Quantum/Nuclear Physics

WORKSHEET #2

Name: ________________________

1. What is the energy of a quantum of 475 nm light?

$E = hf = 6.63\times10^{-34}\ J\cdot s \cdot (3.00\times10^{8}\ m/s\ /\ 475\times10^{-9}\ m) =$ $\boxed{4.19\times10^{-19}\ J}$

or

$E = hf = hc/\lambda = 1.24\times10^{3}\ eV\cdot nm/475\ nm =$ $\boxed{2.61\ eV}$

2. Electrons are ejected from a metal surface with speeds ranging up to 4.60 x 10^5 m/s when light with a wavelength of 625 nm is incident on it. (a) What is the work function? (b) What is the cutoff frequency for this surface?

a. $\Phi = hf - KE$

$= 6.63\times10^{-34}\ J\cdot s \cdot (3.00\times10^{8}\ m/s\ /\ 625\times10^{-9}\ m) - 0.5 \cdot 9.11\times10^{-31}\ kg \cdot (4.60\times10^{5}\ m/s)^2$

$=$ $\boxed{2.22\times10^{-19}\ J}$

b. Setting KE = 0 J, $\Phi = hf$

$f = \Phi/h = 2.22\times10^{-19}\ J/6.63\times10^{-34}\ J\cdot s =$ $\boxed{3.35\times10^{14}\ Hz}$

3. Find the minimum film thickness for destructive interference in reflected light for a thin film. Figure on a first minima deal. The film's index of refraction is 1.45. It is illuminated by light that has wavelength of 525 nm.

$2t = n\lambda/n_f$

$t = \lambda/2n_f = 525\ nm/(2 \cdot 1.45) = 181.0345\ nm =$ $\boxed{181\ nm}$

4. Light of wavelength 350.0 nm in incident on a potassium surface. Electrons are emitted that have a maximum kinetic energy of 1.31 eV. Find (a) the work function of potassium, (b) the cutoff wavelength, (c) the cutoff frequency.

a. $\Phi = hf - KE = hc/\lambda - KE = (1.24\times10^{3}\ eV\cdot nm/350.0\ nm) - 1.31\ eV =$ $\boxed{2.23\ eV}$

b. Setting KE = 0, $\Phi = hc/\lambda$

$\lambda = hc/\Phi = 1.24\times10^{3}\ eV\cdot nm/2.23\ eV =$ $\boxed{556\ nm}$

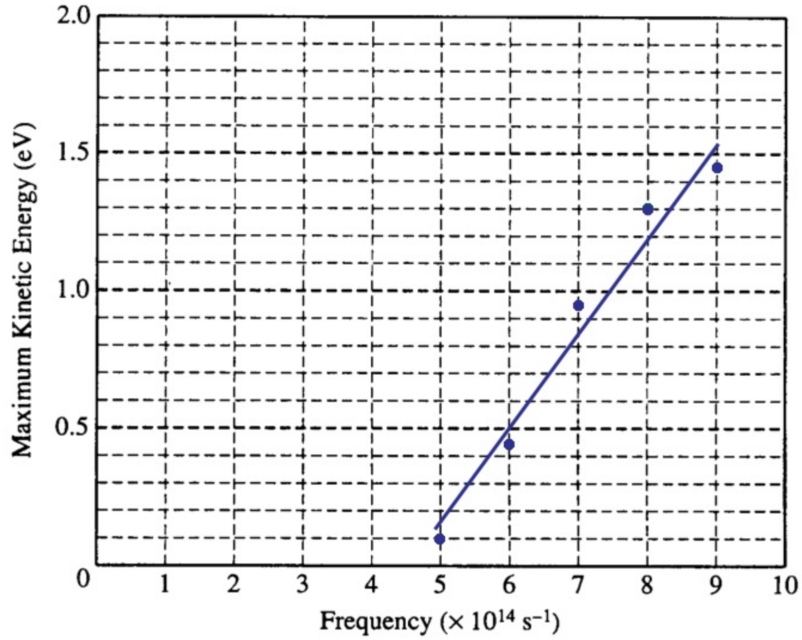
c. $f = c/\lambda = 3.00\times10^{8}\ m/s\ /\ 556\times10^{-9}\ m =$ $\boxed{5.40\times10^{14}\ Hz}$

5. A series of measurements were taken of the maximum kinetic energy of photoelectrons emitted from a metallic surface when light of various frequencies is incident on the surface.

a. The table below lists the measurements that were taken. On the axes below, plot the kinetic energy versus light frequency for the five data points given. Draw on the graph the line that is your estimate of the best straight-line fit to the data points.

b. From this experiment, determine a value of Planck's constant ***h*** in units of electron volt-seconds. Briefly explain how you did this.

Light Frequency (10^{14} s^{-1})	Maximum Kinetic Energy (electron volts)
5.00	0.10
6.00	0.45
7.00	0.95
8.00	1.30
9.00	1.45



a. See plot above for points and estimated line of best fit. (Make sure you included points as well as the line!!)

b. Units of h equal eV·s. Since the graph shows eV vs. (1/s), h is simply the slope of our line. Taking points on the line (6,0.5) and (8,1.2):
$h = \Delta y/\Delta x = (1.2\text{-}0.7 \text{ eV})/(8\text{-}6 \times 10^{-14} \text{ s}^{-1}) = 0.7/2\times10^{-14}$ eV·s = **3.5×10^{-15} eV·s**

6. You have three metals – lithium, aluminum, and mercury. Their work functions are: 2.30 eV, 4.10 eV, and 4.5 eV respectively. Light with a frequency of 1.0 x 10^{15} Hz is incident on all three metals. Determine (a) which metals will emit electrons and (b) the maximum kinetic energy for those that exhibit the effect.

