Class: XII

SESSION : 2022-2023

SUBJECT: PHYSICS (THEORY)

SAMPLE QUESTION PAPER - 2

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. Which one of the following can produce a parallel beam of light from a point source of light? **[1]**

a) Concave mirror

b) Plane mirror

c) Concave lens

d) Convex mirror

2. The behavior of Ge as a semiconductor is due to the width of **[1]**

a) forbidden band being small and narrow

b) forbidden band being large and wide

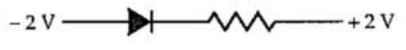
c) conduction band being small and narrow

d) conduction band being large

3. A forward biased diode is **[1]**

a) 

b) 

c) 

d) 

4. Assertion: A larger dry cell has higher emf.
Reason: The emf of a dry cell is proportional to its size. **[1]**

a) If Assertion is true statement but Reason is false

b) If both Assertion and Reason are false statements

c) If both Assertion & Reason are true but the reason is not the correct explanation of the assertion

d) If both Assertion & Reason are true and the reason is the correct explanation of the assertion

5. An observer is 1.8 m from an isotropic point source of light of power 250W. The rms value of the electric field at the position of the observer is nearly: **[1]**

a) 500 Vm^{-1}

b) 50 Vm^{-1}

c) 0.5 Vm^{-1}

d) 5 Vm^{-1}

6. A parallel plate capacitor with plate area A and separation between the plates d, is charged by a constant current I. Consider a plane surface of area A/2 parallel to the plates and drawn simultaneously between the plates. The displacement current through this area is: **[1]**

a) I

b) $\frac{I}{4}$

c) $\frac{I}{8}$

d) $\frac{I}{2}$

7. An electron of a stationary hydrogen atom passes from the fifth energy level to the ground level. The velocity that the atom acquired as a result of photon emission will be (m is the mass of the electron, R, Rydberg; constant and h Planck's constant) **[1]**

a) $\frac{25m}{24hR}$

b) $\frac{24hR}{25m}$

c) $\frac{25hR}{24m}$

d) $\frac{24m}{25hR}$

8. Two coils of self-inductance L_1 and L_2 are placed so close to each other that the effective flux in one coil is completely linked with the other; then the mutual inductance M between them is given by: **[1]**

a) $M = L_1 - L_2$

b) $M = L_1 + L_2$

c) $M = \sqrt{L_1 L_2}$

d) $M = \frac{L_1}{L_2}$

9. Three charges 1 μC, 2 μC, 3 μC are kept at vertices of an equilateral triangle of side 1 m. If they are brought nearer, so that they now form an equilateral triangle of side 0.5 m, then the work done is: **[1]**

a) 0.01 J

b) 11 J

c) 1.11 J

d) 0.11 J

10. The intensity ratio of the maxima and minima in an interference pattern produced by two coherent sources of light is 4:1. The intensities of the used light sources are in ratio: **[1]**

a) 9 : 1

b) 4 : 1

c) 1 : 4

d) 1 : 9

11. Diamond is very hard because **[1]**

a) high melting point

b) it has large cohesive energy

c) it is covalent solid

d) insoluble in all solvents

12. If two charges + q and + 4q are separated by a distance d and a third charge Q is placed on the line joining the above two charges such that all the charges are in equilibrium, the magnitude, sign and position of the charge Q is **[1]**

a) $-\frac{4q}{9}, \frac{d}{3}$

b) q, $\frac{2d}{3}$

c) -q, $\frac{d}{3}$

d) $-\frac{4q}{9}, \frac{2d}{3}$

13. 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

14. Electromagnetic radiation of frequency 3×10^{15} cycles per second falls on a photoelectric surface whose work function is 4.0 eV. Find out the maximum velocity of the photoelectrons emitted by the surface: **[1]**

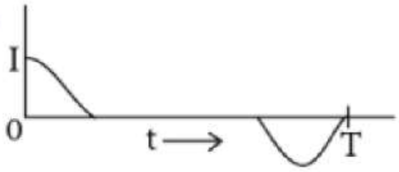
a) None of these

b) 13.4×10^{-19} m/s

c) 1.73×10^{6} m/s

d) 19.8×10^{-19} m/s

15. A metallic ring is dropped down, keeping its plane perpendicular to a constant and horizontal magnetic field. The ring enters the region of the magnetic field at t = 0 and completely emerges out at t = T sec. The current in the ring varies as: **[1]**

a)


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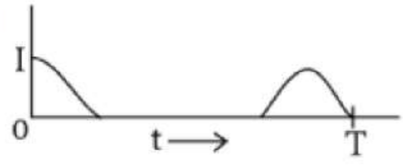
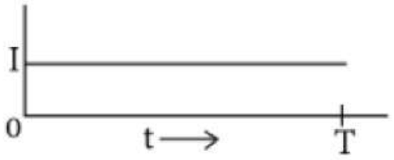
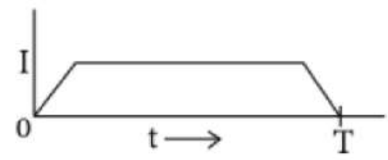


c)


d)


16. **Assertion (A):** The ratio of time taken for light emission from an atom to that for release of nuclear energy in fission is 1 : 100 **[1]**

Reason (R): Time taken of the light emission from an atom is of the order of 10^{-8} s.

