

Problem 1.

A 55 kW radio station broadcasts radio waves isotropically (which means with the same strength in all directions).

- What is the intensity of the radio waves a distance of 2.5 km away from the source?
- What is the maximum electric field strength due to these waves at that location?
- What is the maximum magnetic field strength due to these waves at that location?

a) isotropic radiation \rightarrow energy distributed over surface of sphere of radius 2.5 km. Surface area $A = 4\pi r^2 = 4\pi(2.5 \times 10^3 \text{ m})^2$

$$I = P/A = \frac{55 \times 10^3 \text{ W}}{7.85 \times 10^7 \text{ m}^2} = \boxed{7.00 \times 10^{-4} \text{ W/m}^2} \quad = 7.85 \times 10^7 \text{ m}^2$$

$$b) I_{\text{ave}} = \frac{1}{2} \epsilon_0 E_0^2 = \epsilon_0 E_{\text{rms}}^2 \quad (E_{\text{rms}} = E_0/\sqrt{2})$$

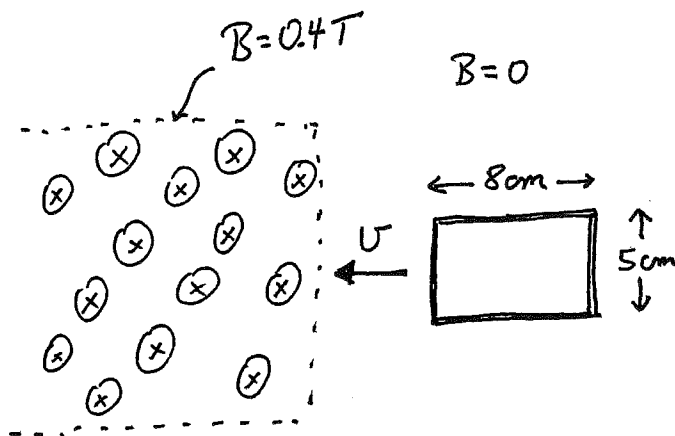
$$\therefore E_{\text{rms}} = \left(\frac{I}{\epsilon_0 \epsilon_0} \right)^{1/2} = \left[\frac{7.00 \times 10^{-4} \text{ W/m}^2}{(8.85 \times 10^{-12} \frac{\text{F}}{\text{m}})(3 \times 10^8 \text{ m/s})} \right]^{1/2} = 0.514 \text{ V/m}$$

$$\text{peak value} = E_0 = \sqrt{2} E_{\text{rms}} = \boxed{0.726 \text{ V/m}}$$

$$c) B_0 = \frac{E_0}{c} = \frac{0.726 \text{ V/m}}{3 \times 10^8 \text{ m/s}} = \boxed{2.42 \times 10^{-9} \text{ T}}$$

Problem 2.

A rectangular coil of wire, of 5 cm in height and 8 cm in width, consisting of 7 turns, is moved with a constant speed of 40 cm/s to the left as shown. It moves from a region of no magnetic field into a region of constant, uniform magnetic field of strength 0.4 T; the direction of the field is into the page.



- What is the direction (clockwise or counterclockwise) of the induced current in the coil as it enters the magnetic field?
- What is the direction of the force induced on the coil due to this induced current?
- What is the flux (magnitude and direction) through the coil when it is completely in the magnetic field?
- If the wire has a resistivity of $1.72 \times 10^{-8} \Omega \cdot m$ and a cross-sectional area of 1.0 mm^2 , what is the magnitude of the current induced in the coil as it moves into the field?
- How much heat per unit time is generated in the wire?

a) increasing flux into page as coil enters \therefore induced current is such as to generate field inside coil that is out of page \therefore **CCW**

b) Force on horizontal wires cancels; net force is due to current in left side which is down the page \therefore right hand rule says force is **to the right** (opposes the motion!)

c) $\phi = NBA \cos \theta = 7(0.4 \text{ T})(5 \times 10^{-2} \text{ m} \times 8 \times 10^{-2} \text{ m}) \cos 0^\circ = \mathbf{0.0112 \text{ Tm}^2}$
 Direction = **out of page**

d) $R = \frac{\rho L}{A} = \frac{(1.72 \times 10^{-8} \Omega \cdot m)(7 \times (10 \text{ cm} + 16 \text{ cm}))}{(1 \times 10^{-3} \text{ m})^2} = 0.0313 \Omega$

$\Delta t = \frac{8 \text{ cm}}{40 \text{ cm/s}} = 0.2 \text{ s}$ $|\mathcal{E}| = \frac{\Delta \phi}{\Delta t} = \frac{(0.0112 \text{ Tm}^2 - 0)}{0.2 \text{ s}} = 0.056 \text{ V}$

$\mathcal{E} = IR$ $I = \mathcal{E}/R = \frac{0.056 \text{ V}}{0.0313 \Omega} = \mathbf{1.79 \text{ A}}$

e) resistive heating: $P = I^2 R = (1.79 \text{ A})^2 (0.0313 \Omega) = \mathbf{0.100 \text{ W}}$
 (0.10 J/s)

Problem 3.

