Name_____

Physics 111 Quiz #6, October 29, 2021

Please show all work, thoughts and/or reasoning in order to receive partial credit. The quiz is worth 10 points total.

I affirm that I have carried out my academic endeavors with full academic honesty.

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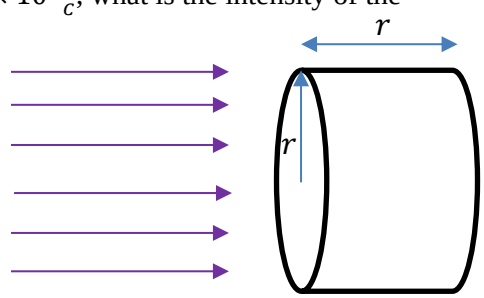
1. Optical tweezers use light to manipulate small structures in aqueous solutions. Suppose violet light ($f = 7.1 \times 10^{14} s^{-1}$) from a laser is used to manipulate a small structure (shown below) and that you can focus the light down to a circular spot with a radius equal to the wavelength of violet light. If the maximum electric field of the light is found to be $E_{max} = 3.7 \times 10^{7} \frac{N}{C}$, what is the intensity of the violet laser light?



$$S = \frac{1}{2} c \epsilon_0 E_{max}^2$$

$$S = \frac{1}{2} \times 3 \times 10^{8} \frac{m}{s} \times 8.85 \times 10^{-12} \frac{C^2}{Nm^2} \times \left(3.7 \times 10^{7} \frac{N}{C}\right)^2$$

$$S = 1.8 \times 10^{12} \frac{W}{m^2}$$

2. What is the magnitude of the force exerted on the cylindrical object from the violet light? Assume that the violet light is completely absorbed by the object.

$$c = f\lambda \rightarrow \lambda = r = \frac{c}{f} = \frac{3 \times 10^{8} \frac{m}{s}}{7.1 \times 10^{14} s^{-1}} = 4.2 \times 10^{-7} m$$

$$A = \pi r^2 = \pi (4.2 \times 10^{-7} m)^2 = 5.6 \times 10^{-13} m^2$$

$$P = \frac{S}{c} = \frac{F}{A} \rightarrow F = \frac{S}{c} A = \frac{1.8 \times 10^{12} \frac{W}{m^2}}{3 \times 10^{8} \frac{m}{s}} \times 5.6 \times 10^{-13} m^2 = 3.4 \times 10^{-9} N$$

3. What is the power output of the laser?

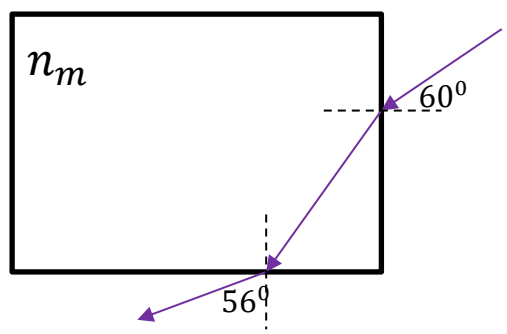
$$S = \frac{P}{A} \rightarrow P = SA = 1.8 \times 10^{12} \frac{W}{m^2} \times 5.6 \times 10^{-13} m^2 = 0.9 W$$

4. Suppose that the violet laser light was a source of polarized light and that this light was shown onto two polarizers. The first polarizer's transmission axis is oriented at $30^0$with respect to the vertical and the second polarizer's transmission axis is vertical. If the electric field of the laser light is vertically oriented, what is the intensity of the laser light that emerges from the second polarizer?

$S_{out,1} = S_0 \cos^2\theta = S_0 \cos^2 30 = 0.75S_0$

$S_{out,2} = S_{in,2} \cos^2\theta = 0.75S_0 \cos^2 30 = 0.56S_0 = 0.56 \times 1.8 \times 10^{12}\frac{W}{m^2} = 1.0 \times 10^{12}\frac{W}{m^2}$

5. Suppose that the violet laser light was incident on a block of material (shown below) with an unknown index of refraction. The light travels through the block of material and emerges from the bottom surface as shown. What is the index of refraction of the block of material if the block is surrounded on all sides by air? Hint: $\sin(90-\theta) = \cos\theta$.



$n_1 \sin\theta_1 = 1.0 \sin 60 = 0.866 = n_m \sin\theta_2$

$n_m \sin\theta_3 = n_1 \sin\theta_4 = 1.0 \sin 56 = 0.829$

$\theta_2 + \theta_3 = 90^0 \rightarrow \theta_3 = 90^0 - \theta_2$

$\sin\theta_3 = \sin(90^0 - \theta_2) = \cos\theta_2$

$n_m \sin\theta_3 = n_m \cos\theta_2 = 0.829$

$\frac{n_m \sin\theta_2}{n_m \cos\theta_2} = \tan\theta_2 = \frac{0.866}{0.829} = 1.045 \rightarrow \theta_2 = 46.3^0$

$n_m \sin\theta_2 = n_m \sin 46.3 = 0.866 \rightarrow n_m = 1.20$