PHY 13.02 Tutorial problems with Solutions.

1.0 (ELECTROSTATICS PART).

Question (1.1)

Calculate the value of two equal charges if they repel one another with a force of 0.1 N when situated 50 cm apart in a vacuum

Solution:

~~f = 10~~ $f = 0.1N$, $r = 50cm = 50 \times 10^{-2} m$, $q = ?$

From $F = \frac{Kq^2}{r^2} \Rightarrow q = \sqrt{\frac{r^2 F}{K}}$

where $K = 9.0 \times 10^9 \frac{Nm^2}{C^2}$.

$$q = \sqrt{\frac{(50 \times 10^{-2})^2 \times 0.1}{9.0 \times 10^9}} = 1.66 \times 10^{-6} C$$

$$q \simeq 1.7 \times 10^{-6} C = \underline{1.7 \mu C}.$$

Question (1.2).

One charge of 2.0C is 1.5m away from −3.0C charge. Determine the force they exert on each other.

Solution:

$F_e = ?$, $q_1 = 2.0c$, $q_2 = -3.0C$, $r = 1.5m$

using $F_e = \frac{K q_1 q_2}{r^2} = \frac{9.0 \times 10^9 \times 2.0 \times (-3.0)}{(1.5)^2}$

$$F_e = \frac{-54 \times 10^9}{2.25} = -24 \times 10^9 N$$

$$\therefore F_e = \underline{-2.4 \times 10^{10} N}$$

Question (1.3):

A helium nucleus has a charge of $+2e$ and a neon nucleus has a charge of $+10e$, where e is the quantity of charge, $1.6\times10^{-19}C$. Calculate the repulsive force exerted on one by the other when they are separated by a distance of $4.0nm$. Assume the system to be in a vacuum.

Solution: $q_1 = 2e$, $q_2 = 10e$, $r = 4.0nm = 4.0\times10^{-9}m$, $F = ?$

Using
$$F = \frac{K q_1 q_2}{r^2} = \frac{9.0\times10^{9}\times 2e \times 10e}{(4.0\times10^{-9})^2} = \frac{180\times10^{9}\times e^2}{16.0\times10^{-18}}$$

$$F = \frac{180\times10^{9}\times(1.6\times10^{-19})^2}{16.0\times10^{-18}} = \underline{2.88\times10^{-10}N}$$

Question (1.4):

The plates of parallel capacitor, $5.0\times10^{-3}m$ apart are maintained at a potential difference of $5.0\times10^{4}V$. Calculate the magnitude of the

i, Electric field intensity between the plates

ii, Force on the electron

iii, Acceleration of the electron

(Electronic charge $q = 1.6\times10^{-19}C$, Mass of the electron $M_e = 9.1\times10^{-31}kg$

Solution:

$$P.d = V = 5.0\times10^{4}V, \quad r = d = 5.0\times10^{-3}m$$

i, From $E = \frac{V}{d}$, we have: $E = \frac{5.0\times10^{4}}{5.0\times10^{-3}} = \underline{1.0\times10^{7}\ F/C}$

ii, $F = qE = 1.6\times10^{-19}\times1.0\times10^{7} = \underline{1.6\times10^{-12}}\ N$

iii, from: $F = ma$ or $F = M_e a \Rightarrow a = F/M_e$

$$\therefore a = \frac{1.6\times10^{-12}}{9.1\times10^{-34}} = 0.176\times10^{-12+34} = 0.176\times10^{22}m/s^2 = \underline{1.7\times10^{21}m/s^2}$$

Question (1.5):

Two equal charges, placed 50 cm apart in vacuum, repel each other with a force of 0.1 N. Calculate the magnitude of each charge.

Solution:

[see page 1, Question 1.1].

(ELECTRICITY PART)

Question:

What shunt resistance is required to convert $1.00\,mA$, ~~0 to 50.0mA~~ $20.0\,\Omega$ meter into an ammeter with range of 0 to $50.0\,mA$?

Solution:

Let the current and resistance in the shunt be I_s and R_s respectively and V_s, V_m be the voltage drop accross the shunt and the meter respectively.

According to Ohm's law:

$$V = IR$$

In the meter; $R = 20.0\,\Omega$ and $I = 1.00\,mA$

$\therefore$ $V_m = IR$ and $V_s = I_s R_s$

But $V_s = V_m$ and $I_s = 50.0\,mA - 1.00\,mA = 49\,mA$

Hence $I_s R_s = IR$

$$\Rightarrow R_s = \frac{IR}{I_s} = \frac{1.00\,mA \times 20.0\,\Omega}{49\,mA} = \frac{20}{49}\,\Omega$$

$$\therefore R_s = \underline{\underline{0.41\,\Omega}}.$$

Question:

The current in a loop circuit that has a resistance of R_1 is $2.00A$. The current is reduced to $1.60A$ when an additional resistor $R_2 = 3.00\,\Omega$ is added in series with R_1. What is the value of R_1?

