Previous Year Question Paper 2020

- Please check that this paper contains **11** printed pages.
- Code number given on the right-hand side of the question paper should be written on the title page of the answer- book by the candidate.
- Please check that this question paper contains **10** questions.
- **Please write down the Serial Number of the question in the answer-book before attempting it.**
- 15-minute time has been allotted to read this question paper. The question paper will be distributed at 10.15 a.m. From 10.15 a.m. to 10.30 a.m., the students will read the question paper only and will not write any answer on the answer-book during this period.

Time Allowed: **3** hours Maximum Marks: **70**

SECTION - A

Note: Select the most appropriate option from those given below each question :

1. Photons of energies 1eV and 2eV are successively incident on a metallic surface of work function 0.5eV. The ratio of kinetic energy of most energetic photoelectrons in the two cases will be **1 Mark**

(A)1: 2
(B)1:1
(C)1:3
(D)1:4

Ans: For the first photon:

$E1 = W + KE1$

$0.5 = 1 + KE1$

$KE1 = 0.5$

For the second photon:

$E2 = W + KE2$

$2 = 0.5 + KE2$

$KE2 = 1.5$

On dividing KE1 and KE2

$$\frac{KE_1}{KE_2} = \frac{0.5}{1.5}$$

$$\frac{KE_1}{KE_2} = \frac{1}{3}$$

So, option C is correct.

2. Which of the following statements is not correct according to Rutherford model ? 1 Mark

(A) Most of the space inside an atom is empty

(B) The electrons revolve around the nucleus under the influence of coulomb force acting on them

(C) Most part of the mass of the atom and its positive charge are concentrated at its center.

(D) The stability of atom was established by the model

Ans: Option D is incorrect according to Rutherford model as he was not able to explain stability of atom

3. The resolving power of a telescope can be increased by increasing: 1 Mark

(A)wavelength of light.

(B)diameter of objective.

(C)length of the tube.

(D)focal length of eyepiece.

Ans: resolving power can be increased by decreasing the wavelength and increasing the diameter of objective.

So, option **(B)** is correct.

4. The magnetic dipole moment of a current carrying coil does not depend upon **1 Mark**

(A) number of turns of the coil.

(B) cross-sectional area of the coil.

(C) current flowing in the coil.

(D) material of the turns of the coil

Ans: The magnetic dipole moment of a current carrying coil depends upon the number of turns, cross sectional area and the current flowing in the coil. So, the correct answer is option D.

5. For glass prism, the angle of minimum deviation will be smallest for the light of **1 Mark**

(A) red colour.

(B) blue colour.

(C) yellow colour.

(D) green colour

Ans: Red light is having maximum wavelength so it angle of minimum deviation will be smallest for it.

6. **A biconvex lens of glass having refractive index 1.47 is immersed in a liquid. It becomes invisible and behaves as a plane glass refractive index of the liquid is** **1 Mark**

(A) 1:47

(B) 1.62 `

(C) 1.33

(D) 1.51

Ans: According to lens maker's formula,

$$\frac{1}{f}\left(\frac{\mu_g}{\mu_l}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

As the biconvex lens dipped in a liquid behaves as a plane sheet of glass,

$f=\infty$

So, $\frac{1}{f}=0$

$$\frac{\mu_g}{\mu_l}-1=0$$

$\mu_g=\mu_l=1.47$

So, the correct answer is option (A).

7. **The resistance of a metal wire increases with increasing temperature on account of** **1 Mark**

(A) decrease in free electron density

(B) decrease in relaxation time.

(C) increase in mean free path.

(D) increase in the mass of electron.

Ans: Relaxation time is defined as the time interval between two successive collisions of electrons in a conductor when current flows through it. The resistance of a conductor increases with an increase in temperature because the thermal velocity of the free electrons increase as the temperature increases. This results in an increase in the number of collisions between the free electrons and a decrease in the relaxation time.

So, the correct answer is option (B).

8. An electric dipole placed in a non-uniform electric field can experience
1 Mark

(A) a force but not a torque.

(B) a torque but not a force.

(C) always a force and a torque.

(D) neither a force nor a torque

Ans: Given an electric dipole placed in a non-uniform electric field. An electric dipole always experiences a torque when placed in uniform as well as non-uniform electric field. But in a non-uniform electric field, the dipole will also experience net force of attraction. So the electric dipole in a non-uniform electric field experiences both torque and force.

9. If the net electric flux through a closed surface is zero, Then we can infer

(A) no net charge is enclosed by the surface.

(B) uniform electric field exists within the surface.

(C) electric potential varies from point to point inside the surface.

(D) charge is present inside the surface.

Ans: If the net electric flux is zero, then no net charge is enclosed by the closed surface. ... Since electric flux is defined as the rate of flow of electric field in a closed area and if the electric flux is zero, the overall electric charge within the closed boundary will be also zero. So, the correct answer is option A. **1 Mark**

10. Kirchhoff's first rule at a junction in an electrical conservation of

(A) energy

(B) charge

(C) momentum

(D) both energy and charge

Ans: The first law of Kirchhoff's is based on charge conservation, as it talks about the summation of current to be zero at any junction, which means that if current is conserved that implies that charge is also conserved. **1 Mark**

So, the correct answer is option B.

Note: Fill in the blanks with appropriate answer:

11. A ray of light on passing through an equilateral glass prism, suffers a minimum deviation equal to the angle of the prism. The value of refractive index of the material of the prism is__________

Ans: The minimum

1 Mark

12. According to Bohr's atomic model, the circumference of the electron orbit is always an_________________ multiple of de Broglie wavelength.

1 Mark

Ans: According to Bohr's atomic model, the circumference of the electron orbit is always an **integral** multiple of de Broglie wavelength.

Explanation: Bohr, in his atomic model, considered an electron to be in form of a standing electron wave and if this wave is to be continuous over the circumference of the stationary orbit that the electron lie in, the circumference must be a integral multiple of its wavelength $(n\lambda)$.

Or

In ß-decay, the parent and daughter nuclei have the same number of_______________ **1 Mark**

Ans: In ß-decay, the parent and daughter nuclei have the same number of **protons** and neutrons.

Explanation: In beta decay number, the mass number of the beta particle remains unchanged and we know that the mass number is the number of protons and neutrons.

13. The number of turns of a solenoid are doubled without changing its length and area of cross-section. The self inductance of the solenoid will become _______________ times **1 Mark**

Ans: The number of turns of a solenoid are doubled without changing its length and area of cross-section. The self inductance of the solenoid will become **4** times.

Explanation: The expression for the self inductance of a solenoid is $L=\frac{\mu_o N^2 A}{l}$.

So, we can see that $L \alpha N^2$.

So, on doubling the number of terms, the self inductance becomes 4 times.

14. Laminated iron sheets are used to minimize _______ in the core of a transformer. **1 Mark**

Ans: Laminated iron sheets are used to minimize **eddy currents** in the core of a transformer.

Explanation: The iron core of a transformer is laminated with the thin sheet; the laminated iron core prevents the formation of eddy currents across the core and thus reduces the loss of energy.

15. The magnetic field lines are ________ by a diamagnetic substance **1 Mark**

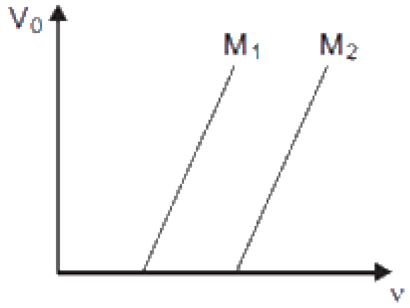
Ans: The magnetic field lines are **feebly repelled** by a diamagnetic substance.

Explanation: Diamagnetic substances are those which develop feeble magnetization in the opposite direction of the magnetizing field. Such substances are feebly repelled by magnets and tend to move from stronger to weaker parts of a magnetic field.

