CBSE Class 12 Physics
Sample Paper - 03 (2019-20)

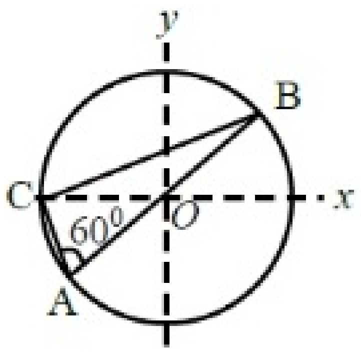
Maximum Marks: 70
Time Allowed: 3 hours

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. Consider a system of three charges $\frac{q}{3}, \frac{q}{3} and - \frac{2q}{3}$ placed at points A, B and C, respectively, as shown in the figure. Take O to be the centre of the circle of radius R and angle CAB = 60°



a. The electric field at point O is $\frac{q}{4\pi\epsilon_0 R^2}$ directed along the negative x-axis

b. The magnitude of the force between the charges at C and B is $\frac{q^2}{54\pi\epsilon_0 R^2}$

c. The potential energy of the system is zero

d. The potential at point O is $\frac{q}{12\pi\epsilon_0 R}$

2. Electric charge

a. is a property of neutrons only

b. is a property of protons only

c. is a property of particles such as atoms,ions,electrons etc

d. is a property of electrons only

3. Electric potential energy of two point charges q and q_0 is

a. $\frac{1}{4\pi\epsilon_0}\frac{qq_0}{r}$

b. $\frac{1}{4\pi\epsilon_0}\frac{qq_0}{r^2}$

c. $\frac{1}{4\pi\epsilon_0}\frac{q}{r}$

d. $\frac{1}{4\pi\epsilon_0}\frac{qq_0}{r^3}$

4. Equal charges q each are placed at the vertices A and B of an equilateral triangle ABC of side a. The magnitude of electric intensity at the centre is:

a. $\frac{\sqrt{2}q}{4\pi\varepsilon_0^2}$

b. $\frac{3q}{4\pi\in_0 a^2}$

c. $\frac{2q}{4\pi\varepsilon_0 a^2}$

d. $\frac{\sqrt{3}q}{4\pi\varepsilon_0 a^2}$

5. A long solenoid with 60 turns of wire per centimeter carries a current of 0.15 A. The wire that makes up the solenoid is wrapped around a solid core of silicon steel K_m = 5200 (The wire of the solenoid is jacketed with an insulator so that none of the current

flows into the core.) the magnetization inside the core is

a. 4.48MA/m

b. 4.88MA/m

c. 4.68MA/m

d. 4.28MA/m

6. Long distance radio broadcasts use short-wave bands because

a. Stratosphere reflects waves in these bands.

b. Troposphere reflects waves in these bands.

c. None of these

d. Ionosphere reflects waves in these bands.

7. In Young's double slit experiment, intensity at a point is (1/4) of the maximum intensity angular position of this point is:

a. $\sin^{-1}\left(\frac{\lambda}{3d}\right)$

b. $\sin^{-1}\left(\frac{\lambda}{2d}\right)$

c. $\sin^{-1}\left(\frac{\lambda}{d}\right)$

d. $\sin^{-1}\left(\frac{\lambda}{4d}\right)$

8. The objective of an astronomical telescope has a large aperture to:

a. Increase span of observation

b. Have high resolving power

c. Reduce spherical aberration

d. Wave low desperation

9. A eye specialist prescribes spectacles having a combination of a convex lens of focal length 40 cm in contact with a concave lens of focal length 25 cm. The power of this combination is

   a. -6.67 D

   b. + 1.5 D

   c. -1.5 D

   d. + 6.67 D

10. The work function of a photoelectric material is 3.32 eV. The threshold frequency will be equal to

    a. 6×10^{14} HZ

    b. 7×10^{14} HZ

    c. 8×10^{14} HZ

    d. 9×10^{14} HZ

11. Fill in the blanks:

    When a bar is placed near a strong magnetic field and it is repelled, then the material of bar is ________.

OR

Fill in the blanks:

Magnetic susceptibility of a diamagnetic substance is ________ by temperature.

12. Fill in the blanks:

    In case of Hall effect for a strip having charge Q and area of cross-section A, the Lorentz force is ________ proportional to Q.

13. Fill in the blanks:

If an ammeter is to be used in place of a voltmeter, then we must connect with the ammeter a high resistance in ________.

14. Fill in the blanks:

________ is the phenomenon of production of a pair of particles (particle + antiparticle), when a gamma ray passes close to the nucleus.

15. Fill in the blanks:

The angle of incidence when a ray of light falls normally on a mirror is ________.

16. Define the activity of a given radioactive substance. Write its SI unit.

17. A radioactive material has a half life of 1 minute. If one of the nuclei decays now, when will the next one decay?

18. A radar has a power of 1 kW and is operating at a frequency of 10 GHz. It is located on a steep mountain top of 600 m. What is the maximum distance upto which it can detect an object located on the surrounding earth's surface?(use radius of earth R = 6400 km)

19. Why is photoelectric emission not possible at all frequencies?

20. Name one impurity each, which when added to pure Si, produces

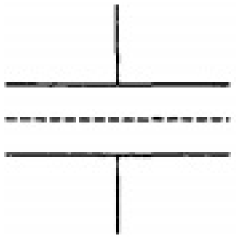
i. n-type and
ii. p-type semiconductor.

OR

What is the main cause of electron's diffusion from n-type region to p-type region, even when there is no external supply used?

Section B

21. Figure shows a sheet of aluminium foil of negligible thickness placed between the plates of a capacitor.
How will its capacitance be affected, if



i. the foil is electrically insulated?
ii. the foil is connected to the upper plate with a conducting wire?

22. Why does the electric field inside a dielectric decrease when it is placed in an external electric field?

23. Derive an expression for the de-Broglie wavelength associated with an electron accelerated through a potential V.
Draw a schematic diagram of a localised wave describing the wave nature of the moving electron.

