CHAPTER 1

EXERCISES

1.1 What is the magnitude of the columbic force between two point charges of values +3.00μC and +5.00μC separated from each other by a distance of 30cm in free space. What is the nature of the force? Answer: F = 1.5N, Repulsive.

1.2 Determine the electrostatic force between two equal charges of 5μC separated by 5cm. Answer: F = 90N

1.3 How far does the electron of a hydrogen atom have to be moved from the nucleus for the force of attraction in the electron to equal the weight at the earth surface? Answer: r = 5.03m
Me = 9.1094×10^{-31}kg
Mp = 1.6726×10^{-27}kg
Mn = 1.6749×10^{-27}kg
Charge of electron = -1.6×10^{-19}C
Charge of proton = 1.6×10^{-19}C
Charge of neutron = 0C

1.4 Two small spheres placed 30.0cm apart have equal charges. How many excess electrons must be present on each sphere, if they experienced a repulsive force of 2.30×10^{-22}N (assume free space between them). Answer: n = 300 electrons

1.5 Three charges Q1 = -2.00μC, (0, 0) cm; Q2 = 4.00μC, (0, 10) cm and Q3 = -3.00μC, (15, 0) cm.
a. Find the total electric force on the charge at (0, 0)cm
b. Find the magnitude of the total electric force in (a) above
c. Find the angle that the total electric force makes with the positive x-axis.

Answer: (a) F = (-2.4N) i + (7.2N) j, (b) |F| = 7.6N, (c) θ = 108°

SOLUTIONS

1. $F = \frac{K_0Q_1Q_2}{d^2}$

Where $3\mu C, 5\mu C$ *and* $0.30m$ are charges and distance respectively?

$$F = \frac{9\times10^9 \times 3\mu \times 5\mu}{(0.3)^2} = \mathbf{1.5N\ repulsive}$$

2. $F = \frac{K_0Q_1Q_2}{d^2}$

Where $5\mu C, 5\mu C$ *and* $0.05m$ are charges and distance respectively?

$$F = \frac{9\times10^9 \times 5\mu \times 5\mu}{(0.05)^2} = 90N\ repulsive$$

3. Force between the proton and the electron equals the weight of electron

$$\frac{K_0Q_1Q_2}{d^2} = M_Eg\ ;\ \frac{9\times10^9\times1.6\times10^{-19}\times1.6\times10^{-19}}{d^2} = 9.1094\times10^{-31}\times10$$

$$d = \sqrt{\frac{9\times10^9\times1.6\times10^{-19}\times1.6\times10^{-19}}{9.1094\times10^{-31}\times10}} = \mathbf{5.03m}$$

4. $F = \frac{K_0Q_1Q_2}{d^2}$

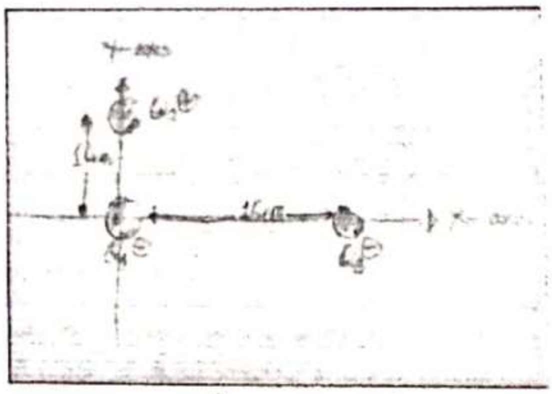
$Q_1 = Q_2 = Q$

$$2.30\times10^{-22} = \frac{9\times10^9\times Q^2}{(0.3)^2}$$

$$Q = \sqrt{\frac{2.30\times10^{-22}\times0.3\times0.3}{9\times10^{-9}}} = 4.8\times10^{-17}C$$

$$Q = ne^-$$

$$n = \frac{Q}{e^-} = \frac{4.8\times10^{-17}C}{1.6\times10^{-19}C} = \mathbf{300 electrons}$$



5.

$$F_{net-x} = KQ_1\left(\frac{Q_3}{d^2_{1,3-x}} + \frac{Q_2}{d^2_{1,2-x}}\right)$$

$$F_{Net-x} = 9\times10^9\times2\times10^{-6}\left(\frac{3\times10^{-6}}{(0.15)^2} + \frac{4\times10^{-6}}{0^2}\right) = (-2.4N)i$$

$$F_{net-y} = KQ_1\left(\frac{Q_3}{d^2_{1,3-y}} + \frac{Q_2}{d^2_{1,2-y}}\right)$$

$$F_{Net-y} = 9\times10^9 \times 2\times10^{-6}\left(\frac{4\times10^{-6}}{(0.1)^2} + \frac{3\times10^{-6}}{0^2}\right)$$
$$= (+7.2N)j$$

$$\boldsymbol{F_{net} = (-2.4N)i + (7.2N)j}$$

5b. $|F| = \sqrt{F_x^2 + F_y^2} = \sqrt{(-2.4)^2 + (7.2)^2}$

$$|F| = 7.6N$$

5c. $\beta = tan^{-1}\left(\frac{F_y}{F_x}\right) = tan^{-1}\left(-\frac{7.2}{2.4}\right) = -72°$

72° in the negative x axis or 108° in the positive x axis

CHAPTER 2

EXERCISES

2.1 An electron of charge e = 1.6×10^{-19}C is situated in a uniform electric field of intensity or field strength 120,000Vm^{-1}. Find the force on it, its acceleration, and the time it takes to travel 20mm from rest. (Mass of electron, m = 9.1×10^{-31}).
Answer: F = 1.92×10^{-14}N, a = 2.12×10^{16}m/s², t = 1.37×10^{-9}S

2.2 (a) what are the magnitude and direction of the electric field 2cm from a fixed point charge of 3.0×10^{-10}C.
(b) How far away from the point charge does the field drop to 20% of its original value
Answer: (a) = 6.8×10^3N/C and outward
(b) = 4cm

2.3 A neutral water molecule (H_2O) in its vapor state has an electric dipole moment of magnitude 6.2×10^{-30}C.m.
a. How far apart are the molecules centers of positive and negative charge?
b. If the molecule placed in an electric field of 1.5×10^4N/C, what maximum torque can the field exert on it?
Answer: (a) 3.9×10^{-12}m
(b) 9.3×10^{-26}N.m

2.4 What is the magnitude of a point charge whose electric field 50cm away has the magnitude of 2.0N/C?
Answer: 5.56×10^{-11}C

SOLUTION

1. $E = 120{,}000Vm^{-1}$ And $Q = 1.6 \times 10^{-19}C$ and $mass = 9.1\times10^{-31}kg$

$$F = EQ = 120{,}000 \times 1.6\times10^{-19} = 1.92\times10^{-14}N$$

b) $a = \frac{F}{m} = \frac{1.92\times10^{-14}}{9.1\times10^{-31}} = 2.11\times10^{16}m/s^2$

c) Distance travelled = 20mm = 0.002m

$$S = ut + \frac{1}{2}at^2, where\ u = 0$$

$$S = \frac{1}{2}at^2$$

$$0.002 = \frac{1}{2}\times 2.11\times10^{16}\times t^2$$

$$t = 1.37\times10^{-9} second$$

2. $d = 2cm = 0.02m$ and $Q = 3\times10^{-10}C$

$$E = \frac{KQ}{d^2} = \frac{9\times10^9\times3\times10^{-10}}{(0.02)^2} = 6750N/C$$

b) $E_1 = E;\ E_2 = 20\%E(that\ is, 0.2E)$

$$E_1d_1^2 = E_2d_2^2$$

$$d_2 = \sqrt{\frac{E_1d_1^2}{E_2}} = \sqrt{\frac{E\times2^2}{0.2E}} = 4.47cm$$

3. $\mu = 6.2\times10^{-30}Cm^{-1};\ Q = 1.6\times10^{-19}C$

a. $\mu = Q\times d$

$$d = \frac{\mu}{Q} = \frac{6.2\times10^{-30}}{1.6\times10^{-19}} = 3.875\times10^{-11}m$$

b) $E = 1.5\times10^4NC^{-1}$

$$\tau_{max} = E\times Q\times d$$

$$\tau_{max} = 1.5\times10^4\times1.6\times10^{-19}\times3.875\times10^{-11}$$

$$\tau_{max} = 9.3\times10^{-26}Nm$$

4. $d = 0.5m: E = 2NC^{-1}$

$$E = \frac{KQ}{d^2}$$

$$Q = \frac{Ed^2}{K} = \frac{2\times(0.5)^2}{9\times10^9} = 5.56\times10^{-11}C$$

