## Q. No. 2 Part (i) REDUCTION OF COULUMB'S FORCE

When the medium between two charges is a medium other than free space, coulomb's force is **reduced. Permitivity** is the property of a medium which reduces electrostatic force between charges.

Coulomb's force between charges in a medium other than space is given by

$$F_{med} = \frac{kq_1q_2}{r^2} \Rightarrow F_{med} = \frac{1}{4\pi\varepsilon}\frac{q_1q_2}{r^2} \quad -①$$

Relative permitivity is the ratio of permitivity of medium to permitivity of free space.

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_o} \Rightarrow \varepsilon = \varepsilon_o \varepsilon_r$$

Hence eq ① becomes

$$F_{med} = \frac{1}{4\pi\varepsilon_o\varepsilon_r}\frac{q_1q_2}{r^2}$$

$$F_{med} = \frac{F_{vac}}{\varepsilon_r} \quad \text{or} \quad F_{vac} = \varepsilon_r F_{med}$$

This shows that $F_{med} > F_{vaccum}$

Hence the force between two charges in a medium other than free space is less.

---

## Q. No. 2 Part (ii) BOHR'S ATOMIC MODEL

Bohr proposed planetary model for an atom. The postulates are :

**1st Postulate:** Electrons revolve around the nucleus in fixed orbits (energy levels) The centripetal force is provided by coulomb's force of attraction between negatively charged electrons and positively charged nucleus.

$$F_{centripetal} = F_{coulomb} \Rightarrow \frac{mv^2}{r} = \frac{kq_1q_2}{r^2} \Rightarrow \frac{mv^2}{r} = \frac{ke^2}{r}$$

**2nd Postulate:** Electrons can not revolve in any arbitrary orbit. Only those orbits are possible for which angular momentum is an integral multiple of $\frac{h}{2\pi}$.

$$L = \frac{nh}{2\pi} \qquad mvr = \frac{nh}{2\pi}$$

**3rd Postulate:** Electrons do not emit energy continuously. They emit energy when they make a transition from one energy state to other. Energy of emitted photon is equal to difference between energy levels.

$$hF = E_n - E_p$$

**Q. No. 2 Part (iii)**

## GREATER SPEED

**ANSWER:**

**Electron** has a greater speed than proton if they have the same de-broglie wavelength.

**EXPLANATION:**

De-Broglie wavelength is given by

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

$$v = \frac{h}{m\lambda}$$

$$v \propto \frac{1}{m}$$

$m_e = 9.11 \times 10^{-31}\ kg$
$m_p = 1.67 \times 10^{-27}\ kg$

Speed is inversely proportional to the mass of particle. As we know that mass of electron is less than mass of proton. $m_e < m_p$

Thus the speed of electron will be more than speed of proton.

---

**Q. No. 2 Part (iv)**

## NUMERICAL

**DATA:**

$q = 3\mu C = 3 \times 10^{-6} C$

radius $= \frac{15cm}{100} = 0.15m$

distance from centre $r = \frac{27cm}{100} = 0.27m$

**FORMULA:**

$$E = \frac{kq}{r^2}$$

**SOLUTION:**

Electric field at a distance of 27cm from centre is

$$E = \frac{kq}{r^2}$$

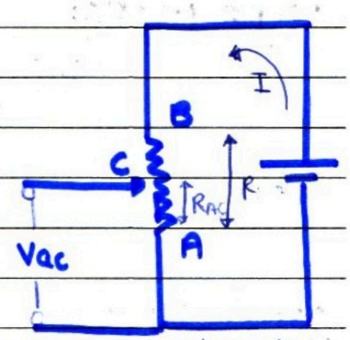
$$= \frac{(9 \times 10^9)(3 \times 10^{-6})}{(0.27)^2}$$

$$E = 370370\ NC^{-1}$$

Q. No. 2 Part (ix)

## Rheostat as Potential Divider

A rheostat is used as potential divider as shown in diagram. Potential divider helps us to get a variable potential difference from a fixed potential difference. Consider a battery provides potential V to resistor of resistance R then current I is




$$V = IR \Rightarrow I = \frac{V}{R}$$

The potential difference between A and sliding contact C is given by

$$V_{AC} = I R_{AC} \Rightarrow V_{AC} = \left(\frac{V}{R}\right) R_{AC} \Rightarrow V_{AC} = \frac{R_{AC}}{R} V$$

Hence by moving sliding contact C ratio $R_{AC}/R$ can be varied between **0 and 1**. If C is moved away from A, length of wire included in circuit increases hence Resistance R increases. If moved towards A, length decreases hence resistance decreases.

