Q23. Using Bohr's postulates, obtain the expression for the total energy of the electron in the stationary states of the hydrogen atom. Hence draw the energy level diagram showing how the line spectra corresponding to Balmer series occur due to transition between energy levels.

Answer: Total Energy of electron in hydrogen atom = K.E + P.E

Centripetal force is due to the electrostatic attractive force between nucleus and electron

$F = \frac{mv^2}{r}$ →(1)

Where m= mass of electron
v= velocity of electron
r= radius of the orbit in which electron rotates.

Electrostatic force $F = \frac{1}{4\pi\epsilon_0}\frac{Ze.e}{r^2}$ → (2)

From equation (1) and (2)

$\frac{mv^2}{r} = \frac{1}{4\pi\epsilon_0}\frac{Ze.e}{r^2}$ →(3)

Or $K.E = \frac{mv^2}{2} = \frac{1}{4\pi\epsilon_0}\frac{Ze.e}{2r}$ →(4)

As per Bohr's postulates electron has discrete energy state: Electron rotates in non radiating orbits where its angular momentum is integral multiple of $\frac{h}{2\pi}$

$$mvr = n\frac{h}{2\pi}$$

$$v = \frac{nh}{2\pi mr} \rightarrow (5)$$

From equation (3) and (5)

$$\frac{m\left(\frac{nh}{2\pi mr}\right)^2}{r} = \frac{1}{4\pi\epsilon_0}\frac{Ze.e}{r^2}$$

$$\frac{mn^2h^2}{r4\pi^2m^2r^2} = \frac{1}{4\pi\epsilon_0}\frac{Ze.e}{r^2}$$

$$\frac{n^2h^2}{r\pi m} = \frac{Ze.e}{\epsilon_0}\ or\ r = \frac{n^2h^2\epsilon_0}{\pi mZe^2}\ \text{for H atom Z} = 1\text{ , therefore r} = \frac{n^2h^2\epsilon_0}{\pi me^2} \rightarrow (6)$$

Electric Potential Energy= Potential X Charge

P.E $=\frac{1}{4\pi\epsilon_0}\frac{Ze}{r}\times(-e) = -\frac{1}{4\pi\epsilon_0}\frac{Ze^2}{r} \rightarrow (7)$

Therefore Total Energy = K.E + P.E   putting values from equation (4) and (7) we get

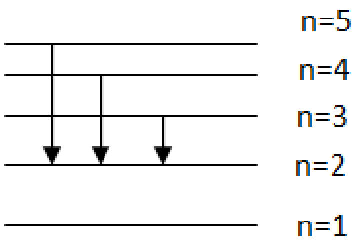
Total Energy$=\frac{1}{4\pi\epsilon_0}\frac{Ze.e}{2r} - \frac{1}{4\pi\epsilon_0}\frac{Ze^2}{r} = -\frac{1}{4\pi\epsilon_0}\frac{Ze^2}{2r}$

Putting the value of r from equation (6)

Total Energy$=\frac{1}{4\pi\epsilon_0}\frac{Ze^2}{\frac{n^2h^2\epsilon_0}{\pi me^2}}$, putting Z=1

Total Energy $=-\frac{me^4}{4{\epsilon_0}^2n^2h^2}$ Putting the values of m, e, h and ϵ_0 we get Total Energy $=-\frac{13.6}{n^2}$

Energy Level Diagram for Spectral Line of Balmer Series: Electron transition for higher level (n>2) and terminating at n=2 gives Balmer Series spectral line.



Therefore the energy difference when electron transit to 2nd orbit (n=2)

$$\Delta E = E_2 - E_n = -13.6\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$$

Where n>2, n=3, 4, 5...

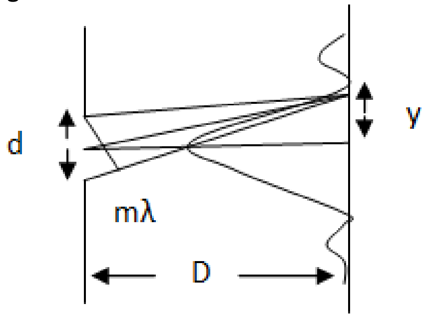
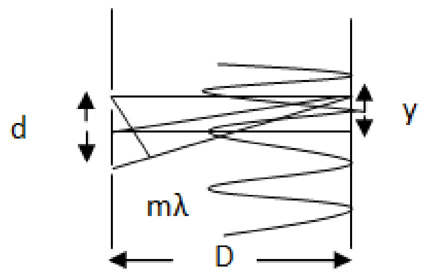
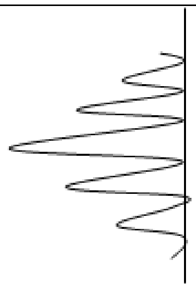
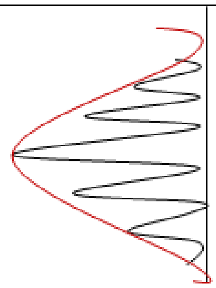
In 2nd orbit energy of electron

$E_2 = -\frac{13.6}{n^2} = -\frac{13.6}{2^2}$=-3.4 eV

Q24. (a) In what way is diffraction from each slit related to the interference pattern in a double slit experiment?

