2} \text{ or } F_g = \frac{G m_1 m_2}{r^2}$$ *where G is the universal gravitational constant.*

At this point some teachers may wish to introduce or develop the "field" concept applied to the gravitational field associated with a mass. The masses referred to relate to the property of mutual attraction of matter and not to the property of inertia. Mass measured by gravitational attraction is called gravitational mass. Gravitational mass is proportional to inertial mass; and is expressed in the same units.

The concept of gravitational mass versus inertial mass will not be subject to examination.

The relationship between gravitational force and distance is the first example of the inverse square law to be encountered. Since this law applied to many fields, an understanding of it at this point is desirable. The limitation of this law to point or spherical sources with uniform mass distribution should be emphasized.

The weight of an object is the net gravitational force acting on the object.

The magnitude of the gravitational force varies with the location of the object with reference to the earth. Thus weight is not an invariant property of an object.

The weight of an object is directly proportional to its mass.

The acceleration due to gravity is a constant at any one location, and is the ratio of an object's weight to its mass.

Topics	Understandings and Fundamental Concepts	
		Since weigh
		Newton's sec freely fall acceleratio
		Spring bala weight meas ("weighing") measurement 100 grams we and so fort
B. Uniform Circular motion	Uniform circular motion is the motion of an object at constant speed along a circular path.	Circular mot dynamics. T be used.
*1. Centripetal acceleration	Centripetal acceleration is a vector quantity directed toward the center of curvature. Its magnitude is directly proportional to the square of the speed and inversely proportional to the radius of the path.	*Minimum quan* *applications*
*2. Centripetal force	The force which causes centripetal acceleration is centripetal force. It is a vector quantity directed toward the center of curvature. Its magnitude is directly proportional to the product of the mass and the centripetal acceleration.	*Minimum qua* *applications*
*C. Momentum	Momentum is a vector quantity. Its magnitude is equal to the product of the mass and the velocity. Its direction is the same as that of the velocity.	
*1. Impulse	Impulse is a vector quantity with a magnitude equal to the product of the	*Minimum qua* *situations*

nderstandings and Fundamental Concepts	Supplementary Information
	Since weight is a force it is a vector quantity. Newton's second law applied to the motion of a freely falling body, where F = weight (W) and a = acceleration of gravity (g). $W = mg$. Spring balances graduated in newtons may be used in weight measurements, but comparison of masses ("weighing") on a balance should be referred to as measurement of mass. To one significant figure; 100 grams weigh 1 newton, 200 grams weigh 2 newtons, and so forth.
niform circular motion is the motion of an object at constant speed along circular path.	Circular motion should be treated as a problem in dynamics. The term "centrifugal force" should not be used.
entripetal acceleration is a vector uantity directed toward the center f curvature. Its magnitude is irectly proportional to the square f the speed and inversely pro- ortional to the radius of the path.	*Minimum quantitative requirements are limited to applications of the relationship* $a = \frac{v^2}{r}$
he force which causes centripetal cceleration is centripetal force. t is a vector quantity directed oward the center of curvature. Its agnitude is directly proportional o the product of the mass and the entripetal acceleration.	*Minimum quantitative requirements are limited to applications of the relationship* $F_c = \frac{mv^2}{r}$
omentum is a vector quantity. Its agnitude is equal to the product of he mass and the velocity. Its irection is the same as that of the elocity.	
mpulse is a vector quantity with a agnitude equal to the product of the	*Minimum quantitative requirements are limited to situations dealing with constant forces.*

Topics	Understandings and Fundamental Concepts	
	unbalanced force and the time the force acts. Its direction is the same as that of the force.	
*2. Change of momentum	When an unbalanced force acts on an object, there is a change of momentum which is equal to the impulse.	From Newton's $F\Delta t$ (impulse) conventional impulse and m *Minimum requ are limited in which the*
*3. Law of conservation of momentum	When no resultant external force acts on a system, the total momentum of the system remains unchanged.	*Minimum quan simple recoi*
	When two bodies interact their total momentum remains unchanged.	Graphical so is <u>not</u> requi suggested th energy.
4. Third law of motion	If one object exerts a force on a second, the second exerts a force on the first that is equal in magnitude and opposite in direction.	The third la momentum. T equal in mag the total mo If the terms that these f example, if pushes down back on the on the book table (react
IV. Work and energy	When work is done on or by a system the total energy of the system is changed. Energy is needed to do the work.	

nbalanced force and the time the orce acts. Its direction is the ame as tha. the force.

hen an unbalanced force acts on an bject, there is a change of omentum which is equal to the impulse.

From Newton's second law, $F = ma$ or $F = \frac{\Delta mv}{\Delta t}$ and $F\Delta t$ (impulse) = Δmv (change of momentum). Δmv is the conventional way of writing change of momentum. Both impulse and momentum are vector quantities.

Minimum requirements in using the relationship above are limited to changes in velocity and to situations in which the momentum and impulse are colinear.

hen no resultant external force acts n a system, the total momentum of he system remains unchanged.

Minimum quantitative requirements will be limited to simple recoil or explosion problems.

hen two bodies interact their total omentum remains unchanged.

Graphical solution of conservation of momentum problems is not required. If such problems are included it is suggested they be considered after a study of kinetic energy.

f one object exerts a force on a econd, the second exerts a force n the first that is equal in agnitude and opposite in direction.

The third law is implied by the law of conservation of momentum. The forces act for the same time and are equal in magnitude and opposite in direction; therefore, the total momentum remains the same.

If the terms action and reaction are used, emphasize that these forces act on different objects. For example, if a book is resting on a table, the book pushes down on the table (action) and the table pushes back on the book (reaction), or the table pushes up on the book (action) and the book pushes down on the table (reaction).

hen work is done on or by a system he total energy of the system is hanged. Energy is needed to do the ork.

Topics	Understandings and Fundamental Concepts	
*A. Work	Work is done on an object when a force displaces the object.	*Min cas the*
	Work is a scalar quantity that is equal to the product of the component of force acting in the direction of the motion and the displacement of the object.	
1. The joule	The joule is the MKS unit of work. It is the work done when a force of one newton acts through a distance of one meter in the direction of the force.	Sin may or The Wor tra It uti
*B. Energy	Energy is transferred when work is done. Energy is a scalar quantity.	
*1. Potential energy	Potential energy is the energy an object has because of its position or condition. Under ideal conditions it is equal to the work required to bring the object to that position or condition.	*Min ene gra* Thi in Ene spr ext pha

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Understandings and Fundamental Concepts	Supplementary Information
Work is done on an object when a force displaces the object.	*Minimum quantitative requirements are limited to cases in which the force and the displacement have the same direction.*
Work is a scalar quantity that is equal to the product of the component of force acting in the direction of the motion and the displacement of the object.	
The joule is the MKS unit of work. It is the work done when a force of one newton acts through a distance of one meter in the direction of the force.	Since a newton is equal to a $\frac{\text{kilogram meter}}{\text{second}^2}$, a joule may also be expressed as a $\frac{(\text{kilogram meter})}{\text{second}^2}$ (meter) or $\frac{\text{kilogram meter}^2}{\text{second}^2}$. The same units are used to measure work and energy. Work can be done only by the transfer of energy. Work transfers energy from one object or system to another. It should be noted that it is not possible to utilize all the energy of a system.
Energy is transferred when work is done. Energy is a scalar quantity.	
Potential energy is the energy an object has because of its position or condition. Under ideal conditions it is equal to the work required to bring the object to that position or condition.	*Minimum quantitative requirements relating to potential energy of position will be limited to position in a gravitational field.* This concept may be extended, for example, to position in an electric or magnetic field. Energy of condition may be illustrated with a coiled spring. Potential energy of condition may be extended to include the potential energy acquired during phase changes.

Topics	Understandings and Fundamental Concepts	
*2. Gravitational potential energy	If work is done on an object against gravitational force, there is an increase in the gravitational potential energy of the object.	Emphasize the nee discussing potent
	If work is done by gravitational force on an object, there is a decrease in the gravitational potential energy of the object.	Ideal conditions constant g.
	The change in gravitational potential energy is equal to the product of the weight of the body and the vertical change of height.	*Minimum quantita applications of is small. This example of the u*
*3. Kinetic energy	Kinetic energy is the energy an object has because of its motion. Like all energy it is a scalar quantity. Kinetic energy is equal to one-half the product of the mass and the speed squared.	The equation KE = law of motion and $w = fs$ ar $\therefore w = ma$ since $v^2 = 2a$ $w = \frac{1}{2}mv^2 =$
	Under ideal conditions it is equal to the work required to stop the object, or bring the object from rest to that speed.	*Minimum quantita problems involvi* $w = KE$ *Relativistic eff*
*C. Power	Power is the time-rate of doing work. It is a scalar quantity.	*Minimum quantita problems involvi* $Power = \frac{work}{time} =$
1. The watt	The watt is the MKS unit of power. It is equal to one joule per second.	

Understandings and Fundamental Concepts

Supplementary Information

If work is done on an object against gravitational force, there is an increase in the gravitational potential energy of the object.

Emphasize the need for a reference level in discussing potential energy in a gravitational field.

If work is done by gravitational force on an object, there is a decrease in the gravitational potential energy of the object.

Ideal conditions assume the absence of friction and constant g.

The change in gravitational potential energy is equal to the product of the weight of the body and the vertical change of height.

Minimum quantitative requirements will be limited to applications of the relationship $\Delta PE = mg\Delta h$ where Δh is small. This is an approximation, and is another example of the use of an idealized situation.

Kinetic energy is the energy an object has because of its motion. Like all energy it is a scalar quantity. Kinetic energy is equal to one-half the product of the mass and the speed squared.

The equation $KE = \frac{1}{2}mv^2$ may be derived from the second law of motion and the definition of work.

$$w = fs \text{ and } f = ma \quad \text{where a is constant.}$$

$$\therefore w = mas$$

$$\text{since } v^2 = 2as$$

$$w = \tfrac{1}{2}mv^2 = KE$$

Under ideal conditions it is equal to the work required to stop the object, or bring the object from rest to that speed.

Minimum quantitative requirements are limited to problems involving the relationship

$$w = KE = \tfrac{1}{2}mv^2$$

Relativistic effects will not be considered.

Power is the time-rate of doing work. It is a scalar quantity.

Minimum quantitative requirements are limited to problems involving the relationships.

$$Power = \frac{work}{time} = \frac{w}{t} = \frac{Fs}{t} = Fv$$

The watt is the MKS unit of power. It is equal to one joule per second.

Topics	Understandings and Fundamental Concepts	
*V. Conservation of energy	In any transfer of energy among objects in a closed system, the total energy of the system remains constant.	*Minimum quanti problems invol*
	Under ideal conditions the gain of kinetic energy equals the loss in potential energy, or the loss of kinetic energy equals the gain in potential energy.	The change in change in kine energy plus th This law is so energy because The law of con whenever appro
A. Friction	Friction is a force opposing the relative motion of two objects in contact.	Work done agai kinetic or pot however, incre
	When an object moves against friction, work is done.	Energy used in into internal e internal energy
VI. Internal Energy and Heat	Internal energy is the total kinetic and potential energy associated with the motions and relative positions of the molecules of an object, apart from any kinetic or potential energy of the object as a whole.	An increase in increases the its molecules or increases t results in a c levels of atom
	When one object gains internal energy from another object, the energy in transit is heat.	
A. Mechanical equivalent of heat	Heat and mechanical energy are both forms of energy; therefore, they can be measured in the same units.	The kilocalori One kilocalori

Understandings and Fundamental Concepts	Supplementary Information
In any transfer of energy among objects in a closed system, the total energy of the system remains constant.	*Minimum quantitative requirements are limited to problems involving $\Delta PE = -\Delta KE$ under ideal conditions.*
Under ideal conditions the gain of kinetic energy equals the loss in potential energy, or the loss of kinetic energy equals the gain in potential energy.	The change in energy of a system is equal to the change in kinetic energy plus the change in potential energy plus the change in internal energy. This law is sometimes called the conservation of mass-energy because of the equivalence of mass and energy. The law of conservation of energy should be stressed whenever appropriate.
Friction is a force opposing the relative motion of two objects in contact.	Work done against friction does not increase the kinetic or potential energy of an object. It may, however, increase the internal energy of the object.
When an object moves against friction, work is done.	Energy used in doing work against friction is converted into internal energy. This may be used to introduce internal energy and heat.
Internal energy is the total kinetic and potential energy associated with the motions and relative positions of the molecules of an object, apart from any kinetic or potential energy of the object as a whole.	An increase in the internal energy of an object either increases the kinetic energy of the random motion of its molecules which results in a rise in temperature or increases their potential energy of position which results in a change of phase, or raises the energy levels of atoms.
When one object gains internal energy from another object, the energy in transit is heat.	
Heat and mechanical energy are both forms of energy; therefore, they can be measured in the same units.	The kilocalorie and the joule are both units of energy. One kilocalorie is equivalent to 4185 joules.

Topics	Understandings and Fundamental Concepts	
B. Temperature	Temperature is that property of matter which determines the direction of the exchange of internal energy between objects. The object at lower temperature will gain internal energy.	The tota temperat mass, na
1. Absolute temperature	Absolute temperature is directly proportional to the average kinetic energy of random motion of the molecules of an ideal gas.	An ideal elastic forces o
a. Absolute zero	An object is at absolute zero when its internal energy is a minimum.	By extra absolute of the m would ap absence to moder a substa At absol a minimu transfer In pract closely,
C. MKS temperature scales	Temperature measurements are commonly referred to arbitrarily selected fixed temperatures which are readily reproducible. The degree is a fundamental unit.	In 1954 Conferen of water thermome value of
1. Celsius	On the Celsius scale the freezing point of water is 0 degree and the boiling point is 100 degrees.	The expr avoided.
*2. Kelvin	On the Kelvin scale absolute zero is the zero point.	*Minimum conversi*

Understandings and Fundamental Concepts	Supplementary Information
Temperature is that property of matter which determines the direction of the exchange of internal energy between objects. The object at lower temperature will gain internal energy.	The total internal energy does not depend on temperature alone. It also depends on the object's mass, nature, and phase.
Absolute temperature is directly proportional to the average kinetic energy of random motion of the molecules of an ideal gas.	An ideal gas is one which consists of perfectly elastic particles of negligible size which exert no forces on each other, except during collisions.
An object is at absolute zero when its internal energy is a minimum.	By extrapolation of the relationship between the absolute temperature and the average kinetic energy of the molecules of an ideal gas, absolute zero would appear to represent zero kinetic energy, or the absence of all molecular motion. However, according to modern theory, at absolute zero the molecules of a substance have a minimum amount of energy. At absolute zero the internal energy of an object is a minimum; therefore, no internal energy can be transferred to another object. In practice, absolute zero may be approached very closely, but cannot be reached.
Temperature measurements are commonly referred to arbitrarily selected fixed temperatures which are readily reproducible. The degree is a fundamental unit.	In 1954 the size of the degree was set by the General Conference of Weights and Measures. The triple point of water, selected as the standard fixed point of thermometry, was defined as 273.16°K, or 0.01°C. The value of 273°K is satisfactory for class use.
On the Celsius scale the freezing point of water is 0 degree and the boiling point is 100 degrees.	The expression "centigrade temperature" should be avoided.
On the Kelvin scale absolute zero is the zero point.	*Minimum quantitative requirements will be limited to conversions between Kelvin and Celsius scales.*

Topics	Understandings and Fundamental Concepts
D. Exchange of internal energy	When there is an exchange of internal energy, and if there is no conversion to other forms of energy, the total internal energy of the system remains constant.
1. Kilocalorie	The kilocalorie is a unit of heat and is equal to the heat required to change the temperature of one kilogram of water one degree Celsius at 4°C.
*2. Specific heat	The specific heat of a substance is the ratio of the quantity of heat required to raise the temperature of a unit mass of the substance one degree Celsius to the quantity of heat required to cause the same change in temperature of the same mass of water.
3. Change of phase	During a change of phase there is a change in internal energy but no change in temperature.
*a. Heat of fusion	The heat of fusion is the number of kilocalories required to change one kilogram of a substance from the liquid phase at its melting point, with no change in temperature.

