COMMON QUARTERLY EXAMINATION – 2022

Std – XII

Physics

Time : 3.00 Hours **Marks : 70**

Part – I

Note : i) Answer all the questions. Choose the most appropriate answer from the given four alternatives and write the option code and the corresponding answer.

15 X 1 = 15

1) c) 900 V m^{-1}
2) b) line absorption
3) c) C remains same. C is doubled
4) d) energy density
5) c) 480 W
6) a) straight line
7) a) 2A
8) c) 0.46 W
9) b) 1.2 Am^2
10) b) 45^0
11) c) refraction
12) d) equal to that of glass
13) c) Nm^2C^{-1}
14) b) 7.07A
15) a) $\chi_m = \frac{C}{T - T_C}$

Part – II

6 x 2 = 12

Note : Answer any six Questions. Question No. 24 is Compulsory.

16) Why does sky appear blue?

- According to the law of Rayleigh's scattering, violet colour which has the shortest wavelength gets much scattered during day time.
- The next scattered colour is blue. As our eyes are more sensitive to blue colour than violet colour the sky appears blue during day time

17) Give any two uses of IR radiation.

It is used in,

- producing dehydrated fruits
- green housed to keep the plants warm,
- heat therapy for muscular pain or sprain
- TV remote as a signal carrier, to look through haze fof or mist
- night vision or infrared photography

18) State Coulomb's law in electrostatics.

- According to Coulomb law, the force on the point charge q_2 exerted by another point charge q_1 is

$$\vec{F}_{21} = k \frac{q_1 q_2}{r^2} \hat{r}_{12}$$

where $\hat{r}_{12} \rightarrow$ unit vector directed from q_1 to q_2
k $\rightarrow$ the proportionality constant.

19) State Faraday's laws of electromagnetic induction

First law

Whenever magnetic flux linked with a closed circuit changes, an emf is induced in the circuit which lasts in the circuit as long as the magnetic flux is changing.

Second law

The magnitude of induced emf in a closed circuit is equal to the time rate of change of magnetic flux linked with the circuit.

20) State Ampere's circuital law.

The line integral of magnetic field over a closed loop is μ_0 times net current enclosed by the loop.

$$\oint \vec{B}\,\vec{dl} = \mu_0 I_{elclosed}$$

where $I_{enclosed}$ is the net current linked by the closed loop C.

21) Is an ammeter connected in series or parallel in a circuit? Why?

1. An ammeter is a low resistance instrument and it is always connected in series to the circuit
2. An ideal ammeter has zero resistance
3. In order to increase the range of an ammeter n times, the value of shunt resistance to be connected in parallel is

$$S = \frac{Rg}{n-1}$$

22) What is peltier effect?

When an electric current is passed through a circuit of a thermocouple, heat is evolved at one junction and absorbed at the other junction. This is known as Peltier effect.

23) How will you define Q – factor?

It is defined as the ratio of voltage across L or C at resonance to the applied voltage.

$$\text{Q-factor} = \frac{Voltage across\ LorC\ at\ resonance}{Appliedvoltage}$$

24) A sample of HCl gas is placed in a uniform electric field of magnitude 3×10^4 N C^{-1}. The dipole moment of each HCl molecule is 3.4×10^{-30} Cm. Calculate the maximum torque experienced by each HCl molecule.

Solution

The maximum torque experienced by the dipole is when it is aligned perpendicular to the applied field.

$\tau_{max} = pE \sin 90^0$

$\tau_{max} = 3.4 \times 10^{-30} \times 3 \times 10^4$

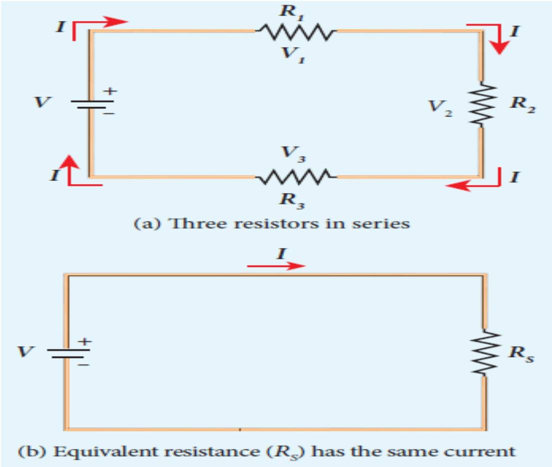
$\tau_{max} = 10.2 \times 10^{-26}$ Nm

Part – III

Note : Answer any six questions. Question No. 33 is compulsory. 6 x 3 = 18

25) Explain the equivalent resistance of a series resistor network.

Resistors in series



When two or more resistors are connected end to end, they are said to be in series. The resistors could be simple resistors or bulbs or heating elements or other devices. Three resistors R_1, R_2 and R_3 connected in series. The amount of charge passing through resistor R_1 must also pass through resistors R_2 and R_3 since the charges cannot accumulate anywhere in the circuit. Due to this reason, the current I passing through all the three resistors is the same. According to Ohm's law, if same current pass through different resistors of different values, then the potential difference across each resistor must be different. If V_1, V_2 and V_3 be the potential differences (voltage) across each of the resistors R_1, R_2 and R_3 respectively, then we can write $V_1 = IR_1$, $V_2 = IR_2$ and $V_3 = IR_3$. But the supply voltage V must be equal to the sum of voltages(potential differences) across each resistor.

$$V = V_1 + V_2 + V_3 = IR_1 + IR_2 + IR_3$$
$$V = I(R_1 + R_2 + R_3)$$
$$V = IR_S$$

where RS is the equivalent resistance.

$$R_S = R_1 + R_2 + R_3$$

26) Write advantages and disadvantages of AC over DC.

