

**CBSE Class 12 Physics**  
**Sample Paper 07 (2020-21)**

**Maximum Marks: 70**

**Time Allowed: 3 hours**

**General Instructions:**

- i. All questions are compulsory. There are 33 questions in all.
- ii. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
- iii. Section A contains ten very short answer questions and four assertion reasoning MCQs of 1 mark each, Section B has two case based questions of 4 marks each, Section C contains nine short answer questions of 2 marks each, Section D contains five short answer questions of 3 marks each and Section E contains three long answer questions of 5 marks each.
- iv. There is no overall choice. However internal choice is provided. You have to attempt only one of the choices in such questions.

**Section A**

1. Dielectric constant of water is 80. What is its permittivity?
2. In the Rutherford scattering experiment, the distance of closest approach for an  $\alpha$ -particle is  $d_0$ . If  $\alpha$ -particle is replaced by a proton, then how much kinetic energy in comparison to  $\alpha$ -particle will be required to have the same distance of closest approach  $d_0$ ?

OR

Imagine removing one electron from  $\text{He}^4$  and  $\text{He}^3$ . Their energy levels, as worked out on the basis of Bohr model will be very close. Explain why?

3. 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?
4. When a tiny circular obstacle is placed in the path of light from a distant source, a bright spot is seen at the centre of the shadow of the obstacle. Explain why?

OR

What will be the effect on the interference fringes, if red light is replaced by blue light?

5. An astronomical telescope uses two lenses of powers 10 D and 1 D. What is its magnifying power in normal adjustment?
6. Calculate the momentum of a photon having frequency  $5 \times 10^{13}$  Hz. Given that  $h = 6.6 \times 10^{-34}$  Js and  $c = 3 \times 10^8$  ms<sup>-1</sup>.
7. In a parallel plate capacitor, how is the capacity affected, when without changing the charge:
  - i. the distance between the plates is doubled
  - ii. the area of the plate is halved.

OR

Is potential difference a scalar or a vector?

8. How does conductivity of a semiconductor change with rise in temperature?
9. Horizontal and vertical components of earth's magnetic field at a place are 0.22 T and 0.38 T respectively. Find the resultant intensity of earth's magnetic field.
10. Give two advantages of LED's over the conventional incandescent lamps.
11. **Assertion (A):** In an electromagnetic wave, the magnitude of the magnetic field vector is much smaller than the magnitude of the electric field vector.

**Reason (R):** The energy of electromagnetic waves is shared equally by the electric and magnetic fields.

- a. Both A and R are true and R is the correct explanation of A
  - b. Both A and R are true but R is NOT the correct explanation of A
  - c. A is true but R is false
  - d. A is false and R is also false
12. **Assertion (A):** Cobalt-60 is useful in cancer therapy.

**Reason (R):** Cobalt-60 is a source of  $\gamma$ -radiations capable of killing cancerous cells.

  - a. Both A and R are true and R is the correct explanation of A
  - b. Both A and R are true but R is NOT the correct explanation of A
  - c. A is true but R is false
  - d. A is false and R is also false
13. **Assertion:** A circular loop carrying current lies in X, Y - plane with its centre at origin



having a magnetic flux in negative z-axis.

**Reason:** Magnetic flux direction is independent of the direction of current in the conductor.

- a. Both A and R are true and R is the correct explanation of A
- b. Both A and R are true but R is NOT the correct explanation of A
- c. A is true but R is false
- d. A is false and R is also false

14. **Assertion (A):** Only a change of magnetic flux with time, will maintain an induced current in the coil.

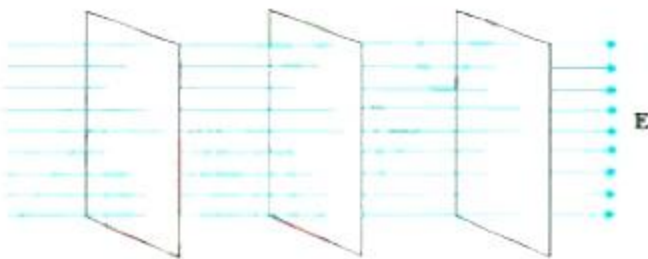
**Reason (R):** The presence of a large magnetic flux will maintain an induced current in the coil.

- a. Both A and R are true and R is the correct explanation of A
- b. Both A and R are true but R is NOT the correct explanation of A
- c. A is true but R is false
- d. A is false and R is also false

### Section B

15. **Read the source given below and answer any four out of the following questions:**

When an object is moved against the electric field it gains some amount of energy which is defined as the electric potential energy. For any charge, the electric potential is obtained by dividing the potential energy by the quantity of charge and the surface which is the locus of all points which are at the same potential is known as the equipotential surface.



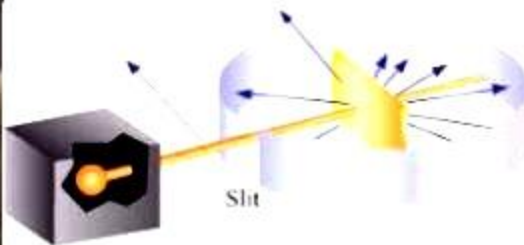
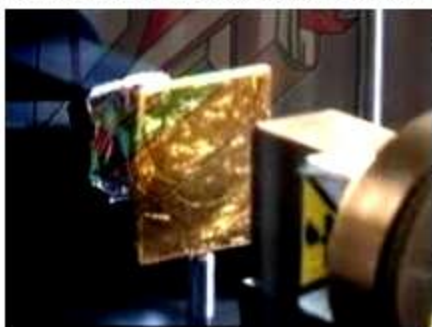
Equipotential Surfaces for a uniform electric field

- i. Equipotentials at a great distance from a collection of charges whose total sum is not zero are approximate:
  - a. spheres
  - b. planes
  - c. paraboloids
  - d. ellipsoids

- ii. Work done in carrying an electron from A to B lying on equipotential surface on one volt potential is
  - a. 1 eV
  - b. 10 eV
  - c. 1 volt
  - d. Zero
- iii. Electric potential is:
  - a. scalar
  - b. vector
  - c. both
  - d. none of these
- iv. The shape of the equipotential surface for a point charge:
  - a. sphere
  - b. rectangular
  - c. circle
  - d. irregular
- v. Electric potential due to the electric dipole is:
  - a. spherically symmetric
  - b. cylindrically symmetric
  - c. irregular distributed
  - d. none of these

**16. Read the source/case study given below and answer any four out of the following questions:**

Rutherford performed one of the revealing experiments in atomic physics that is now known as the gold foil experiment. Some radioactive heavy elements emit alpha particles (helium nuclei), and a beam of these particles was directed at thin gold foil.