CHAPTER 3

EXERCISES

3.1 The nucleus of an atom has a charge of 3e where e is the electronic charge. Find the flux through a sphere of radius 1Å (1Å $=10^{-10}$m) answer: 5.43 × 10-⁸Nm²/C

3.2 A physicist surrounded a point charge of 5.0μC with a sphere of radius 0.26m centered on the charge. Calculate the electric flux through the sphere. Answer: 5.66 × 10⁵Nm²/C

3.3 What will be the magnitude of the electric field strength at a point of 5.0cm from an infinite line of charge of linear charge density 18.0μC/cm situated in a medium of relative permittivity 1.5? Answer: 4.3 × 10⁸N/C

3.4 A negative point charge 4.8μC is surrounded by a sphere with radius 0.55m centered on the charge. Find the magnitude of the electric field and electric flux through the sphere due to this charge. Answer: 1.43 × 10⁵N/C, 5.42×10⁵Nm²/C?

SOLUTION

($\varphi = 8.85 \times 10^{-12} Fm^{-1}$ *is the permittivity of free space*)

1. $e = 1.6 \times 10^{-19} C$

$$3e = 3 \times 1.6 \times 10^{-19} C$$

$$\varphi = \frac{Q}{\varepsilon_o} = \frac{3 \times 1.6 \times 10^{-19}}{8.85 \times 10^{-12}} = \mathbf{5.424 \times 10^{-8} Nm^2C^{-1}}$$

2. $Q = 5\mu C = 5 \times 10^{-6} C$

$$\varphi = \frac{Q}{\varepsilon_0} = \frac{5 \times 10^{-6}}{8.85 \times 10^{-12}} = \mathbf{5.65 \times 10^6 Nm^2C^{-1}}$$

3. $r = 5cm = 0.05m; \lambda = 18\mu Ccm^{-1} = 18 \times 10^{-4} Cm^{-1}; \varepsilon_r = 1.5$

$$E = \frac{\lambda}{2\pi r\varepsilon_0\varepsilon_r} = \frac{18 \times 10^{-4}}{2 \times \pi \times 0.05 \times 8.85 \times 10^{-12} \times 1.5} = \mathbf{4.32 \times 10^8 NC^{-1}}$$

4. $Q = 4.8\mu C = 4.8 \times 10^{-6} C; r = 0.55m$

$$E = \frac{K_0 Q}{r^2} = \frac{9 \times 10^9 \times 4.8 \times 10^{-6}}{0.55^2} = \mathbf{1.43 \times 10^5 NC^{-1}}$$

b) $\varphi = \frac{Q}{\varepsilon_0} = \frac{4.8 \times 10^{-6}}{8.85 \times 10^{-12}} = \mathbf{5.424 \times 10^5 Nm^2C^2}$

CHAPTER 4

EXERCISES

4.1 Josh stored an electric potential energy of 2.5J in a vacuum of 1.00m³ by a field E. If the field is reduced to ¼ of its initial value, how much energy is stored per cubic meter? Answer: 0.2J/m³

4.2 A professor accelerated an electron of mass 9.1 × 10¹⁵N/C between two parallel charged plates of separation 1.7cm. Calculate the velocity with which the electron leaves a hole in the positive plate if it is accelerated near the negative plate. Answer: 4.2 × 10¹²m/s

4.3 Professor Ikechukwu placed two point charges such that charge Q1 = 3.0μC is placed at x = 0 and charge Q2 = 2.0μC is located at x = 50cm. Calculate the work done by an external force to bring a charge Q3 of magnitude 1.5μC from x = 100cm (k = 9 × 10⁹C²/Nm²) answer: 9.5 × 10-²J

4.4 If Professor Ikechukwu was to calculate the total potential energy of the system of three charges in question (4.3) above, what would the value be? Answer: 2.0 × 10-¹J

4.5 What is the electric potential energy between a proton and an electron in a sodium atom of radius 5.9 × 10-²⁰m? Answer: -5.28 × 10-⁷J

SOLUTION

1. Energy density(U)$=\frac{energy}{volume} = \frac{2.5}{1} = 2.5Jm^{-1}$

The proportional relationship between energy density (U) and electric field intensity (E) is given by: $\frac{U_1}{U_2} = \frac{E_1^2}{E_2^2}$

$$(Note\ U = \frac{1}{2}\varepsilon_0 E^2)$$

$$U_1 = 2.5Jm^{-3}; U_2 = ?;\ E_1 = E; E_2 = \frac{1}{4}E$$

$$\frac{2.5}{U_2} = \frac{E^2}{(0.25E)^2}$$

$$U_2 = \frac{2.5 \times (0.25E)^2}{E^2} = 0.15625Jm^{-3} = \mathbf{0.2Jm^{-3}}$$

2. $E = 9.1 \times 10^{15} NC^{-1}; M_E = 9.1 \times 10^{-31} kg; Q_E = 1.6 \times 10^{-19} C; u = 0ms^{-1}; v = ?; s = 1.7 \times 10^{-2} m$

$$F = M_E a = Q_E E$$

$$hence; a = \frac{Q_E E}{M_E}$$

$$v^2 = u^2 + 2aS$$

$$v = \sqrt{\frac{2Q_E ES}{M_E}}$$

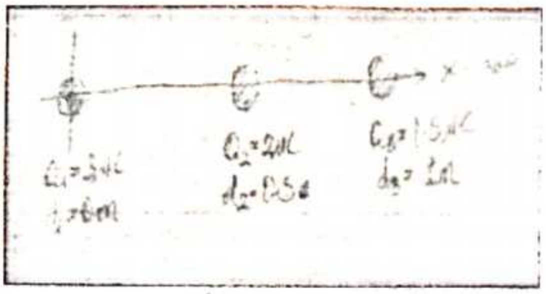
$$v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 9.1 \times 10^{15} \times 1.7 \times 10^{-2}}{9.1 \times 10^{-31}}}$$

$$v = 7.4 \times 10^{12} ms^{-1}$$

3. $W = K_0 Q_3 (\frac{Q_1}{r_{1,3}} + \frac{Q_2}{r_{2,3}})$

$$W = 9 \times 10^9 \times 1.5 \times 10^{-6} (\frac{3 \times 10^{-6}}{1} + \frac{2 \times 10^{-6}}{0.5})$$

$$W = 9.5 \times 10^{-2} J$$

4. 

$$W_{total} = K_0 (\frac{Q_1 Q_2}{d_{1,2}} + \frac{Q_2 Q_3}{d_{2,3}} + \frac{Q_1 Q_3}{d_{1,3}})$$

$$W_t = 9 \times 10^9 (\frac{3 \times 10^{-6} \times 2 \times 10^{-6}}{0.5} + \frac{2 \times 10^{-6} \times 1.5 \times 10^{-6}}{0.5} + \frac{3 \times 10^{-6} \times 1.5 \times 10^{-6}}{1})$$

$$W_{total} = 2.025 \times 10^{-1} J$$

5. $W = \frac{K_O Q_P Q_E}{d} = \frac{9 \times 10^9 \times 1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{5.9 \times 10^{-20}}$

$$Work = 3.91 \times 10^{-9} J$$

CHAPTER 5

EXERCISE

5.1 Calculate the capacitance of two plate's area $4cm^2$ separated by 1mm. Answer: 3.54pf

5.2 A 6μf capacitor is charged by a 12V battery and then disconnected. It is then connected to an unchanged 3μf capacitor. What is the final potential difference across each capacitor? Answer: 8V

5.3 Capacitor C_1 = 5μf and C_2 = 8μf are connected in series across a 9V battery. How much energy do they store? Answer: 1.25×10^{-4}J