16. Why cannot we use Si and Ge fabrication of visible LEDs? **1 Mark**

Ans: We cannot use Silicon or germanium in the fabrication of LEDs because they produce energy in the form of heat, and not in the form of Visible light of IR. It is not much sensitive to temperature.

17. The variation of the stopping potential photosensitive surface the frequency (v) of the light incident on two different photosensitive surface M1 and M2 is shown in the figure. Identify the surface which has greater value of the work function. 1 Mark



Ans: As per the figure given above the stopping potential the variation of the stopping potential photosensitive surface the frequency (v) of the light incident on two different photosensitive surface M1 and M2.

So the figure representation is for the same value of V0 but ν differs in both the case and the work function depends on the value of v that means greater the value of greater is the work function hence surface M2 has greater value of work function as, $v_2 > v_1$.

18. How does an increase in doping concentration affect the width of depletion layer of a p-n junction diode ? 1 Mark

Ans: If we increase doping, the number of majority charge carriers (holes on the p-side and electrons on the n-side) will also grow. This would result in an increase in the width of the depletion layer, which is dependent on charge carriers.

19. The nuclear radius of $^{27}_{13}Al$ is 4.6 fermi. Find the nuclear radius of $^{64}_{29}Cu$? 1 Mark

Ans: We know that the expression for nuclear radius is $R = E_o A^{1/3}$

where,

R is the nuclear radius

R_o is a constant

A is the mass number

$$\frac{R_{Al}}{R_{Cu}}=\left(\frac{27}{64}\right)^{1/3}$$

$$\frac{R_{Al}}{R_{Cu}}=\frac{3}{4}$$

This can be written as,

$$R_{Cu}=\frac{4}{3}R_{Al}$$

On putting the value of R_{Al}, we get,

$$R_{Cu}=\frac{4}{3}\times 4.6$$

$$R_{Cu}=6.1 \text{ fermi}$$

So, the nuclear radius of $^{64}_{29}Cu$ is $R_{Cu}=6.1$ fermi.

Or

A proton and an electron have equal speed find the ratio of de Broglie Wavelengths associated with them **1 Mark**

Ans: The expression for de Broglie wavelength is,

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

The expression of de Broglie wavelength for an electron is,

$$\lambda_e=\frac{h}{m_e v} \quad ....(1)$$

Similarly, the expression of de Broglie wavelength for a proton is,

$$\lambda_p=\frac{h}{m_p v} \quad ....(2)$$

On dividing equation (1) and (2),

$$\frac{\lambda_e}{\lambda_p} = \frac{m_p v}{m_e v}$$

$$\frac{\lambda_e}{\lambda_p} = \frac{m_p}{m_e}$$

Now, we know that $\frac{m_p}{m_e} = \frac{1836}{1}$

$$\frac{\lambda_e}{\lambda_p} = \frac{1836}{1}$$

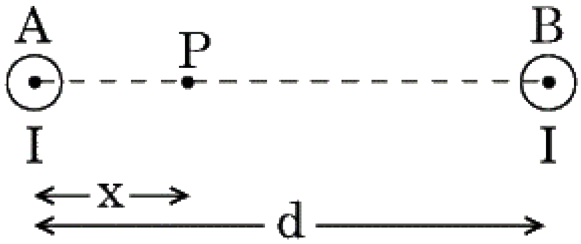
So, the ratio of de Broglie wavelength associated to an electron and a proton is 1836:1.

20. **How is displacement current produced between the plates of a parallel plate capacitor during charging?** **1 Mark**

Ans: In between the plates of the capacitor due to the time-varying electric field, there is a change in electric flux which constitute a current. This current is known as displacement current.

SECTION-B

21. **Two long straight parallel wires A and B separated by a distance d, carry equal current I flowing in same direction as shown in the figure**



2 Marks

(a) Find the magnetic field at a point P situated between them at a distance x from one wire.

Ans: The magnetic field due to wire A at the point P is,

$$B_1 = \frac{\mu_o I}{2\pi x}$$

The magnetic field due to the wire B at the point P is,

$$B_2 = \frac{\mu_o I}{2\pi(d-x)}$$

So, the net magnetic field is,

B=B1-B2

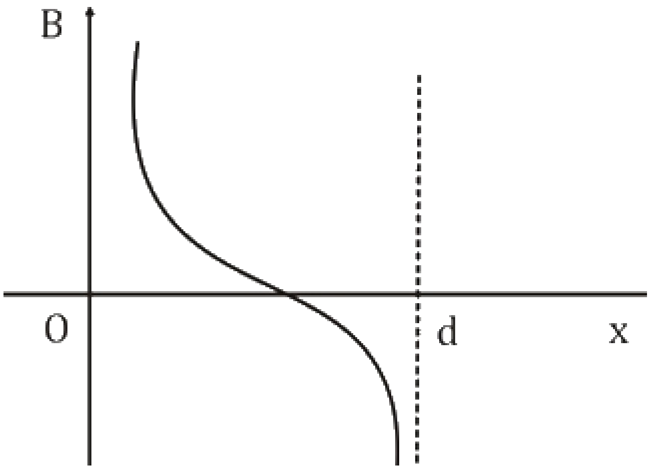
$$B = \frac{\mu_o I}{2\pi}\left(\frac{1}{x} - \frac{1}{d-x}\right)$$

$$B = \frac{\mu_o I}{2\pi}\left[\frac{d-2x}{x(d-x)}\right]$$

This is the desired expression.

(b) Show graphically the variation of the magnetic field with distance x for 0 < x < d

Ans: The graphical representation of the variation of the magnetic field with distance x for 0<x<d is:



22. Using Bohr's atomic model, derive the expression for the radius of nth orbit of the revolving electron in a hydrogen atom. 2 Marks

Ans: In accordance to the Bohr's postulates,

$$L_n = mv_n r_n = \frac{nh}{2\pi}$$

For a dynamically stable orbit present in the hydrogen atom,

$$F_e = F_c$$

$$\frac{mv_n^2}{r_n} = \frac{1}{4\pi\varepsilon_o}\frac{e^2}{r_n^2}$$

$$mv_n^2 = \frac{1}{4\pi\varepsilon_o}\frac{e^2}{r_n}$$

$$v_n^2 = \frac{e^2}{4\pi\varepsilon_o m r_n}$$

On taking square root on both the sides,

$$v_n = \frac{e}{\sqrt{4\pi\varepsilon_o m r_n}} \quad ..(1)$$

We also know that,

$$v_n = \frac{nh}{2\pi m r_n} \quad ..(2)$$

On equating equation (1) and equation (3),

$$\frac{e}{\sqrt{4\pi\varepsilon_o m r_n}} = \frac{nh}{2\pi m r_n}$$

On squaring both sides, we get,

$$\frac{e^2}{4\pi\varepsilon_o m r_n} = \frac{n^2 h^2}{4\pi^2 m^2 r_n^2}$$

$$\frac{e^2}{\varepsilon_o} = \frac{n^2 h^2}{\pi m r_n}$$

$$r_n = \frac{n^2 h^2 \varepsilon_o}{\pi m e^2}$$

This is the desired expression.

Or

2 Marks

(a) Write two main observations of photoelectric effect experiment which could only be explained by Einstein's photoelectric equation.

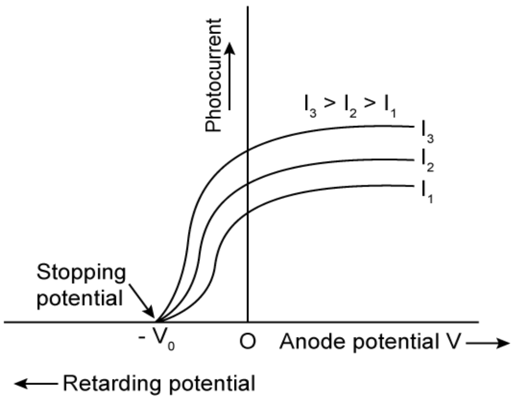
Ans: The two main observations of photoelectric effect experiment which could only be explained by Einstein's photoelectric equation are:

(1) There is a particular frequency below which the emission of electrons does not take place. This frequency is known as threshold frequency.

