be decomposed, Electricity will be set free; and from this, Heat, Light, Magnetism, and Motion can be produced. Thus the commonest object becomes full of fascination to the scientific mind, since in it reside the mysterious forces of Nature.

These various forces can be classified either as attractive or repellent. Under their influence the atoms or molecules resemble little magnets with positive and negative poles. They approach or recede from one another, and so tend to arrange themselves according to some definite plan. "The atoms march in time, moving to the music of law." A crystal is but a specimen of "molecular architecture" built up by the forces with which matter is endowed. Forces continually ebb and flow, but the sum of energy through the universe remains the same. In time all the possible changes may be rung, and the various forms of energy subside into one uniformly-diffused heat-quiver, but in that will exist the representation of all the forces which now animate creation.

XI.

APPENDIX.

APPENDIX.

QUESTIONS.

THE following questions are those which the author has used in his classes, both as a daily review and for examination. A standing question, which has followed every other question, has been: "*Can you illustrate this?*" Without, therefore, a particular request, the pupil has been accustomed to give as many practical examples as he could, whenever he has made any statement or given any definition.

I. **Introduction.** — Define matter. A body. A substance. Name and define the two kinds of properties which belong to each substance. State the suppositions of the Atomic Theory. What is a molecule? An atom?

Describe the two kinds of change to which matter may be subjected. What is the principal distinction between Physics and Chemistry? Mention some phenomena which belong to each. Why are these branches intimately related?

Name the general properties of matter. Define magnitude. Size. Distinguish between size and mass. Why are feathers light and lead heavy? Why is it necessary to have a standard of measure? What are the French and English standards? Give the history of the English standard. Is the American yard an exact copy of the English? Give an account of the French system. By what name is this system commonly known? Is either of these systems founded on a natural standard? Why is it desirable to have such a standard?

Define Impenetrability. Give some apparent exceptions, and explain them. Define Divisibility. Is there any limit to the divisibility of matter? Define Porosity. Is the word *porous* used here in its common acceptation? What practical use is made in the arts of the property of porosity? Describe the experiment of the Florence academicians.

Define Inertia. Does a ball, when thrown, stop itself? Why is it difficult to start a heavy wagon? Why is it dangerous to jump from the cars when in motion? (Compare First Law of Motion.) Define Indestructibility. Has the earth at all times contained the same quantity of matter that it does now?

Name the specific properties of matter. Define Ductility. How is iron wire made? Platinum wire? Gilt wire? Define Malleability.

Describe the manufacture of gold-leaf. Is copper malleable? Define Tenacity. Name and define the three kinds of Elasticity. Illustrate the elasticity of compression as seen in solids. In liquids. In gases. What is said about the relative compressibility of liquids and gases?

Illustrate the elasticity of expansion as seen in solids, liquids, and gases. Define Elasticity of Torsion. What is a Torsion balance? Define Hardness. Does this property depend on density? Define Density. Define Brittleness. Is a hard body necessarily brittle? Name a brittle and a hard body.

II. Motion and Force.—Define motion, absolute and relative. Rest. Velocity. Force. What are the resistances to motion? Tell what you can about friction. Why does oil diminish friction? What uses has friction? What law governs the resistance of air or water? Define Momentum.

Show that motion is not imparted instantaneously. State the three laws of motion and the proof of each. If a ball be fired into the air when a horizontal wind is blowing, will it rise as high as if the air were still? Describe the experiments with the collision balls. Give practical illustrations of action and reaction. If a bird could live, could it fly in a vacuum? Define compound motion.

Define the so-called "parallelogram of forces." The resultant. How can the resultant of two or more forces be found? Name some practical illustrations of compound motion. What is the "resolution of forces"?

Show how one vessel can sail south and another north, driven by the same westerly wind. Explain how a kite is raised. Explain the "split-shot" in croquet.

Explain the towing of a canal-boat. Describe how motion in a curve and circular motion are produced. Explain the centripetal and centrifugal forces.

Show when the centrifugal force becomes strong enough to overcome the force of Cohesion. Of Adhesion. Of Gravity. Apply the principle of circular motion to the revolution of the earth about the sun. What effect does the revolution of the earth on its axis have upon all bodies on the surface?

What would be the effect if the rotation were to cease? Describe the action of the centrifugal force on a hoop rapidly revolved on its axis. Define reflected motion. Give its law.