5.4 A parallel plate capacitor of plate area $0.04m^2$ and plate separation of 0.25mm is charged to 24V. Determine the charge on a plate and the electric field between the plates. Answer: 3.4×10^{-8}C, 9.6×10^4V/m

5.5 The series combination of capacitors C_1 = 2μf, C_2 = 3μf is connected in parallel with C_3 = 5μf. What is the equivalent capacitance of this arrangement? Answer: 6.2μf

SOLUTION

1. $A = 4cm^2 = 4 \times 10^{-4} m^2; d = 1mm = 1 \times 10^{-3} m; \varepsilon_0 = 8.85 \times 10^{-12} Fm^{-1}$

$$C = \frac{\varepsilon_0 A}{d} = \frac{8.85 \times 10^{-12} \times 4 \times 10^{-4}}{1 \times 10^{-3}}$$

$$C = 3.54 \times 10^{-12} F = 3.54pF$$

2. $C_1 = 6\mu F = 6 \times 10^{-6} F; V_0 = 12V; C_2 = 3\mu F = 3 \times 10^{-6} F$

$$C_1 V_0 = V(C_1 + C_2)$$

$$V = \frac{C_1 V_0}{C_1 + C_2} = \frac{6 \times 10^{-6} \times 12}{(6 \times 10^{-6}) + (3 \times 10^{-6})}$$

$$V = 8Volts$$

3. $C_T = \frac{C_1 C_2}{C_1 + C_2} = \frac{5 \times 8}{5 + 8} = \frac{40}{13} \mu F$

$$Energy = \frac{1}{2} CV^2$$

$$Energy = \frac{1}{2} \times \left(\frac{40}{13} \times 10^{-6}\right) \times 9^2$$

$$Energy = 1.25 \times 10^{-4} J$$

4. $A = 0.04m^2; d = 0.25mm = 0.25 \times 10^{-3} m; V = 24V$

$$Q = \frac{\varepsilon_0 AV}{d}$$

$$Q = \frac{8.85 \times 10^{-12} \times 0.04 \times 24}{0.25 \times 10^{-3}}$$

$$Q = 3.4 \times 10^{-8} C$$

$$E = \frac{V}{d} = \frac{24}{0.25 \times 10^{-3}} = 9.6 \times 10^4 Vm^{-1}$$

5. $C_{series} = \frac{C_1 C_2}{C_1 + C_2} = \frac{2 \times 3}{2 + 3} = 1.2\mu F$

$$C_{total(parallel)} = 1.2\mu F + 5\mu F = 6.2\mu F$$

CHAPTER 6

EXERCISES

6.1 A parallel plate capacitor consist of two plates each of area 200cm², separated by a 0.4cm air - gap and is connected across a 500V source. Find the charge on it. ($\varepsilon_0 = 8.85 \times 10^{-12}$F/m) Answer: 22nc

6.2 A parallel plate capacitor has area 4.8cm² separation of plates 1.5cm and dielectric constant 6.0 when given charge of 10μc, the potential difference across the plates is half of the maximum acting voltage. Determine the dielectric strength. Answer: 7.85×10^{8}v/m.

6.3 A certain capacitor has a value of 0.20μF when filled with air and 0.482μF when filled with oil. Calculate the dielectric constant of the oil. Answer: k = 2.41

6.4 Find the capacitance of a parallel plate capacitor which consists of two plates, each of area 200cm² and separated by a 0.4cm air - gap. Answer: C_0 = 44.0pF

6.5 Referring to question (6.4), a 500V source is connected across the capacitor and a liquid with K = 2.60 are poured between the plates to fill the air gap. Find the additional charge that will flow into the capacitor from the 500V source. Answer: 35nC

6.6 Find the energy stored in a capacitor of capacitance 1.2μF when charged to 3kv. Answer: 5.4 Joules

6.7 A sheet of plastic 50cm wide and 0.2×10^{-2} cm thick between metal foil of the same width is used to make a 4.0μF capacitor. If the dielectric constant of the plastic is 2.8, find its length. Answer: 6.456m

6.8 A 600μF capacitor discharges through a 100kΩ resistor. Calculate the time it takes the charge on the plates to decay by ⅔. Answer: t = 30.65secs

Hint: $q = Q_0 \exp(-t/RC)$

6.9 An electronic flashlight mechanism used with a camera is activated when a capacitor is discharged through a filament wire. Calculate the maximum charge on the capacitor for a filament that requires 5.4×10^{-3}J to fire properties with a battery of emf 12V. Answer: 9 × 10-4C

6.10 Calculate the equivalent capacitance between points A and B in Fig. 6.5:

6.11 A d.c source of 500V is connected across two capacitors of capacitance 2μF and 3μF in parallel. What is the electric charge through the 2μF?

6.12 What is the work done in moving a positive charge 1.2×10^{-6}C across two points 6cm apart. (Take $\frac{1}{4\pi\varepsilon_0} = 9.05 \times 10^{9}$)

6.13 A simple capacitor, consisting of two insulating parallel plates, has a capacitance of 0.001μF and receives a charge of 1.0μC. What is the potential difference between the plates? What would be the capacitance be if the area of each plate were tripled and the spacing between the plates halved?

6.14 A capacitor which will store enough energy to light a 75W light bulb for 15 minutes is to be built. If the available potential difference is 150V, what capacitance is needed?

6.15 A capacitor consisting of two air spaced parallel plates, each of effective area 1000cm² spaced 0.1cm apart is connected across a constant voltage source of 5000V. Calculate the charge of the capacitor. ($\varepsilon_0 = 8.854 \times 10^{-12}$F/m)

SOLUTION

1. $A = 200cm^2 = 200 \times 10^{-4}m^2; V = 500V; d = 0.4cm = 0.4 \times 10^{-2}m$

$$Q = \frac{\varepsilon_0 AV}{d} = \frac{8.85 \times 10^{-12} \times 2 \times 10^{-2} \times 500}{0.4 \times 10^{-2}}$$

$$Q = 22.125 \times 10^{-9}C = 22nC$$

2. $A = 4.8cm^2 = 4.8 \times 10^{-4}m^2; d = 1.5cm = 1.5 \times 10^{-2}m; \varepsilon_r = 6; Q = 10\mu C = 10 \times 10^{-6}C$

$(Note;\ \varepsilon_r = \frac{\varepsilon_{medium}}{\varepsilon_{vacuum}} = \frac{E_0}{E})$

$$\varepsilon_r = \frac{E_0}{E} = \frac{1}{E} \times \frac{Q}{A\varepsilon_0}$$

$$E = \frac{Q}{A\varepsilon_0\varepsilon_r}$$

$$E = \frac{10 \times 10^{-6}}{4.8 \times 10^{-4} \times 8.85 \times 10^{-12} \times 6}$$

$$E = 3.923 \times 10^8 NC^{-1}$$

$$V = 0.5V_0$$

$$\frac{E_0}{E} = \frac{V_0}{V}$$

$$E_0 = \frac{EV_0}{V} = \frac{3.923\times10^8 \times V_0}{0.5V_0} = \mathbf{7.85 \times 10^8 Vm^{-1}}$$

