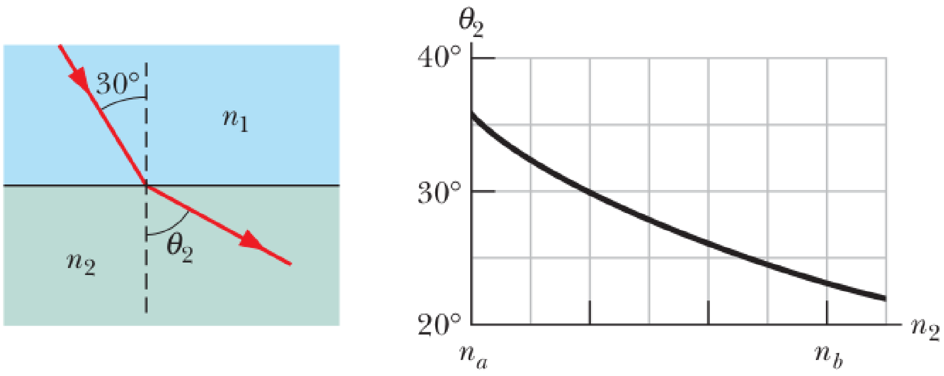
09 – Optics (Ch. 35)

$c = 3 \cdot 10^8$ m/s; $\varepsilon_0 = 8.854 \cdot 10^{-12}$ F/m; $\mu_0 = 1.257 \cdot 10^{-6}$ N/A^2

4) In Fig. (a) a beam of light in material 1 is incident on a boundary at an angle of 30°. The extent to which the light is bent due to refraction depends, in part, on the index of refraction n_2 of material 2. Figure (b) gives the angle of refraction θ_2 versus n_2 for a range of possible n_2 values, from $n_a = 1.30$ to $n_b = 1.90$. What is the speed of light in material 1?



(a) (b)

$$n_2 \sin\theta_2 = n_1 \sin\theta_1$$

4. Note that Snell's law (the law of refraction) leads to $\theta_1 = \theta_2$ when $n_1 = n_2$. The graph indicates that $\theta_2 = 30°$ (which is what the problem gives as the value of θ_1) occurs at $n_2 = 1.5$. Thus, $n_1 = 1.5$, and the speed with which light propagates in that medium is

$$v = \frac{c}{n_1} = \frac{2.998\times10^8 \text{ m/s}}{1.5} = 2.0\times10^8 \text{ m/s}.$$

7) The speed of yellow light (from a sodium lamp) in a certain liquid is measured to be $1.92\text{x}10^8$ m/s. What is the index of refraction of this liquid for the light?

7. The index of refraction is found from Eq. 35-3:

$$n = \frac{c}{v} = \frac{2.998\times10^8 \text{ m/s}}{1.92\times10^8 \text{ m/s}} = 1.56.$$

14) In a double-slit arrangement the slits are separated by a distance equal to 100 times the wavelength of the light passing through the slits. (a) What is the angular separation in radians between the central maximum and an adjacent maximum? (b) What is the distance between these maxima on a screen 50.0 cm from the slits? ($d \sin\theta = n\lambda$ 35-14)

14. (a) For the maximum adjacent to the central one, we set $m = 1$ in Eq. 35-14 and obtain

$$\theta_1 = \sin^{-1}\left(\frac{m\lambda}{d}\right)\Bigg|_{m=1} = \sin^{-1}\left[\frac{(1)(\lambda)}{100\lambda}\right] = 0.010\,\text{rad}.$$

(b) Since $y_1 = D\tan\theta_1$ (see Fig. 35-10(a)), we obtain

$$y_1 = (500\text{ mm})\tan(0.010\text{ rad}) = 5.0\text{ mm}.$$

The separation is $\Delta y = y_1 - y_0 = y_1 - 0 = 5.0$ mm.

29) Two waves of the same frequency have amplitudes 1.00 and 2.00. They interfere at a point where their phase difference is 60.0°. What is the resultant amplitude?

29. **THINK** The intensity is proportional to the square of the resultant field amplitude.

EXPRESS Let the electric field components of the two waves be written as

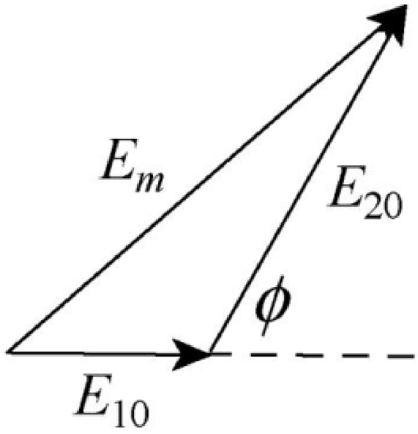
$$E_1 = E_{10}\sin\omega t$$
$$E_2 = E_{20}\sin(\omega t + \phi),$$

where $E_{10} = 1.00$, $E_{20} = 2.00$, and $\phi = 60°$. The resultant field is $E = E_1 + E_2$. We use phasor diagram to calculate the amplitude of E.

ANALYZE The phasor diagram is shown next.

The resultant amplitude E_m is given by the trigonometric law of cosines:

$$E_m^2 = E_{10}^2 + E_{20}^2 - 2E_{10}E_{20}\cos(180° - \phi) .$$



Thus,

$$E_m = \sqrt{(1.00)^2 + (2.00)^2 - 2(1.00)(2.00)\cos 120°} = 2.65 .$$

LEARN Summing over the horizontal components of the two fields gives

$$\sum E_h = E_{10}\cos 0 + E_{20}\cos 60° = 1.00 + (2.00)\cos 60° = 2.00$$

Similarly, the sum over the vertical components is

$$\sum E_v = E_{10}\sin 0 + E_{20}\sin 60° = 1.00\sin 0° + (2.00)\sin 60° = 1.732 .$$

The resultant amplitude is

$$E_m = \sqrt{(2.00)^2 + (1.732)^2} = 2.65 ,$$

which agrees with what we found above. The phase angle relative to the phasor representing E_1 is

$$\beta = \tan^{-1}\left(\frac{1.732}{2.00}\right) = 40.9°$$

Thus, the resultant field can be written as $E = (2.65)\sin(\omega t + 40.9°)$.