

to determine the number of vibrations in a sound? How is the octave of any note produced? How can we ascertain the length of the wave in sound? What length of wave produces the low tones in music? The high tones? Give the illustration of the locomotive whistle. When are two tones in unison? How can we find the length of the wave in *any* musical sound? What is meant by the super-position of sound-waves?

How can two sounds produce silence? What is this effect termed? Illustrate interference by means of a tuning-fork. What are "beats"? Describe the vibration of a cord.

Describe the sonometer. What is the object of the wooden box? Give the three laws of the vibration of cords. What is a node? Describe the experiments illustrating the formation of nodes. What are acoustic figures? Nodal lines?

What is the fundamental tone of a cord? A harmonic? What causes the difference in the sound of various instruments? Does a bell vibrate in nodes? The violin-case? A piano sounding-board? State the fractions representing the relative rates of vibration of the different notes of the scale. How is the sound produced in wind-instruments? How is the sound-wave started in an organ-pipe? In a flute? What determines the pitch? What are sympathetic vibrations? Describe the resonance globe. What is a sensitive flame?

A singing flame? Describe the phonograph. The ear. What is the office of the Eustachian tube? Is there any opening between the external and internal ear? What effect does it have on the hearing to increase or diminish the pressure of the air? How does a concussion sometimes cause temporary deafness? How can this be remedied? What are the limits of hearing? Does the range vary in different persons? What sounds are generally heard most acutely? Are there probably sounds in Nature we never hear? What causes the "whispering of the pines"?

VII. Optics.—Define. A luminous body. A non-luminous body. A medium. A transparent body. A translucent body. An opaque body. A ray of light. Show that neither air nor water is perfectly transparent. Why is the sun's light fainter at sunset than at midday? Define the visual angle. Show how distance and size are intimately related.

State the laws of light. Do they resemble those of sound? What is the velocity of light? How is this proved? Explain the undulatory theory of light.

How does light-motion differ from sound-motion? What is diffused light? Why are some objects brilliant and others dull?

Why can we see a rough surface at any angle, and an image in the mirror at only a particular one? Would a perfectly smooth mirror be visible? How does reflection vary? Define mirrors. Name and define the three kinds.

What is the general principle of mirrors? Why is an image in a plane mirror symmetrical? Why is it reversed right and left? Why is it as far behind the mirror as the object is before it?

Why can we often see in a mirror several images of an object? Why can we see these best if we look into the mirror very obliquely? Why is an image seen in water inverted? When the moon is near the meridian, why can we see the image in the water at only one spot? When do we see a tremulous line of light? What is the action of a concave mirror on rays of light? Define the focus. Center of curvature. Focal distance. Describe the image seen in a concave mirror. What are conjugate foci? Describe the image seen in a convex mirror. Why is it smaller than life? Why can it not be inverted like one seen in a concave mirror?

Define Refraction. Does the partial reflection of light as it passes from one medium to another of different density have a parallel in sound? Why is powdered ice opaque while a block of ice is transparent? Give illustrations of refraction.

Why does an object in water appear to be above its true place? What is the general principle of refraction? State the laws of refraction. Explain total reflection. What is the critical angle? Describe the path of a ray through a window-glass. Is the direction of objects changed? Describe the path through a prism.

Name and describe the different kinds of lenses. What is the effect of a double-convex lens on rays of light? What is this kind of lens often called? Describe the image. Why is it inverted after we pass the principal focus? Why is it decreased in size? What is the effect of a double-concave lens on rays of



light? Describe the image. Why can it not be inverted like one through a double-convex lens? Describe the images seen in the large vases in the windows of drug-stores. What is Aberration?\*

What is mirage? Give its cause.

How is the solar spectrum formed? Name the six principal colors. Show that these six will form white light. Why are the rays separated? What is meant by the dispersive power of a prism? What apparatus possesses this property in a high degree? *Ans.* A triangular bottle filled with a liquid called carbon disulphide ("Popular Chemistry," p. 110). Why does the window of a photographer's dark room sometimes contain yellow glass?