3. $\varepsilon_r = \frac{C_m}{C_0}$

$$C_{medium} = 0.482\mu F; C_{air} = 0.20\mu F$$

$$\varepsilon_r = \frac{0482\mu F}{0.20F} = \mathbf{2.41}$$

4. $A = 200cm^2 = 0.02m^2; d = 0.4cm = 0.004m; \varepsilon_0 = 8.85 \times 10^{-12} Fm^{-1}$

$$C_0 = \frac{\varepsilon_0 A}{d} = \frac{8.85 \times 10^{-12} \times 0.02}{0.004}$$

$$\mathbf{C_0 = 44.25 \times 10^{-12} F = 44.25pF}$$

5. $\varepsilon_r = 2.6; V = 500V$

$$C_m = C_0 \times \varepsilon_r = 44.25 \times 10^{-12} \times 2.6$$

$$C_m = 1.1505 \times 10^{-10} F$$

$$Q_{additional\ charge} = Q_{liquid\ gas} - Q_{air\ gap}$$

$$Q_{additional\ charge} = V(C_m - C_0)$$

$$Q_{additional} = 500 \times 10^{-10}(1.1505 - 0.4425)$$

$$\mathbf{Q_{additional} = 3.54 \times 10^{-8} C = 35.4nC}$$

6. $Energy = \frac{1}{2}CV^2$

$$Energy = \frac{1}{2} \times (1.2 \times 10^{-6}) \times (3 \times 10^3)^2$$

$$\mathbf{Energy = 5.4 Joules}$$

7. Breadth=50cm=0.5, $d = 0.2 \times 10^{-2} cm = 0.2 \times 10^{-4} m; C = 4\mu F = 4 \times 10^{-6} F; \varepsilon_r = 2.8; length(L) = ?$

$$C_m = \frac{\varepsilon_r \varepsilon_0 A}{d} = \frac{\varepsilon_r \varepsilon_0 LB}{d}$$

$$L = \frac{C_m d}{\varepsilon_0 \varepsilon_r B} = \frac{4 \times 10^{-6} \times 0.2 \times 10^{-4}}{2.8 \times 8.85 \times 10^{-12} \times 0.5}$$

$$\mathbf{Length = 6.45682m}$$

8. $Q_t = Q_0(1 - e^{-\frac{t}{RC}})$ (the discharge formula)

$$Q_t = \frac{2}{5}Q; Q_0 = Q; C = 600 \times 10^{-6} F;$$

$$R = 100 \times 10^3 \Omega; t = ?$$

$$\frac{2}{5}Q = Q(1 - e^{-\frac{t}{600\times10^{-6}\times100\times10^3}})$$

$$t = Ln\left(1 - \frac{2/5\,Q}{Q}\right) \times -60$$

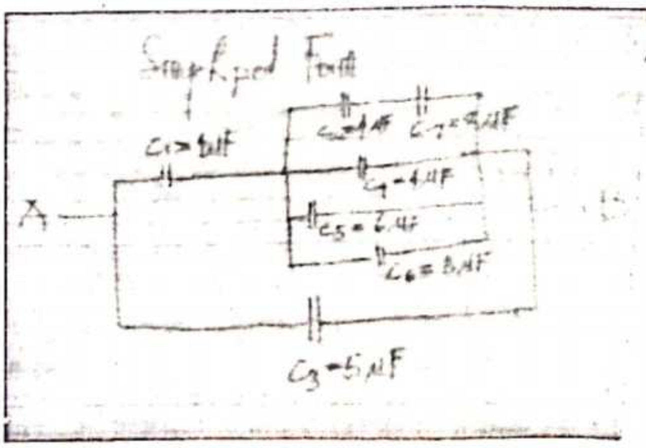
$$\mathbf{t = 30.65 seconds}$$

9. $Energy = \frac{1}{2}QV$

$$Q = \frac{2Energy}{V} = \frac{2 \times 5.4 \times 10^{-3}}{12}$$

$$\mathbf{Q = 9 \times 10^{-4} C}$$

10.



$$C_2\ amd\ C_7(C_{2,7}) = \frac{4 \times 8}{4 + 8} = 2.67\mu F$$

$$C_{2,7} + C_4 + C_5 + C_6 = 2.67 + 4 + 6 + 2 = 14.67\mu F$$

$$C_{above}\ and\ C_1 = \frac{4 \times 14.67}{4 + 14.67} = 3.143\mu F$$

$$C_{effective} = 5 + 3.143 = \mathbf{8.143\mu F}$$

11. $Q_2 = C_2 V = 3 \times 10^{-6} \times 500$

$$Q_2 = 1.5 \times 10^{-3}C$$

12. $Q = 1.2 \times 10^{-6}C; d = 6cm = 0.06m; k = 9 \times 10^9 Nm^2C^{-2}$

$$Work = \frac{K_0Q^2}{d} = \frac{9 \times 10^9 \times (1.2 \times 10^{-6})^2}{0.06}$$

$$Work = 2.16 \times 10^{-1}J$$

13. $C = 0.001\mu; Q = 0.1\mu C$

a) $V = \frac{Q}{C} = \frac{1\mu}{0.001\mu} = 1000volts$

b) $\frac{C_1d_1}{A_1} = \frac{C_2d_2}{A_2}$

$$C_1 = 0.001 \times 10^{-6}F; A_1 = A; d_1 = d;$$

$$C_2 = ?; A_2 = 3A; d_2 = 0.5d$$

$$C_2 = \frac{C_1d_1A_2}{A_1d_2} = \frac{1 \times 10^{-9} \times d \times 3A}{A \times 0.5d}$$

$$C_2 = 6 \times 10^{-9}F$$

14. $P = 75W; t = 15mins = 900secs; V = 150V; C = ?$

$$Pt = \frac{1}{2}CV^2$$

$$C = \frac{2Pt}{V^2} = \frac{2 \times 75 \times 900}{150^2}$$

$$C = 6F$$

15. $A = 1000cm^2 = 0.1m^2; d = 0.1cm = 0.001m^2; V = 500V$

$$Q = \frac{\varepsilon_0 AV}{d} = \frac{8.85 \times 10^{-12} \times 0.1 \times 500}{0.001}$$

$$Q = 4.425 \times 10^{-7}C$$

CHAPTER 7

EXERCISES

7.1. Determine the equivalent resistance of the resistors shown here. Answer: 2Ω

7.2. A 6μf capacitor is charged through a 5-kΩ resistor by a 500 power supply. How long does it require for the capacitor to acquire 99% of its final charge. Answer: t = 0.14s

7.3. A 1.5-V flashlight battery typically has an internal resistance of 0.30Ω. What is its terminal voltage when it supplies 48mA to a load? What power does it deliver to the load? Answer: 1.49V, 0.07W.

7.4. Consider a meter whose coil has a resistance of 20.0Ω and that deflects full scale when the current in its coil is 1.00mA. The corresponding potential difference for full-scale deflection is Answer: 0.02V

7.5. An 1800W toaster, a 1.3kW electric frying pan and a 100W lamp are plugged into the same 20A, 120V circuit. What current is dock by each device respectively and what is the resistance of each device respectively.

Answer: I_1 = 15A, I_2 = 11A, I_3 = 0.83A, R_1 = 8Ω, R_2 = 11Ω, R_3 = 144Ω

7.6. An ammeter was designed to read 1.0A at full scale using a galvanometer with a full scale sensitivity of 50μA and resistance of 30Ω. Find the resistance of the shunt used.

Answer: 1.5mΩ

7.7. According to the question in 7.6 above, if a voltmeter that reads from 0 to 15V is to be designed, what will be the resistance of the multiplier used? Answer: 300kΩ

SOLUTION

1. $R_{between\ 3ohm\ amd\ 6ohm} = \frac{3 \times 6}{3+6} = 2ohms$

$$R_{series} = 2ohms + 2ohms = 4ohms$$

$$R_{effective} = \frac{4 \times 4}{4+4} = 2ohms$$

2. $t_{99\%\ charge} = 4.61 \times time\ constant$

$$\tau = RC = 5 \times 10^3 \times 6 \times 10^{-6}$$

$$\tau = 0.03$$

$$t_{99\%} = 4.61 \times 0.03 = 0.14seconds$$

3. $E = 1.5V; r = 0.30ohms; I = 48mA = 0.048A$

$$V = E - Ir$$

$$V = 1.5 - (0.048 \times 0.3)$$

$$V = 1.49V$$

$$P = IE = 0.048 \times 1.5$$

$$\boldsymbol{P = 0.07Watts}$$

4. $R = 20ohms; I = 1mA = 0.001A$

$$V = IR = 0.001 \times 20 = \boldsymbol{0.02V}$$

5. $P_{toast} = 1800W; P_{pan} = 1300W; P_{lamp} = 100W; I = 20A; V = 120V$

$$I_{toaster} = \frac{P_{toaster}}{V} = \frac{1800}{120} = \boldsymbol{15A}$$

$$I_{pan} = \frac{P_{pan}}{V} = \frac{1300}{120} = 10.83A \cong \boldsymbol{11A}$$

$$I_{lamp} = \frac{P_{lamp}}{V} = \frac{100}{120} = \boldsymbol{0.83A}$$

$$R_{toaster} = \frac{V}{I_{toaster}} = \frac{120}{15} = \boldsymbol{8ohms}$$

$$R_{lamp} = \frac{V}{I_{lamp}} = \frac{120}{11} = 10.9 \cong \boldsymbol{11ohms}$$

$$R_{pan} = \frac{V}{I_{lamp}} = \frac{120}{0.83} = \boldsymbol{144.6ohms}$$

6. $R_S = \frac{I_g R_g}{I - I_g}$

$$R_S = \frac{50 \times 10^{-6} \times 30}{1 - (50 \times 10^{-6})} = 1.5 \times 10^{-3} = \boldsymbol{1.5m\Omega}$$

