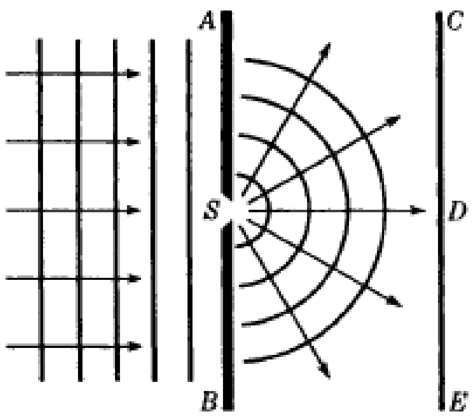
:Interference of Light Waves

Light can be diffracted when it passes by an edge, just like water waves and sound waves can. Reflection and refraction can be explained when light is modeled as a wave. What led scientists to believe that light has wave properties? They discovered that light could be made to interfere. When you look at objects that are illuminated by a white light source such as a nearby lightbulb, you are seeing **incoherent light,** which is light with unsynchronized wave fronts. The effect of incoherence in waves can be seen in the example of heavy rain falling on a swimming pool. The surface of the water is choppy and does not have any regular pattern of wave fronts or standing waves. Because light waves have such a high frequency, incoherent light does not appear choppy to you. Instead, as light from an incoherent white light source illuminates an object, you see the superposition of the incoherent light waves as an even, white light.

Huygens principle

When waves pass through an aperture or past the edge of an obstacle, they always spread to some extent into the region which is not directly exposed to the oncoming waves. This phenomenon is called diffraction. In order to explain this bending of light, Huygens nearly three centuries ago proposed the rule that "each point on a wave front may be regarded as a new source of waves". In Fig.1 let a set of plane waves approach the barrier AB from the left, and let the barrier contain an opening S of width somewhat smaller than the wavelength. At all points except S the waves will be either reflected or absorbed, but S will be free to produce a disturbance behind the screen. It is found experimentally, in agreement with the above principle, that the waves spread out from S in the form of semicircles.



.Figure 1. Diffraction of waves passing through a small aperture

Young' s experiment

The original experiment performed by Young is shown schematically in Fig. 2. Sunlight was first allowed to pass through a pinhole S and then, at a considerable distance away, through two pinholes S_1 and S_2. The two sets of spherical waves emerging from the two holes interfered with each other in such a way as to form a symmetrical pattern of varying intensity on the screen AC. Since this early experiment was performed, it has been found convenient to replace the pinholes by narrow slits and to use a source giving monochromatic light, i.e., light of a single wavelength. In place of space of spherical wave fronts we now have cylindrical wave fronts, represent equally well in two dimensions by the same Fig. 2. If the circular lines represent crests of waves, the intersections of any two lines represent the arrival at those points of two waves with the same phase or with phases differing by a multiple of 2π. Such points are therefore those of maximum disturbance or brightness. A close examination of the light on the screen will reveal evenly spaced light and dark bands or fringes.

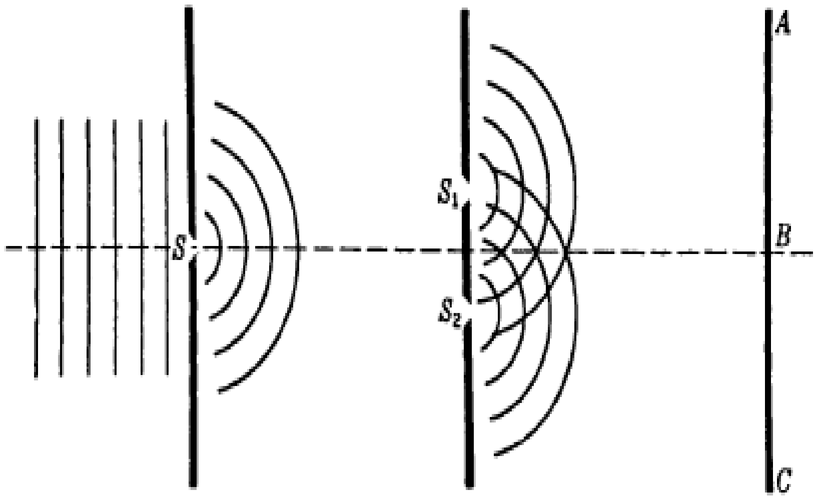


Fig.2. Experimental arrangement for Young's double-slit experiment.