Advantages:

(i) The generation of AC is cheaper than that of DC.
(ii) When AC is supplied at higher voltages, the transmission losses are small compared to DC transmission.
(iii) AC can easily be converted into DC with the help of rectifiers.

Disadvantages:

(i) Alternating voltages cannot be used for certain applications such as charging of batteries, electroplating, electric traction etc.
(ii) At high voltages, it is more dangerous to work with AC than DC.

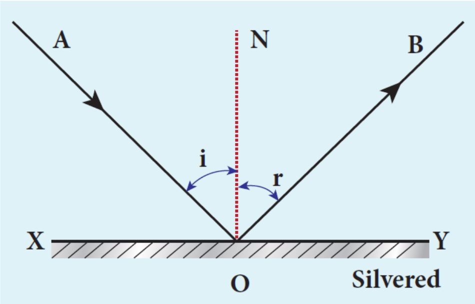
27) State the law of reflection.

According to laws of reflection,

(i) The incident ray, reflected ray and normal to the reflecting surface are all coplanar (ie. lie in the same plane).

(ii) The angle of incidence i is equal to the angle of reflection r.

$$i = r$$

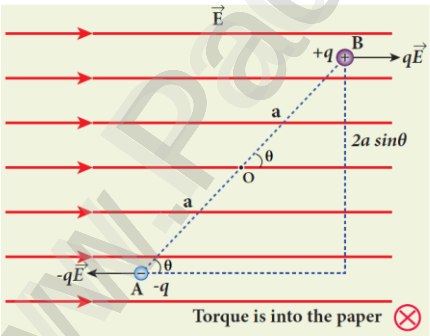


28) What are Fraunhofer lines? How are they useful in the identification of elements present in the sun?

Fraunhofer lines

When the spectrum obtained from the Sun is examined, it consists of large number of dark lines (line absorption spectrum). These dark lines in the solar spectrum are known as Fraunhofer lines. The absorption spectra for various materials are compared with the Fraunhofer lines in the solar spectrum, which helps in identifying elements present in the Sun's atmosphere.

29) Derive an expression for the torque experienced by a dipole due to a uniform electric field.



Consider an electric dipole of dipole moment $\vec{p}$ placed in a uniform electric field $\vec{E}$ whose field lines are equally spaced and point in the same direction. The charge $+q$ will experience a force $q\,\vec{E}$ in the direction of the field and charge $-q$ will experience a force $-q\,\vec{E}$ in a direction opposite to the field. Since the external field $\vec{E}$ is uniform, the total force acting on the dipole is zero. These two forces acting at different points will constitute a couple and the dipole experience a torque. This torque tends to rotate the dipole. The total torque on the dipole about the point O

$$\vec{\tau} = \overrightarrow{OA}\ X\ (-q\vec{E}) + \overrightarrow{OB}\ X\ q\vec{E}$$

Using right-hand corkscrew rule. It is found that total torque is perpendicular to the plane of the paper and is directed into it.

The magnitude of the total torque $\tau = |\overrightarrow{OA}||(-q\vec{E})|\sin\theta + |\overrightarrow{OB}||(q\vec{E})|\sin\theta$

$$\tau = qE\ .\ 2a\sin\theta$$

where θ is the angle made by $\vec{p}$ with $\vec{E}$. Since $p = 2aq$, the torque is written in terms of the vector product as

$$\tau = \vec{p} \times \vec{E}$$

The magnitude of this torque is $\tau = pE \sin\theta$ and is maximum when $\theta = 90^0$.
This torque tends to rotate the dipole and align it with the electric field $\vec{E}$. Once $\vec{p}$ is aligned with $\vec{E}$, the total torque on the dipole becomes zero.

30) What are the difference between Coulomb force and gravitational force.

Coulomb force	Gravitational force
It acts between two charges .	It acts between two masses
It can be attractive or repulsive.	It is always attractive
It is always greater in magnitude.	It is always lesser in magnitude
It depends on the nature of the medium.	It is independent of the medium
If charges are in motion, another force called Lorentz force come in to play in addition to Coulomb force .	Gravitational force is the same whether two masses are at rest or in motion

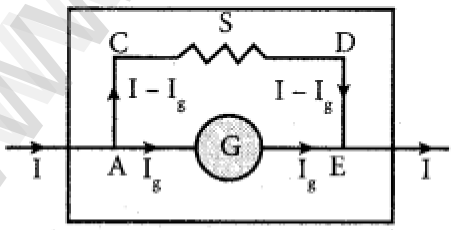
31) Discuss the conversion of galvanometer into a ammeter.

Conversion of galvanometer into ammeter and voltmeter:

A galvanometer is a very sensitive instrument to detect the current. It can be easily converted into an ammeter and voltmeter.

(i) Galvanometer to an Ammeter:

An ammeter is an instrument used to measure the current flowing in the electrical circuit. The ammeter must offer low resistance such that it will not change the current passing through it. So ammeter is connected in series to measure the circuit current.



Ammeter

A galvanometer is converted into an ammeter by connecting a low resistance in parallel with the galvanometer. This low resistance is called shunt resistance S. The scale is now calibrated in ampere and the range of ammeter depends on the values of the shunt resistance.

Let I be the current passing through the circuit. When current I reach junction A, it divides into two components. Let I_g be the current passing through the galvanometer of resistance R_g through a path AGE and the remaining current $(I – I_g)$ passes along the path ACDE through shunt resistance S.

