Class: XII

SESSION : 2022-2023

SUBJECT: PHYSICS (THEORY)

SAMPLE QUESTION PAPER - 25

with SOLUTION

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

General Instructions:

(1) There are 35 questions in all. All questions are compulsory
(2) This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.
(3) Section A contains eighteen MCQ of 1 mark each, Section B contains seven questions of two marks each, Section C contains five questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 marks each.
(4) There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.
5. Use of calculators is not allowed.

Section A

1. Pure silicon at 300 K has equal electron n_e and hole (n_h) concentration of $1.5 \times 10^{16} m^{-3}$. Doping by indium increases nh to 4.5×10^{22} m^{-3}. The n_e in the doped silicon is: **[1]**

   a) 3×10^{19} b) 5×10^9

   c) 2.25×10^{11} d) 9×10^5

2. The potential difference between the terminals of a cell in open circuit is 2.2 volt. With resistance of 5 ohm across the terminals of a cell, the terminal potential difference is 1.8 volt. The internal resistance of the cell is: **[1]**

   a) $\frac{7}{12}$ ohm b) $\frac{10}{9}$ ohm

   c) $\frac{12}{7}$ ohm d) $\frac{9}{10}$ ohm

3. When a p-n junction is reverse biased: **[1]**

   a) no change in current take place b) height of the potential barrier decreases

   c) electrons and holes are attracted towards each other and move towards the depletion region d) electrons and holes move away from the junction depletion region

4. A ray of light from a denser medium strikes a rarer medium at an angle of incidence i. If the angle of reflection is r and the angle of refraction is r' and the **[1]**

reflected and refracted rays make an angle of 90^{o} with each other, then the critical angle will be:

a) $\sin^{-1}$ (sin r')

b) $\sin^{-1}$ (tan r')

c) $\sin^{-1}$ (tan r)

d) $\sin^{-1}$ (sin r)

5. A sinusoidal electromagnetic wave is propagating in vacuum in the +*z*-direction. If at a particular instant and at a certain point in space the electric field is in the +*x*-direction and has magnitude 4.00 V/m, what are the magnitude and direction of the magnetic field of the wave at this same point in space and instant in time? **[1]**

a) 12.4 nT, -y direction

b) 12.7 nT, +y direction

c) 13.3 nT, +y direction

d) 13.0 nT, -y direction

6. A plane electromagnetic wave in a non-magnetic dielectric medium is given by $\vec{E} = \overrightarrow{E_0}$ $(4 \times 10^{-7}$ x - 50t) with distance being in meter and time in seconds. The dielectric constant of the medium is: **[1]**

a) 4.8

b) 5.8

c) 2.4

d) 8.2

7. Kamla peddles a stationary bicycle the pedals of the bicycle are attached to a 100 turn coil of area 0.10m^2. The coil rotates at half a revolution per second and it is placed in a uniform magnetic field of 0.02 T perpendicular to the axis of rotation of the coil. What is the maximum voltage generated in the coil? **[1]**

a) 0.314 V

b) 0.628 V

c) 0.714 V

d) 0.554 V

8. Which of the following parameters is the same for all hydrogen-like atoms and ions in their ground states? **[1]**

a) Radius of the orbit

b) Speed of the electron

c) Orbital angular momentum of the electron

d) Energy of the atom

9. Charge motion with in the Gaussian surface gives changing physical quantity as: **[1]**

a) electric flux

b) Gaussian surface area

c) electric field

d) charge

10. On introducing a thin film in the path of one of the two interfering beam, the central fringe will shift by one fringe width. If μ = 1.5, the thickness of the film is: (wavelength of monochromatic light is λ) **[1]**

a) 3λ

b) λ

c) 2λ

d) 4λ

11. When n–type of semiconductor is heated, **[1]**

a) number of electrons increases while that of holes decreases

b) number of electrons and holes remains same

c) number of holes increases while that of electrons is same

d) number of electrons and holes increases equally

12. Light of two different frequencies whose photons have energies 1 and 2.5 eV respectively, successively illuminate a metal whose work function is 0.5 eV. The ratio of the maximum speeds of the emitted electrons will be: **[1]**

a) 1 : 5

b) 1 : 4

c) 1 : 2

d) 1 : 1

13. The point charges Q and -2Q are placed some distance apart. If the electric field at the location of Q is E, then the electric field at the location of -2Q will be: **[1]**

a) -2E

b) $-\frac{3E}{2}$

c) -E

d) $-\frac{E}{2}$

14. For the structural analysis of crystals, X-rays are used because: **[1]**

a) wavelength of X-rays is of the order of nuclear size

b) X-rays are coherent radiations

c) X-rays have wavelength of the order of interatomic spacing

d) X-rays are highly penetrating radiations

15. A metal disc of radius R rotates with an angular velocity ω about an axis perpendicular to its plane passing through its centre in a magnetic field of induction B acting perpendicular to the plane of the disc. The induced emf between the rim and the axis of the disc is: **[1]**

a) $-B\pi R^2$

b) $-\frac{BR^2\omega}{2}$

c) $-B\pi R^2\omega$

d) $-\frac{2B\pi^2 R^2}{\omega}$

16. **Assertion (A):** Electric appliances with metallic bodies have three connections whereas an electric bulb has a two-pin connection.
Reason (R): Three-pin connections reduce the heating of connecting wires. **[1]**

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

17. **Assertion (A):** The ionising power of β-particle is less compared to β-particles but their penetrating power is more. **[1]**
Reason (R): The mass of β-particle is less than the mass of α-particle.

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 but R is true.

18. **Assertion (A):** A conducting rod is moving in a uniform magnetic field such that the length of the rod, its velocity and the magnetic field are mutually perpendicular, then, an emf will be induced between the ends of the rod. **[1]**
Reason (R): As the rod moves as stated above, free electrons in it will experience magnetic force towards an end of 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 but R is true.

Section B

19. State two important properties of the photon which are used to write Einstein's photoelectric equation. Define **[2]**
i. stopping potential and
ii. threshold frequency, using Einstein equation and drawing necessary plot between relevant quantities

20. A magnetic dipole is under the influence of two magnetic fields. The angle between the field directions is 60° and one of the fields has a magnitude of 1.2×10^{-2} tesla. If the dipole comes to stable equilibrium at an angle of 15° with this field, what is the magnitude of the other field? **[2]**

OR

Distinguish between a diamagnetic substance and a paramagnetic substance.

