Name____

Physics 111 Quiz #6, February 28, 2014

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. An object is placed at $x = 0$ on an optical bench. Two converging lenses ($f_{c_1} = 26mm$ and $f_{c_2} = 15mm$) are located at $x = 40mm$ and $x = 150mm$ respectively. Where is the final image of the object located with respect to the object's location at $x = 0$?

   Using the thin lens equation we calculate the image distance of the object from the first lens. We have $\frac{1}{d_{o1}} + \frac{1}{d_{i1}} = \frac{1}{f_{c_1}} \rightarrow \frac{1}{d_{i1}} = \frac{1}{f_{c_1}} - \frac{1}{d_{o1}} = \frac{1}{26mm} - \frac{1}{40mm} = 0.0135mm^{-1} \rightarrow d_{i1} = 74.3mm$. From the first lens, the image is located $74.3mm$ to the right of the lens, or at a point on the optical bench of $x = 114.3mm$. This image becomes the object for the second lens. We need to calculate the object distance for the second lens. We have $d_{o2} = 150mm - 114.3mm = 35.7mm$. Using the thin lens equation a second time we can determine the final location of the image with respect to the second lens. We have $\frac{1}{d_{o2}} + \frac{1}{d_{i2}} = \frac{1}{f_{c_2}} \rightarrow \frac{1}{d_{i2}} = \frac{1}{f_{c_2}} - \frac{1}{d_{o2}} = \frac{1}{15mm} - \frac{1}{35.7mm} = 0.039mm^{-1} \rightarrow d_{i2} = 25.9mm$. The final image is located $25.9mm$ to the right of the second lens and this produces a real image. With respect to the object located at $x = 0$, the final image is located at a point on the optical bench $x_f = 150mm + 25.9mm = 175.9mm$.

2. If the image height is measured and found to be $h_i = 8.3cm$, what is the size of the original object?

   The total magnification is given by $M_T = \left(\frac{-d_{i1}}{d_{o1}}\right)\left(\frac{-d_{i2}}{d_{o2}}\right) = \left(\frac{74.3mm}{40mm}\right)\left(\frac{25.9mm}{35.7mm}\right) = 1.35$.

   Then the object height is $M_T = \frac{h_i}{h_o} \rightarrow h_o = \frac{h_i}{M_T} = \frac{8.3cm}{1.35} = 6.2cm$.

3. Suppose that in the first problem, we replace the $26mm$ focal length converging lens with a diverging lens with the same magnitude of the focal length. In this case the location of the real image formed will
   a. move closer to the converging lens.
   b. remain at the same location as it originally was.
   c. move farther away from the converging lens.
   d. actually not be found since the image formed is actually virtual.

4. Suppose that $8.04keV$ copper x-rays with intensity S_0 were incident on a sample of bone and that the transmitted x-ray intensity was measured to be 81.5% of the incident x-ray intensity. Next, suppose that the bone sample were removed and a sample of water of the same size as the bone sample was put in its place. The same x-ray source was used, and the transmitted x-ray intensity through the water sample was measured to be 87.5% of the incident x-ray intensity. What Hounsfield unit would be associated with the bone?

The Hounsfield unit for bone is determined from $HU = \left(\frac{\mu_{bone} - \mu_{water}}{\mu_{water}}\right) \times 1000$. Here we need the absorption coefficients for bone and water. For bone we have $S = S_0 e^{-\mu_{bone} x} \rightarrow \mu_{bone} x = -\ln\left(\frac{S}{S_0}\right) = -\ln(0.815) = 0.2046$ while for water $S = S_0 e^{-\mu_{water} x} \rightarrow \mu_{water} x = -\ln\left(\frac{S}{S_0}\right) = -\ln(0.875) = 0.1335$. Therefore the Hounsfield unit for bone is $HU = \left(\frac{\mu_{bone} - \mu_{water}}{\mu_{water}}\right) \times 1000 = \left(\frac{0.2046 - 0.1335}{0.1335}\right) \times 1000 = 533$.

Physics 111 Equation Sheet

Electric Forces, Fields and Potentials

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

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

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

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

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

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

$$W_{A,B} = q\Delta V_{A,B}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

$N_A = 6.02\times10^{23}$

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

Electric Circuits

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$S = S_0 e^{-\mu x}$$

$$CT = HU = \left(\frac{\mu - \mu_w}{\mu_w}\right)\times1000$$

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

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

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

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

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

$$PE_{gravity} = mgy$$

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

$$x_f = x_i + v_{ix}t + \tfrac{1}{2}a_x t^2$$

$$v_{fx} = v_{ix} + a_x t$$

$$v_{fx}^2 = v_{ix}^2 + 2a_x\Delta x$$