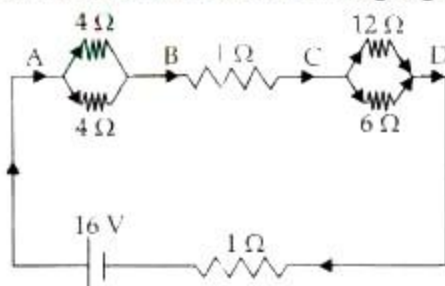


- i. Who discovered the electron?
  - a. Rutherford

- b. Chadwick
  - c. Thomson
  - d. Edison
- ii. Rutherford's scattering experiment is related to the size of the:
- a. nucleus
  - b. atom
  - c. neutron
  - d. electron
- iii. Rutherford's alpha-particle scattering experiment eventually led to the conclusion that:
- a. Mass and energy are related
  - b. Electrons occupy space around the nucleus
  - c. Neutrons are buried deep in the nucleus
  - d. The point of impact with matter can be precisely determined
- iv. Rutherford's experiment on the scattering of  $\alpha$ -particles showed for the first time that the atom has:-
- a. electron
  - b. proton
  - c. neutron
  - d. nucleus
- v. The nucleons are:
- a. Protons and electrons
  - b. Neutrons and electrons
  - c. Protons and neutrons
  - d. none of these

### Section C

17. A network of resistors is connected to a 16 V battery with an internal resistance of 1 ohm, as shown in the following figure. Compute the equivalent resistance of the network.





18. On what factors does
- magnifying power and
  - resolving power of a compound microscope depend?

OR

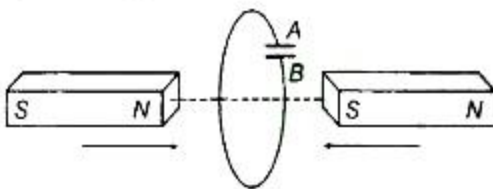
A ray of light of frequency of  $5 \times 10^{14}$  Hz is passed through a liquid. The wavelength of light measured inside the liquid is found to be  $450 \times 10^{-9}$  m. Calculate refractive index of the liquid.

19. Two identical charged bodies have  $12\mu\text{C}$  and  $-18\mu\text{C}$  charge respectively. These bodies experience a force of 48 N at certain separation. The bodies are touched and placed at the same separation again. Find the new force between the bodies.

OR

Define electric field intensity. Write its SI unit. Write the magnitude and direction of electric field intensity due to an electric dipole of length  $2a$  at the mid-point of the line joining the two charges.

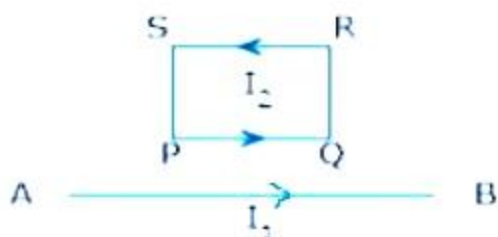
20. State Lenz's law. Show that Lenz's law is in accordance with the law of conservation of energy.
21. Predict the polarity of the capacitor in the situation described by adjoining as shown in figure. Explain the reason too.



22. From the relation  $R = R_0 A^{1/3}$  where  $R_0$  is a constant and  $A$  is the mass number of a nucleus, show that the nuclear matter density is nearly constant (i.e. independent of  $A$ ).
23. A spherical surface of radius of curvature  $R$  separates air (refractive index = 1) from glass (refractive index 1.5). The centre of curvature is in the glass. A point object  $P$  placed in air is found to have a real image  $Q$  in the glass. The line  $PQ$  cuts the surface at point  $O$  and  $PO = OQ$ . Find the distance  $PO$ .
24. What do you mean by magnetic lines of force? Why two such lines do not cross each other?

OR

In the figure, straight wire AB is fixed; while the loop is free to move under the influence of the electric currents flowing in them. In which direction does the loop begin to move? Justify.



25. i. Why does the sun appear reddish at sunset or sunrise?  
ii. For which colour, the refractive index of prism material is maximum and minimum?

#### Section D

26. How is a wave front defined? Using Huygen's construction draw a figure showing the propagation of a plane wave reflecting at the interface of the two media. Show that the angle of incidence is equal to the angle of reflection.
27. A cell of emf  $E$  and internal resistance  $r$  is connected to two external resistances  $R_1$  and  $R_2$  and a perfect ammeter. The current in the circuit is measured in four different situations:
- Without any external resistance in the circuit
  - With resistance  $R_1$  only
  - With  $R_1$  and  $R_2$  in series combination
  - With  $R_1$  and  $R_2$  in parallel combination

The currents measured in the four cases are 0.42 A, 1.05 A, 1.4 A and 4.2 A, but not necessarily in that order. Identify the currents corresponding to the four cases mentioned above.

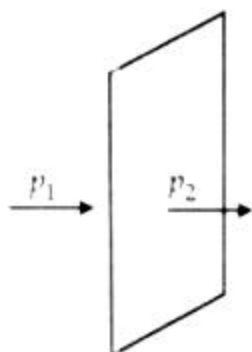
OR

A cell of emf  $E$  and internal resistance  $r$  is connected across a variable resistor  $R$ . Plot a graph showing variation of terminal voltage  $V$  of the cell versus the current  $I$ . Using the plot, show the emf of the cell and its internal resistance can be determined.

28. State Gauss' law in electrostatics. Using this law, derive an expression for the electric field due to a uniformly charged infinite plane sheet.

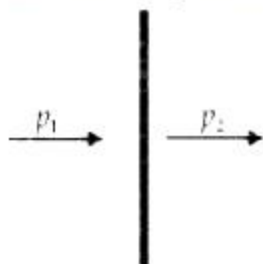
OR

- i. An electric dipole is kept first to the left and then to the right of a negatively charged infinite plane sheet having a uniform surface charge density. The arrows  $p_1$  and  $p_2$  show the directions of its electric dipole moments in the two cases.



Identify for each case, whether the dipole is in stable or unstable equilibrium. Justify each answer

- ii. Next, the dipole is kept in a similar way (as shown), near an infinitely long straight wire having uniform negative linear charge density.

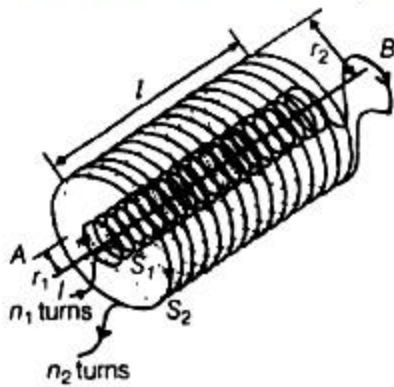


Will the dipole be in equilibrium at these two positions? Justify your answer.