When there is an exchange of internal energy, and if there is no conversion to other forms of energy, the total internal energy of the system remains constant.

This is an application of conservation of energy to heat.

The kilocalorie is a unit of heat and is equal to the heat required to change the temperature of one kilogram of water one degree Celsius at 4°C.

This is an operational definition. If the temperature is not specified, it is approximate because the heat capacity of water is a function of temperature.

The specific heat of a substance is the ratio of the quantity of heat required to raise the temperature of a unit mass of the substance one degree Celsius to the quantity of heat required to cause the same change in temperature of the same mass of water.

Specific heats are numerically the same in all systems of units.

Minimum quantitative requirements are limited to applications of the relationship $\Delta Q = mc\Delta t$ and exchange problems involving two objects.

During a change of phase there is a change in internal energy but no change in temperature.

The term "phase" is used instead of "state" to avoid confusion with other conditions, such as state of equilibrium.

The energy absorbed or liberated in a change of phase does not change the average internal kinetic energy, and does not produce a change of temperature. It does, however, produce a change in molecular potential energy.

The heat of fusion is the number of kilocalories required to change one kilogram of a substance from the solid to the liquid phase at its melting point, with no change in temperature.

The same amount of energy is liberated when an equal mass of the substance freezes.

Minimum quantitative requirements are limited to applications of the relationship $Q = mH_f$

Topics	Understandings and Fundamental Concepts	
*b. Heat of vapor-ization	The heat of vaporization is the number of kilocalories required to change one kilogram of a substance from the liquid to the gaseous phase at the boiling point, with no change in temperature.	The same mass of t o vapori work is d *Minimum q applicati*
VII. Kinetic Theory of Gases	Gases are composed of molecules in constant random motion. In gases of low density, the average distance of separation of molecules is large in comparison with their diameters and the total actual volume of the gas molecules is negligible in comparison with the volume occupied by the gas. In gases of low density, the forces between molecules are considered to be negligible.	
A. Pressure	Pressure exerted by a gas is due to collisions of gas molecules with the walls of the container.	
B. Gas laws	The product of the pressure and volume of an ideal gas is directly proportional to the product of the number of molecules and the absolute temperature.	*Minimum r involving and tempe*

Understandings and Fundamental Concepts	Supplementary Information
The heat of vaporization is the number of kilocalories required to change one kilogram of a substance from the liquid to the gaseous phase at the boiling point, with no change in temperature.	The same amount of energy is liberated when an equal mass of the substance condenses. The heat of vaporization is a constant only when no external work is done. *Minimum quantitative requirements are limited to applications of the relationship* $Q = mH_v$
Gases are composed of molecules in constant random motion. In gases of low density, the average distance of separation of molecules is large in comparison with their diameters and the total actual volume of the gas molecules is negligible in comparison with the volume occupied by the gas.	
In gases of low density, the forces between molecules are considered to be negligible.	
Pressure exerted by a gas is due to collisions of gas molecules with the walls of the container.	
The product of the pressure and volume of an ideal gas is directly proportional to the product of the number of molecules and the absolute temperature.	*Minimum requirements are limited to simple proportions involving the relationships among pressure, volume, and temperature for a fixed mass of gas.*

Topics	Understandings and Fundamental Concepts	
I. Introduction to Waves	A wave is a vibratory disturbance that is propagated from a source.	Wave phe an under study of
		A distin space. distinct the dist medium f waves, o the mate do not m
		For some example, are peri
		Wave beh easily a behavior
		Many of reflecti can be s using a quantita velocity
		Compact most sup microwav
A. Transfer of energy	Wave motion transfers energy from one point to another with no transfer of mass between the points.	Transfer particle
B. Pulses and periodic waves	A wave may be classified as a pulse or a periodic wave.	Wave con pulses a these co other fo

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WAVE PHENOMENA

Understandings and Fundamental Concepts	Supplementary Information
A wave is a vibratory disturbance that is propagated from a source.	Wave phenomena may be introduced by pointing out that an understanding of wave phenomena is needed for the study of sound and light. A distinction is made between a material medium and space. The word "material" is used to emphasize the distinction between a medium and space. For example, the disturbance in a wave may be a displacement of the medium from its rest position as in water waves, sound waves, or waves in a rope or spring. The particles of the material medium vibrate around rest positions, but do not move along with the wave as does the energy. For some waves no material medium is necessary. For example, light, radio, and other electromagnetic waves, are periodic disturbances in electromagnetic fields. Wave behavior in a material medium can be studied most easily and used to establish typical patterns of wave behavior. Many of the phenomena of periodic waves, such as reflection, refraction, diffraction and interference, can be studied both qualitatively and quantitatively using a ripple tank. With the aid of a stroboscope quantitative measurements of frequency, wavelength, and velocity can be made. Compact and convenient apparatus is now available from most suppliers to demonstrate wave characteristics using microwaves.
Wave motion transfers energy from one point to another with no transfer of mass between the points.	Transfer of mass does not refer to the vibration of particles around rest positions.
A wave may be classified as a pulse or a periodic wave.	Wave concepts are introduced by a consideration of pulses and periodic waves in a material medium. Later these concepts are used in the study of light and other forms of electromagnetic radiation.

Topics	Understandings and Fundamental Concepts	Supplementar
1. Pulses in a material medium	A pulse is a single vibratory disturbance which moves from point to point.	A pulse through a material mediur oscillation of the particles arou Use a coiled spring or a rubber t characteristics. Superposition m this point.
a. Speed	In a uniform material medium, a pulse has a constant speed.	The speed of a pulse depends upon properties of the medium, and, tc on the nature of the pulse.
b. Reflection and transmission	When a pulse reaches a boundary with a different medium, part of the pulse will be reflected at the boundary and part will be transmitted through the second medium.	In some cases, practically all of reflected; for example, by a pane ripple tank.
2. Periodic waves	A periodic wave is a series of regular disturbances.	*Development is limited to simple*
C. Types of wave motion	Two simple types of wave motion are longitudinal and transverse.	
1. Longitudinal waves	In longitudinal waves the disturbance is parallel to the direction of travel of the wave.	Longitudinal waves are sometimes waves. Sound waves and compress spring are examples of longitudi
2. Transverse waves	In transverse waves the disturbance is at right angles to the direction of travel of the wave.	Electromagnetic waves and waves of transverse waves. The distur plane perpendicular to the direc
a. Polarization	A transverse wave is polarized when the disturbance is in a single plane. Longitudinal waves cannot be polarized.	

Understandings and Fundamental Concepts	Supplementary Information
A pulse is a single vibratory disturbance which moves from point to point.	A pulse through a material medium causes an oscillation of the particles around a rest position. Use a coiled spring or a rubber tube to show these characteristics. Superposition may be introduced at this point.
In a uniform material medium, a pulse has a constant speed.	The speed of a pulse depends upon the nature and properties of the medium, and, to a lesser degree on the nature of the pulse.
When a pulse reaches a boundary with a different medium, part of the pulse will be reflected at the boundary and part will be transmitted through the second medium.	In some cases, practically all of the pulse will be reflected; for example, by a pane of glass in a ripple tank.
A periodic wave is a series of regular disturbances.	*Development is limited to simple sinusoidal waves.*
Two simple types of wave motion are longitudinal and transverse.	
In longitudinal waves the disturbance is parallel to the direction of travel of the wave.	Longitudinal waves are sometimes called compressional waves. Sound waves and compressional waves in a spring are examples of longitudinal waves.
In transverse waves the disturbance is at right angles to the direction of travel of the wave.	Electromagnetic waves and waves in a rope are examples of transverse waves. The disturbance may be in any plane perpendicular to the direction of the wave motion.
A transverse wave is polarized when the disturbance is in a single plane.	
Longitudinal waves cannot be polarized.	

Topics	Understandings and Fundamental Concepts	
3. Other types of waves	Other types of waves are possible.	Large oce transvers Waves of transmitt
II. Common Characteristics of Periodic Waves		
A. Frequency	Frequency is the number of cycles occurring per unit time.	A cycle, changes c the mediu repeating *The "cycl* HERTZ, *wi* *acceptanc* Note that dimension
*B. Period	The period is the time required for the completion of a cycle. It is the reciprocal of the frequency.	*Minimum q* *applicati*
C. Amplitude	The amplitude of the wave is the maximum displacement of a particle of the medium from the rest position	In the li is genera such as c of air, o
D. Phase	Points on a periodic wave having the same displacement from their equilibrium position and moving in the same direction are said to be in phase.	This defi sinusoida
E. Wavelength	The wavelength is the distance between two consecutive points in phase.	Wavelengt peak-to-p zeros.

ics	Understandings and Fundamental Concepts	Supplementary Information
types ves	Other types of waves are possible.	Large ocean waves include both longitudinal and transverse vibrations and are called elliptical waves. Waves of "twist", called torsional waves, may be transmitted by a thin metal rod.
acter- eriodic		
y	Frequency is the number of cycles occurring per unit time.	A cycle, as applied to a wave, consists of series of changes occurring in orderly sequence be means of which the medium returns to its initial condition prior to repeating the series. *The "cycle per second" has recently been given the name* HERTZ, *with the symbol Hz . The term is gaining acceptance but is not required.* Note that the cycle is dimensionless; hence, the dimension of frequency is t^{-1} (sec^{-1}).
	The period is the time required for the completion of a cycle. It is the reciprocal of the frequency.	*Minimum quantitative requirements are limited to application of the relationship* $T = \frac{1}{f}$.
e	The amplitude of the wave is the maximum displacement of a particle of the medium from the rest position	In the literature of wave motion the word displacement is generalized to include any physical disturbance, such as changes in a transverse electric field, density of air, or density of an electron cloud.
	Points on a periodic wave having the same displacement from their equilibrium position and moving in the same direction are said to be in phase.	This definition of phase is limited to simple sinusoidal waves of constant amplitude.
h	The wavelength is the distance between two consecutive points in phase.	Wavelength may be measured in a material medium from peak-to-peak, trough-to-trough, or between alternate zeros.

Topics	Understandings and Fundamental Concepts	Supp
*F. Speed	The speed of a wave is equal to the product of the frequency and the wavelength.	*Minimum quantitative requi applications of the relati*
1. Effect of medium	The speed of a wave depends on the properties of the medium.	When a wave passing from o experiences a change in sp wave does not change. The is determined by the frequ
2. Dispersive medium	A dispersive medium is one in which the speed of a wave depends on its frequency.	Discussion of this relatio refraction of waves is stu Glass is a dispersive medi Dispersion may be observed
3. Non-dispersive medium	A nondispersive medium is one in which the speed does not depend on the frequency.	Air and water are nondispe of low amplitude.
G. Doppler effect	The Doppler effect is the variation in an observed frequency when there is relative motion between source and receiver.	No medium is involved in t magnetic waves.
1. Sound	There is an increase in observed pitch when the distance between source and receiver is decreasing. There is a decrease in observed pitch when the distance between source and receiver is increasing.	If the distance between th is changing at a constant is constant, though higher Application of the Doppler waves will be studied late
H. Wave propagation		
1. Wave fronts	A wave front is the locus of adjacent points of the wave which are in phase.	

tandings and Fundamental Concepts	Supplementary Information
speed of a wave is equal to the luct of the frequency and the elength.	*Minimum quantitative requirements are limited to applications of the relationship $v = f \lambda$.*
speed of a wave depends on the perties of the medium.	When a wave passing from one medium to another experiences a change in speed, the frequency of the wave does not change. The wavelength in the new medium is determined by the frequency and the new speed.
ispersive medium is one in which speed of a wave depends on its quency.	Discussion of this relationship may be left until the refraction of waves is studied. Glass is a dispersive medium for light. Dispersion may be observed in a ripple tank.
ondispersive medium is one in ch the speed does not depend on frequency.	Air and water are nondispersive media for sound waves of low amplitude.
Doppler effect is the variation an observed frequency when there is ative motion between source and ceiver.	No medium is involved in the transmission of electromagnetic waves.
ere is an increase in observed ch when the distance between source d receiver is decreasing.	If the distance between the source and the receiver is changing at a constant rate, the observed pitch is constant, though higher than the transmitted pitch.
ere is a decrease in observed tch when the distance between urce and receiver is increasing.	Application of the Doppler effect to electromagnetic waves will be studied later.
wave front is the locus of adjacent ints of the wave which are in ase.	

Topics	Understandings and Fundamental Concepts	
2. Huygens' principle	Every point on a waye front may be considered a source of wavelets with the same speed.	This provid the known sl later time. This may be
III. Periodic Wave Phenomena		
A. Reflection	Periodic waves can be reflected from the boundaries of a medium. The incident ray, the reflected ray, and the normal to the surface are all in the same plane. When a wave is reflected from a surface, the angle of incidence is equal to the angle of reflection.	
B. Refraction	Refraction is the change in the direction of a wave that occurs when the wave passes obliquely through a boundary with a change in its speed.	
[*] 1. Snell's law	The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant called the relative index of refraction. The incident ray, the refracted ray, and the normal to the boundary are all in the same plane.	*Minimum quar* *applications* *A very usef* *is n_1 sin θ* A medium of sometimes s Snell's law light is stu Quantitativ ripple tank

Understandings and Fundamental Concepts	Supplementary Information
Every point on a wave front may be considered a source of wavelets with the same speed.	This provides a geometrical method for finding, from the known shape of a wave front, the shape at some later time. This may be introduced when diffraction is studied.
Periodic waves can be reflected from the boundaries of a medium.	
The incident ray, the reflected ray, and the normal to the surface are all in the same plane.	
When a wave is reflected from a surface, the angle of incidence is equal to the angle of reflection.	
Refraction is the change in the direction of a wave that occurs when the wave passes obliquely through a boundary with a change in its speed.	
The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant called the relative index of refraction.	*Minimum quantitative requirements are limited to applications of the relationship* $\frac{\sin \theta_1}{\sin \theta_2} = \frac{n_2}{n_1} = K$. *A very useful form of Snell's law for problem solving is* $n_1 \sin \theta_1 = n_2 \sin \theta_2$.
The incident ray, the refracted ray, and the normal to the boundary are all in the same plane.	A medium of relatively higher index of refraction is sometimes said to have a greater optical density. Snell's law may be developed when refraction of light is studied. Quantitative work with refraction is difficult in a ripple tank.