(b) Two wavelength of sodium light 590 nm and 596 nm are used, in turn, to study the diffraction taking place at a single slit of aperture 2 x 10^{-4}m. The distance between the slit and the screen is 1.5.m. Calculate the separation between the positions of the first maxima of the diffraction pattern obtained in the two cases.

Answer: (a)

Single slit diffraction pattern: A path difference of 1 wavelength produces a minimum since the light from the centre of the slit differs by half a wavelength this gives destructive interference  Condition for minimum $y = \frac{m\lambda D}{d}$	In double slit interference : path difference of 1 wavelength produces constructive interference  Condition for maximum $y = \frac{m\lambda D}{d}$
 Actual double slit interference pattern	 Envelop shows single slit diffraction

(b) Given d= 2 x 10^{-4} m, D=1.5 m,$\lambda_1 = 590 \times 10^{-9} m$, $\lambda_2 = 596 \times 10^{-9} m$

For first maxima

$$d sin\theta = \frac{3\lambda_1}{2}, since\ \theta\ is\ very\ small\ sin\theta \approx \theta \approx tan\theta$$

$$or\ d tan\theta = \frac{3\lambda_1}{2}\ or\ d.\frac{y_1}{D} = \frac{3\lambda_1}{2}\ or\ y_1 = \frac{3\lambda_1 D}{2d}\ for\ the\ other\ wavelength\ y_2 = \frac{3\lambda_2 D}{2d}$$

Therfore the path difference $\Delta y = \frac{3D}{2d}(\lambda_2 - \lambda_1) = \frac{3\times1.5\times(596-590)\times10^{-9}}{2\times2\times10^{-4}} = 6.75 \times 10^{-4} m$

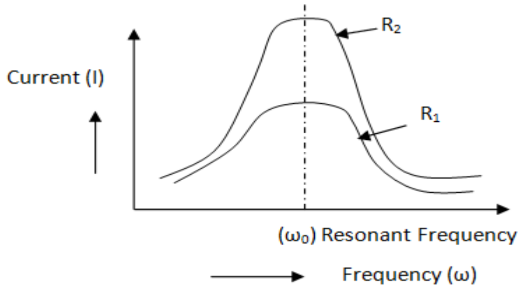
Q25. In a series LCR circuit connected to an ac source of variable frequency and voltage *v* = *v_m* sin*ωt*, draw a plot showing the variation of current (I) with angular frequency (ω) for two different values of resistance R_1 and R_2 (R_1>R_2). Write the condition under which the phenomenon of resonance occurs. For which values of the resistance out of the two curves, a sharper resonance is produced? Define Q-factor of the circuit and give its significance.

Answer:

(i) We know that rms current in LCR circuit is given by

$$I = \frac{E}{\sqrt{R^2 - \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

If R_1>R_2 then current for R_1 will be less i.e. I_1<I_2.
Variation of current with angular frequency in LCR circuit is as shown



(ii)Condition for resonance Also for current to be maximum, denominator should be minimum possible when

$$\omega L = \frac{1}{\omega C}$$

That is resistance offered to the ac by inductance should be equal to the resistance offered by capacitor. Also resonant frequency

$$\omega = \frac{1}{\sqrt{LC}} = \omega_0$$

(iii) Sharper resonance is produced by curve of R_2, the curve peak is not flattened to much as compared to R_1.

(iv)Q-factor: Sharpness of resonance is decided by Q-factor and is defined as ratio of resonant frequency to the difference of half power frequency, mathematically

$$Q - factor = \frac{1}{R}\sqrt{\frac{L}{C}}$$

Physical Significance: since R_1>R_2 therefore Q-factor of R_1 is less than Q-factor of R_2 hence sharpness of R_2 is more.

Q26. While travelling back to his residence in the car, Dr. Pathak was caught up in a thunderstorm. It became very dark. He stopped driving the car and waited for thunderstorm to stop. Suddenly he noticed a child walking alone on the road. He asked the boy at his residence. The boy insisted that Dr. Pathak should meet his parents. The parents expressed their gratitude to Dr. Pathak for his concern for safety of the child.