21. State the necessary conditions for nuclear fusion to occur. **[2]**

22. Give two examples each of **[2]**
i. elemental
ii. compound inorganic and
iii. compound organic semiconductors

23. An electron in an atom revolves around the nucleus in an orbit of radius 0.53 Å. Calculate the equivalent magnetic moment if the frequency of revolution of the electron is 6.8×10^9 MHz. **[2]**

OR

A galvanometer having 30 divisions has a current sensitivity of 20 μA/division. It has a resistance of 20 μ. How will you convert it into an ammeter measuring upto 1 ampere? How will you convert this ammeter into voltmeter reading upto 1 volt?

24. The following table gives data about the single slit diffraction experiment: **[2]**

Wavelength of light	Half angular width of the principal maxima
λ	θ
$p\lambda$	$q\theta$

Find the ratio of the widths of the slits used in the two cases. Would the ratio of the half angular widths of the first secondary maxima, in the two cases, be also equal to q?

25. An n-type semiconductor has excess of free electrons while a p-type semiconductor has a deficiency of these. But when a p-n junction is formed, all the electrons do not flow from the n-region to the p-region. Why? **[2]**

Section C

26. Two bar magnets of length 0.1 m and pole strength 75 Am each, are placed on the same line. The distance between their centres is 0.2 m. What is the resultant force due to one on the other when **[3]**
    i. the north pole of one faces the south pole of the other and
    ii. the north pole of one faces the north pole of the other?

27. a. Define electric flux. Write its SI unit. **[3]**
    b. Using Gauss' law, prove that the electric field at a point due to a uniformly charged infinite plane sheet is independent of distance from it.
    c. How is the field directed if
        i. the sheet is positively charged?
        ii. negatively charged?

28. i. Which segment of electromagnetic waves has the highest frequency? How are these waves produced? Give one use of these waves. **[3]**
    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?

OR

In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of 2.0×10^{10} Hz and amplitude 48 V m^{-1}.
a. What is the wavelength of the wave?
b. What is the amplitude of the oscillating magnetic field?
c. Show that the average energy density of the E field equals the average energy density of the B field. [$c = 3 \times 10^8$ ms^{-1}]

29. Give reason for each of the following observations : **[3]**
    i. The resultant intensity at any point on the screen varies between zero and four times the intensity, due to one slit, in young's double-slit experiment.

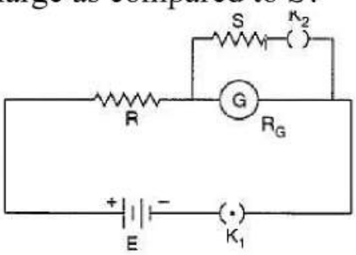
ii. A few coloured fringes, around a central white region, are observed on the screen when the source of monochromatic light is replaced by white light in Young's double-slit experiment.

iii. The intensity of light transmitted by a polaroid is half the intensity of the light incident on it.

OR

In Young's double slit experiment, using light of wavelength 400 nm, interference fringes of width 'X' are obtained. The wavelength of light is increased to 600 nm and the separation between the slits is halved. If one wants the observed fringe width on the screen to be the same in the two cases, find the ratio of the distance between the screen and the plane of the interfering sources in the two arrangements.

30. The current flowing in the galvanometer G when the key K_2 is kept open is I. On closing the key K_2 the current in the galvanometer becomes $\frac{1}{n}$, where n is an integer. Obtain an expression for resistance R_g of the galvanometer in terms of R, S, and n. To what form does this expression reduce when the value of R is very large as compared to S? [3]



Section D

31. The Bohr model for the H-atom relies on the Coulomb's law of electrostatics. Coulomb's law has not directly been verified for very short distances of the order of angstroms. Supposing Coulomb's law between two opposite charge + q_1, $-q_2$ is modified to [5]

$|\vec{F}| = \frac{q_1 q_2}{(4\pi\varepsilon_0)} \frac{1}{r^2}, \quad r \geq R_0$

$= \frac{q_1 q_2}{4\pi\varepsilon_0} \frac{1}{R_0^2} \left(\frac{R_0}{r}\right)^{\epsilon}, r \leq R_0$

Calculate in such a case, the ground state energy of an H-atom, if $\varepsilon = 0.1$, $R_0 = 1$ $\mathring{A}$

OR

Obtain an expression for the frequency of radiations emitted when a hydrogen atom de-excites from level n to level (n - 1). For large n, show that the frequency equals the classical frequency of revolution of the electron in the orbit.

32. a. In a quark model of elementary particles, a neutron is made of one up quarks [charge $(\frac{2}{3})$ e] and two down quarks [charges $-(\frac{1}{3})$ e]. Assume that they have a triangle configuration with side length of the order of 10^{-15} m. Calculate the electrostatic potential energy of neutron and compare it with its mass 939 MeV. [5]

b. Repeat above exercise for a proton which is made of two up and one down quark.

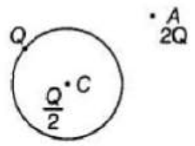
OR

i. Explain using suitable diagrams, the difference in the behaviour of a

a. conductor and

b. dielectric in the presence of external electric field. Define the terms polarisation of a dielectric and write its relation with susceptibility.

ii. A thin metallic spherical shell of radius R carries a charge Q on its surface. A point charge Q/2 is placed at its centre C and another charge + 2Q is placed outside the shell at a distance x from the centre as shown in the figure. Find



a. the force on the charge at the centre of shell and at the point A,

b. the electric flux through the shell.

33. Use the mirror equation to deduce that: **[5]**

a. an object placed between f and 2f of a concave mirror produces a real image beyond 2f.

b. a convex mirror always produces a virtual image independent of the location of the object.

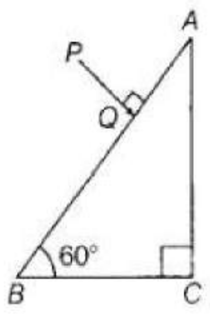
c. the virtual image produced by a convex mirror is always diminished in size and is located between the focus and the pole.

d. an object placed between the pole and focus of a concave mirror produces a virtual and enlarged image.

[**Note:** This exercise helps you deduce algebraically properties of images that one obtains from explicit ray diagrams.]

OR

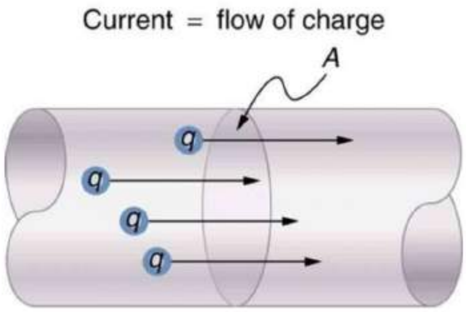
A ray PQ incident normally on the refracting face BA is refracted in the prism BAC made of material of refractive index 1.5. Complete the path of ray through the prism. From B which face will the ray emerge? Justify your answer.



