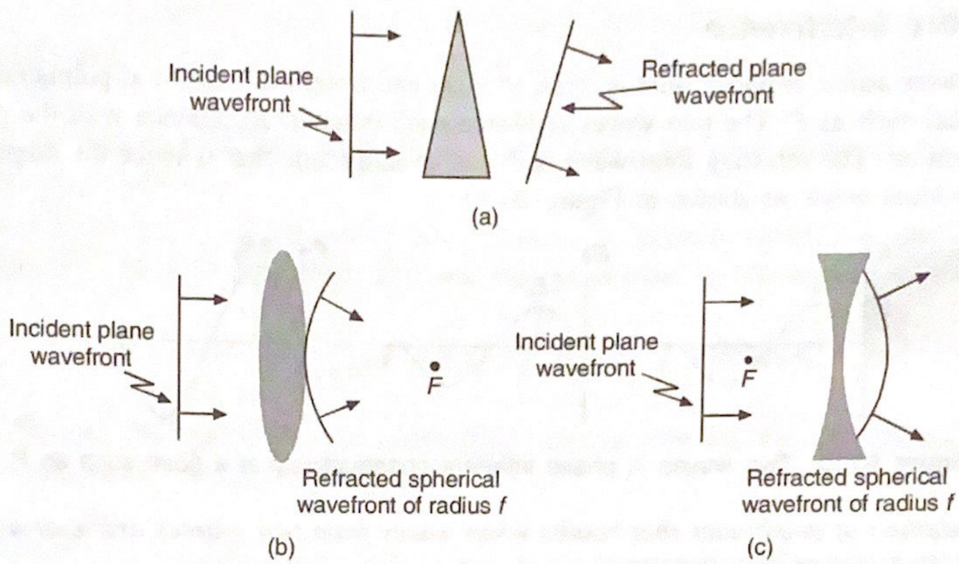

Figure 10.8 Refraction of plane wave by (a) a prism, (b) a convex lens, (c) a concave lens.

10.7 INTERFERENCE

- Light is an electromagnetic wave consisting of oscillating electric and magnetic fields. Most optical detectors including our eyes cannot respond to the oscillating electric field directly. The important quantity, sensitive to our eyes, is the *intensity* I which is proportional to the square of the amplitude E_m of the electric field:

$$I = \frac{c\varepsilon_0}{2} E_m^2 \qquad (10.2)$$

- When two or more light waves pass through a given point, their electric fields combine according to the *principle of superposition* and produce a resultant electric field at the point. The intensity I of the light (which, in turn, is related to its brightness) is proportional to the square of the resultant electric field strength.
- The modification in the distribution of light intensity due to the superposition of two or more waves is called *interference*.
- Consider two light waves with the *same amplitude* and *frequency* emitted *in phase* by two sources S_1 and S_2, as shown in Figure 10.9. The solid arcs are *crests* (electric field is maximum in some direction) and the dashed arcs are *troughs* (electric field is a maximum in the opposite direction).

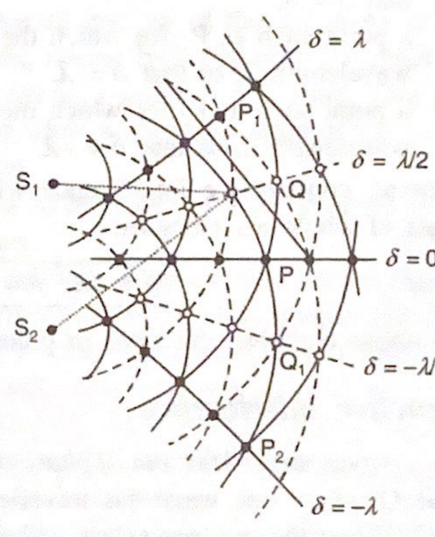

Figure 10.9 Spherical wavefronts produced by two coherent point sources S_1 and S_2. The filled circles represent points of constructive interference, where the path difference $\delta = n\lambda$. The open circles represent points of destructive interference, where the path difference $\delta = (n + 1/2)\lambda$.

