PHYS201 **Midterm II** **August 17, 2010**

NAME__________________________**Signature**_____________________**Section #**___

Work out the following three problems. Show all work to receive full credit. Put your final answers in boxes. Do not forget to put the units. The last two sheets contain helpful equations.

1. Please note that each part of this problem is on a different topic.

(a) Molybdenum has a work function of 4.20 eV. (i) Find the cutoff wavelength for the photoelectric effect. (ii) What is the stopping potential if the incident light has a wavelength of 180 nm?

(b) Some of the energy levels of a hypothetical one-electron atom (not hydrogen) are given in the table below

n	1	2	3	4	5	∞
E_n(eV)	-15.60	-5.30	-3.08	-1.45	-0.80	0.0

Calculate (i) the ionization energy of the ground state electron, (ii) the wavelength of the photon emitted when the atom makes a transition from the energy state n=3 to the ground state.

(c) X-rays having energy of 300 keV undergo Compton scattering from a target. The scattered rays are detected at 37° relative to the incident ray. Find (i) the Compton shift at this angle, (ii) energy of the scattered x-ray and the energy of the recoiling electron. (42 points)

a) (i) $\lambda_c = \frac{hc}{\phi} = \frac{1240 \text{ eV-nm}}{4.20 \text{ eV}} = \boxed{295.2 \text{ nm}}$

(ii) $eV_0 = hf - \phi = \frac{hc}{\lambda} - \phi = \frac{1240 \text{ eV-nm}}{180 \text{nm}} - 4.20\text{eV} = 2.69\text{eV}$

$\boxed{V_0 = -2.69\text{V}}$

b) (i) $E_{\text{ionization}} = E_\infty - E_1 = 0 - (-15.60\text{eV}) = \boxed{15.60 \text{ eV}}$

(ii) $hf = E_i - E_f \Rightarrow \frac{hc}{\lambda} = E_i - E_f \Rightarrow \lambda = \frac{hc}{E_i - E_f} = \frac{hc}{E_3 - E_1} = \frac{1240\text{eV-nm}}{(-3.08+15.6)\text{eV}}$

$\Rightarrow \boxed{\lambda = 99.04 \text{nm}}$

c) (i) $\lambda' - \lambda = \lambda_c(1 - \cos 37^\circ) = 0.00243 \text{ nm } (1 - 0.799)$

$\boxed{= 4.89 \times 10^{-4} \text{nm}}$

(ii) $E' = \frac{hc}{\lambda'} = \frac{hc}{\lambda + 4.89\times10^{-4}\text{nm}}$

$\lambda = \frac{hc}{E} = \frac{1240 \text{ eV-nm}}{300\times10^3\text{eV}} = 413\times10^{-5}\text{nm}$

$\Rightarrow E' = \frac{1240 \text{ eV-nm}}{(413\times10^{-5} + 4.89\times10^{-4})\text{ nm}} = \boxed{268 \text{ keV}}$

$E_e = E - E' = \boxed{32 \text{ keV}}$

2. Young's double-slit experiment is performed with 580 nm light and a distance of 2.00 m between the slits and the screen.
(a) Determine the separation d between the two slits if the fifth interference minimum is observed at y= 4 mm from the central maximum on the screen.
(b) What is the phase difference between the two wave fronts which arrive at y=4 mm from the central maximum.
(c) Suppose each slit has a width a. Find the width a of the slit if the first diffraction minimum is at the same angle as the fifth interference minimum.
(d) How many interference maxima will occur within the envelope of the first diffraction minimum? (~~30~~ points)

28

(a) For fifth interference minimum

$$d\sin\theta = (m+\tfrac{1}{2})\lambda \quad \text{with } m=4 \text{ and } \sin\theta \approx \frac{y}{R}$$

4 + 3

$$\Rightarrow \quad d\,\frac{y}{R} = 4.5\lambda$$

$$d = \frac{4.5\lambda}{(y/R)} = \frac{4.5\lambda R}{y} = \frac{(4.5)(580\times10^{-9})\,2}{4\times10^{-3}}$$

$$= \boxed{1.31\times10^{-3}\,m}$$

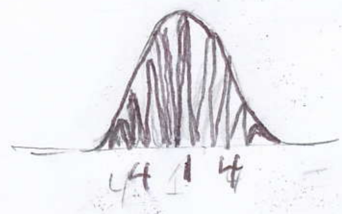
(b) $$\phi = k\delta = \frac{2\pi}{\lambda}\, d\sin\theta = \frac{2\pi}{\lambda}(m+\tfrac{1}{2})\lambda$$

$$= 2\pi(4.5) = \boxed{9\pi \text{ rad}}$$

(c) $$a\sin\theta = \lambda$$

$$a = \frac{\lambda}{\sin\theta} = \frac{\lambda}{4.5\,\frac{\lambda}{d}} = \frac{d}{4.5} = \frac{1.31\times10^{-3}}{4.5} = \boxed{2.91\times10^{-4}\,m}$$

(d) $$N = 4+1+4 \boxed{= 9}$$



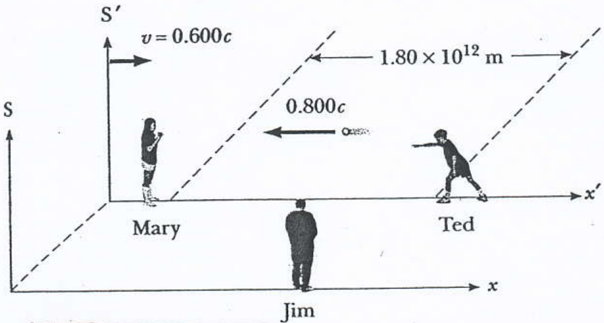
3. Ted and Mary are playing a game of catch in frame S', which is moving at 0.600c with respect to frame S, while Jim, at rest in frame S watches the action. (See figure below). Ted throws the ball to Mary at 0.800c (according to Ted), and the separation (measured in S') is 1.80×10^{12} m.

(a) According to Mary, what is the velocity (magnitude and direction) of the ball and how long does the ball take to reach her?

(b) According to Jim, how far apart are Ted and Mary?

(c) According to Jim, what is the velocity (magnitude and direction) of the ball?

(d) According to Jim, how long does the ball take to reach Mary? (30 points)



a) $V = V_x' = \boxed{-0.800c\,\hat{i}}$ since Mary and Ted are in the same reference frame

$t' = \frac{L_0}{v} = \frac{1.8 \times 10^{12} m}{0.800c} = \boxed{7500\,s}$

b) $L = \frac{L_0}{\gamma} = L_0\sqrt{1-\frac{u^2}{c^2}} = (1.80 \times 10^{12} m)\sqrt{1-\left(\frac{0.600c}{c}\right)^2}$

$\boxed{L = 1.44 \times 10^{12} m}$

(c) $V_x = \frac{V_x' + u}{1 + \frac{V_x' u}{c^2}} = \frac{-0.800c + 0.600c}{1 + (-0.800)(0.600)} = \boxed{-0.385c\,\hat{i}}$

d) According to Jim, the ball approaches Mary at a speed of $(0.385c + 0.600c) = 0.985c$, since according to Jim, Mary is moving toward the ball at speed $0.600c$. Thus

$t = \frac{L}{0.985c} = \frac{1.44 \times 10^{12} m}{(0.985)(3 \times 10^8 m/s)} = \boxed{4.88 \times 10^3\,s}$