The value of shunt resistance is so adjusted that current I produce full-scale deflection in the galvanometer. The potential difference across galvanometer is the same as the potential difference across shunt resistance.

$$V_{galvanometer} = V_{shunt} \Rightarrow I_g R_g = (I - I_g)S$$

$$S = \frac{I_s}{(I - I_g)} R_g \quad \text{(or)} \quad I_g = \frac{S}{S + R_g} 1 \Rightarrow I_g \propto I$$

Since, the deflection in the galvanometer is proportional to the current passing through it.

$$\theta = 1g\, I_g \Rightarrow \theta\, Ig \Rightarrow \theta \propto I$$

So, the deflection in the galvanometer measures the current I passing through the circuit (ammeter). Shunt resistance is connected in parallel to a galvanometer. Therefore, the resistance of the ammeter can be determined by computing the effective resistance, which is

$$\frac{1}{R_{eff}} = \frac{1}{R_g} + \frac{1}{S} \Rightarrow R_{eff} = \frac{R_g S}{R_g + S} = R_a$$

Since, the shunt resistance is a very low resistance and the ratio *SRg* is also small. This means, R_g is also small, i.e., the resistance offered by the ammeter is small. So, when we connect ammeter in series, the ammeter will not change the resistance appreciably and also the current in the circuit. For an ideal ammeter, the resistance must be equal to zero. Hence, the reading in the ammeter is always lesser than the actual current in the circuit. Let I_{ideal} be current measured from ideal ammeter and I_{actual} be the actual current measured in the circuit by the ammeter. Then, the percentage error in measuring a current through an ammeter is

$$\frac{\Delta I}{I} \times 100\% = \frac{I_{ideal} - I_{actual}}{I_{actual}} \times 100\%$$

32) Mention the various energy losses in a transformer.

Energy losses in a transformer: Transformers do not have any moving parts so that its efficiency is much higher than that of rotating machines like generators and motors. But there are many factors which lead to energy loss in a transformer.

(i) Core loss or Iron loss:

This loss takes place in the transformer core. Hysteresis loss and eddy current loss are known as core loss or Iron loss. When the transformer core is magnetized and demagnetized repeatedly by the alternating voltage applied across the primary coil, hysteresis takes place due to which some energy is lost in the form of heat.

Hysteresis loss is minimized by using steel of high silicon content in making transformer core. Alternating magnetic flux in the core induces eddy currents in it. Therefore there is energy loss due to the flow of eddy current, called eddy current loss which is minimized by using very thin laminations of the transformer core.

(ii) Copper loss:

Transformer windings have electrical resistance. When an electric current flows through them, some amount of energy is dissipated due to Joule heating. This energy loss is called copper loss which is minimized by using wires of larger diameter.

(iii) Flux leakage:

Flux leakage happens when the magnetic lines of the primary coil arc not completely linked with the secondary coil. Energy loss due to this flux leakage is minimized by winding coils one over the other.

33) If the resistance of the coil is 3Ω at 20 °C and $\alpha = 0.004/°C$, then determine resistance At 100 °C.

Solution:

The resistance of a nichrome wire at 20°C, R_0 = 3Ω

Temperature coefficient of resistance, α = 0.004/°C

Resistance at the boiling point of water, RT =?

The temperature of the boiling point of water, T = 100 °C

$R_T = R_0 (1 + \alpha T) = 3[1 + (0.004 \times 100)]$

$R_T = 3(1 + 0.4) = 3 \times 1.4$

$R_T = 4.2\ \Omega$

As the temperature increases, the resistance of the wire also increases.

Part – IV

Note : Answer all the questions. **5 x 5 = 25**

34) a) Write down Maxwell equations in integral form.

Maxwell's equations in integral form:

Electrodynamics can be summarized into four basic equations, known as Maxwell's equations. These equations are analogous to Newton's equations in mechanics. Maxwell's equations completely explain the behavior of charges, currents and properties of electric and magnetic fields. So we focus here only in integral form of Maxwell's equations:

(i) First equation is nothing but the Gauss's law. It relates the net electric flux to net electric charge enclosed in a surface. Mathematically, it is expressed as

$$\oint \vec{E}.d\vec{A} = \frac{Q_{enclosed}}{\varepsilon_0}$$

Where $\vec{E}$ is the electric field and Q enclosed is the charge enclosed. This equation is true for both discrete or continuous distribution of charges. It also indicates that the electric field lines start from positive charge and terminate at negative charge. This implies that the electric field lines do not form a continuous closed path. In other words, it means that isolated positive charge or negative charge can exist.

(ii) Second equation has no name. But this law is similar to Gauss's law in electrostatics. So this law can also be called as Gauss's law in magnetism. The surface integral of magnetic field over a closed surface is zero. Mathematically,

$$\oint \vec{B}.d\vec{A} = 0$$

where $\vec{B}$ is the magnetic field. This equation implies that the magnetic lines of force form a continuous closed path. In other words, it means that no isolated magnetic monopole exists.

(iii) Third equation is Faraday's law of electromagnetic induction. This law relates electric field with the changing magnetic flux which is mathematically written as

$$\oint \vec{E}\,.\,\vec{dl} = ddt\ \Phi_B$$

where $\vec{E}$ is the electric field. This equation implies that the line integral of the electric field around any closed path is equal to the rate of change of magnetic flux through the closed path bounded by the surface.