24. In a single slit diffraction experiment, the width of the slit is halved. How does it affect the size and intensity of the central maximum?

25. An electron in the ground state of hydrogen atom is revolving in anti-clockwise direction in a circular orbit. The atom is placed normal to the electron orbit makes an angle of 30^o in the magnetic field. Find the torque experienced by the orbiting electron.

26. In the study of Geiger-Marsden experiment on scattering of a-particles by a thin foil of gold, draw the trajectory of α-particles in the coulomb field of target nucleus. Explain briefly how one gets the information on the size of the nucleus from this study.
From the relation $R = R_0 A^{\frac{1}{3}}$, where, R_0 is constant and A is the mass number of the nucleus, show that nuclear matter density is independent of A.

OR

Show that the radius of the orbit in hydrogen atom varies as n^2, where n is the principal quantum number of the atom.

27. Draw the energy band diagrams of p-type and n-type semiconductors.A

semiconductor has equal electron and hole concentration $6 \times 10^8 m^{-3}$. On doping with a certain impurity, electron concentration increases to $8 \times 10^{12} m^{-3}$. Identify the type of semiconductor after doping

OR

Name the semiconductor device that can be used to regulate an unregulated DC power supply. With the help of I-V characteristics of this device, explain its working principle.

Section C

28. A point charge of $2.0\mu C$ is at the centre of a cubic Gaussian surface 9.0 cm on edge. What is the net electric flux through the surface?

29. Define current sensitivity and voltage sensitivity of a galvanometer. Increasing the current sensitivity may not necessarily increase the voltage sensitivity of galvanometer. Justify

30. Two different coils have self inductances, L_1 = 8mH and L_2 = 2mH. At a certain instant, the current in the two coils is increasing at the same constant rate and the power supplied to the two coil is the same.
Find the ratio of :
    a. induced voltage
    b. current and
    c. energy stored in the two coils at that instant?

31. i. Which segment of electromagnetic waves has the highest frequency? How are these waves produced? Give one use of these waves.
    ii. Which EM waves lie near the high-frequency end of visible part of EM spectrum? Give its one use. In what way, this component of light has harmful effects on humans?

32. i. Describe briefly, with the help of suitable diagram, how the transverse nature of light can be demonstrated by the phenomenon of polarisation?
    ii. When unpolarised light passes from air to a transparent medium, under what condition does the reflected light get polarised?

OR

Ray optics is based on the assumption that light travels in a straight line. Diffraction effects (observed when light propagates through small apertures/slits or around small obstacles) disprove this assumption. Yet the ray optics assumption is so commonly used in understanding location and several other properties of images in optical instruments. What is the justifications?

33. The ground state energy of hydrogen atom is -13.6 eV . What are the kinetic and potential energies of the electron in this state?

34. i. Why is a photodiode operated in reverse bias mode?
 ii. For what purpose is a photodiode used?
 iii. Draw its I-V characteristics for different intensities of illumination.

Section D

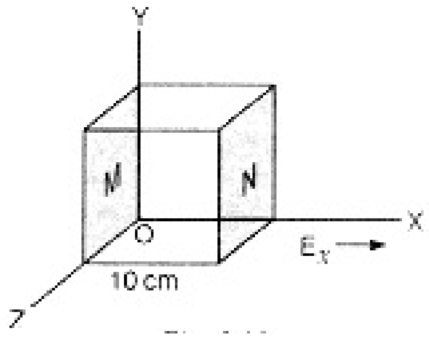
35. i. Derive an expression for drift velocity of electrons in a conductor. Hence, deduce Ohm's law.
 ii. A wire whose cross-sectional area is increasing linearly from its one end to the other, is connected across a battery of V volts. Which of the following quantities remain constant in the wire?
  a. Drift speed
  b. Current density
  c. Electric current
  d. Electric field

 Justify your answer.

OR

In Fig., the electric field is directed along positive X- direction and given by $E_x = 5\ A\ x + 2\ B$,

where E is in NC^{-1} and x is in metre. A and B are constants with dimensions.



Taking A = 10 $NC^{-1}m^{-1}$ and B = 5 $NC^{-1}m^{-1}$, calculate

i. the electric flux through the cube.
ii. net charge enclosed within the cube

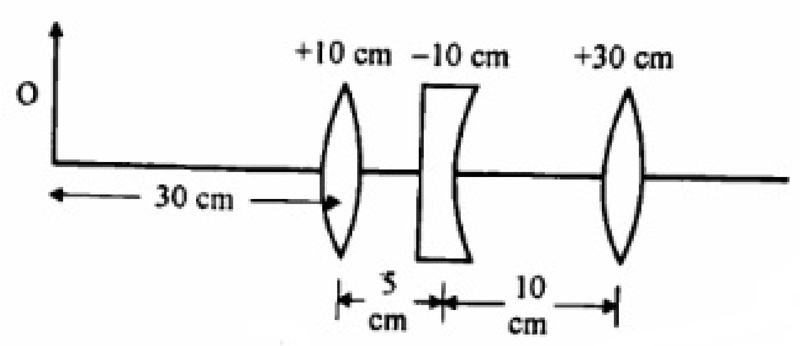
36. A step-up down transformer operated on a 2.5 kV line. It supplies a load with 20 A. The ratio of the primary winding to the secondary is 10: 1. If the transformer is 90% efficient, calculate

i. the power output
ii. the voltage and
iii. the current in the secondary coil.

OR

A potentiometer wire of length 100 cm has a resistance of 10Ω. It is connected in series with a resistance and an accumulator of emf 2V and of negligible internal resistance. A source of emf 10 mV is balanced against a length of 40 cm of the potentiometer wire. What is the value of the external resistance?

