STATE OF IOWA
1930

Courses of Study for High Schools

PHYSICS

Issued by the Department of Public Instruction
AGNES SAMUELSON, *Superintendent*

Published by
THE STATE OF IOWA
Des Moines

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FOREWORD

This course of study is one of a series of curriculum publications to be presented the high schools of the state from time to time by the Department of Public Instruction. It has been prepared by a subject committee of the Iowa High School Course of Study Commission working under the immediate direction of an Executive Committee. If it is of concrete guidance to the teachers of the state in improving the outcomes of instruction, the major objective of all who have contributed to its construction will have been realized.

From the start the need of preparing working materials based upon cardinal objectives and adaptable to classroom situations was emphasized. The use of the course of study in the development of proper pupil attitudes, ideals, habits, and skills was the criterion for selecting and evaluating subject matter material. At the same time it was important to consider the relation of the single course of study unit to the variety of textbooks used in the high schools of the state. The problem before the committees was that of preparing suitable courses of study representing the best in educational theory, practice, and research, and organized in such a way as to guide the teachers in using the textbook to greater advantage in reaching specified outcomes of instruction.

The selection of texts in this state is a function of the local school boards. The Department of Public Instruction and the committees do not recommend any particular text as essential to the working success of this course of study. The titles listed on the following pages are not to be interpreted as having official endorsement as against other and newer publications of value. They were found upon investigation to be in most common use in the high schools of the state at the time the units were being prepared; a follow-up survey might show changes.

Although many valuable studies have been made in the effort to determine what to teach and how to teach it, and to discover how children learn, these problems have not been solved with finality. For that reason and because no fixed curriculum can be responsive to changing needs, this course of study is to be considered as a report of progress. Its revision in accordance with the enriched content and improved procedures constantly being developed is a continuous program of the Department of Public Instruction. Your appraisal and evaluation of the material as the result of your experience with it are sincerely requested.

ACKNOWLEDGMENTS

The Department of Public Instruction takes this opportunity of thanking the many college specialists, school administrators, and classroom teachers who have helped with this program. Without the active coöperation of the educational forces of the state it could not have been attempted. It has had that coöperation both in general and specific ways. The support given by the Iowa State Teachers Association and the High School Principals' Section has enabled the Executive Committee to meet and also to hold meetings with the Commission as a whole and with the chairman of subject committees.

Special acknowledgment is given the Executive Committee for its significant leadership in organizing the program and to Dr. T. J. Kirby for his valuable services in directing its development. Sincere gratitude is also expressed to the various committees for their faithful and skillful work in completing the subject matter reports assigned them and to Dr. C. L. Robbins for his careful and painstaking work in editing the manuscripts. The state is deeply indebted to the High School Course of Study Commission for its expert and gratuitous service in this enterprise. Credit is due the publishers for making their materials accessible to the committees and to all who served in advisory or appraisal capacities. Many of their names may not have been reported to us, but we acknowledge our appreciation to every one who has shown an interest in this significant program.

In the following committee list, the positions held by members are given as of the school year 1928-1929.

IOWA HIGH SCHOOL COURSE OF STUDY COMMISSION

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Neil Lutes, Science Department, High School, Dubuque
Wm. B. Zuker, Head of Department of Chemistry, University of Dubuque, Dubuque

AGNES SAMUELSON
Superintendent of Public Instruction

GENERAL INTRODUCTION

At the first general meeting of the various subject committees a suggestive pattern for the courses of study, embodying the fundamental needs for teaching, was projected. Four crucial factors that should be emphasized in any course of study to make it an instrument that would cause teachers to consult it for guidance in the performance of their daily work were set forth as follows: objectives, teacher procedures, pupil activities, and evidences of mastery.

Objectives—The meaning of objectives as here used is those concepts which are set up for pupils to achieve. As used in current practice, there is a hierarchy of objectives as shown by the fact that we have objectives of general education, objectives for various units of our educational system such as those proposed by the Committee on Cardinal Principles, objectives for subjects, objectives for a unit of instruction, and objectives for a single lesson. In each level of this hierarchy of objectives a constant element is expressed or implied in the form of knowledge, a habit, an attitude, or a skill which pupils are expected to acquire.

In the entire field of secondary education no greater problem confronts us than that of determining what these fundamental achievements are to be. What shall be the source of those objectives, is a problem of too great proportions for discussion here, but it is a problem that each committee must face in the construction of a course of study. A varying consideration of objectives by the various committees is evident in the courses of study they have prepared. The value of the courses varies in terms of the objectives that have been set up, according to the value of the objective in social life, according to the type of mental techniques which they stimulate and exercise, and according to the objectivity of their statement.

Pupil Activities—In our educational science we are attaching increasing significance to self-activity on the part of the learner. Recognition is made of the fundamental principle that only through their own activity pupils learn and that the teacher's rôle is to stimulate and direct this activity. No more important problem faces the curriculum-maker than that of discovering those fundamental activities by which pupils learn. In a well-organized course of study, that series of activities, in doing which pupils will attain the objectives set up, must be provided. These activities must not be chosen in a random fashion, but care must be taken that appropriate activities for the attainment of each objective are provided.

Teacher Procedures—With the objectives determined and the activities by which pupils learn agreed upon, the function of the teacher in the pupil's learning process must be considered. In a course of study there should appear those teacher procedures of known value which make learning desirable, economical, and permanent. Here our educational science has much to offer. Where research has demonstrated with a high degree of certitude that a given technique is more effective in the learning process than others, this technique should be included in a course of study. Common teaching errors with sug-

gested procedures to replace them may be included. Pupil difficulties which have been discovered through research should be mentioned and methods of proven value for meeting these difficulties should be included. Suggested ways of utilizing pupils' experiences should be made. And as important as any other feature is the problem of motivating learning. Whatever our educational research has revealed that stimulates the desires of pupils to learn should be made available in a course of study. Valuable types of testing should be incorporated as well as effective type assignment. The significance of verbal illustrations as evidence of comprehending the principle at issue should be featured as a procedure. Where there is a controlling procedure of recognized value such as is recognized in general science—bringing the pupil into direct contact with the phenomena studied—forceful effort for the operation of this procedure should be made.

Evidences of Mastery—What are to be the evidences of mastery of the objectives set up? There are all degrees of mastery from the memoriter repetition of meaningless terms up to a rationalized comprehension that shows grasp of both the controlling principles involved and the basic facts necessary to a clear presentation of the principles. These evidences of mastery may be in the form of dates *to be known,* formulae *to be able to use,* types of problems *to be able to solve,* quality of composition *to produce,* organization of materials *to be made,* floor talks *to be able to give,* papers *to be able to write.*

In no part of educational procedure is there need for more effort than in a clear determination of those evidences, by which a well-informed teaching staff can determine whether a pupil has a mastery of the fundamental objectives that comprise a given course. As we clarify our judgments as to what comprises the essential knowledge, habits, attitudes, and modes of thinking involved in a certain course, we can set forth with more confidence the evidences of mastery. Teachers are asking for the evidences of mastery that are expected of pupils, and courses of study should reveal them.

While these four elements constitute the basic pattern, the principle of continuity from objective to pupil activity, to teacher procedure, to evidence of mastery was stressed. The maker of a course of study must bear in mind that what is needed is an objective having accepted value; a pupil activity, in performing which, pupils gain a comprehension of the objective that is now being considered; that a teacher procedure is needed which evidence has shown is best adapted to stimulating pupils to acquire this objective for which they are striving; and that evidences of mastery must be incorporated into the course by which to test the degree of comprehension of the objective now being considered.

The courses of study vary in the degree to which these four fundamental features have been objectified and in the degree to which the principle of continuity from objective to evidence of mastery has been cared for. On the whole they will provide effective guides which teachers will use.

Realizing that these courses of study were prepared by school men and women doing full time work in their respective positions, one fully appreciates the professional zeal with which they worked and the splendid contribution to high school education which they made.

THOMAS J. KIRBY,
Chairman of the Executive Committee

COURSE OF STUDY IN PHYSICS

In presenting this outline of objectives, activities, procedures, and evidences of mastery as a guide to the teachers of physics in the high schools of Iowa, the committee realizes that such an outline at this time is but a first attempt to get teachers to think more constructively in terms of what should be good physics teaching. It is to be hoped that the ideas presented and the suggestions which are made will bear fruit in bringing the teacher to think more critically of his work as a director of pupil activity in this important science.

An outline of this kind serves best those who make constructive use of its content and note down on margins the items which should be included, revised, or omitted. Future outlines should reflect the experience resulting from this earliest attempt at organization. The members of the committee, indeed, anticipate the time when a second and more complete edition of this outline can be prepared for the guidance and inspiration of those who teach physics in our secondary schools.

INTRODUCTION

General Objectives

The pupil is to acquire the ability

To think on his own account about the hows and the whys of the physical world in which he lives

To observe phenomena and to organize his observations and information into coherent units of understanding

To perform experiments either as an individual or as a member of a small group, with the experimentation showing definite knowledge of what the problem is and what steps are being taken to solve it

To display the results of an experiment by some device such as drawing a graph, showing data in tabular form, preparing schematic diagrams, etc., and to discuss from such devices the meaning and the accuracy of the results obtained

To know such theories, principles, laws, etc., as are commonly recognized as fundamental in a first course in physics

General Teacher Procedures

Determine by pre-test the extent of pupil's present knowledge of each unit about to be studied

Devise ways to relate the pupil's advance to new knowledge to previous experience and grasp of knowledge relating to the unit.