(iv) Fourth equation is modified Ampere's circuital law. This is also known as ampere-Maxwell's law. This law relates the magnetic field around any closed path to the conduction current and displacement current through that path.

$$\oint \vec{B}.d\vec{l} = \mu_0 I_{enclosed} + \mu_0 \varepsilon_0 \int_s \vec{E}.d\vec{A}$$

Where $\vec{B}$ is the magnetic field. This equation shows that both conduction and also displacement current produces magnetic field. These four equations are known as Maxwell's equations in electrodynamics.

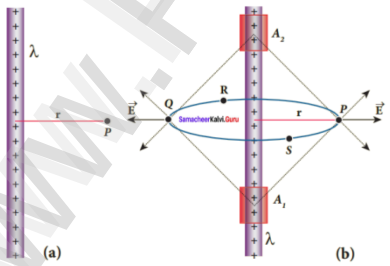
34) b) Obtain the expression for electric field due to an infinitely long charged wire.

Electric field due to an infinitely long charged wire:

Consider an infinitely long straight wire having uniform linear charge density λ. Let P be a point located at a perpendicular distance r from the wire. The electric field at the point P can be found using Gauss law. We choose two small charge elements A_1 and A_1 on the wire which are at equal distances from the point P.

The resultant electric field due to these two charge elements points radially away from the charged wire and the magnitude of electric field is same at all points on the circle of radius r. From this property, we can infer that the charged wire possesses a cylindrical symmetry.

Let us choose a cylindrical Gaussian surface of radius r and length L. The total electric flux in this closed surface is



Electric field due to infinite long charged wire

$$\Phi_E = \oint \vec{E}.d\vec{A} \qquad ...(1)$$

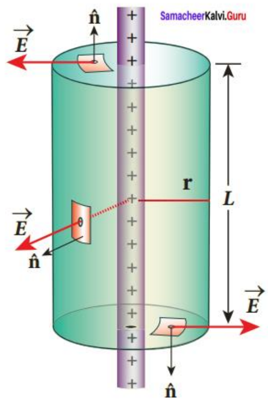
$$\Phi_E = \int_{\text{Curved surface}} \vec{E}.d\vec{A} + \int_{\text{Top surface}} \vec{E}.d\vec{A} + \int_{\text{Bottom surface}} \vec{E}.d\vec{A} \qquad ...(2)$$

It is seen that for the curved surface, $\vec{E}$ is parallel to $\vec{A}$ and $\vec{E}\,.d\,\vec{A} = EdA$. For the top and bottom surface, $\vec{E}$ is perpendicular to $\vec{A}$ and $\vec{E}\,.d\vec{A} = 0$

Substituting these values in equation (2) and applying Gauss law

$$\Phi_E = \int_{\substack{\text{Curved}\\ \text{surface}}} E\,dA = \frac{Q_{encl}}{\varepsilon_0} \quad ...(3)$$

Since the magnitude of the electric field for the entire curved surface is constant, E is taken out of the integration, and Q_{encl} is given by $Q_{encl} = \lambda L$.



Cylindrical Gaussian surface

$$E \int_{\substack{\text{Curved}\\ \text{surface}}} dA = \frac{\lambda L}{\varepsilon_0} \quad ...(4)$$

Here,

$$\Phi_E = \int_{\substack{\text{Curved}\\ \text{surface}}} dA$$

dA = total area of the curved surface = $2\pi rL$. Substituting this in equation (4),

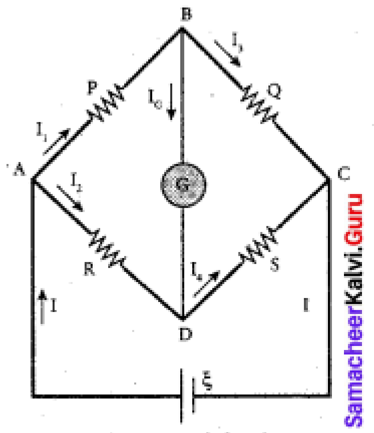
$$E.2\pi rL = \frac{\lambda L}{\varepsilon_0} \text{ (or) } E = \frac{1}{2\pi\varepsilon_0}\frac{\lambda}{r} \quad ...(5)$$

In vector form, $$\vec{E} = \frac{1}{2\pi\varepsilon_0}\frac{\lambda}{r}\hat{r} \quad ...(6)$$

The electric field due to the infinite charged wire depends on 1r rather than 1r^2 for a point charge.Equation (6) indicates that the electric field is always along the perpendicular direction ($\hat{r}$) to wire. In fact, if $\lambda > 0$ then E points perpendicular outward ($\hat{r}$) from the wire and if $\lambda < 0$, then E points perpendicular inward (-$\hat{r}$).

35) a) Obtain the condition for bridge balance in Wheatstone's bridge.

An important application of Kirchhoff's rules is the Wheatstone's bridge. It is used to compare resistances and also helps in determining the unknown resistance in the electrical networks. The – bridge consists of four resistances P, Q, R, and S connected. A galvanometer G is connected between points B and D. The battery is connected between points A and C. The current through the galvanometer is I_G and its resistance is G.



Wheatstone's bridge

Applying KirchhofFs current rule to junction B,

$I_1 - I_G - I_3 = 0$ …….. (1)

Applying Kirchhoff's current rule to junction D,

$I_2 - I_G - I_4 = 0$ …….. (2)

Applying Kirchhoff's voltage rule to loop ABDA,

$I_1P + I_GG - I_2R = 0$ …….. (3)

Applying Kirchhoff's voltage rule to loop ABCDA,

$I_1P + I_3Q - I_4S - I_2R = 0$ …….. (4)

When points B and D are at the same potential, the bridge is said to be balanced. As there is no potential difference between B and D, no current flows through the galvanometer ($I_G = 0$).

