CBSE Class 12 Physics

Sample Paper - 10 (2019-20)

Maximum Marks: 70

Time Allowed: 3 hours

General Instructions:

i. All questions are compulsory. There are 37 questions in all.
ii. This question paper has four sections: Section A, Section B, Section C and Section D.
iii. Section A contains twenty questions of one mark each, Section B contains seven questions of two marks each, Section C contains seven questions of three marks each, and Section D contains three questions of five marks each.
iv. There is no overall choice. However, internal choices have been provided in two questions of one mark each, two questions of two marks, one question of three marks and three questions of five marks weightage. You have to attempt only one of the choices in such questions.

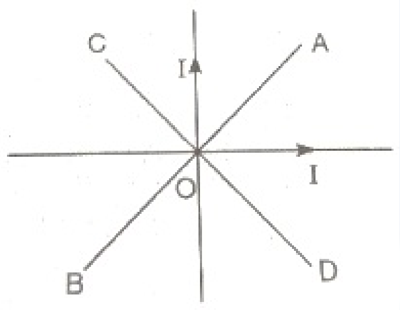
Section A

1. A particle of mass m and charge q is released from rest in a uniform electric field E. The kinetic energy attained by the particle after moving a distance x is
   a. q^2Ex
   b. qEx^2
   c. qEx
   d. qE^2x
2. Which of the following is true about equipotential lines. Electric field lines are
   a. parallel to equipotential lines
   b. opposite to equipotential lines
   c. tangential to equipotential lines
   d. perpendicular to equipotential lines
3. Potentiometer measures the potential difference more accurately than a voltmeter,

because

a. It has a wire of low resistance.
b. It draws a heavy current from external circuit.
c. It does not draw current from external circuit.
d. It has a wire of high resistance.

4. The equivalent resistance of two resistances P and Q which are in parallel is
   a. $\frac{P\times P}{(P+Q)}$
   b. $R=\frac{PQ}{P+Q}$
   c. P + Q
   d. $\frac{Q\times Q}{(P+Q)}$
5. Two equal electric currents are flowing perpendicular to each other as shown in the figure. AB and CD are perpendicular to each other and symmetrically placed with respect to the currents. Where do we expect the resultant magnetic field to be zero?



   a. on AB
   b. on both AB and CD
   c. on both OD and BO
   d. on CD
6. A beam of light has a wavelength of 650 nm in vacuum. What is the wavelength of these waves in the liquid whose index of refraction at this wavelength is 1.47?
   a. 452nm
   b. 442nm
   c. 472nm
   d. 462nm
7. Light of wavelength 5000 Å falls on a plane reflecting surface. What are the wavelength and frequency of the reflected light? For what angle of incidence is the reflected ray normal to the incident ray?
   a. $5300\overset{0}{A}, 6\times 10^{14}\mathrm{Hz}; 65^{\circ}$

b. $5000\overset{0}{A}, 6 \times 10^{14}\text{Hz}; 45^{\circ}$

c. $5200\overset{0}{A}, 6 \times 10^{14}\text{Hz}; 55^{\circ}$

d. $5400\overset{0}{A}, 6 \times 10^{14}\text{Hz}; 50^{\circ}$

8. When light is passed through a prism, the colour which deviates least is:
   a. Red
   b. Blue
   c. Green
   d. Violet<
9. Magnitude of the electric and the magnetic fields in an plane electromagnetic wave are related by
   a. $B_0 = \frac{E_0}{c}$
   b. $B_0 = 2\frac{E_0}{c}$
   c. $B_0 = \frac{E_0}{c\pi}$
   d. $B_0 = \frac{\pi E_0}{c}$
10. Wavelength of light incident on a photocell is 3000 $\overset{0}{A}$, if stopping potential is 2.5 volts, then work function of the cathode of photocell is
    a. 1.64 eV
    b. 1.41 eV
    c. 1.56 eV
    d. 1.52 eV
11. Fill in the blanks: The magnetic force required to demagnetize the material is ________
12. Fill in the blanks: The lines joining the places of equal dip or inclination are called ________ lines.
13. Fill in the blanks:

    Faraday's law gives us the ________ of induced emf.

    OR

    Fill in the blanks: The electric fields created by time-varying magnetic fields having non-vanishing loop integrals are called ________ fields.
14. Fill in the blanks: Density of nucleus matter is the ratio of ________ of nucleus and its volume.

15. Fill in the blanks: The angle of incidence when a ray of light falls normally on a mirror is ________.
16. Write the equation of decay of the radioactive nuclei.
17. Name the absorbing material used to control the reaction rate of neutrons in a nuclear reactor.
18. Name one impurity each, which when added to pure Si, produces
    i. n-type and
    ii. p-type semiconductor.

19. Write the expression for the de-Broglie wavelength associated with a charged particle having charge q and mass m, when it is accelerated by a potential V.

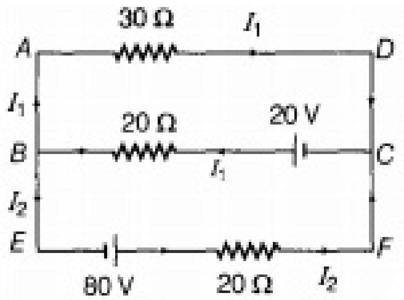
20. Name one impurity each, which when added to pure Si, produces
    i. n-type and
    ii. p-type semiconductor.

OR

Name the type of biasing of a p-n junction diode so that the junction offers very high resistance.

Section B

21. Use Kirchhoff's rules to determine the value of the current I_1 flowing in the circuit shown in the figure.



22. Why are electric field lines perpendicular at a point on an equipotential surface of a conductor?

23. A proton and a deuteron are accelerated through the same accelerating potential.

Which one of the two has

i. greater value of de-Broglie wavelength associated with it and
ii. less momentum?
Give reasons to justify your answer.