Answer the following questions based on the above information:

(a) Why is it safer to sit inside a car during a thunderstorm?
(b) Which two values are displayed by Dr. Pathak in his actions?
(c) Which values are reflected in parents' response to Dr. Pathak?
(d) Give an example of a similar action on your part in the past from everyday life.

Answer: (a)We know that electric field does not exists inside conductor(sphere), here since outside there is thunderstorm it is safer to stay inside car so that car provides shield to the electrostatic field.

(b) Dr. Phatak has good knowledge of physics (i) he is very social gives value human life (ii) helping attitude to have concern of other safety.

(c) Gratitude, giving thanks to the person who helped.

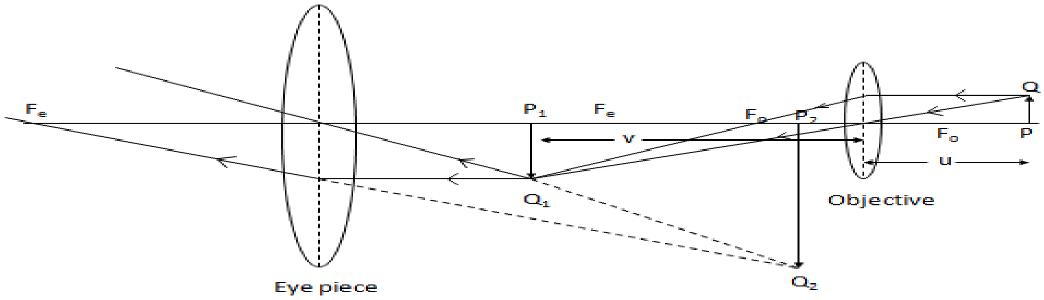
(d) There was a football match going on, suddenly heavy rain with thunderstorm started, to protect us from rain initially we took shelter under a tree, one of our team member realised it is not safe to stay under tree due to thunderstorm as electricity can easily earth through long tree, all of us rushed to parking area took shelter inside a bus which brought us from home.

Q27. (a) Draw a ray diagram showing the image formation by a compound microscope. Hence obtain expression for total magnification when the image is formed at infinity.

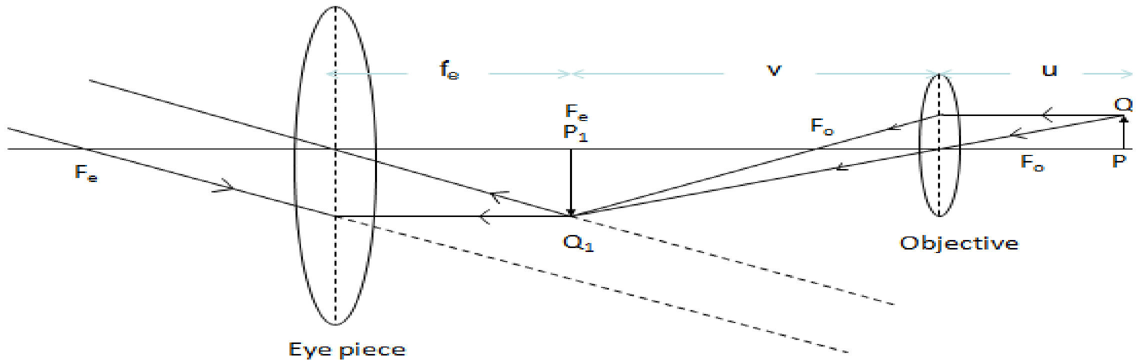
(b) Distinguish between myopia and hypermetropia. Show diagrammatically how these defects can be corrected.

Answer: (a) Compound Microscope**:** It consists of objective and eye piece. The objective is a convex lens of small aperture and small focal length. The aperture of the eye piece lens is slightly greater and the focal length is also small.

Ray diagram when final image is formed at least distance of distinct vision



PQ is an object kept in front of objective ($f_o < u < 2 f_o$), P_1Q_1 is the image formed by objective this image serves as object for eye piece, since P_1Q_1 lies between the focus and optical centre of eye piece hence an extended image P_2Q_2 is formed by eye piece. Thus P_2Q_2 is the final image of PQ produced by the compound microscope.
Ray diagram when final image is formed at infinity: Here the position of eye piece is so adjusted that image formed by objective i.e. P_1Q_1 falls at the focal plane of eye piece, hence final image is formed at infinity



Magnifying Power (M) when image is formed at infinity:

$M = Magnifying\ Power\ of\ Objective\ (M_0) \times MagnifyingPower\ of\ Eyepiece(M_e)$