What is Energy, in the Physical sense of the word? To what is it proportional? Name and define the two forms of energy. How may one form be changed into the other?

What is the law of the Conservation of Energy? What did Faraday say with regard to this law?

III. Attraction. *1.* MOLECULAR FORCES.—Define a molecular force. What two opposing forces act between the molecules of matter? How is this shown? What is the repellent force? Name the attractive forces. Which of these belong to Physics?

1. *Cohesion.*—Define. What are the three states of matter? Define. How can a body be changed from one state to another?

Show that cohesion acts only at insensible distances. Explain the process of welding. Why do drops of dew, etc., take a globular form? Why do not all bodies have this form? Illustrate the tendency of matter to a crystalline structure.

Has each substance its own form? Why is not cast-iron crystalline? Why do cannon become brittle after long use?

Describe the process of tempering and annealing. Explain the Rupert's Drop. How is glassware annealed?

2. *Adhesion.*—Define. What is the theory of filtering through charcoal? Of what use is soap in making bubbles? Define Capillary Attraction. Why will water rise in a glass tube, while mercury will be depressed? Is a tube necessary to show capillary attraction? What is the law of the rise in tubes?

Give practical illustrations of capillary action. Why will not old cloth shrink as well as new, when washed? What is the cause of solution? Why is the process hastened by pulverizing?

Tell what you can about gases dissolving in water. Why does the gas escape from soda-water as soon as drawn? Why do pressure and cold favor the solution of a gas? Describe the diffusion of liquids. Of gases.

Describe the osmose of liquids. Of gases. Why do rose-balloons lose their buoyancy? What is the difference between the *osmose* and the *diffusion* of gases?

2. GRAVITATION.—How does Gravitation differ from Cohesion and Adhesion? What is the law of gravitation? Why does a stone fall to the ground? Will a plumb-line near a mountain hang perpendicularly? Why do the bubbles in a cup of tea gather on the side? How is the earth kept in its place? Define Gravitation. Gravity. Weight.

State the three laws of weight. What is a vertical or plumb-line?

Describe the "guinea-and-feather experiment." What does it prove? Describe Atwood's machine. Deduce the formulas for falling bodies.

How can the time of a falling body be used for determining the depth of a well? How does gravity act upon a body thrown upward? What velocity must be given to a ball to elevate it to any point? How high will it rise in a given time? When it falls, with what force will it strike the ground? Define the Center of Gravity. The line of direction. The three states of equilibrium.

How may the center of gravity be found? Give the general principles of the center of gravity. Describe the leaning tower of Pisa. State some physiological applications of the center of gravity. Why do fat people generally walk so erect?

Define the Pendulum. Arc. Amplitude. What are isochronous vibrations? State the three laws of the pendulum. Who discovered the first law? What is the center of oscillation? How is it found? What is the center of percussion?

Describe the pendulum of a clock. How is a clock regulated? Does it gain or lose time in winter? Describe the gridiron pendulum. The mercurial pendulum. Name the various uses of the pendulum. Describe Foucault's experiment.

IV. The Elements of Machines.—Name and define the elements of machinery. Do the "powers," so called, produce energy? What is the law of mechanics? Illustrate the law. What is a lever? Describe the three classes of levers. The law of equilibrium.

What is the advantage peculiar to each class? Describe the steelyard as a lever. What effect does it have to reverse the steelyard? Describe the arm as a lever. (See "Hygienic Physiology," p. 34.) Would a lever of the first class answer the purpose of the arm? Describe the compound lever.

Describe the hay scale. The wheel and axle. Its law of equilibrium. Describe a system of wheel-work. At which arm of the lever is the P applied?

Describe the various uses of the inclined plane. Its law of equilibrium. What velocity does a body acquire in rolling down an inclined plane? Give illustrations.

Describe the screw. Its uses. Its law of equilibrium. How may its power be increased? What limit is there? Describe the wedge. Its uses. Its law of equilibrium. How does it differ from that of the other powers? Describe the pulley. The use of fixed pulleys. Is there any gain of P in a fixed pulley?

What is the use of a movable pulley? Describe a movable pulley as a lever. Give the general law of equilibrium in a combination of pulleys. What are cumulative contrivances? Is perpetual motion possible? Why?