24. A capacitor of capacitance C is being charged by connecting it across a DC source along with an ammeter. Will the ammeter show a momentary deflection during the process of charging? If so, how would you explain this momentary deflection and the resulting continuity of current in the circuit? Write the expression for the current inside the capacitor.

25. A short bar magnet placed with its axis making an angle θ with a uniform external field B experience a torque. What is the magnetic moment of the magnet?

26. Find out the wavelength of the electron orbiting in the ground state of hydrogen atom.

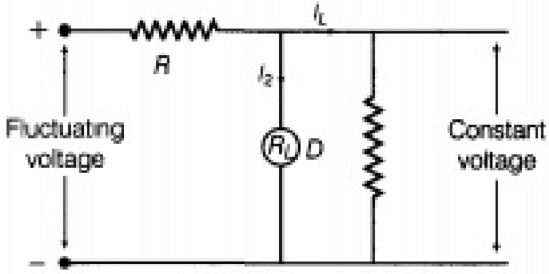
OR

In the ground state of hydrogen atom, its Bohr radius is given as 5.3×10^{-11} m.The atom is excited such that the radius becomes 21.2×10^{-11} m. Find (i) the value of the principal quantum number and (ii) the total energy of the atom in this excited state.

27. Draw the circuit diagram of an illuminated photodiode in reverse bias. How is photodiode used to measure light intensity?

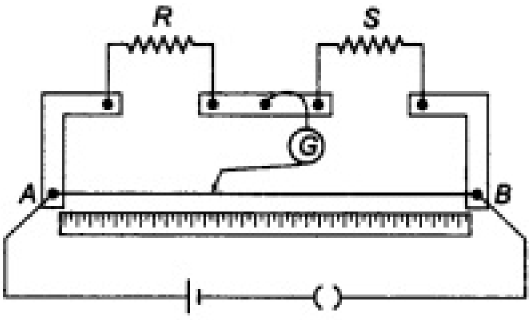
OR

Name the device, D which is used as a voltage regulator in the given circuit and give its symbol.



Section C

28. In a meter bridge, the null point is found at a distance of 60 cm from A. If a resistance of 5Ω is connected in series with S, then null point occurs at 50.0 cm from A. Determine the values of R and S.

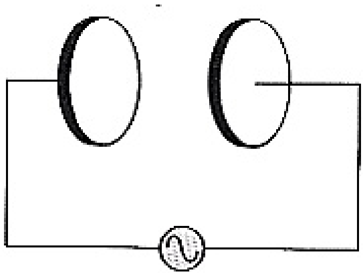


29. Draw a labelled diagram of cyclotron. Explain its working principle. Show that cyclotron frequency is independent of the speed and radius of the orbit.

30. An inductor $200\mu H$, capacitor $500\mu F$, resistor 10Ω are connected in series with a 100 V, variable frequency a.c. source.
Calculate:

    i. frequency at which the power factor of the circuit is unity
    ii. current amplitude at this frequency
    iii. Q-factor

31. A parallel plate capacitor made of circular plates each of radius R = 6.0 cm has a capacitance C = 100 pF. The capacitor is connected to a 230 V ac supply with a (angular) frequency of 300 rad s^{-1}.



    a. What is the rms value of the conduction current?
    b. Determine the amplitude of B at a point 3.0 cm from the axis between the plates.

32. How is resolving power of a microscope affected when

i. wavelength of illuminating radiations is decreased.
ii. the diameter of objective lens is decreased? Justify.

OR

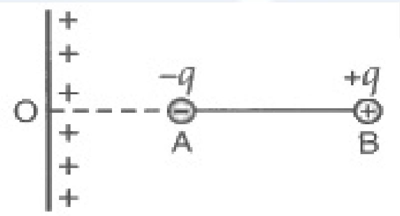
When one of the slits in Young's experiment is covered with a transparent sheet of thickness $3.6 \times 10^{-3} cm$ the central fringe shifts to a position originally occupied by the 30th bright fringe. If $\lambda = 6000 \overset{o}{A}$, find the refractive index of the sheet.

33. A 12.5 eV electron beam is used to bombard gaseous hydrogen at room temperature. What series of wave lengths will be emitted?

34. A Zener diode is fabricated by heavily doping both p-and n-sides of the junction. Explain.
Briefly explain the use of Zener diode as a DC voltage regulator with the help of a circuit diagram.

Section D

35. a. Using Gauss' theorem, obtain an expression for the electric field intensity at a point at a distance r from an infinitely long uniformly charged straight wire.
b. An electric dipole AB consists of charges ± 5 nC and separated by a distance of 2 $\times$ 10^{-3} m [Fig].

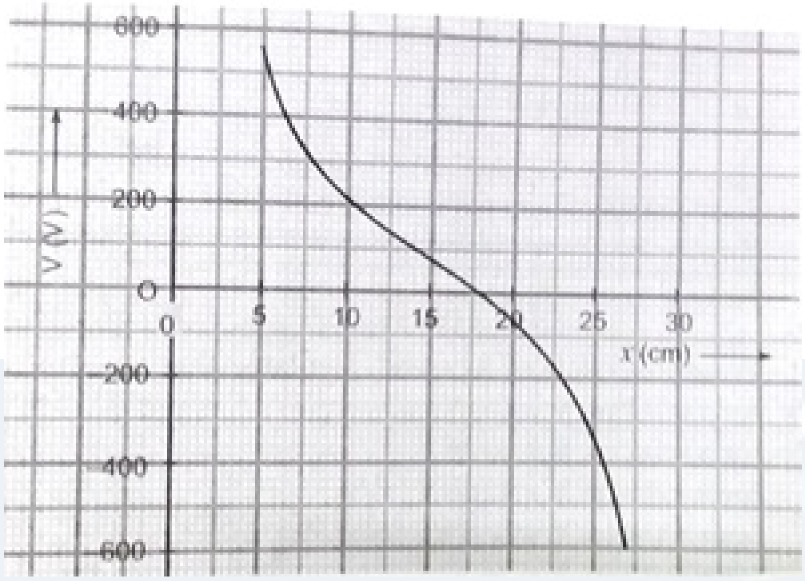


The dipole is placed near a long line charge having linear charge density 4.5×10^{-4} Cm^{-1}, such that the negative charge is at a distance OA = 2· 5 cm from the line charge. Find the force acting on the dipole.