Interference of Coherent Light:

The opposite of incoherent light is coherent light, which is light from two or more sources that add together in superposition to produce smoot wave fronts. A smooth wave front can be created by a point source, as shown in Figure 1-a. A smooth wave front also can be created by multiple point sources when all point sources are synchronized, such as with a laser, as shown in Figure 1-b. Only the superposition of light waves from coherent light sources can produce the interference phenomena that you will examine in this section.

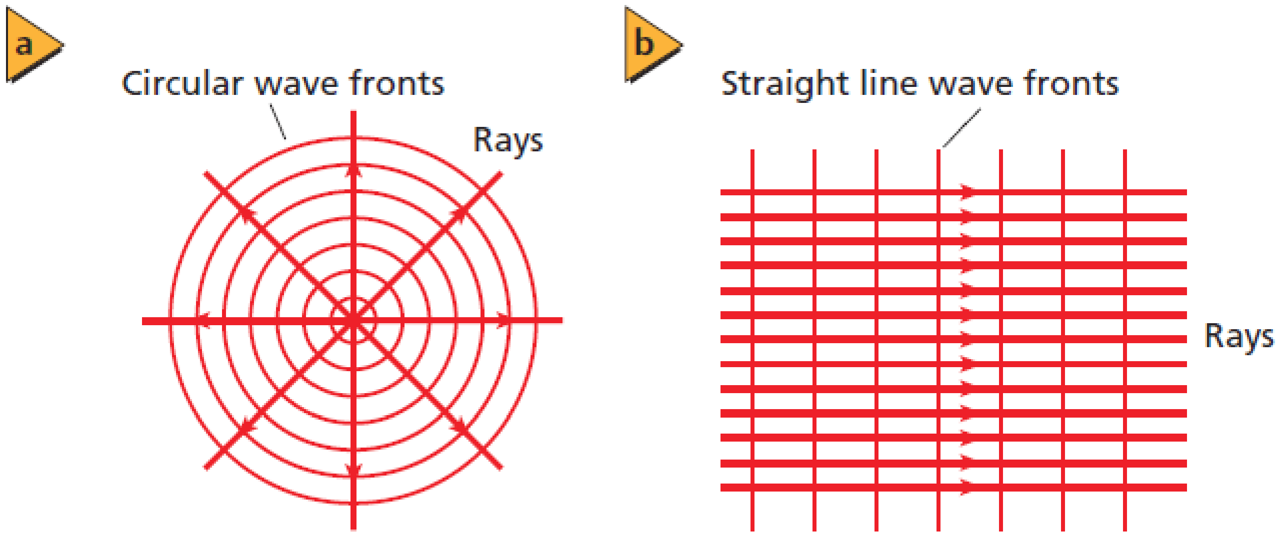


Figure 1 Smooth wave fronts of light are created by point sources **(a)** and by lasers **(b).**

In order to observe interference in light waves, the following conditions must be met:

- **The sources must be coherent- that is, they must maintain a constant phase with respect to each other.** **(Conditions for interference)**
- **The sources should be monochromatic -that is, of a single wavelength.**

Young's Double-Slit Experiment, (Young' s experiment):