(2) The kinetic energy of the electron linearly depends on the frequency and does not depend on the intensity of radiation.

(b) Draw graph variation of photocurrent with the anode potential of a photocell

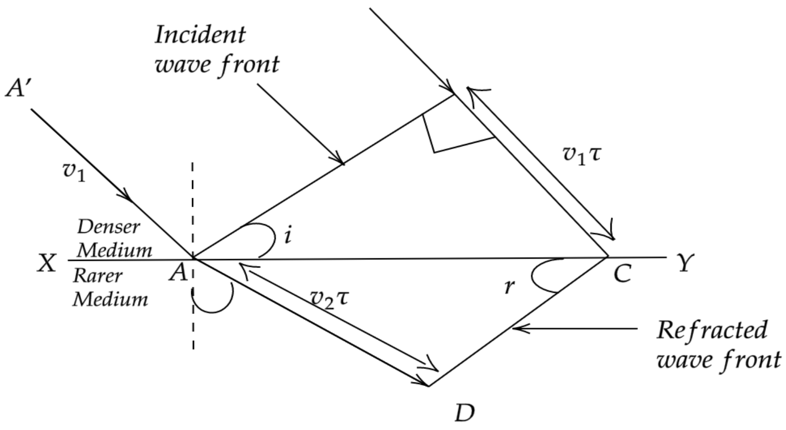
The graph showing the variation of photocurrent with the anode potential of a photocell is:



23. Define the wave front of a travelling wave. Using Huygens principle, obtain the law of refraction at a plane interface when light passes from a rarer to a denser medium. **2 Marks**

Ans: Wave front is an imaginary surface over which an optical wave has a constant phase or in same phase and the shape of a wave front is generally determined by the geometry of the source.

Derivation of law of refraction:



Huygens principle states that:

Every point on a primary wave front act as a source for the secondary wavelets.

These secondary wavelets are connected tangential in the forward direction give secondary wave front.

Here AB acts as incident wave front or we can say as primary wave front.

DC act as refracted wave front or we can say secondary wave front.

Consider the light incise on the denser medium having reflective index μ_1 and get refracted through the are medium having refractive index μ_2.

Now from the figure,

$$\frac{\sin i}{\sin r} = \left(\frac{\frac{BC}{AC}}{\frac{AD}{AC}} \right) = \frac{BC}{AD}$$

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

Now we know that,

$$v \alpha \frac{1}{\mu}$$

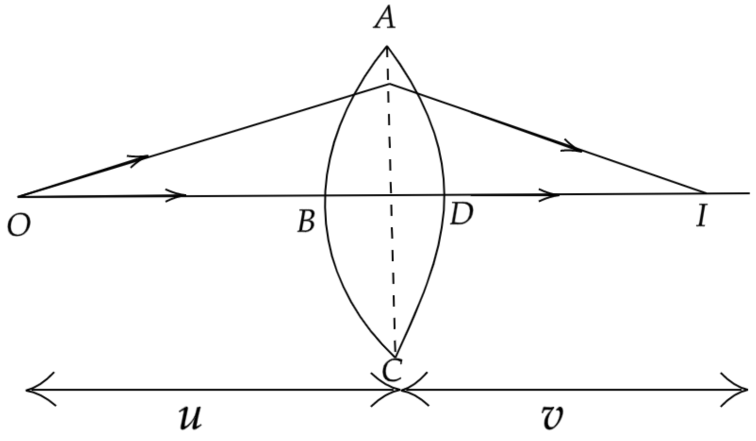
Hence the above equation become,

$$\frac{\sin i}{\sin r}=\frac{\mu_2}{\mu_1}=\text{constant}$$

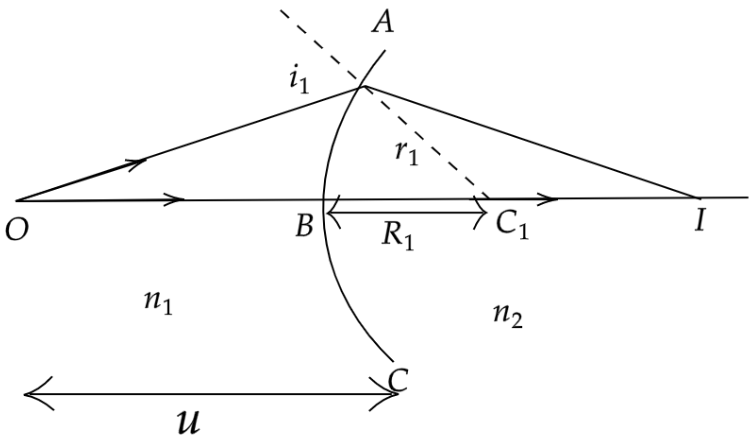
Or

Using lens marker's formula, derive the lens formula $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$ for a biconvex lens. **2 Marks**

Ans: consider the diagram which will show the geometry of the image formation by a biconvex lens.



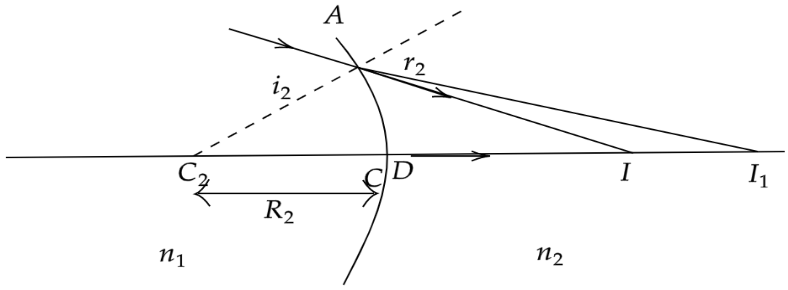
Now applying the equation for refraction at the spherical surface ABC of the biconvex lens we will get,



From the figure,

$$\frac{n_1}{OB}+\frac{n_2}{BI}=\frac{n_2-n_1}{BC_1}$$

Similarly now applying the same procedure on the second surface ADC we will get,



Now from the figure,

$$-\frac{n_2}{DI_1}+\frac{n_1}{DI}=\frac{n_2\text{-}n_1}{DC_2}$$

From this lens we get,

$$BI=DI_1$$

Now adding above two equation we will get,

$$\frac{n_1}{OB}+\frac{n_1}{DI}=\left(n_2\text{-}n_1\right)\left(\frac{1}{BC_1}+\frac{1}{DC_2}\right)\ldots\ldots(1)$$

Let us assume that the object is at infinity then,

$$OB\rightarrow\infty$$

and the image will be at focus, DI=f

So we will get,

$$\frac{n_1}{f}=\left(n_2\text{-}n_1\right)\left(\frac{1}{BC_1}+\frac{1}{DC_2}\right)\ldots\ldots(2)$$

Hence from equation (1) and (2) we will get,

$$\frac{n_1}{OB}+\frac{n_1}{DI}=\frac{n_1}{f}$$

Considering their respective lens and applying sigh conversion we will get, BO = -u and DI = +v

So we will get,

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

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

Above equation is known as the lens makers formula for a biconvex lens.

