

## **CHAPTER - 6**

### **APPLICATIONS OF STATIC FIELDS**

# CHAPTER-6 APPLICATIONS OF STATIC FIELDS

## Exercise 6.1

$$L = 5 \text{ cm}, \quad z = 0.5 \text{ cm}, \quad m_e = 9.1 \times 10^{-31} \text{ kg}, \quad e = -1.6 \times 10^{-19} \text{ C}$$

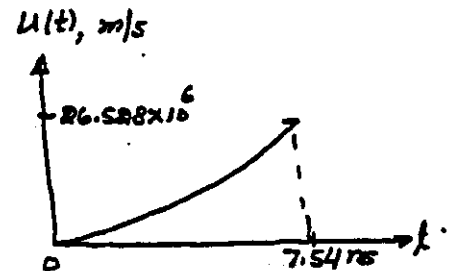
$$U_x = 26.52 \times 10^6 \text{ m/s}, \quad d = 20 \text{ cm}$$

$$\text{From (6.6),} \quad V_0 = - \frac{2m_e L z}{e} \left( \frac{U_x}{d} \right)^2 = 50 \text{ V}$$

$$T = \frac{d}{U_x} = 7.54 \text{ ns}$$

$$Q_z = - \frac{e V_0}{m_e L} = 175.82 \times 10^{14} \text{ m/s}^2$$

$$U(t) = \sqrt{U_x^2 + (Q_z t)^2}$$



## Exercise 6.2

$$z = 2 \text{ cm}, \quad V_0 = 15 \text{ kV}, \quad L = 10 \text{ cm}$$

$$d = \sqrt{\frac{-2Lz m_e}{e V_0}} = 32.66 \text{ mm}, \quad T = \frac{d}{U_x} = 1.232 \text{ ns}$$

$$Q_z = - \frac{e V_0}{m_e L} = 52.747 \times 10^{15} \text{ m/s}^2, \quad U_z = Q_z T = 64.985 \times 10^6 \text{ m/s}$$

$$U = \sqrt{U_x^2 + U_z^2} = 70.188 \times 10^6 \text{ m/s}$$

## Exercise 6.3

$$z = 5 \text{ cm}, \quad T = 12.5 \text{ ns}, \quad \text{since } z = \frac{1}{2} Q_z T^2$$

$$\text{at } z = 5 \text{ cm}, \quad t \rightarrow T \Rightarrow Q_z = \frac{2 \times 5 \times 10^{-2}}{T^2} = 6.4 \times 10^{14} \text{ m/s}^2, \quad U_z = Q_z T = 8 \times 10^6 \text{ m/s}$$

$$\text{Also } |E| = m_e Q_z \Rightarrow E = \frac{m_e}{|e|} Q_z = 3.64 \times 10^3 \text{ V/m}, \quad V_0 = 0.105 E = 182 \text{ V}$$

## Exercise 6.4

$$\vec{E} = 100 \times 10^3 \vec{a}_z \text{ V/m}, \quad U_z = 6 \times 10^7 \text{ m/s}$$

$$Q_z = \frac{|e| E}{m_e} = 1.758 \times 10^6 \text{ m/s}^2, \quad T = \frac{U_z}{Q_z} = 3.413 \text{ ns}$$

$$z = U_z T - \frac{1}{2} Q_z T^2 = 102.375 \text{ mm},$$

Let at  $t = T_1$ , the final energy be 20% of its initial energy. Then

$$U_1 = U_z \sqrt{0.2} = 2.683 \times 10^7 \text{ m/s}, \quad T_1 = \frac{U_1 - U_z}{Q_z} = 1.886 \text{ ns}$$

$$z_1 = U_z T_1 - \frac{1}{2} Q_z T_1^2 = 81.9 \text{ mm}$$

Exercise 6.5  $m_d = 8.38 \times 10^{-12} \text{ kg}$

Time to travel between the two plates:  $T_0 = \frac{2 \text{ mm}}{25} = 80 \mu\text{s}$

Time to travel to the paper after exit:  $T_1 = \frac{8 \times 10^{-3}}{25} = 320 \mu\text{s}$

Total time:  $T = T_0 + T_1 = 400 \mu\text{s}$ ,  $q = -20 \times 10^{-12} \text{ C}$ ,  $V_0 = 2000 \text{ V}$