Point out to the pupil early in the study of a unit, the material he is expected to master and the extent to which he is expected to attain mastery

Plan lecture-demonstrations so that pupils will be stimulated to read intensively for additional information on the topic being presented

Choose laboratory experiments for the individual pupil which will center his attention on phenomena which need to be observed first hand if he is to realize their significance

Devise ways of stimulating pupils to seek and give explanations of phenomena which come within their range of observation

Select and provide the setting for problem type questions to be solved by the class to stimulate thinking in terms of the unit being studied

Pupil Activities

Recall the facts previously learned about the unit being studied

Read assignments which will give information as to what knowledge there is about the unit which is being studied

Observe and make a note of observations in connection with demonstrations by teacher and members of the class

Recall phenomena observed outside the limits of the classroom

Give oral and written explanations in acceptable language of various phenomena after preparing for such explanations by further directed observation and reading

Prepare and give oral and written discussions on topics which have been suggested by the study of a unit

Learn definitions of all the more important terms used in discussing the unit

Learn the important generalizations which the study of the unit is designed to establish

Perform laboratory experiments alone and as member of a small group

Tabulate data and observations in connection with experiments performed in the laboratory

Prepare diagrams to illustrate how apparatus is used in producing and measuring phenomena

Prepare graphs to show relationship between quantities that vary to show the nature of the variation

Work simple problems in which the principles being studied find an application

Make field trips and investigate applications of physical phenomena as found in the industrial life and in the shops and homes of the community

Read references in magazines and books which relate to the unit being studied

Outline and carry on individual projects in connection with a unit

Evidences of Mastery

Ability to

Define important terms readily

State laws and principles correctly

Solve problems of one step correctly

Give oral reports in an interesting and authoritative manner

Recognize important terms in their proper settings

Explain observed phenomena in terms of physics which has been acquired

Use a scientific method of procedure in doing class work and laboratory experiments

Distinguish between relevant and irrelevant material when preparing discussions and papers

Prepare and give oral and written explanations of phenomena in terms of newer and better organized knowledge

Solve problems where there are successive steps in reaching the final solution

Appreciation of

The tremendous industrial development which has followed in the wake of scientific study and discovery

Realization

That changes in social conditions come from the application to industry of the principles discovered as a result of careful and exhaustive research by men of science

Attitude of

Inquiry and investigation

General Objectives	General Teacher Procedures
To define the terms ordinarily used in discussing these theories, principles, laws, etc., and the phenomena with which they deal	Indicate numerical problems whose solution by the pupil will clarify and fix more definitely in his mind the principles involved in their solution
To compute with a fair degree of success, such verbal problems as involve a simple and direct application of some principle of physics in obtaining a solution	Outline individual projects and reports, the preparation and completion of which will afford the pupil a chance to express himself in terms of recently acquired knowledge
To grasp the meaning of physical phenomena and to develop a technique which will enable him increasingly to apply his knowledge of physics as needs for such use are presented by his environment	Select the type of report required in connection with experiments which is best fitted to make significant to the pupil the meaning of the unit it is to illustrate
To use the sources to which one may go to locate material on a topic about which information is being sought and to be discriminative in selecting the sources and information of most value	Stimulate the pupil to make each formal production he prepares worthy of a place on any class program or on the bulletin board
To recognize questions for which physics can furnish a solution and to feel the need of proceeding in an orderly way to find one	Find, and encourage pupils to find, illustrative material which the community possesses to relate the study of a unit to their usefulness as members of the community
To have confidence in the guidance of physics and to turn to it for guidance as problems present themselves for solution	Devise problem situations, test-study material, and tests which will motivate pupils to study fundamental theory which may not of itself possess any compelling interest for stimulating intensive study
To adopt a scientific attitude which reveals itself in the presence of a new situation	Gather from the pupil's questions, the mistakes he makes, and the difficulties he encounters, the points that need further attention, and make them the point of departure for further instruction and study
To see the social significance of the various discoveries of physics and of the scientific methods by which they are found	Give and encourage pupils to give original verbal illustrations of principles
To appreciate the part that the intelligent application of the principles of physics has played in our industrial development	Point out to pupils at opportune times the mental habits which have enabled men to become leaders of scientific thinking in their generation
To speak and write about common physical phenomena with evidence of ability in applying knowledge of physics to the situation being discussed	Check results by practical problems developed from the pupil's own observations
	Encourage pupils to find illustrations of all principles in their environment

Pupil Activities	Evidences of Mastery
Study lists of thought questions and formulate a set of answers in light of newly acquired ideas and an enlarged view of the unit	*Habit of*
Summarize and relate the various units which are studied	Tabulating data systematically and with increasing accuracy as the course progresses
Give original verbal illustrations of principles developed	Preparing diagrams to illustrate important concepts of physics in their application to the needs of home and industrial life
	Gathering current information from magazines, newspapers, etc., such as references, abstracts, pictures suitable as illustrative material in connection with class work
	Seeking sources of newer and better information about physics
	Volunteering explanations of questions about difficulties met with or information desired by other members of the class

I. WORK, POWER, AND THE SIMPLE MACHINES

Unit Objective

To learn from the study of simple machines what work is and how it may be measured and completely accounted for

Specific Objectives

To know for what purpose we use machines

To know mechanical advantage as the ratio of resistance to effort

To understand that a gain in the mechanical advantage of a machine, involves a corresponding loss in the distance the resisting force is overcome

To learn how to use the six simple machines to obtain mechanical advantage in lifting heavy bodies

To see in complex machines a combination of the simple machines

To know that both force and distance, must be taken into account to calculate an amount of work

To regard power as the rate of doing work

To understand the part that friction plays in the operation of machines

To know the use to which a table of coefficients of friction may be put

To learn the meaning and relationship of the terms: output, input, efficiency

Teacher Procedures

Find out what simple machines pupils know, and what questions they would like to have answered about machines

Carry on the class discussion in form of solution of problems dealing with equilibrium of levers

Show experimentally the similarity of the two types of single pulley to levers of the first and second class, also to the wheel and axle

Use simple experiments to illustrate the principle of work and the terms used in discussing it

Bring clearly to mind of the pupils the meaning of work and the factors upon which it depends

Point out the similarity and the differences of the terms, work and power

Discuss the inefficiency of various machines. Devise ways of determining actual values. Also get pupils to suggest means whereby efficiency may be increased

Make plans for the experimental determination of force of friction between paving and automobile tires

Make the discussion of such an experiment in connection with the use of the four-wheel and the two-wheel brake, the means of getting the class to see the factors affecting friction between two surfaces

Take advantage of trips to various places of interest in locality. Have pupil propose list of machines that he saw on trip for class discussion (Suggested places: garages, machine shops, round house, steam shovel, etc.)

Pupil Activities

Formulate an answer to the question, "Why do we use machines?"

Read for information about the lever, and its applications

Use a simple lever to find the weight of some object

Perform an experiment in which the lever's own weight must be considered

Draw diagrams of the three classes of levers, and the various forms of wheel and axle, and work out a common equation for both

Determine the mechanical advantage of some block and tackle by experiment. Get additional data from which to study the efficiency of the block and tackle

Solve verbal problems which involve using different units of work and computing the output, input, efficiency and power of various devices

Determine the force of friction when a piece of rubber tire is pulled beneath a paving block. Vary the conditions of downward pressure, area of touching surfaces, and lubrication

Solve problems, the solution of which is made possible by consulting tables of coefficients of friction

Read assignments made by teacher for definite ideas on how to apply knowledge concerning factors which affect friction between surfaces to the discussion of relative values of the four- and the two-wheel brakes

References

Barnard, Charles, *Tools and Machines*, Silver Burdett

Handbook of Physics and Chemistry, The Chemical Rubber Company, Cleveland, Ohio

Handbook of the Willys-Knight auto for material on sleeve valve

Any auto handbook for the four-wheel brake

Evidences of Mastery

Ability to

Define moment of force, center of gravity, mechanical advantage, velocity ratio, grade, power, work, horsepower, friction, coefficient of friction, efficiency

State

The principle of moments

The principle of work

Three conditions of stability

Make floor talks on

Construction of platform scales

Sleeve valves *vs.* spring valves in auto engines

Roller bearings or ball bearings *vs.* sliding bearings

Friction as a necessity in our industrial development

Four-wheel brakes *vs.* two-wheel brakes

Recognize in the proper connection

Effort, effort arm, effort distance, resistance distance, arm, etc.

Input, output, gm-cm, ft-lb., fixed pulley, movable pulley, etc.

Solve problems where

Moments of force must be considered

Output or input is calculated

Efficiency of machines has to be taken into account

Mechanical advantage is to be found

Horsepower is a factor of solution

Knowing the coefficient of friction enables force of friction between two surfaces to be solved

II. PRESSURE AND BUOYANCY

Unit Objective

To learn and apply important principles relating to the phenomena involved in pressure and buoyancy in fluids

Specific Objectives

To recognize pressure as the definite push on a specified unit of area, and to know that gravity pressure in a liquid is proportional to the density of the liquid and to the depth at which the pressure is found

To know that the pressure in a liquid at a given depth is equal in all directions and is independent of the shape and size of the container

To understand that pressure upon an enclosed fluid is transmitted undiminished in every direction (Pascal's Law)

To recognize the application of Pascal's Law in the hydraulic press, hydraulic brakes, pneumatic drills, etc.

To understand how the pressure of the atmosphere may be determined by measuring the height of the mercury it will support

To appreciate the use made of mercurial and aneroid barometers in weather forecasting and in aviation and aeronautics

To recognize that pumps and siphons owe their action to the fact that air pressure will support liquid columns in a vacuum

Teacher Procedures

Make clear to the pupil what is meant by the term pressure. Point out the factors which determine gravity pressure in a liquid

Demonstrate with suitable experiments that pressure at a given depth in a liquid is equal in every direction but independent of the size or the shape of the container

Explain the action of the hydraulic press showing how a small pressure may be the means of exerting an enormous lifting or crushing force. Show how the principle of work is exemplified in such a device

Use air pump, mercury, and glass tube to show that air pressure will support a column of mercury 29 or 30 inches in length

Show in general discussion how knowing the barometer reading enables the pressure of air to be calculated

Explain the altimeter used by aviators as a modification of the aneriod barometer

Make the data obtained by pupils a starting point for explaining how, if the volume of liquid displaced by either a submerged or a floating body were known in advance, knowing its density would enable the displacement to be calculated

Suggest the possibility of using known values of the density of air and of hydrogen (or helium) to calculate the lifting power of some airship whose dimensions are known

Point out the difference between specific gravity and density. Show how knowing the specific gravity of a substance enables its density to be determined

Pupil Activities

Recall facts learned in general science and in other studies about the pressure of the atmosphere. Observe experiments to emphasize the facts that air exerts pressure

Calculate simple problems to determine the gravity pressure of liquids of various densities, —the depth and unit being specified in each case

Read for definite information the early history of the barometer as a means of measuring atmospheric pressure

Find out how aneroid barometer construction enables it to measure air pressure. Find out how the use of barometer has become of great value in weather forecasting

Study diagrams in reference texts to learn how the action of pumps and siphons depends on the fact that air pressure will support liquid columns in a vacuum

Determine the overflow of several solids in water and make measurements of weight, volume of displacement, etc., upon which to base conclusions as to why bodies lose weight, sink, float, etc., when placed in liquid

Weigh accurately an electric light bulb (vacuum) before and after puncturing. Measure its volume by filling the punctured bulb with water from a graduated cylinder. Use the data found this way to calculate the density of air under laboratory conditions

Solve problems involving the calculation of the lifting effects of various devices from known densities and dimensions

Learn what specific gravity is and how to find it. Determine the specific gravity of a substance which will sink in water

Evidences of Mastery

Ability to

Prepare diagrams from which to explain action of aneroid barometer, operation of siphon, difference in action of force pump and lift pump, and principle of the hydraulic press

Define density, specific gravity, pressure and one atmosphere

Recognize in the proper connection:

62.4 pounds per cubic foot as the density of water

Pounds per cubic foot and grams per cubic centimeter as units of density

Pounds per square inch and grams per square centimeter as units of pressure

State

Archimedes' Principle, general rule for finding the specific gravity of substances

State and apply

Pascal's Law

Four ways of stating the pressure of the air

How barometer readings may be taken to determine changes in altitude

Give floor talks on

Future of lighter-than-air craft

Using the barometer to forecast the weather

How the deep sea diver must take account of pressure

Raising of the undersea boat S-4

Building the Holland tunnel

Specific Objectives	Teacher Procedures
To know that the loss of weight of a body placed in a fluid is equal to the weight of the fluid displaced	Explain the principle of the hydrometer. Point out that a body floats because the forces pushing up on it are in equilibrium with the forces pulling it down
To learn how to determine the density of a substance and how to utilize the information which a table of densities gives	
To calculate the displacement of floating and submerged bodies	
To know methods of finding the specific gravity of a substance	
To use the known value of specific gravity of a substance in finding its density and in making an estimate of its buoyancy	
To understand the use of the hydrometer in determining the specific gravity of liquids and to know some practical uses to which it is adapted	