V. Pressure of Liquids and Gases. 1. HYDROSTATICS.—Define. What liquid is taken as the type? What is the first law of liquids? Explain. Illustrate the transmission of pressure by water. Show how water is used as a mechanical power. Describe the hydrostatic press. Give its law of equilibrium.

What are the uses of this press? What pressure is sustained by the lower part of a vessel of water, when acted on by gravity alone? How does this pressure act? State the four laws which depend on this principle, and illustrate them. What is the weight of a cubic foot of sea water? Fresh water? What is the pressure at two feet? Give illustrations of the pressure at great depths. Describe the hydrostatic bellows. Its law of equilibrium. What is the "hydrostatic paradox"? Give illustrations. Give the principle of fountains. How high will the water rise? How do modern engineers carry water across a river? Did the ancients understand this principle? Give the theory of the Artesian well, and of ordinary wells and springs.

Give the rule for finding the pressure on the bottom of a vessel. On the side. Define the water level. Is the surface of water horizontal? If it were, what part of an approaching ship would we see first? Describe the spirit-level. Define specific gravity. What is the standard for solids and liquids? For gases? Explain the buoyant force of liquids.

What is Archimedes' law? Describe the "cylinder-and-bucket experiment." What does it prove? Give the method of finding the specific gravity of a solid. A liquid.

Is it necessary to use a specific gravity flask holding just 1,000 oz., or would any size answer? Suppose the solid is lighter than water and will not sink, what can you do? Explain the hydrometer. How can you find the weight of a given volume of any substance? The volume of any given weight? The exact volume of a body? Illustrate the action of dense liquids on floating bodies. Why will an iron ship float on water? Where is the center of gravity in a floating body? How do fish sink at pleasure?

2. Hydrodynamics.—Define To what is the velocity of a jet equal? How is the velocity found? Give the rule for finding the quantity of water which can be discharged from a jet in a given time. What is the effect of tubes? Tell something of the flow of water in rivers.

Name and describe the different kinds of water-wheels. Which is the most valuable form? Describe Barker's Mill. How are waves produced? Explain the real motion of the water. How does the motion of the whole wave differ from that of each particle? How is the character of waves modified near the shore? What is the extreme height of "mountain waves"? Define like phases. Unlike phases. A wave-length.

What is the effect if two waves with like phases coincide? With unlike phases? What is this termed?

3. Pneumatics.—Define. What principles are common to liquids and gases? What gas is taken as the type? Describe the air-pump. Can a perfect vacuum be obtained in this way? What is the condenser? Its use? Prove that the air has weight.

Show its elasticity and compressibility. Describe the bottle-imps. What principles do they illustrate? Show the expansibility of the air.

Describe the experiments with the hand-glass. The principle of Hiero's fountain. The Magdeburg hemispheres. What do they prove? Show the upward pressure of the air.

The buoyant force of the air. Would a pound of feathers and a pound of lead balance, if placed in a vacuum? On what principle does a balloon rise? What is the amount of the pressure of the air? Describe the experiment illustrating this. Where do these figures apply?

Describe how the pressure of the air continually varies. Explain Mariotte's (called also Boyle's) law. Describe the barometer. Its uses. Are the terms "fair," "foul," etc., often placed on the scale, to be relied upon? Why is mercury used for filling the barometer? Describe Otto Guericke's barometer.

Describe the action of the lifting-pump. The force-pump. The fire-engine. Compare the action of the lifting-pump with that of the air-pump. What is the siphon? Explain its theory.

Describe the pneumatic inkstand. The hydraulic ram. The atomizer. Show how a current of air drags with it the still atmosphere. What opposing forces act on the air? How high does the air extend? How does its density vary?

VI. Acoustics.—Define. Name and define the two senses of this word. May not the terms "light," "heat," etc., be used in the same way? Illustrate the formation of sound by vibrations.

Show how the sound of a tuning-fork is conveyed through the air. The report of a gun. The sound of a bell. The human voice. Define a sound-wave. In which direction do the molecules of air vibrate? In what form do the waves spread? Can a sound be made in a vacuum? Can a sound come to the earth from the stars?

How do sounds change as we pass above or below the sea-level? Upon what does the velocity of sound depend? Why is this? At what rate does sound travel in the air? In water? In the metals? In iron? What effect does temperature have on the velocity of sound?

Do all sounds travel at the same rate? How does the velocity of sound enable us to determine distance? Upon what does the intensity of sound depend? At what rate does it diminish? Why?

