Physics 8B (Sec 2) <u>Solutions to Second Midterm</u> Nov. 12, 1986

(1)(a) To calculate $\omega = 2\pi\nu = 2\pi(c/\lambda) = c(2\pi/\lambda) = ck$, we know $c = 3 \times 10^8$ m/sec and $k = 1$ (meter)$^{-1}$ is given.
Then $\omega = (3\times10^8)(1)$ sec^{-1} $\Rightarrow$ $\boxed{\omega = 3\times10^8 \text{ sec}^{-1}}$

(b) Using values of k and ω, we have, using $E_0 = 10^3$ volts/m,
$\vec{E}(z,t) = \vec{E_0}\sin(kz-\omega t) = \{1000 \sin(z - [3\times10^8]t)\}\hat{y}$
the magnitude $|\vec{E}(z=4, t=10^{-8})|$ is given by
$|\vec{E}(4,10^{-8})| = 1000\sin(4-[3\times10^8]10^{-8}) = 1000\sin(4-3) =$
$|\vec{E}(4,10^{-8})| = 1000\sin(1 \text{ radian}) = 1000(0.841) = \underline{841 \text{ volts/meter}}$
(where we have ignored $\hat{y}$ in the magnitude since $|\hat{y}| = 1$).

(c) In (b), we saw that $\{1000\sin(z-[3\times10^8]t)\} = 841$ volts/meter when $z = 4$ meters and $t = 10^{-8}$ sec, so the electric field vector $\vec{E}(4,10^{-8}) = (841)\hat{y}$, meaning that the electric field vector $\vec{E}(4,10^{-8})$ is in the <u>positive y-direction</u> at $z = 4$ meters when $t = 10^{-8}$ sec.

(d) <u>Yes</u>, because the $\vec{E}$ vector is $\vec{E}(z,t) = E_0\{\sin(kz-\omega t)\}\hat{y}$ is always along the (positive or negative) y-axis.

(e) The magnetic field of this EM wave has the same maxima and nodes as the electric field, so $\vec{B}(z,t) = \vec{B_0}\sin(kz-\omega t)$, where $\vec{B_0}$ is the amplitude vector of the magnetic field of the wave. Since the EM wave moves in the $(+z)$-direction (because its form is $\sin(kz-\omega t)$) and since $\vec{B}$ is normal to both $\vec{E}$ and the direction in which the wave moves, $\vec{B}$ is in the $(\pm x)$ direction because $\vec{E}$ is in the $(\pm y)$ direction.

(2)(a) Here $f = -3$ inches, the object distance $s = 4$ inches, so

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \Rightarrow \frac{1}{4} + \frac{1}{s'} = -\frac{1}{3} \Rightarrow \frac{1}{s'} = -0.583 \Rightarrow \boxed{s' = -1.72 \text{ inches}}$$

is the image distance s'. This negative value of the image distance means that the image is located 1.72 inches to the left of the center of the lens.

(b) Since the image distance s' is negative, the image is virtual.

(c) The magnitude $|m|$ of the magnification is $|m| = (s'/s)$ so $|m| = (1.72/4) = 0.43$. Since the object is 1 inch high, the image is 0.43 inches high.

(d) Three possible rays are shown on the next page. Their paths are shown and the reasons are as follows. First, recall that the first focal point F is to the right of a diverging lens and the second focal point F' is to the left of a diverging lens, as shown on the drawing. Ray ① leaves the tip of the object parallel to the lens axis, so, after refraction, goes in a direction which, when extrapolated, passes through the second focal point F'. Ray ② passes undeviated through the center of the lens. Ray ③ leaves the object in a direction which would, when extrapolated, pass through the first focal point F. This ray, after refraction, is parallel to the lens axis. The intersection point of the directions of these rays after refraction locates the image of the tip of the arrow, therefore locating the entire image (since the object is normal to the axis).