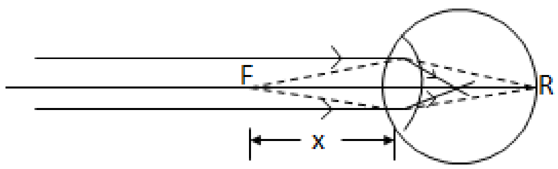
$M_0 = \frac{v}{u} = \frac{Image\ distance}{Object\ distance}, M_e = \frac{Image\ distance}{Object\ distance} = \frac{D}{f_e},$

$Image\ is\ actually\ formed\ at\ infinity\ but\ seen\ at\ least\ distance\ of\ distinct\ vision(D)$

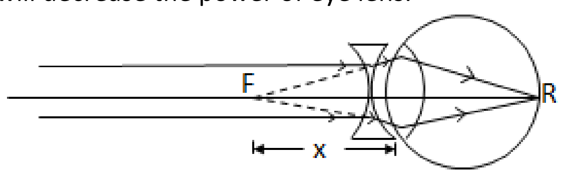
$$M = \frac{v}{u} \times \frac{D}{f_e}$$

(b)

Myopia: Short sighted people cannot see distance objects distinctly, due to some reason the normal (maximum) focal length of eye lens decreases i.e. the power of eye lens increases, hence parallel rays from distance object come to focus in front of the retina and this is why it can't be seen. As the object comes closer to the eye from infinity image shifts back and when object comes to F, the image falls at the retina and can be seen. Hence F is the far point for the defective eye.



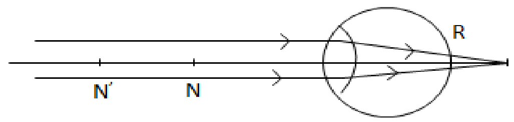
Remedy: Since the normal power of eye lens has increased hence this defect can be corrected for, by using an auxiliary lens in front of the eye lens which will decrease the power of eye lens.



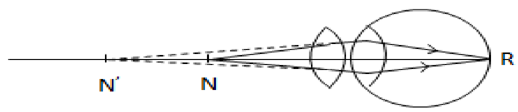
The auxiliary lens will create the image of the distant object at F and this image serves as object for eye lens produce image at the retina and thus the distant object can be seen.

Hypermetropia: Long sighted people can see distant objects distinctly but cannot see nearer objects. Due to some reason normal focal length of eye lens increases i.e. normal power p1 of eye lens decreases and hence parallel rays from distant object come
To focus behind the retina. Hence to see distant *objects focal length of eye lens is decreased by exerting pressure with the ciliary muscles i.e. accommodation starts right from infinity.*

As the objects moves towards the eye, accommodation continues since it has been started earlier it will be exhausted earlier that is it will get exhausted at N′, much before reaching the near point N for the normal eye. Thus for this defective eye near point has shifted from eye.



Remedy: Since the normal power P1 of the eye lens has decreased hence to increase the equivalent power P (P>P1) a power +P2 should be added to P1 i.e. and auxiliary lens convex in nature should be used.



The auxiliary lens produces the image of the object kept at N (near point for the normal eye) at N′ this image serves as object for the eye lens, image is now produced at retina by eye lens. Therefore object kept at N can be seen.

Myopia correction:	**Hypermetropia correction**:
Calculation: Let x = distance of the far point for the defective eye. f = the focal length of the auxiliary lens For the auxiliary lens : u=∞ , v = -x Using the formula for the lens : $\frac{1}{\infty}+\frac{1}{-x}=\frac{1}{f}$ $\therefore f=-x$ The negative sign indicates that the nature of the auxiliary lens is concave.	Calculation: Given x & D = least distance of distinct vision for the defective eye and the normal eye respectively. Let f = the focal length of the auxiliary lens. $\frac{1}{-x}+\frac{1}{D}=\frac{1}{f}$ $\frac{1}{D}-\frac{1}{x}=\frac{1}{f}$ $f=\frac{xD}{x-D}$ $\because x>D$ F is positive, the auxiliary lens is convex.

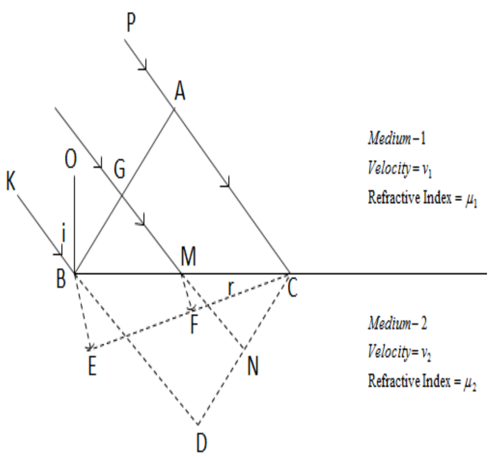
OR

(a) State Huygen's principle. Using this principle draw a diagram to show how a plane wave front incident at the interface of the two media gets refracted when it propagates from a rarer to a denser medium. Hence verify Snell's law of refraction.