Section E

34. **Read the text carefully and answer the questions:** **[4]**

The rate of flow of charge through any cross-section of a wire is called electric current flowing through it. Electric current (I) = $\frac{q}{t}$. Its SI unit is ampere (A). The conventional direction of electric current is the direction of motion of positive charge. The current is the same for all cross-sections of a conductor of the non-uniform cross-section. Resistance is a measure of the opposition to current flow in an electrical circuit.



(i) An example of non-ohmic resistance is:

a) carbon resistance
b) tungsten wire
c) diode
d) copper wire

(ii) Current is:

a) both scalar and vector quantity
b) vector quantity
c) scalar quantity
d) none of these

(iii) In a current-carrying conductor, the net charge is:

a) zero
b) 6.25×10^{-18} coulomb
c) 1.6×10^{-19} coulomb
d) infinite

OR

The current which is assumed to be flowing in a circuit from the positive terminal to negative is called:

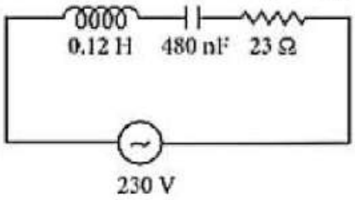
a) none of these
b) conventional current
c) pulsating current
d) direct current

35. **Read the text carefully and answer the questions:** **[4]**

When the frequency of ac supply is such that the inductive reactance and capacitive reactance become equal, the impedance of the series LCR circuit is equal to the ohmic resistance in the circuit. Such a series LCR circuit is known as resonant series LCR circuit and the frequency of the ac supply is known as resonant frequency. Resonance phenomenon is exhibited by a circuit only if both L and C are present in the circuit. We cannot have resonance in a RL or RC circuit.

A series LCR circuit with L = 0.12H, C = 480 nF, R = 23 Ω is connected to a 230

V variable frequency supply.



(i) Find the value of source frequency for which current amplitude is maximum.

(ii) What will be the value of maximum current?

(iii) Find the value of maximum power.

OR

What is the Q-factor of the given circuit?

SOLUTION

Section A

1. **(b)** 5×10^9
   Explanation: Pure silicon at 300 k has equal electron ne and hole (nh) concentration of 1.5 1016 m3. Dopping by indium increases nh to 4.5 1022 m3. The ne in the doped silicon is:
   5×10^9
2. **(b)** $\frac{10}{9}$ ohm
   Explanation: $\frac{10}{9}$ ohm
3. **(d)** electrons and holes move away from the junction depletion region
   Explanation: electrons and holes move away from the junction depletion region
4. **(c)** $\sin^{-1}$ (tan r)
   Explanation: Critical angle for a pair of rarer and denser medium is given by:
   $\sin i_c = \frac{1}{{}^r n_d}$ ....(i)
   Given that reflected and refracted rays make an angle of 90^o, hence the angle of reflection + angle of refraction = 90^o
   or r + r' = 90^o or r' = (90^o - r)
   According to Snell's law,
   $${}^r n_d = \frac{1}{{}^d n_r} = \frac{1}{\sin r' / \sin i}$$
   $$\text{or } \frac{1}{{}^d n_r} = \frac{\sin i}{\sin r'} = \frac{\sin r}{\sin\left(90^\circ - r\right)}$$
   $$= \frac{\sin r}{\cos r} = \tan r \text{ ....(ii)}$$
   Hence, from eqns. (i) and (ii), we get;
   $\sin i_c = \tan r$
5. **(c)** 13.3 nT, +y direction
   Explanation: $B_o = \frac{E_o}{c} = \frac{4}{3 \times 10^8} = 1.33 \times 10^{-8} T = 13.3nT$
   Direction of propogation of wave is in the direction of $\vec{E} \times \vec{B}$, hence direction of $\vec{B}$ is along +y axis.
6. **(b)** 5.8
   Explanation: 5.8

7. **(b)** 0.628 V

Explanation: Maximum voltage is given by:

$e_0 = NBA\omega$

but, $\omega = 2\pi n = 2 \times 3.14 \times 0.5$

Therefore, $e_0 = NBA\omega = 100 \times 0.02 \times 0.1 \times 2 \times 3.14 \times 0.5 = 0.628V$

8. **(c)** Orbital angular momentum of the electron

Explanation: The orbital angular momentum of the electron parameters is the same for all hydrogen-like atoms and ions in their ground states.

9. **(c)** electric field

Explanation: electric field

10. **(c)** 2λ

Explanation: $(\mu - 1)t = \frac{xd}{D}$

where x is the distance through which central fringe will shift.

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

or $(\mu - 1)t = \lambda$

or $(1.5 - 1)t = \lambda$ or $t = 2\lambda$

11. **(d)** number of electrons and holes increases equally

Explanation: Due to heating, a free electron is produced, then simultaneously a hole is also produced.

12. **(c)** 1 : 2

Explanation: If E is the energy of incident photon and W_0 is the work function, then $E - W_0$ = Available energy.

$E - W_0 = \frac{1}{2}mv^2$

or $v = \sqrt{\frac{2\left(E - W_0\right)}{m}}$

$\therefore \quad \frac{v_1}{v_2} = \sqrt{\frac{1-0.5}{2.5-0.5}} = \sqrt{\frac{0.5}{2}} = \frac{1}{2}$

13. **(d)** $-\frac{E}{2}$

Explanation: Electric field of -2Q at the location of charge Q,

$\kappa\frac{(-2Q)}{r^2} = E$

Electric field of Q at the location of -2Q,

$E' = \kappa\frac{Q}{r^2} = -\frac{E}{2}$

14. **(c)** X-rays have wavelength of the order of interatomic spacing

Explanation: The crystals are used as diffraction gratings.

15. **(b)** $-\frac{BR^2\omega}{2}$

Explanation: Radius of the disc = R metre

Area A of the disc = πR^2 metre^2

Angular velocity = ω radian/sec

Frequency of revolution = $\frac{\omega}{2\pi}$ per second

Area swept out per second = $(\pi R^2)(\omega/2\pi)$ metre^2/sec

= $(\omega R^2/2)$ meter^2/sec

Magnetic induction = B tesla

Rate of change in flux = $\left(\frac{\omega R^2}{2}\right)B$

Induced emf, e = $-\frac{\Delta\phi}{\Delta t} = -\frac{R^2\omega B}{2}$ volt.

