Key

Physics 197
Practice Exam Chapters 39, 34
Conceptual Questions: Answer each question. 2 pts apiece.
There may be more than one correct answer for a question.

1. **Two observers each have clocks. One observer is in motion at constant velocity relative to the other.**

a). The stationary clock is referred to as the *proper time* b) the moving clock is referred to as the *proper time.*

c). the moving clock is referred to as the *coordinate time* d). the stationary clock is referred to as the ~~*coordinate time.*~~

$\boxed{\text{b and d}}$

2. Two observers each have clocks. One observer is in an inertial frame relative to the other.

a). The moving clock runs slower relative to the stationary clock.

b). the moving clock runs at the same speed as the stationary clock.

c). the stationary clock runs slower relative to the moving clock.

d). the stationary clock runs faster relative to the moving clock.

e). The moving clock runs faster relative to the stationary clock.

$\boxed{\text{a and d}}$

3. Four metals have the following *work functions*:

a). 12.5 eV b).30.0 eV. c). 15.0 eV. d). 10.0 eV

Rank the metals from lowest to highest stopping potential when light of energy 100 eV is incident upon each metal. larger $\phi \rightarrow$ smaller stopping potential

$\boxed{\text{b, c, a, d}}$

4. Rank the following Compton scatterings from lowest to highest scattered photon energy lower $\theta \rightarrow$ higher energy.

a) $\theta = 20^\circ$ b) $\theta = 70^\circ$ c) $\theta = 10^\circ$ d) $\theta = 30^\circ$

$\boxed{\text{b, d, a, c}}$

5. A body at rest spontaneously explodes into two equal masses. Which of the following statements are true Rest mass isn't conserved

a) The total mass before the collision is equal to the sum of the masses after the explosion

b) The total mass before the collision is less than the sum of the masses after the explosion

c) The total mass before the collision is greater than the sum of the masses after the explosion

$\boxed{\text{c}}$

Low difficulty problems. Complete all problems. 10 points apiece.

1) A space traveler moves at 0.75c and travels for a proper time of 12 years. What is the coordinate time for the trip?

$$\Delta t = \frac{\Delta t_0}{\sqrt{1 - \frac{v^2}{c^2}}} \qquad \Delta t_0 = 12 \text{ years}$$

$$\Delta t = \frac{12 \text{ years}}{\sqrt{1 - \left(\frac{0.75c}{c}\right)^2}} = \frac{12 \text{ years}}{\sqrt{1 - .75^2}}$$

$$\boxed{\Delta t = 18.14 \text{ years}}$$

2. A 6-sided die has a one painted on one side, a four on two sides and a six on three sides.

a). Determine the probability of throwing a four

b). Determine the expectation value for throwing the die.

a) $P(x=4) = \frac{\text{\# of desired outcomes}}{\text{Total Number of outcomes}} = \boxed{\frac{2}{6} = \frac{1}{3}}$

b) $\text{Expectation Value} = \frac{\Sigma \text{ of outcomes}}{\text{\# of outcomes}} = \frac{1(1) + 2(4) + 3(6)}{6}$

$$= \frac{1 + 8 + 18}{6} = \boxed{\frac{27}{6} = 4.5}$$

3. **Determine the wavelength of maximum intensity for a black body with a temperature of 3200 Kelvin.**

$$\lambda_{max} = \frac{.002898 \text{ m}\cdot\text{K}}{3200 \text{ K}}$$

$$\boxed{\lambda_{max} = 9.31 \times 10^{-7} \text{ m} = 931 \text{ nm.}}$$

4) Incident light of wavelength 455 nm is incident upon a metal with work function 2.33 eV. Calculate the stopping potential for the system.

$e\Delta V = hf - \phi \qquad hf = \frac{hc}{\lambda} = \frac{1240\,eV \cdot nm}{\lambda}$

$e\Delta V = \frac{1240\,eV \cdot nm}{455\,nm} - 2.33\,eV = .395\,eV$

$\boxed{\Delta V = .395 \text{ Volts.}}$

Advanced difficulty problems. 25 points apiece.
Do all 4 problems. You must show all work for full credit!!!

1. The function for the radius of an expanding sphere of light is given by:

$$ds^2 = dx^2 + dy^2 + dz^2 - c^2dt^2$$

Determine whether or not the function Is invariant under a Lorentz Transformation.

$x = \gamma(x' + vt') \qquad \gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \; ; \; \gamma^2 = \frac{c^2}{c^2 + v^2}, \; t = \gamma(t' + \frac{vx'}{c^2})$

$ds'^2 = d[\gamma(x' + vt')]^2 + dy'^2 + dz'^2 - c^2 d[\gamma(t' + \frac{vx'}{c^2})]^2$ ignore dy'^2; dz'^2 for now

$ds'^2 = [\gamma(dx' + v\,dt' + t'dv)]^2 - c^2[\gamma(dt' + \frac{v}{c^2}dx' + \frac{x'}{c^2}dv)]^2$

$dv = 0$

$ds'^2 = \gamma^2(dx' + v\,dt')^2 - c^2\gamma^2(dt' + \frac{v}{c^2}dx')^2$

$ds'^2 = \gamma^2[dx'^2 + 2v\,dt'dx' + v^2dt'^2] - c^2\gamma^2[dt'^2 + \frac{2v}{c^2}dx'dt' + \frac{v^2}{c^4}dx'^2]$

two circled terms add to 0.