Describe the three kinds of spectra. The spectroscope. What are its uses? Describe rainbows—primary and secondary. Why is the rainbow circular? How is the rainbow formed? Why must it rain and the sun shine at the same time, to produce the bow? Why is the bow in the sky opposite the sun? How many refractions and reflections form the primary bow? The secondary? How many colors can one receive from a single drop? Define complementary colors. How can they be seen? What

\* To prevent spherical aberration the pupil of the eye can be made very small. The photographer reaches the same result by the use of a diaphragm with a small aperture. "The power of a small orifice to correct the greatest amount of distortion from interfering rays is shown by a simple experiment. The normal eye of an adult can not see to read small print nearer than six inches. Within that distance the type becomes more indistinct the closer it approaches the eye. But if we make a pin-hole through a card and place it close to the eye, we can see to read printed matter of any size even as near as half an inch from the eye. At that distance we can see even the texture of fine cambric with microscopic definition. The cause of this is easily explicable. The rays striking the lens perpendicularly on the center suffer no refraction. The effect of the pin-hole is to exclude all rays but those that impinge perpendicularly on the center of the eye lenses. Hence the image of the object close in front of the eye is pictured on the retina without the interference of the surrounding rays, which would fall obliquely on the lens, and being refracted out of focus would blur the picture. Observation of the effect of a small orifice in correcting aberrant rays, and of the fact that the pupil contracts in near vision, led Haller and some other physiologists to believe that contraction of the pupil was the sole factor in near accommodation. But this view has been sufficiently refuted by other observers."—*Dr. Dudgeon's "Human Eye,"* p. 76.

is the effect of complementary colors when brought in contrast? (In Fig. 163 opposite colors are complementary.) Why do colors seen by artificial light appear differently than by daylight—as yellow seems white, blue turns to green, etc.

Describe Newton's rings. How are these explained according to the wave theory? What causes the play of color in mother-of-pearl? In soap-bubbles? In the scum on stagnant water? In thin layers of mica or quartz?

What can you say about the length of the waves? State the analogy between color and pitch in music. Why is grass green? When is a body white? Black? What is color-blindness?

What is double refraction? What are the two rays termed? What is polarized light? How does a dot appear through Iceland spar? What other methods are there of polarizing light? State some illustrations and practical uses of polarized light.

What is the meaning of the word microscope? Describe the simple microscope. The compound microscope. How is the power of a microscope indicated? Do we see the object directly in a microscope? Why is the object-lens made so small and so convex?

What is the meaning of the word telescope? Describe the reflecting telescope. The refracting telescope. What is the use of the object-lens? The eye-piece? Is the image inverted? Describe the opera-glass.

The stereoscope. The projecting lantern. How are dissolving views produced?

Describe the Camera. The structure of the eye.\* The for-

\* "In the skate's eye, and generally in the eyes of fishes, the cornea is nearly flat, the aqueous humor is insignificant, and there is virtually no anterior chamber, for the crystalline lens comes up close to the cornea. A convex cornea filled by an aqueous humor would be of no use in the water, the refractive index of the water being identical with that of the aqueous humor. Accordingly, the refraction of the rays of light has to be effected entirely by the crystalline lens, which is nearly spherical, and of much greater refractive power than the corresponding organ in animals which pass their lives in the air. The crystalline lens being so nearly spherical in shape and of such high refractive power, the axis of the eye is short. The eye of the turtle, which is so much in the water, is very similar to that of the fish. The crystalline lens is very near the cornea. The lens is smaller proportionally than that of the skate, nor is it nearly so spherical; and its



mation of an image on the retina. The adjustment of the eye. The cause of near and over sightedness. The remedy. Why do old people hold a book at arm's length? Illustrate the duration of an impression. What is the range of the eye?

VIII. Heat.—Define solar energy. In what ways may it become manifested? What is a diathermanous body? Cold? Gases and vapors? Show the intimate relation between light and heat. What is light? What is the theory of heat? Why can we not see with our fingers or taste with our ears? At what rate does nerve-motion travel? (See "Hygienic Physiology," p. 177.) How long does it take a man, six feet in height, to find out what is going on in his foot? *take the same time*

Name the sources of heat. Describe and illustrate each of these. Can force be destroyed? If apparently lost, what becomes of it? What is Joule's law? Define latent, sensible, and specific heat. Explain the paradox, "that freezing is a warming process and thawing a cooling one." Why does "heat expand and cold contract"? What do you say as to the expansion of solids, liquids, and gases? Illustrate the expansion of solids. Is it better to buy alcohol in summer or in winter? What is the thermometer? Describe it. Describe the process of filling and grading. The F., C., and R. scales. Tell what you can about liquefaction. Of a solid. Of a gas. In one case sensible heat becomes latent, in the other latent heat becomes sensible—why is this?