24. Explain the principle of working of a meter bridge. Draw the circuit diagram for determination of an unknown resistance using it. 2 Marks

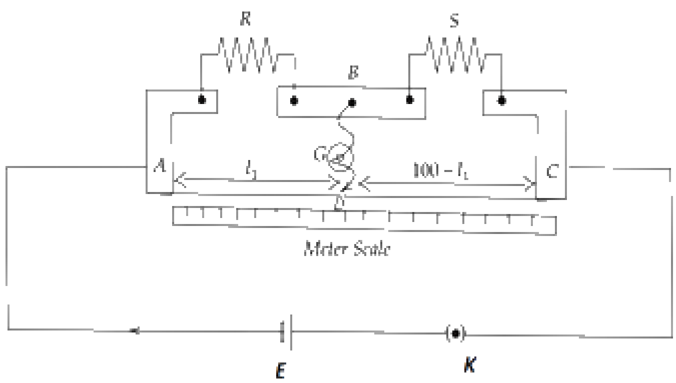
Ans: Meter bridge also known as slide Wire Bridge which is a practical form of wheat-stone bridge, which is used to measure the unknown resistances. The working principle of Meter Bridge is the ratio of the resistance of the two lengths of the wire across the position of jockey, where the galvanometer shows zero deflection which is equal to the ratio of the known resistance R and an unknown resistance S.

Let us assume resistance per cm length of the wire be r.

Now mathematically representing the principle of Meter Bridge,

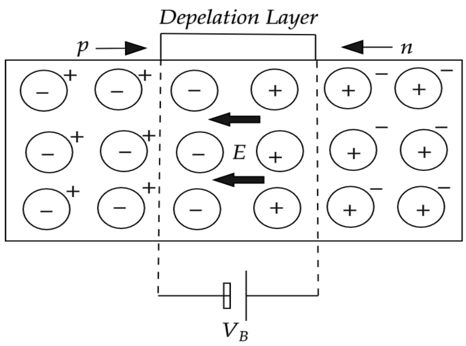
$$\frac{Lr}{(100\text{-}L)r}=\frac{R}{S}$$

$$\Rightarrow S=\frac{100\text{-}L}{L}\times R$$



25. **Explain the terms 'depletion layer, and 'potential barrier, in a p -n junction diode. How are the (a) width of depletion layer, and (b) value of potential barrier affected when the p-n junction is forward biased? 2 Marks**

Ans:



a) Width of the depletion layer:

The depletion region is the layer which is created around the p-n junction which is devoid of free change carriers and also has immobile ions. It is created around the p-n junction due to diffusion of majority carriers across the junction.

When the p-n junction diode is biased with forward biasing, the negative terminal of the battery (potential) repels the electron toward the junction and provides the required energy to cross the junction and recombine with the holes which is also being repelled by the positive terminal. This will lead to the decrease in the width of the depletion layer.

b) Potential Barrier:

It is a potential difference or we can say junction voltage that is developed across the junction due to migration of the majority charge carriers across it when the p-n junction is formed.

It opposes the further migration of the majority charge carriers across the p-n junction and it appears as if a fictitious battery is connected across the p-n junction. The batter acts in such a way that the positive terminal is to the n-region and the negative terminal is to the p-region of the p-n junction.

The value of the potential barrier is 0.3V for Ge and 0.7V for Si semiconductor diodes. Hence the forward bias voltage opposes the potential barrier and due to the reduction in potential barrier thus the width of depletion layer also decreases.

26. N small conducting liquid droplets, each of radius r, are charged to a potential V each, these droplets coalesce to form a single large drop without any charge leakage find the potential of the large drop. 2 Marks

Ans: Given:

N small conducting droplets are present each of radius r and potential of each droplets is V.

Potential of each liquid droplet,

$$V=\frac{kq}{r}$$

$$\Rightarrow q=\frac{Vr}{k}$$

Where, k is a constant term, r is the radius of the droplet and q is the charge of the conducting droplet.

Now for N such liquid droplets the charge will be,

$$Q=Nq=\frac{NVr}{k}$$

Now the radius of the larger drop will be,

$$R=N^{\frac{1}{3}}r$$

As the volume will remain the same in both the case.

The potential of the new droplet will be,

$$V'=\frac{kQ}{R'}$$

$$\Rightarrow V'=\frac{kNVr}{kN^{\frac{1}{3}}r}$$

$$\Rightarrow V'=VN^{\frac{2}{3}}$$

27. Define activity of a sample of a radioactive substance. The value of the disintegration constant of a radioactive substance is $0.0693\,h^{-1}$. Find the time after which the activity of a sample of this substance reduces to one-half that of its present value. 2 Marks

Ans: Activity of a sample of a radioactive substance is defined as the number of disintegration that has taken place in a given sample per second. In other word we can say decaying of a radioactive substance.

Given: The value of disintegration constant of the radioactive substance is $0.0693\,h^{-1}$ or we can say rate constant $k=0.0693\,h^{-1}$

Here we have to find the time after which the activity of a sample reduces to one-half, in short we have to calculate the half life time of the radioactive substances.

Half life, $t_{\frac{1}{2}}=\dfrac{0.693}{k}$

Now putting the k value we will get,

$$t_{\frac{1}{2}}=\frac{0.693}{0.0693h^{-1}}$$

$$\Rightarrow t_{\frac{1}{2}}=10\text{hours}$$

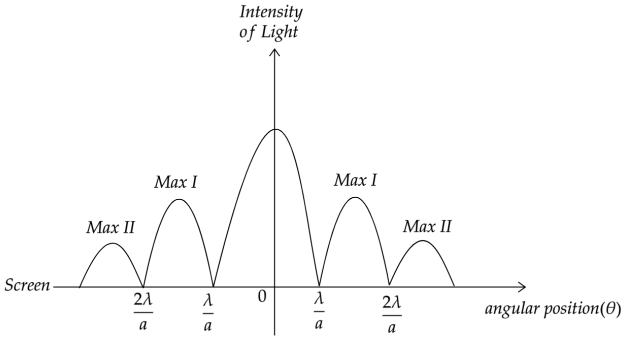
SECTION - C

28. In a single slit diffraction experiment, light of wavelength λ Illuminates the slit of width 'a' and the diffraction pattern observed on a screen. 3 Marks

Ans: In single slit diffraction experiment, let the wavelength of light be λ and the slit width be 'a'.

(a) show the intensity distribution in the pattern with the angular position θ

Ans: The intensity distribution in the patter with the angular position θ can be shown as,



(b) how are the intensity and angular width of central maxima affected when

Ans: We know,

Angular width is inversely propositional to the width of the slit, 'a' which is represented as,

$$\text{Angular Width}=\frac{2\lambda}{a}$$

And the intensity is directly proportional to the area or we can say width of the slip as well as the separation between the slit and screen while angular width has no relation with separation between the slit and screen.

(i) width of slit is increased, and

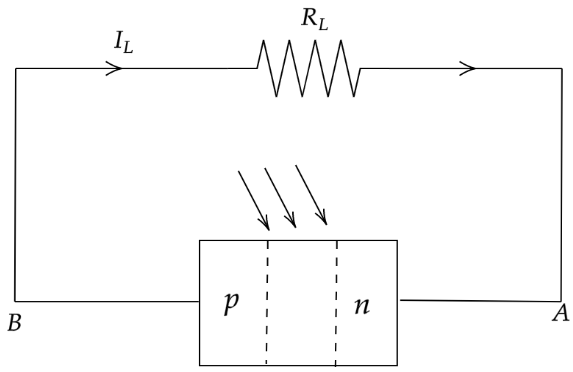
Ans: When the width of the sit 'a' increases then the angular width decreases and the intensity of the central maxima increases.

(ii) separation between slit and screen is decreased

Ans: When the separation between the slit and screen decreases then the intensity of the central maxima also decreases while there is no change in the angular width.