Topics	Understandings and Fundamental Concepts	Supplemen
2. Speed and refraction	When a wave enters a new medium and there is a decrease in speed, the wave bends toward the normal.	Since the frequency of the source, the change in veloc a change in the wave-length
	When a wave enters a new medium and there is an increase in speed, the wave bends away from the normal.	From the geometry of the re wave fronts, teachers may $\frac{\sin\theta_1}{\sin\theta_2} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$
C. Diffraction	Diffraction is the spreading of a wave into the region behind an obstruction.	This concept may be explai principle.
D. Interference	Interference is the effect produced by two or more waves which are passing simultaneously through a region.	
1. Superposition	The resultant disturbance is the algebraic sum of the disturbances due to the individual waves.	If the component disturban the resultant disturbance
a. Constructive interference	Maximum constructive interference occurs at points where the two waves are in phase.	
b. Destructive interference	Maximum destructive interference occurs at points where the phase difference is 180°.	Destructive interference i difference between the wav are the same.
2. Two sources in phase	Two wave sources operating in phase in the same medium produce wave trains that will form symmetrical interference patterns where they cross each other.	Where two crests or two tr or trough of increased amp interference). Where a tr a point of minimum disturb interference). Nodal line interference and represent the path difference to the
	Destructive interference occurs at points where the path distances to the two sources differ by an odd number of half wavelengths.	

Understandings and Fundamental Concepts	Supplementary Information
When a wave enters a new medium and there is a decrease in speed, the wave bends toward the normal.	Since the frequency of the wave depends only on the source, the change in velocity of the wave results in a change in the wave-length.
When a wave enters a new medium and there is an increase in speed, the wave bends away from the normal.	From the geometry of the refraction of two successive wave fronts, teachers may wish to show that $\frac{\sin\theta_1}{\sin\theta_2} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$
Diffraction is the spreading of a wave into the region behind an obstruction.	This concept may be explained in terms of Huygens' principle.
Interference is the effect produced by two or more waves which are passing simultaneously through a region.	
The resultant disturbance is the algebraic sum of the disturbances due to the individual waves.	If the component disturbances are vector quantities, the resultant disturbance is a vector sum.
Maximum constructive interference occurs at points where the two waves are in phase.	
Maximum destructive interference occurs at points where the phase difference is 180°.	Destructive interference is complete when the phase difference between the waves is 180° and their amplitudes are the same.
Two wave sources operating in phase in the same medium produce wave trains that will form symmetrical interference patterns where they cross each other.	Where two crests or two troughs come together, a crest or trough of increased amplitude is formed (constructive interference). Where a trough and a crest come together a point of minimum disturbance results (destructive interference). Nodal lines result from destructive interference and represent the loci of points where the path difference to the source is $(n - \frac{1}{2})\lambda$.
Destructive interference occurs at points where the path distances to the two sources differ by an odd number of half wavelengths.	

Topics	Understandings and Fundamental Concepts	
3. Standing waves	Standing waves are produced when two waves of the same frequency and amplitude travel in opposite directions in the same medium.	Standin with th string
a. Reflection	Standing waves are most commonly produced by the reflection of a wave train at the fixed boundary of the medium.	When th occurs reflect generat *Quantit* Stress lengths
IV. Light	Light is an electromagnetic disturbance that can produce the sensation of sight.	
*A. Speed	The speed of light is equal to the product of the frequency and wavelength.	Various may be *Minimum applica*
1. In space	The speed of light in space is an important physical constant.	An appr speed o
2. In a material medium	The speed of light in a material medium is dependent on the frequency and the medium.	The spe its spe
	The speed of light in a medium is always less than its speed in a vacuum.	
B. Reflection	Light may be reflected.	The def here.

Understandings and Fundamental Concepts	Supplementary Information
Standing waves are produced when two waves of the same frequency and amplitude travel in opposite directions in the same medium.	Standing waves in a stretched string may be shown with the aid of a sonometer. Paper riders on the string will show the location of nodes and antinodes.
Standing waves are most commonly produced by the reflection of a wave train at the fixed boundary of the medium.	When the medium is limited such that reflection occurs at both ends, and the distance between the reflecting surfaces is $\frac{n\lambda}{2}$, standing waves are generated. *Quantitative treatment is not required.* Stress that in any specific case, only specific wavelengths are permitted.
Light is an electromagnetic disturbance that can produce the sensation of sight.	
The speed of light is equal to the product of the frequency and wavelength.	Various methods used for measuring the speed of light may be discussed. *Minimum quantitative requirements are limited to application of the relationship, $c = f\lambda$.*
The speed of light in space is an important physical constant.	An appreciation of the magnitude and importance of the speed of light should be developed.
The speed of light in a material medium is dependent on the frequency and the medium.	The speed of light in air is approximately the same as its speed in vacuum.
The speed of light in a medium is always less than its speed in a vacuum.	
Light may be reflected.	The definition and method of using rays are appropriate here.

Topics	Understandings and Fundamental Concepts	
1. Law of reflection	The incident ray, the reflected ray, and the normal to the surface at the point of incidence are in the same plane. The angle of reflection is equal to the angle of incidence.	
2. Regular reflection	Regular reflection is reflection produced by polished surfaces, usually producing an image of the source. The image formed by a plane reflecting surface is virtual, erect, and the same size as the object; object and image distances are equal.	The law of reflection in the construction o
3. Diffuse reflection	Diffuse reflection is the scattering of light caused by reflection from irregular surfaces.	The law of reflection since the surface is surface are not paral scattered.
C. Refraction	Light crossing a boundary obliquely is refracted if its speed changes.	The relationship betw refracted ray is desc The reversibility of
* 1. Index of refraction	The index of refraction of a medium is the ratio of the speed of light in a vacuum to its speed in the material medium.	The speed of light in speed in free space. refraction of air car *Minimum quantitative* *applications of Snell* *the relationship, v =*

Understandings and Fundamental Concepts	Supplementary Information
The incident ray, the reflected ray, and the normal to the surface at the point of incidence are in the same plane.	
The angle of reflection is equal to the angle of incidence.	
Regular reflection is reflection produced by polished surfaces, usually producing an image of the source.	The law of reflection and ray diagrams should be used in the construction of plane mirror images.
The image formed by a plane reflecting surface is virtual, erect, and the same size as the object; object and image distances are equal.	
Diffuse reflection is the scattering of light caused by reflection from irregular surfaces.	The law of reflection holds for each light ray, but since the surface is irregular, the normals to the surface are not parallel and the reflected light is scattered.
Light crossing a boundary obliquely is refracted if its speed changes.	The relationship between the incident ray and the refracted ray is described by Snell's law.
	The reversibility of light rays should be stressed.
The index of refraction of a medium is the ratio of the speed of light in a vacuum to its speed in the material medium.	The speed of light in air is nearly equal to its speed in free space. For most purposes the index of refraction of air can be taken as unity.

Minimum quantitative requirements are limited to applications of Snell's law, $\frac{\sin \theta_1}{\sin \theta_2} = \frac{n_2}{n_1} = \frac{v_1}{v_2}$ *and the relationship,* $v = \frac{c}{n}$.

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Topics	Understandings and Fundamental Concepts	
☒ 2. Critical angle	The critical angle is the angle of incidence for which the angle of refraction is 90°.	This can greater velocity
		Minimum applicat
3. Total internal reflection	Total internal reflection occurs when light is incident on a surface at an angle greater than the critical angle..	
4. Dispersion	Dispersion is the separation of polychromatic light into its component wavelengths as the light enters a dispersive medium obliquely.	Differen as diffe
	Polychromatic light contains waves of different frequencies.	
	In a material medium each frequency has its own index of refraction; therefore, polychromatic light may be dispersed.	
D. Lenses		*Requirem*
1. Converging lenses	A converging lens is one that is thicker at the middle than at the edges and converges parallel rays of light.	This is is great
a. Images	Converging lenses can form both real and virtual images.	The char by drawi
	A real image is formed when two or more rays leaving one object point meet at a corresponding image point.	Real ima

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The critical angle is the angle of incidence for which the angle of refraction is 90°.

This can occur only when the angle of refraction is greater than the angle of incidence; that is, when the velocity of the light increases.

Minimum quantitative requirements are limited to applications of the relationship $\sin \theta_c = \frac{1}{n}$.

Total internal reflection occurs when light is incident on a surface at an angle greater than the critical angle.

Dispersion is the separation of polychromatic light into its component wavelengths as the light enters a dispersive medium obliquely.

Differences in frequency of light waves affect the eye as differences in color.

Polychromatic light contains waves of different frequencies.

In a material medium each frequency has its own index of refraction; therefore, polychromatic light may be dispersed.

Requirements are limited to thin lenses in air.

A converging lens is one that is thicker at the middle than at the edges and converges parallel rays of light.

This is true if the index of refraction of the lens is greater than that of the surrounding medium.

Converging lenses can form both real and virtual images.

The characteristics of the image should be obtained by drawing ray diagrams.

A real image is formed when two or more rays leaving one object point meet at a corresponding image point.

Real images may be projected on a screen.

Topics	Understandings and Fundamental Concepts	Suppl
	A virtual image is subjective in that it appears to form where an image could not possibly exist because rays do not actually intersect at the image point.	Virtual image cannot be f When a bundle of rays whic source passes through an o incident on the eye as a d then focused on the retina the rays as coming from th cone. The virtual image e observer's eye.
* b. Size and distance of images	The size and location of the image can be calculated from the focal length of the lens and the position and size of the object.	*Minimum quantitative requi use of ray diagrams and to relationships,* $\frac{1}{do} + \frac{1}{di}$ The sign conventions speci left of the lens, and the of the lens as positive. focal length is positive.
2. Diverging lenses	A diverging lens is one that is thinner at the middle than at the edge and diverges parallel rays of light. A diverging lens can produce only a virtual image.	Only ray diagrams are requ
E. Wave nature of light	Much of the behavior of light can be interpreted in terms of wave phenomena.	
1. Interference of light	Interference phenomena can be produced only by waves. Interference patterns may be produced by light. Therefore, light has wave properties.	The Cornell slit-film may interference phenomena.
a. Coherent sources	Sources that produce waves with a constant phase relation are said to be coherent.	Lasers produce coherent li

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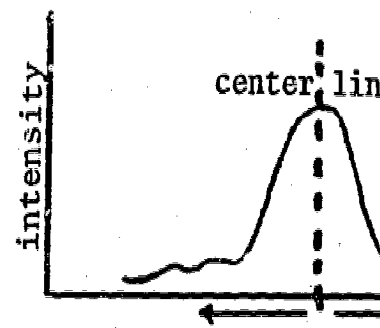
Understandings and Fundamental Concepts	Supplementary Information
A virtual image is subjective in that it appears to form where an image could not possibly exist because rays do not actually intersect at the image point.	Virtual images cannot be formed on a screen. When a bundle of rays which originated at a point source passes through an optical system and is incident on the eye as a diverging cone of rays and then focused on the retina, the observer interprets the rays as coming from the vertex of the diverging cone. The virtual image exists by virtue of the observer's eye.
The size and location of the image can be calculated from the focal length of the lens and the position and size of the object.	*Minimum quantitative requirements are limited to the use of ray diagrams and to applications of the relationships,* $\frac{1}{do} + \frac{1}{di} = \frac{1}{f}$ *and* $\frac{So}{Si} = \frac{do}{di}$. The sign conventions specify the object position on the left of the lens, and the image position on the right of the lens as positive. For converging lenses the focal length is positive.
A diverging lens is one that is thinner at the middle than at the edge and diverges parallel rays of light.	Only ray diagrams are required for diverging lenses.
A diverging lens can produce only a virtual image.	
Much of the behavior of light can be interpreted in terms of wave phenomena.	
Interference phenomena can be produced only by waves.	The Cornell slit-film may be used to observe various interference phenomena.
Interference patterns may be produced by light. Therefore, light has wave properties.	
Sources that produce waves with a constant phase relation are said to be coherent.	Lasers produce coherent light.

Topics	Understandings and Fundamental Concepts	Sup
[*] b. Double slit	Light from two coherent point sources produces a stationary interference pattern.	Young produced two co from a single source crucial experiment le wave theory of light. *Minimum quantitative* *applications of the r* Diffraction gratings presented at this tim
c. Single slit	Light from a point or line source is diffracted and produces interference patterns when passing through a single narrow slit. The width of the central maximum varies directly as the wavelength and inversely as the width of the slit.	 Diffraction pattern f *Minimum requirements* *diffraction pattern a* *among wavelength, sli* *pattern.*
d. Resolution	When light passes through an opening of limited size it is diffracted. If two sources are close, their diffraction patterns may overlap. The resolution of an optical instrument is a measure of its ability to separate images of objects that are close together. The resolution varies directly as the diameter of the opening.	 This places a theoret possible with an opti

Light from two coherent point sources produces a stationary interference pattern.

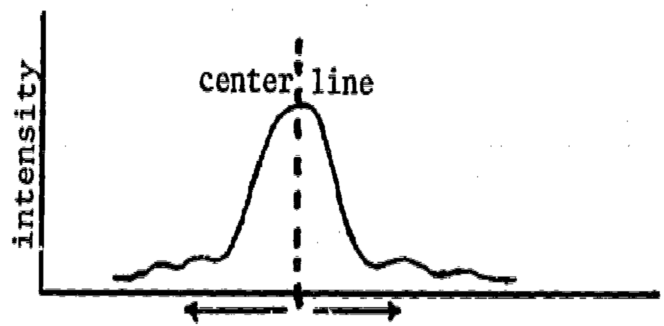
Young produced two coherent sources by passing light from a single source through a double slit. This crucial experiment led to the general acceptance of the wave theory of light.

Minimum quantitative requirements are limited to applications of the relationship $n\lambda = d\frac{x}{L}$*, where* $n = 1$.

Diffraction gratings and the spectroscope may be presented at this time.

Light from a point or line source is diffracted and produces interference patterns when passing through a single narrow slit.

The width of the central maximum varies directly as the wavelength and inversely as the width of the slit.



Diffraction pattern for monochromatic light.

Minimum requirements are limited to recognition of the diffraction pattern and qualitative relationships among wavelength, slit width, and the diffraction pattern.

When light passes through an opening of limited size it is diffracted. If two sources are close, their diffraction patterns may overlap.

The resolution of an optical instrument is a measure of its ability to separate images of objects that are close together.

This places a theoretical limitation on the magnification possible with an optical instrument.

The resolution varies directly as the diameter of the opening.