Explain the speaking-tube. The ear-trumpet. Describe Biot's experiment in the water-pipes of Paris. The speaking-trumpet. What is the refraction of sound?

Define reflection of sound. What is the law? Give some curious instances of reflection. What is the shape of a whispering-gallery? Illustrate the decrease of sound by repeated reflection. Why are sounds more distinct at night than by day? Is it desirable to have a door or a window behind a speaker? What causes the "ringing" of a sea-shell? How are echoes produced? When is the echo repeated? Illustrate the decrease of sound by reflection. What are acoustic clouds?*

* "The influence of wind on the intensity of sound seems due to the fact that, owing to obstructions opposed by the ground, there is a considerable difference between the velocity of the wind close to the ground and the velocity at the height of a few feet above the ground. Thus in a meadow the velocity of the wind at one foot above the surface may be only half what it is at eight feet above the surface. Let us take the velocity of sound at 1,100 feet per second, and suppose that the velocity of a contrary wind is ten feet per second at the surface, and twenty feet per second at the height of eight feet above the surface. Thus, considering this circumstance alone, the wave of sound at the end of a second would be at the surface ten feet in advance of its position at eight feet above the surface; so that the front of the wave, instead of being a vertical plane, would be inclined to the horizon. Thus the sound, instead of proceeding horizontally, becomes turned upward. It only remains to add that this tilting of the front of the wave is not delayed until the end of a second, but begins at the origin of the sound and increases gradually. Hence a ray of sound, so to speak, instead of traveling horizontally is curved upward, and thus passes over the head of a person stationed at a distance from the origin. A contrary wind then diminishes the intensity of sound by lifting the sound off the ground, and the amount of this lifting increases as the distance from the origin increases. The various consequences which may be deduced from the preceding theory have been verified by experiments.

What is the difference between noise and music? Upon what does pitch depend? Describe the siren. How is it used

Thus it follows that a listener when the wind is contrary may expect to recover a sound, which he has lost at a certain distance from its origin, by ascending to some height above the surface. Also the influence of a wind will be but small if the surface be very smooth; thus sounds are heard against the wind much farther over calm water than over land. Again, suppose the origin of the sound to be elevated above the surface: then if the listener be also raised above the surface he may hear a very loud sound made up of two parts, namely, that which has traveled horizontally, and that which has been tilted upward from the ground by the action of the contrary wind. Next, suppose the wind to be *favorable* instead of *contrary*. In this case the higher part of the wave of sound moves more rapidly than the lower, and so the plane front of the wave is tilted *forward*, and the rays of sound are bent *downward* to the advantage of the listener on the ground. Then the influence of the wind on sound has been shown to depend on the circumstance that when the wind is blowing, the velocity of sound is different at different heights above the ground; similar effects will therefore follow if this difference of velocity is produced by any other cause instead of by the wind. Now change of temperature affects the velocity of sound: if the temperature rise one degree of Fahrenheit's thermometer, the velocity increases by about a foot per second. In general, as we ascend in the air during the day the temperature decreases, and therefore so also does the velocity of sound. Thus the result is the same as in the case of a *contrary* wind; the ray of sound is lifted over the head of a person on the ground, so that the audibility of the sound is diminished. The presence of vapor in the atmosphere also affects the propagation of sound; the velocity increases as the quantity of vapor increases. The direct effect, however, is very slight, but indirectly the vapor is of consequence, for it gives to the air a greater power of radiating and absorbing heat, and so promotes inequality of temperature. The variation of temperature is greatest when the sun is shining, so that it is greater by day than by night, and greater in summer than in winter. Hence, according to the theory now explained, sounds ought to be heard more plainly by night than by day, and more plainly in winter than in summer. That sounds are heard more plainly by night than by day is a well-known fact. We have supposed that the temperature *decreases* as we ascend in the atmosphere; but it may happen on some occasion that the temperature at the surface is *lower* than it is a little above the surface. This may be the case, for instance, over the surface of the sea in the day-time, and over the surface of the land by night. Thus the effect on sound will be similar to that of a *favorable* wind. It is obvious that by the combined influence of wind and temperature the results produced may vary much as to degree; for instance, the operation of a contrary wind may be neutralized by that of the temperature rising as we ascend above the surface." See "Proceedings of the Royal Society of Great Britain," volumes XXII. and XXIV.