37. i. Under what conditions is the phenomenon of total internal reflection of light observed? Obtain the relation between the critical angle of incidence and the refractive index of the medium.
ii. Three lenses of focal lengths +10 cm, -10 cm and +30 cm are arranged coaxially as in the figure given below. Find the position of the final image formed by the combination.



OR

With the help of ray diagram, show the formation of image of a point object by refraction of light at a spherical surface separating two media of refractive indices n_1 and n_2 ($n_2 > n_1$)respectively. Using this diagram, derive the relation.

$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$ Write the sign conventions used. What happens to the focal length of convex lens when it is immersed in water?

Answer

Section A

1. (b) The magnitude of the force between the charges at C and B is $\frac{q^2}{54\pi\epsilon_0 R^2}$

   Explanation: The electric field due to charges at A and B are equal and opposite, So at O the electric field is due to C only, which has a magnitude

   $E = \frac{2q}{12\pi_0 R^2} = \frac{q}{6\pi_0 R^2}$

   The potential energy of the system is not zero. Potential at O is zero and Force between B and C

   $F = \frac{\frac{q}{3}\frac{2q}{3}}{4\pi_0 (2RSin60^0)^2} = \frac{q^2}{54\pi_0 R^2}$

2. (c) is a property of particles such as atoms, ions, electrons etc

   Explanation: Every matter is made up of atoms which contain protons, electrons and neutrons.

   Protons are +ve charged particles and electrons are -ve charged particles.

   Because of electric charge these particles experience a force in electrical fields.

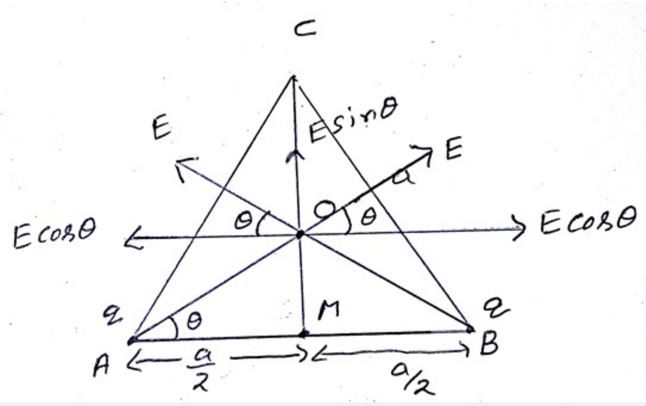
3. (a) $\frac{1}{4\pi\epsilon_0}\frac{qq_0}{r}$

   Explanation: Potential energy of a system of charges is the work done in assembling the charges from infinity to their respective positions. Force between two charges q and q0 placed at a distance r apart is $F = \frac{q_0 q}{4\pi\varepsilon_0 r^2}$ Potential energy of the charges is given by $U = \int_{\infty}^{r} -F\ dr = \int_{\infty}^{r} -\frac{q_0 q}{4\pi\varepsilon_0 r^2}\ dr = \frac{qq_0}{4\pi\varepsilon_0 r}$

4. (b) $\frac{3q}{4\pi\in_0\ a^2}$

Explanation:

If a =side of the triangle then, the height of the equilateral triangle$= \frac{\sqrt{3} \times a}{2}$
Now, the centroid of a triangle divides the median in the ratio 2:1
Therefore, the distance between centroid to any vertices of the equilateral triangle
$= \frac{2}{3}$ of a height of the equilateral triangle
$= \frac{2}{3} \times \frac{\sqrt{3} \times a}{2} = \frac{a}{\sqrt{3}}$



$E_{net} = 2E\sin\theta$
$= 2 \times \frac{1}{4\pi\varepsilon_0} \frac{q \times 3}{a^2} \times \frac{a \times \sqrt{3}}{2\sqrt{3} \times a}$
$= \frac{3q}{4\pi\varepsilon_0 a^2}$

5. (c) 4.68MA/m

   Explanation: $M = \frac{B}{\mu_o} = \frac{\mu_o K_M N i}{\mu_o}$

   $= 5200 \times 60 \times 10^2 \times 0.15$
   $= 4.68 \times 10^6 A/m$

6. (d) Ionosphere reflects waves in these bands.

   Explanation: Long distance radio broadcasts use shortwave bands because only these bands can be reflected by the ionosphere.

7. (a) $\sin^{-1}\left(\frac{\lambda}{3d}\right)$

   Explanation:

   $I = I_{max} cos^2(\phi/2)$
   $\frac{I_{max}}{4} = I_{max} cos^2(\phi/2)$
   $cos(\phi/2) = 1/2$

or, $\frac{\phi}{2} = \frac{\pi}{3}$
therefore,$\phi = \frac{2\pi}{3}$
$= \frac{2\pi}{\lambda}.\Delta x$
where, $\Delta x = dsin\theta$
substituting in equation we get,
$sin\theta = \frac{\lambda}{3d}$
or, $\theta = sin^{-1}(\frac{\lambda}{3d})$.

8. (b) Have high resolving power

Explanation:

The resolving power of a telescope is given by $\frac{D}{1.22\lambda}$
Where D is the diameter of objective. Greater the diameter more is the resolving power.

9. (c) -1.5 D

Explanation:

f_1 = +40 cm $= +\frac{40}{100}\ m$; f_2 = -25 cm $= -\frac{25}{100}m$
$P_1 = \frac{1}{f_1} = \frac{100}{40} = +2.5\ D$
$P_2 = \frac{1}{f_2} = \frac{100}{-25} = -4D$
Power of combination, P = P_1 + P_2 = +2.5D - 4D = -1.5 D.