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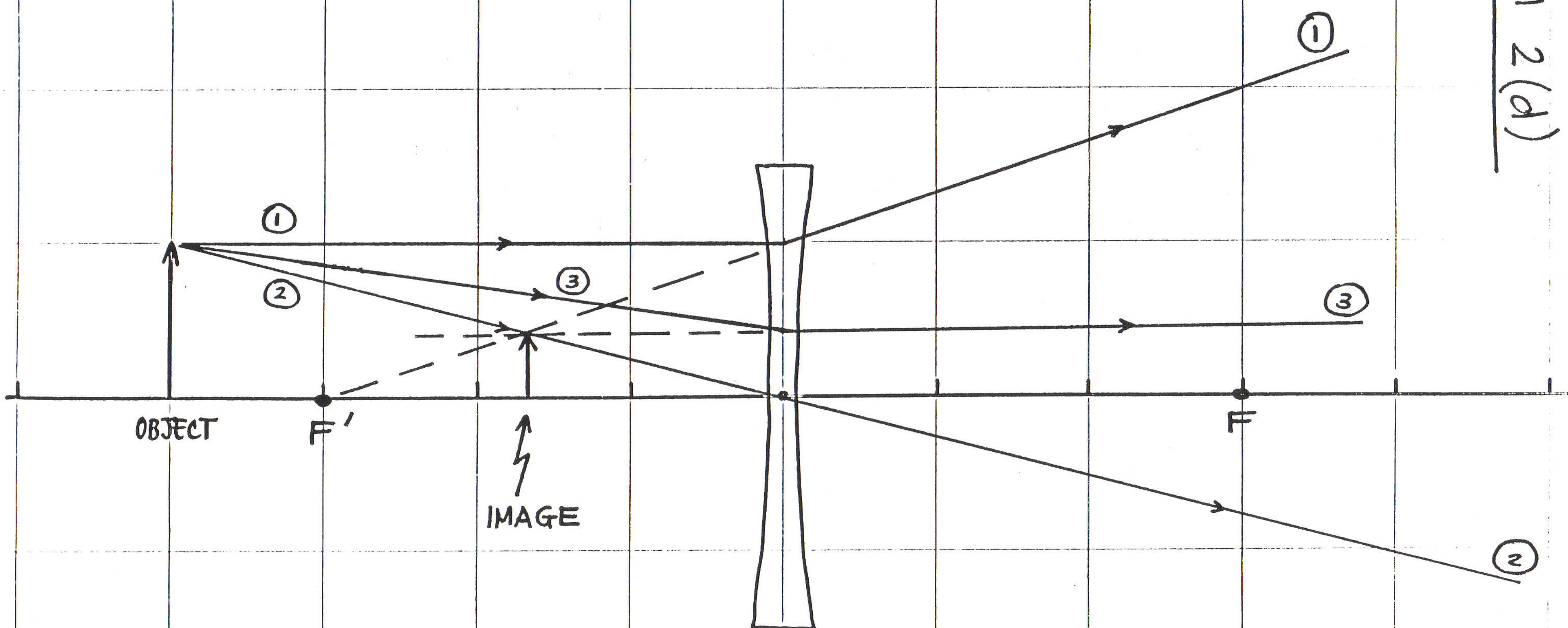
NAME ______________________ DISCUSSION SECTION ________

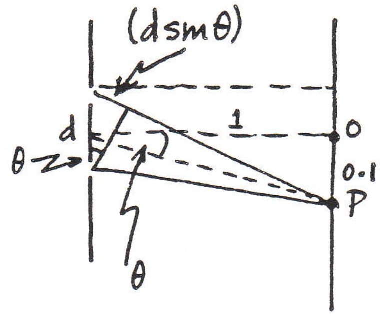
PROBLEM 2(d)

SCALE 1 inch



SOLID LINES = PATHS OF PHOTONS (RAYS)
DASHED LINES = EXTRAPOLATED DIRECTIONS

(3) In a two-slit interference experiment (see Fig. 21.8), p. 645, the path length difference between two rays arriving at a point P located by the angle θ is $\Delta x = d \sin\theta$, where d is the separation between the slits. The angle θ is $\theta = \tan^{-1}(0.1/1) = \tan^{-1} 0.1 = 5.71°$



so $\Delta x = d \sin\theta = (10^{-3})(0.09949) = 9.949 \times 10^{-5}$ meters

The phase difference φ corresponding to a path length difference Δx is $\varphi = (2\pi/\lambda)\Delta x$ where here $\lambda = 6000\,\text{Å} = 6 \times 10^{-7}$ meters, so

$$\varphi = \left(\frac{2\pi}{6\times10^{-7}}\right)(9.949\times10^{-5}) \text{ radians} = 1047 \text{ radians} \Rightarrow \boxed{\varphi = 1047 \text{ rad.}}$$

(Note: rounding errors in calculators may give slightly different values.)

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(4) Since a magnetic field passes through the circular loop, magnetic flux Φ passes through the loop, where

$$\Phi = BA\cos\theta = B(\pi R^2)(\cos 0°) = \pi R^2 B$$

since θ is the angle between $\vec{B}$ and the normal to area A. Then the relation between the flux Φ and the induced current I is

$$\Phi = LI$$

so

$$I = \left(\frac{\pi R^2}{L}\right)B$$

and

$$\boxed{\frac{dI}{dt} = \left(\frac{\pi R^2}{L}\right)\left(\frac{dB}{dt}\right)}$$

since R, L are constants