OR

Two isolated point charges A and B are separated by a distance of 30· 0 cm, as shown in fig.

The charge at A is +3·6 × 10^{-9} C. The variation with distance x from A along AB of the potential V is as shown in fig.



i. State the value of x at which the potential is zero.
ii. Use your answer in (i) to determine the charge at B.
iii. A small test charge is now moved along the line AB from x = 5·0 cm to x = 27 cm. State and explain the value of x at which the force on the test charge will be maximum.

36. A current of 10 A is flowing in a long straight wire situated near a rectangular coil. The two sides, of the coil, of length 0.2 m are parallel to the wire. One of them is at a distance of 0.05 m and the other is at a distance of 0.10 m from the wire. The wire is in the plane of the coil.

i. Calculate the magnetic flux through the rectangular coil.
ii. If the current uniformly to zero in 0.02 s, find the emf induced in the coil and indicate the direction in which the induced current flows.

OR

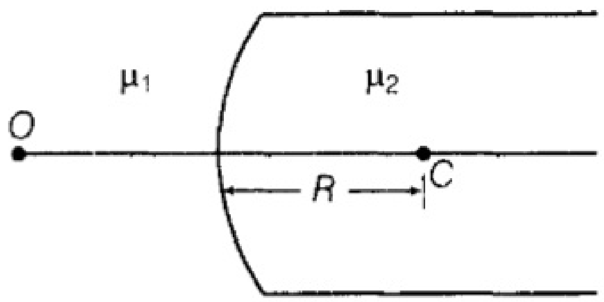
If a piece of metal has a charge $+0.1 \mu C$ and is placed inside a hollow metal sphere of radius 20 cm (without touching it), what is the potential of the sphere? What will the potential of the sphere become, if

a. the sphere is temporarily earthed and then left insulated,
b. the metal subsequently touched the inside of the sphere?

37. a. A point object is placed on the principal axis of a convex spherical surface of radius of curvature R, which separates the two media of refractive indices n_1 and n_2 ($n_2 > n_1$). Draw the ray diagram and deduce the relationship between the object distance (u), image distance (v) and the radius of curvature (R) for refraction to take place at the convex spherical surface from rarer to denser medium.
    b. A converging lens has a focal length of 20 cm in air. It is made of a material of refractive index 1·6. If it is immersed in a liquid of refractive index 1·3, find its new focal length.

OR

Figure shows a convex spherical surface with centre of curvature C separating the two media of refractive indices μ_1 and μ_2. Draw a ray diagram showing the formation of the image of a point object O lying on the principal axis. Derive the relationship between the object and image distance in terms of refractive indices of the media and the radius of curvature R of the surface.



Answer

Section A

1. (c) qEx **Explanation:** If a charge q placed in uniform electric field E experiences force, F = qE, displacement = x W = Force X displacement W = qE x
According to work-energy theorem, Network done = change in Kinetic energy, Hence Kinetic energy attained = qE x.
2. (d) perpendicular to equipotential lines
Explanation: The potential at all points on an equipotential surface is constant and work done in moving a charge on an equipotential surface is zero. Electric field lines show the direction of the electric field at the point. If the electric field lines were tangential, parallel or opposite to the equipotential surface, a tangential field will exist on the surface and work done in moving a charge on the surface is not zero. Therefore electric field lines are always perpendicular to the equipotential surface.
3. (c) It does not draw current from external circuit.
Explanation: Potentiometer measures the potential difference using null deflection method, where no current is drawn from the cell; whereas voltmeter needs a small current to show deflection. So, accurate measurement of p.d is done using a potentiometer.
4. (b) $R = \frac{PQ}{P+Q}$ **Explanation:** The reciprocal of the equivalent resistance of two resistances connected in parallel is equal to the sum of the reciprocals of the two resistances.

$$\frac{1}{R_{eq}} = \frac{1}{P} + \frac{1}{Q}$$
$$\Rightarrow R_{eq} = \frac{PQ}{P+Q}$$

5. (a) on AB
Explanation: on AB
6. (b) 442nm
Explanation: $\mu = \lambda 1/\lambda_2$

$1.47 = \frac{650}{\lambda_2}$

so wavelength is 442 nm.

7. (b) $5000\overset{0}{A}, 6 \times 10^{14}\text{Hz}; 45^{\circ}$ **Explanation:** There is no change in wavelength of light in reflection.

   use $v = \nu\lambda$

8. (a) Red

   Explanation: Refracting index is given by, $\mu = A + \frac{B}{\lambda^2}$, where A & B are constant.

   Wavelength if red color is maximum, hence refractive index of material of prism for red color light is minimum hence red color deviates the least.

9. (a) $B_0 = \frac{E_0}{c}$

   Explanation: $B_o = \frac{E_0}{c}$, where c is speed of light

10. (a) 1.64 eV

    Explanation: Vo = 2.5 V, hence eVo = 2.5 eV

    $$\phi_o = \frac{hc}{\lambda} - 2.5eV = \left(\frac{1240}{300} - 2.5\right) eV \approx 1.64eV$$

11. Coercivity

12. Isoclinical

13. Magnitude

OR

Non-conservative

14. Mass

15. Zero degree

16. $N = N_0 e^{-\lambda t}$

17. Heavy water

18. i. As (Arsenic)
ii. In (Indium)

19. de-Broglie wavelength, $\lambda = h/p = h/\sqrt{2mqV}$
Hint: W = K = qV = $p^2/2m$ or $p = \sqrt{2mqV}$

20. i. As (Arsenic)
ii. In (Indium)

OR

Reverse biasing.

