Name____

Physics 111 Quiz #5, February 16, 2018

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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A $100W$ light bulb can be considered a point source of unpolarized light. At a radial distance of $4m$ a light detector with an area $10cm^2$ is oriented with its normal pointing directly at the light source.

1. If the detector is 75% efficient, what power was recorded on the detector?

$$S_{light} = \frac{P}{A} = \frac{P}{4\pi r^2} = \frac{100W}{4\pi\left(4m\right)^2} = 0.5\tfrac{W}{m^2}$$

$$\rightarrow S_{\det} = S_{light} = \frac{P_{\det}}{A_{\det}} \rightarrow P_{\det} = S_{light}A_{\det} = 0.5\tfrac{W}{m^2} \times \left(10cm^2 \times \left(\frac{1m}{100cm}\right)^2\right) \times 0.75 = 3.75\times10^{-4}\tfrac{W}{m^2}$$

2. Suppose that, instead of the light detector at this distance, a polarizer is placed with its normal pointing directly at the light source. If the transmission axis of the polarizer is horizontal what is the intensity of the light that passes through the polarizer?

$$S = \tfrac{1}{2}S_0 = \tfrac{1}{2}S_{light} = \tfrac{1}{2}\times0.5\tfrac{W}{m^2} = 0.25\tfrac{W}{m^2}$$

3. The light that passes through the polarizer has electric field amplitude given by which of the following?

a. $E_{\max} = \dfrac{kq}{4\pi r^2}$.

b. $E_{\max} = \dfrac{S_0}{c\varepsilon_0}$.

c. $E_{\max} = \dfrac{B_{\max}}{c}$.

d. All of the above.

e. None of the above.

4. The light from the polarizer is directed at a rectangular block of glass ($n_g = 1.5$) at an angle of 39^0 with respect to the normal to the surface of the glass block. The glass block is surrounded on all sides by air and if the glass is $10cm$ thick, how long will it take for the light to travel across the glass block?

On the surface the light is incident:

$$n_{air}\sin\theta_{air} = n_{glass}\sin\theta_{glass} \rightarrow \theta_{glass} = \sin^{-1}\left(\frac{n_{air}}{n_{glass}}\sin\theta_{air}\right) = \sin^{-1}\left(\frac{1.0}{1.5}\sin 39\right) = 24.8^0 .$$

The distance light travels is given from the geometry of the system:

$$\cos\theta_{glass} = \frac{\text{thickness}}{\text{distance}} \rightarrow \text{distance} = \frac{\text{thickness}}{\cos\theta_{glass}} = \frac{0.10m}{\cos 24.8} = 0.11m .$$

The time to travel this distance is:

$$v = \frac{c}{n_{glass}} = \frac{\text{distance}}{\text{time}} \rightarrow time = \frac{n_{glass} \times d}{c} = \frac{1.5 \times 0.11m}{3 \times 10^8 \frac{m}{s}} = 5.5 \times 10^{-10} s$$

5. The light that exits from the glass block has an intensity of $0.023 \frac{W}{m^2}$. This light is incident on a material that absorbs all light that strikes it. What radiation pressure does the light exert on this absorbing material?

$$P_{rad} = \frac{S}{c} = \frac{0.023 \frac{W}{m^2}}{3 \times 10^8 \frac{m}{s}} = 7.7 \times 10^{-11} \frac{N}{m^2}$$

Physics 111 Equation Sheet

Electric Forces, Fields and Potentials

$$\vec{F} = k\frac{Q_1Q_2}{r^2}\hat{r}$$

$$\vec{E} = \frac{\vec{F}}{q}$$

$$\vec{E}_Q = k\frac{Q}{r^2}\hat{r}$$

$$PE = k\frac{Q_1Q_2}{r}$$

$$V(r) = k\frac{Q}{r}$$

$$E_x = -\frac{\Delta V}{\Delta x}$$

$$W = -q\Delta V_{f,i}$$

Magnetic Forces and Fields

$$F = qvB\sin\theta$$

$$F = IlB\sin\theta$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$\varepsilon_{induced} = -N\frac{\Delta\phi_B}{\Delta t} = -N\frac{\Delta(BA\cos\theta)}{\Delta t}$$