$d = 2 \text{ mm}$

$$U_2 = \frac{-q V_0 T_0}{2 d m_d} = 95.465 \text{ m/s}, \quad U = \sqrt{25^2 + U_2^2} = 98.685 \text{ m/s}$$

Exercise 6.6

$V_0 = 200 \text{ V}$ ,  $L = 5 \text{ mm}$ ,  $d = 1.5 \text{ mm}$ ,  $D = 12 \text{ mm}$

$m = \frac{4\pi}{3} (0.01 \times 10^{-3})^3 (2 \times 10^3) = 1.047 \times 10^{-12} \text{ kg}$ ,  $q = -2 \times 10^{-12} \text{ C}$ ,  $U_x = 20 \text{ m/s}$

$$z = \frac{-q d V_0}{m L} \cdot \frac{1}{U_x^2} (0.5 d + D) = 3.653 \text{ mm}$$

Exercise 6.7  $m = 1.2 \times 10^{-3} \text{ kg}$ ,  $q = -100 \times 10^{-9} \text{ C}$ ,  $V_0 = 5000 \text{ V}$ ,  $d = 1.5 \text{ m}$

When  $x = d$ ,  $z = L_2$  From (6.18),  $L_2 = \sqrt{\frac{|q| V_0 d}{9.81 \text{ m}}} = 25.241 \text{ cm}$

$L = 2 L_2 = 50.482 \text{ cm}$ ,  $T = \sqrt{\frac{2d}{9.81}} = 0.553 \text{ s}$ ,  $U_x = 9.81 \text{ T} = 5.425 \text{ m/s}$

$$U_z = a_z T = \frac{|q|}{m L} V_0 T = 0.456 \text{ m/s}$$

Exercise 6.8  $m = 0.5 \times 10^{-3} \text{ kg}$ ,  $q = -120 \times 10^{-9} \text{ C}$

$$L_2 = \sqrt{\frac{|q| V_0 d}{9.81 \text{ m}}} = 42.84 \text{ cm}, \quad L = 2 L_2 \approx 86 \text{ cm}$$

Exercise 6.9  $E_r = 0.3 \text{ MV/m}$ ,  $V_0 = 240 \text{ kV}$ ,  $R = \frac{V_0}{E_r} = 0.8 \text{ m}$  or  $80 \text{ cm}$

$$Q = 4\pi \epsilon_0 R V_0 = 21.33 \mu\text{C}$$

Exercise 6.10

$r = 1 \text{ cm}$ ,  $R = 1 \text{ m}$

$q = 10 \times 10^{-9} \text{ C}$ ,  $Q = 10 \times 10^{-6} \text{ C}$

$$V_{IR} = \frac{q}{4\pi \epsilon_0} \left[ \frac{1}{r} - \frac{1}{R} \right] = 8.91 \text{ kV}$$

Exercise 6.11  $\theta = 30^\circ$ ,  $V_0 = 100 \text{ V}$ ,  $\tau = 1.5 \text{ n.m/rad}$

Then,  $\frac{dC}{d\theta} = \frac{2\theta\tau}{V_0^2} = 1.571 \times 10^{-4} \text{ F/rad.}$

Exercise 6.12  $\theta = 60^\circ$ ,  $V_0 = \sqrt{\frac{2\theta\tau}{\frac{dC}{d\theta}}} = 141.421 \text{ V}$

Exercise 6.13  $m \frac{dU_x}{dt} \vec{a}_x + m \frac{dU_y}{dt} \vec{a}_y + m \frac{dU_z}{dt} \vec{a}_z = qB[U_y \vec{a}_x - U_x \vec{a}_y]$

Let  $\omega = \frac{qB}{m}$ , then  $\frac{dU_x}{dt} = \omega U_y$  and  $\frac{dU_y}{dt} = -\omega U_x$

$\frac{d^2 U_x}{dt^2} + \omega^2 U_x = 0$   $\frac{d^2 U_y}{dt^2} + \omega^2 U_y = 0 \Rightarrow U_x = U_0 \cos \omega t$ ,  $U_y = -U_0 \sin \omega t$

$\frac{dx}{dt} = U_x \Rightarrow x = \frac{U_0}{\omega} \sin \omega t$ ,  $\frac{dy}{dt} = U_y \Rightarrow y = \frac{U_0}{\omega} \cos \omega t - \frac{U_0}{\omega}$

