Physics 10164 – Summer 2017 – Exam #4

Partial credit will be given provided you show all work and are solving parts of the problem correctly. Points will be deducted if you don't show your work even if you get the right answer. Clearly indicate your answer with a circle or a box and remember to include correct units and significant figures.

1. (25 pts) A spaceship covers the distance to a nearby star at a constant speed in 14.0 years while moving at a rate of 0.975c.

   a) How much time passes during this journey as measured in the Earth's reference frame (in years)?
   b) How far does the ship travel as measured in the Earth's reference frame (in light years)?
   c) How fast would the spaceship need to travel (as a fraction of the speed of light) in order for only 8.50 years to pass on board the ship?

$$\gamma = \frac{1}{\sqrt{1-.975^2}} = 4.5$$

a) $t_E = \gamma \, t_{moving} = \boxed{63.0 \text{ yrs}}$

b) $d_E = v \, t_E = (.975 \, c)(63 \text{ yrs}) = \boxed{61.4 \text{ lt yrs}}$

c) $\gamma \approx \frac{63 \text{ yrs}}{8.50} = 7.41$

$$54.9 = \frac{1}{1-\frac{v^2}{c^2}}$$

$$54.9 \frac{v^2}{c^2} = 53.9$$

$$\boxed{v = 0.991 \, c}$$

2. (25 pts) A metal surface is illuminated with light of wavelength 325 nm. The electrons ejected from the surface can be stopped by a potential difference of 1.50 Volts.

a) What is the cutoff wavelength of the metal, above which no electrons will escape?

b) If the potential difference needed to stop the electrons is doubled, what is the new wavelength of incoming light, assuming the same metal?

$$E_\gamma = \frac{hc}{\lambda} = 6.12 \times 10^{-19} J = 3.825 \, eV$$

a) $KE_{max} = q\Delta V = 2.4 \times 10^{-19} J = 1.5 \, eV$

$$KE = \frac{hc}{\lambda} - \phi \implies \phi = 3.825 - 1.5 = 2.33 \, eV$$

$$\frac{hc}{\lambda_{cut}} = \phi \qquad \lambda_{cut} = \frac{hc}{2.33 \, eV} = \frac{(6.626 \times 10^{-34})(3 \times 10^8)}{3.72 \times 10^{-19}}$$

$$= \boxed{534 \, nm}$$

b) $KE_{max} = 3.0 \, eV$

$$3.0 = E_\gamma - 2.33$$

$$E_\gamma = 5.33 \, eV = 8.53 \times 10^{-19} J = \frac{hc}{\lambda}$$

$$\lambda = \boxed{233 \, nm}$$

#3. (25 pts) Consider a Hydrogen atom with an electron in the energy level n=5. Answer all parts with 3 SF.

a) What is the longest wavelength of light that can be emitted by an electron transitioning out of level n=5? Answer in nm.

b) What is the smallest amount of energy that can be absorbed by an electron in level n=5 (in eV)?

c) What is the maximum possible wavelength of light that an electron in level n=5 can absorb in order for the Hydrogen atom to become ionized? Answer in nm.

a) $n = 5 \rightarrow 4$ (emission, smallest ΔE)

$$\frac{1}{\lambda} = (1.097 \times 10^7)\left(\frac{1}{16} - \frac{1}{25}\right) \Rightarrow \boxed{\lambda = 4050 \text{ nm}}$$

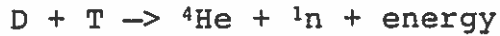b) $n = 5 \rightarrow 6$

$$E = 13.6\left(\frac{1}{25} - \frac{1}{36}\right) = \boxed{0.166 \text{ eV}}$$

c) $$\frac{1}{\lambda} = (1.097 \times 10^7)\left(\frac{1}{25} - \frac{1}{\infty}\right)$$

$$\boxed{\lambda = 2280 \text{ nm}}$$

#4. (25 pts) The new experimental fusion reactor coming online
in Europe uses the D-T reaction to generate energy:

D + T --> ^{4}He + ^{1}n + energy

The mass of deuterium is 2.014102 u.
The mass of tritium is 3.016049 u.
The mass of ^{4}He is 4.002602 u.
The mass of a neutron is 1.008665 u.

Assume that 1.00 kg of water contains 9.50×10^{21} atoms of
Deuterium, and two atoms of Deuterium are needed for each fusion
reaction (we use one of them to make Tritium). Assume also that
the world's average power usage is 15×10^{12} Watts. How many kg
of water are necessary to satisfy the world's energy needs for
one year, assuming this reaction is 100% efficient and all of
its output energy goes into providing energy for the world?
Answer with 2 SF.

$$1.00 \text{ kg of water} = 4.75 \times 10^{21} \text{ reactions}$$

$$E_{reac} = \Delta mc^2 = 17.6 \text{ MeV} = 2.82 \times 10^{-12} \text{ J}$$

$$E_{tot} = (15 \times 10^{12} \text{ W})(3.16 \times 10^7 \text{ s}) = 4.74 \times 10^{20} \text{ J}$$

$$N_{reac} = \frac{4.74 \times 10^{20}}{2.82 \times 10^{-12}} = 1.68 \times 10^{32}$$

$$\# kg = 1.68 \times 10^{32} \text{ reac.} \cdot \frac{1 \text{ kg}}{4.75 \times 10^{21}}$$

$$= \boxed{3.54 \times 10^{10} \text{ kg of water}}$$