(b) When monochromatic light travels from a rarer to a denser medium, explain the following, giving reasons:

(i) Is the frequency of reflected and reflected light same as the frequency of incident light?
(ii) Does the decrease in speed imply a reduction in the energy carried by light wave?

Answer :(a) **Huygen's Principle:**
(i) Every point on a given wave front acts as a fresh source of secondary wavelets which travel in all directions with the speed of light.
(ii)The forward envelope of these secondary wavelets gives the new wave front at any instant.



BC is the section of the refracting surface by the plane of the paper i.e. the out face, separating two media of refractive indices μ_1 and μ_2 ($\mu_1 < \mu_2$)
AB is the section of the incident plane wave front by the plane of the paper at an
instant of time t=0
Both the refracting surface and the plane wave front are perpendicular to the plane of the paper.

v_1 & v_2 = Velocity of light in medium-1 and medium-2 respectively.

PA and KB are perpendiculars dropped on the incident wave front AB and hence they are the incident rays. BO is normal drawn at B on the refracting surface.

$$\angle KBO = i = \text{angle of incidence}$$
$$\angle KBA = 90 \quad \therefore \angle OBA = 90 - i$$
$$\angle OBC = 90 \quad \therefore \angle ABC = 90 - (90 - i) = \text{i}$$

Hence angle of incidence can also be defined as the angle between the incident wave front and the refracting surface. Similarly the angle of refraction can also be defined as the angle between the refracted wave front and the refracting surface.

Had the two medium been same, then the rays from the point G & B would have gone up to N & D respectively during the time t in which ray from a goes up to C so that

$$AC=GN=BD=v_1t \qquad (1)$$

Hence CND would have been the position of the wave front after time t. But since the two medium are different let the ray from B go up to E in time t. So that

$$t=\frac{AC}{v_1}=\frac{BE}{v_2}\rightarrow(2)$$

With B as center and BE as radius we imagine a sphere the section of which by the plane of the paper gives an arc of a circle. CE is drawn tangential to that arc. Then a plane through CE and perpendicular to the plane of the paper would represent the refracted wave front after time t provided we can show that ray from any other point G on the incident wave front also touches the plane through CE after time t.To prove it, from M, MF is drawn perpendicular to CE.

$$\Delta BDC\ \&\ \Delta\text{MNC are similar}\therefore\frac{\text{BD}}{\text{MN}}=\frac{BC}{MC}\rightarrow(3)$$

$$\Delta BEC\ \&\ \Delta\text{MFC are similar}\therefore\frac{\text{BE}}{\text{MF}}=\frac{BC}{MC}\rightarrow(4)$$

$$From\ (3)\ \&\ (4)\ \frac{\text{BD}}{\text{MN}}=\frac{\text{BE}}{\text{MF}}$$

$$Putting\ \text{equation}\ (1)\ \&\ (2)\ \frac{\text{v}_1 t}{MN}=\frac{v_2 t}{MF}\ \text{or}\ \frac{\text{MF}}{\text{v}_2}=\frac{MN}{v_1}$$

That is time taken to go from M to F in medium 2 and time taken to go from M to N in medium 1 is same.

Hence the time taken by the light to go from G to M + M to N is same as the time taken to go from G to M + M to F i.e. from G to F.

Hence CE is the refracted wave front after time t.

$\therefore \angle BCE$ = angle between the refracting surface and the

refracted wave front = angle of refraction = r (using definition)

We now prove Snell's law :

From ΔABC : $\sin i = \frac{AC}{BC}$

From ΔABC : $\sin r = \frac{BE}{BC}$

$$\therefore \frac{\sin i}{\sin r} = \frac{AC/BC}{BE/BC} = \frac{AC}{BE}$$

Putting equation (1) and (2) : $\frac{\sin i}{\sin r} = \frac{v_1 t}{v_2 t}$

$$\frac{\sin i}{v_1} = \frac{\sin r}{v_2}$$

Multiplying both sides by v_0 where v_0 is the velocity of light in vacuum.

$$\frac{v_0}{v_1} \sin i = \frac{v_0}{v_2} \sin r$$

$\mu_1 \sin i = \mu_2 \sin r$ First law proved

Thus above result verifies Snell's law.

From the nature of construction it is evident that the incident ray refracted ray & normal at the point of incidence all lay on the same plane i.e. on the plane of the paper.

(b) (i) Frequency of light never changes when light passes from one medium to other medium. It is the fundamental property of light.

(ii) Energy of light given by $E = h\nu$, since ν i.e. frequency remains unchanged hence energy of light never changes while passing from one medium to other and it is independent of speed.