Topics	Understandings and Fundamental Concepts	
e. Thin films	Interference effects, produced by thin films, are caused by a difference in the optical paths of light reflected from the two surfaces of the film.	*Minimum requ identical ph the film, fo light.*
	Maximum constructive interference occurs when the path difference is an even number of half wavelengths.	If change of should be in studied.
2. Transverse nature of light	The polarization of light waves is evidence of their transverse nature.	
F. Electromagnetic radiation	Electromagnetic radiations are transverse wave disturbances that are propagated through space with the speed of light.	The developme electric and
	Electromagnetic radiations are generated by accelerating charged particles.	
1. Electromagnetic spectrum	The electromagnetic spectrum includes radio waves, infrared, visible light, ultraviolet, x-rays, and gamma rays.	The division ranges of fre derived from frequency ra
	The different effects on receivers are due to differences in frequency.	As the freque radiation bec
	Light is a small portion of the electromagnetic spectrum.	
		Minimum requ standings of and propertie

Understandings and Fundamental Concepts	Supplementary Information
Interference effects, produced by thin films, are caused by a difference in the optical paths of light reflected from the two surfaces of the film.	*Minimum requirements are limited to films in which identical phase shifts occur at both surfaces of the film, for normal incidence and monochromatic light.*
Maximum constructive interference occurs when the path difference is an even number of half wavelengths.	If change of phase on reflection is considered, it should be introduced when pulse reflection is studied.
The polarization of light waves is evidence of their transverse nature.	
Electromagnetic radiations are transverse wave disturbances that are propagated through space with the speed of light.	The development of this concept may be delayed until electric and magnetic fields have been studied.
Electromagnetic radiations are generated by accelerating charged particles.	
The electromagnetic spectrum includes radio waves, infrared, visible light, ultraviolet, x-rays, and gamma rays.	The divisions are not well defined, but rather represent ranges of frequency which overlap. The names were derived from the types of sources as well as from the frequency ranges.
The different effects on receivers are due to differences in frequency.	As the frequency increases, the wave nature of the radiation becomes less apparent.
Light is a small portion of the electromagnetic spectrum.	*Minimum requirements are limited to qualitative understandings of the relative frequencies, wavelengths, and properties of the various portions of the spectrum.*

Topics	Understandings and Fundamental Concepts	
2. Sources of electro-magnetic radiation	Electromagnetic radiation may be produced by various sources.	
a. Con-tinuous spectra	Continuous spectra are produced by incandescent solids and liquids and by incandescent gases under extremely high pressure.	
b. Line spectra	Line spectra are produced by luminous gases and vapors at low pressures. Line spectra originate in the atoms of the chemical elements.	Other types of closely produced. molecular
3. Doppler effect	Electromagnetic radiations exhibit the Doppler effect.	Since the s the observe $f\lambda = c$.
	If the distance between the source and the receiver is decreasing, there is an increase in the observed frequency.	Some types
	If the distance between the source and the receiver is increasing, there is a decrease in the observed frequency.	The radial spectral sh
		The speed o the Doppler it transmit
		When radar frequency o object is a
		The random results in due to a Do

	Understandings and Fundamental Concepts	Supplementary Information
of -c on	Electromagnetic radiation may be produced by various sources.	
ous tra	Continuous spectra are produced by incandescent solids and liquids and by incandescent gases under extremely high pressure.	
tra	Line spectra are produced by luminous gases and vapors at low pressures. Line spectra originate in the atoms of the chemical elements.	Other types of spectra, called band spectra, consisting of closely spaced spectral lines, are sometimes produced. They have their origin in molecules or molecular ions.
	Electromagnetic radiations exhibit the Doppler effect.	Since the speed is constant in space, the changes in the observed frequency and wavelength are such that $f\lambda = c$.
	If the distance between the source and the receiver is decreasing, there is an increase in the observed frequency.	Some types of radar depend on the Doppler effect.
	If the distance between the source and the receiver is increasing, there is a decrease in the observed frequency.	The radial velocity of stars may be found by their spectral shift. The speed of an earth satellite may be determined from the Doppler shift in the frequency of the radio waves it transmits. When radar waves are reflected from a moving object, the frequency of the reflected wave is increased if the object is approaching the receiver. The random motion of molecules in a gas discharge tube results in a spreading of each observed spectral line due to a Doppler shift.

Topics	Understandings and Fundamental Concepts	
I. Static Electricity	Static electricity deals with electrical charges at rest.	The term ' charge in be implied motion.
A. Micro-structure of matter	The basic unit of molecular structure is the atom.	Since this 7-8-9 and atomic str
	Three of the units of which atoms are composed are electrons, protons, and neutrons.	
	Electrons are negatively charged, protons are positively charged, and neutrons are neutral.	
	The protons and neutrons are found in the nucleus of the atom.	
	The electrons are found outside the nucleus.	
	Neutral atoms have equal numbers of electrons and protons.	
	Protons are not readily removed from the nuclei of atoms.	Protons in forces. P explain wh ferred in The electr proton the are equal

Understandings and Fundamental Concepts	Supplementary Information
Static electricity deals with electrical charges at rest.	The term 'at rest' indicates that the net flow of charge in any given direction is zero. It should not be implied that the charges themselves are not in motion.
The basic unit of molecular structure is the atom.	Since this material is usually covered in science 7-8-9 and in chemistry, only a brief review of atomic structure should be necessary at this point.
Three of the units of which atoms are composed are electrons, protons, and neutrons.	
Electrons are negatively charged, protons are positively charged, and neutrons are neutral.	
The protons and neutrons are found in the nucleus of the atom.	
The electrons are found outside the nucleus.	
Neutral atoms have equal numbers of electrons and protons.	
Protons are not readily removed from the nuclei of atoms.	Protons in the nucleus are held together by nuclear forces. Protons are relatively massive. These facts explain why electrons rather than protons are transferred in a charging process. The electron has the smallest negative charge, and the proton the smallest positive charge. These charges are equal in magnitude and opposite in sign.

Topics	Understandings and Fundamental Concepts	
B. Charged objects	An object which has a deficiency of electrons is charged positively; one which has an excess of electrons is charged negatively; and one with an equal number of electrons and protons is neutral.	In genera of electr
		Use the e of an ele
	Unlike charges attract and like charges repel.	
C. Transfer of charges	Charges may be transferred from one object to another.	
1. Conservation of charge	The net charge in a closed system is constant.	This fund
		It may be Pair prod charge.
2. Separation of charge by contact	When different neutral objects are brought together, electrons may be transferred from one to the other.	This is us contact.
3. Conduction	A neutral object may become charged by contact with a charged object.	
	An object charged by conduction acquires the same kind of charge as the charging object.	
4. Induction	Induction is a process by which a charged object causes a redistribution of the charges of another object without contact.	A neutral because o object.
	An object may be charged by induction by temporarily grounding it while it is near to, but not touching, a charged object. It acquires a charge opposite to that of the charging object.	

Understandings and Fundamental Concepts	Supplementary Information
An object which has a deficiency of electrons is charged positively; one which has an excess of electrons is charged negatively; and one with an equal number of electrons and protons is neutral.	In general, matter becomes charged through a transfer of electrons. Use the electroscope to show the presence and nature of an electric charge.
Unlike charges attract and like charges repel.	
Charges may be transferred from one object to another.	
The net charge in a closed system is constant.	This fundamental law should be stressed. It may be pointed out that this law applies universally. Pair production is an example of conservation of charge.
When different neutral objects are brought together, electrons may be transferred from one to the other.	This is usually accomplished by rubbing to increase contact.
A neutral object may become charged by contact with a charged object.	
An object charged by conduction acquires the same kind of charge as the charging object.	
Induction is a process by which a charged object causes a redistribution of the charges of another object without contact.	A neutral object is attracted by a charged object because of a redistribution of charge on the neutral object.
An object may be charged by induction by temporarily grounding it while it is near to, but not touching, a charged object. It acquires a charge opposite to that of the charging object.	

Topics	Understandings and Fundamental Concepts	
D. Elementary charges	Any charge is made up of integral multiples of a minimum charge called the elementary charge.	Evidence for the gr of charge will be s an electric field b
	The charge of the electron is one negative elementary charge.	
	The charge of a proton is one positive elementary charge.	
E. Quantity of charge	The quantity of charge a body possesses depends on its excess or deficiency of electrons.	
	The unit of charge in the MKS system is the coulomb.	The coulomb is def will be considered
		One coulomb repres 6.25×10^{18} electr
		has a magnitude of *constants need not of their magnitude*
F. Coulomb's law	The force between fixed point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.	*Minimum quantitati application of the $F \propto \frac{q_1 q_2}{r^2}$, or $F =$ mately 9×10^9 ne me..rized.*
	When a charged object is brought near another charged object, a force acts on each object.	Charged objects ma when they are smal them.

Understandings and Fundamental Concepts	Supplementary Information
Any charge is made up of integral multiples of a minimum charge called the elementary charge.	Evidence for the granular nature of charge will be studied after the concept of an electric field has been introduced.
The charge of the electron is one negative elementary charge.	
The charge of a proton is one positive elementary charge.	
The quantity of charge a body possesses depends on its excess or deficiency of electrons.	
The unit of charge in the MKS system is the coulomb.	The coulomb is defined in terms of the ampere which will be considered in a later section.
	One coulomb represents an excess or deficiency of 6.25×10^{18} electrons. The elementary charge, e, has a magnitude of 1.6×10^{-19} coulomb. *These constants need not be memorized, but an appreciation of their magnitude should be developed.*
The force between fixed point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.	*Minimum quantitative requirements are limited to application of the relationship:* $F \propto \frac{q_1 q_2}{r^2}$, *or* $F = k\frac{q_1 q_2}{r^2}$. *The value of k, approximately* $9 \times 10^9 \frac{\text{newton - meter}^2}{\text{coulomb}^2}$, *need not be memorized.*
When a charged object is brought near another charged object, a force acts on each object.	Charged objects may be considered to be point charges when they are small compared to the distance between them.

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Topics	Understandings and Fundamental Concepts	Suppl
[*] G. Electric fields	An electric field is said to exist in any region of space in which an electric force acts on a charge.	*Minimum quantitative* *applications of the r*
	An electric field exists around every charged object. The electric field intensity is a vector quantity.	Similarity between el charge or a uniformly gravitational field a
	The magnitude at a point, is equal to the electric force per unit charge, The direction of the field is the direction of the force on a positive charge.	From the relation E = exerted on a charge i product of the charge the MKS system the un comparison, the gravi $(g = \frac{F}{m})$ can be expres
		For any charged condu to its surface.
1. Field around a point charge	The field around a point charge is radial.	The field around a un to that of a point ch
	The intensity of the field varies inversely with the square of the distance from the point charge.	This inverse square l experimentally to a h
	The field around a charged conducting sphere acts as though all the charge were concentrated at the center. The field within a charged conducting sphere is zero.	
2. Field around a uniformly charged rod	The field around a uniformly charged rod is radially directed and its intensity varies inversely with the distance from the rod.	It should be pointed not follow the invers

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An electric field is said to exist in any region of space in which an electric force acts on a charge.

Minimum quantitative requirements are limited to applications of the relationship $E = \frac{F}{q}$.

An electric field exists around every charged object. The electric field intensity is a vector quantity.

Similarity between electric field around a point charge or a uniformly charged spherical body and the gravitational field around a sphere may be pointed out.

The magnitude at a point, is equal to the electric force per unit charge. The direction of the field is the direction of the force on a positive charge.

From the relation $E = \frac{F}{q}$, it follows that the force exerted on a charge in an electric field is the product of the charge and the field intensity. In the MKS system the unit for E is in nt/coul. In comparison, the gravitational field strength ($g = \frac{F}{m}$) can be expressed as newton/kilogram.

For any charged conductor, the field lines are normal to its surface.

The field around a point charge is radial.

The field around a uniformly charged sphere is similar to that of a point charge.

The intensity of the field varies inversely with the square of the distance from the point charge.

This inverse square law relationship has been verified experimentally to a high degree of accuracy.

The field around a charged conducting sphere acts as though all the charge were concentrated at the center. The field within a charged conducting sphere is zero.

The field around a uniformly charged rod is radially directed and its intensity varies inversely with the distance from the rod.

It should be pointed out that this relationship does not follow the inverse square law.

Topics	Understandings and Fundamental Concepts	
3. Field between two parallel charged plates	The field between two parallel charged plates is essentially uniform if the distance between the plates is small compared to the dimensions of the plates.	The essentially u parallel plates p force on a given
4. Electric potential	The electric potential at any point in an electric field is the work required to bring a unit positive charge from infinity to that point.	When a charge is electric field, w potential energy When the charge m is done by the fi charge is decreas In both cases ene The similarity be potential energy
H. Potential difference	The potential difference between two points in an electric field is the change in energy per unit charge as a charge is moved from one point to the other.	
*1. The volt	The MKS unit of electrical potential is the volt. The volt is a potential difference that exists between two points if one joule of work is required to transfer one coulomb of charge from one point to the other against the electric force.	*Minimum quantitat* *applications of t* $volts = \frac{joules}{coulomb}$. $v = \frac{W}{q}$
*2. The electron volt	An electron volt is the energy required to move one elementary charge through a potential difference of one volt.	*Minimum quantitat* *applications of t* $volts = \frac{electron}{elementar}$ *1 electron volt =* $1\ volt = \frac{1.60\ x}{elemen}$ *These values nee*

Understandings and Fundamental Concepts	Supplementary Information
The field between two parallel charged plates is essentially uniform if the distance between the plates is small compared to the dimensions of the plates.	The essentially uniform nature of the field between parallel plates produces a very nearly constant force on a given charge placed anywhere in the field.
The electric potential at any point in an electric field is the work required to bring a unit positive charge from infinity to that point.	When a charge is moved against the force of an electric field, work is done on the charge, and the potential energy of the charge is increased. When the charge moves in response to the field, work is done by the field and the potential energy of the charge is decreased. In both cases energy is conserved. The similarity between electric and gravitational potential energy should be noted.
The potential difference between two points in an electric field is the change in energy per unit charge as a charge is moved from one point to the other.	
The MKS unit of electrical potential is the volt. The volt is a potential difference that exists between two points if one joule of work is required to transfer one coulomb of charge from one point to the other against the electric force.	*Minimum quantitative requirements are limited to applications of the relationship,* $volts = \frac{joules}{coulomb}$. $v = \frac{W}{q}$
An electron volt is the energy required to move one elementary charge through a potential difference of one volt.	*Minimum quantitative requirements are limited to applications of the relationship,* $volts = \frac{electron\ volts}{elementary\ charge}$. $1\ electron\ volt = 1.60 \times 10^{-19}\ joule$ $1\ volt = \frac{1.60 \times 10^{-19}\ joule}{elementary\ charge}$ *These values need not be memorized.*

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Topics	Understandings and Fundamental Concepts	
*3. Electric field in terms of electric potential	The intensity of an electric field may be expressed in terms of the change in potential/unit distance (volts/meter).	The relat shown as Volts = ... Volts/meter = ... *Minimum c* *relations*
I. Granular nature of charge. The Millikan experiment	Millikan measured the forces on charged oil drops in a uniform electric field. He found that the electric forces were always integral multiples of a small constant. Since the force is proportional to the charge, it follows that there is a fundamental unit of charge.	The funda is the ch equal to
II. Electric current	An electric current is a flow of electric charge.	Since the use of su speaking which ar
A. Conductivity in solids	Solids vary in their ability to conduct an electric current.	
	The conductivity of solids depends on the number of free charges per unit volume.	In gener and nonm

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The intensity of an electric field may be expressed in terms of the change in potential/unit distance (volts/meter).