Pupil Activities	Evidences of Mastery
Determine the specific gravity of some liquid by the displacement method	Flowing wells
Use hydrometers to determine the specific gravity of various liquids. Learn special uses which are made of hydrometers in every day life (automobiles, milk, gasoline, etc.)	Solve problems calculating
	Density
	Specific gravity
	Displacement of ships and airships
	Pressure at a given depth
	Force exerted by large piston on hydraulic press
	Total force on bottom of tank
	Total force against dam
	Altitude from barometer reading

III. THE MOLECULAR KINETIC THEORY OF MATTER

Unit Objective

To learn important conceptions about the molecular structure of matter

Specific Objectives

To learn that evaporation may be explained by the movement of the molecules of the liquid

To regard cohesion, adhesion, and surface tension as being caused by forces of attraction between the molecules of the material

To explain capillary phenomena and to know the factors upon which they depend

To regard diffusion in liquids, gases, and solids as evidence of molecular motion

To explain osmotic pressure by the molecular theory

To regard the pressure of an enclosed gas as due to the molecular bombardment against the walls of the container

To learn that the pressure of a given mass of gas at constant temperature is inversely proportional to the volume (Boyle's Law)

To learn that a stress upon elastic material produces a strain which is proportional to the stress (Hooke's Law)

To regard the expansion of a gas caused by an increase in temperature as being due to the increase in the average molecular speeds

Teacher Procedures

Start by making a list of things to explain in terms of what will be learned in this unit (Should be mimeographed and furnished to each pupil. High school texts contain numerous exercises along this line)

Suggest that this unit will give better ways of explaining these phenomena

Discuss the pupils' findings about evaporation and lead pupils to think of the process in terms of the motion of the molecules

Make clear to the pupils the way forces of attraction between the molecules may be considered the cause of phenomena such as cohesion, adhesion, and surface tension

Demonstrate how a needle or a safety razor will float on the surface of water and explain the molecular forces which make such phenomena possible

Perform experiments showing the behavior of water and mercury in capillary tubes

Show some experiments of diffusion which can be explained only on the basis of molecular activity

Present the idea that the pressure of an enclosed gas is due to the bombardment and that the changes in pressure are determined by the changes in the number of blows per second on unit area

Make clear the meaning of stress and strain

Point out five kinds of stress. Emphasize elasticity as being due to forces which exist between the molecules of an elastic substance

Pupil Activities

Make a list of the facts about evaporation which pupils know from their experience

Using various texts as references, prepare a list of the laws of evaporation to be learned

Select from the mimeographed list, those phenomena whose occurrence is wholly or partly due to cohesion, adhesion, or surface tension

Give some interesting examples of surface tension from pupil's own experience and observation

Learn two important rules about capillarity

Give some instances of capillary action

Make a list of cases where capillary phenomena are being used to our advantage

Find diagrams suitable for explaining the action of forces which determine the capillary action for a tube of given size and explain from them why water rises differently when capillary tubes of different diameter are used

Observe diffusion experiments performed by teacher or by a group of pupils and explain observations by molecular activity

Determine experimentally the effect on the volume of an enclosed gas when different pressures are applied

Memorize Boyle's law

Solve problems where use is made of the expression $P V = P'V'$

Perform and observe experiments involving the measurement of strains produced by various types of stresses

Learn the meaning of elastic limit, fatigue, factor or safety, etc.

Memorize Hooke's law

Solve problems involving the use of Hooke's Law

Recall expansion effects which the pupil has noted from previous reading and experience

Evidences of Mastery

Ability to

Define cohesion, adhesion, surface tension, stress, strain, elastic limit, elastic fatigue, elasticity

Solve problems

Involving simple applications of Boyle's Law, Hooke's Law

State rules of importance relating to

Factors affecting rate of evaporation

Elevation or depression of liquids in capillary tubes

Relation of strain to stress when an elastic material is under stress

Relation between volume and pressure of an enclosed gas

Expansion of substances

Give floor talks on

Better methods of testing the strength of materials

Capillarity as it is useful to our community

Molecular physics and better steel machines and skyscrapers

Making the new stadium safe

Explain in terms of the molecular structure of matter

How evaporation takes place

How surface tension makes it possible for a steel razor blade to float on the surface of water

How heating a gas increases its pressure if confined, or increases the volume if free to expand

Specific Objectives

To regard the changes of state of a substance, *e.g.*, ice to steam, as differences in the intensity of vibration and in freedom of motion of the molecules of the substance

To regard all matter as being composed of molecules which are in motion and whose motion is being affected by the forces which exist between molecules and by the energy which is being supplied or subtracted

To regard the molecules of substances as being in motion and to know that forces of attraction exist between molecules of the same or different substances

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Millikan, R. A., *Molecular Physics and Heat,* Ginn

Stewart, O. M., *A Physics for Colleges,* Ginn

Science Bulletin, Iowa State Teachers College, Cedar Falls, Vol. I, No. 5, March, 1929

Teacher Procedures

Discuss what effect the increased activity of the individual molecules may have on the size of a given body

Summarize the facts which this unit has presented to show that the molecules of gases, liquids, and solids are in motion

Pupil Activities

Prepare in outline form the facts which the study of this unit has explained and the points in the molecular kinetic theory which have made the explanation possible

Evidences of Mastery

Identify easily

Illustrations of phenomena due to surface tension, cohesion, adhesion, capillarity, expansion, diffusion

Give facts which support the following points of the molecular theory

Molecules of a substance are in motion

Molecules of a substance move faster at higher of two temperatures

Molecules of different substances have different average velocities at the same temperature

Forces of attraction exist between molecules of the same and of different substances

IV. FORCE, MOTION, AND ENERGY

A. Composition and Resolution of Forces and Motions

B. Acceleration, Inertia, Momentum, and Interaction

C. Kinetic and Potential Energy

Unit Objective

To learn better ways of thinking about the forces and motions which affect us and the universe in which we live

Specific Objectives

A. To learn what a force is and how unit force differs from unit mass

To know how to give a complete description of a force and how to represent single and concurrent forces by means of arrows

To learn the various methods of calculating the sum of concurrent forces and to apply them in finding the resultant of concurrent forces at any given angle

To know how to resolve a given force into desired components in given directions

To solve readily simple problems involving practical application of the principle of the parallelogram of forces

To regard the method of the parallelogram as it is applied in the composition and resolution of forces as an extension of the fundamental processes of addition and division

Teacher Procedures

A. Start with a discussion of ways in which two concurrent forces (*e.g.*, 3 lbs. and 4 lbs.) may be added according to the angle they make with each other. Their sum may be 7 to 1 or 5 for the special angles 0°, 180°, and 90°. Explain the parallelogram method as a special means of adding forces when the angle has other values than the ones already given. A real problem requiring solution by this method can be presented by using three cords fastened together as follows: Two of the free ends can be fastened to a pair of spring balances at the top of the blackboard, the other free end to a screw eye in the floor and drawn taut so the balances have sizeable readings. The pull-up on the screw eye is to be determined. Pupils see more easily that the resultant is a substitute force, if after the parallelogram has been completed at the blackboard and the resultant found, the teacher will erase the lines representing the original forces and check the result by using a third balance on the end of the cord leading to the floor so directed as to make the origin coincide with the previous setting

Illustrate resolution of forces by computing the pulls on hooks holding the ends of a hammock due to the weight of a person lying in it. The push on a lawn mower handle and the pull on the rope in drawing a sled furnish good situations for group discussion of resolution of forces into desired components

Pupil Activities

A. Become familiar with the meaning of terms used in applying the parallelogram method to problems dealing with concurrent forces and motions

Determine by experiment the resultant and the equilibrant of two known forces at some given angle

Make a list of steps to be carried out in determining the resultant of two concurrent forces at some given angle

Use a crane boom and determine experimentally the magnitude of the push of the boom and the pull by the boom cord necessary to hold a known weight at some given position of the crane

Solve problems where resultants of forces are to be found and others where forces are to be resolved into components, choosing the appropriate algebraic or graphic method in each case

Find out how the wing of an airplane may be made to lift its own and passenger weight, and use a diagram to show how these forces act concurrently

Draw diagrams and from them explain how proper methods of tacking enable a yachtsman to sail his craft into the wind

Evidences of Mastery

A. Ability to

Give in the margin the correct response in a word or phrase for figures in parenthesis.

Forces may be represented by (1). 1.....

Three characteristics of a force may be represented in this way. They are: first, its (2), second its (3), and third its (4). 2..... 3..... 4.....

When two forces act simultaneously upon a body the result will be the same as if a single force called their (5) is substituted for them. 5.....

In finding the magnitude of the (5) of two forces the result may be determined by the principle of the (6) of forces. 5..... 6.....

When the (6) is drawn in such a solution the forces are drawn to some convenient (7). The diagonal of such a (6) then represents the (8) of the forces thus represented 7..... 6..... 8.....

In finding the (14) of two forces which go in the same direction, we find their arithmetical (15). If they go in opposite directions from the origin we find their arithmetical (16). When they are at right angles to each other we apply 14..... 15..... 16.....