10. (c) 8 $\times 10^{14}$ HZ

Explanation:

$\phi_0 = h\nu_0$
$3.32 \times 1.6 \times 10^{-19} = 6.6 \times 10^{-34} \times \nu_0$
$\nu_0 = \frac{3.32\times1.6\times10^{-19}}{6.6\times10^{-34}} = 8 \times 10^{14} Hz$

11. Diamagnetic

OR

Not affected

12. Directly

13. Series

14. Pair production

15. Zero degree

16. The activity of a sample is defined as the rate of disintegration taking place in the sample of the radioactive substance.
It is represented by A and SI unit of activity is Becquerel (Bq) and sometimes also expressed in curie after the honour of Madam Curie.
1 Bq = 1 disintegration/second

17. The next nucleus can decay any time.

18. Here, R = 6400 km = 6.4×10^6 m, h = 600 m From the relation
d = $\sqrt{2hR}$
= $\sqrt{2 \times 6.4 \times 10^6 \times 600}$
= 87.6 km
Distance d is independent of the power and frequency of the signal.

19. Photoelectric emission is not possible at all frequencies because below the threshold frequency for photosensitive surface of different atoms emission is not possible.

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

OR

Because of difference in free electron density and mobility between n-type and p-type region.

Section B

21. i. If the foil is insulated, then the system will be equivalent to two identical capacitors connected in series combination in which two plates of each capacitor have separation half of the original separation.
Thus, new capacitance of each capacitor

C' = $\frac{\epsilon_0 A}{\frac{d}{2}} = \frac{2\epsilon_0 A}{d}$ =2C ....(a) $\left[\because c \propto \frac{1}{d}\right]$

$\because$ Two capacitors each of capacitance C' are in series

$\therefore \quad C_{\text{net}} = \frac{2C \times 2C}{2C+2C} = C$

C_{net} = C (Original capacitor)

ii. If the foil is connected to the upper plate with a wire, then the system reduces to a single capacitor whose only distance of separation of the two plates reduces to half of its original one i.e. d' = d/2, keeping all other variables same as before.

$\therefore$ New capacitance, C' = 2C [as we calculated before in equation (a)]

22. It is because the dielectric gets polarized in opposite direction.

23. Let an electron beam is accelerated by potential difference V from the position of rest.

Kinetic energy of the electron, K = eV

Momentum of electron, where, m = mass of an electron

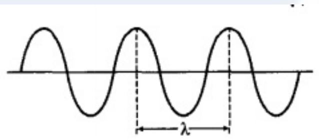
By de-Broglie equation

$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV}}$

Here, h = 6.63 $\times$ 10^{-34} J-s

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

m = 9.1 $\times$ 10^{-31}g $\Rightarrow \lambda = \frac{12.27}{\sqrt{V}} \overset{0}{A}$



A matter wave associated with an electron of definite momentum has single wavelength and extends all over space.

24. Since, size of central maximum $\propto \frac{\lambda}{a}$

Thus, size becomes double and intensity reduces to $\frac{1}{4}th$

25. Magnetic moment associated with electron is given by,

M = $\frac{eh}{4\pi m_e}$

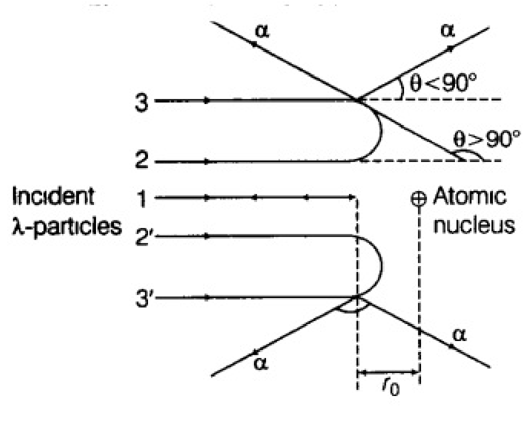
and torque, $\tau = MB\sin\theta$

Here, $\theta = 30^\circ$

$\tau = \frac{eh}{4\pi m_e}B \times \sin 30^\circ = \frac{eh}{4\pi m_e}B \times \frac{1}{2}$

$\tau = \frac{ehB}{8\pi m_e}$
where h is Planck's constant, m_e is electron mass, B is the magnetic field.

26. The Rutherford model, also known as planetary model is a model which tried to describe an atom devised by Ernest Rutherford. Rutherford directed the famous Geiger–Marsden experiment in 1909 which suggested, upon Rutherford's 1911 analysis, that J. J. Thomson's plum pudding model of the atom was incorrect. Trajectory of an α-particles in the Coulomb field of the target nucleus is given below as



From this experiment, the following is observed.

i. Most of the α-particles pass straight through the gold foil. It means that they do not suffer any collision with gold atoms.
ii. About one α-particle in every 8000 α-particles deflect by more than 90°. As most of the α-particles go undeflected and only a few get deflected, this shows that most of the space in an atom is empty and at the centre of the atom, there is a heavy mass, which is most commonly known as nucleus. Thus, with the help of these observations regarding the deflection of a-particles, the size of the nucleus was predicted.
If m is the average mass of the nucleon and R is the nuclear radius, then mass of nucleus = mA, where A is the mass number of the element.
The volume of the nucleus, $V = 4/3\pi R^3$
$\Rightarrow \quad V = \frac{4}{3}\pi\left(R_0 A^{1/3}\right)^3 \Rightarrow V = \frac{4}{3}\pi R_0^3 A$
Density of nuclear matter
$\rho = \frac{mA}{V} \Rightarrow \rho = \frac{mA}{4/3\pi R_0^3 \cdot A} \Rightarrow \rho = \frac{3m}{4\pi R_0^3}$

This shows that the nuclear density in independent of mass number A.

OR

According to the Bohr's theory of hydrogen atom, the angular momentum of revolving electron is given by

$mvr = \frac{nh}{2\pi}$ ....(i)

where, m = mass of the electron, v = velocity of the electron.

r =radius of the orbit, h =Planck's constant and n = principal quantum number of the atom.