Constructive interference

The two waves arrive *in phase* (that is, crest to crest and trough to trough) at points (shown as filled circles) such as *P*. The two waves reinforce each other in accordance with the principle of superposition. The resulting total wave at *P* has an amplitude that is twice the amplitude of either individual wave, as shown in Figure 10.10.

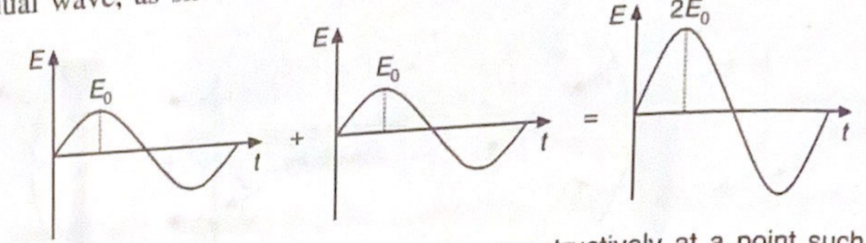

Figure 10.10 Two waves in phase interfere constructively at a point such as P.

The addition of amplitudes that results when waves from two sources arrive at a point in phase is called constructive interference.

Since the intensity of a light wave is proportional to the square of its electric field amplitude, the intensity of the resultant wave is four times that of either wave alone.

Positions of the points of constructive interference. The difference in the distances from S_1 and S_2 to a given point is called the **path difference** δ. The waves are in phase and hence interfere constructively at

- all points along the central line for which the waves have travelled equal distances, so that $\delta = 0$,
- a point such as P_1 for which the wave from S_2 has travelled an extra distance of one wavelength λ, so that $\delta = \lambda$,
- a point such as P_2 for which the wave from S_1 has travelled an extra distance of one wavelength λ, so that $\delta = -\lambda$.

In general, constructive interference will occur wherever the path difference is an integer multiple of whole wavelengths:

$$\boxed{\delta = n\lambda, \quad n = 0, \pm 1, \pm 2, \ldots} \quad \text{(Maxima)} \qquad (10.3)$$

In the above example, the locus of points satisfying this condition is a set of *hyperbolas*.

Destructive interference

The two waves arrive 180° *out of phase* (that is, crest to trough) at points (shown as open circles) such as Q where one wave has travelled one half wavelength farther than the other, so that $\delta = \lambda/2$. When the two waves are added, the resulting electric field is zero (Figure 10.11).

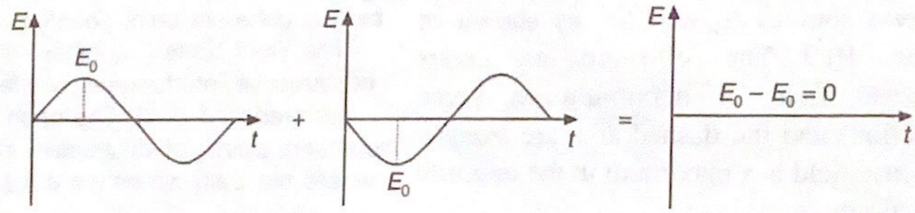

Figure 10.11 Two waves out of phase interfere destructively.

When waves from two sources arrive at a point 180° out of phase, the resultant amplitu is the difference of the two individual amplitudes and this condition is called ***destructive interference.***

In the case of destructive interference of two waves having the same amplitude, the intensity of the resultant wave is zero.

Positions of the points of destructive interference. In general, destructive interference will occur wherever the path difference is an odd integer number of half-wavelengths:

$$\boxed{\delta = \left(n + \frac{1}{2}\right)\lambda, \quad n = 0, \pm 1, \pm 2, \ldots} \qquad \text{(Minima)} \qquad (10.4)$$

- Though the two waves are continually moving forward, the interference pattern of maxima and minima is stationary.

REMARK