Name____

Physics 111 Quiz #4, October 23, 2015

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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The Sun outputs energy though its surface uniformly in all directions. The intensity of radiation that reaches the Earth's cloud tops (the outer atmosphere) is called the solar constant and has a value of $1370\,\frac{W}{m}$.

1. What is the total energy output of the Sun per second if the average separation between the Earth and Sun is $1.496\times10^{11}m$ (also called one astronomical unit in astronomy)?

   From the solar constant we can determine the output energy of the Sun per second (which is called the luminosity in astronomy.) We have

   $$\bar{S} = I = \frac{P}{A} \to P = \bar{S}A = 1370\,\tfrac{W}{m^2}\times4\pi\left(1.496\times10^{11}m\right)^2 = 3.86\times10^{26}W\,.$$

2. What are the maximum values for the electric and magnetic fields in the sunlight that reaches the Earth's location?

   The maximum electric field amplitude is found through the intensity. We have $\bar{S} = I = \tfrac{1}{2}c\varepsilon_0E_{\max}^2 \to E_{\max} = \sqrt{\frac{2\bar{S}}{c\varepsilon_0}} = \sqrt{\frac{2\times1370\,\frac{W}{m^2}}{3\times10^8\,\frac{m}{s}\times8.85\times10^{-12}\,\frac{C^2}{Nm^2}}} = 1016\,\tfrac{N}{C}$ and the maximum magnetic field is $E_{\max} = cB_{\max} \to B_{\max} = \frac{E_{\max}}{c} = \frac{1016\,\frac{N}{C}}{3\times10^8\,\frac{m}{s}} = 3.4\times10^{-6}T$.

3. Suppose that the sunlight that reaches the Earth's atmosphere is incident on a polarizer with its transmission axis vertical. The light that emerges from this polarizer is incident on a second sheet of polarizing material with its transmission axis oriented at 37^0 with respect to the vertical. What is the intensity of the light that emerges from the second polarizer?

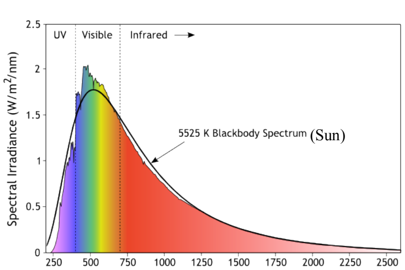
   Sunlight is unpolarized. The intensity that emerges from the first polarizer is $S' = \frac{S_0}{2} = \frac{1370\,\frac{W}{m^2}}{2} = 685\,\frac{W}{m^2}$. This light is passed through a second polarizer and the intensity of the light that emerges is $S'' = S'\cos^2\theta = 685\,\frac{W}{m^2}\cos^2 37 = 437\,\frac{W}{m^2}$.

4. Suppose that the light that emerges from the second polarizer could be allowed to be incident on the projector screen in the front of the room. What radiation pressure would the light exert on the screen if the light were completely reflected?

   The radiation pressure is $P = \frac{2\overline{S}}{c} = \frac{2\times 437\,\frac{W}{m^2}}{3\times 10^8\,\frac{m}{s}} = 2.9\times 10^{-6}\,\frac{N}{m^2}$.

5. The distribution of light from the sun spans from radio waves to x-rays. The output of the sun as a function of wavelength is shown below where x-rays would be on the far left and radio waves on the far right of the graph. From the graph the maximum wavelength of light that reaches the Earth's atmosphere is approximately $500nm$. What frequency does this wavelength correspond? (As an aside the human eye has evolved in such as way as to be sensitive to the wavelengths that are strongest from the Sun, which coincidentally are what we call the visible portion of the electromagnetic spectrum.)

   The frequency of light is $c = f\lambda \rightarrow f = \frac{c}{\lambda} = \frac{3\times 10^8\,\frac{m}{s}}{500\times 10^{-9}\,m} = 6\times 10^{14}\,s^{-1}$.



http://blog.sunspotter.org/2014/03/27/the-making-of-a-magnetogram-part-i-lost-in-a-magnetic-field/

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

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

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

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

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

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

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

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

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

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

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

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

Light as a Wave

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

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

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

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

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

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

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

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

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

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

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

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

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

Light as a Particle & Relativity

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

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

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

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

$$p = \gamma mv$$

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

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

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

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

Nuclear Physics

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

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

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

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

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

Geometry

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

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

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

Misc. Physics 110 Formulae

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

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

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

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

$$PE_{gravity} = mgy$$

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

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

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

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

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