Q1: At dark areas in an interference pattern, the light waves have canceled. Thus, there is zero intensity at these regions and, therefore, no energy is arriving. Consequently, when light waves interfere and form an interference pattern, (a) energy conservation is violated because energy disappears in the dark areas) b) energy transferred by the light is transformed to another type of energy in the dark areas (c) the total energy leaving the slits is distributed among light and dark areas and energy is conserved.

Fresnel's biprism

Soon after the double-slit experiment was performed by Young, the objection was raised that the bright fringes he observed were probably due to some complicated modification of the light by the edges of the slits and not to true interference. Thus the wave theory of light was still questioned. Not many years passed, however, before Fresnel brought forward several new experiments in which the interference of two beams of light was proved in a manner not open to the above objection. One of these the Fresnel biprism experiment, will be described in some detaial.

A schematic diagram of the biprism experiment is shown Fig. 6. The thin double prism P refracts the light from the slit sources S into two overlapping beams ac and be. If screens M

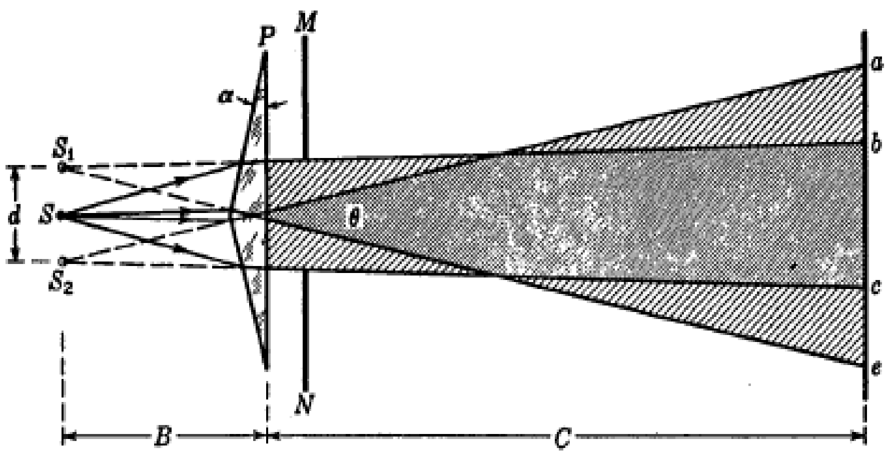


Fig. 6 Diagram of Fresnel's biprism experiment.

and N are placed as shown in the figure, interference fringes are observed only in the region bc. Just as in Young's double-slit experiment, the wavelength of light can be determined from measurements of the interference fringes produced by the biprism. Calling B and C the distances of the source and screen, respectively, from the prism P, d the distance between the virtual images S_1 and S_2 and Δx the distance between the successive fringes on the screen, the wavelength of the light is given from (4) as

$$\lambda = \frac{\Delta x d}{B + C} \qquad (5)$$

In order to find d, the linear separation of the virtual sources we used the eq. of refractive index of prism.

$$n = \frac{\sin(\frac{\alpha + \delta)}{2})}{\sin(\frac{\alpha}{2})}$$

Since α and δ are very small, so sine x= x

$$n = \frac{\frac{\alpha + \delta)}{2}}{\frac{\alpha}{2}} = \frac{\delta + \alpha}{\alpha}$$

$$n\alpha = \delta + \alpha$$

$$\delta = (n - 1)\alpha$$

From the right triangle S_1AS we obtain

$$\sin \delta = \frac{(d/2)}{B}$$

$$\delta = \frac{(d/2)}{B}$$

$$d = 2B\delta$$

$$d = 2(n-1)B\alpha \qquad (6)$$

$$D = B + C \qquad (7)$$

Sub. Eq. (6),(7) in (5) we obtain

$$\Delta x = \frac{(B+C)\lambda}{2B\alpha(n-1)}$$

When we use laser as a source, so B>> C

$$\Delta x = \frac{B\lambda}{2B\alpha(n-1)} = \frac{\lambda}{2\alpha(n-1)}$$

so the Δx independent on the distance between the screen and the two source

Other apparatus depending on division of the wave front Fresnel double-mirror

Two beams can be brought together in other ways to produce interference. In the arrangement known as Fresnel's mirrors, light from a slit is reflected in two plane mirrors slightly inclined to each other. The mirrors produce two virtual images of the slit, as shown in Fig. 6. They act in every respect like the images formed by the biprism, and interference fringes are observed in the region bc, where the reflected beams overlap. The symbols in this diagram correspond to those in Fig. 5, and Eq. 5 is again applicable. It will be noted that the angle 2θ subtended at the point of interference M by the two sources is twice the angle between the mirrors