29. Plot a graph showing variation of de Broglie wavelength ( $\lambda$ ) associated with a charged particle of mass  $m$ , versus  $1/\sqrt{V}$ , where  $V$  is the potential difference through which the particle is accelerated. How does this graph give us the information regarding the magnitude of the charge of the particle?
30. i. State Ampere's circuital law expressing it in the integral form.
- ii. Two long co-axial insulated solenoids  $S_1$  and  $S_2$  of equal length are wound one over the other as shown in the figure. A steady current  $I$  flows through the inner solenoid  $S_1$  to the other end B which is connected to the outer solenoid  $S_2$  through which the some current  $I$  flows in the opposite direction so, as to come out at end A. If  $n_1$  and  $n_2$  are the number of turns per unit length, find the magnitude and direction of the net magnetic field at a point
- a. inside on the axis and



b. outside the combined system.



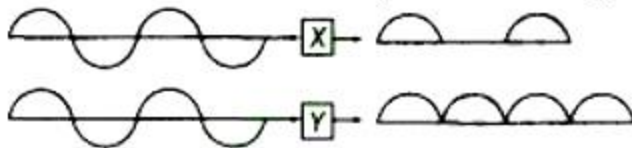
### Section E

31. i. Describe the working principle of a solar cell. Mention three basic processes involved in the generation of emf.  
ii. Why are Si and GaAs preferred materials for solar cells?

OR

An AC signal is fed into two circuits 'X' and 'Y' and the corresponding output in the two cases have the wave forms as shown.

- i. Identify the circuits 'X' and 'Y'. Draw their labelled circuit diagrams.  
ii. Briefly explain the working of circuit Y.  
iii. How does the output waveform from circuit Y get modified when a capacitor is connected across the output terminals parallel to the load resistor?



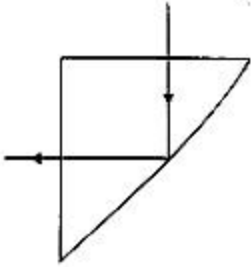
32. An AC source of voltage  $V = V_0 \sin \omega t$  is connected to a series combination of L, C and R. Use the phasor diagram to obtain expressions for the impedance of the circuit and phase angle between voltage and current. Find the condition when current will be in phase with the voltage. What is the circuit in the condition called?

OR

- i. When an AC source is connected to an ideal capacitor, then show that the average power supplied by the source over a complete cycle is zero.  
ii. A lamp is connected in series with a capacitor. Predict your observations when the system is connected first across a DC and then an AC source. What happens in each

case if the capacitance of the capacitor is reduced?

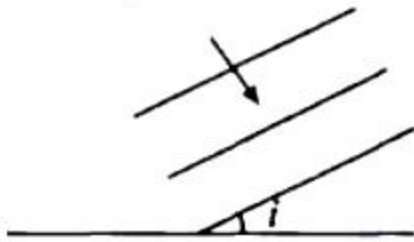
33. A ray of light incident normally on one of the faces of a right angled isosceles prism is found to be totally reflected as shown.



- What is the minimum value of the refractive index of the material of the prism?
- When the prism is immersed in water, trace the path of the emergent ray for the same incident ray indicating the values of all the angles. ( $\mu$  of water =  $\frac{4}{3}$ ).

OR

- In a double slit experiment using the light of wavelength 600 nm, the angular width of the fringe formed on a distant screen is  $0.1^\circ$ . Find the spacing between the two slits.



- Light of wavelength  $500 \text{ \AA}$  propagating in air gets partly reflected from the surface of water. How will the wavelengths and frequencies of the reflected and refracted light be affected?

**CBSE Class 12 Physics**  
**Sample Paper 07 (2020-21)**

**Solution**

**Section A**

1. Since dielectric constant and relative permittivity of a medium represent the same quantity, it implies that the relative permittivity ( $\epsilon_r$ ) of water is 80.

The absolute permittivity ( $\epsilon$ ) of water =  $\epsilon_0 \epsilon_r = 8.854 \times 10^{-12} \times 80 = 7.083 \times 10^{-10} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$

2. Distance of closest approach,

$$d_0 = \frac{2kZe^2}{K.E} = \frac{4kZe^2}{mv^2}$$

Kinetic energy  $\propto Z$  (atomic number)

$$\Rightarrow \frac{K_{\text{proton}}}{K_{\alpha}} = \frac{Z_{\text{proton}}}{Z_{\alpha}} = \frac{1}{2} \Rightarrow K_{\text{proton}} : K_{\alpha} = 1 : 2$$

This means kinetic energy required by proton is half of the kinetic energy required by an alpha particle.

OR

After removing one electron from  $\text{He}^4$  and  $\text{He}^3$ , both the atoms will have only one electron and both will be a hydrogen-like atom. So, their energy levels, as worked out on the basis of Bohr model will be very close. Alternatively we can say that as both the residual nuclei are very heavy compared to the mass of electron removed, therefore, their energy levels, worked out on the basis of Bohr model, will be very close.

3. Since, size of central maximum  $\propto \frac{\lambda}{d}$

So on doubling the width of the slit, the size of the central diffraction band reduces to half. But, the light amplitude becomes double, which increases the intensity four times.

4. Waves diffracted from the edge of the circular obstacle interfere constructively at the center of the shadow of the circular obstacle. As a result, a bright spot is seen at the center of the shadow of the obstacle.

OR

The wave length of blue light is smaller than that of red light.



We know,  $\beta = \frac{D\lambda}{d}$

Therefore, when red light is replaced by blue light, the fringe width will decrease.

5. The magnifying power (in magnitude) of the astronomical telescope in normal

adjustment,  $M = \frac{f_0}{f_e} = \frac{\frac{1}{f_e}}{\frac{1}{f_0}} = \frac{\text{power of eye piece}}{\text{power of objective lens}}$

The objective lens of a telescope is of large focal length (small power), while the eye piece is of small focal length (large power).

$$\therefore M = \frac{10}{1} = 10$$

6. The momentum of a photon is given by

$$p = \frac{h}{\lambda} = \frac{h}{c/\nu} = \frac{h\nu}{c}$$
$$= \frac{6.6 \times 10^{-34} \times 5 \times 10^{13}}{3 \times 10^8} = 1.1 \times 10^{-28} \text{ kg ms}^{-1}$$

7. i.  $C \propto \frac{1}{d}$ , when d is doubled, capacity is halved.  
ii.  $C \propto A$ , when A is halved, capacity is halved.

OR

It is a scalar quantity.

8. The conductivity of a semiconductor increases with temperature.  
9.  $B_H = 0.22 \text{ T}$ ,  $B_V = 0.38 \text{ T}$

$$\text{Resultant, } B = \sqrt{B_H^2 + B_V^2} = \sqrt{(0.22)^2 + (0.38)^2}$$

$$B = \sqrt{0.0484 + 0.1444}$$

$$B = \sqrt{0.1928} = 0.44 \text{ T}$$

10. The two advantages of LED's over the conventional incandescent lamps are

- (i) Low operational voltage and less power.  
(ii) Fast action and no warm-up time required.