7. $R_m = \frac{V}{I_g} - R_g$

$$R_m = \frac{15}{5 \times 10^{-5}} - 30$$

$$R_m = \boldsymbol{299970\Omega \cong 300k\Omega}$$

CHAPTER 9

EXERCISES

9.1. An He^{2+} ion travelling 2×10^5m/s moves perpendicular to a magnetic field of 0.75T. What force does it experience? Answer: 4.8×10^{-14}N

9.2. In a photographic emulsion, the track of a proton moving perpendicular to a magnetic field of 0.60T is observed to be a circular arc of radius 1.2cm. What is the kinetic energy of the proton in electronvolts? Answer: 2480eV

9.3. An electron moves with speed 3.2×10^5m/s in the positive x direction in the presence of a magnetic field B = 0.1i + 0.3j - 0.2k (in teslas). What force does the electron experience? Answer: 5.8×10^{-20}N

9.4. A singly charged ion of lithium has a mass of 1.16×10^{-26}kg. It is accelerated through a voltage of 600V and then enters a magnetic field of 0.60T perpendicular to its velocity. What is the radius of the ion's path in the magnetic field? Answer: 0.016m

9.5. A straight wire lies along the x axis and carries a current of 2.0A in the positive x direction. A uniform magnetic field of 0.08T in the x-y plane makes an angle of 60° with the wire. Determine the magnitude and direction of the magnetic force on a 1.5m segment of the wire. Answer: 0.21N Z - direction

9.6. In a loudspeaker, a permanent magnet creates a magnetic field of 0.12T directed radially outward from the z axis. The voice coil of the speaker has 60 turns and a radius of 0.013m and is positioned in the x-y plane. What force acts on the coil when it carries a current of 1.5A? Answer: 0.88N

9.7. A certain location in the Southern hemisphere, earth's magnetic field has a magnitude of 42μT and points upward at 57° to the vertical. Calculate the flux through a horizontal surface of area 2.5m²

9.8. A long solenoid with radius of 25mm has 100turns/cm. A single loop of wire of radius 5cm is placed around the solenoid, the central axis of the loop and solenoid coinciding. In 10ms the current in the solenoid is reduced from 1.0A to 0.5A at a uniform rate. What is the emf that appears in the loop?

9.9. An elastic conducting material is stretched into a circular loop of 12cm radius. It is placed with its plane perpendicular to a uniform 0.800T magnetic field when released, the radius of the loop starts to shrink it an instantaneous rate of 75.0cm/s. What is the emf induced in the loop at that instant?

9.10. An electric generator consist of 100turns of wire formed into a rectangular loop of length 50cm and width 30cm. If this loop is placed entirely in a uniform magnetic field with magnitude B = 3.50T. What is the maximum value of the emf produced when the loop is spun at 1000rev/min about an axis perpendicular to B?

SOLUTION

1. $Q = 2e^- = 2 \times 1.6 \times 10^{-19}; B = 0.75T; V = 2 \times 10^5 ms^{-1}; \emptyset = 90°$

$$F = QVBsin\emptyset0$$

$$F = 2 \times 1.6 \times 10^{-19} \times 2 \times 10^5 \times 0.75 \times sin90$$

$$\mathbf{Force = 4.8 \times 10^{-14} N}$$

2. $Kinetic\ Energy = \frac{1}{2} \times \frac{(QBR)^2}{m_p}$

$$K.E = \frac{1}{2} \times \frac{(1.6 \times 10^{-19} \times 0.60 \times 1.2 \times 10^{-2})^2}{1.673 \times 10^{-27}}$$

$$K.E = 3.97 \times 10^{-16} Joules$$

$$K.E = \frac{3.97 \times 10^{-16}}{1.6 \times 10^{-19}} \times 1eV$$

$$\mathbf{K.E = 2478.9eV \cong 2480eV}$$

3. $V \times B = 3.2 \times 10^5 \begin{vmatrix} i & j & k \\ 1 & 0 & 0 \\ 0.1 & 0.3 & -0.2 \end{vmatrix}$

$$V \times B = i(0) - j(-64000) + k(96000)$$

$$V \times B = 64000j + 96000k$$

$$F = Q(V \times B)$$

$$F = 1.6 \times 10^{-19}(64000j + 96000k)$$

$$F = (1.024 \times 10^{-14} j + 1.536 \times 10^{-14} k)N$$

$$|F| = \sqrt{(1.024 \times 10^{-14})^2 + (1.536 \times 10^{-14})^2}$$

$$\mathbf{|F| = 1.84 \times 10^{-14} N}$$

4. $m_{lithium} = 1.16 \times 10^{-26} kg; V_{accelarate} = 600V; B = 0.60T$

$$Radius = \sqrt{\frac{2 \times m_{lithium} \times V_{accelerate}}{QB^2}}$$

$$R = \sqrt{\frac{2 \times 1.16 \times 10^{-26} \times 600}{1.6 \times 10^{-19} \times 0.6^2}}$$

$$\mathbf{Radius = 0.0155m \cong 0.016m}$$

5. $B = 0.08T; I = 2A; l = 1.5m; \emptyset = 60°$

$$F = BIlsin\emptyset$$

$$F = 0.08 \times 2 \times 1.5 \times sin60°$$

$$\mathbf{F = 0.208N \cong 0.21N}$$

6. $B = 0.12T; n = 60turns; r = 0.013m; I = 1.5A$

$$F = BI(n2\pi R)$$

$$F = 0.12 \times 1.5(60 \times 2 \times \pi \times 0.013)$$

$$\mathbf{F = 0.8822N \cong 0.88N}$$

7. $B = 42\mu T = 42 \times 10^{-6} T; \emptyset = 57°; A = 2.5m^2$

$$\varphi = ABcos\emptyset$$

$$\varphi = 2.5 \times 42 \times 10^{-6} \times cos57°$$

$$\mathbf{\varphi = 5.72 \times 10^{-5} Wb}$$

8. $Number\ of turns\ per\ unit\ length = 100turnscm^{-1} = 10000turnsm^{-1}$

$$Loop\ area\ of\ solenoid = \pi r^2 = \pi(25 \times 10^{-3})^2 = \frac{\pi}{1600} m^2$$

$$L = r = 0.05m$$

$$E = N\frac{d\varphi}{dt}$$

taking as N = 1 and B as restricted field to core

$$E = \frac{AdB}{dt}$$

$$B = nI\mu_0$$

$$B = 10{,}000 \times (1 - 0.5) \times 4\pi \times 10^{-7}$$

$$B = \frac{\pi}{500} T$$

$$E = \frac{\pi}{1600} \times \frac{\pi}{500} \times \frac{1}{10 \times 10^{-3}}$$

$$E = \frac{\pi^2}{8000} Volts = \mathbf{1.2mV}$$

9. $E = -\frac{Nd\varphi}{dt} = -\frac{NBdA}{dt}$

$$r = 12cm = 0.12m; \frac{dr}{dt} = 75cms^{-1}$$
$$= 0.75ms^{-1}$$

$$\frac{dA}{dt} = 2\pi r\left(\frac{dr}{dt}\right) = 2\pi(0.12)(0.75)$$

$$\frac{dA}{dt} = 0.5655m^2s$$

$$E = -1 \times 0.8 \times 0.5655$$

$$\mathbf{E = -0.452volts}$$

10. $n = 100turns; l = 0.5m; Breadth = 0.3m; A = 0.15m^2; B = 3.50T; f = \frac{1000rev}{min} = \frac{50}{3} rev/sec$

$$E_{max} = (2\pi f)AnB$$

$$E_{max} = (2\pi \times \frac{50}{3}) \times 0.5 \times 0.3 \times 100 \times 0.15$$

$$\mathbf{E_{max} = 1750\pi Volts}$$

CHAPTER 10

EXERCISES

10.1. A capacitor of capacitance 20μF is connected to an ac source whose potential difference varies with time according to the equation v = (12sin {500t})V. (a) calculate the capacitive resistance. (b) Calculate the amplitude of the current.