16. **(d)** A is false and R is also false

Explanation: The electrical appliances with a metallic body like heater, press, etc. have three-pin connections. Two pins are for the supply line and the third pin is for earth connection for safety purposes.

17. **(b)** Both A and R are true but R is not the correct explanation of A.

Explanation: β-particles, being emitted with very high speed compared to α-particles, pass for very little time near the atoms of the medium. So the probability of the atoms being ionised is comparatively less. But due to this reason, their loss of energy is very slow and they can penetrate the medium through a sufficient depth.

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

Explanation: Both A and R are true and R is the correct explanation of A.

Section B

19. Properties of Photon:
    i. For a radiation of frequency v, each photon has an energy, E = hν, associated with it
    ii. The energy of a photon is independent of the intensity of incident radiation.
        a. Stopping potential, V_0, equals that value of the negative potential for which

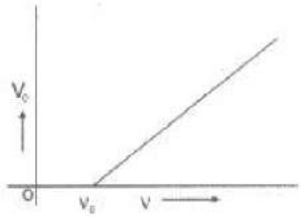
        $|eV_0| = K_{\max}$

        (Alternatively: The stopping potential (V_0) equals that (least) value of the (negative) plate potential that just stops the most energetic emitted photoelectrons from reaching the plate.)
        b. Threshold frequency (ν_0) equals that value of the frequency of incident radiation for which

        $K_{max} = 0$

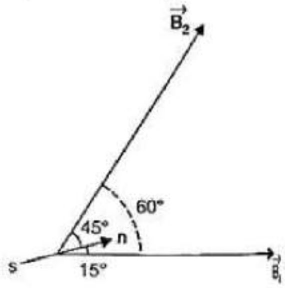
(Or threshold frequency is the minimum value of the frequency of incident radiation for which photoelectrons can be just emitted from that surface or that maximum

frequency of incident radiation below which no photoemission takes place.)
The plot, between V_0 and v has the form shown :



20. Here $\theta = 60^o, B_1 = 1.2 \times 10^{-2}$ *tesla*

$\theta_1 = 15^o, \theta_2 = 60^0 - 15^o = 45°$



In equilibrium, torques due to two fields must balance

$\tau_1 = \tau_2$

$MB_1 \sin\theta_1 = MB_2 \sin\theta_2$

$$B_2 = \frac{B_1 \sin\theta_1}{\sin\theta_2} = \frac{1.2 \times 10^{-2} \times \sin 15^o}{sin 45^o}$$

$$B_2 = \frac{1.2 \times 10^{-2} \times 0.2588}{0.7071}$$

$= 4.4 \times 10^{-3}$ *tesla*

OR

Diamagnetic Substances	Paramagnetic Substances
These are the substances, which are feebly repelled by a magnet. e.g., Bi, Zn, Cu, Ag, Au, diamond C, NaCI, H_2O, Hg, N_2, H_2, etc. exhibited by solids, liquids, and gases.	These are the substances, which are feebly attracted by a magnet, e.g., Al, Na, Pt, Mn, $CuCI_2$, O_2, etc. exhibited by solids, liquids, and gases.
When a diamagnetic substance is placed in a magnetising field, the lines of force prefer not to pass through the substance.	When a paramagnetic substance is placed in a magnetising field, the lines of force prefer to pass through the substance.

21. **High temperature:** The high temperature gives the hydrogen atoms enough energy to overcome the electrical repulsion between the protons.
High pressure: Pressure squeezes the hydrogen atoms together. They must be within 1×10^{-15} meters of each other to fuse.
22. i. Elemental semiconductors: Si and Ge.
ii. Compound Inorganic: CdS, GaAs, etc.

iii. Compound Organic polymers: Polypyrrole, polyaniline, etc.

23. Here e = 1.6×10^{-19} C,

$v = 6.8 \times 10^{9}$ MHz = 6.8×10^{15} Hz, r = 0.53×10^{-10} m

$m = IA = ev \times \pi r^2$

$= 1.6 \times 10^{-19} \times 6.8 \times 10^{15} \times 3.14 \times \left(0.53 \times 10^{-10}\right)^2$

$= 0.96 \times 10^{-23}$ Am^2

OR

Here n = 30, $R_g = 20\ \Omega$

Current sensitivity, $k = 20\mu\text{A}/\text{div}$

$\therefore$ Current required for full-scale deflection is

$I_g = nk = 30 \times 20 = 600\mu\text{A} = 6 \times 10^{-4}\ \text{A} = 0.0006\ \text{A}$

i. For conversion into ammeter I = 1 A

$$\therefore \quad R_s = \frac{T_g}{I - I_g} \times R_g = \frac{0.0006 \times 20}{1 - 0.0006}$$

$$= \frac{25 \times 6}{9994} = 0.15\Omega$$

i.e., a shunt of 0.15 Q should be connected across the galvanometer.

ii. For conversion of resulting ammeter into voltmeter. The resistance of the ammeter formed is

$$R_g' = \frac{R_g R_s}{R_g + R_s} = \frac{20 \times 0.15}{20 + 0.15} = 0.015\Omega$$

Current for full scale deflection, $I'_g = 1$ A

Voltage range, V = 1 V

$\therefore$ Required series resistance, $R = \frac{V}{I_g} - R_g' = \frac{1}{1} - 0.015 = 0.985\Omega$

24. Let a and a' be the slit widths in the two cases. Then

$\theta = \frac{\lambda}{a}$ and $q\theta = \frac{p\lambda}{a'}$

$\therefore \frac{a'}{a} = \frac{p\lambda / q\theta}{\lambda / \theta} = \frac{p}{q}$

Yes, the ratio of the half angular widths of the first secondary maxima in the two cases will be equal to q because,

$$\text{required ratio} = = \frac{\frac{3}{2}\frac{p\lambda}{a'}}{\frac{3}{2}\frac{\lambda}{a}} = p \times \frac{a}{a'} = p \times \frac{q}{p} = q$$

25. Though the p-type and n-type semiconductors have excess free electrons and holes respectively, yet they have an equal number of fixed positive donor ions and negative acceptor ions respectively. When a p-n junction is formed, electrons diffuse from n-region to p-region while holes diffuse from p-region to n-region. As a result, the n-region near the junction becomes increasingly positive and the p-region becomes increasingly negative. This sets up a potential barrier across the junction which opposes the further diffusion of electrons and holes across the junction. That is why all the electrons do not flow from n-region to p-region.