29. With the help of a simple diagram, explain the working of silicon solar cells, giving all three basic processes involved. Draw its I-V characteristics.
3 Marks

Ans: Diagram:



The construction of a silicon solar cell is usually made up of thick layer of n-type semiconductor which is layered by a thin layer of p-type semiconductor. Then the electrodes are placed on the top of the p-type semiconductor and then another electrode for collecting current is attached to the bottom of the n-type semiconductor.

Working principle:

When light strikes on the source of the cell, it get penetrated to the p-n junction which is crested by the fusion of p-type semiconductor and n-type semiconductor. Then the photons are able to create electron and hole pairs. These free electrons in the depletion region will migrate to the p-type and two charges are built up on the opposite side of the junction which crest a potential difference across the junction. Hence when load is connected current will flow through it.

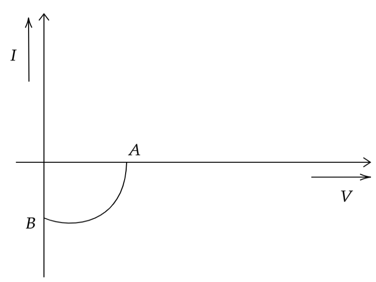
The three basic process involves are:

Generation of electron and hole pair are due to the light close to the junction.

Separation of electros to n side and hole to p side is due to the electric field in the depletion region.

And the electrons reaching n side is collected by front contact and the holes reaching p side are collected by back contact.

I-V Characteristics:

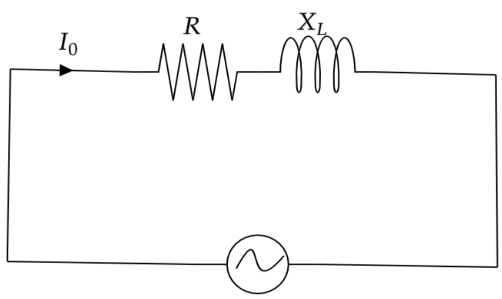


30. **A resistance R and an inductor L are connected in series to asource $V=V_0 \sin\omega t$**

Find the

Which of them is ahead? **3 Marks**

Ans: Diagram:



$V = V_0 sin\omega t$

The given circuit show that the resistor and the inductor are connected in series.

Hence the peak value of current through the circuit will be,

$$I_0=\frac{V_0}{Z}$$

Where the resultant impedance of the circuit will be,

$$Z=\sqrt{R^2+X_L^2}$$

Now the current will become,

$$I_0=\frac{V_0}{\sqrt{R^2+X_L^2}}$$

(a) peak value of the voltage drops across R and L,

Ans: The peak value of the voltage across the resistor R will be,

$$V_R=I_0R=\frac{V_0R}{\sqrt{R^2+X_L^2}}$$

The peak value of the voltage across the inductor L will be,

$$V_L = I_0 X_L = \frac{V_0 X_L}{\sqrt{R^2 + X_L^2}}$$

(b) phase difference between the applied voltage and current.

Ans: The phase difference is the angle between the resistor and inductor,

Hence,

$$\tan\phi = \frac{X_L}{R}$$

$$\Rightarrow \phi = \tan^{-1}\frac{X_L}{R}$$

As in the circuit inductor is present then the voltage will leads the current by an angle of ϕ as the voltage and current in resistor are in same phase.

31. **3 Marks**

(a) Write the expression for the speed of light in a material medium of relative permittivity ε_r and relative magnetic permeability μ_r.

Ans: The speed of electromagnetic waves is represented as,

$$c = \frac{1}{\sqrt{\mu\varepsilon}}$$

Where, ε is the electric permittivity and μ is the magnetic permeability.

Given:

Relative permittivity ε_r

Relative permeability μ_r

We know,

$$\mu = \mu_r \mu_0$$

And $\varepsilon = \varepsilon_r \varepsilon_0$

Now using this speed of the light in the material medium,

$$v=\frac{1}{\sqrt{\mu\varepsilon}}=\frac{1}{\sqrt{\mu_r\mu_0\varepsilon_r\varepsilon_0}}$$

(b) Write the wavelength range and name of the electromagnetic waves are used in

(i) radar systems for aircraft navigation and

Ans: The electromagnetic wave use in radar system for aircraft id the microwave whose wavelength range is in between 1mm to 0.1m.

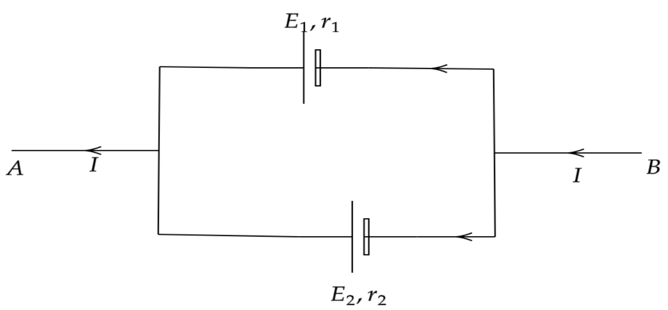
(ii) Earth satellites to observe the growth of the crops.

Ans: The electromagnetic wave used in earth satellites to observe the growth of crops is the infrared wave or we can say IR ray whose wavelength lies in the range $1mm$ to 700nm.

32. **3 Marks**

(a) Two cells of emf E_1 and E_2 have their internal resistances r_1 and r_2 respectively. Deduce an expression for the equivalent emf and internal resistance of their parallel combination when connected across an external resistance R. Assume that the two cells are supporting each other.

Ans:



Given,

Emf are E_1 and E_2.

Internal resistances r_1 and r_2.

Here the total current I is,

$$I = I_1 + I_2 \ldots\ldots(1)$$

Let V is the potential difference between point A and B.

Then $V = E_1 - I_1 r_1$

$$\Rightarrow I_1 = \frac{E_1 - V}{r_1} \ldots\ldots(2)$$

And, $V = E_2 - I_2 r_2$

$$\Rightarrow I_2 = \frac{E_2 - V}{r_2} \ldots\ldots(3)$$

Now putting equation (2) and (3) in equation (1) we will get,

$$I = \frac{E_1 - V}{r_1} + \frac{E_2 - V}{r_2}$$

$$I = \left(\frac{E_1}{r_1} + \frac{E_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

Or we can say,

$$V = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right) - I\left(\frac{r_1 r_2}{r_1 + r_2}\right)$$

If we replace this with a single cell it can be written as,

$$V = E_{equivalenet} - I r_{equivalent}$$

Now on comparing we will get,

$$E_{equivalenet} = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right)$$

$$r_{equivalent} = \left(\frac{r_1 r_2}{r_1 + r_2}\right)$$

(b) In case the cell are identical, each of $E = 5V$ and internal resistance $r = 2\mu$ calculate the voltage across the external resistance $R = 10\Omega$.

Ans: Given:

$r_1 = r_2 = 2\Omega$

$r_{equivalent} = \left(\frac{2\times2}{2+2}\right) = 1\Omega$

$E_1 = E_2 = 5V$

$E_{equivalenet} = \left(\frac{5\times2+5\times2}{2+2}\right) = 5V$

Now the external voltage will be,

$E_{ext} = IR$

$I = \frac{E_{equivalent}}{R+r}$

Now,

$E_{ext} = \frac{E_{equivalent}}{R+r}\times R$

$\Rightarrow E_{ext} = \frac{5V}{10+1}\times 10 = 4.54\,\text{Volts}$

33. **3 Marks**

(a) write an expression of magnetic moment associated with a current (I) carrying circular coil of radius r having N turns

Ans: Magnetic moment of a current carrying circular coil of radius r and having N turns is given as,

M=NIA where A is the area bounded by the circular loop.

