Home work: hand in required

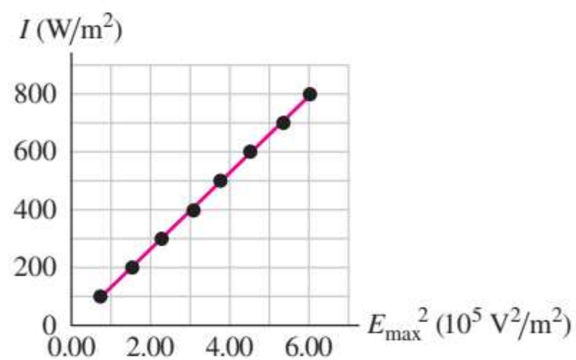
Problem 1

If the eye receives an average intensity greater than $100\,W/m^2$, damage to the retina can occur. This quantity is called the *damage threshold* of the retina.
(a) What is the largest average power (in mW) that a laser beam 1.5 mm in diameter can have and still be considered safe to view head-on?
(b) What are the maximum values of the electric and magnetic fields for the beam in part (a)?
(c) How much energy would the beam in part (a) deliver per second to the retina?
(d) Express the damage threshold in W/cm^2

Problem 2

Because the speed of light in vacuum (or air) has such a large value, it is very difficult to measure directly. To measure this speed, you conduct an experiment in which you measure the amplitude of the electric field in a laser beam as you change the intensity of the beam. Figure P32.49 is a graph of the intensity I that you measured versus the square of the amplitude E_{max} of the electric field (sinusoidal wave). The best-fit straight line for your data has a slope of 1.33×10^{-3} J/(V^2s).
(a) Explain why the data points plotted this way lie close to a straight line.
(b) Use this graph to calculate the speed of light in air.

Figure **P32.49**



Problem 1

(1) $A = \frac{\pi d^2}{4} = \frac{\pi \cdot 1.5^2 \cdot 10^{-6}}{4} = 1.767 \times 10^{-6} m^2$

$P = A \cdot I = 1.767 \times 10^{-6} m^2 \cdot 100 W/m^2 = 0.177 mW.$

$\therefore$ The largest average power is $\boxed{0.177 mW.}$

(2) $E_{max} = \sqrt{2}\bar{E} = \sqrt{I c \mu_0} \cdot \sqrt{2} = \boxed{274.58 V/m}$

$B_{max} = \frac{E_{max}}{c} = \boxed{9.15 \times 10^{-7} T}$

(3) $U = P \cdot t = \boxed{1.77 \times 10^{-4} J}$

(4) $I = 100 W/m^2 = 100 \times 10^{-4} W/cm^2 = \boxed{0.01 W/cm^2}.$

Problem 2.

(1) $I = \bar{S} = \overline{E \times H} = \frac{\bar{E^2}}{c \mu_0}$

Where c and μ_0 are both constants

$E_{max} = \sqrt{2} E_{rms} \Rightarrow I = \frac{E_{max}^2}{2c\mu_0} \Rightarrow I \propto E_{max}^2 \Rightarrow$ Close to a straight line.

(2) $\frac{1}{2c\mu_0} = 1.33 \times 10^{-3} \Rightarrow c = \frac{1}{2 \times 1.33 \times 10^{-3} \times 4\pi \times 10^{-7}} = \boxed{2.99 \times 10^8 m/s}.$

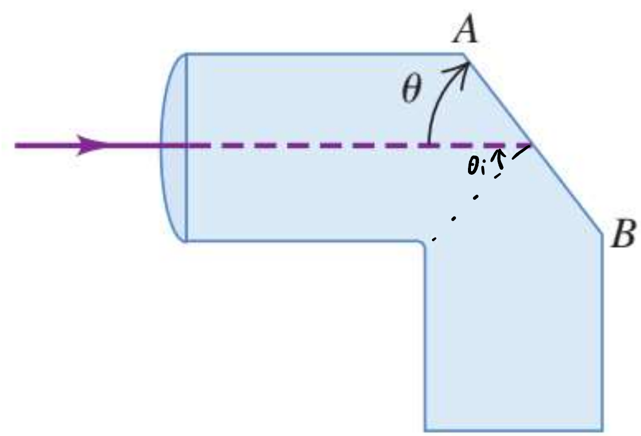
Problem 3

Light enters a solid pipe made of plastic having an index of refraction of 1.60. The light travels parallel to the upper part of the pipe (Fig. E33.15). You want to cut the face AB so that all the light will reflect back into the pipe after it first strikes that face.

(a) What is the largest that θ can be if the pipe is in air?

(b) If the pipe is immersed in water of refractive index 1.33, what is the largest that θ can be?

Figure **E33.15**



Problem 4

The company where you work has obtained and stored five lasers in a supply room. You have been asked to determine the intensity of the electromagnetic radiation produced by each laser. The lasers are marked with specifications, but unfortunately different information is given for each laser:

Laser A: power = 2.6 W; diameter of cylindrical beam = 2.6 mm

Laser B: amplitude of electric field = 480 V/m

Laser C: amplitude of magnetic field = 8.7×10^{-6} T

Laser D: average energy density in beam = 3.0×10^{-7} J/m^3

Calculate the intensity for each laser, and rank the lasers in order of increasing intensity. Assume that the laser beams have uniform intensity distributions over their cross sections. (*Notice the difference between amplitude and the averaged power or energy*)

Problem 3.

(1) All the light will reflect back → total reflection

$$n_1 \sin\theta_i = n_2 \sin\theta_r$$

$$\Rightarrow n_1 \cos\theta = n_2$$

$$\theta = \arccos\frac{1}{1.6} = \boxed{51.32^\circ}$$

(2) $\theta = \arccos\frac{1.33}{1.6} = \boxed{33.77^\circ}$

Problem 4.

Laser A: $P = 2.6W$ $d = 2.6mm$

$A = \frac{\pi d^2}{4} = 5.31 \times 10^{-6} m^2$ $I = \frac{P}{A} = \boxed{4.9 \times 10^5 W/m^2.}$

Laser B: $E_{max} = 480V/m$ $I = \frac{E_{rms}^2}{c\mu_0} = \frac{E_{max}^2}{2c\mu_0} = \boxed{305.58 W/m^2}.$

Laser C: $B_{max} = 8.7 \times 10^{-6} T \Rightarrow E_{max} = B_{max} \cdot C = 2610 V/m^2$

$$I = \frac{E_{rms}^2}{c\mu_0} = \frac{E_{max}^2}{2c\mu_0} = \boxed{9034.83 W/m^2}$$

Laser D: $I = cU = 3 \times 10^8 m/s \cdot 3 \times 10^{-7} J/m^3 = \boxed{90 W/m^2}$

$\boxed{\text{Rank: } I_D < I_B < I_C < I_A}.$