Q28. (a) State the working principle of a potentiometer. With the help of the circuit diagram; explain how a potentiometer is used to compare the emf's of two primary cells. Obtain the required expression used for comparing the emf's.

(b) Write two possible causes for one sided deflection in a potentiometer experiment.

Answer: (a) Working Principle of Potentiometer: The potential drop across the potentiometer wire is directly proportional to the length provided the cross-sectional wire is uniform and constant current flows through potentiometer wire.

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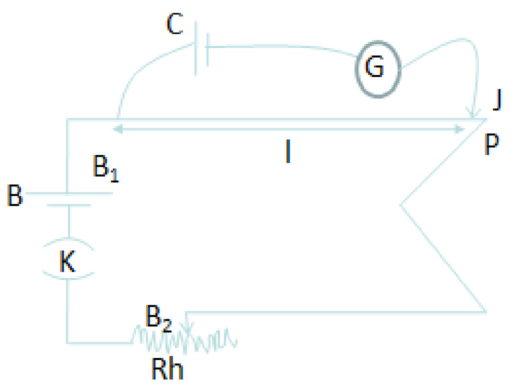
<td>
</td>
<td>If E = V_{B1P} no current flows through the galvanometer and galvanometer shows null deflection.

Let i be the current flowing through the potentiometer wire by the driving cell.

ρ =The resistance per unit length throughout the potentiometer wire.

l= B_1P = The length of the potentiometer wire up to the jockey at null deflection.

Therefore the potential difference across the wire B_1P
$V_{B1P} = i\rho l$
E = emf of the test cell.</td>
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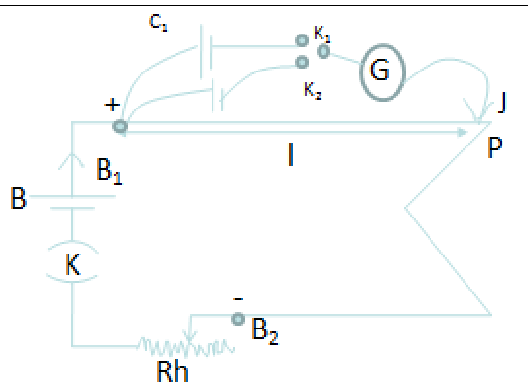
<tr>
<td>
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<td>Comparing emf of two cells: The positive terminal of both the cells for which emf to be compared is connected to B1 and negative of the test cells are connected through a key and galvanometer as shown.
If K1 is closed (K_2 is open) balance point is found by using C_1
$E_1 = i\rho l_1$
If K1 is opened and K2 is closed by measuring C_2 balance point is found
$E_2 = i\rho l_2$
$\frac{E_1}{E_2} = \frac{i\rho l_1}{i\rho l_2} = \frac{l_1}{l_2}$

Thus the ratio of balance length is the ratio of emf of cells.</td>
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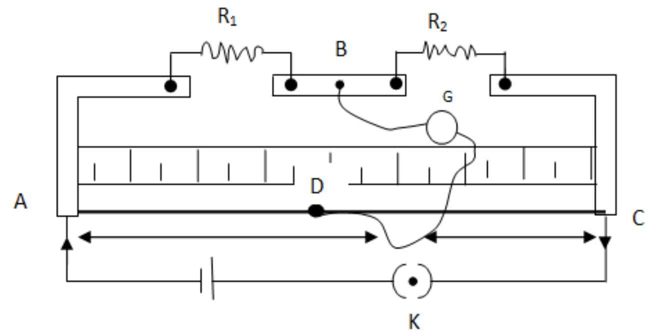
(b) **Reason for one sided deflection across the potentiometer wire**
(i) The potential drop across the whole length of the potentiometer wire is less than the emf of the test cell.
(ii) Test cells positive terminal is not connected to the potentiometer circuit where the driving cell positive terminal is connected.

OR

(a) State Kirchhoff's rules for an electric network. Using Kirchhoff's rules, obtain the balance condition in terms of the resistances of four arms of Wheatstone bridge.



(b) In the meter bridge experimental set up, shown in the figure, the null point 'D' is obtained at a distance of 40 cm from end A of the meter bridge wire. If a resistance of 10 Ω is connected in series with R_1, null point is obtained at AD=60 cm. Calculated the values of R_1 and R_2.

Answer: In complicated networks to find current flowing through different branches we apply Kirchhoff's law.

First law: The algebraic sum of currents meeting at a point is zero. i.e.$\Sigma i = 0$.