Q. No. 2 Part (v)

## NUMERICAL

**DATA:**

mass $m = 300kg$

extension $\Delta L = \frac{0.2cm}{100} = 2 \times 10^{-3} m$

length $L = 2m$

area $A = \frac{15cm^2}{100^2} = 1.5 \times 10^{-3} m^2$

(a) Stress $\sigma = ?$

(b) Strain $\varepsilon = ?$

(c) Young's modulus $Y = ?$

**SOLUTION:**

**(a)** Stress $\sigma = \frac{F}{A}$

$= \frac{mg}{A}$

$= \frac{(300)(10)}{1.5 \times 10^{-3}}$

$= 2000000 \, Nm^{-2}$

**(b)** Strain $\varepsilon = \frac{\Delta L}{L}$

$= \frac{2 \times 10^{-3} m}{2m}$

$= 1 \times 10^{-3}$

**(c)** Young's Modulus $Y = \frac{Stress}{Strain}$

$= \frac{F/A}{\Delta L / L}$

$= \frac{2000000}{1 \times 10^{-3}}$

$= 2000000000 \, Nm^{-2}$

$= 2 \times 10^{9} \, Nm^{-2}$

Q. No. 2 Part (vi) **NUMERICAL**

| **DATA:** | $V = IX_L$ |
|---|---|
| $V = 10V$ | $X_L = \frac{V}{I}$ |
| $f = 200 Hz$ | $= \frac{10}{0.4}$ |
| $I = 0.4 A$ | $X_L = 25\Omega$ |
| $L = ?$ | Now inductance is given by, |
| | $X_L = 2\pi f L$ |
| **FORMULAE:** | $L = \frac{X_L}{2\pi f}$ |
| $V = IX_L$ | $= \frac{25}{2\pi(200)}$ |
| $X_L = 2\pi f L$ | $= \frac{25}{1256.637}$ |
| | $L = 0.01989 L$ |

Q. No. 2 Part (vii) **MAGNETIC FLUX**

**Definition:** Magnetic flux is the **number** of magnetic **field lines** that pass through an area held perpendicular to the field.
It is used to describe the **strength of magnetic field.**

**Symbol:** Magnetic flux is denoted by $\phi_B$

**Formula:** Magnetic flux is given by the cross product of magnetic field intensity $\vec{B}$ and area vector $\vec{A}$.

$$\phi_B = B.A$$
$$\phi_B = BA\cos\theta$$

Hence it depends on field $\vec{B}$ and area $\vec{A}$ and orientation with respect to field.
It is max when $\phi = 0$ and minimum when $\phi = 90$

**Unit:** The unit of magnetic flux is **Weber (Wb)** which is equal to Tesla times $m^2$ $Wb = Tm^2$ $\Rightarrow Wb = \frac{N}{Am} m^2$

$$Wb = NmA^{-1}$$

Q. No. 2 Part (viii)

## NUMERICAL

| DATA: | SOLUTION: |
|---|---|
| $\mathcal{E} = 120V$ | As we know that |
| $R = 1000\Omega$ | $V_t = \mathcal{E} - Ir$ |
| $r = 0.01\Omega$ | $IR = \mathcal{E} - Ir$ |
| Current $I = ?$ | $\mathcal{E} = IR + Ir$ |
| | $\mathcal{E} = I(R+r)$ |
| **FORMULA:** | $I = \frac{\mathcal{E}}{R+r}$ |
| $V_t = \mathcal{E} - Ir$ | $= \frac{120}{1000+0.01}$ |
| $I = \frac{\mathcal{E}}{R+r}$ | $= \frac{120}{1000.01}$ |
| | $I = 0.119998A$ or $I = 0.12A$ |
| | The current is 0.1196198 A. |