Specific Objectives

B. To learn the units used in telling velocities and accelerations

To know and apply the laws governing the motion of bodies whose speed is increasing or decreasing at a uniform rate

To gain correct ideas about the factors upon which the motion of falling bodies depends

To recognize that the motion of falling bodies follows the laws of uniformly accelerated motion

To know how the period of a pendulum is affected by changes in its length and in the acceleration of gravity

To learn from Newton's Laws of Motion the ways in which a body's state of rest or motion is affected by the application of force

To interpret correctly the terms inertia, momentum, reaction as used in stating Newton's Laws

To know the factors determining the amount of centrifugal tendency which a rotating body possesses and to gain ability in applying this knowledge when discussing situations where the centrifugal tendency appears in devices used in every day life

To know the factors upon which the momentum of a moving body depends

Teacher Procedures

B. Introduce the subject of motion and acceleration with common every day illustrations, *e.g.*, by discussing the factors determining how far an automobile will travel in a given day

Develop the ideas of average velocity, velocity and acceleration and make clear how numbers and units are used to express them

While fairly difficult to demonstrate quantitatively, several teachers have demonstration experiments showing how the space passed over by a body moving with constant acceleration varies with the time. One teacher fills a long resonance tube with brine of such density that an egg will descend, slowly gathering speed as it falls. Another teacher slightly moistens a piece of plate glass and presses a piece of squared paper on it. This is then dusted with lycopedium powder. The glass may be tilted by setting spools at each end of one edge. By projecting a ball horizontally the path of the rolling ball is traced out. When the ball rolls without "English" the path traced may be easily interpreted as successive time intervals plotted against distance descended

Preface the study of Newton's laws of motion by demonstrations of inertia of changes in momentum and of reaction and direct the discussion so as to bring about understanding by the pupil of the concepts embodied in the laws as ordinarily stated

Make use of $F = \frac{wv^2}{gr}$ as a means of discussing quantitively the centrifugal tendency as it appears when an automobile rounds a curve on the highway. Show how each quantity in the formula affects the tendency of the automobile to "skid"

Spring the following as a surprise completion test to be followed by discussion of the points involved

When turning a corner an automobile skids on the roadway when the (a) between tires and road bed is not sufficient to furnish the (b) necessary to balance the (c) tendency. Whenever a car is made to follow a curved path, the (c) tendency appears on account of the (d) of the car. In the formula $F = \frac{wv^2}{gr}$ F means (e), w means (f), v means

Pupil Activities

B. Find an account of Galileo's life in an encyclopedia or history of physics and make a report to the class concerning his idea of the rate of descent of falling bodies, and how his experimental proof brought him into dispute with his contemporaries

Make a list of quantities used and units used to state them when uniform motion and uniformly accelerated motion are considered quantitatively

Find out what rules about accelerated motion were derived by Galileo and learn them. Learn three formulas which represent them and memorize the name of the quantity for which each symbol stands

Solve problems where some quantity (distance, time, acceleration, or velocity) is to be determined relative to a body whose motion is uniformly accelerated. It will be helpful to analyze the problem in the following steps: a. factors given, b. factor to be found, c. law or principle to be used, d. formula and equation, e. quantities stated in consistent units, f. answer in proper unit

Determine by experiment how the period of a pendulum is affected by changes in its length, arc, or mass. Learn what the formula $t = \pi\sqrt{\frac{1}{g}}$ tells us about the periods of pendulums and how the value of g may be determined experimentally by means of a pendulum and the formula

Evidences of Mastery

the (17) theorem to find the value of the (14). For any other directions of the two forces the magnitude of the (15) is found by constructing a (18) with the forces drawn to scale. The (14) is then computed by measuring the (19) of the (18) which passes through the (20) 17.....
14.....
15.....
18.....
14.....
19.....
18.....
20.....

B. Engineers and other scientific men commonly state speeds in such units as (1) 1.....

Measuring an acceleration involves measuring a (2) 2.....

Write the words we say in reading "ft/sec^2". The words are (3) 3.....

While a baseball is dropping from a tower, it has (4) 4.....

A gun is discharged with a muzzle pointed to the sky. While the bullet is rising it has (5) 5.....

Laws of Uniformly Accelerated Motion Law I. If acceleration is constant, the speed (6) 6.....

The formula for Law II is (12) and gives the relation of (13) 12.....
13.....

The formula for Law III is (14) and gives the realtion of (15) 14.....
15.....

Specific Objectives

To gain an appreciation of the universality of the Law of Gravitation

C. To understand what energy is and to know whether a given body possesses it in the form of kinetic or potential energy

To derive the energy equation and to know what quantities enable the calculation of potential (lifted weight) or kinetic (moving mass) energy which a body possesses

To make the proper distinction between the terms momentum, kinetic energy, and inertia when they are used in discussing the motion of a given body (an automobile)

To appreciate the Law of Conservation of Energy and to see its operation in connection with the principle of work met in an earlier unit

Teacher Procedures

(g), g means (h), and r means (i). From the formula we may argue that twice as heavy a car has (j) the tendency to skid, driving a car twice as fast makes its tendency to skid ( ) as great and turning at half the radius makes its tendency to skid ( ) as great

Develop the concept that the acceleration (change of momentum) produced in a body is proportional to the force causing it. Also the idea of unbalanced forces and their relation to acceleration

Perform experiments at the lecture table to demonstrate the exchange of momentum between bodies. Make these the means of giving clear concepts of the changes of momentum with mass and velocity

C. Point a class discussion of some question (*e.g.,* Why does a pendulum once started keep on swinging? or What determines the amount of work the falling pile of a pile driver can do? or What enables the fly wheel of a gas engine to do work between explosions?) so that the need for knowing the energy equation may be made apparent

Make every effort to see that pupils gain correct concepts about energy, its forms, and its transformation and its constancy in the universe

An Iowa teacher has found this exercise helpful at this point

Two cars, one weighing 3000 lbs., the other 4200 lbs. cross line AB together at 40 miles per hour. Each driver pushes in the clutch as line AB is crossed and both cars coast along the level street till they come to a stop. Both cars move for some time because of .....
The lighter car stops first because its .....
The heavier car travels the greater distance because it has .....

Pupil Activities

Make a list of illustrations of inertia which are familiar and decide which are of practical value

C. Recall the meaning of the terms work, output, input, foot pound, kilogram—meter as used in an earlier unit (I)

Given that $F = Ma$ (or $F = \frac{Wa}{g}$) multiply both sides by s and eliminate as where it appears by use of Law III, uniformly accelerated motion. Learn the meaning of each member of the newly derived equation. Note that the first member deals with What force? How far? and that the second part deals with What mass? and How fast?

Evidences of Mastery

Falling Bodies

"Falling is motion at (25) and *second* 25.....
that all falling bodies have (26)" 26.....

Teachers often use the "coin and feather" tube to show (27) 27.....

The formula $t = \pi\sqrt{\frac{1}{g}}$ tells us that t, the (30) of the pen- 30.....
dulum, is directly proportional to (31) and 31.....
inversely proportional to (32). When 32.....
one pendulum is 4 times as long as another the (33) of the 33.....
longer will be (34) 34.....
as long as that of the short pendulum. The same pendulum would swing (35) on the 35.....
moon than on the earth because the
(30) of this pen- 30.....
dulum would be on the moon than on the earth. When a clock loses time we (36) 36.....

C. A thing possesses energy when it (1). Energy is of 1.....
two kinds. Lifting a sledge hammer in driving a stake or stretching a spring when opening a screen door illustrate the kind of energy known as (2). This 2.....
kind of energy may be defined as energy possessed by a body

Teacher Procedures

The following is a helpful exercise for learning in terms of the last objective. A device often used as an illustration of the (a) of energy is the swinging pendulum. While the pendulum is swinging, the energy of the bob is continually being (b) from all (c) at the highest point reached to all (d) as the bob passes the lowest point of the swing. At intermediate points the energy is (e). If left to swing for some time the pendulum will (m) because (n). Lord Kelvin took account of this in making the statement that "whenever (o)

Pupil Activities

Find examples of kinetic energy and potential energy and learn what changes could be made in the examples observed to change the amount of the kind of energy illustrated

Solve problems involving the calculation of amounts of energy from proper data. Learn to think in terms of the kind of energy involved and the quantities which determine its amount

Look for examples of machines in the community in which practical application of the centrifugal tendency has made such machines useful to the community

Memorize Newton's Laws of Motion and be on the lookout for examples of their operation as you observe the motion of objects in and out of school. Classify your own observations and compare with other pupils

Use $F = Ma$ (or $F = \frac{Wa}{g}$) multiply both sides by t and eliminate at where it appears, by the use of Law I, uniformly accelerated motion. Learn the relation of impulse and momentum

Learn how an automobile driver can apply his knowledge of momentum

Memorize Newton's Law of Universal Gravitation. Learn the factors which determine the pull or attraction between bodies *e.g.* a cannon ball and the earth, the earth and the moon, two molecules of lead, adjacent molecules of water and glass

Evidences of Mastery

(3). The energy the sledge hammer has at the instant it meets the top of the stake is an example of the kind of energy known as (4). (4) may be defined as the energy a body possess on account of (5)

The equation $Fs = \frac{Wv^2}{2g}$ is known as the (10) equation. The F means (11), s means (12), W means (13), v means (14), and g means (15). The second member of the equation is useful in calculating the (16) of moving bodies, *e.g.*, of a bullet. It is evident from this that the (17) of a body is proportional to the (18) and (19) of the body can be calculated if (20) are known

In the illustration of the pile driver, the (30) of the moving hammer as it hits the head of the pile is equal to the (31) which the hammer possessed just as it was released for the drop. The physicist describes what happened during the drop by saying that (32). The pile driver is thus an illustration of what is termed by physicists the (33) of energy

V.

EXPANSION AND THE MEASUREMENT OF TEMPERATURE AND HEAT

Unit Objective

To learn how different substances behave when heated and to relate what is learned to getting a better answer to the question, What is heat?

Specific Objectives

To know sources of heat

To know difference between temperature and heat

To know how temperature is measured

To know how thermometers are constructed

To learn how to use the thermometer

To be able to convert Fahrenheit and centigrade thermometer readings

To know the importance of expansion of solids

To know the importance of expansion of liquids

To know that water expands as it is cooled or warmed from 4° C

To know how a gas behaves when both its temperature and pressure are changing

To know the theory of heat

To know how heat is measured

To know what is meant by the heat capacity of materials

References

Thermostat, Minneapolis Heat Regulator Company, Minneapolis, Minnesota

Tycos, Quarterly Magazine, Taylor Instrument Company, Rochester, New York (Also other booklets)

Teacher Procedures

Prepare references, both text and supplementary, on therometry, expansion, heat capacity, and measurement of heat

Prepare and administer problems, drill exercises, tests covering these topics

Stress importance of the use of the thermometer, expansion of materials, and heat capacity as they influence our daily life

Demonstration experiments:

- How thermometer is made
- Fixed points of thermometer
- Abnormal expansion of water
- Expansion of solids, ball and ring, thermostat, etc., the law of heat exchange
- Method of mixtures
- Different heat capacities of various materials

Suggest list of floor talks or written reports for pupils

Secure and make available to pupils supplementary material

Pupil Activities

Perform these experiments

- Fixed points of thermometer (linear)
- Expansion of solid (quantitative)
- Retention of heat by water
- Heat transfer (method of mixtures)
- Heat capacity (specific heat)

Make these diagrams

- Graph for centigrade and Fahrenheit conversion

Go on an excursion

- Weather bureau to see use of thermometers

Examine

- Different types of thermometers
- Materials having different rates of expansion
- Materials having different heat capacities

Give floor talks on

- History of the thermometer
- Importance of expansion of solids in industry
- Sources of heat
- Biography of physicists working on heat investigations

Work problems, drill exercises, tests on:

- Thermometry, expansion, heat capacity, and measurement of heat

Evidences of Mastery

Ability to

State the contributions of Galileo, Fahrenheit, Celsius, Davy, Tyndall, Black

Define the terms:

Temperature, heat, fixed points, expansion, heat capacity, specific heat, maximum and minimum thermometer, clinical thermometer, calorie, B.T.U., method of mixtures, Fahrenheit, centigrade, coefficient, thermostat

Explain

- Meaning of temperature
- The theory of heat
- Expansion of solids
- Expansion of liquids
- Expansion of gases
- How heat is measured
  - Calorie
  - B.T.U.
- Heat capacities of different materials

Perform experiments listed under Pupil Activities

Give floor talks on the topics listed under Pupil Activities

Write reports on experiments

Solve independently

Problems, drill exercises, and tests on conversion of thermometer readings, linear expansion, measurement of heat, heat capacity, and heat exchange

VI. TRANSMISSION OF HEAT—THE FURNACE

Unit Objective

To learn about three methods of heat transfer as they are found in furnaces

Specific Objectives

To know how heat is transmitted through solids, liquids, and gases

To know the meaning of convection

To know the meaning of radiation

To know the meaning and the importance of heat insulators

To know how a building should be ventilated

To know the advantages and the disadvantages of hot-air, hot-water, and steam heating systems

To acquire the working principles of the furnace

References

Bulletin, *Action of Valves,* Hoffman Valve Company, Waterbury, Conn.

