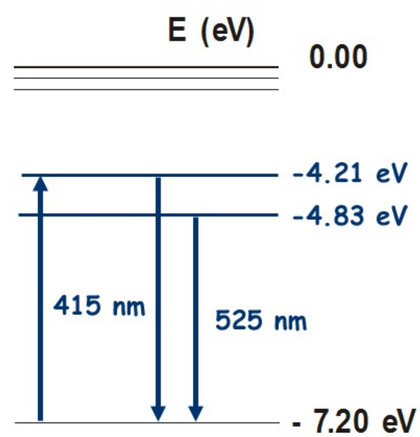
Name: ____________________

1. An atom absorbs light of wavelength 415 nm. Two of the spectral lines given off have wavelengths of 415 nm and 525 nm. (a) Determine the energy levels involved and draw them onto the energy diagram. (b) The ground state for the atom is –7.20 *eV*. What other wavelengths of light could be given off?



a. $E = hf = hc/\lambda = 4.14\times10^{-15}\ eV\cdot s \cdot 3.00\times10^{8}\ m/s\ /\ 415\times10^{-9}\ m$

$= 2.9927711\ eV = 2.99\ eV$

$-7.20\ eV + 2.99\ eV =$ **-4.21 eV**

$E = 4.14\times10^{-15}\ eV\cdot s \cdot 3.00\times10^{8}\ m/s\ /\ 525\times10^{-9}\ m = 2.365714\ eV$

$= 2.37\ eV$

$-7.20\ eV + 2.37\ eV =$ **-4.83 eV**

b. $E = 2.9927711\ eV - 2.365714\ eV = 0.6270568\ eV$

$\lambda = hc/E = 4.14\times10^{-15}\ eV\cdot s \cdot 3.00\times10^{8}\ m/s\ /\ 0.6270568\ eV$

$= 1.9806818\times10^{-6}\ m =$ **1980 nm**

2. Zinc is irradiated by 215 nm light. What is the maximum kinetic energy of the emitted electrons? (The work function for zinc is 4.31 eV)

$hf = \Phi + K_{max}$

$K_{max} = hf - \Phi = hc/\lambda - \Phi = 4.14\times10^{-15}\ eV\cdot s \cdot 3.00\times10^{8}\ m/s\ /\ 215\times10^{-9}\ m - 4.31\ eV$

$= 5.776744\ eV - 4.31\ eV = 1.466744\ eV =$ **1.47 eV**

$1.466744\ eV \cdot 1.6\times10^{-19}\ J/1\ eV = 2.34679\times10^{-19}\ J =$ **2.35×10^{-19} J**

3. In a certain metal, the stopping potential is found to be 4.00 V. When 235 nm light is incident on the metal, electrons are emitted. (a) What is the maximum kinetic energy given to the electrons in eV and J? (b) What is the work function of the metal?

a. $K_{max} = qV$ (where V is stopping potential) = **4.00 eV**

$K_{max}\ (J) = 4.00\ eV \cdot 1.60\times10^{-19}\ J/eV =$ **6.40×10^{-19} J**

b. $\Phi = hf - K_{max} = hc/\lambda - K_{max} = 4.14\times10^{-15}\ eV\cdot s \cdot 3.00\times10^{8}\ m/s\ /\ 235\times10^{-9}\ m - 4.00\ eV$

$= 5.2851064\ eV - 4.00\ eV = 1.2851064\ eV =$ **1.29 eV**

4. The work function for cesium is 1.96 eV. (a) Find the cutoff wavelength for the metal, (b) what is the maximum kinetic energy for the emitted electrons when 425 nm light is incident on the metal?

a. $hf = \Phi$ (for cutoff frequency since $K_{max} = 0$ at that point)

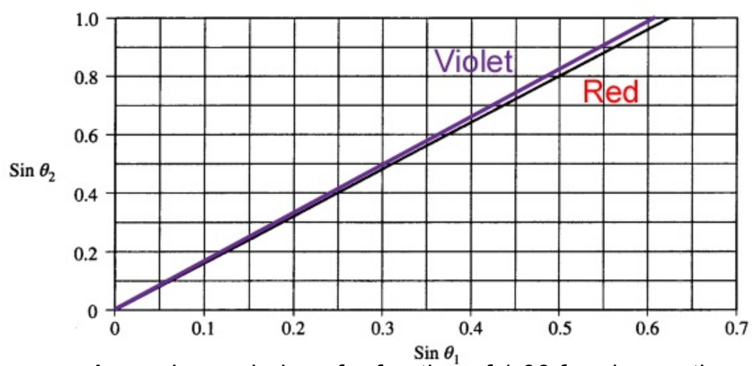
$f = \Phi/h$

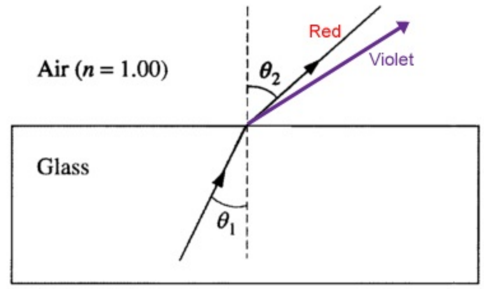
$\lambda = c/f = ch/\Phi = 3.00\times10^{8}\ m/s \cdot 4.14\times10^{-15}\ eV\cdot s\ /\ 1.96\ eV = 6.33673\times10^{-7}\ m =$ **634 nm**