Hence,  $x^2 + (y + \frac{U_0}{\omega})^2 = (\frac{U_0}{\omega})^2 \Rightarrow R = \frac{U_0}{\omega} = \frac{U_0 m}{qB}$

Exercise 6.14 Kinetic energy:  $k = 5 \times 1.6 \times 10^{-19} \text{ J}$   $m = 9.1 \times 10^{-31} \text{ kg}$

Since  $k = \frac{1}{2} m U^2$ ,  $U = \sqrt{\frac{2k}{m}} = 1.326 \times 10^6 \text{ m/s}$   $B = 1.2 \times 10^{-3} \text{ T}$

$R = \frac{mU}{eB} = 6.285 \text{ mm}$   $\omega = \frac{eB}{m} = 2.11 \times 10^8 \text{ rad/s}$

$T = \frac{2\pi}{\omega} = 29.78 \text{ ns}$

Exercise 6.15  $V_0 = 20 \times 10^3 \text{ V} \Rightarrow U = \sqrt{\frac{2eV_0}{m}} = 8.386 \times 10^7 \text{ m/s}$

$B = 50 \times 10^{-3} \text{ T}$ ,  $R = \frac{m}{eB} U = 9.539 \text{ mm}$ .  $D = \pi R = 29.968 \text{ mm}$

Time =  $\frac{D}{U} = 0.357 \text{ ns}$ ,  $2R = 19.08 \text{ mm}$

Exercise 6.16  $R = 0.75 \text{ m}$   $f = 10 \times 10^6 \text{ Hz}$   $m = 1.7 \times 10^{-27} \text{ kg}$

$q = 1.6 \times 10^{-19} \text{ C} \Rightarrow B = \frac{2\pi f m}{q} = 0.668 \text{ T}$

Kinetic energy,  $k = \frac{(qBR)^2}{2m} = 1.888 \times 10^{-12} \text{ J}$  or  $\frac{k}{e} = 11.797 \text{ MeV}$

Exercise 6.17  $R = 0.25 \text{ m}$ ,  $B = 1.2 \times 10^{-3} \text{ T}$ ,  $m = 9.1 \times 10^{-31} \text{ kg}$

$$u = \frac{eBR}{m} = 5.275 \times 10^7 \text{ m/s}, \quad k = \frac{1}{2} m u^2 = 1.266 \times 10^{-15} \text{ J or } 7.91 \text{ keV}$$

$$f = \frac{eB}{2\pi m} = 33.58 \text{ MHz}$$

Exercise 6.18  $m_1 = 26.72 \times 10^{-27} \text{ kg}$   $R_1 = 0.1 \text{ m}$   $R_2 = 0.11 \text{ m}$

$$m_2 = m_1 \frac{R_2}{R_1} = 2.94 \times 10^{-26} \text{ kg}$$

Exercise 6.19  $B = 0.5 \text{ T}$ ,  $E = 1 \times 10^6 \text{ V/m}$

$$u_0 = \frac{E}{B} = 2 \times 10^6 \text{ m/s}, \quad k = \frac{1}{2} m u_0^2 = \frac{1}{2} \times 1.67 \times 10^{-27} u_0^2 \\ = 3.34 \times 10^{-15} \text{ J or } 20.88 \text{ keV}$$

Exercise 6.20  $R = \frac{m u_0}{eB} = \frac{1.67 \times 10^{-27} \times 2 \times 10^6}{1.6 \times 10^{-19} \times 0.5} = 4.175 \text{ cm}$

Distance:  $2R = 8.35 \text{ cm}$

$$\text{Time} = \frac{\pi R}{u_0} = 65.58 \text{ ns}$$

Exercise 6.21

$$n = \frac{BIW}{q A V_{ba}} \quad \text{and} \quad \frac{V_{ba}}{W} = E_H$$

$$\frac{I}{A} = J, \quad \text{Thus,} \quad n = \frac{JB}{q E_H}$$

Exercise 6.22

$$E = \frac{I}{A\sigma} \quad E_H = \frac{V_{ba}}{W}$$

Thus,  $\frac{E_H}{E} = \frac{BI}{q A n} \cdot \frac{A\sigma}{I} \Rightarrow \frac{E_H}{E} = \frac{B\sigma}{nq}$

