LECTURE NOTE FOR ENGINEERING PHYSICS

· second Semester - 2020 (Left over portion)

UNIT-10

CURRENT ELECTRICITY

Electric current :-

Def: Current strength in a conductor is defined as the rate of flow of charge across any cross-section of the conductor.

If a charge 'q' flows across any cross-section in 't' second, current i is given by,

$$i = \frac{q}{t}$$

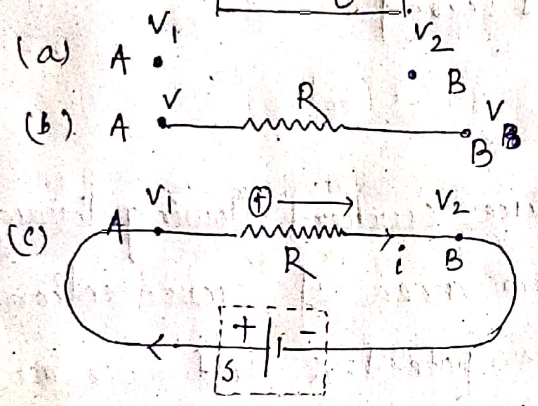


fig - Flow of charge due to potential difference

Consider two bodies A and B charged to potentials 'V_1' and 'V_2' respectively, such that $V_1 > V_2$.

fig (a) - no charge flows and hence their potential remains constant.

fig (b) - If they are connected by means of good conductor with resistance 'R', positive charge flows from V_1 to V_2. (A to B)

fig (c) - Now A and B are connected to a source 's' having its potential difference '$V_1 - V_2$'. Where the source 's' helps in maintaining the potential difference between A and B.

Unit of electric current

(i) C.G.S electro-static unit (esu) :-

$$1 \text{ esu of current} = \frac{1 \text{ esu of charge}}{1 \text{ second}}$$

It is also called statampere.

(ii) C.G.S electro-magnetic unit (emu):-

$$1 \text{ emu of current} = \frac{1 \text{ emu of charge}}{1 \text{ second}}$$

It is also called as abampere.

(iii) S.I unit (ampere):-

$$1 \text{ ampere} = \frac{1 \text{ coulomb}}{1 \text{ second}}$$

Ohm's Law :-

At constant temperature current flowing through a conductor of uniform area of cross-section is proportional to the potential difference across its terminal. This is called ohm's law for conductors.

$$R = \frac{m}{n\tau e^2} \times \frac{l}{a}$$

Where 'R' is the resistance of the conductor.

Application of ohm's law

The main application of ohm's law are :-

To determine the voltage, resistance or current of an electric circuit.

Ohm's law is used to maintain the desire voltage drop across the electronic components.

Ohm's law is also used in dc ammeter and other dc shunts to divert the current.

Series Resistance

The resistances are said to be connected in series if same current flows through all of them.

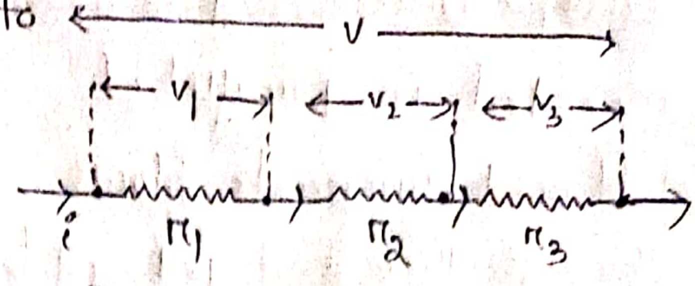


fig- Resistances in series

Consider resistances r_1, r_2 and r_3 are connected in series with each other as shown in the figure.

Let a current (i) flows through all of the resistances. If V_1, V_2 and V_3 are the potential difference across each resistance.

Then we can write,

$$V_1 = ir_1, \quad V_2 = ir_2 \text{ and } V_3 = ir_3$$

'R' is the resistance of the combination then the total potential difference 'V' is given by,

$$V = iR$$

Since, $V = V_1 + V_2 + V_3$

$$\Rightarrow iR = ir_1 + ir_2 + ir_3$$

$$\Rightarrow iR = i(r_1 + r_2 + r_3)$$

$$\boxed{\Rightarrow R = r_1 + r_2 + r_3}$$

Thus if a number of resistances are connected in series with each other then the net resistance of the combination is equal to the sum of their individual resistances.

an electric circuit

Parallel resistance :-

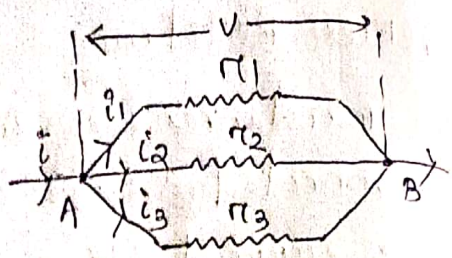


fig- Resistance in Parallel

Resistances are said to be connected in parallel if different currents flows through them and get added afterwards. consider a number of resistances r_1, r_2 and r_3 connected parallel to each other. A current ('i') is divided into three parts and flows through each of these resistances as shown in the figure.

