Name: ______________________________ DISC: ____________ Score: _____ / 20

Instructions:
- Do your own work.
- Answer the questions below in the space provided.
- ***You must show all of your work to received credit for these problems***
- Please place a box around your answers.
- Remember to give the correct units with all numerical answers

Q1	Q2	Q3	Q4
5	10	5	5

SPEED OF LIGHT	$c = 3 \times 10^8 m/s$
h	$6.626 \times 10^{-34} Js$
$\hbar$	$1.0546 \times 10^{-34} Js$
ELECTRON MASS	$m_e = 9.1 \times 10^{-31} kg$
hc	$1240\ eV\ nm$
MOMENTUM	$p = h/\lambda$
PHOTON ENERGY	$E = hc/\lambda$
PARTICLE ENERGY	$E = p^2/2m$
UNCERTAINTY PRINCIPLE	$\Delta x \Delta p \geq \hbar/2$

1. For the electron and photon listed in the table fill in the remaining quantities:

We will make use of the following conversions and constants:

$\mathbf{1\ eV = 1.602 \times 10^{-19} J}$

$\mathbf{m_e = 511\ keV/c^2}$

Table (5 pts.):

ENERGY	WAVELENGTH λ	MOMENTUM p	POSITION UNCERTAINTY
photon: $E = 5\ eV$	$\mathbf{248\ nm}$	$\mathbf{2.67 \times 10^{-27}\ kg\ m/s}$	
electron: $E = 5 \pm 0.1\ eV$	$\mathbf{0.549\ nm}$	$\mathbf{2.26\ keV/c}$	$\mathbf{\geq 154.5\ nm}$

Step 1: Find the wavelength and momentum of the photon:

$$\lambda = \frac{hc}{E} = \frac{(1240\ eV\ nm)}{(5\ eV)} = 248\ nm$$

$$p = \frac{h}{\lambda} = \frac{(6.626 \times 10^{-34} J\ s)}{248\ nm} = 0.0267 \times 10^{-25} = 2.67 \times 10^{-27}\ kg\ m/s$$

Step 2: Find the wavelength and momentum of the electron:

$$p = \sqrt{2mE} = \sqrt{2(511\ keV/c^2)(5\ eV)} = 2.26\ keV/c$$

$$\lambda = \frac{h}{p} = \frac{(6.626 \times 10^{-34} J\ s)}{(2.26\ keV/c)} \frac{1\ eV}{(1.602 \times 10^{-19} J)} = (1.830 \times 10^{-18}\ s) \times \left(3 \times 10^{17} \frac{nm}{s}\right)$$

$$= 0.549\ nm$$

Step 3: Use the energy resolution to find the momentum resolution:

$$p = \sqrt{2mE} = \sqrt{2(511\ keV/c^2)(0.1\ eV)} = 0.320 keV/c$$

Step 4: Apply Uncertainty Relation: $\Delta x \geq \frac{\hbar}{2 \times 2 \times 0.320 \frac{keV}{c}} = \frac{1.0546 \times 10^{-34} J\ s}{1.602 \times \frac{10^{-19} J}{eV}} \frac{1}{1279 \frac{eV}{c}} = 0.000515\ c \times 10^{-12}\ s$

$$\Delta x \geq 0.000515 \left(3 \times 10^{17} \frac{nm}{s}\right) \times 10^{-12}\ s = 0.001545 \times 10^5 nm \geq 154.5\ nm$$

2. Remembering that the energy levels of a hydrogen-like atom can be calculated: $E_n = -13.6\,eV\left(\frac{Z^2}{n^2}\right)$, where n is an integer, and $Z = 1$ for hydrogen. Calculate the following properties of the photon needed to make the following transitions in hydrogen:

Step 1: Find the energy of the transitions: $\Delta E = (-13.6\,eV)\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