Bulletin No. 1, *Humidity in the Home,* Holland Institute of Thermology, Holland, Michigan

Booklets on furnaces of different types from dealers
- Mueller Furnace Company, Knoxville, Tenn.
- Richardson and Boynson Co., New York City

Science Classroom, December, 1926

Tycos, Taylor Instrument Company, Rochester, New York

Booklets and advertisements of insulation materials, celotex, masonite, wood, and mineral

Teacher Procedures

Develop this unit by stressing the application of the methods by which heat is transmitted

Secure and make available to pupils supplementary booklets, pamphlets, bulletins, sales literature, and advertisements of furnaces and insulating material

Secure from furnace dealer small furnace model

Demonstration experiments
- Conduction
- Convection
- Radiation
- Value of insulating materials (celotex, thermofill, masonite, etc.)

Show pupils how your school building is heated
- Discuss univent, split system, etc.

Suggest list of topics for floor talks

Prepare problems, drill exercises, and tests over these topics

Assign to different pupils a discussion of the merits of four types of heating

Pupil Activities

Perform these experiments
- Conductivity of metals
- Thermostat
- Convection currents
- Model hot-water heater
- Radiometer
- Test insulation materials (see advertisements)

Make these diagrams
- Cross sectional of furnaces, hot-air heating system, hot-water heating system

Go on excursions
- Interview furnace dealers
- Inspect heating and ventilating system of your school building or a theater

Examine
- Different heating installation

Give floor talks on
- The advantages of each type of heating system (hot-air, hot-water, steam)
- The univent
- Manufacture of insulating materials
- Sales talk for furnace
- Why use insulating materials in building
- Relation of ventilation and heating to health
- How this high school is heated and ventilated
- How a theater is cooled in summer

Work problems, drill exercises, tests over these topics

Evidences of Mastery

Ability to

State the contributions of Fahrenheit, Celsius, Davy, Dewar

Define the terms
- Conduction, convection, radiation, thermostat, humidifier, insulator, univent, split system

Explain
- The methods of transmission of heat
- The advantages and disadvantages of
  - Hot-air heating
  - Hot-water heating
  - Steam heating
- How buildings are heated and ventilated
- The selection of a furnace

Perform the experiments on
- Conduction, convection, and radiation
- Testing insulating materials
- Give floor talks on the topics listed under Pupil Activities
- Write reports on experiments, exercises, and observations

Solve independently
- Problems, drill exercises, and tests

VII. MELTING AND BOILING

Unit Objective

To know meaning and importance of heat changes involved when solids change to liquids or liquids to solids

Specific Objectives

To know meaning and importance of heat of fusion of water

To know importance of expansion due to freezing of water

To know meaning of melting or fusing point

To know effect of pressure on melting point

To know application of the heat of fusion of ice to our daily life

To know that heat is absorbed when water is converted into steam

To know that heat is absorbed when a liquid changes to vapor

To know what is meant by boiling point

To know effect of pressure on boiling point of water

To know importance of the heat of vaporization of water in our daily life

To know factors governing evaporation

To know importance of relative humidity

References

Pamphlets and booklets on refrigerators, pressure cookers, etc. (Fridigaire and various other companies)

Teacher Procedures

Develop this unit by showing the importance of the heat of fusion and its relation to our social and industrial life

Show importance of the heat of vaporization and its applications

Prepare bibliography of texts and supplementary reading

Secure and make available to pupils booklets on mechanical refrigeration from various manufacturers

Conduct demonstration experiments

- Which is the better refrigerant, ice or ice water?
- The amount of heat required to melt ice
- The amount of heat required to boil water
- Determination of dew point and relative humidity
- Experiments to show factors affecting evaporation

Make (or have pupils make) diagrams of ice plant, mechanical refrigerators, etc.

Suggest list of floor talks

Plan and conduct excursions

- Ice plant, refrigerator display in store, others depending on local conditions

Prepare and administer problems, drill exercises, tests covering these topics

Pupil Activities

Perform these experiments

- Find the amount of heat required to melt one pound of ice (heat of fusion of ice)
- Find the amount of heat required to completely boil a pound of water (heat of vaporization of water)
- Measurements of dew point and relative humidity

Make diagrams

- Cross sectional diagrams of mechanical refrigerator

Go on excursions:

- Ice plant
- Store to see refrigerator exhibits, pressure cookers, etc.

Examine

- Refrigerators
- Humidifiers
- Boilers

Give floor talks

- Freezing of water
- Mechanical refrigeration
- Manufacture of ice
- Sell a refrigerator
- The Frigidaire
- Fractional distillation
- Effect of heat of fusion of ice on climate
- Relative humidity in industry

Work problems, drill exercises, tests on these topics

Show motion picture

Evidences of Mastery

Ability to

State the contributions of Black

Define the terms :

Fusion, vaporization, evaporation, dew point, relative humidity, melting point, boiling point, regelation, sublimation, solidification, condensation, distillation, fractional distillation, refrigerator, condensor, evaporator, wet-dry bulb thermometer

Explain

Meaning and importance of the heat of fusion of ice

80 cal. to melt 1 gr. ice

Meaning and importance of the heat of vaporization of water

540 cal. to boil 1 gr. water

Factors governing evaporation

Perform experiments, qualitative as well as quantitative, listed under Pupil Activities

Give floor talks on topics listed under Pupil Activities

Write reports on topics listed under Pupil Activities

VIII. WORK AND HEAT

Unit Objective

To know how heat energy may be converted into mechanical energy and used to do work and how mechanical energy or work may be converted into heat energy

Specific Objectives

To know quantitative relations existing between work and heat

To know and understand meaning of conservation of energy

To know that friction in the form of wasted work develops heat

To know underlying principles of the steam engine

To know effect of steam engine on the industrial and social life of the American people

To know underlying principles of the steam turbine

To know types of boilers, *i.e.*, water tube, and fire tube

To know underlying principles of the Diesel engine

To know underlying principles of the internal combustion engine

To know what is meant by four-cycle engine

Teacher Procedures

Develop the assignment of this unit with emphasis on the meaning of the development of physics in our social and industrial life as shown by these engines

Stress the importance of the principles of transformation and conservation of energy and their meaning

Furnish pupils with bibliography on history of steam engine and its influence on civilization

Develop importance of these labor saving machines in our industrial and economic life (transportation, power, etc.)

Develop importance of scientific research

Demonstrate or have pupils perform experiments on transformation of mechanical energy into heat energy

Demonstrate or have pupils perform experiments to show quantitative relations between heat and work

Have pupils take excursions to power or heating plants to examine boilers, engines

Secure automobile motor that can be stripped to show operating parts

Secure and make available pamphlets, booklets, diagrams, etc., on boilers, steam engines, Diesel and internal combustion engine

Suggest topics for floor talks or written reports

Prepare problems, drill exercises, and tests on mechanical equivalent of heat, conservation of energy, and the transformation of heat and mechanical energy

Pupil Activities

Perform experiments

- Production of heat by friction
- Mechanical equivalent of heat

Draw diagrams of

- Steam engine
- Four strokes of four cycle engine

Go on excursion

- To power or heating plant to study boilers, engines, and turbines

Examine

- Motor of automobile

Give floor talks on

- Influence of steam engine on advances in civilization
- Substitution of labor-saving machines
- Influence of the automobile on civilization
- History of the steam engine
- Joule's experiments on conversion of mechanical energy into heat
- The steam turbine
- The Diesel engine

Work problems on conversion units of heat and work

Respond to tests, drills, etc.

Evidences of Mastery

Ability to

State the contributions of Joule, Watt, Carnot, Newcomen, Rowland, Rumford

Define the terms

Work, heat energy, mechanical energy, friction, fire tube, water tube, machine, internal combustion engine, reciprocating

Explain

Mechanical equivalent of heat

778 ft.-lbs. equivalent to 1 B.T.U.

427 gr.-m equivalent to 1 cal.

Conservation of energy

That heat energy may be converted into mechanical energy or work, and that mechanical energy or work may be converted into heat energy

Industrial and social importance of steam engine, turbine, internal combustion engine, and Diesel engine

Perform the experiment: mechanical equivalent of heat

Make labeled diagrams of the problems

Give floor talks on topics listed under Pupil Activities

Solve independently:

Problems, drill exercises, and tests

References

Andrade, E. N., *Engines,* Harcourt, Brace

Chart of Locomotive, Railway and Locomotive Engineering, New York

The Balanced Ration, Zenith-Detroit Corporation, Detroit, U. S. A.

Charts Showing Engines and Parts, Norman W. Henley Publishing Company, New York

Elements of the Automobile, V. I. S., Iowa State College, Ames, Iowa (An excellent film, standard size, Reels 4 and 5 explain the engine and reel 6 explains the carburetor)

Fraser and Jones, *Motor Vehicles,* D. Van Nostrand

Inside Information about your Car, Standard Oil Company (Indiana) Chicago (1929)

Notes by Teacher

IX. MAGNETISM

Unit Objective

To gain an understanding and an appreciation of magnets and magnetism in order to relate this knowledge to the interpretation of magnetic effects in connection with the production and flow of the electric current

Specific Objectives

To determine the difference between magnetic, nonmagnetic, and diamagnetic substances

To learn the types of magnets and the methods of making them

To learn how the polarity of a magnet may be determined and how like and unlike poles behave

To determine the fields of force about magnets and how the lines of force travel

To understand the construction and use of the magnetic compass

To learn the difference between temporary and permanent magnets

To understand the meaning of magnetic declination and dip

To understand the molecular theory of magnetism

Teacher Procedures

Tell the history of magnetism

Demonstrate the difference between magnetic and nonmagnetic substances

Explain and demonstrate magnetic induction

Show the fields of force around different types of magnets and between different polar combinations by means of iron filings

Explain and demonstrate permeability

Explain carefully the molecular theory of magnetism

Tell briefly of terrestrial magnetism

Make magnets with a magnet and with a piece of magnetite by induction, and hammering a steel rod in a north-south position

Pupil Activities

Examine magnetite, bar magnets, horseshoe magnets, cobalt, nickel, wood, copper, glass for their behavior with a sensitive magnetic compass

Study magnetic polarity with magnets and compass

Make temporary magnets with tacks, filings, etc.

