Name____

Physics 111 Quiz #5, October 24, 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. Suppose that you have a $100W$ light bulb. At a distance of $r = 1m$ from the light bulb, what is the maximum amplitude of the electric field?

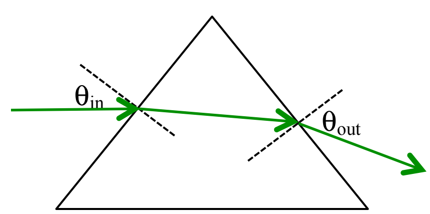
$$S = \frac{P}{A} = \frac{P}{4\pi r^2} = \frac{1}{2}c\varepsilon_0 E_{max}^2$$

$$\rightarrow E_{max} = \sqrt{\frac{P}{2\pi c\varepsilon_0 r^2}} = \sqrt{\frac{100W}{2\pi \times 3\times 10^8 \frac{m}{s} \times 8.85\times 10^{-12} \frac{C^2}{Nm^2} \times (1m)^2}} = 77.4\frac{N}{C}$$

b. Suppose that you have a source of horizontally polarized light. How many polarizers would be needed to rotate the polarization of this light so that it is vertical and a maximum in intensity?

1. One oriented at 90^0 to the incident light.
2. Two, each oriented 45^0 to the other.
3. Three, each oriented at 30^0 to the other.
4. As many as you can find.
5. No number of polarizers can accomplish this.

c. Green laser light with wavelength $\lambda = 550nm$ is incident at $\theta_{in} = 52^0$ on a triangular piece of glass as shown below. The index of refraction of the glass is $n_g = 1.5$ and the piece of glass is cut into an equilateral triangle. At what angle θ_{out} does the light emerge on the right side of the glass?



$$n_a \sin\theta_{in} = n_g \sin\theta_2 \rightarrow \theta_2 = \sin^{-1}\left(\frac{1.0}{1.5}\sin 52\right) = 31.7^0$$

$$\theta_2 + \alpha = 90 \rightarrow \alpha = 58.3^0$$

$$\alpha + \beta + 60 = 180 \rightarrow \beta = 61.7^0$$

$$\theta_3 + \beta = 90 \rightarrow \theta_3 = 28.3^0$$

$$n_g \sin\theta_3 = n_a \sin\theta_{out} \rightarrow \theta_{out} = \sin^{-1}\left(\frac{1.5}{1.0}\sin 28.3\right) = 45.3^0$$

d. A converging lens is to be used in a projector to view the motion of a bacterium in dish on a screen in the front of a room. If the speed of the bacterium in the dish is $14\,\frac{cm}{s}$ on the screen, what is the speed of the bacterium in the dish? Assume that the lens to screen distance is $3.0m$ and the lens to bacterium in the dish distance is $1.2cm$.

$$M = \frac{d_i}{d_o} = \frac{h_i/t}{h_0/t} = \frac{v_i}{v_o} \rightarrow v_o = \left(\frac{d_o}{d_i}\right) v_i = \left(\frac{1.2cm}{300cm}\right) 14\,\tfrac{cm}{s} = 0.056\,\tfrac{cm}{s} = 0.56\,\tfrac{mm}{s}$$

e. A screen and an object are placed a fixed distance $D = 0.5m$ apart. At what location(s) can a converging lens with focal length $f_c = 4.8cm$ be placed between the object and screen to produce a sharp image?

$$\frac{1}{f_c} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{d_o} + \frac{1}{D - d_o} = \frac{D}{d_o\left(D - d_o\right)} \rightarrow Df_c = Dd_o - d_o^2$$

$$\rightarrow d_o^2 - Dd_o + Df_c = 0$$

$$d_o = \frac{D \pm \sqrt{D^2 - 4Df_c}}{2} = \frac{D}{2}\left(1 \pm \sqrt{1 - \frac{4f_c}{D}}\right) = \frac{0.5m}{2}\left(1 \pm \sqrt{1 - \frac{4 \times 4.8cm}{50cm}}\right)$$

$$d_o = \begin{cases} 0.448m = 44.8cm \\ 0.052m = 5.52cm \end{cases}$$

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

$$F = qvB\sin\theta$$
$$F = ILB\sin\theta$$
$$\tau = NIAB\sin\theta = \mu B\sin\theta$$
$$PE = -\mu B\cos\theta$$
$$B = \frac{\mu_0 I}{2\pi r}$$
$$\varepsilon_{induced} = -N\frac{\Delta\phi_B}{\Delta t} = -N\frac{\Delta(BA\cos\theta)}{\Delta t}$$