b. $K_{max} = hf - \Phi = hc/\lambda - \Phi = 4.14\times10^{-15}\ eV\cdot s \cdot 3.00\times10^{8}\ m/s\ /\ 425\times10^{-9}\ m - 1.96\ eV$

$= 2.92235\ eV - 1.96\ eV =$ **0.96 eV**

5. In an experiment a beam of red light of wavelength 675 nm in air passes from glass into air, as shown. The incident and refracted angles are θ_1 and θ_2, respectively. In the experiment, angle θ_2 is measured for various angles of incidence θ_1, and the sines of the angles are used to obtain the line shown in the following graph.





a. Assuming an index of refraction of 1.00 for air, use the graph to determine a value for the index of refraction of the glass for the red light. Explain how you obtained this value. For this red light, determine the following.

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$n_1 = n_2 \sin\theta_2 / \sin\theta_1 = 1.00 \cdot 0.8/0.5 = \boxed{1.60}$ (0.8/0.5 is slope of graph or $\sin\theta_2/\sin\theta_1$)

b. The frequency in air,

$f = c/\lambda = 3.00\times10^8 \text{ m/s} / 675\times10^{-9} \text{ m} = 4.4444444\times10^{14} \text{ Hz} = \boxed{4.44\times10^{14} \text{ Hz or } 444 \text{ THz}}$

c. The speed in glass,

$v_{glass} = cn_{air}/n_{glass} = 3.00\times10^8 \text{ m/s} / 1.60 = 1.875\times10^8 \text{ m/s} = \boxed{1.88\times10^8 \text{ m/s}}$

d. The wavelength in glass.

$\lambda_{glass} = \lambda_{air} / n_{glass} = 675\times10^{-9} \text{ m}/1.60 = 421.875 \text{ nm} = \boxed{422 \text{ nm}}$

or

$\lambda_{glass} = v_{glass}/f = 1.875\times10^8 \text{ m/s} / 4.4444444\times10^{14} = 421.875 \text{ nm} = \boxed{422 \text{ nm}}$

The index of refraction of this glass is 1.66 for violet light, which has wavelength 425 nm in air.

e. Given the same incident angle θ_1, show on the ray diagram above how the refracted ray for the violet light would vary from the refracted ray already drawn for the red light.

f. Sketch the graph of $\sin\theta_2$ versus $\sin\theta_1$ for the violet light on the figure above that shows the same graph already drawn for the red light.

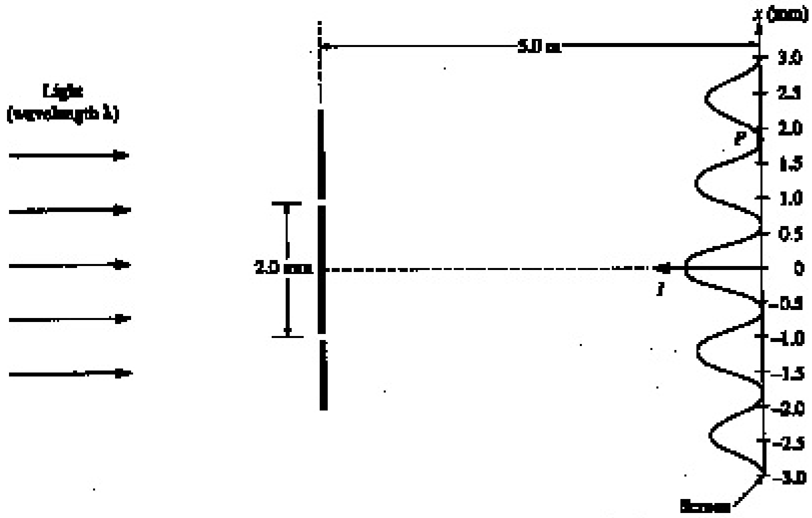
g. Determine the critical angle of incidence θ_c, for the violet light in the glass in order for total internal reflection to occur.

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$\sin\theta_1 = n_2 \sin\theta_2 / n_1 = 1.00 \cdot \sin(90°)/1.66 = 0.60241$

$\theta_1 = \sin^{-1}(0.60241) = 37.0427° = \boxed{37.0°}$

6. Coherent monochromatic light of wavelength l in air is incident on two narrow slits, the centers of which are 2.00 mm apart. The interference pattern observed on a screen 5.00 m away is represented by the drawing below.