If 'V' is the potential difference across the combination, then we can write

$$V = i_1 r_1 = i_2 r_2 = i_3 r_3$$

$$i_1 = \frac{V}{r_1}, \quad i_2 = \frac{V}{r_2}, \quad i_3 = \frac{V}{r_3}$$

If 'R' is the resistance of the combination, then

$$i = \frac{V}{R}$$

since, $i = i_1 + i_2 + i_3$

$$\frac{V}{R} = \frac{V}{r_1} + \frac{V}{r_2} + \frac{V}{r_3}$$

$$\Rightarrow \frac{V}{R} = V\left(\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}\right)$$

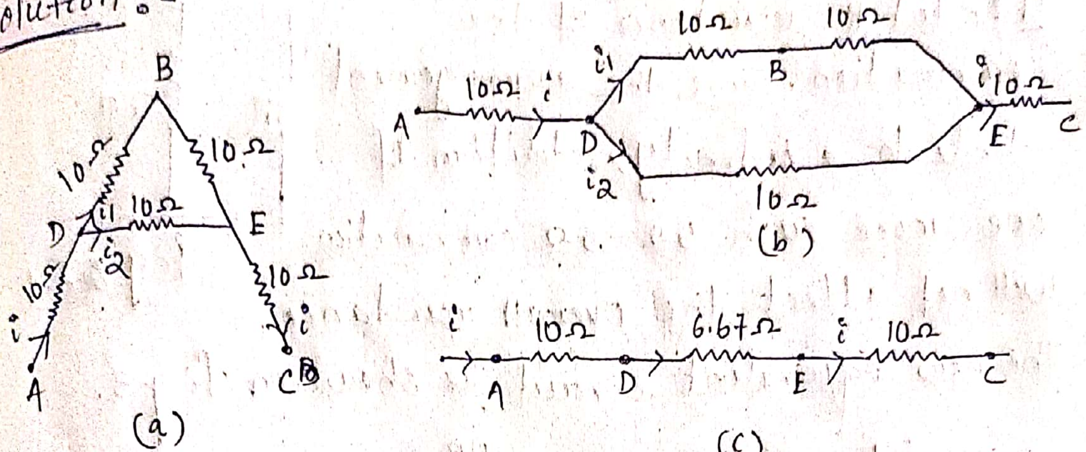
$$\boxed{\Rightarrow \frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}}$$

Thus, if a number of resistances are connected in parallel, the reciprocal of the resistance of the combination is equal to the sum of the reciprocals of their individual resistances.

Example

(1) A letter 'A' is constructed of a uniform wire of resistance 100 ohm m^{-1}. The sides of the letter are 0.20 m long and the cross piece in the middle is 0.10 m. While the apex angle is 60°. Find the resistance of the letter between the two ends of the legs.

Solution :-



(fig-1)

The arrangement of resistance as per statement is shown in fig-1(a)

Resistance in arm DBE = 10 + 10 = 20 ohm

If, r = resistance between points D and E [fig-1(b)]

$$\frac{1}{r} = \frac{1}{20} + \frac{1}{10} = \frac{3}{20}$$

$$r = \frac{20}{3} = 6.67 \text{ ohm}$$

From fig-1(c) it is clear that resistances between AD, DE and EC are in series, therefore total resistance

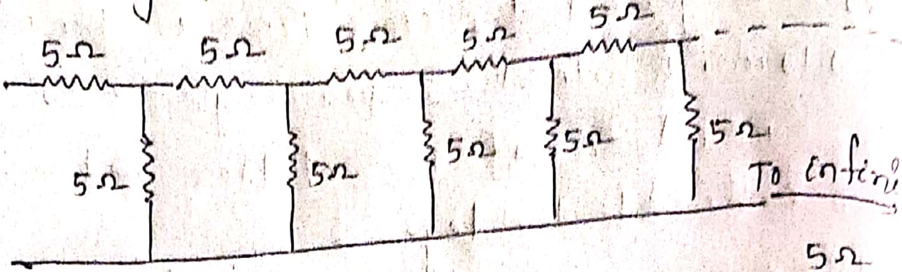
~~[illegible]~~

$$R = 10 + 6.67 + 10 = 26.67 \text{ ohm}$$

charge),

Example-2

Find the equivalent resistance of the circuit as shown in fig-2.



