Physics 10164 - Exam 5

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. (20 pts) A spaceship travels to a star that is measured to be 12 light years away in Earth's reference frame. The ship travels at a speed of 0.92c. 1 light year = 9.46 x 10^{15} meters.

a) How long (in years) does the trip take in Earth's reference frame?

b) How long (in years) does the trip take in the ship's reference frame?

c) What is the distance from the Earth to the star as measured in the ship's reference frame?

a) $t_{rest} = \frac{d_{rest}}{v} = \frac{12}{.92} = \boxed{13 \text{ yrs}} = 4.1 \times 10^8 s$

b) $t_{ship} = \frac{t_{rest}}{\gamma}$ $\gamma = \frac{1}{\sqrt{1-.92^2}} = 2.55$

$= \frac{13}{2.55} = \boxed{5.1 \text{ yrs}} = 1.6 \times 10^8 s$

c) $l_{ship} = \frac{l_{rest}}{\gamma} = \frac{12 \text{ ly}}{2.55} = 4.7 \text{ ly}$

or $\boxed{4.5 \times 10^{16} m}$

2. (30 pts) A photon of wavelength 486 nm is incident on Lithium, which has a work function of 2.30 eV.

a) What what maximum velocity do the electrons leave the Lithium?

b) Can the electrons escape from Aluminum, which has a work function of 4.08 eV?

c) If this 486 nm photon is absorbed by a Hydrogen atom with an electron in level n = 2, to what level will the electron jump?

a) $\frac{hc}{\lambda} = 4.09 \times 10^{-19} J = 2.56 eV$

$(KE)_{max} = 2.56 - 2.30 = 0.26 eV$

$\frac{1}{2} m v^2 = 4.16 \times 10^{-20} J$

$v^2 = 9.13 \times 10^{10}$ $\boxed{v = 3.0 \times 10^5 m/s}$

b) $\frac{hc}{\lambda} = 2.56 < \phi_{Al}$ $\boxed{no}$

c) $2.56 eV = 13.6\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$

$0.188 = \frac{1}{4} - \frac{1}{n^2}$

$-.0618 = -\frac{1}{n^2}$ $n = \sqrt{\frac{1}{.0618}}$

$= \boxed{4}$

3. (20 pts) Carbon-14 has a half-life of 5730 years. An old piece of wood is found at an archeological site that contains 1.5% of its original abundance of Carbon-14. How old is the wood, in years?

$$.015 = e^{-.693t/T_{1/2}}$$

$$-4.2 = -\frac{.693t}{5730}$$

$$t = \frac{(4.2)(5730)}{.693} = \boxed{34,700 \text{ yrs}}$$

4. (30 pts) The following reaction can be used to power a nuclear reactor:

1 neutron + ^{235}U --> ^{88}Sr + ^{136}Xe + 12 neutrons.

The mass of a neutron is 1.008665 amu.
The mass of ^{235}U is 235.043923 amu.
The mass of ^{88}Sr is 87.905614 amu.
The mass of ^{136}Xe is 135.907220 amu.

a) Find the energy (in MeV) released in each reaction.

b) If a house uses 2000 Kilowatt-hours per month, how much ^{235}U in kg would be needed to power the house? Ignore the mass of the input neutron in the reaction.

a) $M_{in} = 1.008665 + 235.043923$

$= 236.052588$

$M_{out} = 87.905614 + 135.907220 + 12(1.008665)$

$= 235.916814$

$\Delta m = 236.052588 - 235.916814$

$= 0.135774 \text{ amu} \cdot \frac{931.5 \text{ MeV}}{\text{amu}}$

$= \boxed{126 \text{ MeV}} = 2.0 \times 10^{-11} \text{ J}$

b) $E = 2000 \text{ kW}\cdot\text{hr} \cdot \frac{3.60 \times 10^6 \text{ J}}{\text{kW}\cdot\text{hr}} = 7.2 \times 10^9 \text{ J}$

$N = \frac{7.2 \times 10^9 \text{ J}}{2.0 \times 10^{-11} \text{ J}} = 3.57 \times 10^{20}$ atoms.

$= 8.4 \times 10^{22} \text{ amu} = \boxed{1.4 \times 10^{-4} \text{ kg}}$