The relationship between v/m and nt/coul. may be shown as follows

$$\text{Volts} = \frac{\text{joules}}{\text{coul.}} = \frac{\text{nt.m.}}{\text{coul.}}$$

$$\frac{\text{Volts}}{\text{meter}} = \frac{\text{nt.}}{\text{coul.}}$$

Minimum quantitative requirements are limited to the relationship, $E = \frac{v}{m}$.

Millikan measured the forces on charged oil drops in a uniform electric field. He found that the electric forces were always integral multiples of a small constant. Since the force is proportional to the charge, it follows that there is a fundamental unit of charge.

The fundamental unit of charge (the elementary charge) is the charge of an electron or proton and is equal to 1.6×10^{-19} coulomb.

An electric current is a flow of electric charge.

Since the word "current" means a flow of charge, the use of such phrases as "current flow" is, strictly speaking, redundant. However, the use of terms which are in general use may clarify concepts.

Solids vary in their ability to conduct an electric current.

The conductivity of solids depends on the number of free charges per unit volume.

In general, metals are good conductors of electricity and nonmetals are poor conductors.

Topics	Understandings and Fundamental Concepts	S
	Conductors are substances in which there are many free electrons.	No solid is a perfect solids, such as glass conductivity is so lo they may be considere
	Insulators are substances in which there are few free electrons.	Some materials whose metals and insulators
B. Conductivity in liquids	Liquids vary in their ability to conduct an electric current.	
	Many chemical compounds, called electrolytes, dissociate in aqueous solution into positively and negatively charged particles called ions. In such solutions both positive and negative ions are free to move; therefore, the solutions can conduct an electric current.	Water is the most com solutions. Motion of positive ch equivalent to motion other direction. Experiments in electr granular nature of ch
C. Conductivity in gases	Ionized gases conduct electric current.	Ionized gases, known common phase of matte found in space outsid stars, the streams of and the Van Allen bel of this fourth phase
	Gases, which are normally composed almost entirely of neutral molecules, may be ionized by such means as high energy radiation, electric fields, and collisions with particles.	
	In an ionized gas there may be positive ions, negative ions, and electrons which are free to move.	
D. Conditions necessary for a current	A potential difference is required to maintain a flow of charge between two points in a conductor.	

rstandings and Fundamental Concepts

luctors are substances in which
re are many free electrons.

ulators are substances in which
re are few free electrons.

uids vary in their ability to
duct an electric current.

y chemical compounds, called
ctrolytes, dissociate in aqueous
ution into positively and negatively
rged particles called ions. In
h solutions both positive and
ative ions are free to move;
refore, the solutions can conduct
electric current.

ized gases conduct electric
rent.

es, which are normally composed
ost entirely of neutral molecules,
be ionized by such means as high
rgy radiation, electric fields,
collisions with particles.

an ionized gas there may be
sitive ions, negative ions, and
ectrons which are free to move.

potential difference is required to
intain a flow of charge between two
ints in a conductor.

Supplementary Information

No solid is a perfect insulator, but in some solids, such as glass and fused quartz, the conductivity is so low that, for practical purposes, they may be considered nonconductors.

Some materials whose resistivities lie between metals and insulators are called semiconductors.

Water is the most common solvent in electrolytic solutions.

Motion of positive charges in one direction is equivalent to motion of negative charges in the other direction.

Experiments in electrolysis may be used to show the granular nature of charge.

Ionized gases, known as plasma, are the fourth and most common phase of matter in the universe. Plasma is found in space outside our protective atmosphere. The stars, the streams of ions that radiate from the stors, and the Van Allen belts around our planet are examples of this fourth phase of matter.

Topics	Understandings and Fundamental Concepts	
E. Unit of current	The unit of current is the ampere. It is a fundamental unit. A current of one ampere transfers charge at the rate of one coulomb per second.	The ampe
F. Resistance	Resistance is the ratio of the potential difference across a conductor to the current in it.	*AC consic*
1. Unit of resistance	The MKS unit of resistance is the ohm. The resistance in ohms is the ratio of the potential difference in volts to the current in amperes.	The symbo
2. Resistance in conductors	The resistance of a conductor of uniform cross-section and composition varies directly as its length and inversely as its cross-sectional area.	This rela is the re P is its cross-sec *of this r* In the me is defin 1 meter or 20° C
*3. Ohm's law	Generally, in metals the ratio of potential difference to current is constant at constant temperature. This relationship is known as Ohm's law.	Ohm's la Ohm's la a genera relation temperat is of gr In vacuu electrol

The unit of current is the ampere. It is a fundamental unit.

The ampere will be defined later under magnetism.

A current of one ampere transfers charge at the rate of one coulomb per second.

Resistance is the ratio of the potential difference across a conductor to the current in it.

AC considerations are excluded.

The MKS unit of resistance is the ohm.

The symbol "Ω" is used to represent the ohm.

The resistance in ohms is the ratio of the potential difference in volts to the current in amperes.

The resistance of a conductor of uniform cross-section and composition varies directly as its length and inversely as its cross-sectional area.

This relationship is expressed as $R = P\frac{L}{A}$, where R is the resistance of the given conductor in ohms, P is its resistivity, L is its length, and A is its cross-sectional area. *Only a qualitative understanding of this relationship is required.*

In the metric system the resistivity of a substance is defined as the resistance of a cube with edges 1 meter long at a given temperature (usually 0° C or 20° C).

Generally, in metals the ratio of potential difference to current is constant at constant temperature. This relationship is known as Ohm's law.

Ohm's law is usually expressed mathematically as $V = IR$. Ohm's law is specific for certain materials and not a general law of electricity. However, since this relationship holds for metallic conductors at constant temperature found in ordinary electric circuits, it is of great practical importance.

In vacuum tubes, transistors, gas discharges, and electrolytic cells, the relationship may not be linear.

Topics	Understandings and Fundamental Concepts	
4. Temperature	In general, the resistance of metals increases with increasing temperature.	At extremely low no measurable re known as superco
	The resistance of nonmetals and solutions usually decreases with increasing temperature.	In some material the relationship depends upon the
G. Conservation of charge and energy in electric circuits	A circuit is a closed path in which a current can exist.	*Minimum requirem standing of seri individually. S not be required.*
	Circuit components may be connected in series, or in parallel, or in combinations of these.	*Internal resista* However, these c laboratory work
		The correct meth and voltage shou *construction of*
1. Conservation of charge	The algebraic sum of the currents entering any circuit junction is equal to zero.	This is Kirchoff
		For any point in entering the poi currents leaving
2. Conservation of energy	The algebraic sum of all the potential drops and applied voltages around a complete circuit is equal to zero.	This is Kirchoff
		For any simple c is equal to the
		The relationship resistance in D Kirchoff's laws

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Understandings and Fundamental Concepts	Supplementary Information
In general, the resistance of metals increases with increasing temperature.	At extremely low temperatures some materials have no measurable resistance. This phenomenon is known as superconductivity.
The resistance of nonmetals and solutions usually decreases with increasing temperature.	In some materials, for example, certain semiconductors, the relationship between temperature and resistance depends upon the temperature range.
A circuit is a closed path in which a current can exist.	*Minimum requirements will be limited to an understanding of series and parallel D.C. circuits individually. Series-parallel combinations will not be required.*
Circuit components may be connected in series, or in parallel, or in combinations of these.	*Internal resistance and line drop are not required.* However, these concepts may be discussed when doing laboratory work on circuits.
	The correct method of using meters to measure current and voltage should be discussed. *Details of the construction of meters are not required.*
The algebraic sum of the currents entering any circuit junction is equal to zero.	This is Kirchoff's first law. For any point in a circuit the sum of the currents entering the point is equal to the sum of the currents leaving it.
The algebraic sum of all the potential drops and applied voltages around a complete circuit is equal to zero.	This is Kirchoff's second law. For any simple circuit, the sum of the voltage drops is equal to the applied voltage. The relationships among current, voltage, and resistance in D.C. circuits may be derived from Kirchoff's laws, and Ohm's law.

Topics	Understandings and Fundamental Concepts	
*3. Series circuits	A series circuit is one in which there is only one current path.	
	In a series circuit ° the current is the same in all its components. ° the total resistance is the sum of the resistances of its components. ° the potential drops across the individual components are proportional to their resistances. ° the sum of the potential drops is the same as the total applied potential.	*Minimum qua* *applicatio* *relationsh* I_t V_t R_t
*4. Parallel circuits	A parallel circuit is one in which there is more than one current path.	
	In a parallel circuit ° the potential drop is the same across each branch of the circuit. ° the total current is the sum of the branch currents. ° the sum of the reciprocals of the branch resistances equals the reciprocal of the combined resistance.	*Minimum qua* *applicatio* *ships:* $I_t =$ $V_t =$ $\frac{1}{R_t} =$
*5. Electric power	Electric power is the time rate at which electrical energy is expended.	Since the done per u
	For conductors which obey Ohm's law, the power in watts is equal to the product of current in amperes and the potential difference in volts.	P = $\frac{\text{joules}}{\text{coul.}}$ From the r V = IR. Th
		Minimum qu *applicatio* *current, v*

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A series circuit is one in which there is only one current path.

In a series circuit
- the current is the same in all its components.
- the total resistance is the sum of the resistances of its components.
- the potential drops across the individual components are proportional to their resistances.
- the sum of the potential drops is the same as the total applied potential.

Minimum quantitative requirements are limited to applications of Ohm's law and the following relationships:

$$I_t = i_1 = i_2 = i_3 \ldots$$
$$V_t = v_1 + v_2 + v_3 \ldots$$
$$R_t = r_1 + r_2 + r_3 \ldots$$

A parallel circuit is one in which there is more than one current path.

In a parallel circuit
- the potential drop is the same across each branch of the circuit.
- the total current is the sum of the branch currents.
- the sum of the reciprocals of the branch resistances equals the reciprocal of the combined resistance.

Minimum quantitative requirements are limited to applications of Ohm's law and the following relationships:

$$I_t = i_1 + i_2 + i_3 \ldots$$
$$V_t = v_1 = v_2 = v_3 \ldots$$
$$\frac{1}{R_t} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} \ldots$$

Electric power is the time rate at which electrical energy is expended.

Since the drop in potential represents the work done per unit charge, it follows that, in MKS units,

$$P = \frac{\text{joules}}{\text{coul.}} \times \frac{\text{coul}}{\text{sec.}} = \frac{\text{joules}}{\text{sec.}} = \text{watts.}$$

For conductors which obey Ohm's law, the power in watts is equal to the product of current in amperes and the potential difference in volts.

From the relationship above, $P = VI$. From Ohm's law $V = IR$. Thus, $P = I^2R$.

Minimum quantitative requirements are limited to applications involving relationships among power, current, voltage, and resistance.

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Topics	Understandings and Fundamental Concepts	Supp
		The relationship betwe power should be discus
*6. Electric energy and heat	The energy used in an electric circuit is the product of the power developed and the time during which the flow of charges persists.	*Minimum quantitative r applications of the re* *Energy transferred = V* Energy in joules may b using the constant in Point out that this re principle of conservat be made to Joule's ori Convenient forms are: $Q = I^2Rt$, $Q = \frac{V^2}{R}t$, and
III. Magnetism		The general properties compass should be fami of these concepts may this section.
A. Magnetic force	In addition to gravitational and electrostatic forces, there is also a magnetic force. A magnetic force is a force between charges in relative motion.	
B. Magnetic field	A magnetic field exists in a region where magnetic forces may be detected.	Magnetic fields exist and electric currents.

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The relationship between electrical and mechanical power should be discussed.

The energy used in an electric circuit is the product of the power developed and the time during which the flow of charges persists.

Minimum quantitative requirements are limited to applications of the relationships,

Energy transferred $= VIt = I^2Rt = Pt$.

Energy in joules may be converted to kilocalories using the constant in the reference table.

Point out that this relationship assumes the principle of conservation of energy. Reference may be made to Joule's original work.

Convenient forms are:

$Q = I^2Rt$, $Q = \frac{V^2}{R}t$, and $Q = VIt$.

The general properties and uses of magnets and the compass should be familiar to students. A review of these concepts may serve as an introduction to this section.

In addition to gravitational and electrostatic forces, there is also a magnetic force.

A magnetic force is a force between charges in relative motion.

A magnetic field exists in a region where magnetic forces may be detected.

Magnetic fields exist in the regions around magnets and electric currents.

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Topics	Understandings and Fundamental Concepts	
1. Direction	The direction of the field is, by convention, the direction in which the N-pole of a compass would point in the field.	
2. Magnetic flux lines	A magnetic field is mapped by magnetic flux lines (lines of force). Magnetic flux lines are imaginary lines useful in mapping a field. The lines show the direction of the field. Flux lines always form closed paths and never cross.	The MKS unit of f
3. Flux density	The flux density is the number of flux lines per unit area and is proportional to the intensity of the field. It is the force exerted per unit current per unit length when the current is perpendicular to the field.	*For testing purpo* *be* $\frac{\textit{newtons}}{\textit{ampere meter}}$ Recently, this un tesla is T. The field strengt gauss. A gauss i A $\frac{\text{weber}}{\text{meters}^2}$ is equa The symbol for fl sometimes called
a. Permeability	Permeability is the property of a material which changes the flux density in a magnetic field from its value in a vacuum.	The permeability of a vacuum which

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The direction of the field is, by convention, the direction in which the N-pole of a compass would point in the field.

A magnetic field is mapped by magnetic flux lines (lines of force),

The MKS unit of flux is the weber.

Magnetic flux lines are imaginary lines useful in mapping a field. The lines show the direction of the field. Flux lines always form closed paths and never cross.

The flux density is the number of flux lines per unit area and is proportional to the intensity of the field. It is the force exerted per unit current per unit length when the current is perpendicular to the field.

For testing purposes the units of flux density will be $\frac{newtons}{ampere\ meter}$ *or* $\frac{webers}{square\ meter}$.

Recently, this unit was named tesla. The symbol for tesla is T.

The field strength of magnets is commonly measured in gauss. A gauss is the cgs unit of flux density. A $\frac{weber}{meters^2}$ is equal to 10^4 gauss.

The symbol for flux density is B. Flux density is sometimes called magnetic induction.

Permeability is the property of a material which changes the flux density in a magnetic field from its value in a vacuum.

The permeability of air is nearly the same as that of a vacuum which is one.