Exercise 6.23  $W = 50 \text{ cm}$   $B = 1.6 \text{ T}$   $R = 1150 \Omega$   $I = 2 \text{ A}$

$$V_0 = IR = 2300 \text{ V}$$

$$u_0 = \frac{V_0}{BW} = 2875 \text{ m/s}$$

Exercise 6.24

$B = 0.5 \text{ T}$

$r = 10 \text{ cm}$

$V_0 = 0.25 \text{ V}$

$$U_0 = \frac{V_0}{rB} = 5 \text{ m/s}$$

Exercise 6.25

$L = 2.54 \text{ cm}$

$d = 5.08 \text{ cm}$

$N = 1500 \text{ Turns}$

$B = 1.5 \text{ T}$

$I = 12.5 \text{ A}$

$\text{Area: } A = dL = 12.903 \text{ cm}^2$

$$T = \frac{N I A B}{\pi} = 11.55 \text{ N}\cdot\text{m}$$

Exercise 6.26

max. force experienced by a conductor,

$$F_m = BIL = 476.25 \times 10^{-3} \text{ N}$$

Thus, the force on a conductor:  $F = F_m \sin \theta$

The torque on each conductor:

$$T(\theta) = rF = \frac{5.08 \times 10^{-2}}{2} \times 476.25 \times 10^{-3} \sin \theta = 12.097 \sin \theta \text{ mN}\cdot\text{m}$$

Average torque experienced by a conductor

$$T_{\text{avg}} = \frac{1}{2\pi} \int_0^\pi T(\theta) d\theta = 3.851 \times 10^{-3} \text{ N}\cdot\text{m}$$

Torque developed by the motor:  $T = 2N T_{\text{avg}} \approx 11.55 \text{ N}\cdot\text{m}$

Problem 6.1  $L = 5 \text{ cm}$   $d = 10 \text{ cm}$   $V_0 = 10 \text{ kV}$   $m_p = 1.67 \times 10^{-27} \text{ kg}$ .

$$U_x = \sqrt{\frac{2 \times 2000 \times 1.6 \times 10^{-19}}{1.67 \times 10^{-27}}} = 6.191 \times 10^5 \text{ m/s} \quad T = \frac{d}{U_x} = 161.536 \text{ ns}$$

$$a_2 = \frac{eV_0}{m_p L} = 1.916 \times 10^{13} \text{ m/s}^2, \quad U_2 = a_2 T = 3.095 \times 10^6 \text{ m/s}$$

$$U = \sqrt{U_x^2 + U_2^2} = 3.157 \times 10^6 \text{ m/s}, \quad k = \frac{1}{2} m_p [U^2 - U_x^2] = 8 \times 10^{-15} \text{ J}$$

or 50 keV.

Problem 6.2  $U = U_0 - \frac{qE}{m} t$  and  $x = U_0 t - \frac{1}{2} \frac{qE}{m} t^2$   $m = 3.4 \times 10^{-27} \text{ kg}$

$$E = 50 \text{ kV/m} \quad U_0 = 2 \times 10^6 \text{ m/s}$$

$$\text{When } t=0, U=0 \Rightarrow T = \frac{mU_0}{eE} = 850 \text{ ns}$$

$$x = U_0 T - \frac{1}{2} \frac{eE}{m} T^2 = 85 \text{ cm}$$

$$U_{0.2} = \sqrt{0.5} U_0 = 1.414 \times 10^6 \text{ m/s}, \quad t_1 = \frac{U_0 - U_{0.2}}{eE/m} = 248.959 \text{ ns}$$

$$x_1 = U_0 t_1 - \frac{1}{2} \frac{eE}{m} t_1^2 = 42.5 \text{ cm}$$

Problem 6.3  $m = 9.1 \times 10^{-31} \text{ kg}$   $E = 10 \text{ kV/m}$   $U_0 = 0.8 \times 10^6 \text{ m/s}$

$$a = \frac{eE}{m} = 8.791 \times 10^{14} \text{ m/s}^2, \quad \text{Since } x = at^2 + U_0 t \Rightarrow \text{When } x = 3 \text{ cm}$$