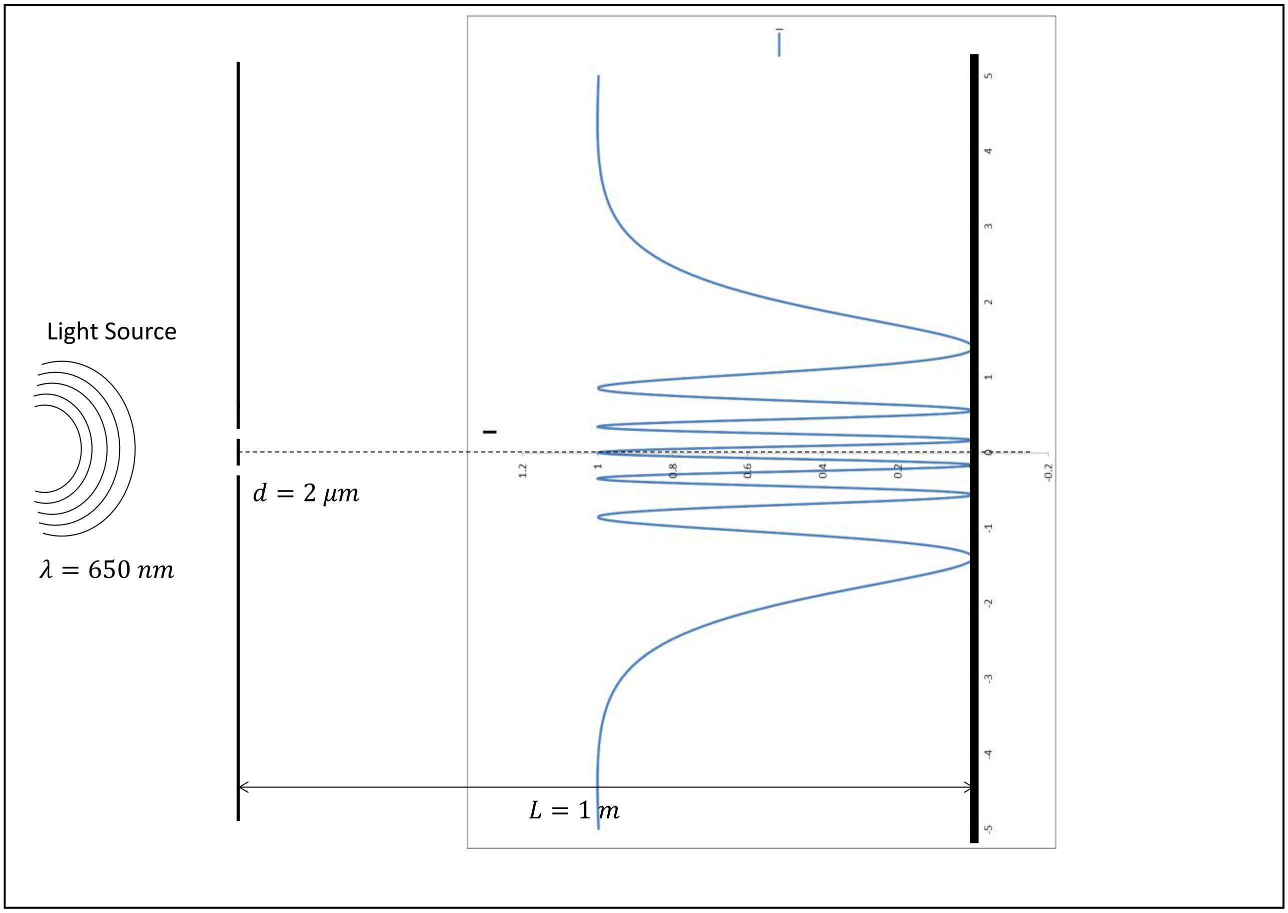
Step 2: Find the wavelength associated with each transition: $\lambda = \frac{(1240\,eV\,nm)}{\Delta E}$