11. (d) A is false and R is also false

**Explanation:** A is false and R is also false

12. (a) Both A and R are true and R is the correct explanation of A

**Explanation:** Cobalt 60 is the radioactive isotope of cobalt.  $\gamma$ -radiation emitted by it is used in radiation therapy is cancer as it destroys cancerous cells. So, assertion and reason are true and reason explains assertion.

13. (c) A is true but R is false

**Explanation:** The direction of the magnetic field due to the current-carrying conductor

can be found by applying the right-hand thumb rule or right-hand first rule. When an electric current is passed through a circular conductor, the magnetic field lines near the centre of the conductor are almost straight lines. Magnetic flux direction is determined only by the direction of the current.

14. (c) A is true but R is false

**Explanation:** A is true but R is false

### Section B

15. i. (a) sphere  
 ii. (d) zero  
 iii. (a) scalar  
 iv. (a) sphere  
 v. (b) cylindrically symmetric
16. i. (c) Thomson  
 ii. (a) nucleus  
 iii. (b) Electrons occupy space around the nucleus  
 iv. (d) nucleus  
 v. (c) Protons and neutrons

### Section C

17. In AB arm resistors are in parallel, similarly, in CD arm both of the resistors are in parallel and they present in series with resistor in BC arm and 1 ohm along with battery.

$$\text{In AB arm} = \frac{4 \times 4}{(4+4)} = 2 \text{ ohm}$$

$$\text{In CD arm} = \frac{12 \times 6}{(12+6)} = 4 \text{ ohm}$$

thus 1ohm with battery and 1ohm, 2ohm and 4ohm are in series so

$$\text{Equivalent Resistance} = 1 + 1 + 2 + 4 = 8 \text{ ohm}$$

18. i. Magnifying power,

$$\mathbf{M} = -\frac{L}{f_o} \left( 1 + \frac{D}{f_e} \right)$$

Therefore, magnifying power of a compound microscope depends upon the focal lengths of the objective and the eye-piece of the microscope.

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

Therefore, resolving power of a microscope depends upon the wavelength of light used to illuminate the object, refractive index of the glass forming the objective and the semi-vertical angle of the cone, in which the rays from the object enter the

objective.

OR

Here,  $\nu = 5 \times 10^{14}$  Hz

Wavelength of light inside the liquid,

$$\lambda = 450 \times 10^{-9} \text{ m}$$

Therefore, velocity of light inside the liquid,

$$\begin{aligned} v &= \nu \lambda = 5 \times 10^{14} \times 450 \times 10^{-9} \\ &= 2.25 \times 10^8 \text{ ms}^{-1} \end{aligned}$$

Hence, refractive index of the liquid,

$$\mu = \frac{c}{v} = \frac{3 \times 10^8}{2.25 \times 10^8} = 1.33$$

19. When two identical bodies having different magnitude of charge are touched, the redistribution of charge takes place and both the bodies acquire same charge.

$\therefore$  Charge on each body after touching

$$= \frac{12-18}{2} = -3\mu\text{C}$$

The new force between the bodies

$$F = \frac{1}{4\pi\epsilon_0} \cdot \frac{3 \times 10^{-6} \times 3 \times 10^{-6}}{x^2}$$

$$\text{but } 48 = \frac{1}{4\pi\epsilon_0} \cdot \frac{12 \times 10^{-6} \times 18 \times 10^{-6}}{x^2}$$

$$\therefore F = \frac{48 \times 3 \times 10^{-6} \times 3 \times 10^{-6}}{12 \times 10^{-6} \times 18 \times 10^{-6}} = \frac{48 \times 3 \times 3}{12 \times 18} = 2 \text{ N}$$

OR

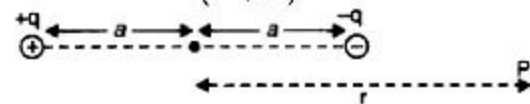
The force experienced by a unit positive charge placed at that point is termed as the electric field intensity.

Its formula is given as  $E = \frac{F}{q_0}$

The SI unit of electric field intensity =  $\text{NC}^{-1}$

Electric field at any equatorial point of a dipole is

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \cdot \frac{\vec{p}}{(r^2 + a^2)^{\frac{3}{2}}}$$



At the mid-point of the dipole,  $r = 0$ ,



Hence,  $\vec{E} = \frac{1}{4\pi\epsilon_0} \cdot \frac{\vec{p}}{a^3}$

The direction of  $\vec{E}$  is from positive charge to negative charge.

20. Lenz's law states that the direction of induced emf is such, that it produces a current which opposes the change in magnetic flux that produced it.

Mathematically,

$$e = -N \frac{d\phi}{dt}$$

Suppose a magnet is moved towards a closed coil. The direction of induced emf in it by Lenz's law opposes its inward motion. As a result, the magnet will be moved towards the coil against this opposing force. In such a case work will have to be done. This work is converted into electrical energy in the form of induced emf. Thus, Lenz's law is in accordance with the law of conservation of energy.

21. According to figure shown in the question, induced current is in anti-clockwise, when seen from left hand side and its direction is in clockwise when seen from right hand side (direction of current seen from both sides are identified from Lenz's law). Thus, direction of induced current is in clockwise sense.

This implies that plate A of the capacitor is at the higher potential than plate B (since current is directed from higher to lower potential), i.e. B is a negative plate while A is a positive plate.

22. The relation between radius and mass number of the nucleus is  $R = R_0 A^{1/3}$

Where,  $R_0 = 1.2 \text{ fm}$ ,  $R$  = radius of nucleus and  $A$  = mass number

Nuclear density,

$$\rho = \frac{\text{Mass of nucleus}}{\text{Volume of nucleus}} = \frac{mA}{\frac{4}{3}\pi(R_0 A^{1/3})^3}$$

$$\rho = \frac{mA}{\frac{4}{3}\pi R_0^3 A} \Rightarrow \rho = \frac{m}{\frac{4}{3}\pi R_0^3}$$

So as per above formula, density of nucleus does not depend on mass number of nucleus rather it is same for all the atoms and it is roughly in the order of  $10^{17} \text{ kg/m}^3$  which is very large as compared to our everyday observed densities.