$t = 54 \text{ ns}$

$$U = \frac{eE}{m} t + U_0 = 1.029 \times 10^7 \text{ m/s}$$

Problem 6.4  $L = 2 \text{ cm}$   $V_0 = 200 \text{ V}$ ,  $E = \frac{V_0}{L} = 10 \text{ kV/m}$

$$a_2 = \frac{eE}{m} = 1.758 \times 10^{15} \text{ m/s}^2, \quad U = a_2 t \Rightarrow x = \frac{1}{2} a_2 t^2$$

$$\text{When } x = L, \quad t = T \Rightarrow T = \sqrt{\frac{2L}{a_2}} = 4.77 \text{ ns}$$

$$U = a_2 T = 8.385 \times 10^6 \text{ m/s}, \quad k = \frac{1}{2} m U^2 = 31.99 \times 10^{-18} \text{ J}$$

$= 200 \text{ eV}$

Problem 6.5  $u_0 = 2 \times 10^6 \text{ m/s}$   $u = \frac{eE}{m} t + u_0$   $x = \frac{1}{2} \frac{eE}{m} t^2 + u_0 t$

$q = \frac{eE}{m} = 17.582 \times 10^{14} \text{ m/s}^2$  when  $x = 2 \text{ cm}$   $t = 7.54 \text{ ns}$

$u = at + u_0 = 15.257 \times 10^6 \text{ m/s}$

Energy gain:  $\frac{1}{2} m [u^2 - u_0^2] = 1.04 \times 10^{-16} \text{ J}$  or  $650.58 \text{ eV}$

Problem 6.6  $u_{x0} = 100 \text{ m/s}$   $u_{y0} = 100 \text{ m/s}$   $\vec{E} = 200 \times 10^3 \vec{a}_x \text{ V/m}$

$q = 100 \text{ nC}$   $m = 2 \times 10^{-3} \text{ kg}$   $u_x = \frac{qE}{m} t + u_{x0} = 200 \text{ m/s}$

$u = \sqrt{u_x^2 + u_{y0}^2} = 223.607 \text{ m/s}$ ,  $y = u_{y0} t$

and  $x = \frac{1}{2} \frac{qE}{m} t^2 + u_{x0} t$  when  $t = 10 \text{ s}$ ,  $x = 1500 \text{ m}$  and  $y = 1000 \text{ m}$

Problem 6.7  $\vec{E} = 150 \times 10^3 \vec{a}_x \text{ V/m}$   $u_0 = -32.48 \times 10^6 \text{ m/s} \vec{a}_x$

$q_x = \frac{eE}{m} = 1.437 \times 10^{13} \text{ m/s}^2$

$m = 1.67 \times 10^{-27} \text{ kg}$

$u_x = u_{0x} + q_x t$  and  $x = \frac{1}{2} q_x t^2 + u_{0x} t$

When  $t = T$ ,  $u_x = 0 \Rightarrow T = -\frac{u_{0x}}{a_x} = 2.26 \mu\text{s}$  and  $x = -36.7 \text{ m}$

$k_i = \frac{1}{2} m u_{0x}^2 = 8.809 \times 10^{-13} \text{ J}$  or  $5.51 \text{ MeV}$

Problem 6.8  $m = \frac{4\pi}{3} \left( \frac{0.025 \times 10^{-3}}{8} \right)^3 \times 2 \times 10^9 = 1.636 \times 10^{-11} \text{ kg}$

$u_x = 10 \text{ m/s}$   $D = 5 \text{ mm}$   $L = 2.5 \text{ cm}$   $d = 1.5 \text{ mm}$   $E = 100 \text{ kV/m}$

$V_0 = EL = 2.5 \text{ kV}$

$z = \frac{-q d}{m L} V_0 \left( \frac{1}{u_x} \right)^2 (0.5d + D) = 0.132 \text{ mm}$   $q = -0.25 \text{ pC}$

Problem 6.9  $z = 5 \text{ mm}$   $\sin u$   $E = \frac{V_0}{L}$

$E = \frac{zm}{-qd} u_x^2 \frac{1}{0.5d + D} = 3.794 \times 10^6 \text{ V/m}$   
 $= 3.794 \text{ MV/m}$



Problem 6.10 Let  $T_1$  and  $T_2$  be the times to travel distances  $d$  and  $D$ .