$n = 1 \rightarrow n = 3$	$\frac{1}{3^2} - \frac{1}{1^2} = -0.889$	$E = -13.6\,eV \times -0.889 = 12.09\,eV$	$\frac{(1240\,eV\,nm)}{12.09\,eV} = 102.56\,nm$
$n = 1 \rightarrow n = 2$	$\frac{1}{2^2} - \frac{1}{1^2} = -0.74$	$E = -13.6\,eV \times -0.74 = 10.06\,eV$	$\frac{(1240\,eV\,nm)}{10.06\,eV} = 123.26\,nm$
$n = 4 \rightarrow n = 5$	$\frac{1}{5^2} - \frac{1}{4^2} = -0.0225$	$E = -13.6\,eV \times -0.0225 = 0.306\,eV$	$\frac{(1240\,eV\,nm)}{0.306\,eV} = 4052.3\,nm$
$n = 2 \rightarrow n = 3$	$\frac{1}{3^2} - \frac{1}{2^2} = -0.139$	$E = -13.6\,eV \times -0.139 = 1.890\,eV$	$\frac{(1240\,eV\,nm)}{1.890 eV} = 656.1\,nm$
$n = 3 \rightarrow n = 4$	$\frac{1}{4^2} - \frac{1}{3^2} = -0.0486$	$E = -13.6\,eV \times -0.0496 = 0.66\,eV$	$\frac{(1240\,eV\,nm)}{0.66 eV} = 1876\,nm$

Table (10 pts.):

TRANSITION	WAVELENGTH λ	ENERGY E
$n = 1 \rightarrow n = 3$	$102.56\,nm$	$12.09\,eV$
$n = 1 \rightarrow n = 2$	$123.26\,nm$	$10.06\,eV$
$n = 4 \rightarrow n = 5$	$4052.3\,nm$	$0.306\,eV$
$n = 2 \rightarrow n = 3$	$656.1\,nm$	$1.890\,eV$
$n = 3 \rightarrow n = 4$	$1876\,nm$	$0.66\,eV$

3. A beam of red light $\lambda = 650\ nm$ impinges a screen with two slits spaced $d = 2\ \mu m$ apart.



Sketch (1 pts.):
Table (4 pts.):

a) On the diagram sketch the interference pattern you expect from two-slit interference.

b) Fill in the following table for the interference minima ($d \sin\theta = \left(m + \frac{1}{2}\right)\lambda$):

Minimum	Angle	Position
$m = 1$	$\mathbf{29.2°}$	$\mathbf{0.0349\ m}$
$m = 2$	$\mathbf{54.4°}$	$\mathbf{1.397\ m}$
$m = 3$	$\boldsymbol{undefined}$	$\boldsymbol{undefined}$
$m = 4$	$\boldsymbol{undefined}$	$\boldsymbol{undefined}$

Step 1: Find the angle associated with each m: $\boldsymbol{\theta = asin\left[\frac{\left(m+\frac{1}{2}\right)\lambda}{d}\right] = asin\left[\frac{\left(m+\frac{1}{2}\right)(650\ nm)}{2\ \mu m}\right]}$

$$\boldsymbol{m = 1:\ \theta = asin\left[\frac{\left(\frac{3}{2}\right)(650\ nm)}{2\ \mu m}\right] = asin(487.5 \times 10^{-3}) = 29.2°}$$

$$\boldsymbol{m = 2:\ \theta = asin\left[\frac{\left(\frac{5}{2}\right)(650\ nm)}{2\ \mu m}\right] = asin(812.7 \times 10^{-3}) = 54.4°}$$

$$\boldsymbol{m = 3:\ \theta = asin\left[\frac{\left(\frac{7}{2}\right)(650\ nm)}{2\ \mu m}\right] = asin(1137.8 \times 10^{-3}) = undefined}$$

The argument is greater than 1. That's OK. This just means that we cannot get any interference minima after the second minimum. Remember, the interference pattern is *geometry dependent*.

Step 2: Using $L = 1\ m$ and our trig functions we can locate in space the interference minima on the screen:

$$\boldsymbol{m = 1: y = L\tan 29.2° = 0.558\ m}$$

$$\boldsymbol{m = 2: y = L\tan 54.4° = 1.397\ m}$$