If an electron of mass m and velocity v is moving in a circular orbit of radius r, then the centripetal force is given by

$F_c = mv^2/r$........(ii)

Also, if the charge on the nucleus is Ze, then the force of electrostatic attraction between the nucleus and the electron will provide the necessary centripetal force

$\Rightarrow F_c = F_e$

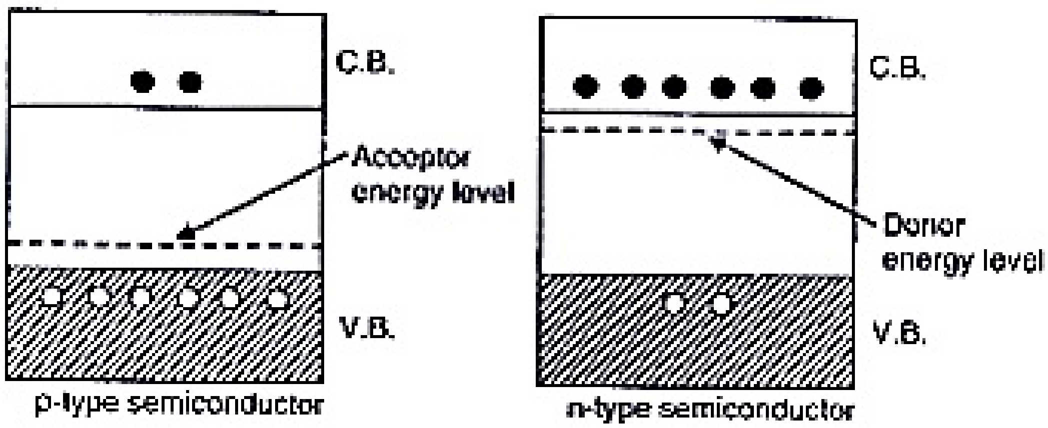
$\Rightarrow \quad \frac{mv^2}{r} = \frac{ke^2}{r^2} \quad [\because Z = 1]$

$\Rightarrow \quad r = \frac{e^2 \cdot k}{mv^2}$ ....(iii)

From Eq. (i). we get Putting this value is Eq. (iii), we get

$r = \frac{ke^2 4\pi^2 m^2 r^2}{m \cdot n^2 h^2}$

$\Rightarrow \quad r = \frac{n^2 h^2}{ke^2 4\pi^2 m} \Rightarrow r \propto n^2$

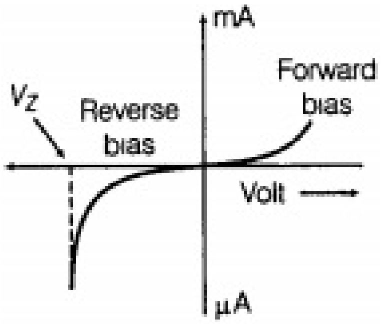
27. 

As the electron concentration increases on doping, so the resulting semiconductor is of n-type.

OR

Zener diode is used for regulating the unregulated voltage supply

Principle:- After breakdown a large current can be produced this is reverse breakdown region. The voltage across it remains constant, equal to the breakdown voltage for large reverse current.



Section C

28. Given, $q = 2.0\mu C = 2.0 \times 10^{-6} C$

The total flux through the surface of the cube (using Gaussian theorem) is given by

$\phi = \frac{q}{\varepsilon_0}$

$= \frac{2.0 \times 10^{-6}}{8.854 \times 10^{-12}}$

$= 2.26 \times 10^5 Nm^2C^{-1}$

29. The definition of current sensitivity and voltage sensitivity are given

$\rightarrow$ Let the deflection produced in applying voltage V is α then

Voltage sensitivity $= \frac{\alpha}{v} = \frac{NBA}{kR}$

The voltage sensitivity may be increased by (i) increasing, N, B, A (ii) decreasing k and

Current sensitivity $= \frac{NBA}{k}$ can be increased by

(i) increasing NBA (ii) decreasing k.

Hence increasing the current sensitivity may not necessarily increase the voltage sensitivity of a galvanometer.

30. From $e = L\frac{dI}{dt}, \frac{e_1}{e_2} = \frac{L_1}{L_2} = \frac{8}{2} = 4$

Since, P = e I = constant

$\frac{dI_1}{dt} = \frac{dI_2}{dt}$

$P_1 = P_2 = P$

$e_1I_1 = e_2I_2$

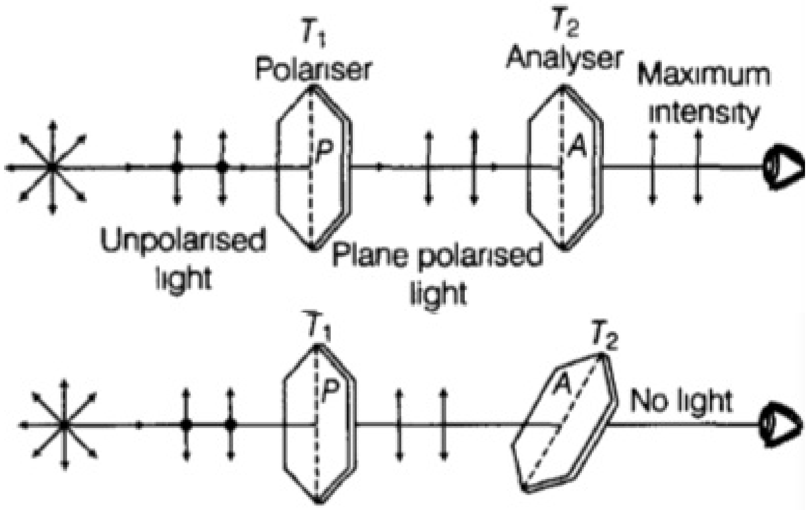
$\therefore \frac{I_1}{I_2} = \frac{e_2}{e_1} = \frac{1}{4}$

$$\frac{I_1}{I_2}=\frac{e_2}{e_1}$$
$$U=\frac{1}{2}LI^2$$
$$\therefore \frac{U_1}{U_2}=\frac{\frac{1}{2}L_1}{\frac{1}{2}L_2}\left(\frac{I_1}{I_2}\right)^2=\frac{8}{2}\left(\frac{1}{4}\right)^2=\frac{1}{4}$$

31. i. Gamma(γ) rays have the highest frequency(as these waves have the highest energy) in the electromagnetic waves. These rays are of the nuclear origin and are produced during the disintegration of radioactive atomic nuclei and during the decay of certain subatomic radioactive particles, associated with the decay of alpha(α) and beta(β) rays. They are used in the treatment of cancer and tumors i.e. in radiotherapy/chemotherapy.

    ii. Ultraviolet(UV) rays lie near the high-frequency end of visible part of EM spectrum. These rays are used to preserve food stuff and in water purifiers to kill the germs for giving pure drinking water. The harmful effect from exposure to ultraviolet (UV) radiation can be life-threatening and include premature ageing of the skin, suppression of the immune systems, damage to the eyes and skin cancer.