Graph fields of force about different types and combinations of magnets using iron filings

Make a magnet by placing a steel bar in the earth's field and jarring it lengthwise with a hammer

Destroy a magnet by dropping it violently crosswise to the earth's field

Explore the laboratory with a compass for unsuspected magnetic objects

Evidences of Mastery

Ability to

State the contributions of Gilbert, Ampere, Faraday

Define the terms

Lodestone, magnetic substance, diamagnetic substance, unit magnetic pole, retentivity, induction, line of force, permeability, isogonic line, isoclinic line, agonic line, magnetic meridian, dipping needle, dip, declination

Explain

How magnets may be made and destroyed

How a compass behaves in the presence of a magnetic object

How molecules behave in a piece of iron preceding and during magnetism

How lines of force are arranged about magnets as shown by iron filings

How like and unlike magnetic poles behave when brought together

Make a list of five uses of magnets

Show how the earth behaves like a magnet

Name and explain the different kinds of compasses

X. STATIC ELECTRICAL PHENOMENA

Unit Objective

To learn the nature of the static charge and to know this charge may be used to build up a difference of potential

Specific Objectives

To study the formation of a static charge by friction

To learn the difference between conductor and insulator

To learn the behavior of an electriscope and how it may be used to determine the nature of the charge

To understand the electron theory of a charge and how it explains electrification by friction

To learn the parts and use of a condenser

To learn the relationship of static electricity to lightning and how the static charge may be converted into current electricity

Teacher Procedures

Tell of the historical discovery of static electricity

Explain the production of an electric charge by friction

Show the difference between a conductor and a nonconductor

Explain the action of an electroscope, and how to charge it by induction and by conduction

Explain carefully the electron theory of an electric charge

Show by means of an electroscope how the distribution of a charge depends upon the shape of the charged object

Explain the production of lightning

Explain and demonstrate the condenser principle, its types and uses

Demonstrate with an induction machine

Compare the properties of an electric charge with those of a magnetic charge

Pupil Activities

Electrify objects such as combs, fountain pens, sealing wax, silk, fur, ebony, glass, etc., by friction

Observe attraction and repulsion by means of pith balls

Study the behavior of an electroscope to a charged object

Learn to determine a charge with an electroscope

Study the parts and behavior of a static machine

Be able to work problems concerning the strength of an electric field

Evidences of Mastery

Ability to

State the contributions of Thales, Gilbert, and Franklin

Define

Kinds of electricity, conductor, insulator, induction, electric charge, condenser, element, molecule, atom, electron, volt, farad, ohm, and ampere

Explain

How an electroscope works and how it may be used to determine an unknown charge

How a body may become electrically charged

Fully the atomic theory of matter

Of what a condenser consists and how it may store up an electric charge

How the amount of the charge depends upon the shape of the object

How an electrophorus or other type of static machine may build an electric charge

How a lightning rod works

XI. ELECTRIC CURRENTS

A. Voltaic Cells as Sources of Electric Current
B. Resistance in Connection with Electric Circuit
C. The Electric Current as a Producer of Heat
D. Magnetic Effect of the Electric Circuit

Unit Objective

To understand how electricity behaves in the electric circuit

Specific Objectives

A. To observe the phenomena of electroplating and to learn of its commercial applications

To learn how a voltaic cell generates a difference of potential and why this charge will flow

To learn of what an electric circuit consists

To learn what the units of current flow, resistance, and differences of potential are

To learn what the five types of primary cells are and the use and importance of each

To know the important use of the dry cell in particular

To learn the meaning of Ohm's law $I = E/R$ and how to use it in simple problems

To learn how to apply Ohm's law to cells connected in series and in parallel

To learn the cause and prevention of polarization

To know the structure and use of the two types of secondary cells

To understand electrolysis and the general electrolytic cell

Teacher Procedures

A. Demonstrate actual electroplating, using solutions such as copper sulfate, silver nitrate, nickel chloride, etc.

Describe briefly some commercial uses of electrochemical effects such as electrotyping, electroplating, and general electrometallurgy

Tell of the history of the voltaic cell

Explain carefully the voltaic cell, especially the chemical action that goes on within it

Explain polarization, what it is, and how it may be provided

Explain Ohm's law and demonstrate, using both voltmeter and ammeter

Explain and demonstrate the different kinds of groupings of cells in circuits, including problems on each

Make drawings of the circuits of the voltmeter and the ammeter explaining how each works

Explain the advantages of parallel wiring over series for house lighting

Demonstrate the electrolysis of water, and carefully explain what goes on within the cell. Explain the difference between an electrolytic and voltaic cell

Explain the laws of electrolysis

Pupil Activities

A. Set up cells for electroplating, using electrodes and electrolytes

Look up commercial electroplating and electrometallurgy

Examine different types of voltaic cells noting the materials of the electrodes, the electrolytes used, the containers, and the voltage and amperage produced by each

Each student will make one or more voltaic cells, and measure the voltage and amperage produced by each

Using dry cells, measure the voltage and amperage produced by series, parallel, and series-parallel connections

Examine the parts and construction of a storage battery

Observe how the amalgamation of the zinc plate in a gravity cell holds back local action

Prove experimentally Ohm's law

Prove the laws of resistance by the use of the voltmeter, ammeter, and dry cells

Set up an electrolytic cell and perform the electrolysis of water

Evidences of Mastery

A. Ability to

State the contributions of Volta, Ohm, Galvani

Define the terms

Electric current, voltaic cell, electrode, circuit, ion, electroylsis, electrolytic cell, anode, cathode, electrolyte

Make drawings of the circuit of the voltmeter and of the ammeter

Explain

Polarization and how it may be prevented

The production of different voltages by different combinations of metals in the same electrolyte

The difference in the strength and pressure produced by series and parallel groupings

Solve problems of the following types

Find the current strength if two or more cells are connected in series

Find the voltage of a cell if the resistance and the current strength are known

Find the current strength if two or more cells are connected in parallel

Make a drawing of an electrolytic cell and explain its action

Explain the difference between a voltaic cell and an electrolytic cell

State Faraday's three laws of electrolysis

Specific Objectives	Teacher Procedures
B. To know the effect of resistance upon amperage and voltage drop in a conductor	B. Demonstrate how the addition of resistance to a circuit will lower the amperage of a current
To understand the structure and simple use of the rheostat and of the potentiometer	Show how to measure resistance by the voltmeter-ammeter method and by the Wheatstone bridge method, and explain the fundamental principle of each circuit
To understand the action and use of the microphone	Explain the action of the carbon microphone
To understand the use and importance of the shunt, and the relationship of resistances connected in series and in parallel	Explain the principle of the shunt
	Give practical examples of uses of the above
To understand the voltmeter-ammeter method of measuring resistance	
To understand the principles of the Wheatstone bridge and its use in measuring resistance	
C. To understand the production of heat by electrical resistance	C. Explain the principle of the conversion of electrical energy into heat energy
To understand Joule's laws of heat	
To know about some household devices for the production of heat by electricity	Demonstrate various electrical devices that are designed to produce heat
To study the effect of conductor overloading and the use of fuse wire	Demonstrate all available types of incandescent lamps, explaining their principles, candle power, current consumption, cost, and other desirability
To learn the function of resistance in the incandescent lamp, the various types of lamps, their desirability and use	Explain the operation and use of the arc and the resistance types of electric furnaces
To know the principles of the carbon arc and resistance types of electric furnaces	Explain the principle and importance of wiring to accomodate the current to be carried
To study electric wiring with a view to minimizing heat production	Explain Joule's law carefully

Pupil Activities	Evidences of Mastery
B. Examine electrical devices that depend upon electrical resistance for their operation, such as electric irons, fuses, grills, toasters, etc.	B. Measure resistance by the Wheatstone bridge method
Examine a rheostat and resistance bow	Measure resistance by the voltmeter-ammeter method
Measure resistance by the voltmeter-ammeter method	Explain:
	Carbon microphone, potentiometer, shunt
Measure resistance by the Wheatstone bridge method	Voltage drop in the branches of a shunt
	Voltage drop in a circuit
Make drawings of the above circuits	Calculate the total resistance for two or more resistances connected in series; also connected in parallel
C. Examine some common electrical devices that generate heat such as the flatiron, grill, radiant heater, soldering iron	C. Define
	Incandescence, fusion, arc
Examine a fuse and explain its action and use	Explain
Examine the different kinds of incandescent lamps and learn their comparative candle power, current consumption, and cost	The relationship of heat to resistance
	The relationship of heat to the amount of current consumed
If possible, examine carbon arc and mercury vapor lamps, arc and resistance furnaces, and be able to explain their principles	The relationship of heat to the time of current flow
	The action of a fuse
	The principle of the incandescent lamp, and tell briefly of each kind in common use
	Make drawing and explain the two types of electric furnaces

Specific Objectives	Teacher Procedures
D. To determine the direction of flow of the magnetic lines of force about a conductor	D. Show the existence of a magnetic field about a conductor by means of a small compass
To learn how to determine the direction of flow of an electric current in a conductor by means of a magnetic compass	Explain carefully the rule for determining the direction of the current flow when the direction of the magnetic field is known
To learn the magnetic behavior of a helix or solenoid	Show the magnetic behavior of a helix
To understand the electromagnet	Show the principle of the electromagnet giving some practical uses such as the buzzer, telegraph, telephone receiver
To understand the uses and applications of the electromagnet in the St. Louis motor	Explain carefully the difference between a voltmeter and an ammeter
To understand the action and use of the galvanometer, and its modifications for use as an ammeter or a voltmeter or a watt-hour meter	Explain the principle of the galvanometer, including types
	Explain briefly the watt-hour meter

Pupil Activities	Evidences of Mastery
D. Study the behavior of the magnetic field about a wire carrying current by means of a compass. Prove the rule for determining the direction of current flow	D. Define Helix, solenoid, meter
Study the magnetic field about a helix. Make a magnet by placing a piece of steel within the helix	State and apply the right hand rule for determining the direction of current flow in a conductor
Make an electromagnet and explain its action	State and apply the right hand rule for determining the polarity of a coil
Make a drawing of a galvanometer and explain its principles	Explain the magnetic behavior of a helix and its application to the electromagnet
Make drawings of the circuit of the voltmeter and the ammeter	Explain the principle of the galvanometer
	Make drawings of the voltmeter and of the ammeter and explain their action

XII.
INDUCED CURRENTS, GENERATORS, AND TRANSFORMERS

A. Generators
B. Transformers

Unit Objective

To acquire a knowledge of the action of induced currents and some of the uses made of induction

Specific Objectives

A. To learn the phenomena of generating an electric current in a conductor by passing it through a magnetic field so as to cut magnetic lines of force

To apply Fleming's rule for the determining of the direction of an induced current

To know how to determine the amount of the induced current

To understand the principles of the direct and of the alternating current dynamo, and the use of the commutator and slip rings

To know the commercial types of dynamos

To know the meaning of single and of polyphase current

To understand the principles of energy transformation in the dynamo

B. To know the principle of the transformer

To know the types and uses of the transformer

To know the circuit of the induction coil, and understand the action of its parts and its uses

To learn of some of the places in which induction coils are used

To know how to explain an eddy current, a choke coil, and impedance

Teacher Procedures

A. Explain the importance of the discovery of electromagnetic induction by Henry and Faraday

Explain and demonstrate how passing a conductor through a magnetic field will set up an electric current in the conductor