In the given circuit, Considering outward direction of current as positive and inward as negative then at the point F

According to Kirchhoff's first law, at junction F

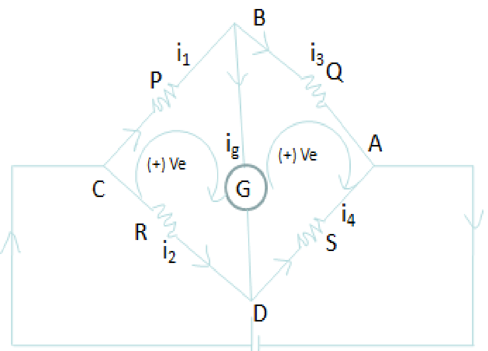
$I_1 + I_2 = I_3$

Second law: In a closed mesh of electrical conductors the algebraic sum of product of resistance and the respective current in the different branches is equal to the total e.m.f applied in the closed mesh.

$$\sum iR = \sum E$$

Using Kirchhoff's law we now find the condition for null deflection in a Wheatstone bridge

Four resistance P,Q,R and S are joined end to end to form a closed circuit. These close networks of conductors form a closed circuit. This close network of conductors is known as Wheatstone bridge. Between any pair of opposite junctions say A & C a battery is connected and between the other pair of opposite junctions a galvanometer is connected. We assigned the current flowing in the different branches from the logical consideration.



Given : G = The resistance of the galvanometer
Let i_1, i_2, i_3, i_4 & i_g be the current flowing through the branches of resistance P, R, Q, S and G respectively.

Applying Kirchhoff's first law :

(1) At the point C :

$$\sum i = i - i_1 - i_2 = 0 \quad \text{or } i_2 = i - i_1 \rightarrow (1)$$

(2) At the point B :

$$\sum i = i_1 - i_3 - i_g = 0 \text{ or } i_3 = i_1 - i_g \rightarrow (2)$$

(3) At the point D :

$$\sum i = i_2 + i_g - i_4 = 0 \text{ or } i_4 = i - i_1 + i_g \rightarrow (3)$$

Applying Kirchhoff's second law :

In closed mesh CBDC :

$$i_1 P + i_g G - i_2 R = 0$$

Putting equation(1) : $i_1 P + i_g G - (i - i_1)R = 0$

$$or\ (P + R)i_1 + i_g G - iR = 0 \rightarrow (4)$$

(ii) In closed mesh BADB

$$i_3 Q - i_g G - i_4 S = 0 \rightarrow (5)$$

Putting equation(2) in equation (5)

$$(i_1 - i_g)Q - i_g G - (i - i_1 + i_g)S = 0$$

$$\text{or } i_1(Q + S) - i_g(Q + G + S) - iS = 0 \rightarrow (6)$$

To eliminate i_1 from the equations multiplying equation(4) by (Q + S) and (6) by (P + R) and substracting

$$i_1(Q + S)(P + R) + i_g G(Q + S) - iR(Q + S) = 0$$

$$i_1(Q + S)(P + R) - i_g(P + R)(Q + G + S) - iS(P + R) = 0$$

$$i_g[G(Q + S) + (Q + S + G)(P + R)] - i[R(Q + S) - S(P + R)] = 0$$

$$i_g = \frac{i(RQ - SP)}{G(Q + S) + (Q + S + G)(P + R)} \rightarrow (6)$$

From equation (6) we can find the current flowing through the galvanometer. For null deflection ig=0 from equation (6) ig=0 only if (RQ-PS)=0 or **P/Q=R/S** is the condition for null deflection.

(b) $\frac{R_1}{R_2} = \frac{AD}{DC} = \frac{40}{60} \rightarrow (1)\ \ also\ \frac{R_1+10}{R_2} = \frac{60}{40} \rightarrow (2)$

Dividing (2) by (1)

$\frac{R_1+10}{R_1} = \frac{60}{40} \times \frac{60}{40} = \frac{9}{4}$

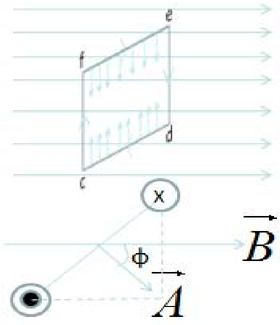
R_1= 8 Ω

From (1): R_2 = 12Ω

Q29. (a) Derive the expression for the torque on a rectangular current carrying loop suspended in a uniform magnetic field.

(b) A proton and a deuteron having equal momenta enter in a region of uniform magnetic field at right angle to the direction of the field. Depict their trajectories in the field.

Answer:
(a)Torque on a current carrying coil



Theory: Given n = the number of turns in the coil

l & b = the length of each vertical & horizontal side of the coil respectively (assuming) the coil to be rectangular

i = the current flowing through the coil.

B = the induction vector of the magnetic field in which the coil is suspended.