Section C

26. When N faces South

Pole Strength (m) = 75 Am

North pole of magnet 1 attract the south pole of magnet 2

$$F_1 = \frac{\mu_0}{4\pi} \times \frac{m^2}{r^2} \left[\frac{\mu_0}{4\pi} = 4\pi \times 10^{-7}\right]$$

$$= \frac{10^{-7} \times (75)^2}{(0.1)^2} = 5625 \times 10^{-7} \times 10^2 = 5625 \times 10^{-5}$$

North pole of magnet 1 pull north pole of magnet 2

$$F_2 = \frac{\mu_0}{4\pi} \times \frac{m^2}{r^2} = \frac{10^{-3} \times (75)^2}{(0.2)^2}$$

$$= \frac{5625 \times 10^{-5}}{4} = 1406.25 \times 10^{-5} \text{ N}$$

Now, South of magnet 1 repels South of magnet 2

$$F_3 = 10^{-7} \times \frac{m^2}{r^2}$$

$$= \frac{10^{-7} \times 75^2}{(0.2)^2} = 1406.25 \times 10^{-5} \text{ N}$$

South of magnet 1 attracts the norht of magnet 2

$$F_4 = \frac{10^{-7} \times 75^2}{(0.3)^2} = \frac{5625 \times 10^{-5}}{9} = 625 \times 10^{-5}$$

$\therefore$ Net force of magnet 2 due to 1 = $F_1 + F_4 - F_2 - F_3$

$= (5625 + 625 - 2 \times 406.25) \times 10_{-5} = 3437.5 \times 10^{-5}$

i. The north pole of one faces the south pole of other = 3.4×10^{-2} N (attraction)

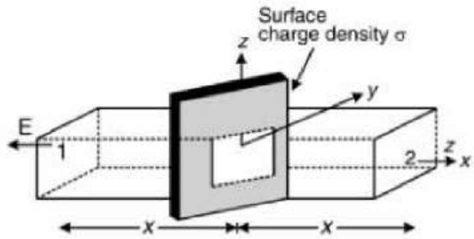
ii. The north pole of one faces the north pole of other = 3.4×10^{-2} N (repulsion)

27. a. Electric flux is defined as the number of electric field lines passing through an area normal to the surface. Alternatively, surface integral of the electric field is defined as the electric flux through a closed surface

$\phi = \oint \vec{E} \cdot \overrightarrow{ds}$

SI unit: $\frac{N \cdot m^2}{C}$ or volt.metre

b.



Outward flux through the Gaussian surface,

$2EA = \sigma A/\varepsilon_0$

$\therefore \quad E = \sigma/2\varepsilon_0$

In vector form, $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$

where $\hat{n}$ is a unit vector normal to the plane, away from it.

Hence, electric field is independent of the distance from the sheet.

c. i. For positively charged sheet, the electric field is directed away from the sheet.

ii. For negatively charged sheet, the electric field is directed towards the plane of sheet.

28. 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.

OR

Given, $\nu = 2.0 \times 10^{10}$ Hz, $E_0 = 48$ Vm^{-1}

a. wavelength of the wave is $\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{2.0 \times 10^{10}} = 1.5 \times 10^{-2}$ m

b. $B_0 = \frac{E_0}{c} = \frac{48}{3 \times 10^8} = 1.6 \times 10^{-7}$

c. The average density of the electric field is given by

$U_e = \frac{1}{2}\varepsilon_0 E^2$

and the average density of the magnetic field is given by

$$U_B = \frac{B^2}{2\mu_0}$$

But $B = \frac{E}{c}$ and $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$, hence, the above equation becomes

$$U_B = \frac{B^2}{2\mu_0} = \frac{E^2}{2\mu_0 \times \frac{1}{\mu_0 \varepsilon_0}} = \frac{1}{2}\varepsilon_0 E^2 = U_e$$

Hence, proved.

29. i. The resultant intensity, at any point on the screen, is given by

$$I = 4\, I_0 \cos^2 \frac{\phi}{2}$$

For constructive interference :

$\phi = 0, 2\pi, 4\pi$ and so on

$\Rightarrow$ I = 0 for minimum intensity

For destructive interference :

$\phi = \pi, 3\pi, 5\pi$ and so on

$\Rightarrow$ I = 4 I_0 for maximum intensity

Thus, intensity varies between zero and four times the intensity, due to each slit, in Young's double-slit experiment.

ii. The interference patterns due to different colours of white light overlap incoherently. The central bright fringes for different colours are at the same position. Therefore the central fringe is white and the fringes closest, on either side of central white fringe, are red and the farthest will appear blue. After a few fringes, no clear fringe pattern is seen.

iii. A polaroid consists of a long chain of molecules aligned in a particular direction. The electric vector (associated with the propagating light wave) along the direction of the aligned molecules gets absorbed. Thus, if the light, from an ordinary source, passes through a polaroid, it is observed that its transmitted intensity gets reduced by half.

OR

Fringe width X is same in both cases

In first case, $X = \frac{D_1 \lambda_1}{d}$

In second case, $X = \frac{D_2 \lambda_2}{d/2}$

$$\therefore \frac{D_1 \lambda_1}{d} = \frac{D_2 \lambda_2}{d/2}$$

or $\frac{D_1}{D_2} = 2 \cdot \frac{\lambda_2}{\lambda_1} = \frac{2 \times 600}{400} = \frac{3}{1} = 3 : 1$

30. With key K_2 open, the current I in the galvanometer is given by $I = \dfrac{E}{R+R_G}$

When K_2 is closed, the equivalent resistance, say R', of the parallel combination of S and R_G is given by

$$R' = \frac{SR_G}{S+R_G}$$

The total current, say I' drawn from the battery would now be

$$I' = \frac{E}{R+R'}$$

This current gets subdivided in the inverse ratio of S and R_G. Hence the current I'' through G, would now be given by

$$I'' = \frac{S}{S+R_G} I' = \frac{S}{\left(S+R_G\right)} \frac{E}{(R+R')}$$

$$= \frac{SE}{\left(S+R_G\right)\left[R+\dfrac{SR_G}{S+R_G}\right]}$$

$$= \frac{SE}{RS+RR_G+SR_G}$$

But $I'' = \dfrac{I}{n} = \dfrac{1}{n}\left(\dfrac{E}{R+R_G}\right)$

$$\therefore \quad \frac{E}{n\left(R+R_G\right)} = \frac{S.E}{RS+RR_G+SR_G}$$

Or $nRS + nSR_G = RS + RR_G + SR_G$

Or $(n-1)\ RS = RR_G - (n-1)SR_G$

Or $(n-1)\ RS = R[R - (n-1)S]$

$$\therefore \quad R_G = \frac{(n-1)RS}{R-(n-1)S}$$

This is the required expression

When R >> S, we have

$R_G = \dfrac{(n-1)RS}{R} = (n-1)S$, this is the required result.