Section B

21. Gustav Kirchhoff's Current Law is one of the fundamental laws used for circuit analysis. His current law states that for a parallel path the total current entering a circuit junction is exactly equal to the total current leaving the same junction. This is because it has no other place to go as no charge is lost.
In other words the algebraic sum of ALL the currents entering and leaving a junction must be equal to zero as: $\Sigma I_{IN} = \Sigma I_{OUT}$

In closed-loop ABEFCDA,

$-80 + 20I_2 - 30I_1 = 0$

$20I_2 - 30I_1 = 80$ ...(i)

In closed-loop BEFCB,

$-80 + 20I_2 - 20 + 20I_1 = 0$

$20I_2 + 20I_1 = 100$ ...(ii)

On solving Eqs. (i) and (ii), we get

$I_1 = \frac{2}{5} = 0.4\text{A}$

22. Electric field is always normal to the equipotential surface, because no work is done to move a test charge q_0 on the equipotential surface,

i.e. $W = q_0(V_A - V_B) = 0 \Rightarrow V_A - V_B = 0$

$\Rightarrow -\int \vec{E}.\overrightarrow{dl} = 0$

$\Rightarrow \vec{E} \perp \overrightarrow{dl}$

23. i. de-Broglie wavelength is given by $\lambda = \frac{h}{\sqrt{2mV_0q}} \Rightarrow \lambda \propto \frac{1}{\sqrt{m}}$ [V_0 and q are same, because proton and deuteron have been accelerated by same potential and have same charge].
Since, mass of proton is less as compared to a deuteron. So, it will have higher value of de-Broglie wavelength associated with it.
ii. de-Broglie wavelength is given by
$\lambda = h/p \Rightarrow p = h/\lambda$
As, $\lambda_d < \lambda_p$
So, $p_d > p_p$

24. Yes, the ammeter will show the momentary deflection.
This momentary deflection occurs due to the fact that the conducting current flows through connecting wires during the charging of capacitor. This leads to deposition of charge at two plates and hence, varying electric field of increasing nature is produced between the plates which in turn produces displacement current in space between two plates, which maintains the continuity with the conduction current.

Expression for the current $I = \epsilon_0 \frac{d\phi_E}{dt}$, where $\frac{d\phi_E}{dt}$ is the rate of change of electric flux with time.

25. $\tau = MB\sin\theta$
$M = \frac{\tau}{B\sin\theta}$

26. Radius of ground state of hydrogen atom $= 0.53A^\circ = 0.53 \times 10^{-10}m.$
According to de Broglie relation 2πr = nλ
For ground state n=1
$2 \times 3.14 \times 0.53 \times 10^{-10} = 1 \times \lambda$
therefore, $\lambda = 3.32 \times 10^{-10}m$
$\Rightarrow \lambda = 3.32A^\circ$

OR

i. According to the question,

Given, $r_1 = 5.3 \times 10^{-11}$ m and $r_2 = 21.2 \times 10^{-11}$ m

$n_1 = 1$

We know that, $r \propto n^2$

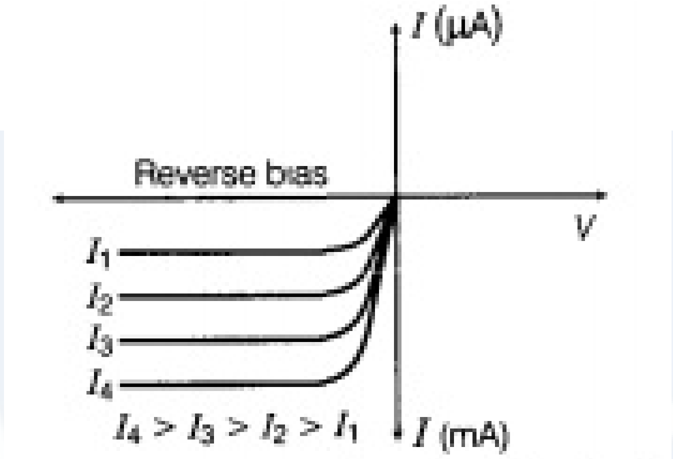
$$\frac{r_1}{r_2} = \frac{n_1^2}{n_2^2} \Rightarrow \frac{1}{n_2^2} = \frac{5.3\times10^{-11}}{21.2\times10^{-11}}$$

$$\Rightarrow \quad n_2^2 = 4 \Rightarrow n_2 = 2$$

ii. We know that,

$$E = \frac{-13.6}{n^2} = \frac{-13.6}{4} = -3.4\text{eV}$$

27. Circuit diagram of illuminated photodiode in reverse bias is shown below.



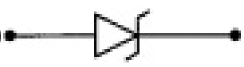
Reverse bias currents through a photodiode

A change in the photo current indicates a change in the **light intensity**, if a reverse bias is applied.

OR

Device - Zener diode.

Symbol is

P(anode)  N(cathode

Section C

28. The meter bridge works on the principle of Wheatstone bridge. At balance condition:

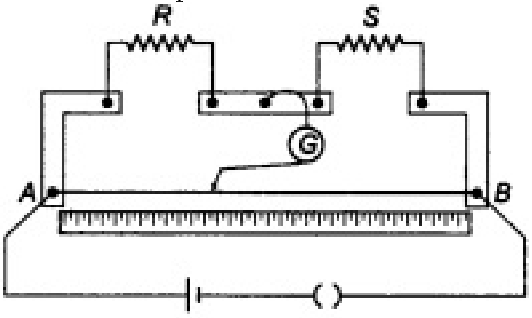
$$\frac{R}{S} = \frac{l_1}{100-l_1}$$

where l_1 is distance measured from A to the Null point.

In a meter bridge, the null point is found at a distance of 60 cm from A.