Topics	Understandings and Fundamental Concepts	Supple
4. Magnetic field around a straight conductor	The magnetic lines of force caused by a current in a straight conductor are concentric circles around the conductor, in a plane perpendicular to the conductor.	The direction of the fiel appropriate hand rule.
5. Magnetic field around a loop	The field of a loop carrying a current is such that the faces of the loop show polarity.	The polarity can be deter rule.
6. Magnetic field around a solenoid	The lines of magnetic flux around a solenoid emerge from the N-pole of the solenoid and enter the S-pole.	
	Inside a solenoid the lines of force are nearly parallel to its axis and perpendicular to its faces.	
	The magnetic field streng.h of a solenoid is proportional to the number of turns, the current, and the permeability of the core.	A solenoid having a ferro electromagnet. The field core adds to the external The field strength of a s its shape.
C. Force on a current-carrying conductor in a magnetic field	A force is exerted on a current-carrying conductor in a magnetic field, if the conductor is not parallel to the magnetic flux. The force is perpendicular to both the field and the current.	The direction of the forc considering the increase of the conductor (additi the other side (subtracti the force can also be de appropriate hand rule.
D. Force between two straight parallel conductors	The force between two straight parallel conductors in space is proportional to the product of their currents and inversely proportional to the distance between them. If the current directions are the same, the force is one of attraction. If the current directions are	This relationship is used ampere is defined as that present in each of two p length and one meter apa a force of exactly 2 x 1

Understandings and Fundamental Concepts	Supplementary Information
The magnetic lines of force caused by a current in a straight conductor are concentric circles around the conductor, in a plane perpendicular to the conductor.	The direction of the field can be determined by the appropriate hand rule.
The field of a loop carrying a current is such that the faces of the loop show polarity.	The polarity can be determined by the appropriate hand rule.
The lines of magnetic flux around a solenoid emerge from the N-pole of the solenoid and enter the S-pole.	
Inside a solenoid the lines of force are nearly parallel to its axis and perpendicular to its faces.	
The magnetic field strength of a solenoid is proportional to the number of turns, the current, and the permeability of the core.	A solenoid having a ferromagnetic core is known as an electromagnet. The field of the atomic magnets in the core adds to the external field. The field strength of a solenoid is also affected by its shape.
A force is exerted on a current-carrying conductor in a magnetic field, if the conductor is not parallel to the magnetic flux. The force is perpendicular to both the field and the current.	The direction of the force may be determined by considering the increase of flux density on one side of the conductor (additive fields) and the decrease on the other side (subtractive fields). The direction of the force can also be determined by using an appropriate hand rule.
The force between two straight parallel conductors in space is proportional to the product of their currents and inversely proportional to the distance between them. If the current directions are the same, the force is one of attraction. If the current directions are	This relationship is used to define the ampere. One ampere is defined as that unvarying current which, if present in each of two parallel conductors of infinite length and one meter apart in free space, will produce a force of exactly 2×10^{-7} newtons per meter of length.

Topics	Understandings and Fundamental Concepts	
	opposite, the force is one of repulsion.	
		The cou the amp
		The for fields
E. Magnetic effects of moving charges	Charges in motion produce magnetic fields and are affected by them.	
[*] 1. Force on a moving charge	The force on a charge moving in a magnetic field is proportional to the charge, the flux density, and the component of the velocity perpendicular to the field.	*Minimum applicc velocit*
	The direction of the force is perpendicular to the field and to the velocity.	A metho should
		A movin paralle when th
2. Force on a loop or solenoid	A single loop or a solenoid carrying a current experiences a torque in a magnetic field.	
a. The galvanometer	This torque applied to a coil provides the basis for the operation of the galvanometer and the electric motor.	*No detc*
F. Magnetic nature of matter	All substances exhibit magnetic properties.	Diamag parama These magnet

opposite, the force is one of repulsion.

The coulomb is the charge transferred by a current of the ampere in one second.

The force is due to the interaction of the magnetic fields of the two currents.

fects Charges in motion produce magnetic fields and are affected by them.

a The force on a charge moving in a
1arge magnetic field is proportional to the charge, the flux density, and the component of the velocity perpendicular to the field.

Minimum quantitative requirements are limited to applications of the relationship, $F = qvB$, where the velocity and field are perpendicular.

The direction of the force is perpendicular to the field and to the velocity.

A method for determining the direction of the force should be presented.

A moving charge experiences no force when moving parallel to a magnetic field; the force is maximum when the motion is perpendicular to the field.

a A single loop or a solenoid carrying a current experiences a torque in a magnetic field.

This torque applied to a coil
o- provides the basis for the operation of the galvanometer and the electric motor.

No details of the construction of meters are required.

ure All substances exhibit magnetic properties.

Diamagnetic substances reduce the flux density; paramagnetic substances increase the flux density. These effects are generally weak except for ferromagnetic substances which are strongly paramagnetic.

Topics	Understandings and Fundamental Concepts	
	The field around a permanent magnet is due to atomic currents (revolving and spinning electrons).	Atoms of magnetic ma microscopic cluster. Within a domain, th Normally, thermal ag of the domains. In a magnetic field of others. If the boundaries p the substance is a
1. Field around a permanent magnet	Certain natural substance are magnets. Magnets may be made. Magnets attract magnetic materials. The attractive force is concentrated at regions known as poles. Like poles repel each other and unlike poles attract. The continuous lines of magnetic flux associated with a magnet emerge from the north pole and enter the south pole.	
IV. Electromagnetic Induction	An electric potential is induced across a conductor when relative motion between the flux and the conductor produces a change in the flux linked by the conductor. The magnitude of the induced potential is proportional to the rate at which the flux linked by the conductor changes. If the conductor is part of a complete circuit, the induced potential produces a current in the circuit.	A changing magnetic

Understandings and Fundamental Concepts	Supplementary Information
The field around a permanent magnet is due to atomic currents (revolving and spinning electrons).	Atoms of magnetic materials are grouped in microscopic clusters called domains. Within a domain, the fields of the atoms are additive. Normally, thermal agitation causes a random arrangement of the domains. In a magnetic field, some domains grow at the expense of others. If the boundaries persist after removal of the field, the substance is a permanent magnet.
Certain natural substance are magnets.	
Magnets may be made.	
Magnets attract magnetic materials. The attractive force is concentrated at regions known as poles. Like poles repel each other and unlike poles attract.	
The continuous lines of magnetic flux associated with a magnet emerge from the north pole and enter the south pole.	
An electric potential is induced across a conductor when relative motion between the flux and the conductor produces a change in the flux linked by the conductor.	A changing magnetic field constitutes a moving field.
The magnitude of the induced potential is proportional to the rate at which the flux linked by the conductor changes.	
If the conductor is part of a complete circuit, the induced potential produces a current in the circuit.	

Topics	Understandings and Fundamental Concepts	Sup
	The direction of the induced current is such that its magnetic field opposes the change that induced it.	This relationship i example of the law
[*] A. Magnitude of an induced electromotive force	The magnitude of an induced electromotive force is directly proportional to the flux density, the length of the conductor, and the speed of the conductor relative to the flux.	*Minimum quantitati applications of the the velocity and f* The direction of th determined by an ap
B. Generator principle	A conducting loop rotated in a uniform magnetic field experiences a continual change in the total magnetic flux lines linking the loop. This change induces a potential across the ends of the loop which alternates in direction and varies in magnitude between zero and a maximum. The magnitude of the induced potential is proportional to the component of the velocity perpendicular to the field and the intensity of the magnetic field. When the loop is part of a complete circuit, the induced potential causes a current in the loop. Since the induced potential is alternating, the current is an alternating current.	When the plane of t field, the induced When the plane of t the induced potent
V. Electromagnetic radiation	Accelerating charges generate electromagnetic radiations which are propagated by an interchange of energy between electric and magnetic fields.	If electromagnetic only be reviewed n taken up at this p Periodic electroma oscillating charge

The direction of the induced current is such that its magnetic field opposes the change that induced it.

This relationship is known as Lenz's law and is an example of the law of conservation of energy.

The magnitude of an induced electromotive force is directly proportional to the flux density, the length of the conductor, and the speed of the conductor relative to the flux.

Minimum quantitative requirements are limited to applications of the relationship, $E = Blv$, where the velocity and field are perpendicular.

The direction of the induced potential may be determined by an appropriate hand rule.

A conducting loop rotated in a uniform magnetic field experiences a continual change in the total magnetic flux lines linking the loop. This change induces a potential across the ends of the loop which alternates in direction and varies in magnitude between zero and a maximum.

When the plane of the loop is perpendicular to the field, the induced potential is zero.

When the plane of the loop is parallel to the field, the induced potential is a maximum.

The magnitude of the induced potential is proportional to the component of the velocity perpendicular to the field and the intensity of the magnetic field.

When the loop is part of a complete circuit, the induced potential causes a current in the loop. Since the induced potential is alternating, the current is an alternating current.

Accelerating charges generate electromagnetic radiations which are propagated by an interchange of energy between electric and magnetic fields.

If electromagnetic radiation was studied earlier, it need only be reviewed now. Otherwise that section should be taken up at this point.

Periodic electromagnetic radiation is caused by oscillating charges.

Topics	Understandings and Fundamental Concepts	
VI. Electron Beams		
A. Thermionic emission	Incandescent objects emit electrons.	A space charge will objects which will i electrons.
B. Electron beams in an electric field	In an electric field between two conductors the electrons move from the cathode to the plate. The cathode is negative and the plate is positive.	
C. Control of electron beams	Electron beams are controlled by electric and/or magnetic fields.	
	In an electric field the beam is deflected by a force which is parallel to the field and directed toward the positive plate.	
	In a magnetic field the beam is deflected by a force which is perpendicular to both the beam and the field.	An appropriate hand the direction of def
D. Charge to mass ratio	The ratio of the charge on an electron to its mass can be determined by measuring the effects of a known magnetic field on a beam of electrons of known kinetic energy.	The $\frac{e}{m}$ ratio may be c Since the electror ences centripetal
	A beam of electrons of known kinetic energy can be obtained by accelerating them in a known electric field. This method is used to determine the ratio of charge to mass of other particles.	The electron gains through a change i Therefore, the pot kinetic energy gai $\frac{1}{2}\ mv^2 = Ve$ (2) a Dividing both side Since the centripe by the magnetic fi

Incandescent objects emit electrons.

A space charge will be developed around incandescent objects which will impede the continued emission of electrons.

In an electric field between two conductors the electrons move from the cathode to the plate. The cathode is negative and the plate is positive.

Electron beams are controlled by electric and/or magnetic fields.

In an electric field the beam is deflected by a force which is parallel to the field and directed toward the positive plate.

In a magnetic field the beam is deflected by a force which is perpendicular to both the beam and the field.

An appropriate hand rule should be used to determine the direction of deflection.

The ratio of the charge on an electron to its mass can be determined by measuring the effects of a known magnetic field on a beam of electrons of known kinetic energy.

A beam of electrons of known kinetic energy can be obtained by accelerating them in a known electric field. This method is used to determine the ratio of charge to mass of other particles.

The $\frac{e}{m}$ ratio may be obtained in the following way:

Since the electron follows a curved path, it experiences centripetal acceleration. $(a_c = \frac{v^2}{r})$ (1)

The electron gains kinetic energy $(\frac{1}{2} mv^2)$ by moving through a change in electrical potential (V). Therefore, the potential energy (Ve) lost equals the kinetic energy gained by the electron.

$\frac{1}{2} mv^2 = Ve$ (2) and $v^2 = \frac{2Ve}{m}$ (3)

Dividing both sides of (3) by r: $\frac{v^2}{r} = \frac{2Ve}{mr}$ (4)

Since the centripetal force on the electron provided by the magnetic field is equal to Bev,

Topics	Understandings and Fundamental Concepts	
		$Bev = F = ma = \frac{m}{}$ $Bev = m\ (\frac{2Ve}{mr})$ From (3) $v = \sqrt{}$ Substituting in $Be\ \sqrt{\frac{2Ve}{m}} = m(\frac{2V}{mr}$ Since V, B and r *This relationshi*
E. Mass of the electron	Since the charge of an electron is known from Millikan's oil-drop experiment, the mass of an electron can be determined from the charge to mass ratio.	

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Understandings and Fundamental Concepts	Supplementary Information
	$Bev = F = ma = \frac{mv^2}{r} = m(\frac{2Ve}{mr})$ (5) $Bev = m(\frac{2Ve}{mr})$ (6) From (3) $v = \sqrt{\frac{2Ve}{m}}$ Substituting in (6) $Be\sqrt{\frac{2Ve}{m}} = m(\frac{2Ve}{mr})$ and $\frac{e}{m} = \frac{2V}{B^2r^2}$ Since V, B and r can be measured, $\frac{e}{m}$ may be obtained. *This relationship and its derivation are not required.*
Since the charge of an electron is known from Millikan's oil-drop experiment, the mass of an electron can be determined from the charge to mass ratio.	

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ATOMIC AND NUCLEAR PHYSICS

Topics	Understandings and Fundamental Concepts	
I. Dual Nature of Light	Light exhibits the characteristics of waves and particles.	This duality is true fo The dual nature of mati Some phenomena are mor use of the wave model more appropriate for o
A. Wave phenomena	Interference, polarization, and diffraction can be explained only on the basis of a wave theory.	A review of these phen
B. Particle phenomena	The photoelectric effect can be explained only on the basis of a particle theory.	
1. Photo-electric effect	The photoelectric effect is the emission of electrons from an object when certain electromagnetic radiation strikes it.	According to the wave be related to the inte radiation should cause if sustained long enou
	The rate of emission of photoelectrons depends on the intensity of the incident radiation.	
	The maximum energy of photoelectrons depends only on the frequency of the incident radiation and the nature of the surface.	The emission of photoe
	For each photo-emissive material there is a minimum frequency below which no photoelectrons will be emitted.	

ATOMIC AND NUCLEAR PHYSICS

Understandings and Fundamental Concepts	Supplementary Information
Light exhibits the characteristics of waves and particles.	This duality is true for all electromagnetic radiation.
	The dual nature of matter will be studied later.
	Some phenomena are more easily explained by the use of the wave model while the particle model is more appropriate for others.
Interference, polarization, and diffraction can be explained only on the basis of a wave theory.	A review of these phenomena may be useful.
The photoelectric effect can be explained only on the basis of a particle theory.	
The photoelectric effect is the emission of electrons from an object when certain electromagnetic radiation strikes it.	According to the wave theory, the maximum energy should be related to the intensity of the radiation and any radiation should cause the emission of photoelectrons if sustained long enough.
The rate of emission of photoelectrons depends on the intensity of the incident radiation.	
The maximum energy of photoelectrons depends only on the frequency of the incident radiation and the nature of the surface.	The emission of photoelectrons is a random phenomenon.
For each photo-emissive material there is a minimum frequency below which no photoelectrons will be emitted.	

