SPH4U Unit 5 Questions

55. a) From the Earth's frame of reference, the ball will appear to move at 280 m/s forward while the light will move at c or 300 000 000 meters per second. The ball will be affected by the motion of the plane, while the light will not be affected since light moves at the same speed relative to all inertial frames of reference due to the Constancy of the Speed of Light.

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b) I would not expect my watch to be affected by time dilation if I was in a plane moving at 300 meters per second because this speed is not close enough to see an effect. The effect is not seen on my watch because 300 meters per second is far less than the speed of light which is 300 000 000 meters per second. If my watch was moving at a speed close to the speed of light, they I would expect time dilation to affect my watch.

Support yor argument using math

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56. a) No, the two clocks will not be synchronized after one year because of time dilation. The clock on the Earth will move faster than the clock that is in a high speed because it is moving slower. Since the orbiting clock is will be moving at a high speed, then the orbiting clock's time, when compared to the synchronized clock, will move slower.

b)

$$\frac{1}{\sqrt{1-\frac{(0.5c)^2}{c^2}}} = \frac{1}{\sqrt{1-0.5^2}} = \frac{1}{\sqrt{1-0.25}} = \frac{1}{\sqrt{0.75}} \cong 1.1547$$

If the speed of light was twice the speed than the satellite, then time dilation would be highly noticeable, especially over the course of a whole year.

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57. a)

$$\vec{v} = \frac{\overrightarrow{\Delta d}}{\Delta t}$$

$$0.99c = \frac{\overrightarrow{\Delta d}}{2.2\times10^{6}\ s}$$

$$\overrightarrow{\Delta d} = 0.99c(2.2\times10^{-6}\ s) = 2.178c\times10^{-6}\ s = 6.534\times10^{2}\ m = 653.4\ m$$

According to Newtonian mechanics, the muon will travel 653.4 metres until it decays into other particles.

b)

$$\Delta t_m = \frac{2.2\times10^{-6}\ s}{\sqrt{1-\frac{(0.99c)^2}{c^2}}} = \frac{2.2\times10^{-6}\ s}{\sqrt{1-0.99^2}} = \frac{2.2\times10^{-6}\ s}{\sqrt{1-0.9801}} = \frac{2.2\times10^{-6}\ s}{\sqrt{0.0199}} \cong 15.595\times10^{-6}\ s$$
$$\cong 1.56\times10^{-5}\ s$$

According to an observer in Earth's frame of reference, the length at which the muon will last is 15.6 microseconds.

c)

$$\overrightarrow{\Delta d} = 0.99c\left(\frac{2.2\times10^{-6}\ s}{\sqrt{0.0199}}\right) = \frac{653.4\ m}{\sqrt{0.0199}} \cong 4631.83\ m$$

The muon will travel approximately 4.6 kilometers when viewed moving at 0.99c.

d) With Newtonian mechanics, the muon will travel at 0.6 kilometers, while relativistic mechanics shows that the muon will travel at 4.6 kilometers; over seven and a half times faster than Newtonian mechanics. This type of evidence is excellent support for the theory of relativity because it states that the length of time for an event to happen, in this case a muon decaying into other particles, is drastically different when moving at velocities near to the speed of light.

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58. a)

$$L_{mA} = L_{sA}\sqrt{1-\frac{v^2}{c^2}} = (60\ m)\sqrt{1-0.7^2} = 42.85\ m$$ ✔

The length of spaceship A, relative to an observer on Earth, is approximately 42.85 metres.

b)

$$L_{mB} = L_{sB}\sqrt{1-\frac{v_B^2}{c^2}}$$

$$60\ m = (120\ m)\sqrt{1-\frac{v_B^2}{c^2}}$$

$$0.357 \cong \sqrt{1-\frac{v_B^2}{c^2}}$$

$$0.1275 = 1-\frac{v_B^2}{c^2}$$

$$\frac{v_B^2}{c^2} = 0.8725$$

$v_B \cong 0.934c$✔
The speed of spaceship B, relative to an observer on Earth, is approximately 0.934 times the speed of light.

c)
$m_{mA} = \frac{m_{sA}}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{1500\ kg}{\sqrt{1-0.8725}} = 42008.4\ kg$xxx v= 0.70c / please, review

The mass of the spaceship, relative to the observer on Earth, is approximately 42000 kilograms.