23. Given:  $\mu_2 = 1.5$ ;  $\mu_1 = 1$ ;  $OP = OQ = x$  (let)

For refraction at spherical surfaces from rarer to denser,

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

Applying sign convention,  $v = x$  and  $u = -x$

$$\frac{1.5}{x} - \frac{1}{-x} = \frac{1.5-1}{R}$$

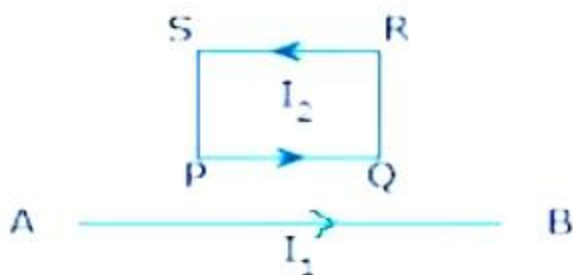
$$\frac{2.5}{x} = \frac{1}{2R}$$

$$\text{or } x = 5R$$

24. The magnetic field line is the path along which an isolated north pole will tend to move, if it is free to do so.

Two magnetic field lines can not intersect each other. It is because, if they do so, then at the point of intersection, the magnetic field will have two directions along the tangents to the two field lines.

OR



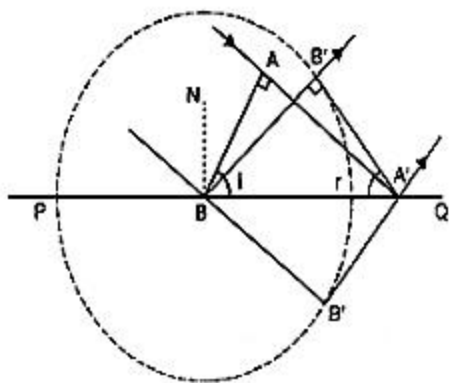
Since current in arm PQ and in wire AB are in same direction, therefore wire AB will attract the arm PQ with a force (say  $F_1$ ). But wire AB repels the arm RS with a force (say  $F_2$ ) as the currents are in opposite directions.

Now, since arm PQ is closer to the wire AB,  $F_1 > F_2$  i.e. the loop will move towards the wire.

25. i. At the sunrise or sunset time, the rays from sun cover a larger thickness of atmosphere because sun is nearer the horizon as the blue colour scatters away and red colour which is least scattered is visible from earth.
- ii. As the refractive index of prism is inversely proportional to the wavelength of light, so the refractive index of prism is maximum for violet colour and is minimum for red colour.

#### Section D

26. When light is emitted from a source, then the particles present around it begins to vibrate. The locus of all such particles which are vibrating in the same phase is termed as wavefront.



Let PQ be reflecting surface. Let a plane wavefront AB moving through the medium (air) towards the surface PQ meet at the point B. Let  $c$  be the velocity of light and  $t$  be the time of A to reach  $A'$  then  $AA' = ct$ .

By the Huygen's principle, secondary wavelets starts from B and cover a distance  $ct$  in time  $t$  and reaches at  $B'$ .

To obtain new wavefront, draw circles with point B as centre and  $ct$  ( $AA' = BB'$ ) as radius. Draw a tangent  $A'B'$  from the point  $A'$ .

Then  $A'B'$  represents the reflected wavelets which travels at right angle. Therefore, incident wavefront AB and reflected wavefront  $A'B'$  and normal lies in the same plane.

In  $\triangle ABA'$  and  $B'BA'$

$AA' = BB' = ct$  [ $\because AA' = BB' = BD =$  radii of same circle]

$BA' = BA'$  [common]

$\angle BAA' = \angle BB'A'$  [each  $90^\circ$ ]

$\therefore \triangle ABA' \cong \triangle B'BA'$  [by R.H.S.]

$\angle ABA' = \angle B'A'B$  [C.P.C.T.]

$\therefore$  Incident angle  $i =$  reflected angle  $r$

$\angle i = \angle r$

Hence the proof.

27. Internal resistance usually means the electrical resistance inside batteries and power supplies that can limit the potential difference that can be supplied to an external load. Internal resistances within power supplies are normally constant and independent of use unless the power supply gets hot as a result of short circuits or low resistance loads. The current relating to corresponding situations are as follows

i. Without any external resistance,  $I_1 = E/R$

In this case, effective resistance of circuit is minimum, so current is maximum.

Hence,  $I_1 = 4.2A$ .



ii. With resistance  $R_1$  only  $I_2 = \frac{E}{r+R_1}$

In this case, effective resistance of circuit is more than situations (i) and (iv) but less than

So,  $I_2 = 1.05A$ .

iii. With  $R_1$  and  $R_2$  in series combination,

$$I_3 = E/(r + R_1 + R_2)$$

In this case, effective resistance of circuit is maximum, so current is minimum.

Hence,  $I_3 = 0.42A$

iv.  $I_4 = \frac{E}{r+R_1 R_2 / (R_1 + R_2)}$

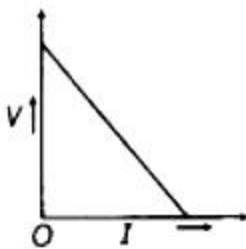
In this case, the effective resistance is more than (i) but less than (ii) and (iii). So,  $I_4 = 1.4A$

OR

Internal resistance usually means the electrical resistance inside batteries and power supplies that can limit the potential difference that can be supplied to an external load.

We know that,  $V = E - Ir$

The plot between  $V$  and  $I$  is a straight line of positive intercept and negative slope as shown in figure below.



The value of potential difference corresponding to zero current gives emf of the cell.

Maximum current is drawn when terminal voltage is zero, so

$$V = E - Ir$$

$$\Rightarrow 0 = E - I_{\max}r \Rightarrow r = \frac{E}{I_{\max}}$$

Internal resistances within power supplies are normally constant and independent of use unless the power supply gets hot as a result of short circuits or low resistance loads. In that case, the internal resistance is likely to increase slightly.

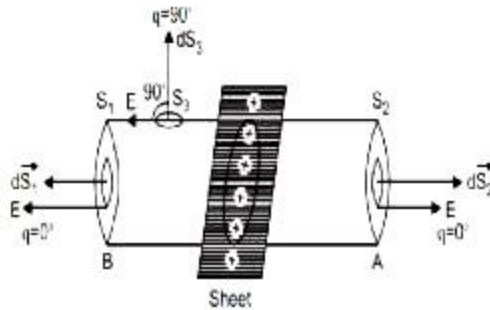
28. Gauss Theorem: The net outward electric flux through a closed surface is equal to  $\frac{1}{\epsilon_0}$  times the net charge enclosed within the surface.

$$\oint \vec{E} \cdot d\vec{S} = \frac{1}{\epsilon_0} \sum q$$

### Electric field due to a uniformly charged infinite plane sheet:

Let electric charge be uniformly distributed over the surface of a thin, non-conducting infinite sheet. Consider a cylindrical Gaussian surface having two plane faces A and B lying on the opposite sides and parallel to the charged sheet and the cylindrical surface perpendicular to the sheet as shown in figure.