Section D

31. Let us consider the case when $r \le R_0 = 1\mathring{A}$

Let $\varepsilon = 2 + \delta$

electrostatic force is given by F = $\frac{q_1 q_2}{4\pi\varepsilon_0} \cdot \frac{R_0^{\delta}}{r^{2+\delta}} = \frac{xR_0^{\delta}}{r^{2+\delta}}$

where, $\frac{q_1 q_2}{4\pi_0 \varepsilon_0}$ = x = $\left(1.6 \times 10^{-19}\right)^2 \times 9 \times 10^9$

= 2.04 × 10^{-29} Nm^2

The electrostatic force of attraction between the positively charged nucleus and negatively charged electrons provides the necessary centripetal force.

$\frac{mv^2}{r} = \frac{xR_0^{\delta}}{r^{2+\delta}}$ or $v^2 = \frac{xR_9^{\delta}}{mr^{1+\delta}}$ ...(i)

mvr = nh ⇒ r = $\frac{nh}{mv} = \frac{nh}{m}\left[\frac{m}{xR_0^{\delta}}\right]^{1/2} r^{(1+\delta)/2}$ [Applying Bohr's second postulates]

Solving this for r, we get $r_n = \left[\frac{n^2\hbar^2}{mxR_0^{\delta}}\right]^{\frac{1}{1-\delta}}$

where, r_n is the radius of n th orbit of electron. For n = 1 and substituting the values of constant, we get

$$r_1 = \left[\frac{\hbar^2}{mxR_0^{\delta}}\right]^{\frac{1}{1-\delta}}$$

$$\Rightarrow \quad r_1 = \left[\frac{1.05^2 \times 10^{-68}}{9.1 \times 10^{-31} \times 2.3 \times 10^{-28} \times 10^{419}}\right]^{\frac{1}{29}}$$

= 8 × 10^{-11} = 0.08 nm (< 0.1 nm)

This is the radius of orbit of the electron in the ground state of the hydrogen atom. Again using Bohr's second postulate, the speed of electron is given by ;

$$v_n = \frac{nh}{mr_n} = nh\left(\frac{m\alpha R_0^{\delta}}{n^2\hbar^2}\right)^{\frac{1}{1-\delta}}$$

For n = 1, the speed of electron in ground state is given by v_1 = $\frac{h}{mr_1} = 1.44 \times 10^6 \mathrm{m/s}$

The kinetic energy of electron in ground state is given by:-

$KE = \frac{1}{2}mv_1^2 = 9.43 \times 10^{-19} J = 5.9$ eV

Potential energy of electron in ground state till R_0

$$U = \int_0^{R_0} F dr = \int_0^{R_0} \frac{x}{r^2} dr = -\frac{x}{R_0}$$

Potential energy from R_0 to r, $U = \int_{R_0}^{r} F dr = \int_{R_0}^{r} \frac{xR_0^{\delta}}{r^{2+\delta}} dr'$

$$U = +xR_0^{\delta}\int_{R_0}^{r} \frac{dr}{r^{2+\delta}} = +\frac{xR_0^{\delta}}{-1-\delta}\left[\frac{\mathbf{1}}{r^{1+\delta}}\right]_{R_0}^{r}$$

$$U = -x\left[\frac{R_0^{\delta}}{r^{1+\delta}} - \frac{1}{R_0} + \frac{1+\delta}{R_0}\right]$$

$$U = -x\left[\frac{R_0^{-19}}{r^{-0.9}} - \frac{1.9}{R_0}\right]$$

$$= \frac{2.3}{0.9} \times 10^{-18} [(0.8)^{0.9} - 1.9] \text{ J} = -17.3 \text{ eV}$$

Hence total energy of electron in ground state is given by= (-17.3 + 5.9) = -11.4 eV

OR

The frequency v of the emitted radiation when a hydrogen atom de-excites from level n to level (n - 1) is

$E = hv = E_2 - E_1$

$$v = \frac{1}{2}\frac{mc^2\alpha^2}{h}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \text{ where } \alpha = \frac{2\pi Ke^2}{ch}$$

$$v = \frac{1}{2}\frac{mc^2\alpha^2}{h}\left[\frac{1}{(n-1)^2} - \frac{1}{n^2}\right] = \frac{mc^2\alpha^2}{2h}\left[\frac{n^2-(n-1)^2}{n^2(n-1)^2}\right]$$

$$= \frac{mc^2\alpha^2[(n+n-1)(n-n+1)]}{2h\, n^2(n-1)^2}$$

$$v = \frac{mc^2\alpha^2(2n-1)}{2h\, n^2(n-1)^2}$$

For large n, (2n - 1) = 2n, and (n - 1) = n

$$v = \frac{mc^2\alpha^2 \cdot 2n}{2h\, n^2 \cdot n^2} = \frac{mc^2\alpha^2}{h\, n^3}$$

Putting $\alpha = \frac{2\pi Ke^2}{ch}$ we get, $v = \frac{mc^2}{h\, n^3} \cdot \frac{4\pi^2 K^2 e^4}{c^2 h^2}$

$$v = \frac{4\pi^2 m K^2 e^4}{n^3 h^3} \text{ .....(i)}$$

In Bohr's atom model, velocity of electron in nth orbit is $v = \frac{n\, h}{2\pi mr}$ and radius of nth orbit is $r = \frac{n^2h^2}{4\pi^2 mKe^2} (\because Z = 1)$

Frequency of revolution of electron, $v = \frac{\upsilon}{2\pi r} = \frac{nh}{2\pi mr}\left(\frac{4\pi^2 mKe^2}{2\pi \,.\, n^2h^2}\right)$

$$v = \frac{Ke^2}{nh \cdot r} = \frac{Ke^2}{nh}\left(\frac{4\pi^2 mKe^2}{n^2h^2}\right)$$

$$v = \frac{4\pi^2 mK^2e^4}{n^3h^3}$$

which is the same as (i)

Hence for large values of n, classical frequency of revolution of electron in nth orbit is the same as the frequency of radiation emitted when hydrogen atom de-excites from level (n) to level (n - 1).