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59.
$$\Delta E = mc^2 = P\Delta t$$
$$m = \frac{P\Delta t}{c^2} = \frac{(3\times10^9\ W)\left(30\ days\times24\frac{hours}{day}\times60\frac{min}{hours}\times60\frac{s}{min}\right)}{\left(3\times10^8\frac{m}{s}\right)^2} = \frac{(3\times10^9\ W)(2.592\times10^6\ s)}{\left(3\times10^8\frac{m}{s}\right)^2}$$
$$= 0.864\times10^{-1}\ kg = 8.64\times10^{-2}\ kg$$
The amount of mass that the nuclear power plant converts into energy in one month is 0.0864 kilograms.

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60. a)
$$E_k = E_{total} - E_{rest} = \frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}} - mc^2$$
$$= \frac{(1.67\times10^{-27}\ kg)\left(3\times10^8\frac{m}{s}\right)^2}{\sqrt{1-0.9999^2}} - (1.67\times10^{-27}\ kg)\left(3\times10^8\frac{m}{s}\right)^2$$
$$\cong \frac{15.01\times10^{-11}\ J}{0.0141415} - 15.01\times10^{-11}\ J \cong 1061.39\ J$$
The kinetic energy required to accelerate a single proton from a rest position of 0.9999c is approximately 1061.39 joules.

b)
$$r = \frac{E_k}{E_{rest}} = \frac{\frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}}}{mc^2} = \frac{mc^2\sqrt{1-\frac{v^2}{c^2}}^{-1}}{mc^2} = \frac{1}{\sqrt{1-0.9999^2}} \cong 70.71$$
The ratio of the kinetic energy to the energy of a proton at rest is

c) No particle can be accelerated to the speed of light since the particle's mass would become infinite, the length to become zero, and the time to be "dilated" to infinity. It would also require an infinite amount of energy to accelerate the particle.

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61. a)

$$E = hf = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34}\, J\cdot s)\left(3\times10^{8}\,\frac{m}{s}\right)}{5.9\times10^{-7}\, m} = 3.37\times10^{-19}\, J$$

The energy of a quantum of light with a wavelength of 590 nanometres is approximately 337 zeptojoules.

b)

$$E_k = \frac{hc}{\lambda} - W = \frac{3.37\times10^{-19}\, J}{1.6\times10^{-19}\,\frac{J}{eV}} - 3\ eV = 2.10625\ eV - 3\ eV = -0.89375\ eV$$

No, this color of light will not be able to produce photoelectrons since the kinetic energy of the photoelectrons is negative and won't allow the photoelectrons to move outwards or cross the threshold frequency. The frequency in the electrons needs to be higher.

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62. a)

$E_k = \frac{hc}{\lambda} - W = \frac{(6.63\times10^{-34}\, J\cdot s)\left(3\times10^{8}\frac{m}{s}\right)}{6.3\times10^{-7}\, m} - 1.5\ eV = 3.16\times10^{-19}\, J - 1.5\ eV \cong 2\ eV - 1.5\ eV =$
$0.5\ eV$xxx

The maximum kinetic energy of the photoelectrons is 0.5 electronvolts.

Express eV in joules

Answer incorrect

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b)

$$E_k = eV_o$$

$V_o = \frac{E_k}{e} = \frac{3.16\times10^{-19}\, J - 1.5\ eV}{1.6\times10^{-19}} = \frac{3.16\times10^{-19}\, J - 0.8\times10^{-19}\, J}{1.6\times10^{-19}} \cong 1.5\ V$??

The cutoff potential required to stop the photoelectrons is approximately 1.5 volts.

Recheck based on a)

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63. a) If the light was made brighter, then there would be more photons hitting the surface of the metal per second. Since the photons are only coming at a higher rate, this will not increase the frequency or the kinetic energy. There will be no photoelectrons since the frequency is still below the frequency threshold.

b) If the light is made brighter, then there will be more photons hitting the surface of the metal per second that are capable of creating photoelectrons. What will happen is that there will be more photoelectrons since the frequency threshold has already been crossed.

c) If the frequency of the light is gradually increased, then the kinetic energy will rise. Once the electrons cross the frequency threshold, then photoelectrons will be created. As the frequency gradually increases, therefore the kinetic energy will gradually increase and the photoelectrons will move faster.

