FALL 2004 · PHYSICS 3
TR SECTION
MIDTERM

(1) IF ONE OF THE TWO SOURCES OF SOUND WAS MOVING, SO THAT THE FREQUENCY WAS DOPPLER-SHIFTED

(2) B

(3) C

(4) B

(5) A

(6) D

(7) E

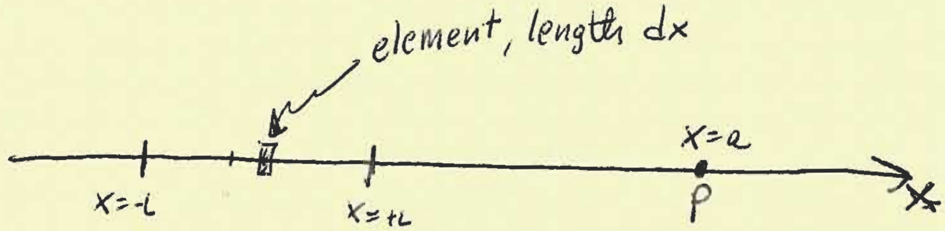
(8) C

(9A) POSITIVE X DIRECTION

(9B) $F = \frac{kQ}{a^2} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{a^2}$ IN POSITIVE X DIRECTION

(IT WOULD BE AS ~~[illegible]~~ POINT CHARGE)

9C



Consider the electric field due to an element of length dx, charge dQ

$$dQ = \frac{Q\,dx}{2L}$$

$$dE_x = k\frac{dQ}{b^2} = \frac{k}{2L}\frac{Q\,dx}{b^2}$$

where b = distance between element of length dx and the point P.
If this element is at coordinate x, then $b = a - x$

$$\Rightarrow dE_x = \frac{k}{2L}\frac{Q\,dx}{(a-x)^2}$$

$$E_x = \int_{-L}^{L} dE_x = \frac{kQ}{2L}\int_{-L}^{L}\frac{dx}{(a-x)^2} = \frac{kQ}{2L}\left[\frac{+1}{a-x}\right]_{-L}^{L}$$

$$E_x = \frac{kQ}{2L}\left[\frac{1}{a-L} - \frac{1}{a+L}\right] = \frac{kQ}{2L}\frac{a+L-a+L}{a^2-L^2}$$

$$\boxed{E_x = k\frac{Q}{a^2-L^2}}$$

Sanity check, as $a \gg L$, $a^2 - L^2 \doteq a^2$

so $E_x \sim k\frac{Q}{a^2}$ AGREES WITH ANSWER 9B

9D

Consider the force due to the electric field on a small piece of the 2nd rod.

Let x = position of the piece of 2nd rod $(a-d < x < a+d)$

dx = length of the piece of 2nd rod

dq = charge of the piece of 2nd rod

$$dq = \frac{q}{2d}\,dx$$

From previous problem

$$dF_x = dq\,E_x(x) = dq\left[k\,\frac{Q}{x^2-L^2}\right] = \frac{k}{2d}\,\frac{qQ\,dx}{x^2-L^2}$$

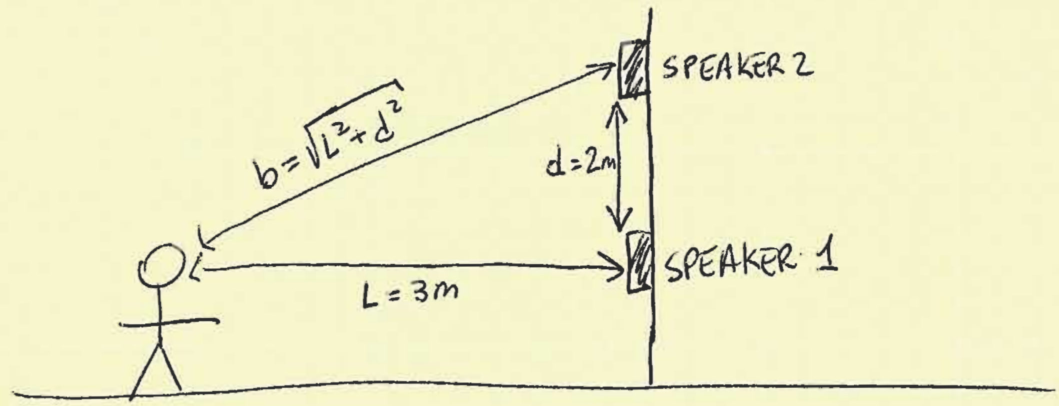
$$F_x = \frac{k}{2d}\,qQ\int_{a-d}^{a+d}\frac{dx}{x^2-L^2} = \frac{k}{2d}\,qQ\left[\frac{1}{2L}\log\frac{x-L}{x+L}\right]_{a-d}^{a+d}$$

From Table of integrals

$$F_x = \frac{kqQ}{4dL}\left[\log\frac{a+d-L}{a+d+L} - \log\frac{a-d-L}{a-d+L}\right]$$

$$F_x = \frac{kqQ}{4dL}\left[\log\frac{(a+d-L)(a-d+L)}{(a+d+L)(a-d-L)}\right] = \frac{kqQ}{4dL}\log\left[\frac{a^2-(d-L)^2}{a^2-(d+L)^2}\right]$$

(10)



(a) Wave at ~~speaker~~ listener at some time t due to speaker 1

$$y_1 = A_1 \cos(kL - \omega t)$$

Wave at listener at same time t due to speaker 2

$$y_2 = A_2 \cos(kb - \omega t)$$

Phase difference

$$\Delta\phi = k(L-b) = \frac{\omega}{v}(L-b) = \frac{2\pi f}{v}\left(L - \sqrt{L^2+d^2}\right)$$

$$\Delta\phi = \frac{2\pi\ 300}{343}\left(3 - \sqrt{9+4}\right) \text{rad} = \frac{2\left(3-\sqrt{13}\right)300\pi}{343} \text{rad}$$

$$\Delta\phi = -3.33 \text{ rad} = \underline{-191^\circ}$$

(b) Want $\Delta\phi = -\pi$

$$-\pi = \frac{2\pi f}{v}\left(L - \sqrt{L^2+d^2}\right) \qquad f = \frac{v}{2\left(\sqrt{L^2+d^2} - L\right)}$$

$$f = \frac{343}{2\left(\sqrt{13}-3\right)} \text{Hz} \qquad \boxed{f = 283 \text{ Hz}}$$