

Name (printed) Version 3

Name (signature as on ID) Key

Lab Section _____

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

Note: The speed of light in air is $c = 3.00 \times 10^8$ m/s.

$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$

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 15.0 m from the other source, the interference between these two waves is

- (a) constructive
(b) destructive

path difference is $15\text{m} - 3\text{m} = 12\text{m} = 6\lambda$

constructive

a

(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

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

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

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

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

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

b

(5 pts) 3. The number of $4f$ states for a hydrogen atom is

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

$$l = 3$$

$$m_l = -3, -2, -1, 0, 1, 2, 3$$

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

g

(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

a

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

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

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

c

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

photon transfers some energy to the electron

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

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

c

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

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

K decreases so v decreases and λ increases

(5 pts) 7. In the Bohr model the electron in a particular energy state of a hydrogen atom has angular momentum $4(h/2\pi)$. The energy of this state is

e

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

$$L = n\left(\frac{h}{2\pi}\right) \text{ so } n=4$$

$$E = \frac{-13.6 \text{ eV}}{n^2} = -0.85 \text{ eV}$$

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 2.4 mm. What is the width of the slit?

Ans. 0.833 mm

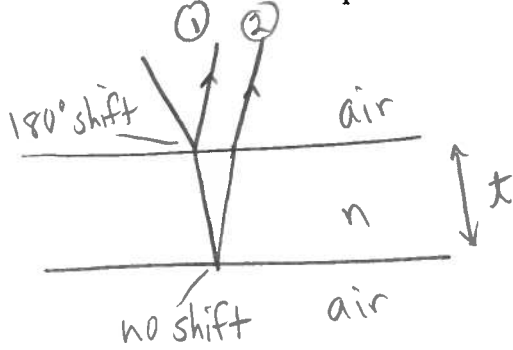
$$\lambda = \frac{c}{f} = \frac{3 \times 10^8 \text{ m/s}}{6 \times 10^{14} \text{ Hz}} = 5.0 \times 10^{-7} \text{ m}$$

$y_1 = \frac{R\lambda}{a}$ is the distance from the center of the central maximum to the first minimum

$$2y = 2.4 \text{ mm so } y_1 = 1.2 \text{ mm}$$

$$a = \frac{R\lambda}{y_1} = \frac{(2\text{m})(5 \times 10^{-7} \text{ m})}{1.2 \times 10^{-3} \text{ m}} = 8.33 \times 10^{-4} \text{ m} = 0.833 \text{ mm}$$

(16 pts) 9. A glass plate that has refractive index $n = 1.50$ and that is 3.00×10^{-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 constructive interference between the light reflected from the upper and the lower surfaces of the plate?



Ans. 600 nm

net 180° shift due to reflections, so condition for constructive interference is

$$2t = (m + \frac{1}{2}) \frac{\lambda_0}{n}$$

$$\lambda_0 = \frac{2tn}{m + \frac{1}{2}} = \frac{2(3 \times 10^{-7} \text{ m})(1.5)}{m + \frac{1}{2}} = \frac{900 \text{ nm}}{m + \frac{1}{2}}$$

m	λ_0
0	1800 nm
1	600 nm ← visible
2	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 2.8 eV. What is the maximum wavelength of light that will produce photoelectrons from this surface?

Ans. 365 nm

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

$$\phi = \frac{hc}{\lambda} - K_{\max} = \frac{(4.136 \times 10^{-15} \text{ eV}\cdot\text{s})(3 \times 10^8 \text{ m/s})}{200 \times 10^{-9} \text{ m}} - 2.8 \text{ eV}$$

$$\phi = 6.2 \text{ eV} - 2.8 \text{ eV} = 3.4 \text{ eV}$$

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

$$\lambda_{\max} = \frac{hc}{\phi} = \frac{(4.136 \times 10^{-15} \text{ eV}\cdot\text{s})(3 \times 10^8 \text{ m/s})}{3.4 \text{ eV}}$$

$$\lambda_{\max} = 365 \text{ nm}$$

11.

(10 pts) a) An electron has de Broglie wavelength 90.0 nm. What is the wavelength of a photon that has the same energy as the kinetic energy of this electron?

for the electron, $p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34} \text{ J}\cdot\text{s}}{90 \times 10^{-9} \text{ m}}$ Ans. 6.68 nm

$$p = 7.37 \times 10^{-27} \text{ kg}\cdot\text{m/s}$$

$$E = \frac{p^2}{2m} = \frac{(7.37 \times 10^{-27} \text{ kg}\cdot\text{m/s})^2}{2(9.11 \times 10^{-31} \text{ kg})} = 2.98 \times 10^{-23} \text{ J}$$

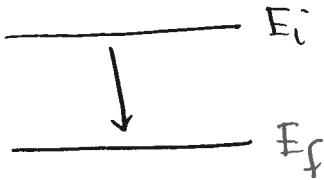
for the photon,

$$E = \frac{hc}{\lambda}, \quad \lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3 \times 10^8 \text{ m/s})}{2.98 \times 10^{-23} \text{ J}}$$

$$\lambda = 6.68 \times 10^{-3} \text{ m} = 6.68 \text{ nm}$$

(7 pts) b) An atom undergoes a transition from a state with energy -3.0 eV to a state with energy -8.0 eV . What is the wavelength of the photon emitted in this transition?

Ans. 248 nm



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

$$\lambda = \frac{hc}{E_i - E_f} = \frac{(4.136 \times 10^{-15} \text{ eV}\cdot\text{s})(3 \times 10^8 \text{ m/s})}{-3 \text{ eV} - (-8 \text{ eV})}$$

$$\lambda = 2.48 \times 10^{-7} \text{ m} = 248 \text{ nm}$$