Solution:

$I_1 = 2.00A$, $R_2 = 3.00\Omega$, $I_2 = 1.6A$, $R_1 = ?$

Since R_1 and R_2 are in series connection;

$$R_{eq} = R_1 + R_2$$

The current is I_1 when R_1 was the only resistor. The voltage is thus;

$$V_1 = I_1 R_1 = 2.00 R_1$$

However, when R_2 is added to R_1 the current dropped to $I_2 = 1.6A$.

with $R_{eq} = R_1 + R_2$, the voltage now is:

$$V_2 = I_2 R_{eq} = I_2 (R_1 + R_2) = 1.6 (R_1 + R_2)$$

Since there is a drop in the current due to the increase in the resistance, the voltage has to be constant.

$$\Rightarrow \quad V_1 = V_2$$

$$2.00 R_1 = 1.6 (R_1 + R_2)$$

$$2.00 R_1 = 1.6 R_1 + 1.6 R_2$$

$$(2.00 - 1.6) R_1 = 1.6 R_2 = 1.6 (3)$$

$$0.4 R_1 = 4.8$$

$$\Rightarrow R_1 = \frac{4.8}{0.4} = \underline{\underline{12 \Omega}}$$

$$R_1 = \underline{\underline{12 \Omega}}$$

Question:

A television repairman needs a 100 Ω resistor to repair a malfunctioning set. He is temporarily out of resistors of this value. All he has in his toolbox are a 500 Ω resistor and two 250 Ω resistors. How can he obtain the desired resistance using the resistors he has on hand?

Solution:

Let $R_1 = 500\,\Omega$, $R_2 = 250\,\Omega$, $R_3 = 250\,\Omega$

The required resistance is 100 Ω. These three resistors can be connected in parallel to obtain their equivalent

Thus; $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$$\frac{1}{R_{eq}} = \frac{1}{500} + \frac{1}{250} + \frac{1}{250} = \frac{1+2+2}{500}$$

$$\frac{1}{R_{eq}} = \frac{5}{500} \Rightarrow R_{eq} = \frac{500}{5}$$

$\therefore R_{eq} = \underline{100\,\Omega}$ which is required resistance

Hence by connecting R_1, R_2 and R_3 in parallel, the repairman can have the required resistance of 100 Ω

(MAGNETISM PART)

Qtsn:
A wire carrying a current of 10A and 2 meters in length is placed in a field of flux density 0.15T ($Wb\,m^{-2}$). What is the force on the wire if it is placed
(a) at right angles to the field.
(b) at 45° to the field
(c) along the field.

~~Question~~ Solution to Example 1

Given facts:
$I = 10A$, $l = 2m$, $B = 0.15T$, $F = ?$

(a) at right angle

$F = BIl = 0.15 \times 10 \times 2$
$F = 3.0N$

(b) at 45° , $\theta = 45°$

$F = BIl\sin\theta = 0.15 \times 10 \times 2 \times \sin 45$
$F = 2.12\,N$

(c) along the field, $\theta = 0°$

$F = BIl\sin\theta = 0$
since $\sin 0 = 0$

$\underline{F = 0}$

Qstn: A uniform magnetic field $B = 3.0\,G$, exist in the $+x$-direction A proton ($q = +e$) shoots through the field in the y-direction with a speed of $5.0 \times 10^6\,m/s$. Find the magnitude of the force on the proton.

Solution to Example 2:

Given facts:
$B = 3.0\,G = 3.0 \times 10^{-4}\,T$
$q = +e = 1.6 \times 10^{-19}\,C$
$v = 5.0 \times 10^6\,m/s$

since B and q are perpendicular, $F = qvB$

$\Rightarrow F = 1.6 \times 10^{-19} \times 5.0 \times 10^6 \times 3.0 \times 10^{-4}$
$F = 24.0 \times 10^{-19}\,N$
$F = \underline{2.4 \times 10^{-18}}\,N$

Solution to Example 3:

$n = 10^{25}$, $t = 10^{-3} m$, $B = 1T$, $q = 1.6 \times 10^{-19} C = e$, $I = 10A$