The condition of balanced meter bridge is

$\frac{R}{S}=\frac{l_1}{100-l_1}$



given $l_1=60\ cm$

$\frac{R}{S}=\frac{60}{100-60}=\frac{60}{40}=\frac{3}{2}$

$\Rightarrow \frac{R}{S}=\frac{3}{2}$ ...(i)

Again, applying the condition when S and 5Ω are connected in series

$\frac{R}{S'}=\frac{l_1}{100-l_1}$ with $l_1=50\ cm$

and $S'=5+S$

$\frac{R}{S+5}=\frac{50}{50}\Rightarrow\frac{R}{S+5}=1$ ...(ii)

From Equations , (i) and (ii), we get

$\frac{3}{2}S=S+5\Rightarrow\frac{3}{2}S-S=5$

$\Rightarrow S=10\Omega$

substituting value of 'S' in (i)

$\frac{R}{S}=\frac{3}{2}$

$\Rightarrow\frac{R}{10}=\frac{3}{2}$

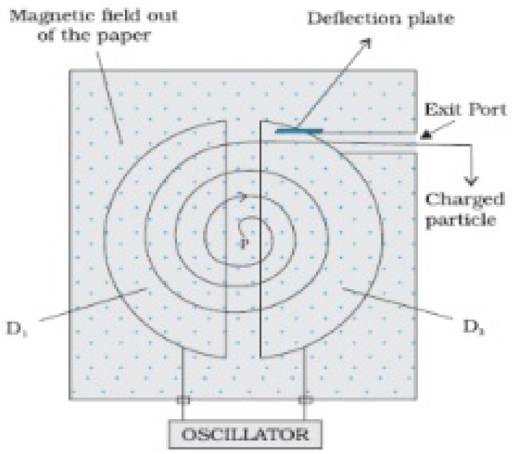
$\Rightarrow R=\frac{3\times10}{2}$

$\Rightarrow R=\frac{30}{2}$

$\Rightarrow R=15\Omega$

$\therefore R=15\Omega\ and\ S=10\Omega.$

29. Cyclotron is a device by which the positively charged particles like protons, deutrons, etc. can be accelerated. The labelled diagram of cyclotron is shown in the Figure.



Working Principle: The cyclotron uses crossed electric and magnetic fields which increases the kinetic energy of a charged particle without changing its frequency of revolution.

Here, Magnetic lorentz force is equal to the Centripetal force. Thus,

$F_c = F_m$

$\frac{mv^2}{r} = q\,v\,B$

Thus, $\frac{v}{r} = \frac{Bq}{m}$

Now, time taken to describe a semi-circle is,

$t = \frac{\pi r}{v} = \frac{\pi m}{Bq}$

Thus, period of rotation, T = 2t

$T = \frac{2\pi m}{Bq}$

The frequency of rotation of particle known as cyclotron frequency is,

$\nu_c = \frac{1}{T} = \frac{Bq}{2\pi m}$

From the above equation we can see, cyclotron frequency is independent of the speed and radius of the orbit.

30. i. Power factor

$\cos\theta = \frac{R}{Z} = 1$

R = Z

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

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

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

$\omega^2 = \frac{1}{LC}$ or $\omega = \frac{1}{\sqrt{LC}}$

$2\pi v = \frac{1}{\sqrt{LC}}$

$\nu = \frac{1}{2\pi\sqrt{LC}}$

$\omega_0 = \frac{1}{2\pi\sqrt{LC}}$

$= \frac{1}{\sqrt{200\times10^{-6}\times500\times10^{-6}}}$

$= 3.16 \times 10^{-3}\ rad\ s^{-1}$

$\omega_0 = 3.16 \times 10^{-3} rad/s$

ii. The current amplitude at this frequency, $I_0 = \frac{V}{R} = \frac{100}{10} = 10A$

iii. The Q-factor, $Q = \frac{X_L}{R} = \frac{\omega_0 L}{R}$

$= \frac{3.16\times10^{-3}\times200\times10^{-6}}{10} = 6.32 \times 10^{-8}$

31. a. Here, a = 6.0 cm

C = 100 pF = $100 \times 10^{-12} F$

$\omega = 300\ rads^{-1}$

E_{rms} = 230V

$I_{rms} = \frac{E_{rms}}{X_C} = \frac{E_{rms}}{\frac{1}{\omega C}} = E_{rms} \times \omega C$

$\therefore I_{rms} = 230 \times 300 \times 100 \times 10^{-12}$

$= 6.9 \times 10^{-6} A = 6.9 \mu A$

b. Since,I = I_D whether I is steady d.c. or a.c. This is shown below:

$I_D = \varepsilon_0 \frac{d(\phi_E)}{dt} = \varepsilon_0 \frac{d}{dt}(EA) (\because \phi_E = EA)$

Or $I_D = \varepsilon_0 A \frac{dE}{dt}$

$= \varepsilon_0 A \frac{d}{dt}\left(\frac{Q}{\varepsilon_0 A}\right) \left(\because E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A}\right)$

$I_D = \varepsilon_0 A \times \frac{1}{\varepsilon_0 A} \frac{dQ}{dt} = \frac{dQ}{dt} = I$

We know that

$B = \frac{\mu_0}{2\pi} \frac{r}{R^2} I_D$

This formula goes through even if I_D (and therefore B) oscillates in time. The formula shows that they oscillate in phase. Since I_D = I , we have

$B = \frac{\mu_0 r I}{2\pi R^2}$

If I = I_0 , the maximum value of current, then amplitude of B = maximum value of B

$= \frac{\mu_0 r I_0}{2\pi R^2} = \frac{\mu_0 r \sqrt{2}\ I_{rms}}{2\pi R^2}\ \left(\because I_0 = \sqrt{2}\ I_{rms}\right)$

$$= \frac{4\pi \times 10^{-7} \times 0.03 \times \sqrt{2} \times 6.9 \times 10^{-6}}{2 \times 3.14 \times (0.06)^2} T$$
$$= 1.63 \times 10^{-11} T$$

32. For a microscope,

 Resolving power $= \frac{2\mu \sin\theta}{\lambda}$

 i. When λ is decreased, resolving power increases.
 ii. When diameter of objective lens is decreased, θ decreases, $\sin\theta$ decreases. Hence resolving power of microscope also decreases.