Sol^n:- Let R = resistance of the combination. Since the arrangement tends to a infinity, addition of one more such 5Ω–5Ω combination will not affect the overall resistance. The new equivalent circuit as shown in fig-3.

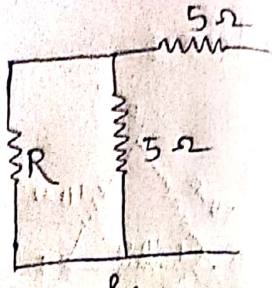


fig-2.1

$$\text{Net resistance} = 5 + \frac{5R}{5+R}$$

$$\therefore 5 + \frac{5R}{5+R} = R$$

$$25 + 5R + 5R = 5R + R^2$$

$$R^2 - 5R - 25 = 0$$

$$R = \frac{5 \pm \sqrt{25+100}}{2} = \frac{5 \pm \sqrt{125}}{2} = \frac{5 + 11.8}{2}$$

Negative sign can be rejected as it leads to a negative resistance.

$$\therefore R = \frac{5+11.8}{2} = 8.09\,\Omega$$

Example-3 :-

Determine the resistance of the circuit as shown in fig-4.

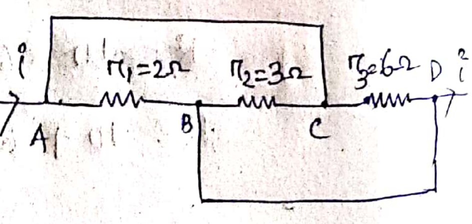


fig-3

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Sol^n:- Points A and C are connected by a lead of zero resistance. Therefore, they are at same potential.

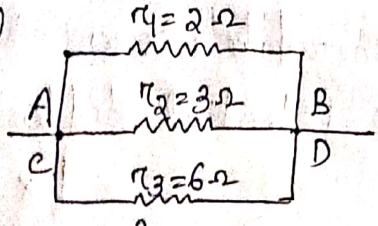

fig- 3.1

Thus, they can be considered to coincide with each other. similarly B and D also being at same potential can be considered to coincide with each other. The circuit gets reduced to the one shown in fig 4.1. since the three resistances are in parallel with each other, net resistance 'R' is given by

$$\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} = \frac{1}{2} + \frac{1}{3} + \frac{1}{6}$$

$$\frac{1}{R} = \frac{3+2+1}{6} = \frac{6}{6} = 1$$

$R = 1$ ohm.

Example - 4

Find the ammeter and voltmeter reading in the circuit shown in fig-4.

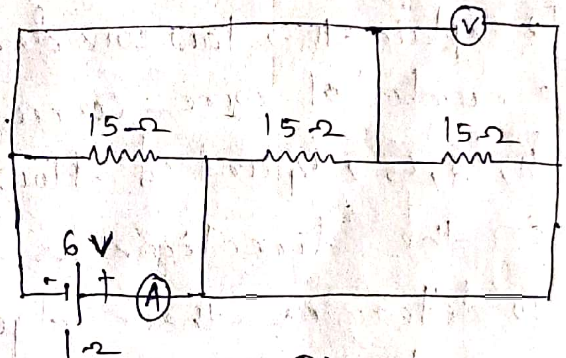

Fig-4

Sol^n:- on examining the circuit carefully we find that all the three resistances are connected in parallel with each other. Therefore, resistance of the combination is

$$\frac{1}{R} = \frac{1}{15} + \frac{1}{15} + \frac{1}{15} = \frac{3}{15} = \frac{1}{5}$$

$R = 5\Omega$

∴ Total resistance of the circuit

$$R_T = R + 1 = 5 + 1 = 6\Omega$$

Total current $i = \frac{6}{6} = 1A$ $\quad i = \frac{V}{R}$

This gives the reading of ammeter.

This current gets divided equally in all the three resistance.

Therefore, current in each resistance $= \frac{1}{3}A$

$\therefore$ potential difference across 1.5 Ω resistance

$$= \frac{1}{3} \times 15 = 5\,\Omega$$

This gives the reading of voltmeter.

Kirchhoff's Law

First law

It states that the algebraic sum of currents meeting at a point is zero.

This law may be called Kirchhoff's current law (KCL).

To explain this law consider a number of wires connected at a point P. currents i_1, i_2, i_3, i_4 and i_5 flow through these wires in the direction as shown in fig.