$V_H = ?$

using $V_H = \frac{BI}{net} = \frac{1 \times 10}{10^{25} \times 1.6 \times 10^{-19} \times 10^{-3}} = \frac{10}{1.6} \times 10^{-25} \times 10^{19} \times 10^{3}$

$$V_H = 6.25 \times 10^{-3} V = \underline{6.25 mV}$$

Solution to Example 4:

$I = 0.5A$, $t = 4mm = 4 \times 10^{-3} m$, $B = 0.2T$, $V_H = 6.0mV = 6.0 \times 10^{-3} V$

$n = ?$

from $V_H = \frac{BI}{net} \Rightarrow n = \frac{BI}{etV_H}$

$$\therefore n = \frac{0.2 \times 0.5}{1.6 \times 10^{-19} \times 4 \times 10^{-3} \times 6.0 \times 10^{-3}}$$

$$n = \frac{0.1}{38.4} \times 10^{19} \times 10^{3} \times 10^{3} = 0.0026 \times 10^{25}$$

$n = 2.6 \times 10^{22}$ electrons per ~~cubed~~ meter cubed

Solution to Example 5:

$N = 10$, $A = 4 \times 10^{-2} m^2$, $B = 10^{-2} T$

(a) $E = ?$ when $t = 0.5$ seconds

(b) $E = ?$ when $\theta = 60°$ with $t = 0.2$ sec.

(a)

$$E = \frac{BAN}{t} = \frac{10^{-2} \times 4 \times 10^{-2} \times 10}{0.5} = 8.0 \times 10^{-2-2+1}$$

$$E = 8.0 \times 10^{-3} V = \underline{8.0 mV}$$

(b)

$$E = \frac{BAN - BAN\cos\theta}{t} = \frac{8.0 \times 10^{-3} - (10^{-2} \times 4 \times 10^{-2} \times 10 \cos 60°)}{0.2} = \frac{8.0 \times 10^{-3} - (4.0 \times 10^{-3})\cos 60°}{0.2}$$

$$E = 20 \times 10^{-3} \cos 60° = 20 \times 10^{-3}(0.5) = 10 \times 10^{-3} V$$

$E = \underline{10 mV}$ or $E = \underline{10^{-3} V}$

Solution to Example 6:

Given facts: $M_e = 9.1 \times 10^{-31}$ kg , $q = -e = 1.6 \times 10^{-19}$ C

$r = 2.0$ cm $= 2 \times 10^{-2}$ m , $B = 4.5 \times 10^{-3}$ T , $v = ?$

using the relation:

$$B = \frac{M_e v}{qr} \Rightarrow v = \frac{Bqr}{M_e}$$

$$v = \frac{4.5 \times 10^{-3} \times 1.6 \times 10^{-19} \times 2.0 \times 10^{-2}}{9.1 \times 10^{-31}}$$

$$v = \underline{\underline{15.82 \times 10^{6}}} \text{ m/s}$$

Solution to Example 7:

Given:

$M_\alpha = 6.68 \times 10^{-27}$ kg , p.d , $V = 1.0$ kV $= 1000$ V

$B = 0.20$ T , $r = ?$, $q = +2e = 2 \times 1.6 \times 10^{-19}$ C

$q = 3.2 \times 10^{-19}$ C

To obtain the radius r, consider the energy conservation principle

The potential energy loss during this acceleration is equal to the kinetic energy gain.

$\Rightarrow$ If the potential energy is qV and the kinetic energy K.E is $\frac{1}{2}mv^2$, then

$$\frac{1}{2}mv^2 = qV \Rightarrow v^2 = \frac{2qV}{m}$$

$$\therefore v = \sqrt{\frac{2qV}{m}}$$

here $m = M_\alpha \Rightarrow v = \sqrt{\frac{2qV}{M_\alpha}}$

using the relation: $B = \frac{M_\alpha v}{qr}$ or $r = \frac{M_\alpha v}{Bq} = \frac{M_\alpha v}{Bq}$

$$\Rightarrow r = \frac{M_\alpha}{Bq}\sqrt{\frac{2qV}{M_\alpha}} = \frac{1}{B}\sqrt{\frac{2qVM_\alpha^2}{q^2 M_\alpha}} = \frac{1}{B}\sqrt{\frac{2VM_\alpha}{q}}$$

$$\therefore r = \frac{1}{B}\sqrt{\frac{2VM_{\alpha}}{q}} = \frac{1}{0.20}\sqrt{\frac{2 \times 1000 \times 6.68 \times 10^{-27}}{3.2 \times 10^{-19}}}$$

$$r = \underline{\underline{0.032\,m}}$$

or $r = \underline{\underline{32\,mm}}$.