Now collect dx'^2 terms and dt'^2 terms:

$$ds'^2 = \left[\gamma^2 dx'^2 - c^2\gamma^2\left(\frac{v^2}{c^4}dx'^2\right)\right] + \left[\gamma^2 v^2 dt'^2 - c^2\gamma^2 dt'^2\right]$$

factor out dx'^2 and dt'^2

$$ds'^2 = dx'^2\left[\gamma^2\left(1 - \frac{c^2v^2}{c^4}\right)\right] + dt'^2\left[\gamma^2\left(v^2 - c^2\right)\right]$$

$$ds'^2 = dx'^2\left[\gamma^2\left(\frac{c^2 - v^2}{c^2}\right)\right] + dt'^2\left[\gamma^2\left(v^2 - c^2\right)\right]$$

$$ds'^2 = dx'^2\left[\gamma^2\left(\frac{1}{\gamma^2}\right)\right] + dt'^2\left[\left(\frac{c^2}{c^2 - v^2}\right)\left(v^2 - c^2\right)\right]$$

$$ds'^2 = dx'^2 - dt'^2\left[\left(\frac{c^2}{c^2 - v^2}\right)\left(c^2 - v^2\right)\right]$$

$$ds'^2 = dx'^2 - c^2 dt'^2$$

$$ds'^2 = dx'^2 + dy'^2 + dz'^2 - c^2 dt'^2$$

Expression is invariant under a Lorentz Transformation.

2. A body spontaneously breaks up into 2 parts, which move in opposite directions. The parts have rest mass 1.4 kg and 1.9 kg respectively, and speeds of 0.45c and 0.48c.

a). Determine the rest mass of the original body.

b). Determine the kinetic energy given to the two pieces by analyzing the rest mass difference.

a) $E_{initial} = E_{final}$) $E_{final} = \frac{m_0 c^2}{\sqrt{1-\frac{v^2}{c^2}}}$, $E_i = m_0 c^2$

$$m_0 c^2 = \frac{m_{01} c^2}{\sqrt{1-\frac{v_1^2}{c^2}}} + \frac{m_{02} c^2}{\sqrt{1-\frac{v_2^2}{c^2}}}$$

$$m_0 = \frac{1.4\,kg}{\sqrt{1-.45^2}} + \frac{1.9\,kg}{\sqrt{1-.48^2}}$$

$$m_0 = 3.734\,kg.$$

$$\Delta m = m_0 - \Sigma m_i = 3.734\,kg - 3.3\,kg$$

$$\Delta m = .4335\,kg$$

$$KE = \frac{m_0 c^2}{\sqrt{1-\frac{v^2}{c^2}}} - m_0 c^2 = mc^2 - m_0 c^2 = \Delta m c^2$$

$$KE = .4335\,kg + (2.988 \times 10^8\,m/s)^2$$

$$KE = 3.896 \times 10^{16}\ \text{Joules}$$

$$= 6.242 \times 10^{-3}\,eV = 6.242\,meV.$$

3. 600 nm light strikes a metal, resulting in a stopping potential eV_1. 456 nm light strikes the same metal, resulting in a second stopping potential eV_2. If $eV_1 = 0.40eV_2$, calculate the work function ϕ of the metal.

$hf_1 = \frac{hc}{\lambda_1} = \frac{1240 eV \cdot nm}{600 nm} = 2.07 eV$

$hf_2 = \frac{hc}{\lambda_2} = 2.72 eV$

$\lambda_1 = 600 nm \quad \lambda_2 = 456 nm.$

$eV_1 = hf_1 - \phi \quad eV_2 = hf_2 - \phi$

Now use parameter $eV_1 = .40 eV_2$

$hf_1 - \phi = .40(hf_2 - \phi)$ Solve for ϕ

$hf_1 - \phi = .40hf_2 - .4\phi$

$2.07 eV - \phi = .4(2.72 eV) - .4\phi$

$-\phi + .4\phi = .4(2.72 eV) - 2.07 eV$

$-.6\phi = 1.088 eV - 2.07 eV$

$-0.6\phi = -.982 eV$

$\phi = \frac{.982 eV}{0.6 eV} = 1.64 eV.$

4. **The average time after excitement that a group of electrons radiates spectral lines is 1.0 x 10^{-8} seconds. Use the Heisenberg uncertainty principle to determine the line width $\Delta\lambda$ of the spectral line, given that the spectral line has a wavelength of 7500 angstroms. You must derive the expression for $\Delta\lambda$.** $\lambda = 7500 \times 10^{-10}$ m.

$\Delta E \Delta t \geq \frac{h}{4\pi}$ Need to find an expression for ΔE involving $\Delta\lambda$:

$E = \frac{hc}{\lambda} = hc\lambda^{-1}$ $dE = hc\,d\lambda^{-1} = -hc\lambda^{-2}d\lambda$

$dE \rightarrow \Delta E, \; d\lambda \rightarrow \Delta\lambda$

$\Delta E = hc\lambda^{-2}\Delta\lambda = \frac{hc\Delta\lambda}{\lambda^2}$ Replace ΔE with this expression

$\Delta E \Delta t \rightarrow \frac{hc\Delta\lambda}{\lambda^2}\Delta t \geq \frac{h}{4\pi}$ we now want to solve for $\Delta\lambda$:

$\Delta\lambda = \frac{h\lambda^2}{hc4\pi\Delta t} = \frac{\lambda^2}{4\pi\Delta t c} = \frac{(7500 \times 10^{-10}\,m)^2}{4\pi(1 \times 10^{-8}s)(2.998 \times 10^{8}\,m/s)}$

$\Delta\lambda = 1.615 \times 10^{-14}\,m = .0001615\,\text{Å}$