32. a. $q_d = -\frac{1}{3}e$ [charge on down quark]

$q_u = +\frac{2}{3}e$ [charge on up quark]

Potential energy for charges is given by $U = \frac{kq_1q_2}{r}$

$$k = \frac{1}{4\pi\epsilon_0}$$

$$U = \frac{kq_1q_2}{r} + \frac{kq_1q_3}{r} + \frac{kq_2q_3}{r}$$

$$\therefore U_n = \frac{1}{4\pi\varepsilon_0}\frac{\left(-q_d\right)\left(-q_d\right)}{r} + \frac{\left(-q_d\right)q_u}{4\pi\varepsilon_0} + \frac{q_u\left(-q_d\right)}{4\pi\varepsilon_0 r}$$

$$= \frac{q_d}{4\pi\varepsilon_0 r}\left[+q_d - q_u - q_u\right] \text{ [Talking sign of charge]}$$

$$= \frac{qd}{4\pi\varepsilon_0 r}\left[q_d - 2q_u\right] = \frac{9\times 10^9 \times \frac{1}{3}e}{10^{-15}}\left[\frac{1}{3}e - 2\cdot\frac{2}{3}e\right]$$

[nature sign of charges taken already]

$$= \frac{9\times 10^9 \times e}{3\times 10^{-15}}\cdot\frac{e}{3}[1-4] \text{ Joule}$$

$$= \frac{-3\times 9\times 10^9 \times 1.6\times 10^{-15}}{9\times 10^{-15}} \text{ Joule} = -7.68 \text{ x}10^{-14} \text{ J}$$

$$\frac{-7.68X10^{-14}}{1.6X10^{-19}} = -4.8 \times 10^{-14+19} \text{ e V} = 4.8 \times 10^5 \text{ e V} = -0.48 \times 10^6 \text{ e V}$$

U = -0.48 MeV

So, charges inside neutron [$1q_u$ and $2q_d$] are attracted by the energy of 0.48 MeV.

The energy released by a neutron when converted into energy is 939 MeV.

$$\therefore \text{ Required ratio } = \frac{1-0.481\text{MeV}}{939\text{MeV}} = 0.0005111 = 5.11 \times 10^{-4}$$

b. P.E. Of proton consists of 2 up and 1 down quark

$r = 10^{-15}$ m

$$q_d = -\frac{1}{3}e, q_u = \frac{2}{3}e$$

$$U_p = \frac{1}{4\pi\varepsilon_0}\frac{q_u \times q_u}{r} + \frac{q_u\left(-q_d\right)}{4\pi\varepsilon_0 r} + \frac{q_u\left(-q_d\right)}{4\pi\varepsilon_0 r}$$

$$= \frac{q_u}{4\pi\varepsilon_0 r}\left[q_u - q_d - q_d\right]$$

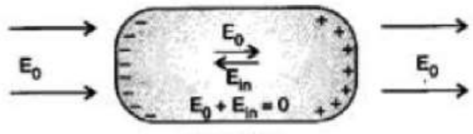
$$= \frac{q_u}{4\pi\varepsilon_0 r}\left[q_u - 2q_d\right] = \frac{9\times 10^9}{10^{-15}}\frac{2}{3}e\left[\frac{2}{3}e - 2\cdot\frac{1}{3}e\right] = 0$$ potential energy is zero for this case.

OR

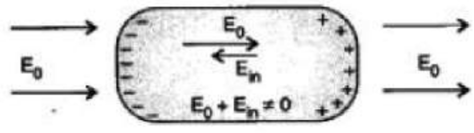
i. a. In the presence of electric field, the free charge carriers, in a conductor, move the charge distribution in the conductor re-adjusting itself so that the net electric field within the conductor becomes zero.

b. In a dielectric, the external electric field induces a net dipole moment, by stretching/reorienting the molecules. The electric field, due to this induced dipole moment, opposes, but does not exactly cancel, the external electric field.
Polarisation: Induced dipole moment, per unit volume, is called the polarization. For linear isotropic dielectrics having a susceptibility χ_c, we have

$P = \chi_c E$



Conductor



Dielectric

ii. a. Net force on the charge $\frac{Q}{2}$, placed at the centre of the shell is zero.

Force on charge 2Q kept at point A

$F = E \times 2Q$

$$= \frac{1\left(\frac{3Q}{2}\right)2Q}{4\pi\varepsilon_0 r^2} = \frac{3Q^2}{4\pi r^2 \varepsilon_0}$$

b. Electric flux through the shell,

$\phi = \frac{Q}{2\varepsilon_0}$ (because charge enclosed is Q/2)

33. a. The mirror formula is:

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

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

Now for a concave mirror, $f < 0$ and for an object on the left $u < 0$.

$2f < u < f$

or $\frac{1}{2f} > \frac{1}{u} > \frac{1}{f}$

or $-\frac{1}{2f} < -\frac{1}{u} < -\frac{1}{f}$

or $\frac{1}{f} - \frac{1}{2f} < \frac{1}{f} - \frac{1}{u} < \frac{1}{f} - \frac{1}{f}$

or $\frac{1}{2f} < \frac{1}{v} < 0$

This implies that $v < 0$ so that real image is formed on left. Also the above inequality implies that

$2f > v$

or $|2f| > |v|$ [$\because$ 2f and v are -ve]

i.e. real image is formed beyond 2f.

b. Now, for convex mirror, $f > 0$ and for an object of left, $u < 0$.

From mirror formula

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

$$\Rightarrow \frac{1}{v} > 0 \text{ or } v > 0$$

This shows that whatever be the value of u, a convex mirror form a virtual image on the right.

c. For convex mirror f > 0 and for an object on left u < 0, so from mirror formula,

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} \; [\because \text{ v is +ve, u is -ve}]$$

$$\Rightarrow \frac{1}{v} > \frac{1}{f} \text{ or } v < f \left(\therefore \; -\frac{1}{u} \text{ is a +ve quantity} \right)$$

This shows that the image is located between the pole and the focus of the mirror. Also from the mirror formula,

$$\frac{1}{v} > -\frac{1}{u}\left(\because \frac{1}{f} > 0 \right)$$

Multiply v to both sides,

$$\therefore \frac{v}{v} > -\frac{u}{v} \; [\because \text{ v is +ve}]$$

$$1 > m \; (\because \; u < 0)$$

Magnitude of magnification, $m = \dfrac{v}{|u|} < 1$

So the image is diminished in size.

d. From the mirror formula, for a concave mirror, f < 0 and for an object located between the pole and focus of a concave mirror,

f < u < 0

$$\therefore \frac{1}{f} > \frac{1}{u}$$

$$\text{or } \frac{1}{f} - \frac{1}{u} > 0$$

$$\text{or } \frac{1}{v} > 0 \text{ or } v > 0 \left(\therefore \frac{1}{v} = \frac{1}{f} - \frac{1}{u} \right)$$

i.e. a virtual image is formed on the right.