32. i. When an unpolarised light incident on a tourmaline crystal T_1 (polariser), then intensity of transmitted light passing through T_1, cut to its half. Let, another crystal, T_2 be placed in the path of transmitted light by T_1 and one full rotation is given to it. Gradually change in intensity of the transmitted light is observed with the rotation of the second crystal. The intensity of the transmitted light is maximum when the axes of the two crystals, T_1 and T_2 are parallel to each other and minimum when their axes are perpendicular to each other.
    Since, the intensity of polarised light on passing through a tourmaline crystal changes with the relative orientation of its crystallographic axis with that of polariser, which implies that light wave must be of transverse in nature. Because a transverse wave containing electric and magnetic filed components vibrating perpendicular to each other and also perpendicular to the direction of propagation of the wave, can only be polarised.



ii. It happens when angle of incidence is equal to the polarising angle falling on a transparent surface, then reflected light is completely polarised. In this situation, refractive index of the refracting surface is given by $\mu = \tan i_p$. This is also called Brewster's law, which states that the tangent of the polarising angle for a transparent medium is equal to the refractive index of the medium. Also, the reflected and refracted light wave are mutually perpendicular to each other.

OR

Typical sizes of the apertures involved in ordinary optical instruments are much large than the wavelength of light. Consequently, the diffraction effects of light are negligibly small in these instruments. Hence, the assumption that light travels in straight lines can be safely used in the optical instruments.

33. Here, Ground Energy, E = -13.6 eV

Kinetic energy, $E_k = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{2r} [E_k = 2E_p]$

and Potential energy, $E_p = -\frac{1}{4\pi\varepsilon_0} \frac{e^2}{r} \left[\because E_p = \frac{-k\ q_1 q_2}{r}\right]$

Total energy, $E = E_k + E_p$

$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{2r} - \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r}$

$E = -\frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r}\right)$

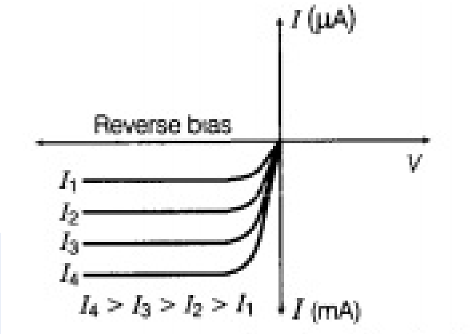
$-13.6 = -\frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r}\right)$

$\therefore \frac{1}{4\pi\varepsilon_0} \frac{e^2}{r} = 27.2$

$\therefore E_k = \frac{1}{4\pi\varepsilon_0} \frac{e^2}{2r} = \frac{27.2}{2} eV = 13.6EV$

$$E_p = -\frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r} = -27.2\ eV$$

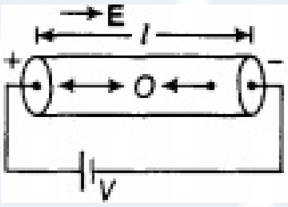
34. i. Photodiode is connected in reverse bias and feeble reverse current flows due to thermally generated electron-hole pair, known as **dark current**. When light of suitable frequency (v) such that hv > E_S, where E_S is the band gap incident on diode, additional electron-hole pair generated and current grows in the circuit.
ii. Photodiode is used as an optical detector.
iii. Circuit diagram of illuminated photodiode in reverse bias is shown below.



Reverse bias currents through a photodiode

Section D

35. i. Let v_d be the drift velocity.



Electric field produced inside the wire is

E =V/I ...(i)

Force on an electron, F = - E e

Acceleration of each electron= - Ee/m [∵ from Newton's law, a = F/m]

where, m is mass of electron.

Velocity created due to this acceleration $= \frac{Ee}{m}\tau$.

where, τ is the time span between two consecutive collision. This ultimately becomes the drift velocity in steady state.

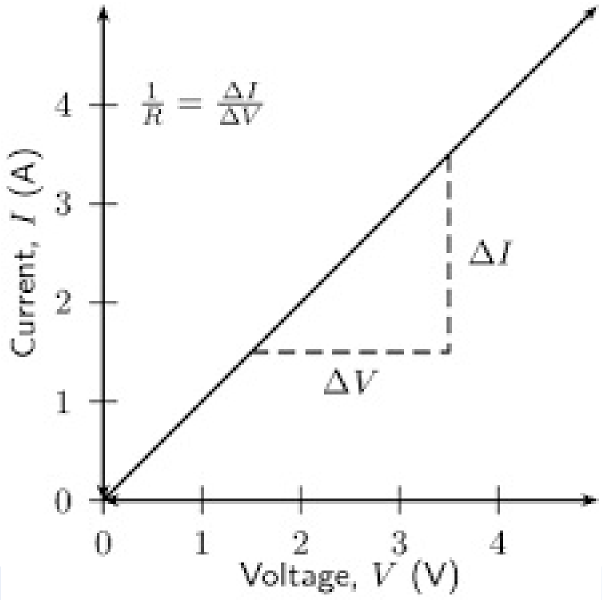
So, $v_d = \frac{Ee}{m}\tau = \frac{e}{m}\tau \times \frac{V}{l}$ [from Eq. (i)]