Q. No. 2 Part (x)

| Emf | Potential Difference |
|---|---|
| **Definition** | |
| Emf is the work done in moving a positive charge across the **terminals** of battery. Every emf is a potential difference | Potential difference is the work done in moving a charge between **any two points** in the circuit. Every potential difference is not an emf. |
| **Open Circuit** | |
| Emf is **present** even when no current is flowing in the circuit. | Potential difference is **absent** when no current is flowing in the circuit. |
| **Relation** | |
| emf is the **cause**. It always remains **constant.** | Potential difference is the **effect.** It does **not** remain constant. |

Q. No. 2 Part (xi)

**MODERATORS:** Moderator is a device which is used to **slow down** the neutrons. In **U-235**, fission is performed by **low energy** neutrons having energy of about **0.025 eV.** However, the neutrons released in fission reaction have energy of several MeV. Thus moderator is used to slow down the neutrons so they can perform **further fission.** It is made of light material like **heavy water** and **graphite** which do not absorb neutrons.

**CONTROL RODS:** Controls rods are used to keep fission reaction in **critical state.** Output power should remain constant. Only one neutron released in fission should perform further fission so that fission is in **normal** state and fission chain reaction progresses with uniform speed. Control rods can be moved **in** or **out**. They are made of **boron, cadmium, hafnium** which **absorb neutrons** and thus controls the number of neutrons that perform further fission.

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Q. No. 2 Part (xii)

## MAGNETIC FORCE

**ANSWER:** The magnetic force acting on a stationary charged particle placed in a uniform magnetic field is **zero.**

**EXPLANATION:** The force by magnetic field on a charge is given by.

$$F_B = qvB\sin\theta$$

For a charged particle to experience magnetic force

(i) it should be moving, a stationary particle does not produce a magnetic field and does not experience a magnetic force

(ii) it should have a component of velocity perpendicular to magnetic field.

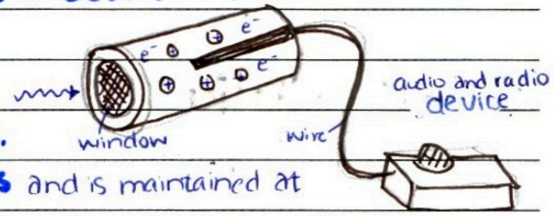
When it is stationary, $F_B = q(0)B\sin\theta$

$$F_B = 0$$

Hence it does not experience a magnetic force.

**Q. No. 2 Part (xiii)** GEIGER-MULLER COUNTER

Geiger Muller counter is a **radiation detector.** It is used to **detect** radiations and produce a **sound**.




A geiger muller counter consists of a **tube** with a gas at **low potential.**

A **rod** is connected along **its axis** and is maintained at **high potential.** It is connected through wire to an audio device

**WORKING:** When a **photon** enters the tube through the **window**, it **ionizes** some atoms of the gas. **Electrons** are removed from them. Since the wire is at high potential, electrons are attracted towards the wire. When flowing through the wire, they ionize other atoms in their way. In this way an **avalanche of electrons** is created and a pulse is produced. The audio device detects this **pulse** and produces a **sound.**

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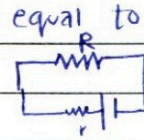
**Q. No. 2 Part (xiv)** MAXIMUM OUTPUT POWER:

**Maximum Power Transfer Theorem** states that power delivered to a load is maximum if the resistance / impedance of source is equal to the resistance /impedance of load.




Power delivered is given by

$P_{out} = IV$

$P_{out} = I^2R$

$= \left(\frac{\mathcal{E}}{R+r}\right)^2 R$

$= \frac{\mathcal{E}^2}{(R+r)^2} R$

$= \frac{\mathcal{E}^2}{R^2+2Rr+r^2} R$

$= \frac{\mathcal{E}^2}{R^2+2Rr+r^2+2Rr-2Rr} R$

$= \frac{\mathcal{E}^2}{R^2-2Rr+r^2+4Rr} R$

$$P_{out} = \frac{\mathcal{E}^2 R}{(R-r)^2+4Rr}$$

if $R=r$, the denominator is minimum so power is maximum.