We know that the force experienced by the current carrying conductor placed in a magnetic field is

$\vec{F} = i(\vec{l} \times \vec{B}) \rightarrow (1)$

Force on each wire 'de' and 'fc'

$|\vec{F}| = ibB\sin(90-\phi) = ibB\sin\phi$

where ϕ = angle between the normal to the plane of the coil and the direction of the magnetic field.

The direction of the force on the wires 'de' & 'fc' are in the plane of the coil along the downward and upward direction respectively and hence cancel out.

The force on the two vertical wires 'cd' and 'ef' by using equation(1) are found to have magnitude

$F = ilB\sin 90^0 = ilb$

Applying the right hand curl rule for vector product the directions of the force are as shown in the figure. These two forces being equal in magnitude, opposite in direction parallel and non co-planer constitute a couple.

Moment of the couple $\Gamma = ilB \times OC$

$\Gamma = ilBb\sin\phi = i(lb)B\sin\phi = iAB\sin\phi$

Since there are n turns in the coil the total torque experienced by the current carrying coil in the magnetic field

$\Gamma = niAB\sin\phi$

(b)

When charge particle enters into the magnetic field, the force exerted by magnetic field on the charge provides the required centripetal force

$$\frac{mv^2}{r} = q(\vec{v} \times \vec{B}) \; or \; r = \frac{mv}{qB}$$

Both deuteron and proton has same charge and velocity hence they will execute circular path of same radius.

OR

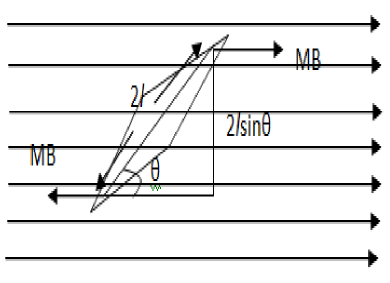
(a) A small compass needle of magnetic moment 'm' is free to turn about an axis perpendicular to the direction of uniform magnetic field 'B'. The moment of inertia of the needle about the axis is 'I'. The needle is slightly disturbed from its stable position and then released. Prove that it executes simple harmonic motion. Hence deduce the expression for its time period.

(b) A compass needle, free to turn in a vertical plane orients itself with its axis vertical at a certain place on the earth. Find out the values of (i) horizontal component of earth's magnetic field and (ii) angle of dip at the place.

Answer: (a) Given m=Magnetic moment=Mx2*l*, where M=Pole strength, 2*l*=length

B = Uniform Magnetic field

I = Moment of inertia of the needle about the axis.



The magnetic field exerts force MB on north and south pole of the needle. If θ be the inclination of the needle with the magnetic field. Then torque due to this equal and opposite force

$$\tau = MB \times 2lsin\theta = mBsin\theta \rightarrow (1) \; sine \; MX2l = m$$

Therefore $I \times \frac{d^2\theta}{dt^2} = -mBsin\theta = -mB\theta \rightarrow (2) \; sin\theta \approx \theta$

$$\tau \propto -\frac{d^2\theta}{dt^2}$$

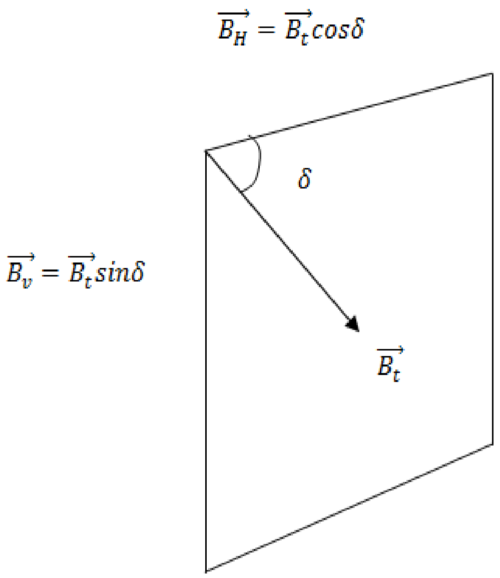
Negative sign indicates restoring nature. Therefore the motion is SHM.

Time period $T = 2\pi\sqrt{\frac{angular\ displacement}{angular\ accelaration}} = 2\pi\sqrt{\frac{I}{MB}} \rightarrow (3)$

Equation (3) gives the time period of oscillation.

(b) (i) Since the needle is aligned vertically the horizontal component of earth's magnetic field is ZERO.

(ii) Resolving earth's magnetic field into horizontal and vertical component as shown.



$\overrightarrow{B_t}$ =Earth's magnetic field.

$\overrightarrow{B_H} = \overrightarrow{B_t}cos\delta$ = Horizontal component

$\overrightarrow{B_v} = \overrightarrow{B_t}sin\delta$ = Vertical component

$$tan\delta = \frac{B_v}{B_H}$$