We know that current in the conductor i = neAv_d (where, n is number of free electrons in a conductor per unit volume)

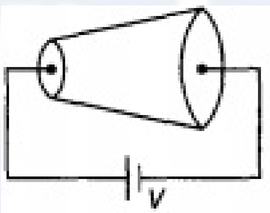
$i = neA \times \frac{e}{m}\tau\frac{V}{l} \Rightarrow i = \frac{ne^2A\tau V}{ml}$

$\Rightarrow \quad i = V/R \quad [\because\ R = ml/ne^2A\tau]$

$i \propto V$ as Resistance of the wire remains constant throughout the experiment. This is Ohm's law.



ii. The setup is shown in the figure. Here, electric current remains constant throughout the length of the wire. Electric field also remains constant which equal to V/l. Current density changes as area of cross section changes continuously and hence drift speed change according to the formula j = nev_d



here, n = number of electrons per unit volume
e = electronic charge
v_d = drift velocity

OR

Since the electric field has X-component only, the angle θ between the direction of electric field and the area vectors representing the four faces of the cube (except the faces M and N shown shaded) is $\pi/2$ in each case.
Therefore, electric flux through each of these four faces,
$\phi = E_x S \cos\theta = E_x S \cos \pi/2 = 0$
The electric field varies along X-axis as given by
$E_x = 5 A x + 2 B$

Therefore, magnitude of electric field at face M (x = 0),

$E_M = 5\,A\,x + 2\,B = 5 \times 10 \times 0 + 2 \times 5 = 10\ NC^{-1}$

and magnitude of electric field at face N (x = 0.1 m),

$E_N = 5\,A\,x + 2B = 5 \times 10 \times 0 \cdot 1 + 2 \times 5 = 15\ NC^{-1}$

The electric flux through the face M,

$\phi_M = E_M\,S\cos\theta = 10 \times (0 \cdot 1 \times 0 \cdot 1)\cos 0° = 0 \cdot 10\ NmC^{-1}$ (inwards)

The electric flux through the face N,

$\phi_N = E_N\,S\cos\theta = 15 \times (0 \cdot 1 \times 0 \cdot 1)\cos 0° = 0 \cdot 15\ NmC^{-1}$ (outwards)

Therefore, net electric flux through the cube,

$\phi = \phi_N - \phi_M = 0 \cdot 15 - 0 \cdot 10 = 0 \cdot 05\ NmC^{-1}$

Now, from Gauss' theorem, we have

$q = \varepsilon_0 \phi$

$= 8 \cdot 854 \times 10^{-12} \times 0 \cdot 05 = 4 \cdot 43 \times 10^{-13}$ C

36. According to the question , $V_P = 2.5 \times 10^3 \mathrm{V}$, Input current, $I_P = 20\mathrm{A}$

Also, $\frac{N_p}{N_s} = 10\% \Rightarrow \frac{N_s}{N_P} = \frac{1}{100}$

$$Output Power = \frac{90}{100} \times \left(25 \times 10^3\right) \times (20\mathrm{A}) = 4.5 \times 10^4 \mathrm{W}$$

i. $\therefore\ V_s/V_p = N_s/N_p \Rightarrow V_s = N_s/N_p \times V_p$

   Voltage $V_S = \frac{1}{10} \times 2.5 \times 10^3 \mathrm{V} = 250\mathrm{V}$

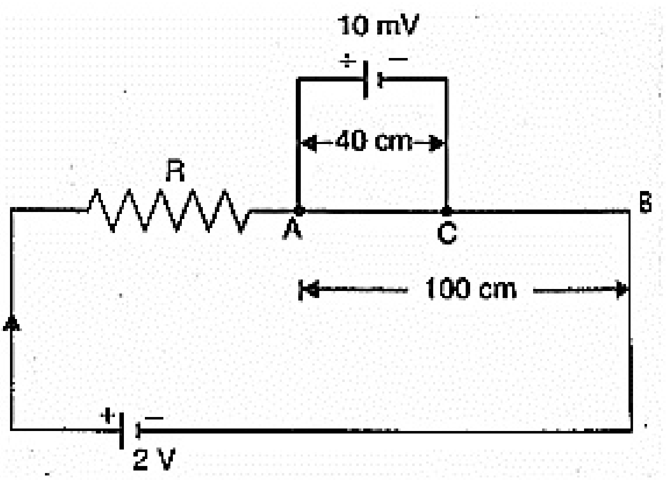
ii. $V_\mathrm{S} I_\mathrm{s} = 4.5 \times 10^4 \mathrm{W}$

   Current, $I_S = \frac{4.5 \times 10^4}{V_S} = \frac{4.5 \times 10^4}{250}$

   $\Rightarrow \quad I_S = 180\mathrm{A}$

OR

Let AB be the potentiometer wire and R, the external resistance, as shown in the figure. Potential drop across the wire AB = current $\times$ resistance



$= \left(\frac{2}{R+10}\right) \times 10 = \frac{20}{R+10}$

Therefore, the potential drop per cm of the wire is

$\frac{20}{100(R+10)} V cm^{-1}$

The fall of potential across 40 cm of the wire is

$= \frac{40\times20}{100(R+10)} = \frac{8}{R+10} V$

Which must be equal to the emf of the source when the balance is achieved.