A doctor examines a mole using a 15.0 cm focal length magnifying glass (convex lens) which she holds 13.5 cm from the mole.

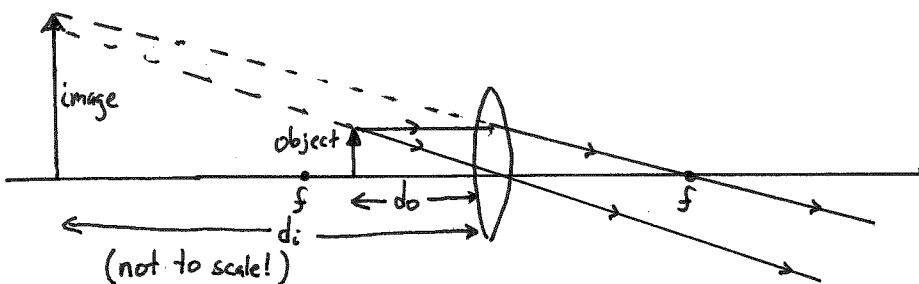
a) Where is the image? (indicate if it is on the object side or the opposite side of the lens, and how far it is from the lens).

b) If the mole has a diameter of 5.00 mm, how big is the image?

c) Is the image inverted or right-side-up?

d) Is the image real or virtual?

e) She now holds the magnifying glass further from the mole, in such a way that she sees a real, inverted image that is 5.00 mm in diameter (same size as the actual mole). What distance is the lens from the mole now?



$$\begin{aligned} \text{a)} \quad \frac{1}{d_o} + \frac{1}{d_i} &= \frac{1}{f} \\ \therefore \frac{1}{d_i} &= \frac{1}{f} - \frac{1}{d_o} = \frac{1}{15\text{cm}} - \frac{1}{13.5\text{cm}} \\ &= -7.41 \times 10^{-3} \text{ cm}^{-1} \end{aligned}$$

$$\therefore d_i = -135 \text{ cm}$$

on object side of lens

$$\text{b)} \quad m = -\frac{d_i}{d_o} = -\frac{(-135\text{cm})}{13.5\text{cm}} = +10 = \frac{h_i}{h_o}$$

$$\therefore h_i = 10h_o = 10(5\text{mm}) = 50\text{mm in diameter}$$

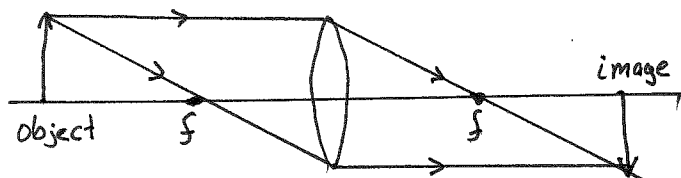
c) image is right side up
($m = +10$, $h_i = \text{positive}$; see sketch)

d) image is virtual
(on object side of lens)

$$\begin{aligned} \text{e)} \quad m &= -1 = -\frac{d_i}{d_o} & \therefore d_i &= d_o \\ & & \therefore \frac{1}{d_i} + \frac{1}{d_o} &= \frac{1}{d_o} + \frac{1}{d_o} = \frac{1}{f} \\ & & &= \frac{2}{d_o} = \frac{1}{f} \end{aligned}$$

$$\begin{aligned} \therefore d_o &= 2f \\ &= 2(15.0\text{cm}) \end{aligned}$$

$$d_o = 30.0 \text{ cm}$$



Problem 4.

- a) In an electromagnetic wave, what is oscillating?
- b) Which kind of simple lens, diverging or converging, is commonly used to correct myopia (near-sightedness)?
- c) Unpolarized light passes through two sheets of polarizing material whose transmission axes make an angle of 60 degrees with each other. If the intensity of the light after the first polarizer is 20 W/m^2 , what is the intensity after the second polarizer?
- d) Blue light in a vacuum has a wavelength of 480 nanometers. Diamond has an index of refraction of 2.4. What is the speed of blue light in diamond? What is the wavelength in diamond? Does the frequency change?

a) The electric and magnetic fields are oscillating

b) Diverging (concave) lens

c) Malus' Law : $I = I_0 \cos^2 \theta$

$$I_0 = 20 \text{ W/m}^2$$

$$I = 20 \text{ W/m}^2 (\cos 60^\circ)^2 = \boxed{5 \text{ W/m}^2}$$

d) $n = \frac{c}{v}$ $v = \frac{c}{n} = \frac{3.00 \times 10^8 \text{ m/s}}{2.4} = \boxed{1.25 \times 10^8 \text{ m/s}}$

$$\lambda' = \frac{\lambda}{n} = \frac{480 \text{ nm}}{2.4} = \boxed{200 \text{ nm}}$$

No, f remains the same in diamond as in air

Ignore for this year...
↓
we will cover this material after Test #3