10.2. A resistor of resistance 44.7Ω is connected to an AC voltage that varies with time according to the equation (71sin {100t}) V. Write down the formula for the instantaneous current as a function of time.

10.3. A 200Ω resistor, a 20H inductor and a 5mF are connected in series and then connected to an AC source whose potential difference varies with time according to the equation v = 120sin (15t) V. (a) Calculate the impedance of the circuit (b) Calculate the amplitude of the current (c) Calculate the amplitude of the voltages across the resistor, inductor and capacitor.

10.4. The tuning circuit of a radio consist of a series combination of 1000Ω resistor, 0.004H inductor, and a variable capacitor. To what capacitance should the capacitor be dialed, if the radio is to pick a signal whose frequency is 2 × 10⁶Hz?
(Hint: the capacitor should be dialed to a value that makes the resonant frequency equal the frequency of the signal)

10.5. A 500Ω resistor, a 60H inductor and 0.006F capacitor are connected in series and then connected to a potential difference that varies with time according to v = 20sin(20t)V. Calculate the average power dissipated in the circuit.

10.6. Suppose R = 25Ω, L = 30mH and C = 12μF and they are connected to a 90V ac (rms) 500Hz source. Calculate (a) Current in the circuit (b) Voltmeter reading across each element.

SOLUTION

1. $C = 20\mu F = 20 \times 10^{-6}F$
$$V_t = 12sin500t$$
$$X_C = \frac{1}{\omega C} = \frac{1}{500 \times 20 \times 10^{-6}} = 100ohms$$
$$I_0 = \omega CV_0 = 500 \times 20 \times 10^{-6} \times 12 = \mathbf{0.12A}$$
2. $R = 44.7ohhms$
$$V_t = 71sin100t$$
$$I_t = \frac{V_t}{R} = \frac{71sin100t}{44.7} = \mathbf{1.588sin100t}$$
3. $R = 200ohms; L = 20H; C = 5mF = 0.005F; V_t = 120sin15t$
$$Z = \sqrt{(X_L - X_C)^2 + R^2}$$
$$Z = \sqrt{(\omega L - \frac{1}{\omega C})^2 + R^2}$$
$$Z = \sqrt{(15 \times 20 - \frac{1}{15 \times 0.005})^2 + 200^2}$$
$$Z = \sqrt{(300 - \frac{40}{3})^2 + 200^2}$$
$$Z = 349.5ohms \cong 350ohms$$
$$I_0 = wCV_0$$
$$I_o = 15 \times 0.005 \times 120$$
$$I_o = 9A$$
$$I_{rms} = \frac{I_o}{\sqrt{2}} = \frac{9}{\sqrt{2}} = \mathbf{4.5\sqrt{2}A}$$
$Across\ Resistor V_0 = I_O R = 9 \times 200 = \mathbf{1800V}$
$Across\ Inductor V_0 = I_O X_L = 9(300) = \mathbf{2700V}$ \
$Across\ capacitor V_0 = I_o X_C = 9\left(\frac{40}{3}\right) = \mathbf{120V}$
4. $R = 1000ohms; L = 0.004H; f_o = 2 \times 10^6 Hz$
$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

$$\sqrt{LC} = \frac{1}{2\pi f_0}$$

$$C = \frac{1}{L} \times (\frac{1}{2\pi f_o})^2$$

$$C = \frac{1}{0.004} \times (\frac{1}{2\pi \times 2 \times 10^6})^2$$

$$\mathbf{C = 1.58 \times 10^{-12} F = 1.58pF}$$

5. $R = 500ohms; L = 60H; C = 0.006F;$

$$V_t = 20sin20t$$

$$P_{average} = \frac{1}{2} I_0 V_O cos\emptyset$$

$$Z = \sqrt{(X_L - X_C)^2 + R^2}$$

$$Z = \sqrt{(\omega L - \frac{1}{\omega C})^2 + R^2}$$

$$Z = \sqrt{(20 \times 60 - \frac{1}{20 \times 0.006})^2 + 500^2}$$

$$Z = 1292.3ohms$$

$$cos\emptyset = \frac{R}{Z} = \frac{500}{1292.3}$$

$$I_0 = \omega C V_o = 20 \times 0.006 \times 20 = 2.4A$$

$$P_{avearage} = \frac{1}{2} \times 2.4 \times 20 \times \frac{500}{1292.3}$$

$$= \mathbf{9.29Watts}$$

6. $R = 25ohms; L = 30mH = 0.03H; 12\mu F; V_{rms} = 90V; f = 500Hz$

$$Z = \sqrt{(X_L - X_C)^2 + R^2}$$

$$Z = \sqrt{(2\pi f L - \frac{1}{2\pi f C})^2 + R^2}$$

$$Z = \sqrt{(2\pi \times 500 \times 0.03 - \frac{1}{2\pi \times 500 \times 12\mu})^2 + 25^2}$$

$$Z = 72.19ohms$$

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{90}{72.19} = \mathbf{1.25A}$$

The voltameter reading = root − mean − squared voltage = 90V

CHAPTER 11

EXERCISES

11.1. What is the energy of the photon that will raise a hydrogen atom from its ground state to the n = 4 excited state.

11.2. Calculate the speed of an electron in the second Bohr orbit

11.3. What frequency of light would excite the electron of a hydrogen atom for each of the following states (a) n = 2 to n = 5 (b) From n = 2 to n = ∞

11.4. What is the photon energy of visible light having wavelength 6328nm?

11.5. An FM radio station broadcast at a frequency of 98.9MHz and radiates 750KW of power. How many photons are radiated from the station's antenna each second?

11.6. Use the Bohr model to determine the ionization energy of Helium ion which has a single electron

SOLUTION

1. $E = 13.6eV\left(\frac{Z^2}{n^2}\right)$

$Z = atomic\ no; n = primciple\ Q.N$

$$E = 13.6\left(\frac{1^2}{4^2}\right) = \mathbf{0.85eV}$$

2. $E = 13.6eV\left(\frac{Z^2}{n^2}\right) = \frac{1}{2}M_E v^2$

$$E = 13.6\left(\frac{1^2}{2^2}\right) = 3.4eV = 5.44 \times 10^{-19}J$$

$$v = \sqrt{\frac{2 \times E}{M_e}}$$

$$v = \sqrt{\frac{2 \times 5.44 \times 10^{-19}}{9.1 \times 10^{-31}}}$$

$$\mathbf{v = 1.09 \times 10^6 ms^{-1}}$$

3. $\Delta E = 2.18 \times 10^{-18}(\frac{1}{n_{initial}^2} - \frac{1}{n_{final}^2})$

$$n_{inital} = 2; n_{final} = 5$$

$$\Delta E = hf = 2.18 \times 10^{-18}(\frac{1}{2^2} - \frac{1}{5^2})$$

$$f = \frac{2.18 \times 10^{-18}}{6.63 \times 10^{-34}}\left(\frac{1}{4} - \frac{1}{25}\right)$$

$$\mathbf{f_{2\,to\,5} = 6.9 \times 10^{14} Hz}$$

$$\Delta E = 2.18 \times 10^{-18}(\frac{1}{n_{initial}^2} - \frac{1}{n_{final}^2})$$

$$n_{inital} = 2; n_{final} = \infty$$

$$\Delta E = hf = 2.18 \times 10^{-18}(\frac{1}{2^2} - \frac{1}{\infty^2})$$

$$f = \frac{2.18 \times 10^{-18}}{6.63 \times 10^{-34}}\left(\frac{1}{4} - 0\right)$$

$$f_{2\,to\,\infty} = 8.2 \times 10^{14} Hz$$

4. $E = \frac{hc}{\lambda}$

$$\lambda = 6328nm = 6328 \times 10^{-9} m$$

$$E = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{6328 \times 10^{-19}}$$

$$Energy\ of\ photon = 0.085J$$

5. $photon\ per\ second(N) = \frac{P}{hf}$

$$f = 98.8MHz = 98.8 \times 10^6 Hz; P = 750KW = 750 \times 10^3 W$$

$$N = \frac{750 \times 10^3}{6.63 \times 10^{-34} \times 98.8 \times 10^6}$$

$$N = 1.145 \times 10^{31} photons\ per\ second$$

6. $E = 13.6eV\left(\frac{Z^2}{n^2}\right)$

$$Z = atomic\ no = 2; n = primciple\ Q.N = 1$$

$$E = 13.6\left(\frac{2^2}{1^2}\right) = 54.4eV$$

CHAPTER 12

EXERCISES

12.1. A 0.01nm gamma ray strikes an electron at rest and scatters directly backward. From conservation of momentum and energy, compute the relativistic momentum and energy, compute the wavelength of the scattered photon and the kinetic energy of the electron which is knocked forward. Answer: 0.01485nm; 40.5keV.

