Physics 202 MWF 10:20 Spring 2009 (Ford)

Name (printed) Version 2

Name (signature as on ID) key

Lab Section

Exam IV Chapts. 26, 28, 29 in Young/Geller

Note: The speed of light in air is $c = 3.00 \times 10^8$ m/s.
1 eV = 1.60×10^{-19} J

Multiple choice questions. Circle the correct answer. No work need be shown and no partial credit will be given.

(5 pts) 1. Two coherent speakers emit electromagnetic waves that have wavelength 2.0 m. At a point 3.0 m from one source and 7.0 m from the other source, the interference between these two waves is

b (a) destructive
(b) constructive

path difference is $7m - 3m = 4m = 2\lambda$

Constructive

(5 pts) 2. A monochromatic beam of laser light passes through two very narrow parallel slits. The light passes through air to a screen that is 5.0 m from the slits. It is observed that near the center of the screen, adjacent bright fringes are separated by 1.2 mm. If the entire apparatus (slits, screen and the space between them) is submerged in water that has refractive index 1.33, the separation between adjacent bright fringes becomes

c (a) 1.6 mm
(b) 1.2 mm (doesn't change)
(c) 0.90 mm
(d) none of the above

$y_m = R\frac{m\lambda}{d}$

$\Delta y = \frac{R\lambda}{d}$

in water, $\lambda = \frac{\lambda_{air}}{n}$

$\Delta y = \frac{1.2\,mm}{1.33} = 0.90\,mm$

(5 pts) 3. The number of $2p$ states for a hydrogen atom is

(a) zero
(b) 3
d (c) 5
(d) 6
(e) 7
(f) 10
(g) 14
(h) none of the above

$\ell = 1$

$m_\ell = -1, 0, +1$

$m_s = \pm\frac{1}{2}$

(5 pts) 4. Light falling on a metal surface causes electrons to be emitted from the metal by the photoelectric effect. As the wavelength of the light is decreased, the maximum kinetic energy of the photoelectrons

b (a) decreases
(b) increases
(c) stays the same

$K_{max} = \frac{hc}{\lambda} - \phi$

λ smaller means K_{max} larger

(5 pts) 5. When a photon of light scatters off a free electron that is initially at rest, the wavelength of the photon

(a) decreases
b (b) increases
(c) stays the same

photon transfers some energy to the electron

$E = \frac{hc}{\lambda}$ so smaller E means larger λ

(5 pts) 6. When the kinetic energy of an electron increases, its de Broglie wavelength

a (a) decreases
(b) increases
(c) stays the same

$\lambda = \frac{h}{p} = \frac{h}{mv}$

K increases, v increases and λ decreases

(5 pts) 7. In the Bohr model the electron in a particular energy state of a hydrogen atom has angular momentum $3(h/2\pi)$. The energy of this state is

(a) zero
(b) -13.6 eV
(c) -3.4 eV
d (d) -1.5 eV
(e) -0.85 eV
(f) none of the above

$L = n\left(\frac{h}{2\pi}\right)$ so $n = 3$

$E = -\frac{13.6\,eV}{n^2} = -1.5\,eV$

Show all your work. Partial credit will be given if earned. Write your answers in the blanks provided.

(16 pts) 8. Coherent laser light with frequency 6.00×10^{14} Hz passes through a narrow slit and falls on a screen that is 2.00 m from the slit. The distance on the screen between the minima on either side of the central bright fringe is 1.2 mm. What is the width of the slit?

Ans. 1.67 mm

$$\lambda = \frac{c}{f} = \frac{3\times10^{8}\ m/s}{6\times10^{14}\ Hz} = 5.0\times10^{-7}\ m$$

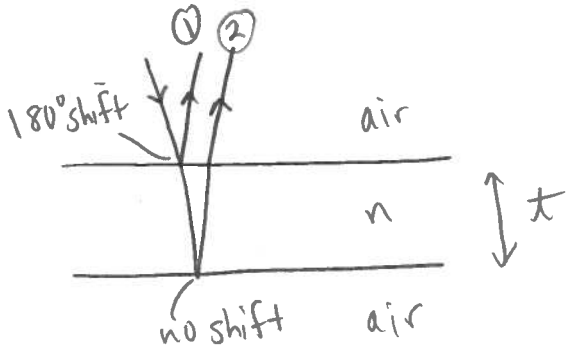
$Y_1 = \frac{R\lambda}{a}$ is the distance from the center of the central maximum to the first minimum