Explain Fleming's three finger rule for the direction of the induced current

Explain Lenz's law of induction

Explain with drawings the alternating and the direct current generators

Explain the use of the commutator and of slip rings

Describe the different methods of winding the stator

Describe the different methods of winding the rotor

Explain how single phase or polyphase current may be produced

If possible, take a field trip to the nearest power plant

B. Explain the principle of the transformer

Explain with drawings and models the different types of transformers

Explain and demonstrate the induction coil

Explain self-induction

Describe briefly the production of eddy currents

Explain impedance

Explain the principle of the choke coil

Pupil Activities

A. With the aid of coils and magnets study and prove the laws of Lenz and Fleming

Show how rotating a coil of wire between two permanent magnetic poles will set up an electric current in the coil

Make drawings and be able to explain the circuit of a series wound, shunt wound, and compound wound dynamos

Examine the construction of different types of dynamos in the laboratory

Study the parts and action of the demonstration dynamo

B. Make simple transformers and study their principle

Study the properties of a transformer in creating a magnetic field and in generating an electric current

Experiment with an induction coil noting its parts, and make a drawing of its circuit

Evidences of Mastery

Ability to

A. Define dynamo, armature, field

State the laws of Lenz, and of Fleming

Explain

The construction and make drawings of the three types of dynamos

With drawings the difference between single phase and polyphase current

The use of the commutator and of slip rings

With drawings the difference between alternating and direct current

Describe

Some of the different types of stator and rotor construction

B. Define inductance, impedance

Make a drawing of a simple transformer and explain its action

Make a drawing of the circuit of an induction coil

State five uses of a transformer

Explain the action of a choke coil

XIII. SOUND

Unit Objective

To acquire a fund of knowledge about common sound phenomena and to learn such principles of wave motion as will enable the pupil to understand the cause of these phenomena and the applications which man has made of them

Specific Objectives

To learn facts of importance relating to the production and transmission of sound by various materials

To learn the terms used in describing the wave motion which results when vibrating bodies produce sound

To recognize in any connection the relationship of velocity, frequency, and wave length as expressed by the equation v = nl

To know quality, intensity, and pitch as the three characteristics of sound and to understand what feature of wave motion produces each characteristic

To learn the use of such devices as the siren, the manometric flame, the Helmholz resonator, etc., in studying the characteristics of a sound

To understand how direct and reflected waves unite to produce resonance and how the wave length of a sound of known frequency may be determined by use of a resonance column

Teacher Procedures

Use a long wire spiral or rubber cord to produce a transverse wave which will serve to illustrate the features of progressive wave motion

Point out the way in which the material vibrates in a longitudinal wave as contrasted with the transverse type

Show how the diagram of a transverse wave may be used to represent the features of the sound wave which is of the longitudinal type

Relate differences noted by pupils to the terms pitch, intensity, and quality

As need arises in the class discussion the siren, the manometric flame, etc., should be used to show the feature of wave motion related to each of the three sound characteristics

Discuss with the class such topics as the acoustics of rooms, the use of sounding boards, etc.

Relate reënforcement and interference to what pupils have observed in using a resonance column to measure a wave length

Use two tuning forks of nearly the same pitch to demonstrate the phenomenon of beats (''wow-wow's'' as the piano tuner refers to it)

Use the sonometer to teach the terms fundamental and overtone (Slit Dennison reënforcement rings make good riders)

Use an organ pipe to show how an overtone sounding together with the fundamental produces a tone which differs from the fundamental in quality

Make the class discussion of resonance columns a means of pointing out the use made of Helmholz resonators to study quality

Pupil Activities

Recall ways in which sound has been observed to result from, to be associated with, or to be transmitted by vibrating bodies

Read for information on the transmission of sound, *e.g.*, velocity, media, effect of temperature, etc.

Learn the important terms and rules relating to wave motion

Learn the relation v = nl as it applies to all forms of wave motion

Suggest ways in which sounds the pupil has heard (*e.g.*, over radio) differ from each other. Prepare to give verbal reports of such ways to the class

Recall echos which have been observed. Explain their cause

Try the effect of setting a vibrating tuning fork on the laboratory table or against the panel of a door

Measure the wave length of the sound produced by a tuning fork of known frequency as it is reënforced by a resonance column

Pupils and teacher together prepare curves to illustrate (a) sound of frequency 20, (b) sound of frequency, 30 (c) union of two sounds in (a) and (b) to produce 10 beats

Describe the conditions whereby a succession of beats can be secured

Read topics discussing the blending of different overtones with the fundamental as the cause of differences in quality of sounds

Compare data secured by different groups while measuring wave lengths of sounds by the resonance method. Note important differences

Find illustrations in familiar musical instruments of the application of the three laws of vibrating strings

Evidences of Mastery

Ability to

Define wave length, frequency, octave, major triad, fundamental, resonance, echo, etc.

Give floor talks on

Sound ranging in the World War

How victrola records are made

The use and control of echos in auditoriums and classrooms

Famous echoes

Making the ''talkies'' talk

Give readily

Definite information about the velocity of sound and the effect of temperature on it

The distinction between a musical sound and a noise

Ways in which two musical sounds may differ from one another

Factors upon which the intensity of sounds heard by an observer depends

Three laws relating to the vibrating of strings

Understand the use made of such devices as

The siren, the manometric flame, the Helmholz resonator, the megaphone, the microphone

Recognize the relationship of

Frequency to pitch

Wave form to quality

Amplitude to intensity

Specific Objectives

To represent graphically the union of sounds of different frequencies and to learn from the graph how "beats" are produced

To understand how changes in the size and tension of vibrating strings modify the sounds they produce

To learn what pitches constitute a musical scale and how musical instruments are constructed and used to produce them

To learn how sounds are recorded and produced by the victrola, the dictaphone, the microphone, and other devices of similar nature

References

Bragg, Sir William, *The World of Sound,* G. Bell and Sons, London

Miller, D. C., *The Science of Musical Sounds,* Macmillan, 1922

Pitkin and Marston, *The Art of Sound Pictures,* Chapters 8 and 10 on Sound, D. Appleton, 1930

Simplex Player Action, Simplex Player Action Company, Worcester, Mass.

Tyndall, John, *Sound,* D. Appleton

Teacher Procedures

Show the general trend of three laws of vibrating strings by using the sonometer

Present before the class the computation of the frequencies of a diatonic scale by starting with the first tone as 24 vibrations per second

Pupil Activities

Read for information about the mathematical relation in frequencies of the tones in the so-called diatonic scale. What is (a) an octave? (b) a major triad? (c) a third? (d) a fifth? (e) an even tempered scale? (f) the international standard of pitch?

Give reports to the class on the use and operation of such devices as the dictaphone, the victrola, the microphone, etc., in recording and reproducing sounds

Evidences of Mastery

Represent diagramatically

Such features of wave motion in a transverse wave as wave length, amplitude, crest, trough, node

The union of two sounds of frequencies n = 20 and n = 30 to produce 10 beats per second

How the wave form of a pure fundamental differs from the wave form when fundamental is combined with the first overtone

Solve problems involving

Effect of temperature changes on speed of sound

Use of equation $v = nl$

Determination of frequency of tones in diatonic scale when frequency of first tone is known

Determination of wave length from resonance column determined experimentally

XIV. LIGHTING OUR HOMES AND PUBLIC BUILDINGS

Unit Objective

To understand what are the proper conditions of illumination in the school room, the home, the office

Specific Objectives

To learn and apply the inverse square law of intensity

To understand the use of the Bunsen or the Rumford photometer in comparing light intensities

To recognize the foot-candle as a measure of illumination

To understand the use of the foot-candle meter

To know the proper use of the foot-candle in stating lighting requirements for various purposes

References

Luckiesh, M., *Lighting the Home,* Century

Light, Its Use and Abuse, The New York Edison Company, New York

The Foot-Candle Meter for Measurements of Illumination, Westinghouse Lamp Co., New York

Illumination Values and Their Measurements, Westinghouse Lamp Company, New York

Practical Experiments on Light for High School Physics Courses, National Lamp Works, General Electric Co., Cleveland

Amateur Photographer's Handbook, Collins Crowell Company, New York

Teacher Procedures

Provide the setting for a discussion by the class of lighting conditions as variously observed by individual pupils

Require definite information about lighting conditions which were observed. Point out any lack of definiteness in the information given

Suggest references to be read which will enable the pupil to make future reports of this kind more definitely

Use apparatus and diagrams as a starting point in discussing the use of some type of photometer to determine the light intensity of different sources

Use the foot-candle meter, or diagrams illustrating its use, to show the use which may be made of the foot-candle meter in measuring the intensity of illumination of a given surface

Pupil Activities

Recall the rule of intensity as used for sound

Make a rather careful investigation of such existing conditions of lighting as may be observed in the next 24 hours

Prepare a report, discussing conditions as found, also making suggestions as to changes which should be made where poor conditions were found

Perform an experiment in which the candle power of a light of unknown brightness is compared with that of a standard lamp

Measure the intensity of illumination in various classrooms, halls, etc., under varying conditions of light source and illumination requirements

Make a list of terms and phrases which are of help in giving accurate information about illumination

Work verbal problems dealing with the use of the inverse square law, the determination of intensity of illumination in foot-candles, etc.

From texts, pamphlets, etc., prepare a card giving in summarized form useful data about proper illumination for various needs in terms of the foot-candle

Visit a photographer and find out what methods he uses to secure the proper amount of illumination for various kinds of work he does

Evidences of Mastery

Ability to

Define foot-candle, candle power, lumen

Explain the principle of some type of photometer, the use of a foot-candle meter

Use in a practical way the inverse square law, the foot-candle meter

Plan the proper illumination for such rooms as the physics laboratory, the study hall, the kitchen, the study table

Give floor talks on

Proper illumination in our homes

How to measure the candle power of a lamp by means of a Bunsen photometer

Recognize what is desirable and what is to be avoided in planning illumination for specific purposes

Desire to have provided illuminating conditions which shall be conducive to health

XV. MIRRORS, LENSES, AND OPTICAL INSTRUMENTS

Unit Objective

To understand how the use of lenses and mirrors in optical devices renders the human eye a more effective means of vision

Specific Objectives

To learn the laws of reflection which make the plane mirror useful in the home, the shop, the car, etc.

To understand the optical phenomena which make the curved mirror adaptable to special use in lamp reflectors, reflecting telescopes, rear view mirrors, etc.

To understand the laws of refraction which make the simple lens useful for such purposes as reading glasses, simple microscopes, linen testers, etc.