A common method for producing two coherent light sources is to use a monochromatic source to illuminate a barrier containing two small openings (usually in the shape of slits). The light emerging from the two slits is coherent because a single source produces the original light beam and the two slits serve only to separate the original beam into two parts (which, after all, is what is done to the sound signal from the side-by-side loudspeakers at the end of the preceding section). Any random change in the light emitted by the source occurs in both beams at the same time, and as a result interference effects can be observed when the light from the two slits arrives at a viewing screen.
If the light traveled only in its original direction after passing through the slits, as shown in Figure 2-a, the waves would not overlap and no interference pattern would be seen. Instead, as we have discussed in our treatment of Huygens's principle (Ch.2), the waves spread out from the slits as shown in Figure 2-b. In other words, the light deviates from a straight-line path and enters the region that would otherwise be shadowed. As noted in Ch.2, this divergence of light from its initial line of travel is called **diffraction.**

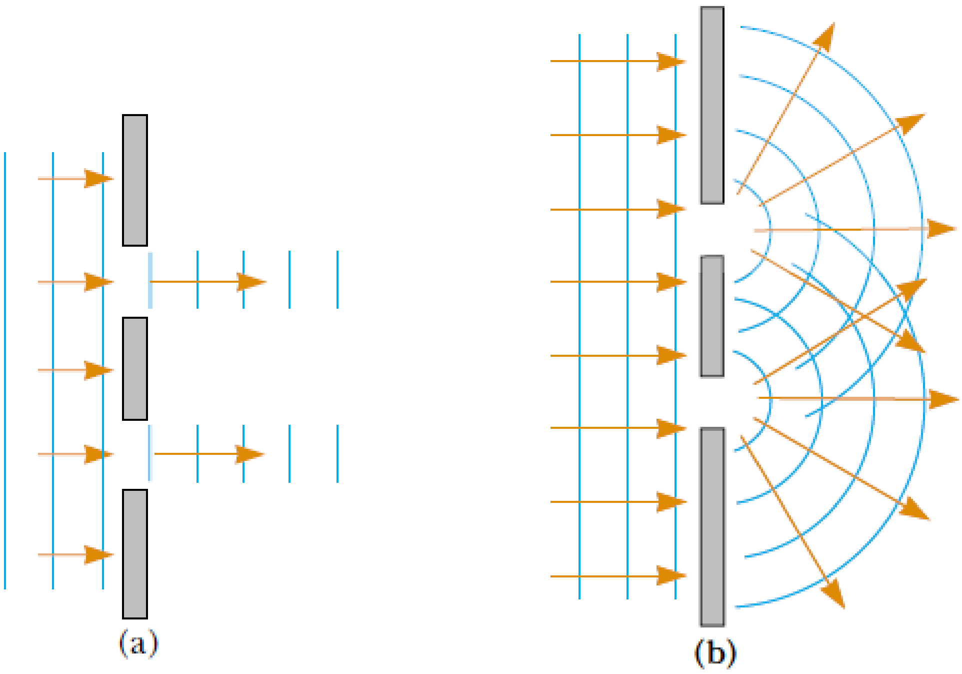


Figure 2-(a) If light waves did not spread out after passing through the slits, no interference would occur. (b) The light waves from the two slits overlap as they spread out, filling what we expect to be shadowed regions with light and producing interference fringes on a screen placed to the right of the slits.

Interference in light waves from two sources was first demonstrated by Thomas Young in 1801. A schematic diagram of the apparatus that Young used is shown in Figure 37.2a. Plane light waves arrive at a barrier that contains two parallel slits S_1 and S_2. These two slits serve as a pair of coherent light sources because waves emerging from them originate from the same wave front and therefore maintain a constant phase relationship. The light from S_1 and S_2 produces on a viewing screen a visible pattern of bright and dark parallel bands called fringes (Fig. 37.2b). When the light from S_1 and that from S_2 both arrive at a point on the screen such that constructive interference occurs at that location, a bright fringe appears.