12.2. A 200MeV photon strikes a stationary proton. If the photon is back scattered (Θ = π), what is the kinetic energy of the recoiling proton? Answer: 4691MeV

12.3. X-rays of 500KeV are incident on the target of almost free electrons. Find the energy and the angle of the scattered photons if the recoil energy of the electron is 350keV. Answer: 150MeV; 1.7°.

12.4. The threshold wavelength for potassium is 558nm. What is the work function of potassium? What is the stopping potential when light of 400nm is used? Answer: 2.228eV; 0.88V

12.5. Monochromatic light of wavelength 450nm is incident on a clean sodium surface of work function 2.3eV. Determine (a) the energy of a photon of this light; (b) the maximum kinetic energy of emitted electrons; (c) the threshold frequency for sodium and (d) the magnitude of the momentum of a photon in the incident light. Answer: 2.8eV; 0.5eV; 5.6×10^{14}Hz; 1.5×10^{-27}kgm/s.

12.6. The surface of a metal alloy is illuminated with 280nm light in the presence of oxygen. As the surface gradually becomes corroded, the stopping potential changes from 1.3 to 0.7V. Determine the corresponding changes, if any in (a) the maximum kinetic energy of electrons ejected fro1m the surface, (b) the work function and (c) threshold frequency. Answer: 1.3 to 0.7eV; 3.1 to 3.7eV; 7.6×10^{14} to 8.9×10^{14}Hz.

12.7. A surface is irradiated with monochromatic light of variable wavelength. Above a wavelength of 5000Å, no photoelectrons are emitted from the surface. With an unknown wavelength, a stopping potential of 3V is necessary to eliminate the photoelectric current. What is the unknown wavelength? Answer: 2266Å.

12.8. Light of wavelength 4000Å liberates photoelectrons from a certain metal. The photoelectrons now enter a uniform magnetic field having an induction of 10^{-4}T. The electrons move normal to the field lines so that they travel circular paths. The largest circular path has a radius of 5.14cm. Find the work function for the metal. Answer: 0.788MeV.

12.9. The threshold wavelength for potassium is 558nm. What is the work function of potassium? What is the stopping potential when light of 4000m is used?

12.10. A surface is irradiated with monochromatic light of variable wavelength about a wavelength of 5000Å, no photoelectrons are emitted from the surface with an unknown wavelength, a stopping potential of 3V is necessary to eliminate the photoelectric current. What is the unknown wavelength?

12.11. X - rays of wavelength 0.2nm are scattered from a block of material. The scattered X - rays are observed at an angle of 45° to the incident beam. Calculate the wavelength of the scattered wavelength.

SOLUTION

$$\textbf{Comptons effect(wavelength shift)}$$
$$\textbf{for electron}; \Delta\lambda = 2.34 \times 10^{-12}(1 - \cos\emptyset)$$
$$\textbf{for photons}; \Delta\lambda = 1.32 \times 10^{-15}(1 - \cos\emptyset)$$

1. $\lambda_0 = 0.01nm;\ \lambda_c = 0.00243nm;\ \emptyset = 180°$

$$\lambda_n = (\lambda_c(1 - \cos\emptyset)) + \lambda_0$$
$$\lambda_n = (0.00243(1 - \cos 180°)) + 0.01$$
$$\lambda_n = \mathbf{0.01486nm}$$
$$K.E = 1243nmeV(\frac{1}{\lambda_o} - \frac{1}{\lambda_n})$$
$$K.E = 1243\left(\frac{1}{0.01} - \frac{1}{0.01486}\right)$$
$$\mathbf{K.E = 40652eV = 40.65KeV}$$

2. $E = \frac{1243nmeV}{\lambda_0}$

$$\lambda_0 = \frac{1243nmeV}{E} = \frac{1243nmeV}{200MeV} = 6.2 \times 10^{-15}m$$
$$\lambda_n = (\lambda_c(1 - \cos\emptyset)) + \lambda_0$$
$$\lambda_n = \left(1.32 \times 10^{-15}(1 - \cos\pi)\right) + 6.2 \times 10^{-15}$$
$$\lambda_n = 8.86 \times 10^{-15}m$$
$$K.E = 1243nmeV(\frac{1}{\lambda_0} - \frac{1}{\lambda_n})$$
$$K.E = 1243nmeV\left(\frac{1}{6.2 \times 10^{-15}} - \frac{1}{8.86 \times 10^{-15}}\right)$$
$$\mathbf{K.E = 60.2MeV}$$

3. $E_0 = 500KeV; K.E = 350KeV; E_n = ?$

$$E_n = E_o - K.E$$
$$E_n = 500 - 350 = \mathbf{150KeV}$$

4. $\emptyset = \frac{hc}{\lambda_o} = \frac{1243nmeV}{\lambda_0}; \lambda_o = 558nm$

$$\emptyset = \frac{1243nmeV}{558nm} = \mathbf{2.228eV}$$
$$K.E = eV_s = 1243nmeV(\frac{1}{\lambda_0} - \frac{1}{\lambda_n})$$
$$V_S = 1243nmVolts(\frac{1}{400nm} - \frac{1}{558nm})$$
$$\mathbf{V_s = stopping\ potential = 0.88volts}$$

5. $\lambda_0 = 450nm; \emptyset = 2.3eV$

$$E = \frac{1243nmeV}{\lambda_0} = \frac{1243nmeV}{450nm} = \mathbf{2.762eV}$$
$$K.E = E - \emptyset;$$
$$K.E = 2.762 - 2.3$$
$$\mathbf{K.E = 0.462eV}$$
$$\emptyset = hf_o$$
$$f_o = \frac{\emptyset}{h} = \frac{2.3eV}{6.63 \times 10^{-34}} = \frac{2.3 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}}$$
$$\mathbf{f_0 = 5.55 \times 10^{14}Hz}$$
$$P = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{450 \times 10^{-9}}$$
$$\mathbf{P = 1.5 \times 10^{-27}kgms^{-1}}$$

6. A. $\lambda = 280nm; V_{a-1} = 1.3V; V_{a-2} = 0.7$

$$\Delta K.E = K.E_1\ to\ K.E_2$$
$$K.E = eV$$
$$\mathbf{\Delta K.E = (1.3eV)\ to\ (0.7eV)}$$

B. $E = \frac{1243nmeV}{\lambda} = \frac{1243nmeV}{280nm} = 4.44eV$

$$\emptyset_1 = E - K.E_1; \emptyset_1 = 4.44 - 1.3 = 3.14eV$$
$$\emptyset_2 = E - K.E_2; \emptyset_2 = 4.44 - 0.7 = 3.7eV$$
$$\mathbf{\Delta\emptyset = (3.14eV)\ to\ (3.7eV)}$$

C. $f_1 = \frac{\emptyset_1}{h}$

$$f_1 = \frac{3.14 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}} = 7.6 \times 10^{14}Hz$$
$$f_2 = \frac{\emptyset_2}{h}$$
$$f_2 = \frac{3.74 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}} = 9.0 \times 10^{14}Hz$$
$$\mathbf{\Delta f = (7.6 \times 10^{14}Hz)to(9.0 \times 10^{14}Hz)}$$