By symmetry, the electric field strength at every point on the flat surface is the same and its direction is normal outwards at the points on the two plane surfaces and parallel to the curved surface.



Total electric flux,

$$\begin{aligned} \oint \vec{E} \cdot d\vec{S} &= \int_{S_1} \vec{E} \cdot d\vec{S}_1 + \int_{S_2} \vec{E} \cdot d\vec{S}_2 + \int_{S_3} \vec{E} \cdot d\vec{S}_3 \\ \oint \vec{E} \cdot d\vec{S} &= \int_{S_1} E \cdot dS_1 \cos 0 + \int_{S_2} E \cdot dS_2 \cos 0 + \int_{S_3} E dS_3 \cos 90 \\ \oint \vec{E} \cdot d\vec{S} &= E \int_{S_1} dS_1 + E \int_{S_2} dS_2 + 0 \\ \oint \vec{E} \cdot d\vec{S} &= 2E \int_{S_1} dS_1 = 2Ea \dots\dots (i) \end{aligned}$$

If  $\sigma$  is charge per unit area of sheet and 'a' is the intersecting area, the charge enclosed by Gaussian surface =  $\sigma a$

According to Gauss's theorem

$$\begin{aligned} \text{Total electric flux} &= \oint \vec{E} \cdot d\vec{S} = \frac{1}{\epsilon_0} q \\ \oint \vec{E} \cdot d\vec{S} &= \frac{1}{\epsilon_0} \sigma a \dots\dots (ii) \end{aligned}$$

From (i) and (ii) we have,

$$E = \frac{\sigma}{2\epsilon_0}$$

Thus electric field strength due to an infinite flat sheet of charge is independent of the distance of the point and is directed normally away from the charge.

OR

- i.  $p_1$ : stable equilibrium

$p_2$ : unstable equilibrium

The electric field, on either side, is directed towards the negatively charged sheet and its magnitude is independent of the distance of the field point from the sheet. For position,  $p_1$  dipole moment and electric field are parallel For position  $P_2$  they are anti-parallel. In the case of  $P_1$  dipole makes  $180^\circ$  angle with electric field hence in the stable equilibrium whereas in case  $P_2$  dipole makes  $0^\circ$  angle with the electric field hence unstable.

- ii. The dipole will not be in equilibrium in any of the two positions. The electric field due to an infinite straight charged wire is non-uniform ( $E \propto \frac{1}{r}$ ). Hence, there will be a net non-zero force on the dipole in each case.

29. Consider a particle of mass  $m$ , charge  $q$ . Let it be accelerated through a potential difference  $V$  to gain speed  $v$  and Kinetic energy  $KE$ .

$$KE = qV = \frac{1}{2} mv^2$$

Now, we can rearrange the expression to get

$$v = \sqrt{\frac{2qV}{m}}$$

The de-Broglie wavelength is given by the equation:

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

Substituting the value of  $v$ , we get

$$\lambda = \frac{h}{\sqrt{2mqV}}$$

This is analogous to the equation of a straight line passing through the origin:  $y = mx$  where  $m$  is the slope of the line.

Hence, we can see that if we plot the graph of  $\lambda$  vs  $V$ , we would get a straight line with slope:

$$S = \frac{h}{\sqrt{2mq}}$$

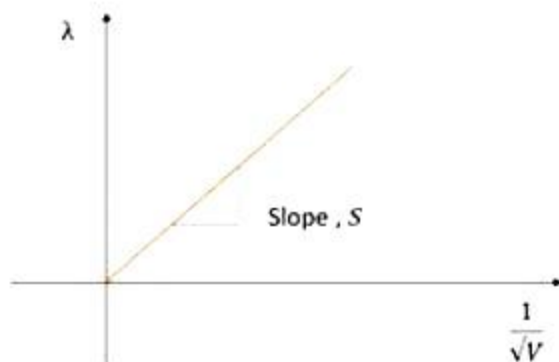
On rearranging,

$$q = \frac{h^2}{2mS^2}$$

Hence, as we know  $q$ ,  $h$  and we can determine  $S$  from the graph, we can calculate the magnitude of charge on the particle.

The graph is drawn below:

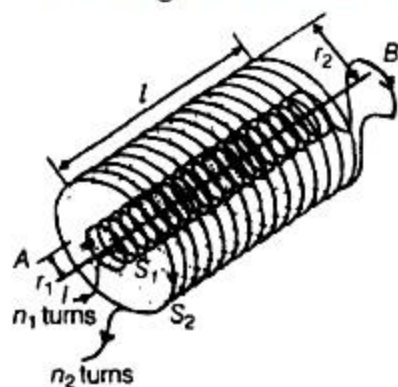




30. i. Ampere's circuital law: The line integral of the magnetic field around a closed path is  $\mu_0$  times of total current enclosed by the path.

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I$$

- ii. a. The magnetic field due to a current carrying solenoid:



$$B = \mu_0 n I$$

where  $n$  = number of turns per unit length

$i$  = current through the solenoid

Now, the magnetic field due to solenoid  $S_1$  will be in the upward direction and the magnetic field due to  $S_2$  will be in the downward direction (by right-hand screw rule).

$$B_{net} = B_{S1} - B_{S2}$$

$$B_{net} = \mu_0 n_1 I - \mu_0 n_2 I = \mu_0 I (n_1 - n_2)$$

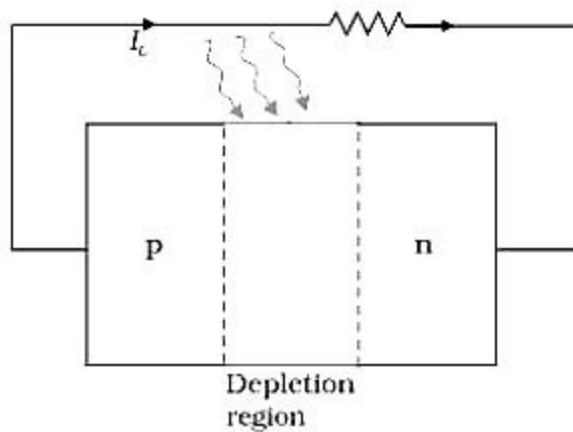
The direction of field is in the upward direction.

- b. The magnetic field is zero outside a solenoid.

### Section E

31. i. A solar cell is a semiconductor device that converts photons of solar light into electricity.

A typical illuminated p-n junction solar cell is shown in the figure.



When light falls on the n-type layer, which is on top of the solar cell, it gets absorbed. The absorbed energy knocks out electrons, which flow across the p-n junction to create a current. The current flows through the p-layer. Load resistance is connected across the metal contacts of n-type and p-type layers to store the electricity. After flowing through the load resistance, the current flows back into the n-layer. Thus, a current  $I_L$  is generated without any mechanical input energy. Obviously, the output of a solar cell is d.c.