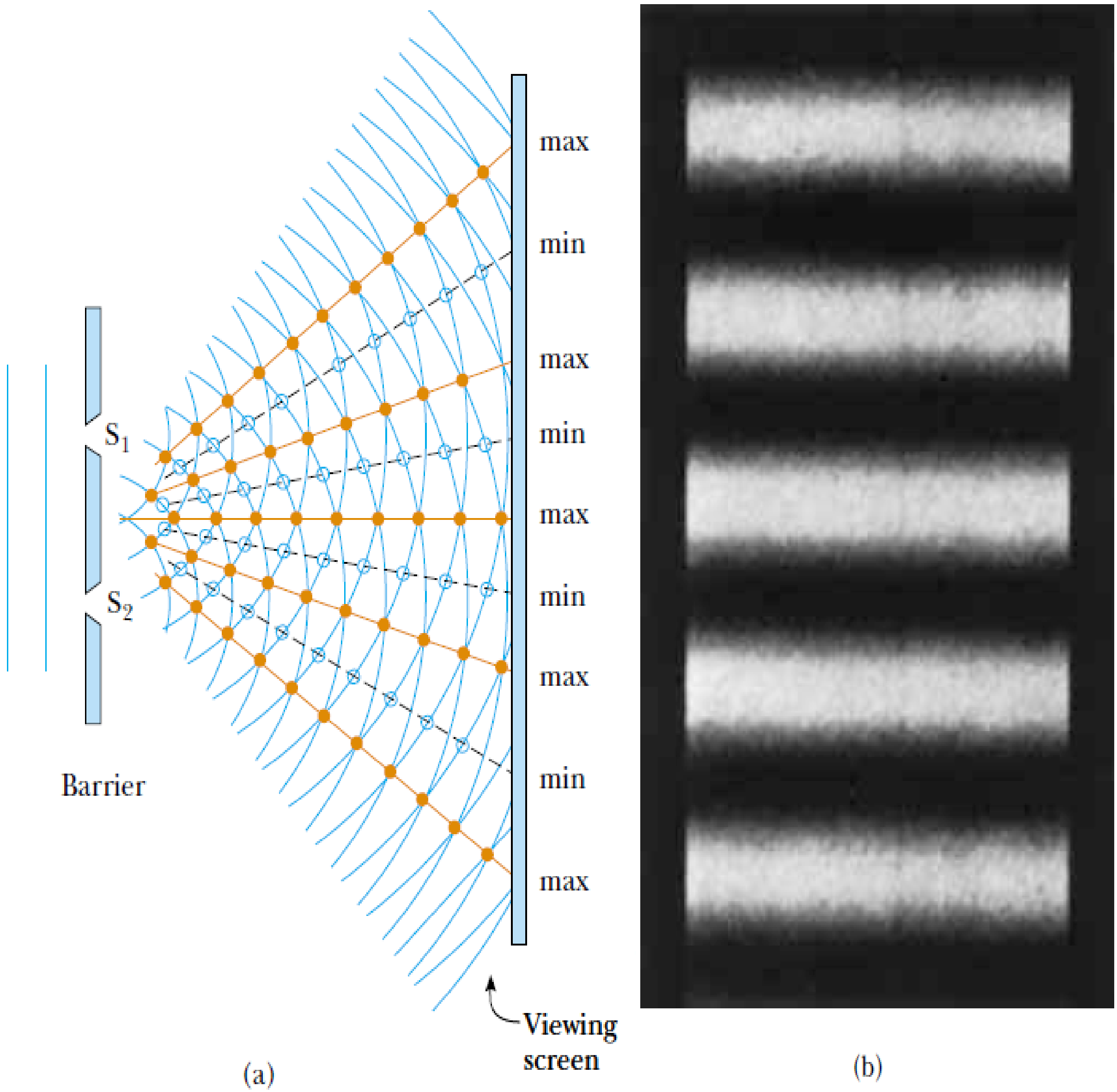


Figure 37.2 (a) Schematic diagram of Young's double-slit experiment. Slits S_1 and S_2 behave as coherent sources of light waves that produce an interference pattern on the viewing screen (drawing not to scale). (b) An enlargement of the center of a fringe pattern formed on the viewing screen.