Explain how a freezing mixture "makes ice-cream." State the theory of vaporization. Of distillation. Since rain comes from the ocean, why is it not salt? Describe the theory of boiling. What is the boiling-point? Do all liquids boil at the same temperature? What would be the effect, if this were the

density, and consequently its refractive power, is somewhat less. Hence it has proportionally a longer focus. The cornea is more convex than that of the skate. The fish having no eyelids nor any lachrymal apparatus, its cornea will be apt to become dim by exposure to the air, but the turtle is well supplied with the requisite apparatus for maintaining the transparency of the eye in air. Ophidian reptiles have no eyelids or lachrymal apparatus, but they do not require them, as their cornea is transparent though dry.

—Dr. Dudgeon's "Human Eye," p. 50.

case? Upon what does the boiling-point depend? Why does pressure raise the melting-point of most substances but lessen that of ice? Why does salt-water boil at a higher temperature than fresh-water? Why will milk boil over so easily? Why will soup keep hot longer than boiling water? Does the air, dissolved in water, have any influence on the boiling-point? Can you measure the height of a mountain by means of a tea-kettle and a thermometer? Show how cold water may be used to make warm water boil. At what temperature will water boil in a vacuum? Why? Can we heat water in the open air above the boiling-point? What becomes of the extra heat? What is the latent heat of water? Upon what principle are buildings heated by steam? Have you ever seen any steam?

Define evaporation. Does snow evaporate in the winter? What can be done to hasten evaporation? Why is a saucepan made broad? Why do we cool ourselves by fanning? Why does an application of spirits to the forehead allay fever? Why does wind hasten the drying of clothes? Describe a vacuum-pan. Why is evaporation hastened in a vacuum? Why is evaporation a cooling process? How is ice manufactured in the tropics? What is the spheroidal state?

Name and define the three modes of communicating heat. Give illustrations showing the relative conducting power of solids, liquids, and gases. What substances are the best conductors? Is water a good conductor? Air? What is the principle of ice-houses? Fire-proof safes? Why do not flannel and marble appear to be of the same temperature? Is ice always of the same temperature? Describe the convective currents in heating water. Where must the heat be applied? Where should ice be applied in order to cool water? Describe the convective currents in heating air. Upon what principle are hot-air furnaces constructed? Ought the ventilator at the top of a room to be opened in winter? At the bottom? Is interplanetary space warmed by the sunbeam?

Does the heat of the sun come in through our windows? Does the heat of our stoves pass out in the same way? Show how the vapor in the air helps to keep the earth warm. Explain the Radiometer. The relation between absorption and reflection.



What is the elastic force of steam at the ordinary pressure of the air? What is the difference between a high-pressure and a low-pressure engine? Which is used for a locomotive? Why? Describe the governor. What is the object of a fly-wheel?

How does the capacity of the air for moisture vary? What is the principle on which dew, rain, etc., depend? Show that a change in density produces a change in temperature. What effect does this have on the temperature of elevated regions? Does an ounce of air on a mountain-top contain the same quantity of heat as the same weight at the foot? How is dew formed?

Upon what objects will it collect most readily? Why will it not form on windy nights? Why is rice-straw used in Bengal in making ice? What is a fog? Why do fogs form over ponds in the early evening? Cause of fogs over the Newfoundland banks? How does a fog differ from a cloud? Why do clouds remain suspended in the air? Describe the different kinds of clouds. Describe the formation of rain. Snow.

How are winds produced? Land-and-sea breezes? Trade-winds? Oceanic currents? Tell about the Gulf Stream. Explain the influence which water has on climate. Of what practical use is the air in water? Describe the apparent exception which exists in the freezing of water. Describe the two processes by which pure water can be obtained. How is an excessive deposit of dew prevented?