Now we can write the area as,

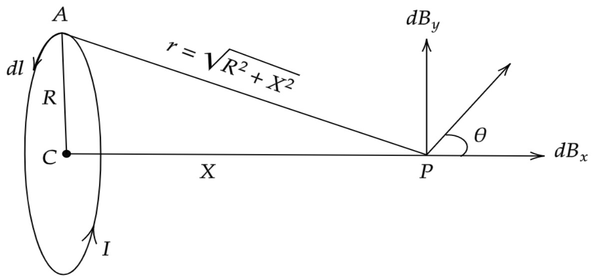
$A = \pi r^2$

On putting the magnetic moment will be,

$M = NIA = NI\pi r^2$

(b) consider the above-mention places in YZ planes with its magnetic Field due it at point (x,0,0).

Ans:



Now according to the above figure due to the current carrying element dl which at A the magnetic field at P is given as,

$$dB=\frac{\mu_0 I}{4\pi}\frac{\left|\vec{dl}\times\vec{r}\right|}{r^3}$$

Since vector dl and r perpendicular to each other, $dl\times r = dl\,r$

Now it become,

$$dB=\frac{\mu_0 I}{4\pi}\frac{dl}{r^2}$$

From the figure, $r^2=X^2+R^2$

Hence,

$$dB=\frac{\mu_0 I}{4\pi}\frac{dl}{X^2+R^2}$$

Consider a current elements opposite to that of A that is on B, then we can see that the Y component of the magnetic field the current element get cancelled and that of X component is present.

Now,

$$dB_X=dB\cos\theta$$

The net magnetic field at P will be,

$$B=\int dB_X=\int dB\cos\theta$$

$$\Rightarrow B=\int \frac{\mu_0 I}{4\pi}\frac{dl}{X^2+R^2}\cos\theta$$

From figure, $\cos\theta=\frac{R}{\sqrt{X^2+R^2}}$

$$\Rightarrow B=\int \frac{\mu_0 I}{4\pi}\frac{dl}{X^2+R^2}\frac{R}{\sqrt{X^2+R^2}}$$

$$\Rightarrow B=\frac{\mu_0 I}{4\pi}\frac{R}{\left(X^2+R^2\right)^{\frac{3}{2}}}\int dl$$

$$\Rightarrow B=\frac{\mu_0 I}{4\pi}\frac{R}{\left(X^2+R^2\right)^{\frac{3}{2}}}2\pi R$$

$$\Rightarrow B=\frac{\mu_0 IR^2}{2\left(X^2+R^2\right)^{\frac{3}{2}}}$$

Or

3 Marks

(a) Define current sensitivity of a galvanometer. Write its Expression

Ans: Current sensitivity of a galvanometer is defined as the ratio of deflection produced in a galvanometer to the current flowing through it.

We can also say it as the deflection per unit current.

Expression for the current sensitivity as,

$$S_i=\frac{\theta}{I}$$

Where, θ is the deflection and the I is the current.

So its SI unit is radian per ampere.

(b) A galvanometer has resistance G and shows full scale deflection for current Ig.

Ans: We have a galvanometer having resistance G and shows full scale deflection that is Ig.

(i) How can it be converted into an ammeter to measure current up to IO (IO>Ig) ?

Ans: A galvanometer can be converted into an ammeter by connecting a shut parallel to it so as to measure the current up to IO.

Expression for such type of connection is,

$$\left(I_o - I_g\right)R_s = I_g G.$$

Where, RS is the shunt resistance.

(ii) What is the effective resistance of this ammeter?

Ans: As the shut is connected in parallel with the galvanometer the effective resistance will be,

$$R_{eff} = \frac{R_S G}{R_S + G}$$

Where, $R_s || G$.

34. **The nucleus $^{235}_{92}Y$, initially at rest, decays into $^{231}_{90}X$ by emitting 234 231 4 an α particle $_{92}Y \rightarrow {}_{90}X + {}_{2}He + energy$.**

The binding energies per nucleon, the daughter nucleus and α particle are 7.8MeV, 7.835MeV and 7.07MeV respectively. Assuming the daughter nucleus to be formed in the unexcited state and neglecting its share in the energy of the reaction, find the speed of the emitted α particle.

(Mass of α particle = 6.68×10^{-27}) **3 Marks**

Ans: Given: The binding energies per nucleon is 7.8MeV, the daughter nucleus is 7.835MeV and the α particle is 7.07MeV.

We know the energy released is,

$$Q = \left[M\left(^{231}X\right) + M\left(^{4}He\right) - M\left(^{235}Y\right)\right]c^2$$

$=\left[(7.835\times231)+(7.07\times4)-(7.8\times235)\right]\text{MeV}$

$=\left[1809.9+28.28-1833\right]\text{MeV}$

$=5.18\times1.6\times10^{-13}\text{J}$

Now this entire kinetic energy is taken by the α particle as,

$$\frac{1}{2}mv^2=5.18\times1.6\times10^{-13}\text{J}$$

Mass of the α particle = 6.68×10^{-27}

Now,

$$\frac{1}{2}6.68\times10^{-27}v^2=5.18\times1.6\times10^{-13}\text{J}$$

$$\Rightarrow v^2=\frac{2\times5.18\times1.6\times10^{-13}}{6.68\times10^{-27}}$$

$$\Rightarrow v=\sqrt{\frac{2\times5.18\times1.6\times10^{-13}}{6.68\times10^{-27}}}$$

Hence the speed of the α particle is,

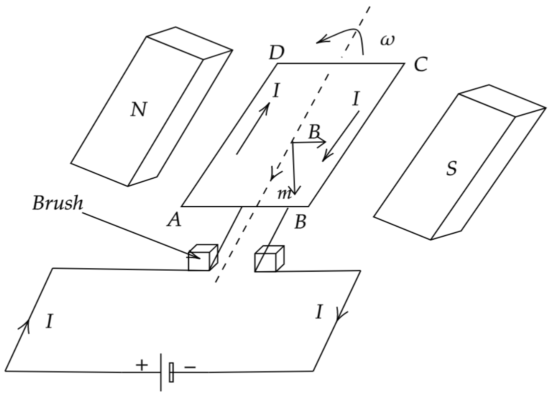
$v=1.57\times10^{7}\text{ms}^{-1}$.

SECTION - D

35. **5 Marks**

(a) Derive the expression for the torque acting on the rectangular current carrying coil of a galvanometer. Why is the magnetic field made radial.

Ans:



From the figure let us consider a loop ABCD in a uniform magnetic field strength donated as B and a current through the path is I.

The magnetic forces of AB and Cd are equal and opposite to each other but have a different kind of action.

Hence the force produce in the rectangular coil ABCD be,

$\tau = F \times PD$

Where PD is the perpendicular distance between two force arm i.e $b\sin\theta$ and the force is also represented as, $F = IlB$ where, l is the length of the rectangular coil, I is the current flowing through is and B is the magnetic field strength.

Now torque,

$\tau = IlBb\sin\theta$

Where $lb = A$,

$\tau = IAB\sin\theta$

The magnetic field is made radial because I is not directly proportional to ϕ. We can ensure this proportionality by having $\theta = 90°$. This is possible only when the magnetic field. In such filed the plane of rotating coil is always parallel to B.