To learn the optical principles which render the eye a means of vision

To learn the points of similarity and difference in the optical systems of the eye and the camera

To understand how variations in the curvature of the lenses of eye glasses serve as a means of correcting defective vision

To understand how lenses are used in telescopes to make long range vision possible

Teacher Procedures

Stimulate the class to bring in situations where their vision has been extended by the use of devices whose power was due to the use of mirrors and lenses

Darken the lecture room and use candles before a large rectangular piece of plate glass to show the nature of image formations. Make use of blackboard diagrams to bring out points to be learned

Use candle, concave mirror, screen and optical bench to show how a concave mirror receives and reflects a light to form images (A good way to use this material is to provide a long shelf across the middle of the blackboard space as an optical bench. Then draw diagrams to correspond to various positions of the object and image with reference to mirror which should be kept fixed)

Use the Hartl optical disc and a triangular prism; show how a ray of light bends toward the base in entering and leaving. Then use two or more rays and two prisms placed base to base; then apex to apex

Relate the shape of and the bending of light rays by concave mirrors and lenses to the previous demonstrations with prisms

In a way similar to the one used in case of the concave mirror, show how a convex lens receives and transmits light to form real and virtual images

With a white cardboard screen, show that a convex lens may or may not have a real focus, depending on the position of the object and then how a concave lens never has a real focus

Relate the various parts of the eye to corresponding parts of the camera. Show how the eye and the camera are provided with a means of adjustment to allow for sharply focused images on the object being seen

Pupil Activities

Prepare a list of such devices giving in each case the effect that the use of the lens or mirror produced. Urge classification on some basis

Use a paper milk container and thin waxed paper to make a pin hole camera. Use lamp black and shellac dissolved in alcohol for darkening inside of chamber. Use a covering from another can to make a device for holding the waxed paper as a screen

Examine plane, concave, and convex mirrors. Read for more definite information regarding their use

Use a plane mirror and determine by experiment the way the reflected light reaches the eye to form

The image of a point

The image of an arrow

The image of a scalene triangle

Perform an experiment to locate the images formed by concave mirror. Determine from data obtained by this means the focal length and the radius of curvature of the mirror

Prepare in tabular form the facts about the location, size, position, and type of image formed by a concave mirror when the object is at various positions along the principal axis

Examine simple microscopes, linen testers, lenses from eye glasses, reading glasses, etc. Follow up by reading for more definite information regarding the use of lenses

Start a glossary of terms used in describing the structure and use of mirrors as an optical device. This list will also apply to lenses with mirror changes and a few additional terms

Perform an experiment to locate the images formed by a convex lens. Use the lens at various relative positions from the object. From the data obtained find the focal length of the lens from the lens formula

Evidences of Mastery

Ability to

Define principal focus, focal length, radius of curvature, principal axis, secondary axis, conjugated foci, real image, virtual image, convex lens, convex mirror, concave lens, concave mirror, angle of incidence, angle of refraction

Identify in any discussion of lenses or mirrors the meaning of f, F, F' D_o (or p), D_i (or q)

Apply the lens (mirror) formula, the size rule, the laws of reflection, the bending of rays in refraction

Display in tabular form the description of the images formed by a lens or mirror for different relative positions of the object with reference to the lens or mirror

Illustrate graphically how lenses (or mirrors) are used in one (or several) different optical devices to change the light so images will be formed

Give a floor talk on

The human eye as a camera

The camera as a substituting eye

The use of eye glasses to correct defective vision

Reflectors on headlights and flood lights

Recognize in the proper connection

Angle of refraction

Angle of incidence

Specific Objectives

To learn how a system of lenses and a mirror in the compound microscope makes possible the observation of minute details in objects too small for the eye alone to see

To understand how the projection lantern and the motion picture projector make group inspection of photographic scenes possible

To learn from current articles in books and periodicals how scientific principles are being applied to develop television

References

How to Use a Kodak, Eastman Kodak Company, Rochester, New York

Photograpic Lenses, Bausch and Lomb Optical Company, Rochester, New York

Sheldon and Grisewold, *Television,* D. Van Nostrand, New York, 1929

Davis, William S., *Practical Amateur Photography,* Little Brown

Talbot, *Moving Pictures,* D. Van Nostrand

Teacher Procedures

Show by using one lens as crystalline lens and another lens as a spectacle lens how eye glasses are used to correct near-sightedness and far-sightedness. Then discuss how glasses correct what is known as astigmatism

Direct reading and provide for the discussion of the application of the fundamental principles of mirrors and lenses to devices which extend the power of vision of the human eye

Pupil Activities

Given a diagram showing the shape of a lens, the principal axis, the principal foci, and the optical center of the lens, complete the diagram to show the position, location and size of the image by construction

Study the eye as an optical instrument of precision. Read references, examine charts, diagrams, or models or all of these for more definite knowledge

Use lenses or an optical bench to construct models of the telescope and the compound microscope. Measure their magnification

Work problems where application is made of the lens (mirror) formula and the size rule

Find out how television may become a means of extending our means of vision

Evidences of Mastery

Angle of reflection

Normal to the surface

Real image

Describe the position of image and object with such terms as

At principal focus

At twice focal length

At center of curvature

Beyond center of curvature

In front of the lens

Behind the lens

Appreciation of

The part which lenses and mirrors have played in extending our range of vision and correcting defects productive of discomfort and ill health

XVI. THE PHENOMENA OF COLOR

Unit Objective

To acquire an increasing fund of knowledge useful as a means of explaining and understanding such color phenomena and references to them as come within the range of the average person's reading and observation

Specific Objectives

To learn how a prism produces a spectrum

To learn why there is a rainbow

To learn how elementary wave theory becomes a means of explaining color and related phenomena

To learn how the presence or absence of certain colors may be brought about

To learn how colored processes in printing have made better pictures available

To know why blue light bulbs are the best to use for certain types of merchandising

To know how colored motion pictures are taken and then shown in technicolor

To understand references to intra-red and ultra-violet rays

References

Snow and Froelich, *Theory and Practice of Color,* The Prang Co.

Pitkin and Marston, *The Art of Sound Pictures,* D. Appleton, 1929 (Chapter XI is on Color)

Teacher Procedures

Create a situation which will lead pupils to contribute their own observations about and knowledge of color phenomena such as rainbows, mixing and blending of colors, effect of variously colored artificial lights, etc.

Show the effects of dispersion by means of a beam of white light passed through a triangular prism and recombined by a second prism

Relate color and wave length in light to pitch and wave length in sound

Show the effect of mixing colors by means of Newton's color disks. Suggest that this effect is different from that produced when pigments of the same colors are mixed

Use a pair of glass plates and sodium light to show the interference of light waves

Furnish pupils with a study test for the unit. The following examples are from a completion test which one teacher has found very effective in motivating pupils to master important points in the unit. It is meant to be suggestive

The (1) of light depends upon the length of the wave producing the light. White light is a complex mixture of (2). When a beam of white light passes through a prism each (3) is refracted at a different (4) and a colored band or (5) is formed, thus bringing about the phenomena known as (6)

Incandescent vapors or gases give a (18) spectrum while incandescent solids give (19) spectra. The (20) spectrum of the (21) helped us discover the new element (22) which was not known in Kirchoff's time

Pupil Activities	Evidences of Mastery
Name the colors of the rainbow	Ability to
	Show
With a triangular prism and a narrow slit view the spectrum of light beams	That color of an object depends on the wave lengths present in the light source on the wave lengths that are transmitted or reflected
From white light source	
From sodium light source	
From potassium light source	
From white light viewed through sodium flame	Black object is neither transmitting nor reflecting wave lengths
Learn how different types of spectra are produced	The position of intra-red and ultra-violet with reference to the spectrum
Continuous spectrum	Name the colors of the spectrum in order of wave length
Bright line spectrum	
Dark line spectrum	Recognize in the proper connection
Examine the spectrum of a white light source with a red glass, a green glass, a blue glass, both red and green between the eye and the spectrum	Fraunhofer lines as dark lines in color spectrum
	Colors of rainbow as due to dispersion
Examine each of the following:	Red light as longer wave lengths
White light viewed through red glass (also blue glass)	Violet light as shorter wave lengths
Blue light viewed through a red glass	White light as a mixture of wave lengths
White light viewed through red and blue glass simultaneously	Sodium D-line as bright line spectrum
Red light viewed through a blue glass	Give floor talks on
Mix equal parts of yellow and blue pigments (*e.g.,* yellow and blue crayon) and compare the result with what the color disk method produces for the same mixing of colors	How color came to the movies
	Meaning of Fraunhofer lines
Learn that the color of an object depends on the light it gets and on the light it transmits or reflects to the eye	Parts and use of the spectroscope
	Overcoming spherical and chromatic aberration in high power lenses
Read pamphlets and articles dealing with the use of achromatic lenses in cameras and other high grade optical instruments	

XVII. INVISIBLE RADIATIONS AND RADIO

A. Wave Transmission
B. Radioactive Phenomena

Unit Objective

To study wave transmission and reception, and the behavior of radioactive substances

Specific Objectives

A. To understand the principles of wave vibration

To learn the relationship of light, heat, ultra-violet waves, X rays, cosmic rays, and radio waves

To learn radio wave types

To understand the changing of sound waves into radio waves

To understand the vacuum tube, its principle, types and uses

To be able to outline the way in which radio reception is carried out

To explain the essential features of the fundamental types of radio circuits

To tell briefly of television

B. To learn of the behavior of cathode and of Coolidge tubes

To learn about the production and use of X rays

To study the phenomena of radio-active substances

To learn of the phenomena of atomic energy and of the atomic destruction of radio-active elements

Teacher Procedures

A. Explain the wave spectrum, showing the relative positions of heat, light, ultra-violet waves, X rays, cosmic rays, and radio waves

Explain carrier waves, and the damping of waves

Explain the parts and principles of the two-, three-, and four-element vacuum tubes

Explain how sound waves are transformed into electric waves

Explain how radio waves may be transformed into sound waves

Explain briefly the essential parts of a standard receiving set, and of a simple transmitting set

Explain with diagrams, the crystal circuit, the regenerative circuit, the tuned radio frequency circuit, including the neutrodyne principle, and the superheterodyne

Tell briefly of the present status of television, and of the vitaphone

B. Explain briefly the cathode and Coolidge tubes

Explain the production of X rays, and if possible demonstrate

Explain Becquerel rays and the action of radium

Explain carefully atomic disintegration

Pupil Activities

A. Review the principles of heat and light waves

Learn the relationship of the various types of waves to each other

Look up what references may be found upon them

Learn the difference between the carrier wave and the impressed wave

Study the various steps in radio reception

Study the various steps in radio transmission

Study the vacuum tube, its parts, action, and uses

Make drawings of the crystal, regenerative, tuned radio frequency, and superheterodyne circuits

Study the fundamental principles of each of the above circuits

If possible, build some radio circuits

B. Look up in the literature all that can be found upon the cathode tube, the Coolidge tube, X rays, and radium

Note the use of radium and of X rays

Study carefully the disintegration of radium and the expenditure of atomic energy

Evidences of Mastery

A. Ability to

Identify

Hertzian waves, vacuum tube, coherer, crystal

Tell what each of these men contributed to radio: Maxwell, Hertz, Marconi, De-Forest, Armstrong, Hazeltine and others

Name the various kinds of waves in order of their wave lengths

Explain the difference between a carrier wave and a damped wave

Outline briefly the various parts in a radio receiver

Outline briefly the various parts in a radio transmitter

Make a drawing of a vacuum tube and explain the function of its parts

Explain briefly the various general types of radio circuits

B. Identify

Becquerel, Curie, Coolidge, Crookes

Explain the production of X rays

Explain the disintegration of radium and its display of atomic energy

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