Substituting $I_G = 0$ in equation, (1), (2) and (3), we get

$I_1 = I_3$ …….. (5)

$I_2 = I_4$ …….. (6)

$I_1P = I_2R$ …….. (7)

Substituting the equation (5) and (6) in equation (4)

$I_1P + I_1Q - I_2R = 0$

$I_1(P + Q) = I_2 (R + S)$ …….. (8)

Dividing equation (8) by equation (7), we get

$P+QP = R+SR$

$1 + QP = 1 + SR$

$\Rightarrow QP = SR$

$PQ = RS$ …….. (9)

This is the bridge balance condition. Only under this condition, galvanometer shows null deflection. Suppose we know the values of two adjacent resistances, the other two resistances can be compared. If three of the resistances are known, the value of unknown resistance (fourth one) can be determined.

35) b) Derive the mirror equation and the equation for lateral magnification.

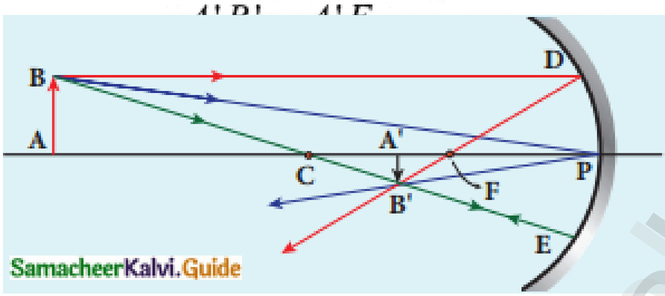
1. AB is an object considered on the principal axis of a concave mirror.
2. Consider three paraxial rays from point B on the object.
3. The three reflected rays intersect at the point 'B'.
4. A perpendicular drawn as A' B' to the principal axis is the real, inverted image of the object AB.
5. Δ BPA and Δ B'PA are similar

$$\frac{A'B'}{AB}=\frac{PA'}{PA}$$

Mirror equation

Δ DPF and Δ B′A′ F are also almost similar

$$\frac{A'B'}{PD}=\frac{A'F}{PF}$$



$$\frac{PA'}{PA}=\frac{PA'-PF}{PF}$$

PA = -u, PA′ = -v, PF = -f

$$\frac{-v}{u}=\frac{-v(-f)}{-f}$$

$$\frac{v}{u}=\frac{v-f}{f}$$

$$\frac{v}{u}=\frac{v}{f}-1$$

$$\frac{1}{u}=\frac{1}{f}-\frac{1}{v}$$

$$\boxed{\frac{1}{v}+\frac{1}{u}=\frac{1}{f}}$$

This is called mirror equation.

Lateral magnification

$$\text{Magnification (m)} = \frac{\text{height the image (h')}}{\text{height of the object (h)}}$$

$$\frac{A'B'}{AB}=\frac{PA'}{PA}$$

$$\frac{-h'}{h}=\frac{-v}{u}$$

$$m=\frac{h'}{h}=\frac{-v}{u}$$

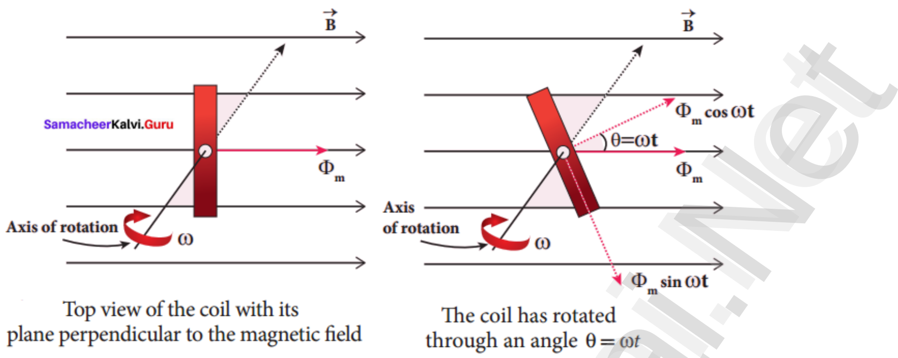
Using mirror equation

$$m=\frac{f-v}{f}=\frac{f}{f-u}$$

36) a) Show mathematically that the rotation of a coil in a magnetic field over one rotation induces an alternating emf of one cycle.

Induction of emf by changing relative orientation of the coil with the magnetic field:

Consider a rectangular coil of N turns kept in a uniform magnetic field $\vec{B}$. The coil rotates in anti-clockwise direction with an angular velocity ω about an axis, perpendicular to the field. At time = 0, the plane of the coil is perpendicular to the field and the flux linked with the coil has its maximum value Φ_m = BA (where A is the area of the coil).



In a time t seconds, the coil is rotated through an angle θ (= ωt) in anti-clockwise direction. In this position, the flux linked is $\Phi_m \cos \omega t$, a component of Φ_m normal to the plane of the coil (figure (b)). The component parallel to the plane ($\Phi_m \sin \omega t$) has no role in electromagnetic induction.

