Name_____

Physics 111 Quiz #5, October 20, 2025

Please show all work, thoughts and/or reasoning to receive partial credit. The quiz is worth 10 points total, and all parts may not be of equal weight.

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

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1. A cell phone emits $0.6W$ of $1.6GHz$ radio waves. What is the intensity of the radio waves at a distance $3cm$ from the antenna on the phone in any direction? Assume the radio waves emitted from the phone pass through a sphere $3cm$ in radius centered on the cell phone.

$$S = \frac{P}{A} = \frac{0.6W}{4\pi(0.03m)^2} = 53.1\frac{W}{m^2}$$

2. What are the amplitudes of the electric and magnetic field at a distance $3cm$ from the antenna on the phone?

$$S = \frac{1}{2}c\epsilon_0 E_{max}^2 \rightarrow E_{max} = \sqrt{\frac{2S}{c\epsilon_0}} = \sqrt{\frac{2 \times 53.1\frac{W}{m^2}}{3 \times 10^8\frac{m}{s} \times 8.85 \times 10^{-12}\frac{C^2}{Nm^2}}} = 200\frac{N}{C}$$

$$E_{max} = cB_{max} \rightarrow B_{max} = \frac{E_{max}}{c} = \frac{200\frac{N}{C}}{3 \times 10^8\frac{m}{s}} = 6.7 \times 10^{-7}T$$

Or

$$S = \frac{c}{2\mu_0}B_{max}^2 \rightarrow B_{max} = \sqrt{\frac{2\mu_0 S}{c}} = \sqrt{\frac{2\times4\pi\times10^{-7}\frac{Tm}{A}}{3\times10^8\frac{m}{2}}} = 6.7 \times 10^{-7}T$$

3. The radio waves from the cell phone are a source of polarized light. Suppose that the radio waves from the cell phone are allowed to interact with a polarizer whose transmission axis is vertical. The radio waves that exit the first polarizer are then allowed to interact with a second polarizer whose transmission axis is 50^0 to the vertical. If 30% of the radio waves incident on the first polarizer emerge from the second polarizer, at what angle did the radio waves strike the first polarizer measured with respect to the vertical?

$S_{out,1} = S_{in} \cos^2 \theta_{in,1}$

$S_{out,2} = S_{in,1} \cos^2 \theta_{in,2} = S_{in} \cos^2 \theta_{in,1} \cos^2 \theta_{in,2}$

$$\cos \theta_{in,1} = \sqrt{\frac{S_{out,2}}{S_{in} \cos^2 \theta_{in,2}}} = \sqrt{\frac{0.3 S_{in}}{S_{in} \cos^2 50}} \rightarrow \theta_{in,1} = \cos^{-1}(0.852) = 31.6^0$$

4. Suppose the cell phone radio waves are incident on a glass window surrounded on all sides by air an angle $\theta = 35^0$ measured with respect to the normal to the glass. At what angle will the radio waves enter the glass window if the index of refraction of glass is $n_{glass} = 1.5$?

$$n_{air} \sin \theta_{air} = n_{glass} \sin \theta_{glass} \rightarrow \theta_{glass} = \sin^{-1}\left(\frac{n_{air}}{n_{glass}} \sin \theta_{air}\right)$$

$$\theta_{glass} = \sin^{-1}\left(\frac{1.0}{1.5} \sin 35\right) = 22.5^0$$

5. Suppose that you are holding the phone up to your ear and that 2.7% of the cell phone's emitted radio waves strike your eardrum. That is, 2.7% of the intensity in part 1, hits your eardrum. What force would be exerted on your eardrum if all of the radio waves were reflected by your eardrum? Assume your eardrum is a circle of diameter $1cm$.

$$P_{ref} = \frac{2S}{c} = \frac{2 \times 0.027 \times 53.1 \frac{W}{m^2}}{3 \times 10^8 \frac{m}{s}} = 9.6 \times 10^{-8} \frac{N}{m^2}$$

$$P_{ref} = \frac{F}{A} \rightarrow F = P_{ref} A = 9.6 \times 10^{-8} \frac{N}{m^2} \times \pi (0.5 \times 10^{-2} m)^2 = 7.5 \times 10^{-13} N$$