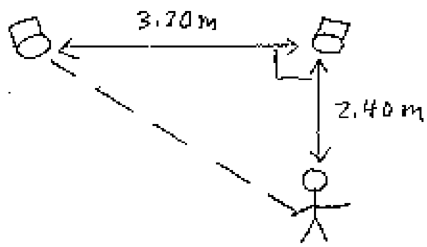
PROBLEM SET 9

CHAPTER 17 : 8, 12 } 5 marks each
CHAPTER 26 : 8, 20, 30 }

CHAPTER 17 #8

$v = 343\ m/s$



Since the speakers are out of phase, destructive interference is obtained when

$\Delta x = n\lambda$, where $n = 1, 2, \ldots$

and Δx is the path difference between the speakers and the person.

$$\Delta x = \sqrt{3.20^2 + 2.40^2} - 2.40 = 1.6\ m$$

The frequency of the waves is

$$f = \frac{v}{\lambda} = \frac{nv}{\Delta x}$$

The smallest frequency occures when $n = 1$

$$\therefore f = \frac{v}{\Delta x} = \frac{343}{1.6} = \underline{214\ Hz}$$

CHAPTER 17 #12

For a diffraction horn loudspeaker, with a doorway of width D

$$\sin\theta_H = \frac{\lambda_H}{D}$$

For a circular speaker of diameter D

$$\sin\theta_C = 1.22\,\frac{\lambda_C}{D}$$

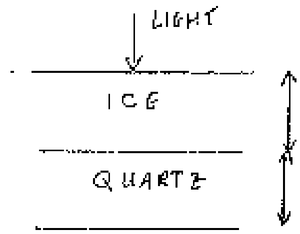
For the same diffraction angle, θ

$$\theta_H = \theta_C \equiv \theta$$

$\therefore\ \lambda_H = D\sin\theta$ and $\lambda_C = \frac{D}{1.22}\sin\theta$

$$\boxed{\frac{\lambda_H}{\lambda_C} = 1.22}$$

CHAPTER 26 # 8



$d_I = 2.0\,cm \qquad n_I = 1.309$

$d_Q = 1.1\,cm \qquad n_Q = 1.544$

$x = v t \Rightarrow t = \dfrac{x}{v}$

$t = t_I + t_Q = \dfrac{d_I}{v_I} + \dfrac{d_Q}{v_Q}$

The index of refraction is $n = \dfrac{c}{v} \Rightarrow \dfrac{1}{v} = \dfrac{n}{c}$

$\therefore\ t = \dfrac{n_I d_I + n_Q d_Q}{c}$

In vacuum, $x = ct \Rightarrow t = \dfrac{x}{c}$

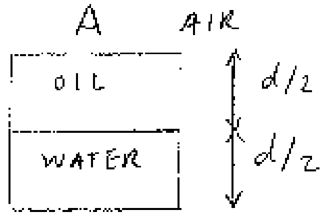
For the same time in both cases.

$\dfrac{x}{c} = \dfrac{n_I d_I + n_Q d_Q}{c}$

$x = n_I d_I + n_Q d_Q = 1.309 \times 2.0 + 1.544 \times 1.1$

$\boxed{x = 4.3\,cm}$

CHAPTER 26 #20



$n_{AIR} = 1.00$
$n_{OIL} = 1.48$
$n_{WATER} = 1.33$

$d = 30.0\text{ cm}$

First consider the effective depth of the water looking from the oil

$$d' = \frac{d}{2}\left(\frac{n_{OIL}}{n_{WATER}}\right)$$

Thus the effective depth of oil is

$$d_{EFF} = d' + d/2$$

Now consider the effective depth of the oil looking from the air

$$d'' = d_{EFF}\left(\frac{n_{AIR}}{n_{OIL}}\right) = \left(d' + \frac{d}{2}\right)\left(\frac{n_{AIR}}{n_{OIL}}\right)$$

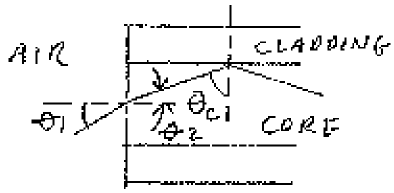
$$= \left[\frac{d}{2}\left(\frac{n_{OIL}}{n_{WATER}}\right) + \frac{d}{2}\right]\left(\frac{n_{AIR}}{n_{OIL}}\right)$$

$$= \frac{d}{2}\left[\frac{n_{AIR}}{n_{WATER}} + \frac{n_{AIR}}{n_{OIL}}\right] = \frac{d}{2} n_{AIR}\left(\frac{1}{n_{WATER}} + \frac{1}{n_{OIL}}\right)$$

$$= \frac{30}{2} \times 1\left(\frac{1}{1.33} + \frac{1}{1.48}\right)$$

$$\boxed{d'' = 21.4\text{ cm}}$$

CHAPTER 26 # 30



$n_{FLINT} = 1.667$ (core)

$n_{CROWN} = 1.523$ (cladding)

$n_{AIR} = 1.000$

$\theta_1 = ?$

$$\sin\theta_C = \frac{n_{CROWN}}{n_{FLINT}}$$

$$\theta_2 = 90° - \theta_C \implies \cos\theta_2 = \sin\theta_C = \frac{n_{CROWN}}{n_{FLINT}}$$

Snell's law

$$n_{AIR}\sin\theta_1 = n_{FLINT}\sin\theta_2$$

$$\sin\theta_1 = \frac{n_{FLINT}}{n_{AIR}}\sin\theta_2$$

But $\sin\theta_2 = \sqrt{1-\cos^2\theta_2} = \sqrt{1-\left(\frac{n_{CROWN}}{n_{FLINT}}\right)^2}$

$$\therefore \theta_1 = \sin^{-1}\left[\frac{n_{FLINT}}{n_{AIR}}\sqrt{1-\left(\frac{n_{CROWN}}{n_{FLINT}}\right)^2}\right]$$

$$= \sin^{-1}\left[\frac{1.667}{1.00}\sqrt{1-\left(\frac{1.523}{1.667}\right)^2}\right]$$

$$\boxed{\theta_1 = 42.67°}$$