a. $E = hf = 4.14\times10^{-15}$ eV·s · 1.0×10^{15} Hz = 4.14 eV
Both **lithium and aluminum** will emit electrons. The photons don't have sufficient energy get mercury to emit electrons.

b. $KE_{Li} = hf - \Phi = 4.14 \text{ eV} - 2.30 \text{ eV} =$ **1.84 eV**
$KE_{Al} = hf - \Phi = 4.14 \text{ eV} - 4.10 \text{ eV} =$ **0.04 eV**

7. Radon–222 is formed by the alpha decay of radium. Write out the equation for this decay.

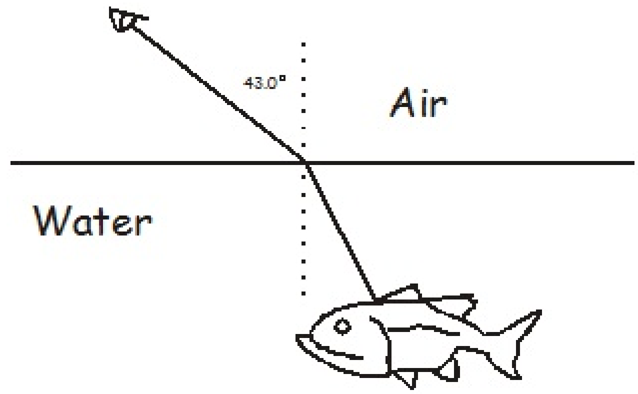
Given from the info above:

$$^{\_\_}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$$

Only the isotope mass of the radium forming the radon via alpha decay needs to be found.
Final equation:

$$\boxed{^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He}$$

8. A beam of light reflects off of a fish that is under the surface of a lake. The ray is refreacted at the surface and is seen by a person in a boat. The angle of refraction is 43.0°. Find: (a) The angle of incidence made by the ray, (b) the fish is 2.20 m below the surface, if the fish rises straight up, at what depth will it no longer be visible to the person in the boat?



a. $n_1 \sin\theta_1 = n_2 \sin\theta_2$
   $\theta_1 = \sin^{-1}(n_2 \sin\theta_2 / n_1) = \sin^{-1}(1.0003 \sin(43.0°)/1.33)$
   $= \boxed{30.9°}$

b. To find critical angle, set $\sin\theta_1 = 1$ (or $\theta_1 = 90°$)
   $\theta_2 = \sin^{-1}(n_1/n_2) = \sin^{-1}(1.0003/1.33) = 48.8°$
   x = distance from normal line; y = depth no longer visible.
   $x/2.20\text{ m} = \tan(30.9°)$
   $x = 2.20\text{ m} \cdot \tan(30.9°) = 1.31667\text{ m}$
   $1.31667\text{ m}/y = \tan(48.8°)$
   $y = 1.31667/\tan(48.8°) = \boxed{1.15\text{ m}}$

9. 615 nm light is incident on a single slit that is 0.250 mm in width. The observing screen is 3.00 m away. Find (a) the position of the first dark fringe and (b) the width of the central bright fringe.

a. $D \cdot \sin\theta = m\lambda$ so $\theta = \sin^{-1}(m\lambda/D) = \sin^{-1}(615\text{ nm}/0.250\text{ mm}) = 0.141°$
   $x/3.00\text{ m} = \tan(0.141°)$ $x = 3.00\text{ m} \cdot \tan(0.141°) = 0.00738\text{ m} = \boxed{7.38\text{ mm}}$

b. width of bright fringe goes from m=1 on one side to m=1 on the other, so:
   $w = 2 \cdot 7.38\text{ mm} = \boxed{14.76\text{ mm}}$

10. A 235 g mass is attached to a spring (k = 145 N/m) and displaced 15.0 cm. The mass is released and allowed to oscillate on a frictionless surface, what is the (a) period of the motion, (b) frequency of the motion, (c) the amplitude of the motion, and (d) the max PE of the thing?

a. T = 2π(m/k) = 2π(0.235 kg / 145 N/m) = **0.253 s**

b. f = 1/T = 1/0.253s = **3.95 Hz**

c. amplitude is equal to the original displacement given in the problem

A = **15.0 cm or 0.150 m**

d. $U_{spring} = \frac{1}{2} kx^2 = 0.5 \cdot 145\ N/m \cdot (0.15\ m)^2$ = **1.63 J**

11. What is the fundamental frequency and wavelength that resonates in a tube that is closed at one end which has a length of 2.35 m?

$\lambda_f = 2.35\ m \cdot 4$ = **9.40 m** (a tube closed on one end = 1/4 fundamental wavelength)

$f_f = s/\lambda = 340\ m/s\ /\ 9.40\ m$ = **36.2 Hz**

12. A diffraction grating has exactly 5 000 lines per centimeter. Helium laser light of wavelength 633 nm is incident on the grating. (a) What is the angle for the first order maxima? (b) If the grating is 1.25 m from a screen, what is the distance from central maxima to the first order maxima?

a. $d = 0.01\ m / 5000 = 2x10^{-6}\ m$

$d \sin\theta = m\lambda$

$\theta = \sin^{-1}(m\lambda/d) = \sin^{-1}(1 \cdot 633x10^{-9}\ m / 2x10^{-6}\ m)$ = **18.45°**

b. $x/L = \tan\theta$

$x = L\tan\theta = 1.25\ m \cdot \tan(18.45°)$ = **0.417 m**