Topics	Understandings and Fundamental Concepts	S
II. The Quantum Theory	The quantum theory was developed to explain phenomena which could not be explained by the classical theory.	
A. The quantum	Atomic oscillators emit or absorb electromagnetic radiation only in discrete amounts called quanta.	The distribution c explained by assum is emitted or absc this theory at the
*1. Planck's constant	The energy of each quantum is proportional to the frequency of the radiation.	*Minimum quantitati applications of th the energy of the*
	The constant of proportionality between the energy of a quantum of electromagnetic radiation and its frequency is called Planck's constant.	*h = Planck's const f = the frequency cycles/sec. (The be memorized.)*
B. Explanation of photoelectric effect	The photoelectric effect could be explained by assuming that electromagnetic radiation is quantized.	In 1905 Einstein p was always quantiz quanta existed onl
1. Photon	A photon is a quantum of light energy.	
	The photons of the electromagnetic radiation act individually and their energies are proportional to their frequency and, therefore, inversely proportional to their wavelength.	This relationship
*2. Photoelectric equation	The maximum kinetic energy of the released electrons is a linear function of the frequency of the photons.	*Minimum quantitat application of th* *The work function* The slope of the The intercept on below which photo material.

Understandings and Fundamental Concepts	Supplementary Information
The quantum theory was developed to explain phenomena which could not be explained by the classical theory.	
Atomic oscillators emit or absorb electromagnetic radiation only in discrete amounts called quanta.	The distribution of black body radiation can be explained by assuming that electromagnetic radiation is emitted or absorbed as quanta. Planck announced this theory at the close of the nineteenth century.
The energy of each quantum is proportional to the frequency of the radiation. The constant of proportionality between the energy of a quantum of electromagnetic radiation and its frequency is called Planck's constant.	*Minimum quantitative requirements are limited to applications of the relationship, $E = hf$, where E is the energy of the electromagnetic radiation in joules, h = Planck's constant (6.63×10^{-34} joule-sec), and f = the frequency of the electromagnetic radiation in cycles/sec. (The value of Planck's constant need not be memorized.)*
The photoelectric effect could be explained by assuming that electromagnetic radiation is quantized.	In 1905 Einstein proposed that electromagnetic radiation was always quantized whereas Planck had proposed that quanta existed only in the neighborhood of the emitter.
A photon is a quantum of light energy.	
The photons of the electromagnetic radiation act individually and their energies are proportional to their frequency and, therefore, inversely proportional to their wavelength.	This relationship may also be expressed as $E = \frac{hc}{\lambda}$.
The maximum kinetic energy of the released electrons is a linear function of the frequency of the photons.	*Minimum quantitative requirements are limited to the application of the relationship, $E_{k\ (max)} = hf - w$.* *The work function, w, depends upon the material.* The slope of the function above is Planck's constant. The intercept on the frequency axis is the frequency below which photoemission will not occur for the material.

Topics	Understandings and Fundamental Concepts	Su
a. Threshold frequency	The minimum frequency needed to eject an electron from the surface of a material is called the threshold frequency.	
	The energy associated with the threshold frequency is called the work function of the material.	
C. Photon-particle collisions	Both energy and momentum are conserved in photon-particle collisions.	Compton used x-rays f in 1922.
1. Photon momentum	The momentum of a photon is inversely proportional to its wavelength.	The Compton effect is conservation of energ collisions. The mome as $p = \frac{E}{c} = \frac{hf}{c} = \frac{h}{\lambda}$. Although the photon c a force, it does not In any frame of refer with the speed of lig
D. Matter waves	Moving particles have wave properties.	De Broglie made this on his intuitive feel that the dual nature nature of matter.
	The wavelength of a particle is inversely proportional to its momentum.	Theoretically, all ma Under ordinary circum is not significant. cance when they are l diffraction patterns length of such partic momenta: For example constant and p = mv f relative to the speed

Understandings and Fundamental Concepts	Supplementary Information
The minimum frequency needed to eject an electron from the surface of a material is called the threshold frequency.	
The energy associated with the threshold frequency is called the work function of the material.	
Both energy and momentum are conserved in photon-particle collisions.	Compton used x-rays for his photon-particle collisions in 1922.
The momentum of a photon is inversely proportional to its wavelength.	The Compton effect is explained in terms of the conservation of energy and momentum in photon-particle collisions. The momentum of the photons is expressed as $p = \frac{E}{c} = \frac{hf}{c} = \frac{h}{\lambda}$. Although the photon carries momentum and can exert a force, it does not and cannot have rest mass. In any frame of reference in space the photon moves with the speed of light and cannot be at rest.
Moving particles have wave properties.	De Broglie made this proposal in 1924. It was based on his intuitive feeling that nature is symmetrical, that the dual nature of light is matched by a dual nature of matter.
The wavelength of a particle is inversely proportional to its momentum.	Theoretically, all matter has wave characteristics. Under ordinary circumstances the wave nature of objects is not significant. The waves have particular significance when they are long enough to produce diffraction patterns which can be observed. The wavelength of such particles is determined from their momenta: For example, $\lambda = \frac{h}{p}$ where h is Planck's constant and p = mv for low energies (speed small relative to the speed of light).

Topics	Understandings and Fundamental Concepts	
		Davisson ar with moving were equ.l
III. Models of the atom		
A. The Rutherford model of the atom	On the basis of scattering experiments Rutherford proposed a model in which the positive charge of an atom, and most of the mass, are considered to be concentrated in a small dense core, called the nucleus of the atom, with electrons widely separated from the nucleus. Most of the atom is space.	Alpha parti were observ The distrib their scatt
1. The alpha particle	The alpha particle is a helium nucleus which consists of two protons and two neutrons.	Many natura particles. results in alpha decay Energies of and 9.0 Mev 1.5×10^7m/
2. Alpha particle scattering	Most of the alpha particles directed at a thin metal foil pass through without being deflected. Some are scattered through angles ranging up to 180 degrees.	The unexpec experiment through ver both the nu particles a experience The angle θ is called t the path le nucleus and alpha parti

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Davisson and Germer produced interference patterns with moving electrons. The observed wavelengths were equal to $\frac{h}{p}$.

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rford the

On the basis of scattering experiments Rutherford proposed a model in which the positive charge of an atom, and most of the mass, are considered to be concentrated in a small dense core, called the nucleus of the atom, with electrons widely separated from the nucleus. Most of the atom is space.

Alpha particles, directed at a thin metallic foil, were observed to be scattered in all directions. The distribution of the particles as a function of their scattering angle was experimentally measured.

pha le

The alpha particle is a helium nucleus which consists of two protons and two neutrons.

Many naturally radioactive substances emit alpha particles. The type of nuclear disintegration which results in the emission of alpha particles is called alpha decay.

Energies of alpha particles used ranged between 4.5 and 9.0 Mev. This corresponds to velocities from 1.5×10^7 m/sec to 2.0×10^7 m/sec.

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Most of the alpha particles directed at a thin metal foil pass through without being deflected. Some are scattered through angles ranging up to 180 degrees.

The unexpected and significant result of this experiment is the deflection of some particles through very large angles, almost 180 degrees. Since both the nuclei of the foil atoms and the alpha particles are positively charged, the alpha particles experience Coulomb forces of repulsion.

The angle θ through which the particle is deflected is called the scattering angle. The distance between the path leading to a head-on collision with the nucleus and the original path actually taken by the alpha particle is called the impact parameter.

Topics	Understandings and Fundamental Concepts	Sup
		As P gets smaller, θ collision, where P = of a head-on collisic
3. Trajectories of alpha particles	Alpha particles are deflected into hyperbolic paths because of the couloumb forces between them and the positively charged nuclei of the metal foil.	The force is expresse the nucleus is Ze, wh the elementary charge equals 2e.
4. Scattering and atomic number	If the energies of the alpha particles are the same, the number of particles scattered beyond a given angle is a function of the charge on each nucleus.	
5. Dimensions of atomic nuclei	The radii of atomic nuclei are small compared with the radii of their respective atoms.	If one neglects relat may be approximated b energy principle to h scattering experiment $\frac{m_\alpha v^2}{2} = \frac{kqZe}{r}$, whe between the center of of the nucleus Ther $r = \frac{2\ kqZe}{m_\alpha v^2}$. This relationship is does not have suffici The radii of atomic n meters.
B. The Bohr model of the hydrogen atom	The Bohr model of the hydrogen atom consists of a positively charged nucleus and a single electron revolving in a circular orbit. Assumptions contrary to classical theory are required to explain this model.	The Bohr model is not of atomic structure a mechanical model.

As P gets smaller, θ gets larger until for a head-on collision, where P = 0, θ is 180°. The probability of a head-on collision is extremely small.

Alpha particles are deflected into hyperbolic paths because of the couloumb forces between them and the positively charged nuclei of the metal foil.

The force is expressed as $F = k\frac{qZe}{r^2}$. The charge on the nucleus is Ze, where Z is the atomic number, e is the elementary charge and q for an alpha particle equals 2e.

g
c

If the energies of the alpha particles are the same, the number of particles scattered beyond a given angle is a function of the charge on each nucleus.

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The radii of atomic nuclei are small compared with the radii of their respective atoms.

If one neglects relativistic effects, this dimension may be approximated by applying the conservation of energy principle to head-on collisions in alpha scattering experiments. Thus,

$$\frac{m_\alpha v^2}{2} = \frac{kqZe}{r},$$

where r represents the distance between the center of the alpha particle and the center of the nucleus Therefore,

$$r = \frac{2\,kqZe}{m_\alpha v^2}.$$

This relationship is valid only when the alpha particle does not have sufficient energy to enter the nucleus. The radii of atomic nuclei are of the order of 10^{-14} meters.

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gen

The Bohr model of the hydrogen atom consists of a positively charged nucleus and a single electron revolving in a circular orbit.

The Bohr model is not a general solution to the problem of atomic structure and has been replaced by a wave mechanical model.

Assumptions contrary to classical theory are required to explain this model.

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Topics	Understandings and Fundamental Concepts	Supplementa
1. Bohr's assumptions	An orbiting electron does not lose energy even though it has an acceleration toward the center.	According to classical theory, lose energy by emitting electro and spiral into the nucleus.
	Only a limited number of specified orbits is permitted. Each orbit represents a particular energy state.	The permitted orbits are those momentum of the electron is an of Planck's constant divided by $mvr = \frac{nh}{2\pi}$
	When an electron changes from one energy state to another, a quantum of energy equal to the difference between the energies of the two states is emitted or absorbed.	The change in energy is given b E_1 and E_2 are the respective ene and f is the frequency of the ra
2. Energy levels	When gas molecules are bombarded by electrons, the gas molecules can accept energy only in discrete amounts.	In 1914 J. Frank and G. Hertz fu concepts of stationary states or by bombarding gas molecules with molecules of gas accepted energy only in discrete amounts. Excit different for different gases.
	The process of raising the energy of atoms is called excitation.	
	Excitation energies are different for different gases.	Electrons with energies lower th excitation energies collided ela gas molecules.
	Excited atoms subsequently release the energy as photons.	The Frank-Hertz experiment demon exciting atoms; other methods ar electrical discharge, and electr
		The potential energy necessary t an atom to a higher state is cal resonance potential.

Understandings and Fundamental Concepts	Supplementary Information
An orbiting electron does not lose energy even though it has an acceleration toward the center.	According to classical theory, the electron should lose energy by emitting electromagnetic radiation and spiral into the nucleus.
Only a limited number of specified orbits is permitted. Each orbit represents a particular energy state.	The permitted orbits are those for which the angular momentum of the electron is an integral multiple of Planck's constant divided by 2 π. $mvr = \frac{nh}{2\pi}$
When an electron changes from one energy state to another, a quantum of energy equal to the difference between the energies of the two states is emitted or absorbed.	The change in energy is given by: $hf = E_1 - E_2$, where E_1 and E_2 are the respective energies of the two states, and f is the frequency of the radiation emitted.
When gas molecules are bombarded by electrons, the gas molecules can accept energy only in discrete amounts.	In 1914 J. Frank and G. Hertz further strengthened the concepts of stationary states or fixed energy levels by bombarding gas molecules with electrons. The molecules of gas accepted energy from the electrons only in discrete amounts. Excitation energies were different for different gases.
The process of raising the energy of atoms is called excitation.	
Excitation energies are different for different gases.	Electrons with energies lower than the discrete excitation energies collided elastically with the gas molecules.
Excited atoms subsequently release the energy as photons.	The Frank-Hertz experiment demonstrates one way of exciting atoms; other methods are thermal excitation, electrical discharge, and electromagnetic excitation.
	The potential energy necessary to change the energy of an atom to a higher state is called the excitation or resonance potential.

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Topics	Understandings and Fundamental Concepts	Supplemen
a. Ground state	The lowest possible energy level is called the ground state.	
b. Ionization potential	The minimum energy necessary to remove an electron from an atom is called the ionization potential.	The minimum energy necessary to from the atom is equal to its p its kinetic energy. The ionization potential is the move an electron from the ground that is, to ionize the atom. Th of hydrogen, for example, is 13
3. Standing waves	Waves which describe the probability of finding the electron at a particular position can exist as standing waves only at certain distances from the nucleus. These distances correspond to the discrete energy levels of the atom.	A standing wave will occur only $\lambda = \frac{h}{mv} = 2\pi r$, then Planck's assum follows. It is convenient to th of wavelengths in an orbit for a
IV. Atomic Spectra	Each element has a characteristic spectrum.	
*A. Excitation and emission	Atoms, excited to energy levels above the ground state, emit energy as photons when their electrons fall to lower energy levels.	*Minimum quantitative requiremen applications of the relationshi* $E_{initial} - E_{final}$, *and the use diagrams.* If sufficient energy is supplie excited to several energy level returns to the ground state, it photon of one particular energy energies equal to the energy di internal states.
*B. Absorption spectra	An atom can absorb those photons whose energies are equal to the energies of photons it can emit when excited.	*Minimum quantitative requiremen applications of the relationshi* $E_{photon} = hf$.

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nderstandings and Fundamental Concepts	Supplementary Information
he lowest possible energy level is alled the ground state.	
he minimum energy necessary to remove n electron from an atom is called he ionization potential.	The minimum energy necessary to remove an electron from the atom is equal to its potential energy minus its kinetic energy. The ionization potential is the energy required to move an electron from the ground state to infinity, that is, to ionize the atom. The ionization potential of hydrogen, for example, is 13.6 ev.
/aves which describe the probability of finding the electron at a particular position can exist as standing waves only at certain listances from the nucleus. These listances correspond to the discrete energy levels of the atom.	A standing wave will occur only when $n\ \lambda = \frac{h}{p}$, or $\lambda = \frac{h}{mv} = 2\pi r$, then Planck's assumption $mvr = \frac{nh}{2\pi}$ follows. It is convenient to think of n as the number of wavelengths in an orbit for a particular energy level.
Each element has a characteristic spectrum.	
Atoms, excited to energy levels above the ground state, emit energy as photons when their electrons fall to lower energy levels.	*Minimum quantitative requirements are limited to applications of the relationship,* $E_{photon} = hf = E_{initial} - E_{final}$, *and the use of simple energy level diagrams.* If sufficient energy is supplied, the electrons may be excited to several energy levels. As each electron returns to the ground state, it can radiate a photon of one particular energy or several photons with energies equal to the energy differences between several internal states.
An atom can absorb those photons whose energies are equal to the energies of photons it can emit when excited.	*Minimum quantitative requirements are limited to applications of the relationship,* $E_{final} - E_{initial} = E_{photon} = hf$.