$P = \frac{\mathcal{E}^2 R}{(R-R)^2+4R^2}$

$= \frac{\mathcal{E}^2 R}{4R^2}$

$$P_{max} = \frac{\mathcal{E}^2}{4R} = \frac{\mathcal{E}^2}{4r}$$

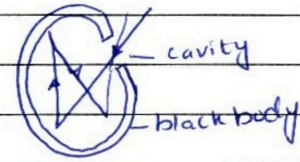
Q. No. 3 (Page 1)

# Black Body Radiations

**Thermal Radiations:** The radiations emitted by a material because of its **temperature** is known as thermal radiations.

All bodies, no matter **hot** or **cold**, radiate because of their temperatures. For example a **sun** having a temperature of **6000 K** radiates yellow light.
Similarly cooler star **Betelgueuse** of temperature **2900 K** radiates orange-red light.
**Humans** having temperature **310 K** radiate infrared radiations which can be detected by **infrared** detector.

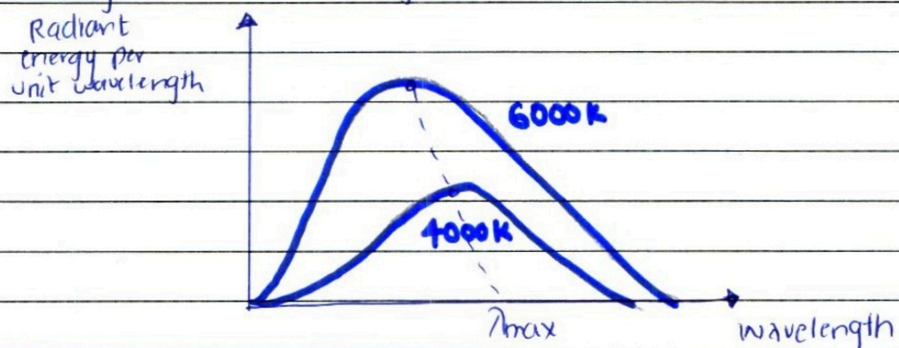
**Black Body:**
"A **perfect** black body is one which **absorbs** and **re-emits** all the **radiations** falling on it."
A small hole in the **cavity** of a metal box acts acts as black body because it absorbs all ~~em~~ incoming radiations.
The inside of cavity is painted black to absorb all radiations.
If the direction of radiations is reversed, the radiations are in thermal equilibrium with walls of the black body.
It will reemit all the absorbed radiations.
**"Radiations emitted by a black body are called blackbody radiations."**



Q. No. 3 (Page 2)

## Graph:

A graph can be plotted between the radiant energy per unit wavelength to the wavelength.




The nature of radiations depends on the temperature of body.

## Conclusions:

**(i)** Radiations of **all wavelengths** are emitted at all temperatures

**(ii)** Radiant energy increases with increase in wavelength to a maximum value. With further increase the radiant energy decreases.

## Stephen Boltsmann Law:

Stephan Boltsmonn law states that the area under the graph shows the amount of radiations emitted at that temperature. This area is greater for higher temperatures. The energy of

**"The energy of radiations is directly proportional to fourth power of temperature."**

$$E \propto T^4$$

$$E = \delta T^4$$

T is temperature in kelvin. **$\delta$** is **stephen's constant**.

Q. No. 3 (Page 3)

$\delta = 5.67 \times 10^{-8} Wm^{-2}K^{-1}$

**Wein's Displacement law:**

Wein's displacement law states that, the peak of wavelength intensity decreases with increase in temperature. With temperature increase, $\lambda_{max}$ shifts to the right.

$$\lambda max \propto \frac{1}{T}$$

$$\lambda max = \frac{constant}{T}$$

Constant = $0.2898 \times 10^{-2}$ mK

Wein was able to explain black body spectrum for shorter wavelengths, Releign Jean explained it for longer wavelength. Complete spectrum could not be explained.