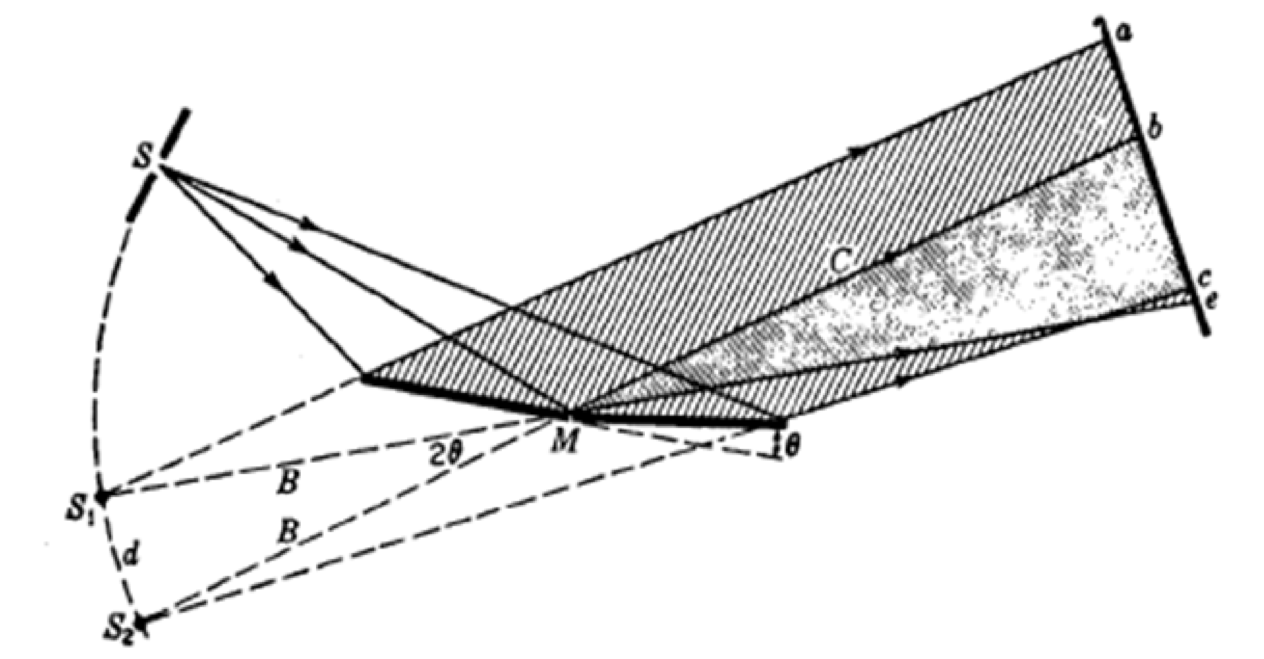
$$\lambda = \frac{\Delta x d}{B + C} \qquad (5) \qquad \Delta x = \frac{\lambda (B + C)}{d} \qquad (6)$$

$$\cos \theta = \frac{d/2}{B}$$

$$\theta = \frac{d/2}{B}$$

$$d = 2\theta B$$

$$\Delta x = \frac{\lambda (B + C)}{2\theta B}$$



.Figure 6 Geometry of Fresnel's mirrors

Lloyd's mirror:

Change of Phase Due to Reflection

An even simpler device, shown in Fig. 7, produces interference between the light reflected in one long mirror and the light directly from the source without reflection. In this arrangement, known as Lloyd's mirror, the quantitative relations are similar to those in the forgoing cases, with the slit and its virtual image constituting the double source.

Young's method for producing two coherent light sources involves illuminating a pair of slits with a single source. Another simple, yet ingenious, arrangement for producing an interference pattern with a single light source is known as *Lloyd's mirror* (Fig. 7.). A point light source is placed at point S close to a mirror, and a viewing screen is positioned some distance away and perpendicular to the mirror. Light waves can reach point *P* on the screen either directly from S to *P* or by the path involving reflection from the mirror. The reflected ray can be treated as a ray originating from a virtual source at point S'. As a result, we can think of this arrangement as a double-slit source with the distance between points S and S' comparable to length *d* in Figure 7. Hence, at observation points far from the source ($L >> d$) we expect waves from points S and S' to form an interference pattern just like the one we see from two real coherent sources. An interference pattern is indeed observed. However, the positions of the dark and bright fringes are reversed relative to the pattern created by two real coherent sources (Young's experiment). This can only occur if the coherent sources at points S and S' differ in phase by 180°. To illustrate this further, consider point *P*', the point where the mirror intersects the screen. This point is equidistant from points S and S'. If path difference alone were responsible for the phase difference, we would see a bright fringe at point P' (because the path difference is zero for this point), corresponding to the central bright fringe of