**IX. Magnetism.**—Define Magnetism. A Magnet. A natural magnet. An artificial one. A bar-magnet. A horseshoe magnet. The poles. The magnetic curves. Describe a magnetic needle. What is the law of magnetic attraction and repulsion? Define magnetic induction. Explain it.

When is a body polarized? Give some illustrations of induced magnetism. Does a magnet lose any force by induction? How do you explain the fact that if you break a magnet each part will have its N. and S. poles?

Describe the process of making a magnet. On what principle will you explain this? Describe the compass. Is the needle true to the pole? What causes it to vary? What is the

line of no variation? Declination? Why does the needle point N. and S.? What is a dipping-needle? Explain. How is a needle balanced?

Where is the N. magnetic pole? How would one know when he reached it? Does the earth induce magnetism? Which end of an upright bar, in the United States, will be the S. pole?

**X.—Electricity.** Define frictional electricity. The electroscope. Difference between static and dynamic electricity. Show the existence of two manifestations of electricity. Give the names applied to each.

State the law. What is the theory of electricity? Define a conductor. An insulator.

What is the best conductor? Best insulator? Is a poor conductor a good insulator? When is a body said to be insulated? Can electricity be collected from an iron rod? Describe a plate-glass electrical machine. What is the use of the chain at the negative pole? Define electrical induction. State Faraday's theory.

What is the relation between induction and attraction and repulsion? Describe the electric chime. Explain. Describe the dancing images. The Leyden jar. What gives the color to the spark? How is the jar discharged?

What are the essentials of a Leyden jar? What is the object of the glass? The tin-foil? State the theory of the charging of the jar. Can an insulated jar be charged? Is the electricity on the surface or in the glass? Can the inner molecules of a solid conductor be charged? Will a rod contain any more electricity than a tube? Why is the prime conductor of an electrical machine hollow? What is the effect of points? Describe the electric whirl. Explain the existence of electricity in the atmosphere. What is the cause of lightning? Thunder? Is there any danger after you once hear the report? Describe the different kinds of lightning. Tell how Franklin discovered the identity of lightning and frictional electricity.

Tell what you can about lightning-rods. In what consists the main value of the rod? Does the lightning ever pass upward from the earth? *Ans.* It does, both quietly and by sudden.



discharge. Has nature provided any lightning-rods? What is St. Elmo's fire? What is the velocity of electricity? Illustrate its instantaneousness. Explain the action of the Voss electrical machine.

Name some of the effects of frictional electricity—(1) Physical, (2) Chemical, (3) Physiological. How are voltaic electricity and chemistry related? Why is voltaic electricity thus named? Tell the story of Galvani's discovery. What was his theory? Give an account of Volta's discovery. How can we form a simple pile? Describe the simple voltaic circuit.

Define the poles. Electrodes. Closing and breaking the circuit. What is necessary to form a voltaic pair? Describe the chemical change. Why does the hydrogen come off from the copper? Tell what you can about the current.

What really passes along the wire? How is this force transmitted? Will a tube, then, convey as much electricity as a rod? Explain the term electric potential.

Describe Smee's battery. Grove's battery. The chemical change in this battery. What are the advantages of Grove's battery? Describe Bunsen's battery. Daniell's battery. The Potassium Bichromate battery. Compare frictional and voltaic electricity.

State the effects of voltaic electricity, (1) Physical—heat and light; (2) Chemical—decomposition of water, electrolysis, electro-plating, electro-plating, etc.; (3) Physiological.

What is the effect of a voltaic current on a magnetic needle? What is a galvanometer? An electro-magnet? Show how a coil can be magnetized. How are bar-magnets made? Describe the magnetic telegraph. How is a message sent? How is one received? What is a sounder? What is the general principle of the telegraph? Describe the relay. Name the use of each instrument. Describe a magneto-electric machine. Describe Wilde's machine. What are induced currents? Describe the Telephone. The Microphone. What is the difference between the acoustic and the magnetic telephone? Explain Ruhmkorff's coil. Thermal electricity. A thermo-electric pile. Describe the electric fish.

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