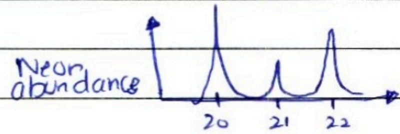
It was later explained by Plank's theory in 1905.

Q. No. 4 (Page 1)

# Mass Spectrograph

## Definition:

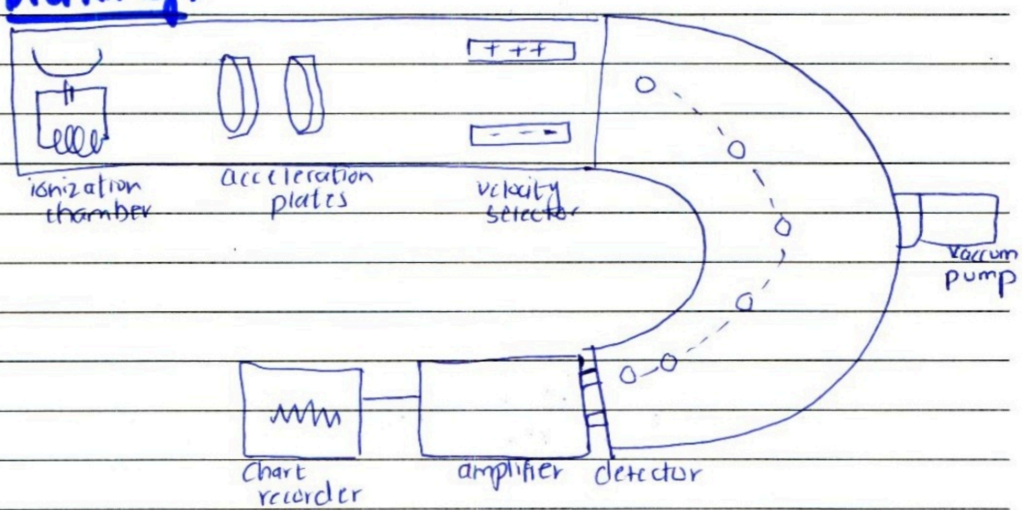
Mass spectrograph is a device used to find **masses** of **isotopes**. It is used to **separate** isotopes on the basis of their masses and also determines relative **abundance** of isotopes.




## Principle:

It is based on the principle that **ions** are deflected in electric and magnetic **fields**.

## Working:




Atoms of isotopes are forced in an **ionization chamber**. This chamber removes electrons from them and they becomes ionized. These ions are **accelerated** by applying a **potential V**.

Q. No. 4 (Page 2)

They are then passed through a **velocity selector** which allows only ions of same speed to pass. It leaves ions of only same speeds.

Since ions are accelerated by applying a potential difference,

$$KE = PE$$

$$\frac{1}{2}mv^2 = qV$$

$$mv^2 = 2qV$$

$$v^2 = \frac{2qV}{m}$$

$$v = \sqrt{\frac{2qV}{m}} \quad -(1)$$

Ions then enter **perpendicularly** in a magnetic field. A magnetic force acts on them which deflects them in a circular path towards the detectors.

The centripetal force is provided by magnetic force.

$$F_c = F_B$$

$$\frac{mv^2}{r} = qvB$$

$$\frac{mv}{r} = qB$$

$$v = \frac{qBr}{m} \quad -(2)$$

Comparing (1) and (2)

$$\sqrt{\frac{2qV}{m}} = \frac{qBr}{m}$$

Squaring

$$\frac{2qV}{m} = \frac{q^2B^2r^2}{m^2}$$

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$$2qV = \frac{q^2B^2r^2}{m}$$

$$2V = \frac{qB^2r^2}{m}$$

Solving for m,

$$m = \frac{qB^2r^2}{2V}$$

**RADIUS:**

Solving for radius,

$$2Vm = qB^2r^2$$

$$r^2 = \frac{2Vm}{qB^2}$$

$$r = \sqrt{\frac{2Vm}{B^2q}}$$

$$r \propto \sqrt{m}$$

This shows that radius is directly proportional to square root of mass.

Hence isotopes of different masses will be deflected differently and can be separated.