The generation of emf by a solar cell, when light falls on, it is due to the following three basic processes: generation, separation and collection-

a) generation of e-h pairs due to light (with  $h\nu > E_g$ ) close to the junction;

b) separation of electrons and holes due to electric field of the depletion region.

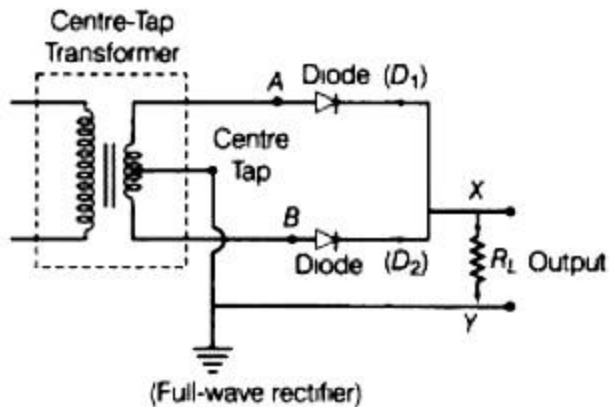
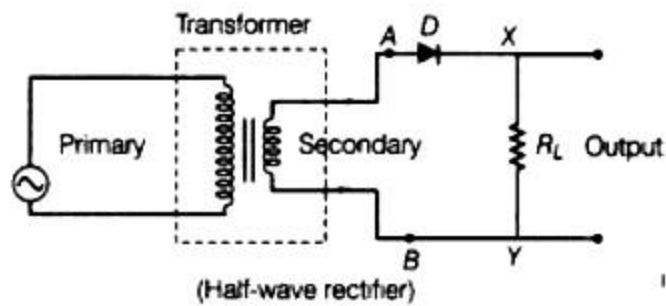
Electrons are swept to n-side and holes to p-side;

c) the electrons reaching the n-side are collected by the front contact and holes reaching p-side are collected by the back contact. Thus p-side becomes positive and n-side becomes negative giving rise to photovoltage. When an external load is connected as shown in Fig., a photocurrent  $I_L$  flows through the load.

- ii. In solar cell, the energy of the sun rays should always be more than the amount of energy required for photoexcitation. The maximum solar irradiance intensity(energy) is equal to 1.5eV. So in order to get better solar efficiency, we should use a material that needs excitation energy less than 1.5eV. Now Si has band gap  $E_g = 1.1\text{eV}$  and GaAs has  $E_g = 1.53\text{eV}$ . Here  $E_g$  of GaAs is more than 1.5eV but we still use it a solar cell material because it has a higher absorption coefficient.

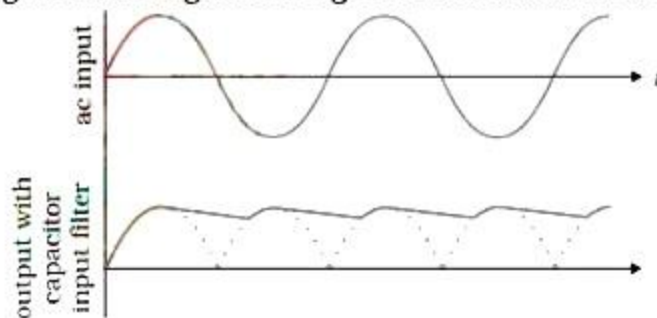
OR

- i. Here X is half-wave rectifier and Y is full-wave rectifier



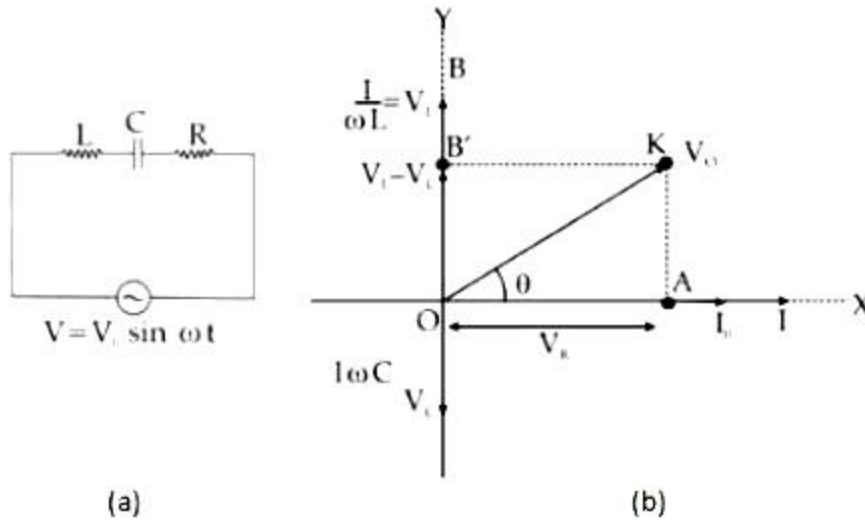
- ii. In case of a full wave rectifier during positive half cycle of ac, diode  $D_1$  is forward biased and diode  $D_2$  is reverse biased and output is taken across the load resistance with a particular polarity. Whereas during negative half cycle of ac, the diode  $D_2$  is forward biased and diode  $D_1$  is reverse biased, and again the output is taken across the load resistance with the same polarity.
- iii. A capacitor of large capacitance is connected in parallel to the load resistor  $R_L$ . When the pulsating voltage supplied by the rectifier is rising, the capacitor  $C$  gets charged. If there is no external load, the capacitor would have remained charged to the peak voltage of the rectified output.

However, when there is no load and the rectified voltage starts falling, the capacitor gets discharged through the load and the voltage across capacitor begins to fall slowly.





32.



Voltage of the source is given as  $V = V_0 \sin \omega t$

Let current of the source be  $I = I_0 \sin \omega t$

The maximum voltage across R is  $\vec{V}_R = \vec{I}_0 R$ , represented along OX.

The maximum voltage across L is  $\vec{V}_L = \vec{I}_0 X_L$ , represented along OY and is  $90^\circ$  ahead of  $I_0$ .

The maximum voltage across C is  $\vec{V}_C = \vec{I}_0 X_C$ , represented along OC and is lagging behind  $I_0$  by  $90^\circ$ .

The voltage across L and C has phase difference of  $180^\circ$ .

Hence, reactive voltage is  $\vec{V}_L - \vec{V}_C$  represented by  $OB'$ .