Then  $T_1 = \frac{d}{u_x} = 150 \mu s$      $T_2 = \frac{D}{u_x} = 500 \mu s$ ,  $T = T_1 + T_2 = 650 \mu s$

$$u_z = \frac{-8V_0}{mL} T_1 = 0.229 \text{ m/s} \quad u = \sqrt{u_x^2 + u_z^2} \approx 10 \text{ m/s}$$

Problem 6.11  $m = 1.2 \times 10^{-3} \text{ kg}$ ,  $q = -50 \times 10^{-9} \text{ C}$ ,  $V_0 = 15 \times 10^3 \text{ V}$ ,  $d = 1 \text{ m}$

$$g = 9.81 \text{ m/s}^2 \quad T = \sqrt{\frac{2d}{g}} = 0.4525 \text{ s} \quad L = 40 \text{ cm}$$

$$Q_z = \frac{q}{mL} V_0 = -1.5625, \quad u_z = Q_z T = -0.706 \text{ m/s}$$

$$z = \frac{1}{2} Q_z T^2 = -15.93 \text{ cm}$$

Problem 6.12 Time to travel a distance of 3m:  $T_3 = \sqrt{\frac{2 \times 3}{9.81}} = 0.7825$

Time to travel 2m after exit:  $T_2 = T_3 - T = 0.3315$

When the particle hits the ground:  $u_x = g T_3 = 7.672 \text{ m/s}$

$u_z$  does not change. Thus,  $u = \sqrt{u_x^2 + u_z^2} = 7.764 \text{ m/s}$

$$z_1 = z + u_z T_2 = -0.392 \text{ m}$$

Problem 6.13  $R = 25 \text{ cm}$      $V_0 = 200 \text{ kV}$      $E = \frac{V_0}{R} = 800 \text{ kV/m}$

$$q = 4\pi\epsilon_0 R V_0 = 5.56 \mu\text{C}$$

$E$  can exist because breakdown  $E$  is  $3 \text{ MV/m}$

Problem 6.14  $r = 2 \text{ cm}$      $R = 20 \text{ cm}$      $V_0 = 500 \text{ V}$

$$q = 4\pi\epsilon_0 V_0 \left[ \frac{rR}{R-r} \right] = 1.235 \text{ nC}$$

Problem 6.15 The kinetic energy must be equal to potential energy.

$$K = \frac{qQ}{4\pi\epsilon r} \Rightarrow r = \frac{qQ}{4\pi\epsilon k}$$

Problem 6.16  $\theta = 30^\circ = 0.524 \text{ rad}$   $V_0 = 100 \text{ V}$   $\tau = 1.2 \text{ N.m/rad}$

From (6.89)  $b = \frac{2\tau\theta}{V_0^2} = 1.257 \times 10^{-4}$  ( $\frac{dC}{d\theta} = b$ )

$\theta = 45^\circ = 0.785 \text{ rad}$   $V_0 = \sqrt{\frac{2\tau\theta}{b}} = 122.47 \text{ V}$

Problem 6.17

(a)  $k_1 = 100 \times 1.6 \times 10^{-19} = 1.6 \times 10^{-17} \text{ J}$     b)  $k_2 = 10 \times 10^3 \times 1.6 \times 10^{-19} = 1.6 \times 10^{-15} \text{ J}$

$u_1 = \sqrt{\frac{2k_1}{m_e}} = 5.93 \times 10^6 \text{ m/s}$      $u_2 = \sqrt{\frac{2k_2}{m_e}} = 5.93 \times 10^7 \text{ m/s}$

$m_e = 9.1 \times 10^{-31} \text{ kg}$

$B = 1.5 \text{ T}$      $r_1 = \frac{m_e u_1}{eB} = 0.022 \text{ mm}$      $r_2 = \frac{m_e u_2}{eB} = 0.225 \text{ mm}$

Problem 6.18  $f = 10 \text{ MHz}$      $\omega = 2\pi f = 62.832 \times 10^6 \text{ rad/s}$      $r = 10 \text{ cm}$

$u = r\omega = 6.283 \times 10^6 \text{ m/s}$      $m_p = 1.67 \times 10^{-27} \text{ kg}$      $k = \frac{1}{2} m_p u^2 = 39.964 \times 10^{-15} \text{ J}$   
or  $206 \text{ keV}$