Also, $\dfrac{1}{v} < \dfrac{1}{|u|}$ or v > |u|

$\therefore |m| = \dfrac{v}{|u|} > 1$ i.e., Image is enlarged.

OR

Now here since light is going from one medium to another (air to glass), refraction is taking place. In case of refraction, we use sell's law according to which

$$\mu = \frac{\sin i}{\sin r}$$

where μ is the refractive index of the second medium (in which light is incident) with respect to first, i is the angle of incidence and r is the angle of refraction. All angles are measured with a normal drawn to the refracting surface at point of incidence.
Now the light is entered normally to the surface on face AB of the prism, so the angle of incidence will be

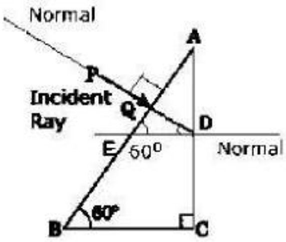
$i = 0^{\circ}$

In such a case, light goes undeviated from its path in the second medium as

$$\sin r = \frac{\sin i}{\mu} = \frac{0}{\mu} = 0$$

So angle of refraction, $r = 0^{\circ}$

So light beam goes straight and meet face AC of prism at D as shown in figure.



Now the normal is perpendicular to face AC of the prism, so ED will be parallel to base BC. Thus,

$\angle QED = \angle ABC = 60^{\circ}$ (alternate angles)

$\angle BQD = 90^{\circ}$ (as PQ is normal to AB)

Now in ΔEQD we can see,

$\angle QED + \angle EQD + \angle QDE = 180^{\circ}$ (Sum of all the angles in interior of a triangle is 180°)

$60^{\circ} + 90^{\circ} + \angle QDE = 180^{\circ}$

$\angle QDE = 180^{\circ} - 150^{\circ} = 30^{\circ}$

So angle of incidence on surface AC of prism is 30°

Now while refraction of a beam from denser medium to rarer medium (here glass to air), if angle of incidence of light beam is greater than critical angle, then the beam undergoes total Internal reflection and return back to same medium. Critical angle is given as

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

where i_c is the critical angle, μ is the refractive index of denser medium with respect to rarer medium.

Here refractive index of glass is $\mu = 1.5 = \frac{3}{2}$

So critical angle is

$i_c = \sin^{-1}\left(\frac{2}{3}\right) = 41.81^0$

which is greater than angle of incidence which is 30°, so beam will not reflect back and will emerge from face AC of the prism. To find the angle of refraction, we will use Snell's law,

$\sin r = \frac{\sin i}{\mu}$

Here angle of incidence, i = 30^0

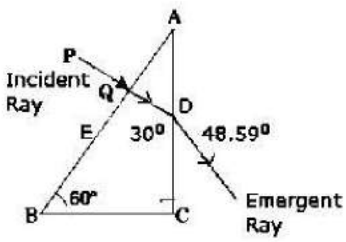
Refractive index of air w.r.t. glass is $\mu = \frac{1}{1.5} = \frac{2}{3}$

i.e. $\sin r = \frac{\sin 30°}{1.5} = \frac{\left(\frac{1}{2}\right)}{\left(\frac{2}{3}\right)} = \frac{3}{4}$

So angle of refraction is

$r = \sin^{-1}\frac{3}{4} = 48.59^o$

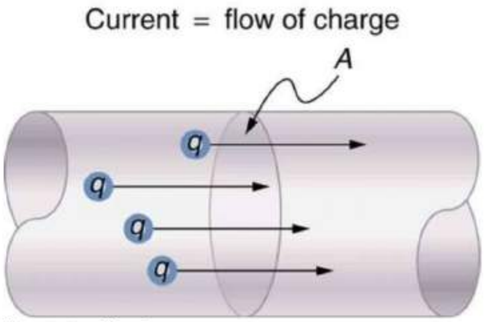
So light ray will emerge from face AC of the prism making an angle of 48.59° with the normal to AC at point of incidence as shown in the figure.



Section E

34. **Read the text carefully and answer the questions:**

The rate of flow of charge through any cross-section of a wire is called electric current flowing through it. Electric current (I) = $\frac{q}{t}$. Its SI unit is ampere (A). The conventional direction of electric current is the direction of motion of positive charge. The current is the same for all cross-sections of a conductor of the non-uniform cross-section. Resistance is a measure of the opposition to current flow in an electrical circuit.



(i) **(c)** diode
Explanation: diode

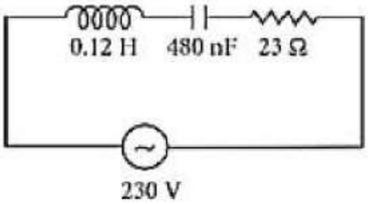
(ii) **(c)** scalar quantity
Explanation: scalar quantity

(iii) **(a)** zero
Explanation: zero

OR

(b) conventional current
Explanation: conventional current

35. **Read the text carefully and answer the questions:**
When the frequency of ac supply is such that the inductive reactance and capacitive reactance become equal, the impedance of the series LCR circuit is equal to the ohmic resistance in the circuit. Such a series LCR circuit is known as resonant series LCR circuit and the frequency of the ac supply is known as resonant frequency. Resonance phenomenon is exhibited by a circuit only if both L and C are present in the circuit. We cannot have resonance in a RL or RC circuit.
A series LCR circuit with L = 0.12H, C = 480 nF, R = 23 Ω is connected to a 230 V variable frequency supply.



(i) Here, L = 0.12 H, C = 480 nF = 480 $\times$ 10^{-9} F, R = 23Ω, V = 230 V
$V_0 = \sqrt{2} \times 230 = 325.22$ V

$$I_0 = \frac{V_0}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

At resonance, $\omega L - \dfrac{1}{\omega C} = 0$

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.12 \times 480 \times 10^9}} = 4166.67 \text{ rad s}^{-1}$$

$$v_R = \frac{4166.67}{2 \times 3.14} = 663.48 \text{ Hz}$$

(ii)

Current, $I_0 = \frac{V_0}{R} = \frac{325.22}{23} = 14.14$ A

(iii)

Maximum power, $P_{max} = \frac{1}{2}\left(I_0\right)^2 R$

$$= \frac{1}{2} \times (14.14)^2 \times 23 = 2299.3 \text{ W}$$

OR

Quality factor $Q = \frac{X_L}{R} = \frac{\omega_r L}{R} = \frac{4166.67 \times 0.12}{23} = 21.74$