OR

The position of the 30$^{\text{th}}$ bright fringe is given by

$x_n = n\frac{\lambda D}{d}$

$x_{30} = 30\frac{\lambda D}{d}$

Hence the shift of the central fringe is

$x_0 = 30\frac{\lambda D}{d}$

But $x_0 = \frac{D}{d}(\mu - 1)t$

$\therefore 30\frac{\lambda D}{d} = \frac{D}{d}(\mu - 1)t$

$\Rightarrow (\mu - 1) = \frac{30\lambda}{t} = \frac{30 \times (6000 \times 10^{-10})}{(3.6 \times 10^{-5})} = 0.5$

or $\mu = 1.5$

33. In ground state, energy of gaseous hydrogen at room temperature = - 13.6 eV.

 When it is bombarded with 12.5 eV electro beam, the energy becomes -13.6 + 12.6 = -1.1 eV

 $\because E_n = \frac{-13.6}{n^2}$ So $n^2 = \frac{-13.6}{-1.1} = 12.3 \Rightarrow n = 3$

 The electron would jump from n = 1 to n = 3,

 where

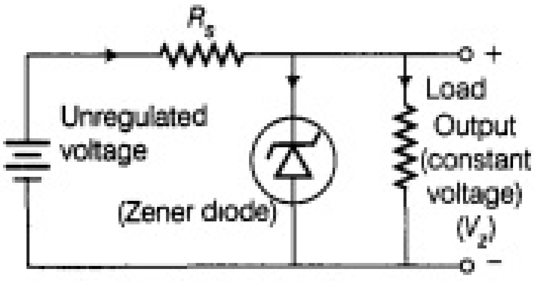
 $$E_3 = -\frac{13.6}{3^2} = -1.5\ eV.$$

 On de-excitation, the electron may jump from n = 3 to n = 2 giving rise to Balmer series. It may also jump from n = 3 to n = 1, giving rise to Lyman series.

So, number of spectral line $= \frac{n(n-1)}{2} = \frac{3(3-1)}{2}$

= 3 spectral lines appear.

34. Zener diode is fabricated by heavily doping of p-n side of junction so as to operate continously without getting damaged in the region of reverse breakdown voltage. The circuit diagram of a voltage regulator using a Zener diode is shown in figure.

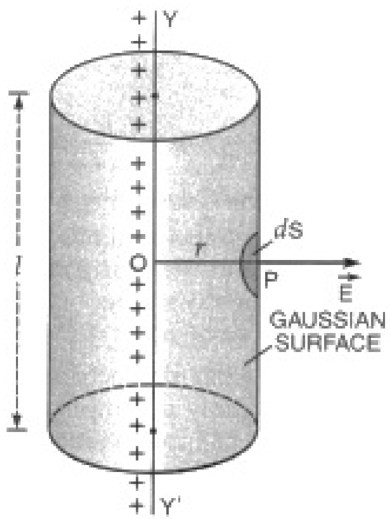


Excess current bypass when $V_{ext} \geq V_z$

Zener diode as voltage regulator: Zener diode is used in regulating fluctuating voltage as shown. It is connected in circuit through resistance R depending on voltage or power rating R_1 is connected in parallel and output is received. On an abrupt increase of voltage across diode becomes constant, equal to breakdown voltage but current rises sharply. Hence, there is an increase in voltage drop R. As R_L is in parallel so voltage across R_L is same.

Section D

35. a. Consider a thin infinitely long straight line charge having a uniform linear charge density λ placed along YY'. Draw a cylindrical surface of radius r and length l about the line charge as its axis.



If E is the magnitude of electric field at point P, then electric flux through the gaussian surface is given by

$\phi = \mathrm{E} \times$ area of the curved surface of a cylinder of cylinder radius r and length l

or

$\phi = \mathrm{E} \times 2\pi\, r\, l$

According to Gauss' theorem, we have $\phi = \frac{q}{\varepsilon_0}$

Now, charge enclosed by the gaussian surface, q = λ l

$\therefore \quad \phi = \frac{\lambda l}{\varepsilon_0}$

Thus,

$\mathrm{E} \times 2\, \pi\, r\, l = \frac{\lambda l}{\varepsilon_0}$

or $\mathrm{E} = \frac{1}{2\pi\varepsilon_0} \frac{\lambda}{r}$

b. Electric field at a distance r from the line charge,

$\mathrm{E} = \frac{1}{2\pi\varepsilon_0} \cdot \frac{\lambda}{r}$

To calculate force on charge -q at point A:

Here, OA = 2·5 cm = 2·5 $\times$ 10^{-2} m

Electric field at point A,

$\mathrm{E}_1 = \frac{1}{2\pi \times 8.854 \times 10^{-12}} \times \frac{4.5 \times 10^{-4}}{2.5 \times 10^{-2}}$

= 3·24 $\times$ 10^8 NC^{-1}

Force on charge - q at point A, $F_1 = qE_1$ = 5 $\times$ 10^{-9} $\times$ 3·24 $\times$ 10^8 = 1·62 N (towards the line charge)

To calculate force on charge +q at point B:

Here, OB = 2·5 $\times$ 10^{-2} + 2 $\times$ 10^{-3} = 2·7 $\times$ 10^{-2} m

Electric field at point B,

$E_2 = \frac{1}{2\pi \times 8.854 \times 10^{-12}} \times \frac{4.5 \times 10^{-4}}{2.7 \times 10^{-2}}$

= 3 $\times$ 10^8 NC^{-1}

Force on charge + q at point B,

$F_2 = qE_2$ = 5 $\times$ 10^{-9} $\times$ 3 $\times$ 10^{-8} = 1·5 N (away from the line charge)

Hence, net force on electric dipole,

F = F_1 - F_2 = 1.62 - 1.5 = 0·12 N (towards the line charge)

OR

i. At x = 18 cm, the potential is zero.

ii. Now, at x = 18 cm, net potential due to the two charges A and B is zero i.e.

$$\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q_A}{x}+\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q_B}{r-x}=0$$

where r is the distance between the two charges.

