Name: Key

Physics 2020 – Fall 2001

Final Exam – Dec. 12, 2001

Multiple Choice (30): _____

Q1 (7): _____ Q2 (8): _____ Q3 (10): _____ Q4 (10): _____

Q5: (12): _____ Q6: (12): _____ Q7 (11): _____

TOTAL (100): _____

Corrections and additions to formula sheet

$R = 1.097 \times 10^{7}\ m^{-1}$ $1\ eV = 1.602 \times 10^{-19}\ J$

Balmer formula
$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Magnetic flux
$$\Phi = BA\cos\theta$$

Kinetic energy
$$KE = \tfrac{1}{2}mv^2$$

Part I: Multiple Choice (3 points each)

Circle the most suitable answer from among those given. If you do not agree with any of the answers write your own.

1. The parent nucleus ${}^{210}_{82}Pb$ decays by both α and β⁻ decay. What are the daughter nuclei of these decays?

a) ${}^{208}_{82}Pb$ and ${}^{210}_{83}Bi$
b) ${}^{208}_{80}Hg$ and ${}^{210}_{81}Tl$
c) ${}^{206}_{80}Hg$ and ${}^{210}_{83}Bi$
d) ${}^{206}_{82}Pb$ and ${}^{210}_{81}Tl$

2. The nucleus $^{214}_{83}Bi$ undergoes α-decay to $^{210}_{81}Tl$ with a half-life of 20 minutes. If you are given a 16 gram sample of pure $^{214}_{83}Bi$, how long will you have to wait to get 15 grams of $^{210}_{81}Tl$?

a) 80 mins
b) 300 mins
c) 20^4 mins
d) 20^{15} mins

3. Which of the following combinations of quantum numbers is <u>not</u> possible for a hydrogen electron orbital?

a) $n = 3, l = 2, m_l = -2, m_s = -1/2$
b) $n = 2, l = 0, m_l = 1, m_s = +1/2$
c) $n = 4, l = 2, m_l = -1, m_s = +1/2$
d) $n = 1, l = 0, m_l = 0, m_s = -1/2$

4. The photon model of light is needed to explain

a) Black body radiation
b) The photoelectric effect
c) Compton scattering
d) All of the above.

5. Rainbows are caused by

a) The law of reflection being slightly different for different colors of light
b) The refractive index of water being slightly different for different colors of light.
c) The speed of light in air being slightly different for different colors.
d) The triangular shape of raindrops.

6. The image formed by a diverging mirror is

a) Always real and inverted
b) Always virtual and upright
c) Always real and upright.
d) Sometimes real and inverted, sometimes virtual and upright.

7. Two resistors R_1 and R_2 are connected in series. The value of the equivalent resistance R_{eq} is:

a) Less than the values of both R_1 and R_2
b) Between the values of R_1 and R_2
c) Greater than the values of both R_1 and R_2
d) It depends on the particular values of R_1 and R_2.

8. Two resistors R_1 and R_2 are connected in parallel. The value of the equivalent resistance R_{eq} is:

a) Less than the values of both R_1 and R_2
b) Between the values of R_1 and R_2
c) Greater than the values of both R_1 and R_2
d) It depends on the particular values of R_1 and R_2.

9. The magnetic field around a long straight wire, carrying a current I

a) Points toward the wire
b) Points away from the wire
c) Points in the same direction as the current
d) None of the above

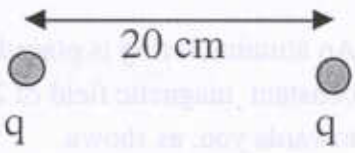
10. 10 μC of charge (made up of a large number of small charged particles) is placed on an insulated solid metal sphere. In equilibrium the charged particles:

a) Is distributed evenly throughout the body of the sphere
b) Resides entirely on the surface of the sphere
c) Is concentrated in the middle of the sphere
d) Is continuously moving around.

Part II: Problems

You must show your working and/or explain your reasoning to receive full credit.