Therefore, the flux linkage at this deflected position is

$$N\Phi_B = NBA \cos \theta$$
$$= NBA \cos \omega t$$

According to Faraday's law, the emf induced at that instant is

$$\varepsilon = -\frac{d}{dt}(N\Phi_B)$$
$$= -\frac{d}{dt}(NBA \cos \omega t)$$
$$= -NBA(-\sin \omega t)\omega$$
$$= NBA\omega \sin \omega t$$

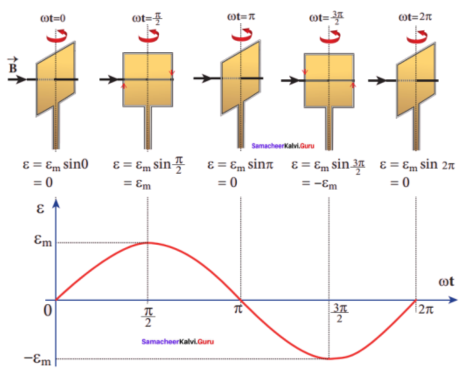
When the coil is rotated through 90° from the initial position, sin ωt = 1, Then the maximum value of induced emf is

$$\varepsilon_m = NBA\omega$$

Therefore, the value of induced emf at that instant is then given by

$$\varepsilon = \varepsilon_m \sin \omega t$$

It is seen that the induced emf varies as sine function of the time angle ωt. The graph between – induced emf and time angle for one rotation of coil will be a sine curve and the emf varying in this manner is called sinusoidal emf or alternating emf.

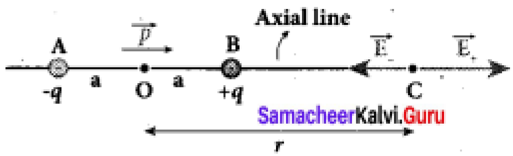


Variation of induced emf as a function of ωt

36) b) Calculate the electric field due to a dipole on its axial line.

Case (I) :

Electric field due to an electric dipole at points on the axial line. Consider an electric dipole placed on the x-ax is as shown in the figure. A point C is located at a distance of r from the midpoint O of the dipole along the axial line. Axial line



Electric field of the dipole along the axial line

The electric field at a point C due to +q is

$$\vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{q}{(r-a)^2} \text{ along BC}$$

Since the electric dipole moment vector $\vec{P}$ is from -q to +q and is directed along BC, the above equation is rewritten as

$$\vec{E}_+ = \frac{1}{4\pi\varepsilon_0} \frac{q}{(r-a)^2} \hat{p} \quad \text{...(1)}$$

where $\hat{p}$ is the electric dipole moment unit vector from -q to +q. The electric field at a point C due to -q is

$$\vec{E}_- = -\frac{1}{4\pi\varepsilon_0} \frac{q}{(r+a)^2} \hat{p} \quad \text{...(2)}$$

Since +q is located closer to the point C than -q, $\vec{E}_+$ is stronger than $\vec{E}$.
Therefore, the length of the $\vec{E}_+$ vector is drawn large than that of $\vec{E}_-$ vector.

The total electric field at point C is calculated using the superposition principle of the electric field.

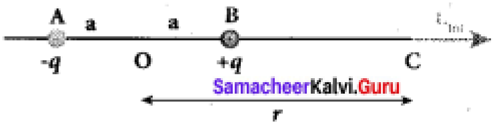
$$\vec{E}_{tot} = \vec{E}_+ + \vec{E}_- \quad \text{...(3)}$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{q}{(r-a)^2} \hat{p} - \frac{1}{4\pi\varepsilon_0} \frac{q}{(r-a)^2} \hat{p}$$

$$\Rightarrow \vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0} \left(\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2} \right) \hat{p} \quad \text{...(4)}$$

$$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0} q \left(\frac{4ra}{(r^2-a^2)^2} \right) \hat{p} \quad \text{...(5)}$$

Note that the total electric field is along $\vec{E}_+$, since +q is closer to C than -q.



Total electric field of the dipole on the axial line

The direction of $\vec{E}_{tot}$ is shown in Figure.

If the point C is very far away from the dipole then (r >> a). Under this limit the term $(r^2 - a^2)^2 \approx r^4$ Substituting this into equation, we get

$$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0}\left(\frac{4aq}{r^3}\right)\hat{p} \quad (r >> a) \quad \ldots(6)$$

SamacheerKalvi.Guru since $2aq\,\hat{p} = \vec{p}$

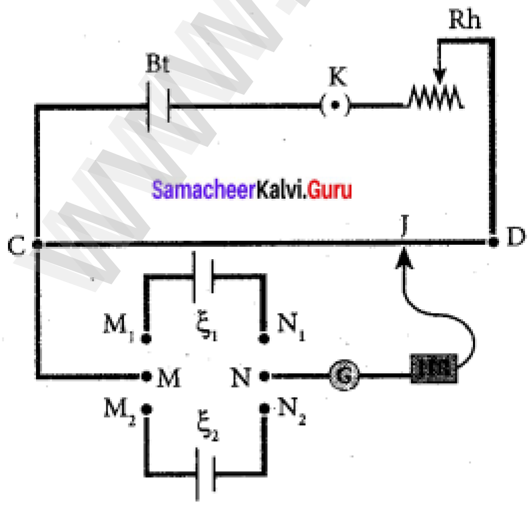
$$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{r^3} \quad (r >> a)$$

If point C is chosen on the left side of the dipole, the total electric field is still in the direction of $\vec{p}$

37) a) How the emf of two cells are compared using potentiometer.

Comparison of emf of two cells with a potentiometer:

To compare the emf of two cells, the circuit connections are made as shown in the figure. Potentiometer wire CD is connected to a battery Bt and a key K in series. This is the primary circuit. The end C of the wire is connected to the terminal M of a DPDT (Double Pole Double Throw) switch and the other terminal N is connected to a jockey through a galvanometer G and a high resistance HR. The cells whose emf ξ_1 and ξ_2 to be compared are connected to the terminals M_1, N_1 and M_2, N_2 of the DPDT switch.