Here, $Q_A = 3\cdot6 \times 10^{-6}$ C, x = 18 cm = 0.18m and

r - x = 30 - 18 = 12cm = 0· 12m

$$\therefore 9\times10^9\times\frac{3\cdot6\times10^{-9}}{0\cdot18}+9\times10^9\times\frac{Q_B}{0\cdot12}=0$$

or $Q_B = -2\cdot4 \times 10^{-6}$ C

iii. Force on the test charge at any point = - potential gradient at that point × charge

From the graph, it follows that the potential gradient (i.e. slope of the graph) and hence the force on the test charge is maximum at the point x = 27 cm.

36. i. Consider a strip of width dr at a distance r from the straight wire. Magnetic field at the location of the strip due to the wire,

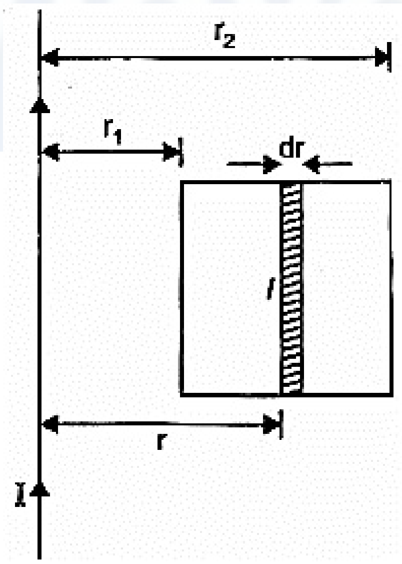
$B=\frac{\mu_0 I}{2\pi r}$ z

Area of strip, dA = ldr

Magnetic flux linked with the strip,

$$d\phi_B=BdA=\frac{\mu I}{2\pi r}ldr$$

Total magnetic flux linked with the coil,



$$d\phi_B=\frac{\mu_0 Il}{2\pi}\frac{dr}{r}$$

$$\int dQ_B=\frac{\mu_0 Il}{2\pi}\int_{r_1}^{r_2}\frac{dl}{r}$$

$$Q_B=\frac{\mu_0 Il}{2\pi}[\log_e r_2-\log_e r_1]$$

$$Q_B=\frac{\mu_0 I\cdot1}{2\pi}[\log_e r]_{r1}^{r2}$$

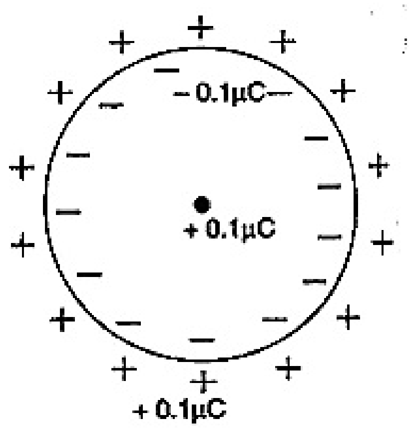
$Q_B = \frac{\mu_0 Il}{2\pi} log_e \frac{r_2}{r_1}$
$\phi_B = \frac{4\pi\times10^{-7}\times10\times0.2}{2\pi} log[\frac{0.10}{0.05}]$
$= 4 \times 10^{-7} log_e 2$
$= 4 \times 0.693 \times 10^{-7}\ Wb$
$2.77 \times 10^{-7}\ Wb$

ii. Induced emf
$|E| = -\frac{d\phi_B}{dt} = \frac{2.77\times10^{-7}}{0.02}\ V$
$= 1.39 \times 10^{-5}\ V$
Magnetic field, due to wire, at the location of the coil is perpendicular to the plane of the coil and directed inwards. When current is reduced to zero, this magnetic field decreases. To oppose this decrease, induced current shall flow clockwise, so that its magnetic field is also perpendicular to the plane of the coil and downward.

OR

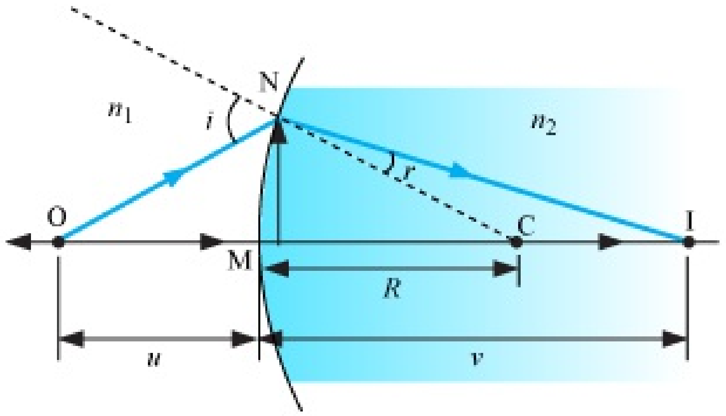
On the inner and outer sphere's surface charges of $-0.1\mu C$ and $+0.1\mu C$ are induced respectively. The potential of the sphere relative to earth is determined solely by the outer surface charge q.
$\therefore V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$
where r is the radius of the sphere
Now, $V = 9 \times 10^9 Nm^2C^{-2}\frac{0.1\times10^{-6}C}{0.2m}$
= 4500 V

a. The potential of the sphere is momentarily reduced to zero when it is earthed. The positive charge on the outer surface disappears but the induced negative charge inside remains. Therefore, the potential of the sphere is zero.



b. The induced negative charge is neutralized when the metal touches the sphere and no charge remains on the metal or sphere. Both are at the same potential i.e. zero potential.

37. a. A refracting surface which forms a part of a sphere of transparent refracting material is called a spherical refracting surface.



The above figure shows the geometry of formation of image / of an object O and the principal axis of a spherical surface with centre of curvature C and radius of curvature R.