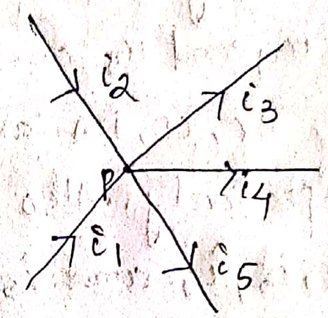

fig - currents meeting at a point

To determine their algebraic sum of electric currents, we follow the following sign conventions.

(i) The currents approaching a given point are taken as positive.

(ii) The current leaving the given point are taken as negative.

Following these sign conventions, we find that i_1 and i_2 are positive while i_3, i_4 and i_5 are negative.

According to Kirchhoff's first law,

$$i_1 + i_2 - i_3 - i_4 - i_5 = 0$$

or $\boxed{\sum i = 0}$

Second law

It states that, in a closed electric circuit, the algebric sum of e.m.f is equal to the algebric sum of the products of resistances and the currents flowing through them.

This law may be called Kirchhoff's voltage law (KVL).

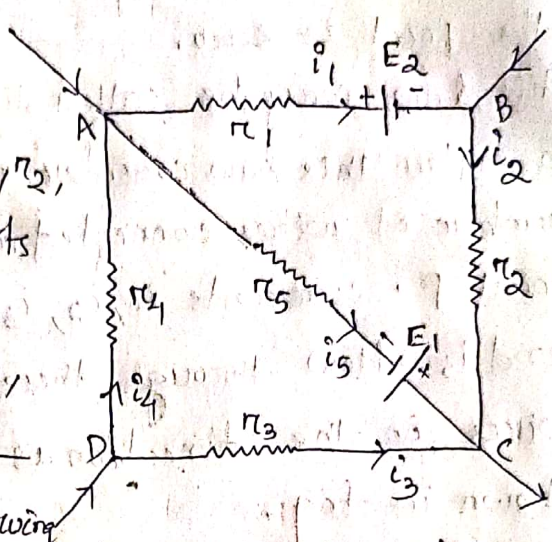

fig-1 A closed electric circuit

Figure-1 shows a closed electric circuit ABCD containing resistances r_1, r_2, r_3, r_4 and r_5 in the parts AB, BC, CD, DA and AC respectively. Also, let i_1, i_2, i_3, i_4 and i_5 be the respective currents flowing in these parts in the directions shown by arrow heads. Two sources of e.m.f's E_1, and E_2 are also connected in the mesh.

In order to use Kirchhoff's voltage we shall follow the following sign conventions.

(i) If the electric current flows through the electrolyte of the cell from negative to positive terminal (fig 2a) the emf of the cell taken as positive (+E).

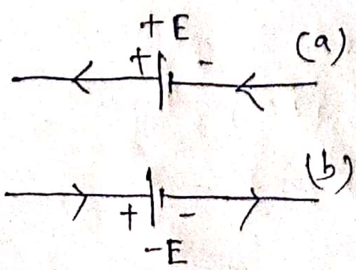

fig-2 Sign conventions for source of a e.m.f

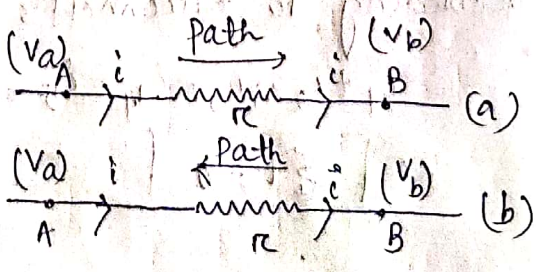

fig-3 sign convention for 'ir'.

(ii) If the electric current flows through the electrolyte of the cell from positive terminal to negative terminal [fig-2(b)] the e.m.f of the cell is taken as negative ($-E$).

(iii) If the path taken to traverse the resistance is along the direction of current [fig-3(b)], the final point (B) is at a lower potential than the initial point (A). The product of current and resistance in this case is taken as negative ($-ir$).

Potential difference = current (i) × resistance (r)
= (potential of final point) − (potential of initial point)
$= V_b - V_a$

Since $V_b < V_a$, ($i \times r$) is negative.

(iv) If the path taken to traverse the resistance against the direction of current [fig 3-(b)], the final point (A) is at potential higher than that of initial point (B). The product of current and resistance in this case taken as positive ($+ir$).

Potential difference = current (i) × resistance (r)
= (potential of final point A) − (potential of initial point B)
$= V_a - V_b$

Since $V_a > V_b$, ($i \times r$) is positive.

It may be noted here that whenever there is a single cell in a closed circuit and the current is unidirectional, the sum of the products of currents and resistances is taken to be equal to the e.m.f. of the cell, irrespective of the direction of current.