1. When two identical charges q are placed 20 cm apart it is found that they repel each other with a force of 5.62 N. What is the size of the charge q? (7 points)

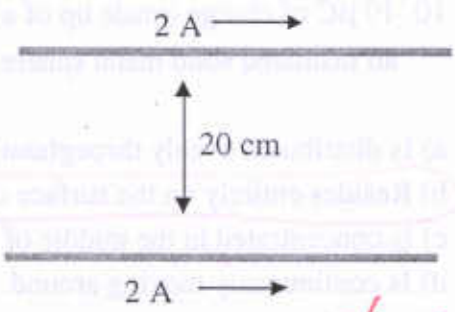


$$F = k\frac{q_1 q_2}{r^2} \Rightarrow 5.62\,N = k\frac{q^2}{(0.2\,m)^2}$$

$$\Rightarrow q^2 = \frac{5.62\,N \times (0.2\,m)^2}{8.99\times10^9\,N m^2/C^2} = 2.5\times10^{-11}\,C^2$$

$$\Rightarrow q = 5.0\times10^{-6}\,C \quad (\text{or } 5\,\mu C)$$

2. Two parallel wires of length 1m are 20 cm apart, and each carries a current of 2 A in the same direction. Determine the size of the force that each wire exerts on the other and whether they attract or repel. Explain your reasoning. (8 points)



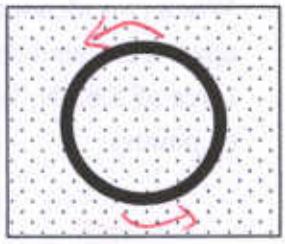
$L = 1\,m$
$I = 2\,A$
$r = 0.20\,m$
$\theta = 90°$

$F = ILB\sin\theta$ $\quad B = \frac{\mu_0 I}{2\pi r}$ $\quad B = 2\times10^{-6}\,T$

$$F = \frac{\mu_0 I^2 L}{2\pi r} = \frac{4\pi\times10^{-7}\,T\,m/A\cdot(2A)^2\cdot 1m}{2\pi\times 0.2\,m} = 4\times10^{-6}\,N$$

Attract

3. An aluminum ring is placed in a region where a uniform constant magnetic field of 2 T points through it, out towards you, as shown.



b) In what direction does the induced current flow round the ring? (5 points)

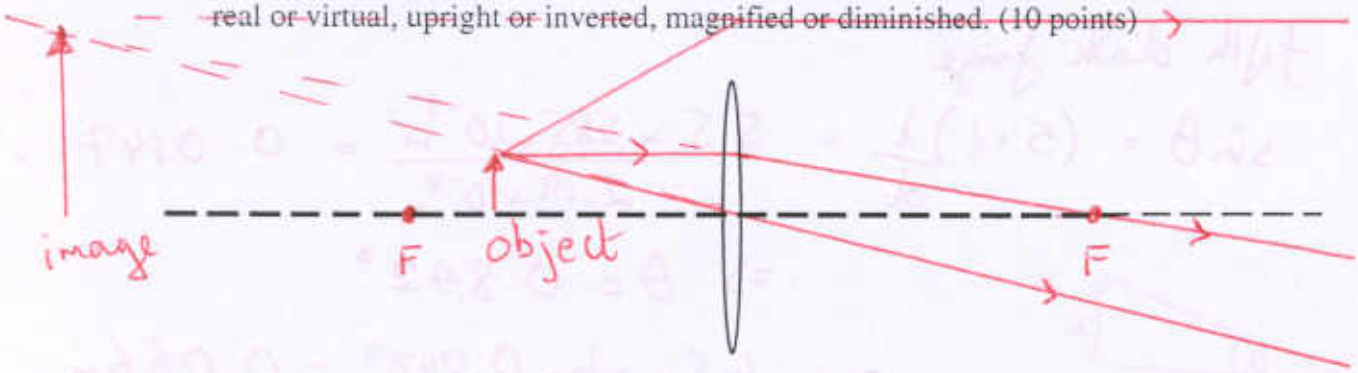
No induced current, flux is not changing.

c) The strength of the magnetic field is ~~not~~ now decreased to zero. What direction does the induced current flow round the ring now? (5 points)