Assumptions:

i. The aperture of the surface is small compared to other distance involved.

ii. NM will be taken to be nearly equal to the length of the perpendicular from the point N on the principal axis.

$\tan \angle \mathrm{NOM}=\frac{\mathrm{MN}}{\mathrm{OM}}$

$\tan \angle \mathrm{NCM}=\frac{\mathrm{MN}}{\mathrm{MC}}$

$\tan \angle \mathrm{NIM}=\frac{\mathrm{MN}}{\mathrm{MI}}$

For ΔNOC, i is the exterior angle.

$\therefore i=\angle \mathrm{NOM}+\angle \mathrm{NCM}$

$i=\frac{\mathrm{MN}}{\mathrm{OM}}+\frac{\mathrm{MN}}{\mathrm{MC}}$ ...(i)

Similarly, $r=\angle \mathrm{NCM}-\angle \mathrm{NIM}$

i.e., $r=\frac{\mathrm{MN}}{\mathrm{MC}}-\frac{\mathrm{MN}}{\mathrm{MI}}$ ...(ii)

By Snell's law,

$n_1 \sin i = n_2 \sin r$

For small angles,

$n_1 i = n_2 r$

Substituting the values of i and r from equations (i) and (ii), we obtain

$$n_1\left(\frac{\mathrm{MN}}{\mathrm{OM}}+\frac{\mathrm{MN}}{\mathrm{MC}}\right)=n_2\left(\frac{\mathrm{MN}}{\mathrm{MC}}-\frac{\mathrm{MN}}{\mathrm{MI}}\right)$$

$$\frac{n_1}{\mathrm{OM}}+\frac{n_2}{\mathrm{MI}}=\frac{n_2-n_1}{\mathrm{MC}} \text{ ...(iii)}$$

Applying new Cartesian sign conventions,

OM = -u, MI = +v, MC = +R

Substituting these in equation (iii), we obtain

$$\frac{n_2}{v}-\frac{n_1}{u}=\frac{n_2-n_1}{\mathrm{R}} \text{ ...(iv)}$$

Above equation is the required equation.

b. Case I: Lens in air

Let the focal length of lens in air be F_{air}

Given that: F_{air} = 20 cm, n_1 = 1(air), n_2 = 1.6

According to lens maker's formula:

$$\frac{1}{F_{air}}=\left[\frac{n_2}{n_1}-1\right]\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

$$\frac{1}{20}=\left[\frac{1.6}{1}-1\right]\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

$$\frac{1}{20}=[0.6]\left[\frac{1}{R_1}-\frac{1}{R_2}\right] \text{...(i)}$$

Case II: Lens in liquid

Let the focal length of lens in liquid be F_{liquid}

Given that: n_1 = 1.3(liquid), n_2 = 1.6

According to lens maker's formula:

$$\frac{1}{F_{\text{liquid}}}=\left[\frac{1.6}{1.3}-1\right]\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

$$\frac{1}{F_{\text{hiquid}}}=[0.2307]\left[\frac{1}{R_1}-\frac{1}{R_2}\right] \text{...(ii)}$$

Diving (i) by (ii), we get

$$\frac{F_{\text{liquid}}}{20}=\frac{0.6}{0.2307}$$

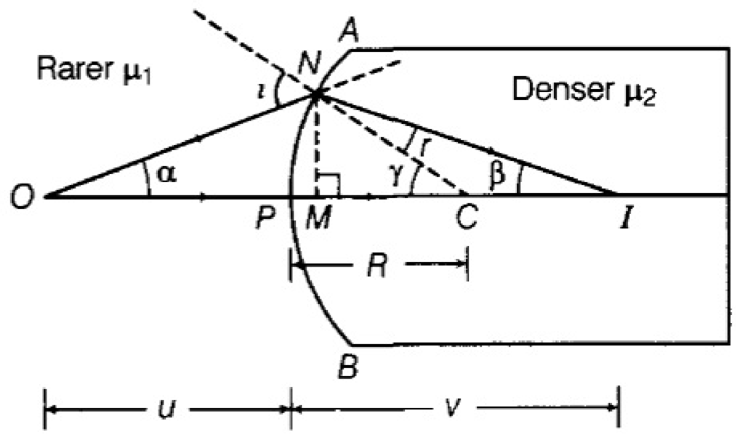
Thus, F_{liquid} = 52.0156 cm

OR

The ray diagram is shown in the figure:

Let, NM = h

The convex spherical refracting surface forms the image of object O at I. The radius of curvature is R



Here $PI=+v\ and\ PO=-u$

In $\triangle NCO \quad i=\gamma+\alpha$ ...(i)

In $\triangle NCI, \quad \gamma=r+\beta$

$\Rightarrow \quad r=\gamma-\beta$ ...(ii)

For small angles α, β and γ and assuming M is very close to P, we have

$\alpha=\tan\alpha=\frac{MN}{MO}=\frac{MN}{PO}=\frac{+h}{-u}$

$\beta=\tan\beta=\frac{MN}{MI}=\frac{MN}{PI}=\frac{h}{v}$

$\gamma\approx\tan\gamma=\frac{MN}{MC}=\frac{MN}{PC}=\frac{h}{+R}$

By Snell's law, $\frac{\mu_2}{\mu_1}=\mu=\frac{\sin i}{\sin r}$

For small i and r,

$\frac{\mu_2}{\mu_1}=\frac{i}{r}$ or $r\mu_2=i\mu_1$

$\mu_2(\gamma-\beta)=(\alpha+\gamma)\mu_1$ [From Eqs. (i) and (ii)]

$(\mu_2-\mu_1)\gamma=\mu_1 a+\mu_2\beta$

$(\mu_2-\mu_1)\left(\frac{h}{R}\right)=\mu_1\left(\frac{h}{-u}\right)+\mu_2\left(\frac{h}{v}\right)$

$\Rightarrow \quad \frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$