7. $\lambda = 5000A°; V_{accelerating} = 3V$

$$K.E = eV = e \times 3V = 3eV$$
$$\emptyset = 12430A°\frac{eV}{\lambda} = \frac{12430A°eV}{5000A°} = 2.48eV$$
$$E = \emptyset + K.E$$
$$E = 2.486 + 3 = 5.486eV$$
$$E = \frac{12430A°eV}{\lambda}$$
$$E = \frac{12430A°eV}{5.486eV} = \mathbf{2266A°}$$

8. $\lambda = 4000A°; B = 10^{-4}T; R = 5.14cm = 0.0514m$

$$E = \frac{12430A°eV}{\lambda} = \frac{12430A°eV}{4000A°} = 3.1075eV$$
$$K.E = \frac{1}{2} \times \frac{Q}{m_e} \times (BR)^2$$
$$K.E = \frac{1}{2} \times \frac{1.6 \times 10^{-19}}{9.1 \times 10^{-31}} \times (5.14 \times 10^{-2})^2$$
$$K.E = 2.323eV$$
$$\emptyset = E - K.E$$
$$\emptyset = 3.1075 - 2.323$$
$$\mathbf{\emptyset = 0.78eV}$$

9. Same as question (12.4)
10. Same as question (12.7)
11. $\lambda_o = 0.2nm; \emptyset = 45°; \lambda_c = 0.00243nm$

$$\lambda_n = (\lambda_c(1 - \cos\emptyset)) + \lambda_0$$
$$\lambda_n = (0.00243(1 - \cos 45°)) + 0.2$$
$$\mathbf{\lambda_n = 0.201nm}$$

CHAPTER 13

EXERCISES

13.1. The half-life of Iodine - 131, used in thyroid treatment is 8 days. At a certain time, an amount of iodine - 131 containing 4×10^{14} nuclei is known to be in a patient's thyroid gland. (a) What will be the Iodine - 131 activity in the thyroid? (b)How many iodine - 131 nuclei will remain after 1 day?
Answer: (a) 4×10^{8}decay/s (b) 3.7×10^{14} nuclei

13.2. A researcher measures 200 counts per minute coming from a radioactive source at midday. At 3 O'clock, she finds that this has dropped to 25 counts per minute. What is the half-life of the radioactive source? Answer: 1 hour

13.3. Suppose that at the start of an experiment, there are 8,000 bacteria. A growth inhibitor and lethal pathogen are introduced into the colony. After two hours, 1,000 bacteria are dead. If the death rates are exponential, how long will it take for the population to drop below 5,000? Answer: 7 hours

13.4. In the question above, how long will it take for two-third of the bacteria to die? Answer: 16.5 hours

13.5. At time t = 0, a radioactive sample contains 3.5μg of pure carbon-11, which has a half-life of 30.4mins. (a) determine the number of nucleus in the sample at t = 0. (b) what is the activity of the sample initially and after 8hrs.

13.6. Find the nucleon radii of the following (a) $^{2}_{1}H$ (b) $^{60}_{27}Co$

13.7. Calculate the binding energy per nucleon for the nucleus $^{23}_{11}Na$

SOLUTION

1. $t_{\frac{1}{2}} = 8days = 691200secs$

$$N = 4 \times 10^{14}nuclei$$
$$A = \lambda N$$
$$A = \frac{0.693}{691200} \times 4 \times 10^{14}$$
$$\mathbf{A = 4 \times 10^{8} decay/second}$$
$$\frac{N_R}{N_0} = \frac{1}{2^n}$$
$$n = \frac{t}{t_{\frac{1}{2}}} = \frac{1}{8}$$
$$N_R = \frac{N_O}{2^n} = \frac{4 \times 10^{8}}{2^{\frac{1}{8}}}$$
$$\mathbf{N_R = 3.7 \times 10^{14} nuclei}$$

2. $time(between\ 12°clock\ to\ 3°clock) = 3hours$

$$N_O = 200counts\ per\ min$$
$$N_R = 25counts\ per\ min$$
$$\frac{N_O}{N_R} = 2^n$$
$$\frac{200}{25} = 2^n$$
$$8 = 2^n$$
$$2^3 = 2^n$$
$$n = 3$$
$$t_{1/2} = \frac{t}{n} = \frac{3hours}{3} = \mathbf{1hour}$$

3. $N_t = N_0 e^{-\lambda t}$

$$N_O = 8000bacteria;$$
$$N_t = 8000 - 1000 = 7000bacteria$$
$$7000 = 8000e^{-2\lambda}$$
$$Ln\left(\frac{7000}{8000}\right) \times -\frac{1}{2} = \lambda$$
$$\lambda = 0.067hr^{-1}$$
$$N_t = N_o e^{-\lambda t}$$
$$5000 = 8000e^{-0.067t}$$
$$Ln\left(\frac{5000}{8000}\right) \times -\frac{1}{0.067} = t$$
$$\mathbf{time\ to\ drop\ below\ 5000 = 7hrs}$$

4. $F_{remaining} = 1 - F_{daed}$

$$F_{remaining} = 1 - \frac{2}{3} = \frac{1}{3}$$
$$Ln(F_{remaining}) = -\lambda t$$
$$Ln\left(\frac{1}{3}\right) = -0.067t$$
$$Ln\left(\frac{1}{3}\right) \times -\frac{1}{0.067} = t$$
$$\mathbf{time\ for \frac{2}{3}\ to\ die = 16.4hours}$$

5. $m = 3.5\mu g = 3.5 \times 10^{-6}g$

$$molar\ mass(m_0) = 11gmol^{-1}; N = ?$$
$$; N_A = 6.02 \times 10^{23}mol^{-1}$$
$$\frac{m}{m_o} = \frac{N}{N_A}$$
$$N = \frac{m \times N_A}{m_o}$$
$$N = \frac{3.5 \times 10^{-6} \times 6.02 \times 10^{23}}{11}$$
$$\mathbf{N(number\ of\ nuclei) = 1.92 \times 10^{17} nuclei}$$
$$A = \frac{0.693}{t_{1/2}} \times N$$

$t_{1/2} = 30.4mins = 1824secs = 0.506hr$

$$A = \frac{0.693}{1824} \times 1.92 \times 10^{171}$$

$$\boldsymbol{A = 7.3 \times 10^{13} dis/sec}$$

$$N_t = N_O e^{-\lambda t}$$

$$A_t = A_0 e^{-\frac{0.693t}{t_{1/2}}}$$

$$A_t = 7.3 \times 10^{13} e^{-\frac{0.693 \times 8}{0.506}}$$

$$\boldsymbol{A_t = 1.27 \times 10^{9} dis/sec}$$

6. $A = mass\ number = 2;$

$R_0(nucleus\ radius) = 1 \times 10^{-15}m$

$$r_h = R_0 A^{1/3}$$

$$r_h = 1 \times 10^{-15} \times 2^{1/3}$$

$$\boldsymbol{r_h = 1.26 \times 10^{-15} m}$$

$$A = mass\ number = 60;$$

$$R_0(nucleus\ radius) = 1 \times 10^{-15}m$$

$$r_{co} = R_0 A^{1/3}$$

$$r_{co} = 1 \times 10^{-15} \times 60^{1/3}$$

$$\boldsymbol{r_{co} = 3.91 \times 10^{-15} m}$$

7. $neutron(n) = 12; proton(p) = 11$

$1amu\ of\ n = 1.00866amu\ and$

$1amu\ of\ p = 1.00728amu$

$$(12 \times 1.00866) + (11 \times 1.00728)$$

$$= 23.184amu$$

$$\Delta m(mass\ defect) = 23.184 - 23$$

$$= 0.184amu$$

$$1amu = 931.5MeV$$

$then, 0.184 \times 931.5 = 171.396MeV$

$Binding\ energy\ per\ nucleon$

$$= \frac{171.396MeV}{23}$$

$$= \boldsymbol{7.5MeV/nucleon}$$

GOODLUCK……