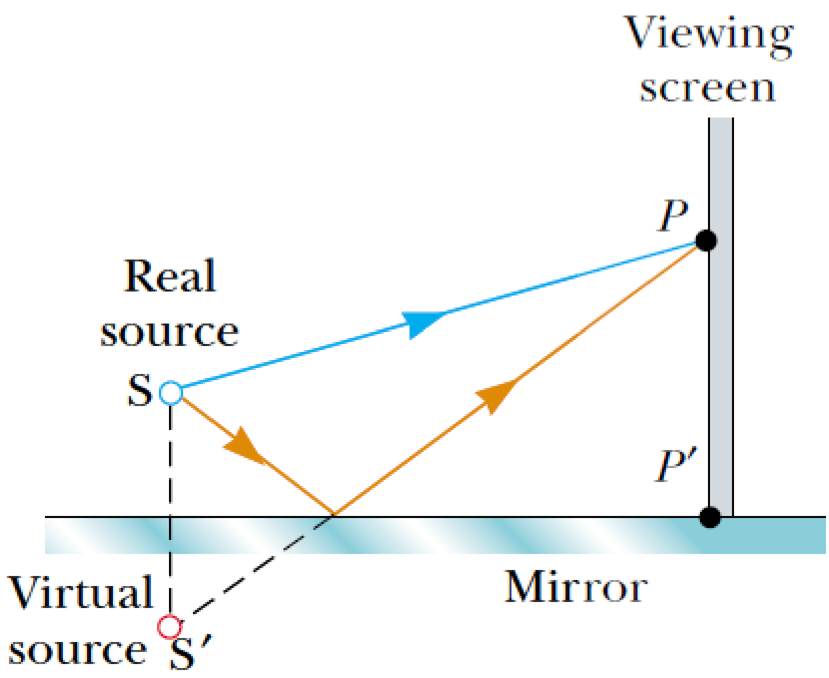


Figure 7. Lloyd's mirror. An interference pattern is produced at point P on the screen as a result of the combination of the direct ray (blue) and the reflected ray (brown). The reflected ray undergoes a phase change of 180°.

the two-slit interference pattern. Instead, we observe a dark fringe at point P'. From this, we conclude that a 180° phase change must be produced by reflection from the mirror. In general, an electromagnetic wave undergoes a phase change of 180° upon reflection from a medium that has a higher index of refraction than the one in which the wave is traveling.

Billet's split lens

Other ways exist for dividing the wave front into two segments and subsequently recombining these at a small angle with each other. For example, one can cut a lens into two halves on a plane through the lens axis and separate the parts slightly, to form two closely adjacent real images of a slit. The images produced in this device, known as Billet's split lens, act like the two slits in Young's experiment. A single lens followed by a biplate (two plane-parallel plates at a slight angle) will accomplish the same result.

The Michelson Interferometer:

The interferometer, invented by the American physicist A. A. Michelson(1852–1931),splits a light beam into two parts and then recombines the parts to form an interference pattern. The device can be used to measure wavelengths or other lengths with great precision because a large and precisely measurable displacement of one of the mirrors is related to an exactly countable number of wavelengths of light.

A schematic diagram of the interferometer is shown in Figure. 9. A ray of light from a monochromatic source is split into two rays by mirror M0, which is inclined at 45° to the incident light beam. Mirror M_0, called a ***beam splitter***,transmits half the light incident on it and reflects the rest. One ray is reflected from M_0 vertically upward toward mirror M_1, and the second ray is transmitted horizontally through M_0 toward mirror M_2. Hence, the two rays travel separate paths L_1 and L_2. After reflecting from M_1 and M_2, the two rays eventually recombine at M_0 to produce an interference pattern, which can be viewed through a telescope. The interference condition for the two rays is determined by their path length differences.

When the two mirrors are exactly perpendicular to each other, the interference pattern is a target pattern of bright and dark circular fringes, similar to Newton's rings. As M_1 is moved, the fringe pattern collapses or expands, depending on the direction in which M_1 is moved. For example, if a dark circle appears at the center of the target pattern (corresponding to destructive interference) and M_1 is then moved a distance $\lambda/4$ toward M_0, the path difference changes by $\lambda/2$.What was a dark circle at the center now becomes a bright circle. As M_1 is moved an additional distance $\lambda/4$

toward M_0, the bright circle becomes a dark circle again. Thus, the fringe pattern shifts by one-half fringe each time M_1 is moved a distance $\lambda/4$. The wavelength of light is then measured by counting the number of fringe shifts for a given displacement of M_1. If the wavelength is accurately known, mirror displacements can be measured to within a fraction of the wavelength.