Constants

$$g = 9.8\tfrac{m}{s^2}$$

$$1e = 1.6\times10^{-19}C$$

$$k = \frac{1}{4\pi\varepsilon_o} = 9\times10^9\tfrac{Nm^2}{C^2}$$

$$\varepsilon_o = 8.85\times10^{-12}\tfrac{C^2}{Nm^2}$$

$$1eV = 1.6\times10^{-19}J$$

$$\mu_o = 4\pi\times10^{-7}\tfrac{Tm}{A}$$

$$c = 3\times10^8\tfrac{m}{s}$$

$$h = 6.63\times10^{-34}Js$$

$$m_e = 9.11\times10^{-31}kg = \frac{0.511MeV}{c^2}$$

$$m_p = 1.67\times10^{-27}kg = \frac{937.1MeV}{c^2}$$

$$m_n = 1.69\times10^{-27}kg = \frac{948.3MeV}{c^2}$$

$$1amu = 1.66\times10^{-27}kg = \frac{931.5MeV}{c^2}$$

$$N_A = 6.02\times10^{23}$$

$$Ax^2 + Bx + C = 0 \rightarrow x = \frac{-B\pm\sqrt{B^2-4AC}}{2A}$$

Electric Circuits

$$I = \frac{\Delta Q}{\Delta t} = neAv_d;\ n = \frac{\rho N_A}{M}$$

$$V = IR = I\left(\frac{\rho L}{A}\right)$$

$$R_{series} = \sum_{i=1}^{N} R_i$$

$$\frac{1}{R_{parallel}} = \sum_{i=1}^{N}\frac{1}{R_i}$$

$$P = IV = I^2R = \frac{V^2}{R}$$

$$Q = CV = \left(\frac{\kappa\varepsilon_0 A}{d}\right)V = (\kappa C_0)V$$

$$PE = \tfrac{1}{2}QV = \tfrac{1}{2}CV^2 = \frac{Q^2}{2C}$$

$$Q_{\text{charge}}(t) = Q_{\max}\left(1-e^{-\frac{t}{RC}}\right)$$

$$Q_{\text{discharge}}(t) = Q_{\max}e^{-\frac{t}{RC}}$$

$$C_{parallel} = \sum_{i=1}^{N} C_i$$

$$\frac{1}{C_{series}} = \sum_{i=1}^{N}\frac{1}{C_i}$$

Light as a Particle & Relativity

$$E = hf = \frac{hc}{\lambda} = pc$$

$$KE_{\max} = hf - \phi = eV_{stop}$$

$$\Delta\lambda = \frac{h}{m_e c}(1-\cos\phi)$$

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$p = \gamma mv$$

$$E_{total} = KE + E_{rest} = \gamma mc^2$$

$$E_{total}^2 = p^2c^2 + m^2c^4$$

$$E_{rest} = mc^2$$

$$KE = (\gamma-1)mc^2$$

Geometry

$$Circles:\quad C = 2\pi r = \pi D \qquad A = \pi r^2$$

$$Triangles:\quad A = \tfrac{1}{2}bh$$

$$Spheres:\quad A = 4\pi r^2 \qquad V = \tfrac{4}{3}\pi r^3$$

Light as a Wave

$$c = f\lambda = \frac{1}{\sqrt{\varepsilon_o\mu_o}}$$

$$S(t) = \frac{energy}{time\times area} = c\varepsilon_o E^2(t) = c\frac{B^2(t)}{\mu_0}$$

$$I = S_{avg} = \tfrac{1}{2}c\varepsilon_o E_{\max}^2 = c\frac{B_{\max}^2}{2\mu_0}$$

$$P = \begin{cases} \frac{S}{c} = \frac{Force}{Area} \\ \frac{2S}{c} = \frac{Force}{Area} \end{cases}$$

$$S = S_o\cos^2\theta$$

$$v = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{c}{n}$$

$$\theta_{inc} = \theta_{refl}$$

$$n_1\sin\theta_1 = n_2\sin\theta_2$$

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

$$M_{total} = \prod_{i=1}^{N} M_i$$

$$S_{out} = S_{in}e^{-\sum_i \mu_i x_i}$$

$$HU = \frac{\mu_w - \mu_m}{\mu_w}$$

Nuclear Physics

$$E_{binding} = (Zm_p + Nm_n - m_{rest})c^2$$

$$\frac{\Delta N}{\Delta t} = -\lambda N_o \rightarrow N(t) = N_o e^{-\lambda t}$$

$$A(t) = A_o e^{-\lambda t}$$

$$m(t) = m_o e^{-\lambda t}$$

$$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

Misc. Physics 110 Formulae

$$\vec{F} = \frac{\Delta\vec{p}}{\Delta t} = \frac{\Delta(m\vec{v})}{\Delta t} = m\vec{a}$$

$$\vec{F} = -k\vec{y}$$

$$\vec{F}_C = m\frac{v^2}{R}\hat{r}$$

$$W = \Delta KE = \tfrac{1}{2}m\left(v_f^2 - v_i^2\right) = -\Delta PE$$

$$PE_{gravity} = mgy$$

$$PE_{spring} = \tfrac{1}{2}ky^2$$

$$|\vec{A}| = \sqrt{A_x^2 + A_y^2}$$

$$\phi = \tan^{-1}\left(\frac{A_y}{A_x}\right)$$

$$\vec{v}_f = \vec{v}_i + \vec{a}t$$

$$v_f^2 = v_i^2 + 2a\Delta x$$

$$\vec{x}_f = \vec{x}_i + \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$