Applying Kirchhoff's second law to the mesh ABC, we can write

$$i_1 r_1 + i_2 r_2 - i_5 r_5 = E_1 - E_2$$

Again, applying Kirchhoff's second law to the mesh ACD, we get

$$i_5 r_5 - i_3 r_3 - i_4 r_4 = E_1$$

The above two equations may be written in the following general form,

$$\boxed{\sum ir = \sum E}$$

Wheatstone Bridge :-

Wheatstone bridge is an electrical arrangement which forms the basis of most of the instruments used to determine an unknown resistance.

It consists of four resistances P, Q, R and S connected in the four arms of a square ABCD. A cell of e.m.f E is connected between the points A and C, through a one way key K_1. A sensitive galvanometer of resistance G is connected between the terminals B and D through another one way key K_2. After closing the keys K_1 and K_2, the resistance P, Q, R and S are so adjusted that the galvanometer shows no deflection. In this position the wheatstone bridge is said

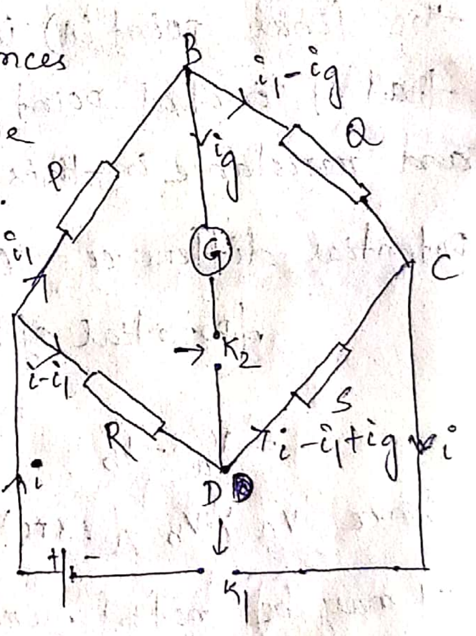

fig - Wheatstone bridge

to be balanced.

Using Kirchhoff's current law, the distribution of current and their directions through various resistances are as shown in the figure.

Now giving positive sign to the currents flowing in clockwise direction, and negative sign to the currents flowing in anti-clockwise direction and applying Kirchhoff's voltage law to the mesh ABD, we can write

$$i_1 P + i_g G - (i - i_1) R = 0 \quad \text{——— (1)}$$

Similarly, applying Kirchhoff's second law to the mesh BCD, we can write

$$(i_1 - i_g) Q - (i - i_1 + i_g) S - i_g \cdot G = 0 \quad \text{——— (2)}$$

The right hand sides of both the equation (1) and (2) are zero because there is no source of e.m.f in the both the closed circuits ABD and BCD.

Since the bridge is balanced, therefore the current 'i_g' flowing through the arm BD is zero.

Putting $i_g = 0$ in eqn (1) and (2), we get.

$$i_1 P - (i - i_1) R = 0$$

$$i_1 P = (i - i_1) R \quad \text{——— (3)}$$

$$i_1 Q - (i - i_1) S = 0$$

$$\Rightarrow i_1 Q = (i - i_1) S \quad \text{——— (4)}$$

Dividing eqn (3) by eqn (4), we get

$$\frac{i_1 P}{i_1 Q} = \frac{(i - i_1) R}{(i - i_1) S}$$

$$\boxed{\Rightarrow \frac{P}{Q} = \frac{R}{S}}$$

This is the required condition for the bridge to be balanced and gives the principle of Wheatstone bridge.

Unit - 11

Electromagnetism and Electro-magnetic induction

Electromagnetism :-

Electromagnetism is a branch of physics, deals with the electromagnetic force that occurs between electrically charged particles.

A charged body ~~of~~ is capable of producing electric charge in a neighbouring conductor. The phenomenon of induction of electricity due to electricity is called electric induction. A magnet is capable of producing magnetism in a neighbouring magnetic substance. This phenomenon of production of magnetism due to magnetism is called magnetic induction. A current flowing through a wire produces a magnetic field around itself. This phenomenon of production of magnetism due to electricity is called magnetic effect of currents. Can we produce electricity due to magnetism? This phenomenon of production of electricity due to magnetism, is called electro-magnetic induction.

Biot-savart's law :-

A wire carrying current has a magnetic field all around it. The intensity, at any point, in this magnetic field can be obtained with the help of "Biot-savart's law".

Consider a small section dl, a of a wire carrying a current (i). Let 'p' be the observation point at a distance 'r' from the centre 'o' of the element. The position vector of 'p' subtends an angle θ with the direction of flow of current in the element dl as shown in figure.

