of vibrations in a given sound; Latour invented the siren, which gave still more accurate results; Colladon and Sturm, by a series of experiments at Lake Geneva, found the velocity of sound in water; Helmholtz made known the laws of harmonics; Lissajous, by means of a mirror attached to the vibrating body, threw the vibrations on a screen in a series of curves, and so rendered them visible; while Tyndall has investigated the causes modifying the propagation of sound, as acoustic clouds, fogs, etc., and popularized the whole subject of acoustics.

VII.

ON LIGHT.

THE sunbeam comes to the earth as simply motion of ether-waves, yet it is the grand source of beauty and power. Its heat, light, and chemical energy work every-where the wonder of life and motion. In the growing plant, the burning coal, the flying bird, the glaring lightning, the blooming flower, the rushing engine, the roaring cataract, the pattering rain—we see only varied manifestations of this one protean energy which we receive from the sun.

ANALYSIS OF LIGHT.

OPTICS, OR THE SCIENCE OF LIGHT.

- 1. Production and Propagation of Light.
  - 1. Definitions.
  - 2. Visual Angle.
  - 3. Laws of Light.
  - 4. Velocity of Light.
  - 5. Theory of Light.
- 2. Reflection of Light.
  - 1. Definition and Law.
  - 2. Action of Rough and Polished Surfaces
  - 3. Mirrors.
    - (1.) *Plane.*
    - (2.) *Concave.*
    - (3.) *Convex.*
- 3. Refraction of Light.
  - 1. Definition, and Illustrations.
  - 2. Laws of Refraction, and Illustrations.
  - 3. Lenses.
    - (1.) *Convex.*
    - (2.) *Concave.*
  - 4. Spherical Aberration.
  - 5. Total Reflection.
  - 6. Mirage.
- 4. Decomposition of Light.
  - 1. The Prismatic Spectrum.
  - 2. Solar Energy.
  - 3. The Normal Spectrum.
  - 4. Interruptions in the Spectrum.
  - 5. The Spectroscope.
  - 6. Three Kinds of Spectra.
  - 7. Color.
  - 8. Complementary Colors.
  - 9. The Rainbow.
  - 10. Chromatic Aberration.
  - 11. Polarization.
    - (1.) *Definition.*
    - (2.) *By Double Refraction.*
    - (3.) *By Reflection.*
    - (4.) *The Polariscope.*
- 5. Optical Instruments.
  - 1. Microscope.
  - 2. Telescope.
  - 3. Opera-glass.
  - 4. Projecting Lantern.
  - 5. Camera.
  - 6. The Eye.
  - 7. The Stereoscope.

OPTICS, OR THE SCIENCE OF LIGHT.

I. PRODUCTION AND TRANSMISSION OF LIGHT.

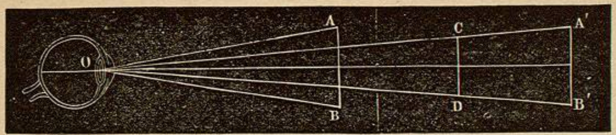
1. Definitions.—A *luminous* body is one that emits light. A *medium* is any substance through which light passes. A *transparent** body is one that obstructs light so little that we can see objects through it. A *translucent* body is one that lets some light pass, but not enough to render objects visible through it. An *opaque* body is one that does not transmit light. A *ray of light* is a single line of light. A *pencil* or *beam of light* is a collection of rays, which may be *parallel*, *diverging*, or *converging*; it may be traced in a dark room into which a sunbeam is admitted by the floating particles of dust which reflect the light to the eye.

2. The Visual Angle is the angle formed at the eye by rays coming from the extremities of an ob-

* The terms transparent and opaque are relative. No substance is perfectly transparent, or entirely opaque. Glass obstructs some light. According to Miller, 7 ft. of the clearest water will arrest one half the light which falls upon it. While Young asserts that the beam of the setting sun, passing through 200 miles of air, loses $\frac{199}{200}$ of its force. On the other hand, gold, beaten into leaf, becomes translucent, transmitting green light; and scraped horn is semi-transparent.

ject. The angle AOB is the angle of vision subtended by the object AB. The size of this angle varies with the distance of the body. AB and $A'B'$ are of the same length, and yet the angle $A'OB'$ is

Fig. 137.



Variation of Visual Angle with Distance.

smaller than AOB, and hence $A'B'$ will seem shorter than AB. The distance and the apparent size of objects are intimately connected, since by experience we have learned to associate them. Knowing the distance of an object, we immediately estimate its size from the visual angle.*

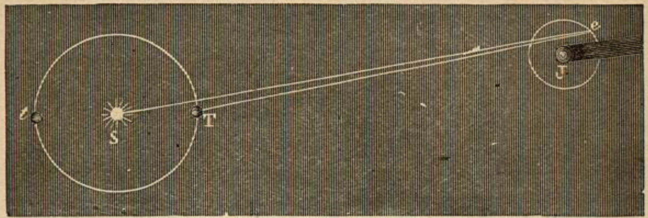
3. Laws of Light. — 1. Light passes off from a luminous body equally in every direction. 2. Light travels through a uniform medium in straight lines. 3. The intensity of light decreases as the square of the distance increases.

4. The Velocity of Light has been determined in various ways. The following was the first method: The planet Jupiter has four moons. As these revolve around the planet, they are eclipsed at regular intervals. In Fig. 138, let J represent Jupiter, e one of the moons, S the sun, and T and t different positions of the earth in its orbit around the sun. When the

* We can *vary the apparent size of any body at which we are looking by increasing or diminishing this angle*—a principle that will be found of great importance in the formation of images by mirrors and lenses.

earth is at T, the eclipse occurs 16 min. and 36 sec. earlier than at t. That interval of time is required

Fig. 138.



The Sun, Earth, and Jupiter.

for the light to travel across the earth's orbit, giving a velocity of about 186,000 miles per second.*

5. Undulatory Theory of Light. — There is supposed to be a fluid, termed *ether*, constituting a kind of universal atmosphere, diffused through space. It is so subtle that it glides among the molecules of bodies as the air does among the branches and the foliage of trees. It fills the pores of all substances, eludes all chemical tests, passes in through the receiver, and remains even in the vacuum of an air-pump. A luminous body sets in motion waves of ether, which go off in every direction. They move at the rate of 186,000 miles per second, and, breaking upon the eye, give the impression of sight. In the wave-motion of light, the vibrations are *transverse* (crosswise).†

* This rate is so great that for all distances on the earth it is instantaneous. A sunbeam would girt the globe quicker than we can wink, if its path could be appropriately curved.

† Thus, if we suppose a star directly overhead and a ray of light coming down to us, we should conceive that some of the particles which com-