The positive terminals of Bt, ξ_1, and ξ_2 should be connected to the same end C. The DPDT switch is pressed towards M_1, N_1 so that cell ξ_1 is included in the secondary circuit and the balancing length l_1 is found by adjusting the jockey for zero deflection.

Then the second cells ξ_2 is included in the circuit and the balancing length l_2 is determined. Let r be the resistance per unit length of the potentiometer wire and I be the current flowing through the wire.

we have.

$\xi_1 = Irl_1$ …… (1)

$\xi_2 = Irl_2$ ……. (2)

By dividing (1) by (2)

$\xi 1 \xi 2 = l1 l2$ ……. (3)

By including a rheostat (Rh) in the primary circuit, the experiment can be repeated several times by changing the current flowing through it.

37) b) Discuss the working of cyclotron in detail.

Cyclotron:

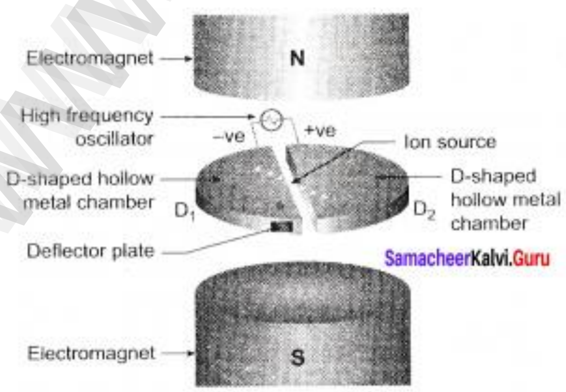
A cyclotron is a device used to accelerate the charged particles to gain large kinetic energy. It is also called as high energy accelerator. It was invented by Lawrence and Livingston in 1934.

Principle:

When a charged particle moves normal to the magnetic field, it experiences magnetic Lorentz force.

Construction:

The particles are allowed to move in between two semicircular metal containers called Dees (hollow D – shaped objects). Dees are enclosed in an evacuated chamber and it is kept in a region with uniform magnetic field controlled by an electromagnet. The direction of the magnetic field is normal to the plane of the Dees. The two Dees are kept separated with a gap and the source S (which ejects the particle to be accelerated) is placed at the center in the gap between the Dees. Dees are connected to high frequency alternating potential difference.



Working:

Let us assume that the ion ejected from source S is positively charged. As soon as ion is ejected, it is accelerated towards a Dee (say, Dee – 1) which has negative potential at that time. Since the magnetic field is normal to the plane of the Dees, the ion undergoes circular path. After one semi-circular path in Dee-1, the ion reaches the gap between Dees. At this time, the polarities of the Dees are reversed so that the ion is now accelerated towards Dee-2 with a greater velocity. For this circular motion, the centripetal force of the charged particle q is provided by Lorentz force.

$mv^2 / r = qvB$

$\Rightarrow r = m / qb\ v$

$\Rightarrow r \propto v$

From the equation, the increase in velocity increases the radius of circular path. This process continues and hence the particle undergoes spiral path of increasing radius. Once it reaches near the edge, it is taken out with the help of deflector plate and allowed to hit the target T. Very important condition in cyclotron operation is the resonance condition. It happens when the frequency f at which the positive ion circulates in the magnetic field must be equal to the constant frequency of the electrical oscillator f_{osc} From equation

$f_{osc} = qB / 2\pi m \quad T = 1/ f_{osc}$

The time period of oscillation is

$T = 2\pi m / qB$

The kinetic energy of the charged paricle is

$K\,E = 1/2\ mv^2 = q^2B^2r^2 / 2\ m$

Limitations of cyclotron:

(a) the speed of the ion is limited

(b) electron cannot be accelerated

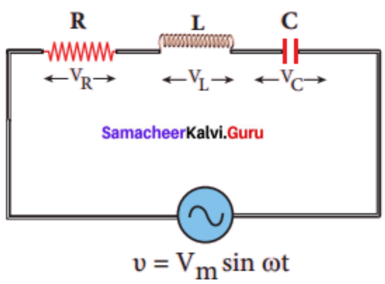
(c) uncharged particles cannot be accelerated

38) a) Derive an expression for phase angle between the applied voltage and current in a series RLC circuit.

AC circuit containing a resistor, an inductor, and a capacitor in series – Series RLC circuit:

Consider a circuit containing a resistor of resistance R, an inductor of inductance L, and a capacitor of capacitance C connected across an alternating voltage source. The applied alternating voltage is given by the equation.

$\upsilon = V_m \sin \omega t \ldots\ldots (1)$



AC circuit containing *R*, *L* and *C*

Let i be the resulting circuit current in the circuit at that instant. As a result, the voltage is developed across R, L and C.

We know that voltage across R (V_R) is in phase with i, voltage across L (V_L) leads i by π/2 and voltage across C (V_C) lags i by π/2.

The phasor diagram is drawn with current as the reference phasor. The current is represented by the phasor

$\vec{OI}$, V_R by $\vec{OA}$; V_L by $\vec{OB}$ and V_C by $\vec{OB}$.

The length of these phasors are

$OI = I_m$, $OA = I_mR$, $OB = I_m,X_L$; $OC = I_mX_c$

The circuit is cither effectively inductive or capacitive or resistive that depends on the value of V_1 or V_c Let us assume that $V_L > V_C$. so that net voltage drop across L – C combination is $V_L < V_C$ which is represented by a phasor $\vec{AD}$.