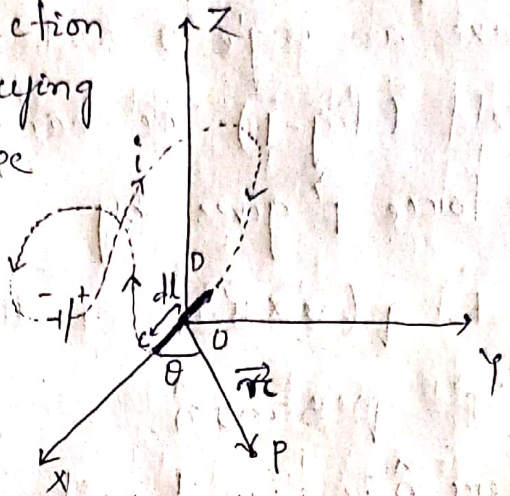

fig-1, strength of magnetic field, at any point due to a wire carrying current

If 'dB' is a magnetic intensity at P due to this small element, it has been observed that

$$dB \propto dl$$
$$\propto i$$
$$\propto \sin\theta$$
$$\propto \frac{1}{r^2}$$

Combining all these factors, we get

$$dB \propto \frac{i\,dl\sin\theta}{r^2}$$

$$dB = K\frac{i\,dl\sin\theta}{r^2} \quad \text{---(1)}$$

Where 'K' is the constant of properctionality and its value depends on the system of units selected

Motion of a charged particle inside a uniform magnetic field or Fleming's left hand rule

Consider a charge 'q' moving through a uniform magnetic field $\vec{B}$ with a velocity $\vec{v}$ in such a way that the direction of motion of charge makes an angle 'θ' with the direction of field (fig-1). The charge 'q' then experiences a force $\vec{F}$ gives by

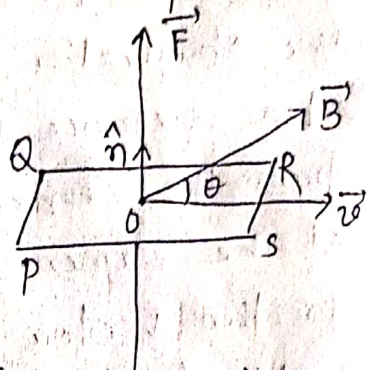

fig-1: Direction of force on a moving charge

$$\vec{F} = q(\vec{v} \times \vec{B}) \quad \text{---(1)}$$

$$\vec{F} = qvB\sin\theta\, \hat{n}$$

Where $\hat{n}$ is a unit vector in a direction perpendicular to the plane PQRS containing $\vec{v}$ and $\vec{B}$ (fig-1).

Direction of force

(i) In general, the direction of force is given by eqn (1) in accordance with the rule of cross product.

(ii) When the motion of charged particle and the direction of lines of force are at right angles to each other, the direction of force $\vec{F}$ can also be determined by Fleming's left hand rule, which can be stated as follows:

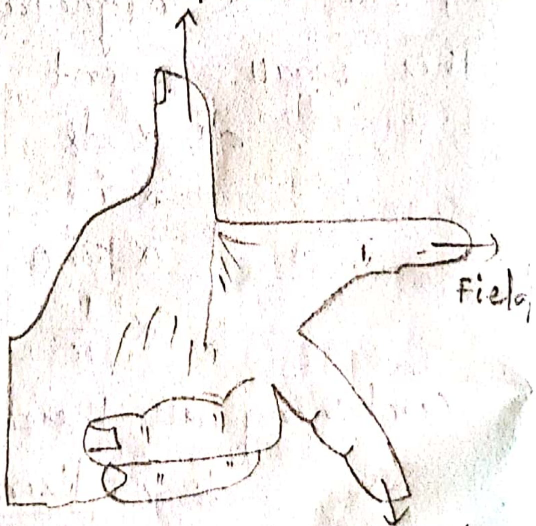

fig. Fleming's left hand rule

"stretch first finger, central finger and the thumb of your left hand in mutually perpendicular directions, If the first finger points to the field, central finger points to electric current (motion of positive charge), the thumb gives the direction of force".

Faraday's Laws of electro-magnetic induction

Faraday's laws deal with the induction of an e.m.f in an electric circuit when magnetic flux linked with the circuit changes. They are stated as follows:

(i) Whenever magnetic flux linked with a circuit changes, an e.m.f is induced in it.

(ii) The induced e.m.f exists in the circuit so long as the change in magnetic flux linked with it continues.

(iii) The induced e.m.f is directly proportional to the negative rate of change of magnetic flux linked with the circuit.

