Name_____

Physics 111 Quiz #5, October 20, 2017

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. A laser shines straight up onto a black foil of mass $25\mu g$. The black foil absorbs the entire light that is incident upon it. What laser power would be needed to suspend the foil in the air?

$$P = \frac{S}{c} = \frac{Power}{c \times A} = \frac{mg}{A}$$

$$Power = mcg = \left(25 \times 10^{-6} g \times \frac{1kg}{1000g}\right) \times 3 \times 10^{8} \tfrac{m}{s} \times 9.8 \tfrac{m}{s^2} = 73.5W$$

2. Unpolarized light with intensity S_0 is incident on a Polaroid sheet. The light that emerges from this 1st Polaroid sheet is then incident on a 2nd Polaroid sheet oriented at an angle θ with respect to the 1st sheet. If the light that emerges from the 2nd Polaroid sheet has been reduced by 90%, what is the angle between the two Polaroid sheets?

This question could be interpreted in two ways. The first is that the light intensity is reduced by 90% from the incident intensity. In this case

$$S_2 = S_1 \cos^2\theta = \tfrac{1}{2} S_0 \cos^2\theta = 0.1 S_0 \rightarrow \cos^2\theta = 0.2 \rightarrow \theta = 63.4^0$$

The second way is that the light intensity emerging from the 2nd polarizer has been reduced by 90% from what entered the 2nd polarizer. In this case:

$$S_2 = S_1 \cos^2\theta = \tfrac{1}{2} S_0 \cos^2\theta = 0.1\left(\tfrac{1}{2} S_0\right) \rightarrow \cos^2\theta = 0.1 \rightarrow \theta = 71.6^0$$

Since it's not clear which case, either answer is acceptable.

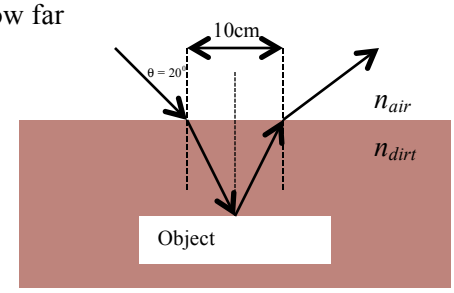
3. Apple's iPhone 6S operates over several frequency bands (ranges of frequencies). Suppose that your iPhone 6S operates at a frequency of $1.9GHz\left(=1.9\times10^{9}s^{-1}\right)$ and that the signals broadcast from your phone occur at a power output of $0.6W$. What are the maximum amplitudes of the electric and magnetic fields at a distance of $10cm$ from the phone? Note that this distance is about the distance from your ear to the center of your brain and you can model the antennae of the phone as a spherical point source of light.

$$S=\frac{Power}{A}=\tfrac{1}{2}c\varepsilon_0E_{\max}^2\rightarrow E_{\max}=\sqrt{\frac{2\times Power}{c\varepsilon_0A}}=\sqrt{\frac{2\times Power}{c\varepsilon_0 4\pi r^2}}$$

$$E_{\max}=\sqrt{\frac{2\times Power}{c\varepsilon_0 4\pi r^2}}=\sqrt{\frac{2\times0.6W}{4\pi\times3\times10^{8}\,\frac{m}{s}\times8.85\times10^{-12}\,\frac{C^2}{Nm^2}(0.1m)^2}}=60\,\tfrac{N}{C}$$

$$B_{\max}=\frac{E_{\max}}{c}=\frac{60\,\frac{N}{C}}{3\times10^{8}\,\frac{m}{s}}=2\times10^{-7}T$$

4. *RaDAR* is an acronym for Radio Detection And Ranging and the radio waves can be used as an imaging tool. Ground penetrating RaDAR is used to map out structures under the ground. Suppose radar waves are directed at an object below the surface and when the radio waves "see" the object below the surface, the radio waves are reflected off of the object. The geometry of the system is shown below. If the index of refraction of dirt is $n_{dirt}\sim2.6$, how far below the surface is the object located?



$$n_{air}\sin\theta=n_{dirt}\sin\theta_2$$

$$\rightarrow\theta_2=\sin^{-1}\left(\frac{n_{air}}{n_{dirt}}\sin\theta\right)=\sin^{-1}\left(\frac{1.0}{2.6}\sin20\right)=7.6^0$$

$$\tan\theta_2=\frac{5cm}{h}\rightarrow h=\frac{5cm}{\tan\theta_2}=37.5cm$$

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

$$F = qvB\sin\theta$$

$$F = IlB\sin\theta$$

$$I = nAv_dq$$

$$\tau = NIAB\sin\theta = \mu B\sin\theta$$

$$PE = -\mu B\cos\theta$$

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

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

Constants

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Electric Circuits

$$I = \frac{\Delta Q}{\Delta t} = nAv_dq$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Light as a Wave

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$PE_{gravity} = mgy$$

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

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

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

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

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

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