The vector sum of  $\vec{V}_R$ ,  $\vec{V}_L$  and  $\vec{V}_C$ , is resultant of OA and  $OB'$ , represented along OK.

$$OK = V_0 = \sqrt{OA^2 + OB'^2}$$

$$\Rightarrow V_0 = \sqrt{V_R^2 + (V_L - V_C)^2} = \sqrt{(I_0 R)^2 + (I_0 X_L - V_C)^2}$$

$$\Rightarrow V_0 = I_0 \sqrt{R^2 + (X_L - X_C)^2}$$

The impedance can be calculated as follows:

$$Z = \frac{V_0}{I_0} = \sqrt{R^2 + (X_L - X_C)^2}$$

When  $X_L = X_C$ , the voltage and current are in the same phase. In such a situation, the circuit is known as non-inductive circuit.

OR

- i. When a source of AC is connected to a capacitor of capacitance  $C$ , the charge on it grows from zero to maximum steady value  $Q_0$ .

The energy stored in a capacitor is,  $E = \frac{1}{2} CV_0^2$  where,  $V_0$  is maximum potential difference across the plates of the capacitor.

The alternating voltage applied is

$$V = V_0 \sin \omega t$$

and the current leads the emf by a phase angle of  $\pi/2$

$$I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right) = I_0 \cos \omega t$$

$\therefore$  Work done over a complete cycle is,

$$W = \int_0^T V I dt = \int_0^T (V_0 \sin \omega t) (I_0 \cos \omega t) dt$$

$$= \frac{V_0 I_0}{2} \int_0^T 2 \sin \omega t \cos \omega t dt$$

$$\therefore W = \frac{V_0 I_0}{2} \int_0^T \sin 2\omega t dt$$

$$W = \frac{V_0 I_0}{2} \left[1 - \frac{\cos 2\omega t}{2\omega}\right]_0^T = 0$$

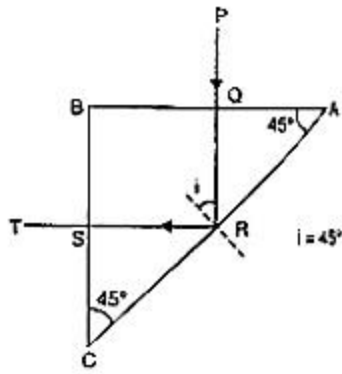
Now as the work done is zero, hence the average power is also zero (as, time can never be zero).

- ii. When a DC source is connected, the condenser is charged but no current flows in the circuit. Because a condenser offers infinite resistance for a DC source and never allows a DC current to flow through it. Therefore, the lamp does not glow. No change occurs even when capacitance of capacitor is reduced.

Now when an AC source is connected with the circuit, the capacitor offers capacitive reactance  $X_C = 1/\omega C$  (where  $\omega$  is the angular frequency of the applied AC voltage). The current flows in the circuit and the lamp glows. On reducing the value of  $C$ , the capacitive reactance,  $X_C$  increases. Therefore, the glowing of the bulb reduces.

33. i. ABC is the section of the prism, B is a right angle. A and C are equal angles i.e.  $A = C = 45^\circ$ .

The ray PQ is normally incident on the face AB. Hence it is normally refracted and the ray QR strikes the face AC at an angle of incidence  $45^\circ$ . It is given that the ray does not undergo refraction but is totally reflected at the face AC. This gives a maximum value for the critical angle as  $45^\circ$ .



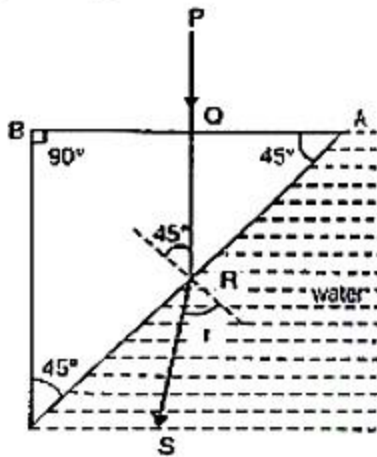
$$\sin C = \sin 45^\circ = \frac{1}{\sqrt{2}} \text{ in the limit}$$

$$\text{Since } \mu = \frac{1}{\sin C} = \frac{1}{\sqrt{2}}$$

$$\text{or, } \mu = \frac{1}{\sin 45^\circ} \text{ or } \mu_{\min} = \sqrt{2}$$

The minimum value of refractive index =  $\sqrt{2}$ .

- ii. When the prism is immersed in water the critical angle for the glass water interface is given by



$$\sin C_1 = \frac{4/3}{\sqrt{2}} = \frac{4}{3\sqrt{2}}$$

$$C_1 = 70.53^\circ$$

The angle of incidence at R continues to be  $45^\circ$  and since  $45^\circ < 70.53^\circ$ , refraction taking place and the refracted ray is RS. The angle of refraction  $r$  is given by

$$\mu_g \sin i = \mu_w \sin r$$

$$9\mu_w = \frac{\sin i}{\sin r}$$

$$\frac{\mu_w}{\mu_g} = \frac{\sin i}{\sin r}$$

$$\sqrt{2} \sin 45^\circ = \frac{4}{3} \sin r$$

$$\sin r = \frac{3\sqrt{2}}{4} \sin 45^\circ = \frac{3\sqrt{2}}{4} \times \frac{1}{\sqrt{2}} = \frac{3}{4}$$

$$r = \sin^{-1} \frac{3}{4} = 48^\circ 36'$$

$\therefore$  The angle of refraction in water =  $48^\circ 36'$



OR

Angular width is given by  $\theta = \frac{\lambda}{d}$  or  $d = \frac{\lambda}{\theta}$

- i. According to the question,  $\lambda = 600nm = 6 \times 10^{-7}m$

$$\theta = \frac{0.1\pi}{180} \text{ rad} = \frac{\pi}{1800} \text{ rad}$$

$$d = \frac{\lambda}{\theta}$$

$$\therefore d = \frac{6 \times 10^{-7} \times 1800}{\pi} = 3.44 \times 10^{-4}m$$

- ii. The frequency of a light depends on its source only.

So, the frequencies of reflected and refracted light will be same as that of incident light.

Reflected light is in the same medium (air).

So its wavelength remains same as  $500\overset{o}{\text{\AA}}$ .

We know that  $\nu = \frac{c}{\lambda}$

$$= \frac{3 \times 10^8}{5000 \times 10^{-10}}$$

$$= 6 \times 10^{18} Hz$$

This is the required frequency of both refracted and reflected light.

We know that,

$$\mu = \frac{\text{speed of light in air}}{\text{speed of light in water}}$$

$$\frac{4}{3} = \frac{3 \times 10^8}{v}$$

$$v = 2.25 \times 10^8 m/s$$

speed of light in water =  $2.25 \times 10^8 m/s$

Wavelength of refracted light is given by  $\lambda' = \frac{v}{\nu} = 0.375 \times 10^{-6}m$

So, wavelength of refracted wave will be decreased.