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64.

$$p = \frac{E}{c} = \frac{140\ eV}{3\times10^{8}\,\frac{m}{s}} = \frac{87.5\times10^{-19}\ J}{3\times10^{8}\,\frac{m}{s}} = 2.91\bar{6}\times10^{-28}\ N\cdot s$$

The momentum of this photon is $2.91\bar{6}\times10^{-28}\ N\cdot s$. Conversion to joules incorrect

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65.

$$p = mv = \frac{h}{\lambda}$$

$$m = \frac{h}{\lambda v} = \frac{6.63\times10^{-34}\ J\cdot s}{(8.4\times10^{-14}\ m)\left(1.2\times10^{5}\,\frac{m}{s}\right)} \cong 6.58\times10^{-24}\ kg$$

The mass of the microscopic object is 6.58×10^{-24} kilograms.

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66.

$$eV = \frac{1}{2}mv^{2} = \frac{1}{2}m\left(\frac{h}{m\lambda}\right)^{2} = \frac{1}{2}\frac{h^{2}}{m\lambda^{2}} = \frac{h^{2}}{2m\lambda^{2}}$$

$$V = \frac{h^2}{2em\lambda^2} = \frac{(6.63\times10^{-34}\ J\cdot s)^2}{2(1.6\times10^{-19}\ C)(9.11\times10^{-31}\ kg)(1\times10^{-11}\ m)^2} = 1.5\times10^4\ V$$

The electric potential difference is 15 000 volts.

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67.

Property	Photon	Electron	Compare/Contrast
Energy (J)	$E = 0.\overline{72}\times10^{-19}\ J$ 2.2eV = 3.52x10^{-19} J	$E = 0.\overline{72}\times10^{-19}\ J$xxx 2.2eV = 3.52x10^{-19} J	Both the photon and the electron have the same amount of energy.
Rest mass (kg)	$m = 0$	$m = 9.11\times10^{-31}\ kg$	The electron has a mass, while the photon does not have any mass.
Speed $\left(\frac{m}{s}\right)$	$v = c = 3\times10^8\ \frac{m}{s}$	$v = \sqrt{\frac{2E}{m}} = \sqrt{\frac{2(0.\overline{72}\times10^{-19}\ J)}{9.11\times10^{-31}\ kg}} \cong 4\times 10^5\ \frac{m}{s}$xxx	The speed of a photon moves at the same speed as light, while an electron moves at a considerably slower speed.
Wavelength (m)	$p = \frac{h}{\lambda} = mv = \frac{E}{c^2}c = \frac{E}{c}$ $\lambda = \frac{hc}{E} = \frac{(6.63\times10^{-34}\ J\cdot s)\left(3\times10^8\frac{m}{s}\right)}{0.\overline{72}\times10^{-19}\ J} \cong 82.05\times10^{-7}\ m$xxx	$\lambda = \frac{h}{mv} = \frac{6.33\times10^{-34}\ J\cdot s}{(9.11\times10^{-31}\ kg)\left(4\times10^5\frac{m}{s}\right)} \cong 1.82\times10^{-9}\ m$xxx	The wavelength of the photon is a little bit bigger than that of the electron.
Momentum $\left(\frac{kg\cdot m}{s}\right)$	$p = \frac{E}{c^2}c = \frac{E}{c} = \frac{0.\overline{72}\times10^{-19}\ J}{3\times10^8\frac{m}{s}} = 2.\overline{42}\times10^{-28}\ N\cdot s$xxx	$p = mv = (9.11\times 10^{-31}\ kg)\left(4\times10^5\ \frac{m}{s}\right) \cong 3.64\times10^{-25}\ N\cdot s$xxx	An electron has a considerably larger amount of momentum than a photon has.

Please, review /,ost answers incorerct

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Marks Earned = 70

Total = 85

Final = 70 / 85 = 82%