(b) An α particle is accelerated through a potential difference of 10kV and move alone x -axis. It enters in a region of uniform magnetic field $B = 2\times10^{-3}$T acting along y -axis. Find the radius of its path. (Take mass of the α particle $= 6.68\times10^{-27}$kg)

Ans: Given:

Mass of α particle $= 6.68\times10^{-27}$kg

$B = 2 \times 10^{-3} T$

$V = 10 kV$

$Q = 2 \times 1.6 \times 10^{-19} C$

We know the radius of circular path is,

$$r = \frac{1}{B}\sqrt{\frac{2mV}{Q}}$$

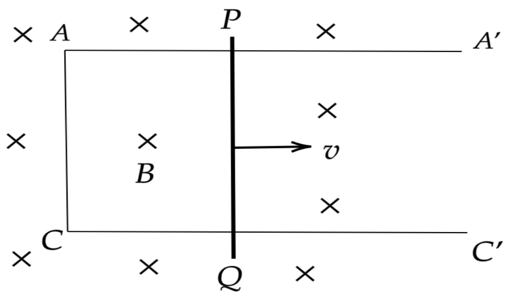
$$\Rightarrow r = \frac{1}{2 \times 10^{-3}}\sqrt{\frac{2 \times 6.68 \times 10^{-27} \times 10 \times 10^{3}}{2 \times 1.6 \times 10^{-19}}}$$

$$\Rightarrow r = \frac{1}{2 \times 10^{-3}}\frac{1}{50} = \frac{1}{10^{2-3}} = \frac{1}{10^{-1}} = 10m$$

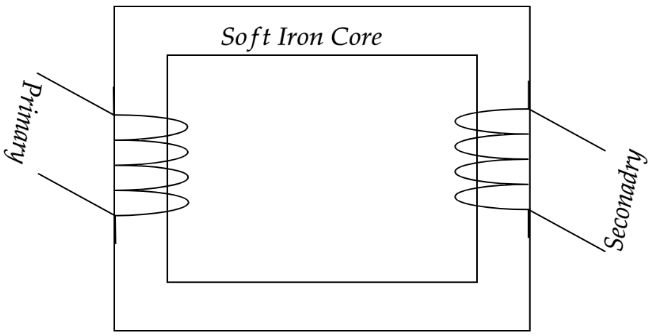
Or

5 Marks

(a) With the help of a labelled diagram, explain the working of a Step -up transformer. Give reasons to explain the following:



Ans: We can explain this with help of the diagram



The transformer work on the principle of the mutual induction that is whenever a current is associated with the primary coil charges then an emf is induced in the secondary coil. Hence when a transformer in which the output that is the secondary voltage is greater than its induce or primary voltage it is known as step up transformer.

Now the induced emf across the primary coil is,

$$E_P = -N_P \frac{d\phi}{dt}$$

Where, NP is the number of turns in a primary coil, ϕ is the flux associate in the coil.

Similarly induced emf in the secondary coil is,

$$E_S = -N_S \frac{d\phi}{dt}$$

Where, NS is the number of turns in a secondary coil, ϕ is the flux associate in the coil.

Taking the ration of both the induced emf,

$$\frac{E_S}{E_P} = \frac{N_S}{N_P}$$

(i) the core of the trans former is laminated

Ans: The core of the transformer is laminated so as to reduce the eddy current produces due to the flow of current

(ii) Thick copper wire is used in windings.

Ans: Thick copper wire is used in winding so as to reduce the heat loss because large amount of heat is produce during this process.

(b) A conducting rod PQ of length 20 cm and resistance 0.1 Ω rests on two smooth parallel rails of negligible resistance AA' and CC'. It can slide on the rails and the arrangement is positioned between the poles of a permanent magnet producing uniform magnetic field B = 0.4 T. The rails, the rod and the magnetic field are in three mutually perpendicular directions as shown in the figure. If the ends A and C of the rails are short circuited, find the

Ans: Given:

Length of PQ = 20cm = 0.2m

Resistance = 0.1Ω

B = 0.4T

(i) external force required to move the rod with uniform velocity v = 10 cm/s, and

Ans: v = 10 cm/s 0.1m/s

Now the external force require to remove the rode will be,

$$F=\frac{B^2vl^2}{R}$$

$$\Rightarrow F=\frac{0.4^2\times0.1\times0.2^2}{0.1}=6.4\times10^{-3}N$$

(ii) power required to do so

Ans: We know power is the product of force and velocity.

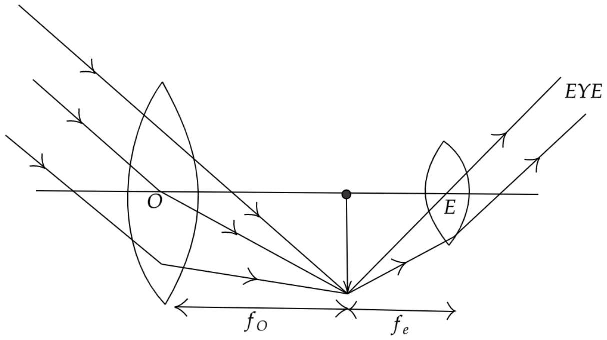
$$P=Fv$$

$$\Rightarrow P=6.4\times10^{-3}\times0.1=0.64\times10^{-3}Watt$$

36. **5 Marks**

(a) Draw the ray diagram of an astronomical telescope when the final image is formed at infinity. Write the expression for the resolving power of the telescope.

Ans: The ray diagram of an astronomical telescope when the final image is formed at infinity is as given below:



Here, fO is the focal length of the objective lens and fe is the focal length of the eyepiece lens.

The expression for resolving power of the telescope is gien as,

$$\text{Resolving power} = \frac{D}{1.22\lambda}$$

Where, D is the diameter of aperture objective lens and the λ is the wavelength.

(b) An astronomical telescope has an objective lens of focal Length 20 m and eyepiece of focal length 1 cm .

Ans: Given:

Focal length of the objective lens = 20cm (fO)

Focal length of eyepiece lens = 1cm = 0.01m (fe)

(i) Find the angular magnification of the telescope.

Ans: Angular magnification of astronomical telescope is given as,

$$\text{Angular Magnification} = \frac{f_O}{f_e} = \frac{20\text{m}}{0.01\text{m}} = 200$$

(ii) If this telescope is used to view of the Moon, find the diameter of the image formed by the objective lens.

Given diameter of the Moon is 3.5×10^6m and radius of lunar orbit 3.5×10^6 is 3.8×10^8m.

Ans: Given:

Diameter of the Moon is $D=3.5\times10^{6}m$.

Radius of lunar orbit is $x=3.8\times10^{8}m$.

Diameter of the image = ??

We know,

$$\frac{D}{d}=\frac{x}{f_o}$$

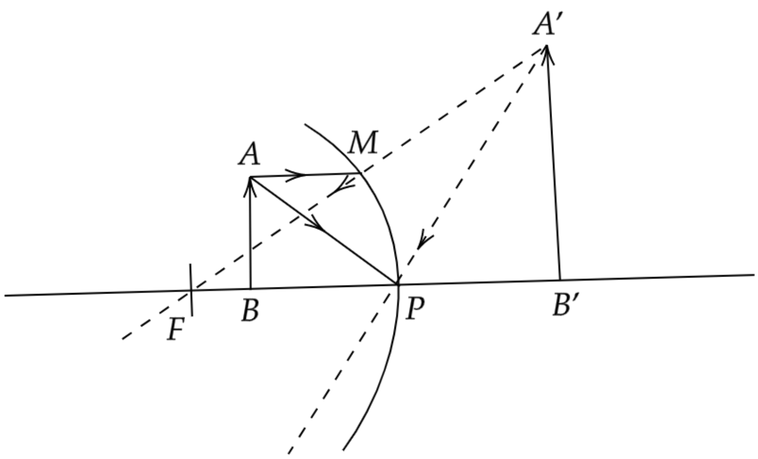
$$d=\frac{Df_o}{x}=\frac{3.5\times10^{6}\times20}{3.8\times10^{8}}=18.4\times10^{-2}m=18.4cm$$

Or

5 Marks

(a) An object is placed in front of a concave mirror it is observed that a virtual image is formed. Draw the ray diagram to show the image formation and hence derive the mirror equation.