Topics	Understandings and Fundamental Concepts	
		Th ph at si It en
C. The hydrogen spectrum	The lines in the emission spectrum of hydrogen occur in several groups known as series.	In cal to Wh in wi Emp spe we al fou
1. Balmer series	The lines in the Balmer Series are due to electrons from an excited state returning to the second energy level. Some of these lines are visible.	
V. The Nucleus	The nucleus is the core of the atom and contains most of the mass of the atom.	
A. Observational tools	Some of the tools used for the study of radioactivity are the electroscope, photographic plates, geiger counters, scintillation counters, and cloud chambers.	A b the sug *no*
B. Accelerators	Accelerators are used to give charged particles sufficient kinetic energy to overcome electrostatic forces and penetrate the nucleus.	6

The photon will be absorbed only when the incident photon has exactly the right energy to raise the atom to a particular energy state; otherwise the photon simply passes through or scatters elastically.

It is possible for an incident photon to have enough energy to ionize the atom.

The lines in the emission spectrum of hydrogen occur in several groups known as series.

In the ground state, n = 1. All the other states are called excited states because energy must be added to the electron in order to move it to these states. When a hydrogen atom absorbs energy, an electron moves into orbits with larger radii and into energy levels with higher energy.

Empirical formulas for the lines of the hydrogen spectrum, developed for the Balmer series, were confirmed by the theoretical work of Bohr. Bohr also predicted other series which were subsequently found.

The lines in the Balmer Series are due to electrons from an excited state returning to the second energy level. Some of these lines are visible.

The nucleus is the core of the atom and contains most of the mass of the atom.

Some of the tools used for the study of radioactivity are the electroscope, photographic plates, geiger counters, scintillation counters, and cloud chambers.

A brief descriptive approach to the application of these tools for studying and detecting particles is suggested. *Knowledge of details of construction is not required.*

Accelerators are used to give charged particles sufficient kinetic energy to overcome electrostatic forces and penetrate the nucleus.

Topics	Understandings and Fundamental Concepts	Sup
	Magnetic and electric fields are used in accelerators to accelerate charged particles.	
	Some accelerators are the Van de Graaff generator, cyclotron, the synchrotron, and the linear accelerator.	A brief descriptive a accelerators is sugge *of construction and c*
C. Nucleons	The particles inside the nucleus are called nucleons.	
D. Atomic number	The atomic number is the number of protons in the nucleus.	The symbol for atomic
	Elements differ from each other in atomic number.	
E. Mass number	The mass number is the total number of protons and neutrons in the nucleus.	The symbol for mass n
F. Nuclear force	Nuclear force is the force which holds the nucleons together. It is a strong short range force.	Nuclear forces operat is less than 10^{-15} met
		Nuclear forces exceed of magnitude.
G. Nuclear mass and binding energy	The mass of the nucleus is less than the total mass of its nucleons. This difference in mass is equivalent to the energy with which the nucleons are bound.	The mass defect is th total mass of the nuc
	The binding energy of the nucleus is the energy that must be supplied to it in order to separate it into its nucleons.	The binding energy is mass defect. The binding energy is nucleons form a nucl

Understandings and Fundamental Concepts	Supplementary Information
Magnetic and electric fields are used in accelerators to accelerate charged particles.	
Some accelerators are the Van de Graaff generator, cyclotron, the synchrotron, and the linear accelerator.	A brief descriptive approach to the operation of these accelerators is suggested. *Knowledge of details of construction and operation is not required.*
The particles inside the nucleus are called nucleons.	
The atomic number is the number of protons in the nucleus.	The symbol for atomic number is Z.
Elements differ from each other in atomic number.	
The mass number is the total number of protons and neutrons in the nucleus.	The symbol for mass number is A.
Nuclear force is the force which holds the nucleons together. It is a strong short range force.	Nuclear forces operate when the distance between nucleons is less than 10^{-15} meters.
	Nuclear forces exceed all other types by many orders of magnitude.
The mass of the nucleus is less than the total mass of its nucleons. This difference in mass is equivalent to the energy with which the nucleons are bound.	The mass defect is the difference in mass between the total mass of the nucleons and the mass of the nucleus.
The binding energy of the nucleus is the energy that must be supplied to it in order to separate it into its nucleons.	The binding energy is the energy equivalent of the mass defect. The binding energy is the energy released when the nucleons form a nucleus.

Topics	Understandings and Fundamental Concepts	
		Binding ener binding ener
H. Isotopes	Nuclei which have the same atomic number but a different number of neutrons are called isotopes.	
VI. Nuclear Reactions		
A. Natural radioactivity	Radioactivity is the disintegration of the nuclei of atoms.	Practically isotopes hav
	Some nuclei of high atomic number are naturally radioactive.	
	In all nuclear reactions, the total charge and the total mass number on both sides of the equation must balance.	
1. Alpha decay	Alpha decay is the emission of an alpha particle from a nucleus.	Example: $_{88}Ra^{226} \rightarrow$ The emissio number by 4
	An alpha particle is the nucleus of a helium atom. It has a mass number of 4 and a charge of +2.	
2. Beta decay	In natural radioactivity beta decay is the emission of a negative electron from a nucleus.	Example: $_{90}Th^{234} \rightarrow$ The emissic atomic numb number.

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Binding energies are usually compared in terms of binding energy per nucleon.

Nuclei which have the same atomic number but a different number of neutrons are called isotopes.

Radioactivity is the disintegration of the nuclei of atoms.

Practically all the naturally occurring radioactive isotopes have atomic numbers greater than 81.

Some nuclei of high atomic number are naturally radioactive.

In all nuclear reactions, the total charge and the total mass number on both sides of the equation must balance.

Alpha decay is the emission of an alpha particle from a nucleus.

Example:

$$_{88}Ra^{226} \rightarrow {}_{86}Rn^{222} + {}_{2}He^{4}$$

The emission of an alpha particle decreases the mass number by 4 and the atomic number by 2.

An alpha particle is the nucleus of a helium atom. It has a mass number of 4 and a charge of +2.

In natural radioactivity beta decay is the emission of a negative electron from a nucleus.

Example:

$$_{90}Th^{234} \rightarrow {}_{91}Pa^{234} + {}_{-1}e^{0}$$

The emission of a negative beta particle increases the atomic number by one, but does not change the mass number.

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Topics	Understandings and Fundamental Concepts	
3. Gamma radiation	Gamma radiation consists of high energy photons originating in nuclear reactions.	Gamma radiation is
	Gamma radiation is emitted when a nucleus in an excited state changes to a more stable state.	The emission of ga atomic or mass num
*B. Half life	The half life of a radioactive element is the time required for one-half of the nuclei of a sample to disintegrate.	*Minimum quantitati* *applications of th* $m_f = \frac{1}{2^n} m_i$ *lives.*
		Each isotope has a
		Half lives range i
C. Atomic mass unit	The atomic mass unit is defined as $\frac{1}{12}$ the mass of an atom of carbon 12.	Oxygen is no longe
D. Mass-energy relationship	Mass is equivalent to energy.	
1. Conservation of mass-energy	During the process of radioactive decay mass-energy is conserved.	
*2. Einstein's mass-energy equation	The energy equivalent of a mass is proportional to the mass and the velocity of light squared.	*Minimum quantitat* *applications of th* From the special $E = mc^2$. Therefo 1 amu = 1.66 x 1 = $\frac{1.49 \text{ x } 1}{1.6 \text{ x } 10}$ = 931 Mev

nderstandings and Fundamental Concepts	Supplementary Information
Gamma radiation consists of high energy photons originating in nuclear reactions.	Gamma radiation is evidence of nuclear energy levels.
Gamma radiation is emitted when a nucleus in an excited state changes to a more stable state.	The emission of gamma radiation does not change the atomic or mass numbers.
The half life of a radioactive element is the time required for one-half of the nuclei of a sample to disintegrate.	*Minimum quantitative requirements are limited to applications of the relationship,* $m_f = \frac{1}{2^n} m_i$ *where* m_f *= final mass after n half lives.* Each isotope has a specific half life. Half lives range in value from 10^{-22} sec. to 10^{17} yrs.
The atomic mass unit is defined as $\frac{1}{12}$ the mass of an atom of carbon 12.	Oxygen is no longer the standard base for mass value.
Mass is equivalent to energy.	
During the process of radioactive decay mass-energy is conserved.	
The energy equivalent of a mass is proportional to the mass and the velocity of light squared.	*Minimum quantitative requirements are limited to applications of the relationship* $E = mc^2$. From the special theory of relativity we find that $E = mc^2$. Therefore, $1 \text{ amu} = 1.66 \times 10^{-27} \text{kg} \times (3.0 \times 10^8)^2 \text{m}^2/\text{sec}^2$ $= \frac{1.49 \times 10^{-10} \text{ joules}}{1.6 \times 10^{-19} \text{ joules/ev}}$ $= 931 \text{ Mev}$

Topics	Understandings and Fundamental Concepts	
		This was confirme Walton in 1932.
E. Induced (artificial) transmutation	Transmutation is a change from one isotope to another of the same or different atomic number because of a gain or loss of protons and/or neutrons by the nucleus. Radioactivity is an example of natural transmutation. Induced transmutations may be produced by bombardment of nuclei.	In 1919, Rutherfo particles and pro $_{7}N^{14} + {}_{2}He^{4} \rightarrow$ This was the firs In 1934, the Joli- alpha particles t- phosphorus. This radioactivity. $_{13}Al^{27} + {}_{2}He^{4}$ The radioactive p isotope of silico $_{15}P^{30} \rightarrow {}_{14}Si^{30}$
1. Beta decay	Beta decay in induced radioactivity includes the emission of positive electrons (positrons) as well as negative electrons from nuclei.	Examples: $_{29}Cu^{64} \rightarrow {}_{28}Ni^{64}$ $_{11}Na^{24} \rightarrow {}_{12}Mg^{24}$
2. The neutron	Neutrons were first discovered by bombarding beryllium with alpha particles.	A very penetratin beryllium and bor particles. $_{4}Be^{9} + {}_{2}He^{4} \rightarrow$ This radiation wa the neutron.

This was confirmed experimentally by Cockcroft and Walton in 1932.

Transmutation is a change from one isotope to another of the same or different atomic number because of a gain or loss of protons and/or neutrons by the nucleus.

In 1919, Rutherford bombarded nitrogen with alpha particles and produced oxygen.

$${}_{7}N^{14} + {}_{2}He^{4} \rightarrow {}_{8}O^{17} + {}_{1}H^{1}$$

This was the first induced transmutation.

Radioactivity is an example of natural transmutation.

Induced transmutations may be produced by bombardment of nuclei.

In 1934, the Joliot-Curies bombarded aluminum with alpha particles to produce a radioactive isotope of phosphorus. This was the first example of induced radioactivity.

$${}_{13}Al^{27} + {}_{2}He^{4} \rightarrow {}_{15}P^{30} + {}_{0}n^{1}$$

The radioactive phosphorus then decays to a stable isotope of silicon.

$${}_{15}P^{30} \rightarrow {}_{14}Si^{30} + {}_{+1}e^{0}$$

Beta decay in induced radioactivity includes the emission of positive electrons (positrons) as well as negative electrons from nuclei.

Examples:

$${}_{29}Cu^{64} \rightarrow {}_{28}Ni^{64} + {}_{+1}e^{0}$$

$${}_{11}Na^{24} \rightarrow {}_{12}Mg^{24} + {}_{-1}e^{0}$$

Neutrons were first discovered by bombarding beryllium with alpha particles.

A very penetrating form of radiation resulted when beryllium and boron were bombarded by alpha particles.

$${}_{4}Be^{9} + {}_{2}He^{4} \rightarrow {}_{6}C^{12} + {}_{0}n^{1}$$

This radiation was identified by Chadwick in 1932 as the neutron.

Topics	Understandings and Fundamental Concepts	
	In nuclear reactions neutrons are often used as bombarding particles because they are uncharged and are not repelled by nuclei. When they are very close to a nucleus they are attracted by it.	It is not ne energy in o reactions; i slowed down the nucleus. neutrons col they do not
F. Nuclear fission	Fission is the breaking of a nucleus. The fragments are, usually, nearly equal in atomic number. Only certain massive nuclei are fissionable.	When slow th U^{235} nucleus parts. This emission of by the relea written: $_{92}U^{235}$ + (Where F_1 and the average Q represents The energy r heavy elemen binding ener average bind
1. Thermal neutrons	Thermal neutrons are neutrons with kinetic energies approximating those of molecules of substances at ordinary temperatures.	Fission of U
2. Moderators	Moderators are materials which are used to slow down neutrons.	When neutron they collide kinetic ene material. The neutrons in elastic The most ef of similar an equilibr

n nuclear reactions neutrons are ften used as bombarding particles ecause they are uncharged and are ot repelled by nuclei. When they re very close to a nucleus they are ttracted by it.

It is not necessary to give neutrons high kinetic energy in order for them to participate in nuclear reactions; it may even be better for them to be slowed down so they may spend some more time near the nucleus. This may be accomplished by letting neutrons collide with nuclei of small mass with which they do not interact.

ission is the breaking of a nucleus. he fragments are, usually, nearly qual in atomic number.

nly certain massive nuclei are issionable.

When slow thermal neutrons are absorbed by U^{235}, the U^{235} nucleus splits, usually into two nearly equal parts. This fission process is accomplished by the emission of a certain average number of neutrons and by the release of energy. The reaction might be written:

$$_{92}U^{235} + {}_0n^1 \rightarrow F_1 + F_2 + \eta\, {}_0n^1 + Q$$

Where F_1 and F_2 are fission fragments, η represents the average number of neutrons emitted per fission, and Q represents the energy.

The energy released per nucleon in the fission of a heavy element is the difference between the average binding energy/nucleon of the original element and the average binding energy/nucleon of the elements formed.

hermal neutrons are neutrons with inetic energies approximating those f molecules of substances at rdinary temperatures.

Fission of U^{235} is induced by thermal neutrons.

oderators are materials which are sed to slow down neutrons.

When neutrons give up energy to nuclei with which they collide, they may finally slow down until their kinetic energy approximates the thermal energy of the material.

The neutrons are slowed down by losing kinetic energy in elastic collision with the nuclei of the moderator. The most effective is a head-on collision with a particle of similar mass. Neutrons in a moderator soon reach an equilibrium state with the atoms of the moderator.

Topics	Understandings and Fundamental Concepts	
		The neutro energies a
		Materials paraffin, the purpo
G. Fusion	Fusion is the process of combining two light nuclei to form a heavier one.	Various is helium an $_{1}H^{3}$ + $_{1}$

The neutrons in this state have the same average kinetic energies as molecules of gases at ordinary temperatures.

Materials containing hydrogen, deuterium, carbon, water, paraffin, and graphite are most commonly used for the purpose of slowing neutrons.

Fusion is the process of combining two light nuclei to form a heavier one.

Various isotopes of hydrogen may combine to produce helium and release energy.

$${}_{1}H^{3} + {}_{1}H^{1} \rightarrow {}_{2}He^{4} + Q$$