By parallelogram law, the diagonal $\vec{OE}$ gives the resultant voltage u of VR and ($V_L – V_C$) and its length OE is equal to V_m. Therefore,

$$V_m^2 = V_R^2 + (V_L - V_C)^2 \quad ...(1)$$

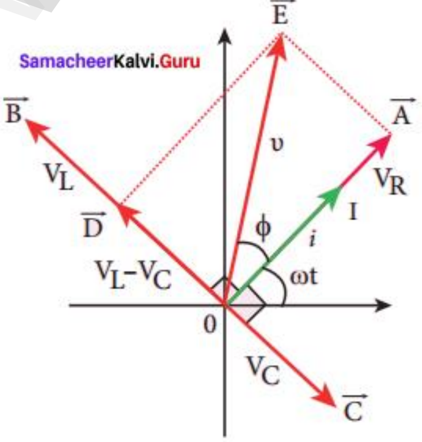
$$= \sqrt{(I_mR)^2 + (I_mX_L - I_mX_C)^2} = I_m\sqrt{R^2 + (X_L - X_C)^2}$$

or $$I_m = \frac{V_m}{\sqrt{R^2 + (X_L - X_C)^2}} \quad ...(2)$$

or $$I_m = \frac{V_m}{Z}$$

Where $$Z = \sqrt{R^2 + (X_L - X_C)^2} \quad ...(3)$$

Z is called impedance of the circuit which refers to the effective opposition to the circuit current by the series RLC circuit. The voltage triangle and impedance triangle are given in the graphical figure.



From phasor diagram, the phase angle between n and i is found out from the following relation

$$\tan \phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{V_R}$$

Special cases Figure: Phasor diagram for a series

(i) If $X_L > X_C$, $(X_L - X_C)$ is positive and phase angle φ is also positive. It means that the applied voltage leads the current by φ (or current lags behind voltage by φ). The circuit is inductive.

$\therefore \upsilon = V_m \sin \omega t;\ i = I_m \sin(\omega t + \varphi)$

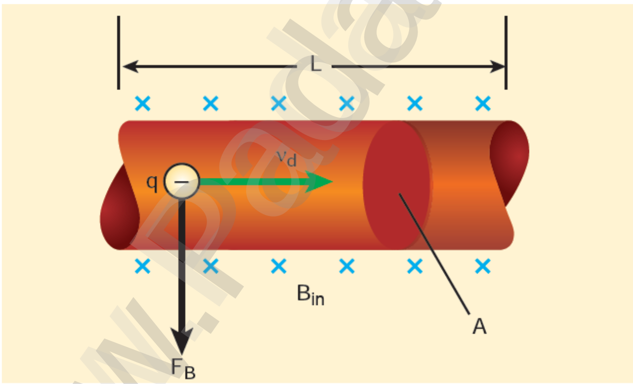
(ii) If $X_L < X_C$, $(X_L - X_C)$ is negative and φ is also negative. Therefore current leads voltage by φ and the circuit is capacitive.

$\therefore \upsilon = Vm \sin \omega t;\ i = Im \sin(\omega t + \varphi)$

(iii) If $X_L = X_C$, φ is zero. Therefore current and voltage are in the same phase and the circuit is resistive.

$\therefore \upsilon = V_m \sin \omega t;\ i = I_m \sin \omega t$

38) b) Derive the expression for the force on a current – current conductor in a magnetic field.



When a current carrying conductor is placed in a magnetic field, the force experienced by the wire is equal to the sum of Lorentz forces on the individual charge carriers in the wire.

Let a current 'I' flows through a conductor of length 'L' and area of cross-section 'A'

Consider a small segment of wire of length 'dl'

The free electorns drift opposite to the direction of current with drift velocity vd

The relation between current and drift velocity is,

$I = n\ A\ e\ v_d ------ (1)$

If the wire is kept in a magnetic field, then average force experienced by the electron in the wire is

$F = -\ e\ (\vec{v}_d\ X\ \vec{B}\ )$

Let 'n' be the number of free electrons per unit volume, then the total number of electrons in the small element of volume, then

$(V = A\ dl)$ is $N = n\ A\ dl$

Hence Lorentz force on the small element,

$\vec{F} = -e\ n\ A\ dl\ (\vec{v}_d\ \ \vec{B}\ ) - - - (1)$

Here length dl is along the length of the wire and hence the current element is

$\mathrm{I}\ \vec{d}\ l = -\ n\ A\ e\ \overrightarrow{dl}\vec{v}$

Put this in equation (1),

$\overrightarrow{dF} = (\ \overrightarrow{dl}\ X\ \vec{B}\ ) - - - (2)$

Therefore, the force in a straight current carrying conductor of length '$\boldsymbol{l}$' placed in a uniform magnetic field

$\vec{\boldsymbol{F}}_{\mathbf{total}} = (\mathbf{I}\ \boldsymbol{l}\ \boldsymbol{X}\ \vec{\boldsymbol{B}}) - - - (3)$

In magnitude,

$F_{total} = \boldsymbol{B}\ \mathbf{I}\ \boldsymbol{l}\ \mathbf{sin}\ \boldsymbol{\theta} - - - (4)$

Special cases :

(i) If the current carrying conductor placed along the direction of magnetic field, then $\theta = 0°$

$\therefore\ \boldsymbol{F} = \mathbf{0}$

(ii) If the current carrying conductor is placed perpendicular to the magnetic field, then $\theta\ = 90°$

$\therefore\ \boldsymbol{F} = \boldsymbol{B}\ \mathbf{I}\ \boldsymbol{l} = \boldsymbol{maximum}$

Prepared by
A. Muthuganesh., M.Sc., M.Phil., B.Ed., PhD.,
Department of Physics,
K. V. S. Matric. Hr. Sec. School,
Thoothukudi – 628002.