Rate of change of magnetic flux = $\frac{d\phi_B}{dt}$

If 'E' is e.m.f induced in the circuit as a result of this change,

$$E \propto -\frac{d\phi_B}{dt} \quad \text{or} \quad E = -K\frac{d\phi_B}{dt}$$

By selecting units of 'E', 'ϕ_B' and 't' in a proper way, we can have

$K = 1$

$$\boxed{E = -\frac{d\phi_B}{dt}}$$

Fleming's right hand rule

It is a rule to find the direction of induced current in a conductor. It can be stated as follows :

Strech first finger, central finger and the thumb of your right hand in three mutually perpendicular ~~points~~ directions. If the first finger points towards the magnetic field, thumb points towards the direction of motion

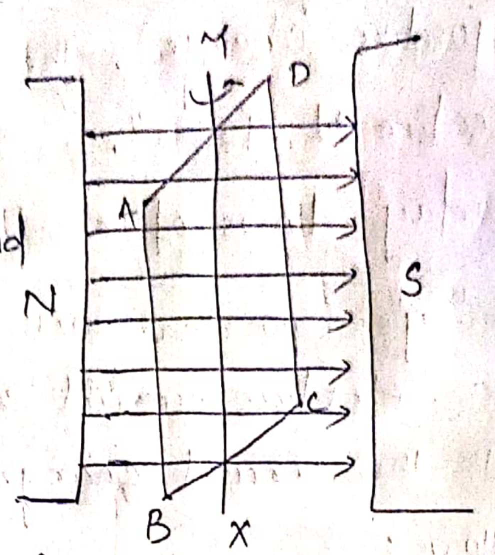

fig-1: A rectangular coil rotating in a uniform magnetic field

of conductor, the direction of central finger ~~gives~~ gives the direction of induced current setup in the conductor.

Consider a coil ABCD turning in between the two pole pieces of a magnet as shown in fig-1. Let the direction of rotation of the coil be such that AB moves out of the plane of the paper while CD moves into. Applying Fleming's right hand rule separately on AB and CD, it can be seen that direction of induced current is from 'B to A' and 'D to C'.

Unit-12

MODERN PHYSICS

Laser and Laser beam

A laser is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. The term "Laser" originated as an acronym for 'light amplification by stimulated emission of radiation.

Spatial coherence also allows a laser beam to stay narrow over great distances (collimation), enabling applications such as laser pointers and lidar.

Principle of Laser :-

Every laser system consists of an active-medium (solid, liquid or a gas) having ions/molecules of atom possessing at least one meta stable state. The basic principle of all lasers is to first bring about population inversion i.e, to have more atoms in the meta-stable state than that in the ground state. This is done by supplying suitable energy to the atoms of the active medium with the help of a pump. This process of bringing about population inversion is known as pumping.

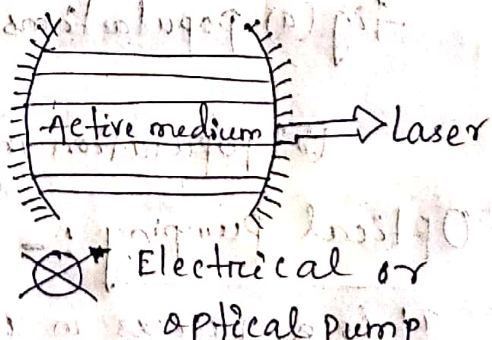

fig: Resonating cavity

Population inversion :-

In normal situation there are more number of atoms in the ground state ready to absorb Photons. In the excited state ready to emit Photons. If the situation is just reversed that is there are more atoms in the excited State. Then in ground state a net emission of Photon can result such a condition is called population inversion.