Note: Figure not drawn to scale.

a. What property of light does this interference experiment demonstrate?

Constructive/destructive interference due to diffraction of waves. (a wave property)

b. At point ***P*** in the diagram, there is a minimum in the interference pattern. Determine the path difference between the light arriving at this point from the two slits.

This is the second destructive interference minimum. The first would be a difference in paths of 0.5λ. The second minimum would be 1.5λ difference in paths (so the two waves arrive 180° out of phase)

c. Determine the wavelength, λ, of the light.

$x_m = m\lambda L/d$

$\lambda = x_m d/mL = 1.25\times10^{-3}\ \text{m} \cdot 2.00\times10^{-3}\ \text{m}/(1 \cdot 5.00\ \text{m}) = 500.\ \text{nm}$

d. Briefly and qualitatively describe how the interference pattern would change under each of the following separate modifications and explain your reasoning.

i. The experiment is performed in water, which has an index of refraction greater than 1.

$x_m = m\lambda L/d$

In water, the λ would be less, so distance between fringes would be less.

ii. One of the slits is covered.

d now stands for the width of the slit rather than the distance between the slits. The width of either slit being less than the distance between them means x would be larger, so the pattern would spread out.

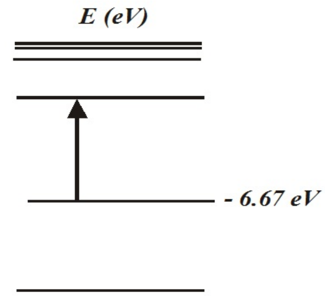
iii. The slits are moved farther apart.

This is the opposite of ii – now d is getting larger, so x will be smaller and the pattern will become tighter with the fringes closer together.

7. What is the energy in eV of a photon of light that has a frequency of 3.5×10^{15} Hz?

$E = hf = 4.14\text{x}10^{-15}\ \text{eV}\cdot\text{s} \cdot 3.5\text{x}10^{15}\ \text{Hz} = 14.49\ \text{eV} = \boxed{14\ \text{eV}}$

8. A mercury atom's electron is excited from its ground state to an energy level of -6.67 eV. While in this excited state, it absorbs a photon that has a wavelength of 577 nm. What is the new energy level of the electron?



$E = hf = hc/\lambda = 4.14\text{x}10^{-15}\ \text{eV}\cdot\text{s} \cdot 3.00\text{x}10^{8}\ \text{m/s} / 577\text{x}10^{-9}\ \text{m}$

$= 2.152513\ \text{eV}$

$-6.67\ \text{eV} + 2.152513\ \text{eV} = -4.517487\ \text{eV} = \boxed{-4.52\ \text{eV}}$

9. A Beryllium-7 nucleus has a mass of 7.016 928 *u*. A neutron has a mass of 1.008 665 *u* and a proton has a mass of 1.007 276 *u*. Calculate (a) the mass defect and (b) the binding energy for Be-7 in MeV.

a. $m = (4 \cdot 1.007\ 276\ \text{u} + 3 \cdot 1.008\ 665\ \text{u}) - 7.016\ 928\ \text{u} = \boxed{0.038171\ \text{u}}$

b. $E = mc^2 = (0.038171\ \text{u} \cdot 1.66\text{x}10^{-27}\ \text{kg/u})(3.00\text{x}10^{8})^2 = 5.7027474\text{x}10^{-12}\ \text{J}$

$5.7027474\text{x}10^{-12}\ \text{J} \cdot (1\ \text{MeV}/1.60\text{x}10^{-13}\ \text{J}) = 35.642171\ \text{MeV} = \boxed{35.6\ \text{MeV}}$

or

$E = mc^2 = 0.038171\ \text{u} \cdot 931\ \text{MeV/uc}^2 \cdot c^2 = 35.537201\ \text{MeV} = \boxed{35.5\ \text{MeV}}$

10. A 2.50 g sample of U-235 undergoes fission. For each decaying nucleus, 208 MeV is released. How many joules of energy in total would be released?

$2.50\ \text{g} \cdot 6.02\text{x}10^{23}\ \text{nuclei} / 235\ \text{g} = 6.4042553\text{x}10^{21}\ \text{nuclei}$

$6.4042553\text{x}10^{21}\ \text{nuclei} \cdot 208\text{x}10^{6}\ \text{eV/nucleus} = 1.332085\text{x}10^{30}\ \text{eV}$

$1.332085\text{x}10^{30}\ \text{eV} \cdot 1.60\text{x}10^{-19}\ \text{J/1 eV} = 2.131336\text{x}10^{11}\ \text{J} = \boxed{2.13\text{x}10^{11}\ \text{J or 213 GJ}}$