Outward flux decreases ⇒ current flows to try and maintain outward flux

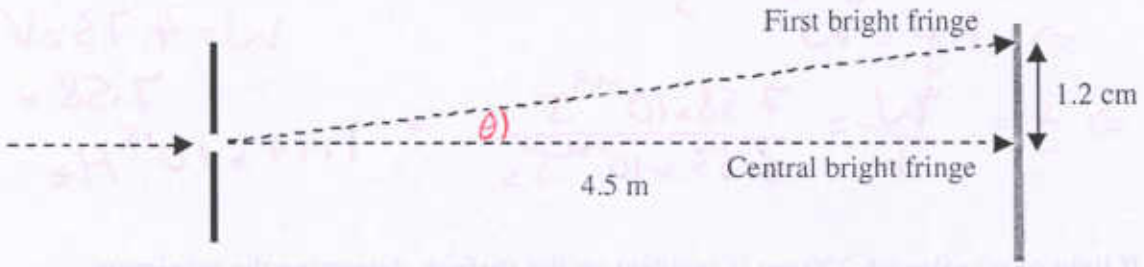
⇒ Counter clockwise

4. An object is placed 4 cm in front of a converging lens that has a focal length of 5 cm. Draw a ray diagram to locate the position of the image, and hence determine if it is real or virtual, upright or inverted, magnified or diminished. (10 points)



Virtual, upright, magnified

5. Laser light of wavelength 585 nm is passed through two narrow. An interference pattern is observed on a screen 4.5 m directly in front of the slits.



a) If the first bright fringe is measured to be 1.2 cm from the central maximum on the screen, how far apart are the narrow slits? (5 points)

$\sin\theta = m\frac{\lambda}{d}$ $\quad \theta = \tan^{-1}\left(\frac{0.012\text{m}}{4.5\text{m}}\right) = 0.0153°$

$\Rightarrow d = \frac{m\lambda}{\sin\theta} = \frac{1 \times 585 \times 10^{-9}}{\sin 0.0153°} = 2.19 \times 10^{-4}\ \text{m}$

(or 0.219 mm)

b) How far apart on the screen are the first bright fringe and the fifth dark fringe? (7 points)

fifth dark fringe

$$\sin\theta = (5+\tfrac{1}{2})\frac{\lambda}{d} = 5.5 \times \frac{585\times10^{-9}\,m}{2.19\times10^{-4}\,m} = 0.0147$$

$$\Rightarrow \theta = 0.842^\circ$$

$$\tan\theta = \frac{x}{4.5m}$$

$$x = 4.5m \times \tan 0.842^\circ = 0.066m \quad (\text{or } 6.6\,cm)$$

$$\Rightarrow \text{Distance is } 6.6cm - 1.2cm = 5.4\,cm$$

6. The work function for a silver surface is 4.73 eV.

a) Find the minimum frequency that light must have to eject electrons from this surface. (6 points)

$hf = W + KE_{max}$

Minimum frequency is when $KE_{max} = 0$

$\Rightarrow hf = W$

$W = 4.73\,eV = 7.58\times10^{-19}\,J$

$$\Rightarrow f = \frac{W}{h} = \frac{7.58\times10^{-19}\,J}{6.63\times10^{-34}\,J\,s} = 1.14\times10^{15}\,Hz$$

b) If light of wavelength 220 nm is incident on the surface, determine the maximum speed with which photoelectrons leave the surface. (6 points)

$$\lambda = 220\,nm \Rightarrow f = \frac{c}{\lambda} = \frac{3.00\times10^{8}\,m/s}{220\times10^{-9}\,m} = 1.36\times10^{15}\,Hz$$

$hf = W + KE_{max}$

$$\Rightarrow KE_{max} = hf - W = 6.63\times10^{-34}\,J\,s \times 1.36\times10^{15}\,Hz - 7.58\times10^{-19}\,J$$

$$= 1.44\times10^{-19}\,J$$

$$\Rightarrow \tfrac{1}{2}mv_{max}^2 = 1.44\times10^{-19}\,J \Rightarrow v_{max} = \sqrt{\frac{2\times1.44\times10^{-19}\,J}{9.11\times10^{-31}\,kg}}$$

$$= 5.62\times10^{5}\,m/s$$

7. a) Briefly explain the Pauli Exclusion Principle and its role in atomic physics. (5 points)

b) Determine the quantum numbers for all the electrons in the ground state of a neutral neon (Ne) atom (Z=10). (6 points)