Physics 10164 - Summer 2016 - 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) Light of wavelength 255 nm shines upon a metal with a work function of 2.21 eV.

(a) What is the maximum speed electrons have when escaping from the metal, in m/s?

(b) What wavelength would need to shine on the metal in order to double the maximum kinetic energy of escaping electrons?

a) $\frac{hc}{\lambda} = \frac{(6.626\times10^{-34})(3\times10^{8})}{255\times10^{-9}} = 7.8\times10^{-19}\,J$

$\phi = 2.21\,eV = 3.54\times10^{-19}\,J$

$(KE)_{max} = \frac{hc}{\lambda} - \phi = 4.26\times10^{-19}\,J$

$\frac{1}{2}(9.11\times10^{-31})v^2 = 4.26\times10^{-19}$

$v = 9.7\times10^{5}\,m/s$

b) New $KE = 8.5\times10^{-19} = \frac{hc}{\lambda} - 3.5\times10^{-19}$

$\frac{hc}{\lambda} = 12.0\times10^{-19}$

$\lambda = \frac{(6.626\times10^{-34})(3\times10^{8})}{12.0\times10^{-19}} = 1.66\times10^{-7}\,m$

or 166 nm

#2. (25 pts) A spaceship passing the Earth has a proper length of 1200 meters, but an observer at rest on Earth's surface measures its length to be 430 meters.

(a) What is the ship's speed, expressed as a fraction of c?
(b) How much time will it take for the ship to travel at this speed from Earth to Mars, a distance of 1.2×10^{11} meters for this question?
(c) During this trip, how much time will elapse according to the ship's onboard clock?

a) $\gamma = \frac{1200}{430} = 2.79 = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

$7.79 = \frac{1}{1-\frac{v^2}{c^2}}$

$7.79 - 7.79\frac{v^2}{c^2} = 1$

$\frac{v^2}{c^2} = \frac{-6.79}{-7.79} = 0.872$

$v = 0.93c$

b) $t = \frac{d}{v} = \frac{1.2 \times 10^{11} m}{(0.93)(3 \times 10^8)} = 430\ s$

c) $t_{proper} = \frac{t_{dilated}}{\gamma} = 150\ s$

#3. (25 pts) Iodine-131 (mass = 131 u) has a half-life of 8.02 days. If 7.5 grams of I-131 is present in a sample at t = 0,

(a) How much I-131 (in grams) will be present after 27 days have passed?
(b) What will be the activity of the I-131 sample at t = 27 days?
(c) After how many days will the activity be 1.00% of its initial value at t = 0?

a) $m(t) = m_0 e^{-\lambda t}$

since $m_{tot} = N_{atom} m_{atom}$

$m(t) \propto N(t)$

$m(t) = 7.5\, e^{-(.0864)(27)}$

$\lambda = -\frac{0.693}{8.02} = 0.0864\, d^{-1}$

$= (7.5)(.097)$

$= 0.73\ g$

$\lambda = 0.0864\, d^{-1} \cdot \frac{1\, d}{86400\, s}$

$= 1.0 \times 10^{-6}\, s^{-1}$

b) $a = \lambda N$

$N = \frac{m_{tot}}{m_{atom}} = \frac{.73 \times 10^{-3}\, kg}{(131\, u)(1.66 \times 10^{-27}\, kg/u)} = 3.36 \times 10^{21}$ atoms

$a = (1.0 \times 10^{-6})(3.36 \times 10^{21}) = 3.4 \times 10^{15}\ Bq$

c) $\frac{a(t)}{a_0} = 0.01 = e^{-\lambda t}$

$-4.605 = -(.0864)t$

$t = 53$ days

#4. (25 pts) Find the energy released in the fusion reaction, in MeV:

$^{2}H + ^{3}H \rightarrow ^{4}He + ^{1}n$

The n represents a neutron with mass 1.008665 u.
The mass of ^{2}H is 2.014102 u.
The mass of ^{3}H is 3.016049 u.
The mass of ^{4}He is 4.002602 u.

If the TCU campus uses about 2.5 billion kW-hr of energy in a given year, how many kg of Hydrogen (about 5.0 u per reaction) would be needed in order to satisfy this?

$$\Delta m = .018884\,u$$

$$E_{reac} = 17.6\ MeV = 2.816 \times 10^{-12}\ J$$

$$E_{TOT} = 2.5 \times 10^{9}\ kW \cdot hr \cdot \frac{3.6 \times 10^{6}\ J}{kW \cdot hr}$$

$$= 9.0 \times 10^{15}\ J$$

$$9.0 \times 10^{15} = N_{reac}(2.816 \times 10^{-12})$$

$$N_{reac} = 3.2 \times 10^{27}$$

$$M_{TOT} = (3.2 \times 10^{27})(5.0\,u)\left(\frac{1.66 \times 10^{-27}\,kg}{u}\right)$$

$$= 26.5\ kg$$