Constants

$$g = 9.8\tfrac{m}{s^2}$$
$$1e = 1.6\times10^{-19}C$$
$$k = \frac{1}{4\pi\varepsilon_o} = 9\times10^9\tfrac{Nm^2}{C^2}$$
$$\varepsilon_o = 8.85\times10^{-12}\tfrac{C^2}{Nm^2}$$
$$1eV = 1.6\times10^{-19}J$$
$$\mu_o = 4\pi\times10^{-7}\tfrac{Tm}{A}$$
$$c = 3\times10^8\tfrac{m}{s}$$
$$h = 6.63\times10^{-34}Js$$
$$m_e = 9.11\times10^{-31}kg = \frac{0.511MeV}{c^2}$$
$$m_p = 1.67\times10^{-27}kg = \frac{937.1MeV}{c^2}$$
$$m_n = 1.69\times10^{-27}kg = \frac{948.3MeV}{c^2}$$
$$1amu = 1.66\times10^{-27}kg = \frac{931.5MeV}{c^2}$$
$$N_A = 6.02\times10^{23}$$
$$Ax^2 + Bx + C = 0 \rightarrow x = \frac{-B\pm\sqrt{B^2-4AC}}{2A}$$

Electric Circuits

$$I = \frac{\Delta Q}{\Delta t} = nAev_d;\quad n = \frac{\rho N_A}{M}$$
$$V = IR = I\left(\frac{\rho L}{A}\right)$$
$$R_{series} = \sum_{i=1}^{N} R_i$$
$$\frac{1}{R_{parallel}} = \sum_{i=1}^{N}\frac{1}{R_i}$$
$$P = IV = I^2R = \frac{V^2}{R}$$
$$Q = CV = \left(\frac{\kappa\varepsilon_0 A}{d}\right)V = (\kappa C_0)V$$
$$PE = \tfrac{1}{2}QV = \tfrac{1}{2}CV^2 = \frac{Q^2}{2C}$$
$$Q_{\text{charge}}(t) = Q_{\max}\left(1-e^{-\frac{t}{RC}}\right)$$
$$Q_{\text{discharge}}(t) = Q_{\max}e^{-\frac{t}{RC}}$$
$$C_{parallel} = \sum_{i=1}^{N} C_i$$
$$\frac{1}{C_{series}} = \sum_{i=1}^{N}\frac{1}{C_i}$$

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

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

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

Light as a Wave

$$c = f\lambda = \frac{1}{\sqrt{\varepsilon_o\mu_o}}$$
$$S(t) = \frac{energy}{time\times area} = c\varepsilon_o E^2(t) = c\frac{B^2(t)}{\mu_0}$$
$$I = S_{avg} = \tfrac{1}{2}c\varepsilon_o E_{\max}^2 = c\frac{B_{\max}^2}{2\mu_0}$$
$$P = \frac{S}{c} = \frac{Force}{Area}$$
$$S = S_o\cos^2\theta$$
$$v = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{c}{n}$$
$$\theta_{inc} = \theta_{refl}$$
$$n_1\sin\theta_1 = n_2\sin\theta_2$$
$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$
$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$
$$M_{total} = \prod_{i=1}^{N} M_i$$
$$S_{out} = S_{in}e^{-\sum_i \mu_i x_i}$$
$$HU = \frac{\mu_w - \mu_m}{\mu_w}$$

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

$$\vec{F} = \frac{\Delta\vec{p}}{\Delta t} = \frac{\Delta(m\vec{v})}{\Delta t} = m\vec{a}$$
$$\vec{F} = -k\vec{y}$$
$$\vec{F}_C = m\frac{v^2}{R}\hat{r}$$
$$W = \Delta KE = \tfrac{1}{2}m\left(v_f^2 - v_i^2\right) = -\Delta PE$$
$$PE_{gravity} = mgy$$
$$PE_{spring} = \tfrac{1}{2}ky^2$$
$$|\vec{A}| = \sqrt{A_x^2 + A_y^2}$$
$$\phi = \tan^{-1}\left(\frac{A_y}{A_x}\right)$$
$$\vec{v}_f = \vec{v}_i + \vec{a}t$$
$$v_f^2 = v_i^2 + 2a\Delta x$$
$$\vec{x}_f = \vec{x}_i + \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$