Ans:



From the diagram,

From $\Delta A'B'F$ and ΔMPF using similarity criteria we get,

$$\frac{A'B'}{MP}=\frac{B'F}{FP}$$

We have,

PM=AB

Now,

$$\frac{A'B'}{AB}=\frac{B'F}{FP}$$

Now from $\Delta A'B'P$ and ΔABP using similarity criteria we get,

$$\frac{AB'}{AB}=\frac{B'P}{BP}$$

Now equation (1) and (2),

$$\frac{B'F}{FP}=\frac{B'P}{BP}$$

Where,

B'F = v+f

BP = u

FP = f

B'P = v

Therefore,

$$\frac{B'F}{FP}=\frac{B'P}{BP}$$

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

Dividing both side by v and applying sign convention we will get,

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

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

Hence proved.

(b) An object is placed 30 cm in front of a Plano -convex lens with its spherical surface of radius of curvature 20 cm. If the refractive index of the material of the lens is 1.5, find the position and nature of the image formed.

Ans: Given: R=20cm

Object distance, u=30cm

By lens maker formula,

$$\frac{1}{f}=(\mu-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

For Plano convex lens,

$R_1=R$

$R_2=\infty$

$\mu=1.5$

Therefore,

$$\frac{1}{f}=(\mu-1)\left[\frac{1}{R}\right]$$

$$\Rightarrow\frac{1}{f}=(1.5-1)\left[\frac{1}{20cm}\right]$$

f=40cm

Now using mirror formula we will get,

$$\frac{1}{40cm}=\frac{1}{v}+\frac{1}{30cm}$$

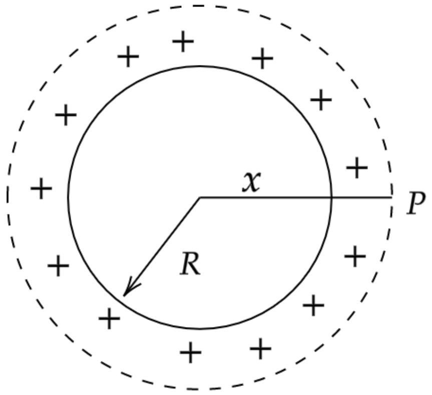
$\Rightarrow$ v=-12cm

Therefore the image is virtual.

37. **5 Marks**

(a) Using Gauss law, derive expression for electric field due to a spherical shell of uniform charge distribution a and radius R at a point lying at a distance x from the center of shell, such that

Ans: Let us assume that R be the radius of the spherical shell and Q be the charge that is uniformly distributed on the source



(i) 0 < x < R, and (ii) x > R

Ans: 0<x<R

For a point inside the shell is,

By using Gauss's Law we can write,

$$E \times 4\pi x^2 = \frac{Q_{in}}{\varepsilon_0}$$

Here x be the distance from the center of the shell and the charge Qin inside the shell is zero.

Hence,

$E=0$

(ii) x>R

For a point outside the shell is,

By using Gauss's law we can write,

$$E \times 4\pi x^2 = \frac{Q_{out}}{\varepsilon_0}$$

Where x is the distance from center of shell and the change Qout is on the surface of the shell.

$$E = \frac{Q_{out}}{4\pi x^2 \varepsilon_0}$$

(b) An electric field is uniform and acts along + x direction in the region of positive x. It is also uniform with the same magnitude but acts in - x direction in the region of negative x. The value of the field is E=200 N/C for x > 0 and E = - 200 N/C for x < 0. A right circular cylinder of length 20 cm and radius 5 cm has its center at the origin and its axis along the x -axis so that one flat face is at x = + 10 cm and the other is at x = -10 cm. Find :

Ans: Given: E=200 N/C for x > 0 and E = - 200 N/C for x < 0.

Right circular cylinder of length 20 cm and radius 5 cm has its center at the origin.

(i) The net outward flux through the cylinder.

Ans: The net outward flux = 2EA

$$\phi = 2EA = 2 \times 200 \times 3.14 \times (0.05)^2 = 3.14 Nm^2C^{-1}$$

(ii) The net charge present inside the cylinder.

Ans: The net change present inside the cylinder, Q is

$$Q = \varepsilon_0 \times \phi = 8.854 \times 10^{-12} \times 3.14 = 27.8 \times 10^{-12} C$$

Or

5 Marks

(a) Find the expression for the potential energy of a system of two point charges q1 and q2 located at $\vec{r}_1$ and $\vec{r}_2$ and respectively in an external electric field $\vec{E}$.

Ans: Given: two point charges q1 and q2 located at $\vec{r}_1$ and $\vec{r}_2$ respectively in an external electric field $\vec{E}$.

Now work done in bringing q1 from the infinity against the electric field is represented as,

$W_1 = q_1 V |\vec{r_1}|$

Similarly work done in bringing q2 from the infinity against the electric field is represented as,

$W_1 = q_1 V |\vec{r_2}|$

Now work done q2 against the filed due to q1

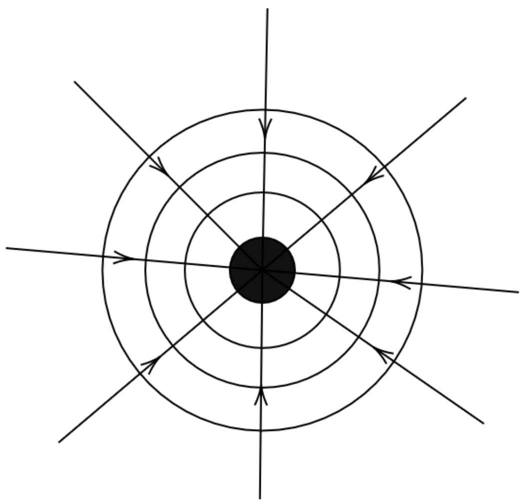
$$W = \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}$$

Hence the potential energy of the system = Total work done in assembling the system.

$$V_{system} = W_1 + W_2 + W = q_1 V|\vec{r_1}| + q_2 V|\vec{r_2}| + \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}$$

(b) Draw equipotential surfaces due to an isolated point charge (— q) and depict the electric field lines.

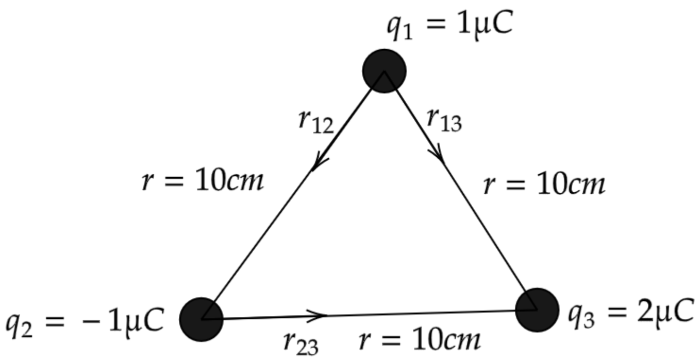
Ans: Equipotential surfaces are always perepmdilar to the electric field. This the diagram of an equipotential surface due to an isolated point charge of -q charge. The electric field lines terminate on negative change or we can say direction of electric field lines are inward.



(c) Three point charges, $1\mu C$ $-1\mu C$, and $2\mu C$ are initially infinite distance apart. Calculate the work done in assembling these charges at the vertices of an equilateral triangle of side 10 cm.

Ans: Three point charges:

$q_1=1\mu C$, $q_2=-1\mu C$ and , $q_3=2\mu C$ are present in an equilateral triangle of side r=10cm



We know,

Work done = Charge in potential energy

$$W=\left[k\frac{q_1q_2}{r_{12}}+k\frac{q_1q_3}{r_{13}}+k\frac{q_2q_3}{r_{23}}\right]$$

Where,

$r_{12}=r_{13}=r_{23}=r=10cm=0.1m$

$$W=\frac{k}{r}\left[q_1q_2+q_1q_3+q_2q_3\right]$$

$$W=\frac{9\times10^9}{0.1}\left[-1+2-2\right]=-9\times10^{10}J$$