$B = \frac{\omega m_p}{e} = 0.66 \text{ T}$

Problem 6.19  $k = 20 \times 10^3 \times 1.6 \times 10^{-19} = 3.2 \times 10^{-15} \text{ J}$      $B_x = 1.25 \text{ T}$

$u_z = \sqrt{\frac{2k}{m_e}} = 8.386 \times 10^7 \text{ m/s}$

$\vec{F} = -e \vec{u} \times \vec{B} = -e u_z B_x \vec{a}_y = -1.677 \times 10^{-11} \vec{a}_y \text{ N}$

$r = \frac{m_e u_z}{e B_x} = 0.382 \text{ mm}$ , Distance:  $2r = 0.764 \text{ mm}$

Problem 6.20  $B = 1.2 \text{ T}$      $I = 500 \text{ A}$      $W = 20 \text{ cm}$     Thickness  $t = 0.2 \text{ cm}$

Area:  $A = wt = 4 \text{ cm}^2$      $V_{ba} = \frac{BIW}{e \cdot A \cdot n} = 22.06 \mu\text{V}$   
 $n = 8.5 \times 10^{28}$

Problem 6.21  $E_z = 20 \text{ kV/m}$      $B_x = 0.5 \text{ T}$ ,  $\vec{u}$  must be in y-direction

$u_y = \frac{E_z}{B_x} = 4 \times 10^4 \text{ m/s}$      $k = \frac{1}{2} \times 1.67 \times 10^{-27} \times (4 \times 10^4)^2$   
 $= 1.336 \times 10^{-18} \text{ J}$  or  $8.35 \text{ eV}$

Problem 6.23  $r = 12 \text{ cm}$   $B = 1.5 \text{ T}$

$$p = m_p u \text{ but } m_p u = e B r \Rightarrow p = e B r = 1.6 \times 10^{-19} \times 1.5 \times 0.12$$

$$= 2.88 \times 10^{-20} \text{ kg-m/s}$$

$$k = \frac{p^2}{2m_p} = 2.483 \times 10^{-13} \text{ J}$$

or  $1.55 \text{ MeV}$

$$m_p = 1.67 \times 10^{-27} \text{ kg}$$

Problem 6.23  $k = 8 \times 10^6 \times 1.6 \times 10^{-19} = 1.28 \times 10^{-12} \text{ J}$   $r = 0.5 \text{ m}$

$$B = \frac{m_p u}{e r} = 0.817 \text{ T}$$

$$u = \sqrt{\frac{2k}{m_p}} = 3.915 \times 10^7 \text{ m/s}$$

$$\omega = \frac{eB}{m_p} = 78.275 \times 10^6 \text{ rad/s or } f = 12.46 \text{ MHz}$$

Problem 6.24  $r = 0.5 \text{ m}$   $f = 10 \text{ MHz}$   $\omega = 2\pi f = 62.832 \times 10^6 \text{ rad/s}$

$$m_d = 3.4 \times 10^{-27} \text{ kg}, \quad B = \frac{\omega m_d}{e} = 1.335 \text{ T}$$

$$k = \frac{(eBr)^2}{2m_d} = 1.678 \times 10^{-12} \text{ J or } 10.5 \text{ MeV}$$

Problem 6.25  $\text{Dia} = 12 \text{ cm}$ ,  $L = 30 \text{ cm} \Rightarrow \text{Area: } A = 360 \times 10^{-4} \text{ m}^2$

$$N = 1200 \text{ Turns} \quad B = 0.8 \text{ T}, \quad I = 120 \text{ A}$$

$$T = \frac{L}{\pi} N I A B = 1.32 \times 10^3 \text{ N.m}$$

Problem 6.26  $N = 25$ ,  $A = 10 \times 10^{-4} \text{ m}^2$   $I = 2 \text{ A}$   $B = 0.5 \text{ T}$   $\theta = 30^\circ$

$$T = m B \sin \theta \text{ where } m = N I A \Rightarrow T = N I A B \sin \theta = 12.5 \times 10^{-3} \text{ N.m}$$

Problem 6.27 Since  $T = m B \sin \theta = N I A B \sin \theta = 0.025 \sin \theta$

$$W = \int_0^\pi T d\theta = \int_0^\pi 0.025 \sin \theta d\theta = 0.05 \text{ J or } 50 \text{ mJ}$$