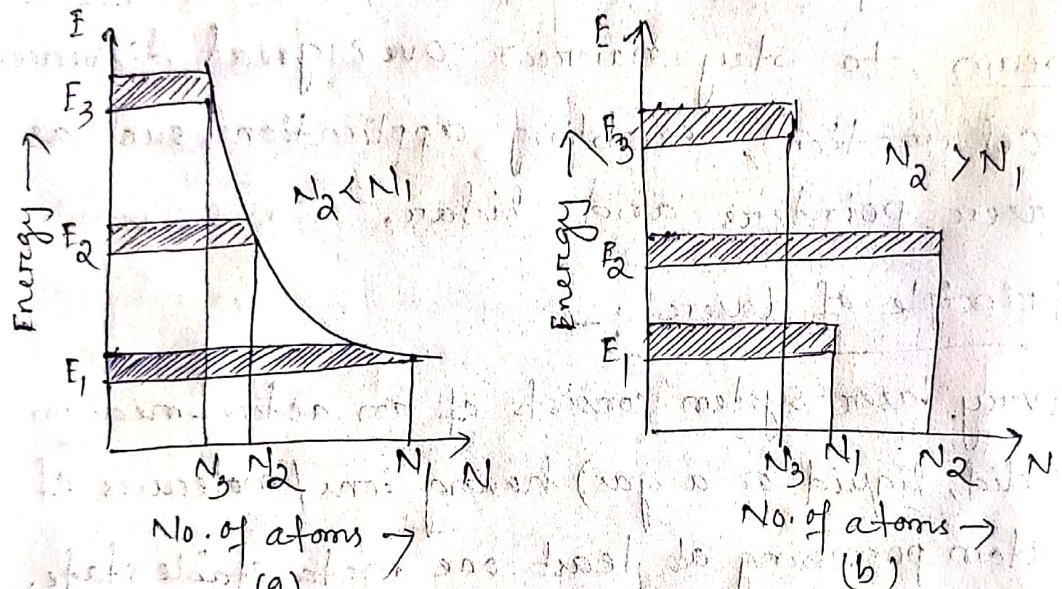

fig (a) populations at different energy states of atoms

(b) population inversion through pumping process

Optical pumping :-

It is a process in which light is used to raise or "pump" electrons from a lower energy level in an atom or molecule to a higher one. It is commonly used in laser construction, to pump the active laser medium so as to achieve population inversion.

properties and application of laser :-

properties of laser :-

Laser are often termed as monochromatic, coherent and collimated source of light. The parameter that monochromaticity, coherent, directionality and high intensity of laser source are as follows :

Monochromaticity :-

Monochromatic means same frequency or wavelength. The wavelength width of the laser emission is generally cofined in the range of 10^{-7} to 10^{-2} A° for high quality of stable laser to a poor quality laser, whereas in the thermal sources wavelength spread is of the order of 10^{3} A°. ($1A° = 10^{-8}cm$)

Coherent :-

Not only laser light is monochromatic but also it's constituent photons are all of the same phase giving the coherent character to the laser light. The light produced by ~~an~~ LED equipped with an optical filter, may will be monochromatic radiation but not coherent. The coherent of laser is due to its uniphase wavefront arising due to its diffraction limited operation.

Directionality :-

Again because of the collimated properties of laser it can travel over large distances without being dispersed. The laser essentially sends out plane waves in a very narrow regular extent governed by the diffraction at the mirror ends of the source. For example, He Ne laser has a beam divergence angle in the order of 0.6° i.e milliradian.

High intensity :-

Laser are extremely bright in comparision to more conventional sources. The emission of photon from typical lasers ranges over $10^{16} - 10^{28}$ photons/sec. Whereas, thermal source emit at the rate of 10^{12} photon/sec.

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Engineering Physics. (sample Question - 2nd sem - 2020.

1. Answer all the questions $10 \times 2 = 20$ marks.

(i) What is scalar quantities and vector quantities?

(ii) Define parallel and anti parallel vectors?

(iii) write Parallelogram law of vector addition?

(iv) check the dimensional correctness

(a) $T = 2\pi\sqrt{\frac{g}{l}}$ (b) $t = 2\pi\sqrt{\frac{m}{F/x}}$ (c) $v^2 - u^2 = 2as$.

(v) find the magnitude.

$\vec{A} = 2\hat{i} + 3\hat{j} + 4\hat{k}$
$\vec{B} = 3\hat{i} + 2\hat{j} + 3\hat{k}$ find $\vec{A} \times \vec{B}$ and $|\vec{A} \times \vec{B}| = ?$

(vi) Find the displacement from A to B?

(vii) what is the difference between speed and velocity?

(viii) A railway train 200 m. long moves with speed of 72 $km\,h^{-1}$. calculate the time taken by the train to cross a bridge 0.8 km long?

(ix) what is specific heat and its unit?

(x) Relation between α, β and γ?

2. Answer any five questions? $6 \times 5 = 30$ marks

(i) write the triangle's law of vector addition?

(ii) Two forces 5N and 20N are acting at an angle 120° between them. find the resultant force in magnitude and direction?

(iii) find the expression for distance travel in t-second.

$s = ut + \frac{1}{2}at^2$

(iv) An aeroplane is flying horizontally at a height of 490 m with velocity 360 $km\,h^{-1}$ a bag containing ration is to be dropped the Jawans on the ground. ~~An article is~~ How far from there should the bag to be released so that it falls over them?

(v) Find the relation between g and G?

(vi) Kepler's law of planetary motion (all three statement)

(vii) Define simple Harmonic motion (Definition with example.

3. Long Question Type (any two). 10 × 2 = 20

(i) Derive relationship between velocity, frequency and wavelength of a wave?

(ii) Deduce Triangle Law of vector addition

(iii) Expression for equation of trajectory, time of flight, maximum Height and Horizontal range for a projectile fired at an angle condition for maximum Horizontal range?

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