Thus, $\frac{8}{R+10} = 10 \times 10^{-3} = \frac{1}{100}$

R + 100 = 800 or R = 790Ω

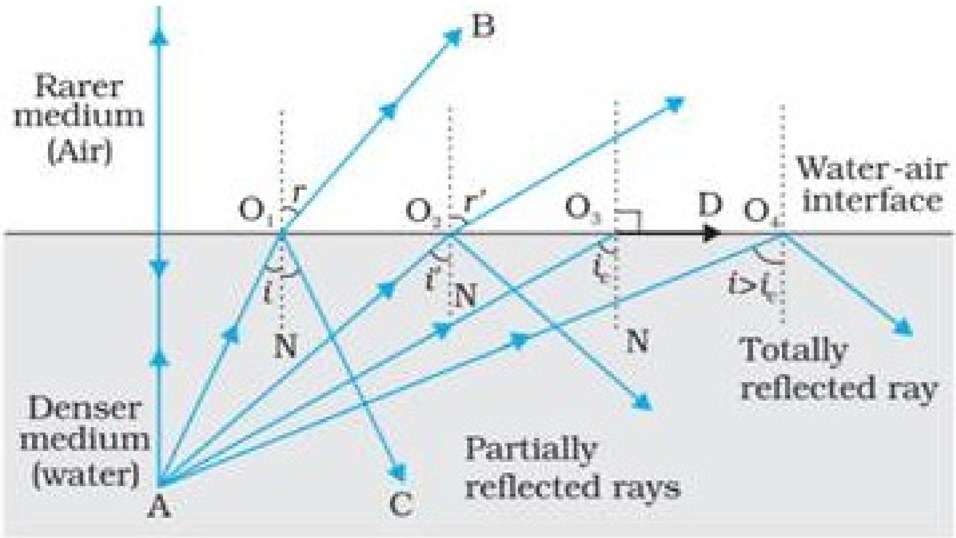
37. i. The conditions for total internal reflection are:

(i) Light must be trying to travel from optically denser medium to optically lighter medium.

(ii) The angle of incidence must be greater than a certain angle known as critical angle.

<u>Derivation:</u>

Suppose light is travelling from medium 1 to medium 2. When light strikes the surface separating the media, some of it refracts and some of it reflects. If we keep increasing the angle of incidence, the refracted ray becomes parallel to the surface. This value of angle of incidence is known as the critical angle. If we increase the angle of incidence, even further, we will have a reflected ray and no refracted ray. Thus, we will have total internal reflection.



Let us consider the condition when the angle of incidence is equal to critical angle, i_c .

By Snell's law,

$$\frac{\sin\ i_c}{sin\ 90} = \frac{n_2}{n_1}$$

where n_1 and n_2 are the refractive indices of medium 1 and medium 2 respectively. Let n_{12} be the refractive index of 1 with respect to 2.

$$\sin\ i_c = \frac{1}{n_{12}}$$

$$i_c = \sin^{-1}\left(\frac{1}{n_{12}}\right)$$

Thus, we have obtained the required relation.

ii. For convex lens of focal length 10 cm,

$$\frac{1}{f_1} = \frac{1}{v_1} - \frac{1}{u_1}$$

$$\frac{1}{10} = \frac{1}{v_1} - \frac{1}{-30} \Rightarrow v_1 = 15 \text{ cm}$$

Object distance for cancave lens u_2 = 15 - 5 = 10 cm

$$\frac{1}{f_2} = \frac{1}{v_2} - \frac{1}{u_2}$$

$$\frac{1}{-10} = \frac{1}{v_2} - \frac{1}{10}$$

$$\Rightarrow v_2 = \infty$$

For third lens,

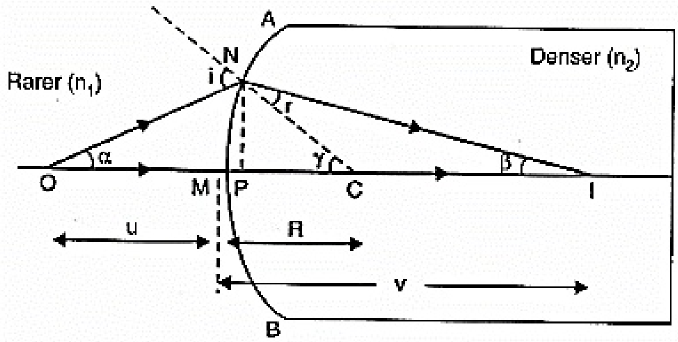
$$\frac{1}{f_3} = \frac{1}{v_3} - \frac{1}{u_3}$$

$$\frac{1}{30} = \frac{1}{v_3} - \frac{1}{\infty} \Rightarrow v_3 = 30 \text{ cm}$$

OR

AMB is a convex surface separating two media of refractive indices n_1 and n_2(n_2 > n_1).

Consider a point object O placed on the principal axis. A ray ON is incident at N and refracts along NI. The ray along ON goes straight and meets the previous ray at I. Thus I is the real image of O.



From Snell's law, $n_2 = \frac{\sin i}{\sin r}$

$n_1 \sin i = n_2 \sin r$

$\frac{n_2}{n_1} = \frac{\sin i}{\sin r}$

or $n_1 i = n_2 r$ [$\because \sin\theta \cong \theta$ as θ is very small]

From $\Delta NOC, i = \alpha + \gamma$

From $\Delta NIC, \gamma = r - \beta$

or $r = \gamma - \beta$

$\therefore n_1(\alpha + \gamma) = n_2(\gamma - \beta)$

or $n_1\alpha + n_2\beta = (n_2 - n_1)\gamma$

But $\alpha \cong \tan\alpha = \frac{NP}{OP} = \frac{NP}{OM}$ [P is close to M]

$\beta \cong \tan\beta = \frac{NP}{PI} = \frac{NP}{MI}$

$\gamma \cong \tan\gamma = \frac{NP}{PC} = \frac{NP}{MC}$

$\therefore n_1 \cdot \frac{NP}{OM} + n_2 \cdot \frac{NP}{MI} = (n_2 - n_1)\frac{NP}{MC}$

or $\frac{n_1}{OM} + \frac{n_2}{MI} = \frac{n_2 - n_1}{MC}$

Using Cartesian sign convention,

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

$\therefore \frac{n_1}{-u} + \frac{n_2}{v} = \frac{n_2 - n_1}{R}$

or $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$