Q. No. 5 (Page 1)

# X- Rays

**"X-rays are electromagnetic radiations of very high frequency and wavelength of the order of Angstrom A° ($10^{-10}$ m)**

## Inner Shell Transitions
## (Characteristic X-rays).

The electrons of the atoms of target material are present in different energy levels, **K, L, M, ...**

An incoming **beam of electrons** can **knock out** an electron from its **inner shell** or energy level. Electrons from higher energy orbits will try to fill this **vacancy** and photons will be emitted called characteristic x-rays. **Energy** of photon will be equal to difference between energy levels. $hf = E_n - E_p$

For example, beam of electrons can knock out an electron from the inner **K-shell**. This will create a vacancy in the K-shell. The electrons from higher shells like L and M will jump to fill this vacancy. In this way K-characteristic x-rays will be emitted.

"**K Characteristic X-rays** are x-rays emitted when electrons from **higher orbits** will jump to **K-shell**."

If electron from L shell jumps to K-shell then

Q. No. 5 (Page 2)

**Kα rays** are emitted.

If election from M shell jumps to K-shell then **Kβ rays** are emitted and so on.

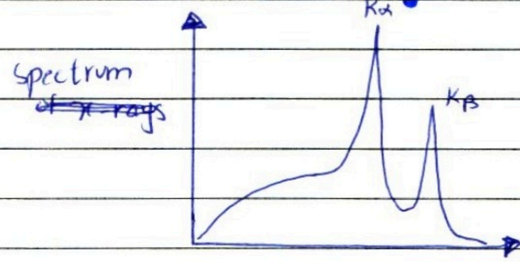
## L- characteristic Rays:

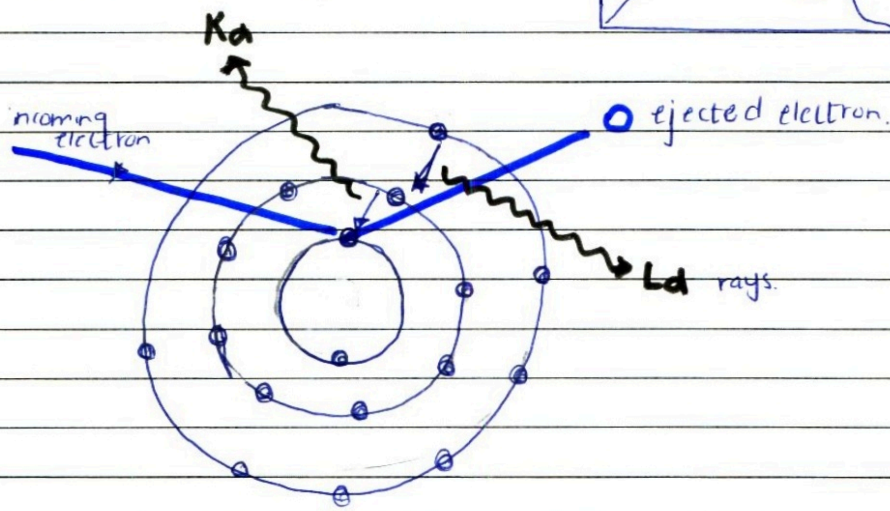
When electrons from L and M shell jump to k shell, it will create vacancies in L and M shells.

When electrons from **higher orbits** jump to **L-shell** L characteristic x-rays will be obtained.

When electron jumps from M to L shell, **Lα rays** are produced.

The **peaks** are due to characteristic x-rays



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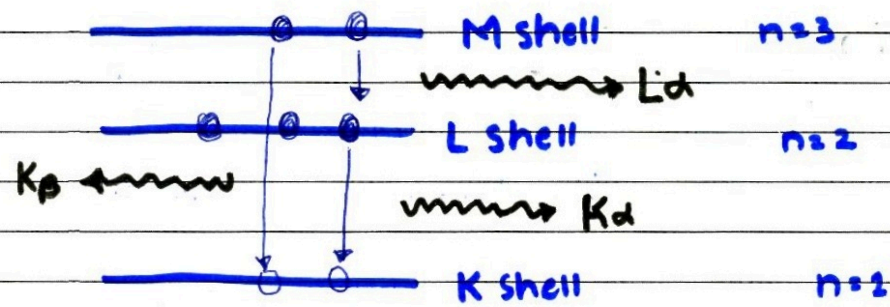