$2Y_1 = 1.2\ mm$ so $Y_1 = 0.60\ mm$

$$a = \frac{R\lambda}{Y_1} = \frac{(2m)(5\times10^{-7}m)}{0.6\times10^{-3}\ m} = 1.67\times10^{-3}\ m = 1.67\ mm$$

(16 pts) 9. A glass plate that has refractive index $n = 1.50$ and that is 6.00×10^{-7} m thick is surrounded by air. The plate is illuminated by a beam of white light that is normal to the plate. What wavelengths in air within the limits of the visible spectrum ($\lambda = 400$ nm to 700 nm) have destructive interference between the light reflected from the upper and the lower surfaces of the plate?

Ans. 450 nm, 600 nm



net 180° shift due to reflections, so condition for destructive interference is $2t = m\frac{\lambda_0}{n}$

$$\lambda_0 = \frac{2tn}{m} = \frac{2(6\times10^{-7}\,m)(1.50)}{m} = \frac{1800\,nm}{m}$$

m	λ_0	
1	1800 nm	
2	900 nm	
3	600 nm	← visible
4	450 nm	←
5	360 nm	

(16 pts) 10. When light of wavelength 200 nm shines on a certain metal surface, the maximum kinetic energy of the photoelectrons is 3.6 eV. What is the maximum wavelength of light that will produce photoelectrons from this surface?

Ans. 477 nm

$K_{max} = \frac{hc}{\lambda} - \phi$

$\phi = \frac{hc}{\lambda} - K_{max} = \frac{(4.136 \times 10^{-15}\ eV{\cdot}s)(3 \times 10^{8}\ m/s)}{200 \times 10^{-9}\ m} - 3.6\ eV$

$\phi = 6.2\ eV - 3.6\ eV = 2.6\ eV$

maximum λ when $K_{max} \to 0$, so $\frac{hc}{\lambda_{max}} = \phi$

$\lambda_{max} = \frac{hc}{\phi} = \frac{(4.136 \times 10^{-15}\ eV{\cdot}s)(3 \times 10^{8}\ m/s)}{2.6\ eV} = 477\ nm$

11.

(10 pts) a) An electron has de Broglie wavelength 60.0 nm. What is the wavelength of a photon that has the same energy as the kinetic energy of this electron?

Ans. 2.99 mm

for the electron, $p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}\ J\cdot s}{60\times10^{-9}\ m}$

$p = 1.10\times10^{-26}\ kg\cdot m/s$

$E = \frac{p^2}{2m} = \frac{(1.10\times10^{-26}\ kg\cdot m/s)^2}{2(9.11\times10^{-31}\ kg)} = 6.64\times10^{-23}\ J$

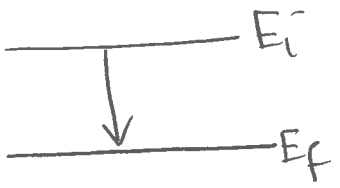
for the photon

$E = \frac{hc}{\lambda}$, $\lambda = \frac{hc}{E} = \frac{(6.63\times10^{-34}\ J\cdot s)(3\times10^{8}\ m/s)}{6.64\times10^{-23}\ J}$

$\lambda = 2.99\times10^{-3}\ m = 2.99\ mm$

(7 pts) b) An atom undergoes a transition from a state with energy -3.0 eV to a state with energy -9.0 eV. What is the wavelength of the photon emitted in this transition?

Ans. 207 nm



$E_i - E_f = \frac{hc}{\lambda}$

$\lambda = \frac{hc}{E_i - E_f} = \frac{(4.136\times10^{-15}\ eV\cdot s)(3\times10^{8}\ m/s)}{-3eV-(-9eV)}$

$\lambda = 2.07\times10^{-7}\ m = 207\ nm$