Name_____

Physics 111 Quiz #5, October 23, 2020

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.

_____

1. A green laser pointer ($\lambda_g = 545nm$) is a source of polarized light. Suppose that the laser pointer puts out light with an intensity of S_o and the light passes through three polarizers. The first polarizer has its transmission axis vertical, the second has its transmission axis at $27^0$to the vertical, and the third has its transmission axis also vertical. If the green light emerges from the third polarizer with an intensity of $0.22S_0$, at what angle was the electric field in the green laser light incident on the first polarizer?

   $S_1 = S_0 \cos^2 \theta_1$

   $S_2 = S_1 \cos^2 \theta_2 = S_0 \cos^2 \theta_1 \cos^2 \theta_2 = S_0 \cos^2 \theta_1 \cos^2 27 = 0.79S_0 \cos^2 \theta_1$

   $S_3 = S_2 \cos^2 \theta_3 = 0.79S_0 \cos^2 \theta_1 \cos^2 \theta_3 = 0.79S_0 \cos^2 \theta_1 \cos^2 27 = 0.63S_0 \cos^2 \theta_1 = 0.22S_0$

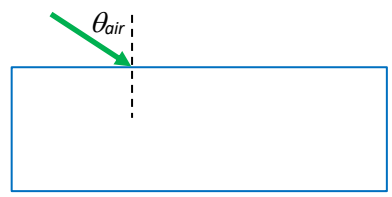
   $\rightarrow \cos^2 \theta_1 = \frac{0.22}{0.63} = 0.35 \rightarrow \theta_1 = \cos^{-1}\left(\sqrt{0.35}\right) = 53.8^0$

2. Suppose the light that emerges from the three polarizers was allowed to strike a thin aluminum sheet (with area $A_{Al} = 0.0037m^2$). If the intensity of the light from the laser is $0.22S_0$, where $S_0 = 80\frac{W}{m^2}$, what would be the acceleration of the aluminum sheet (of mass $1mg$) due to the incident light? Assume the laser beam makes a circular spot of radius $2mm$ on the aluminum sheet and the laser light is completely reflected.

   $P = \frac{2S}{c} = \frac{F}{A} = \frac{ma}{A} \rightarrow a = \frac{2SA}{mc} = \frac{2\times\left(0.22\times80\frac{W}{m^2}\right)\times\left(\pi\left(2\times10^{-3}m\right)^2\right)}{1\times10^{-6}kg\times3\times10^8\frac{m}{s}} = 1.47 \times 10^{-6}\frac{m}{a^2}$

3. Suppose that the laser pointer is shown onto a rectangular block of diamond ($n_d = 2.42$) as shown below. If the angle of incidence on the upper air/diamond interface is $\theta_{air} = 73^0$, will the light be totally internally reflected in the diamond?

For internal reflection the incident light has to exceed the critical angle between air and diamond



$$n_d \sin\theta_c = n_{air} \sin 90 \rightarrow \theta_c = \sin^{-1}\frac{n_{air}}{n_d} = \sin^{-1}\frac{1.00}{2.42}$$

$$\theta_c = 24.4^0$$

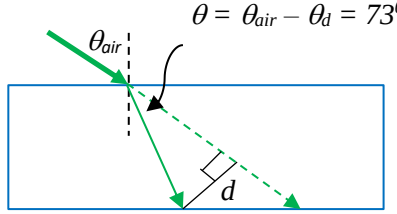
The light strikes the bottom surface at an angle θ_d given by the law of refraction.

$$n_{air}\sin\theta_{air} = n_d \sin\theta_d \rightarrow \sin\theta_d = \frac{n_{air}}{n_d}\sin\theta_{air} = \frac{1.00}{2.42}\sin 73 = 0.395 \rightarrow \theta_d = 23.3^0$$

Since this is less than the critical angle the light will not be internally reflected.

4. If the diamond block is $5mm$ thick, what is the lateral displacement (d) of the beam as shown in the figure below?

$\theta = \theta_{air} - \theta_d = 73^0 - 23.3^0 = 49.7^0$



The speed of light in diamond is: $v = \frac{c}{n_d} = \frac{3\times10^8\frac{m}{s}}{2.42} = 1.25\times10^8\frac{m}{s}$

The distance the light travels across the diamond is $\cos\theta_d = \frac{thickness}{L} \rightarrow L = \frac{thickness}{\cos\theta_d} = \frac{5mm}{\cos 23.3} = 5.44mm$

The lateral displacement is: $\sin\theta = \frac{d}{L} \rightarrow d = L\sin\theta = 5.4mm \times \sin 49.7 = 4.2mm$

5. Suppose that the green laser beam is aimed onto the face of a transparent glass diamond cube, which of the following best illustrates the direction of the beam after it emerged from the diamond cube?

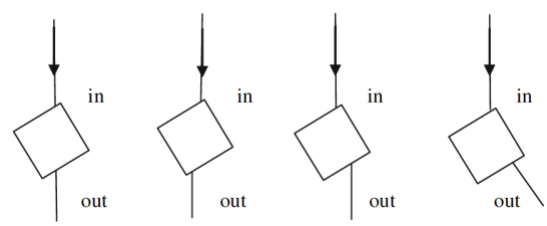
a. 1.

b. 2.

c. 3.

d. 4.

e. None of these show the correct path of the light.



1. 2. 3. 4.

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

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

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

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

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

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

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

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

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

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

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

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

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

$N_A = 6.02\times10^{23}$

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

Electric Circuits

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$P = \frac{S}{c} = \frac{Force}{Area}\ ;\ P = \frac{2S}{c}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$PE_{gravity} = mgy$$

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

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

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

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

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

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