Q. No. 6 (Page 1)

# Ampere's Law

## Definition:

Ampere's law states that

"The sum of length elements in a closed path, multiplied by the component of magnetic field parallel to each element is directly proportional to the current enclosed by that path."

$$B.\Delta l = \mu_o I$$

## Solenoid:

Solenoid is a **coil** which number of turns. When current passes through the coil, it generates a magnetic field around it similar to **bar magnet.**

Solenoid develops a **north** and a **south pole**.
In the interior, field lines are nearly **parallel**, **uniform** and **close** together.
As number of turns are increased, this field lines become more parallel and strong.
Ideal solenoid is reached when length of solenoid is very greater than radius of turns. Interior field is very strong whereas field in the exterior approaches to zero.

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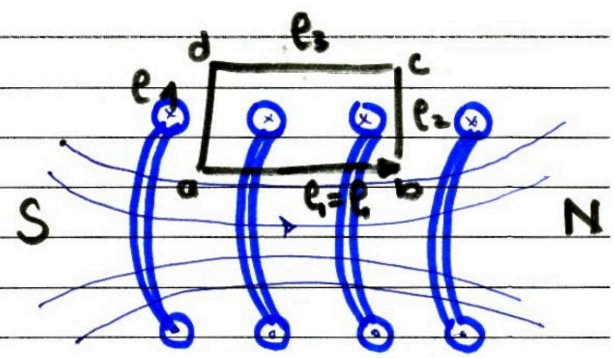


Consider a solenoid of N number of turns and length L.

An amperian path is in the form of rectangle a-b-c-d-a with sides $\ell_1$, $\ell_2$, $\ell_3$, $\ell_4$.

By amperes law,

$$B.\Delta l = \mu_0 I$$

Since it consists of four length elements $\ell_1, \ell_2, \ell_3, \ell_4$

$$B.\ell_1 + B.\ell_2 + B.\ell_3 + B.\ell_4 = \mu_0 I$$

$$B\ell_1 \cos\theta_1 + B\ell_2 \cos\theta_2 + B\ell_3 \cos\theta_3 + B\ell_4 \cos\theta_4 = \mu_0 I \quad \text{--- (1)}$$

here $\theta_1 = 0$, $\theta_2 = 90^\circ$, $\theta_3 = 1800$, $\theta_4 = 270$

$\cos 0 = 1$, $\cos 90 = 0$, $\cos 180 = -1$, $\cos 270 = 0$

But since $\ell_3$ is outside solenoid, so for ideal solenoid $B_3 = 0$. No field lines will pass through $\ell_3$

Hence eq (1) becomes

$$B\ell_1 + 0 + 0 + 0 = \mu_0 I$$

$$B\ell_1 = \mu_0 I$$

if $\ell_1 = \ell$ then,

**Q. No. 6 (Page 3)**

$B l = \mu_0 I$

for N number of turns of solenoid,

$B l = N \mu_0 I$

$B = \frac{N}{L} \mu_0 I$

if $n = \frac{N}{L}$ is the number of turns per unit length then magnetic field of solenoid is given by,

$B = n \mu_0 I$

where $n = \frac{N}{L}$

$\mu_0 =$ permeability

$I =$ current through solenoid

Thus magnetic field of solenoid can be found by using this formula.

$\frac{1}{S} \times \frac{Q}{V}$

As

$Q = CV$

$V = 10V$

$f = 200Hz$

$I = 0.4A$

$X_L = 25$

$2\pi f L = 25$

$V = \mathcal{E} - IR$

$V = \mathcal{E} - Ir$

$IR = \mathcal{E} - Ir$

$I = \frac{\mathcal{E}}{R + r}$

$Q = CV$

$C = \frac{Q}{V}$

RMIVU $E \times \frac{Q_1}{d}$

U

V

I

$Q = CV$

$C = \frac{Q}{V}$

$F = \frac{kq_1q_2}{r^2}$

$= \frac{1}{(2r)^2}$

$= \frac{1}{4}$