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.

17. **Assertion (A):** The average thermal velocity of the electrons in a conductor is zero. **[1]**
Reason (R): The direction of motion of electrons is randomly oriented.

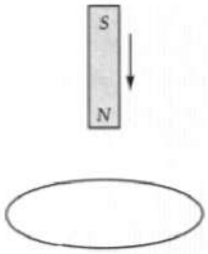
a) Both A and R are true and R is the correct explanation of A.

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):** The bar magnet falling vertically along the axis of the horizontal coil will be having an acceleration of less than g. **[1]**
Reason (R): Clockwise current is induced 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 but R is true.

Section B

19. How long can an electric lamp of 100W be kept glowing by fusion of 2.0 kg of deuterium? Take the fusion reaction as: ${}_{1}^{2}H+{}_{1}^{2}H\rightarrow{}_{2}^{3}He+n+3.2MeV$ **[2]**

20. Describe briefly the experimentally observed features in the phenomenon of photoelectric effect. **[2]**

21. Draw a circuit diagram for p-n junction diode in forward bias. Sketch the voltage-current graph for the same. **[2]**

22. The horizontal component of the earth's magnetic field at a certain place is 3.0×10^{-5} T and the direction of the field is from the geographic south to the geographic north. A very long straight conductor is carrying a steady current of 1A. What is the force per unit length on it when it is placed on a horizontal table and the direction of the current is **[2]**

a. east to west;

b. south to north?

OR

Sketch the magnetic lines of force when two identical magnets are placed a finite distance apart with their S-poles facing each other. Locate the neutral point.

23. Use the expression, $F=q(v\times B)$ to define the SI unit of magnetic field. **[2]**

OR

Which one of the two, an ammeter or a milliammeter, has a higher resistance and why?

24. A soap film of $\mu=\frac{4}{3}$ is illuminated by white light incident at an angle of 45^{o}. The transmitted light is examined by spectroscope and bright fringe is found to be for **[2]**

wavelength of 6000 $\overset{\circ}{A}$ Find the minimum thickness of the film.

25. Mention two advantages and disadvantages of semiconductor devices. **[2]**

Section C

26. Calculate the force acting between two magnets of length 15 cm each and pole strength 80 Am each when the separation between their north poles is 10 cm and that between south poles is 40 cm. **[3]**

27. **[3]**
   i. In what way is diffraction from each slit related to the interference pattern in a double slit experiment.
   ii. Two wavelengths of sodium light 590 nm and 596 nm are used, in turn to study the diffraction taking place at single slit of aperture $2 \times 10^{-4} m$. The distance between the slit and the screen is 1.5 m. Calculate the separation between the positions of the first maxima of the diffraction pattern obtained in the two cases.

OR

Derive the condition $2 \mu t = n\lambda$ for darkness when monochromatic light of wavelength λ is normally incident on a thin oil film of thickness t and refractive index μ.

28. Two-point charges $q_A = +3\mu C$ and $q_B = -3\mu C$ are located 20 cm apart in vacuum, **[3]**
   a. What is the electric field at the midpoint O of the line AB joining the two charges?
   b. If a negative test charge of magnitude $1{\cdot}5 \times 10^{-9}$ C is placed at this point, what is the force experienced by the test charge?

29. A circular coil of wire consisting of 100 turns each of radius 8.0 cm carries a current of 0.40 A. What is the magnitude of the magnetic field $\vec{B}$ at the centre of the coil? **[3]**

30. The oscillating magnetic field in a plane electromagnetic wave is given by $B_y = (8 \times 10^{-6}) \sin\left[2 \times 10^{11} t + 300\pi x\right] T$ **[3]**
   i. Calculate the wavelength of the electromagnetic wave.
   ii. Write down the expression for the oscillating electric field.

OR

   i. Why is the thin ozone layer on top of the stratosphere crucial for human survival? Identify to which part of the electromagnetic spectrum does this radiation belong and write one important application of the radiation.
   ii. Why are infrared waves referred to as heatwaves? How are they produced? What role do they play in maintaining the earth's warmth through the greenhouse effect?

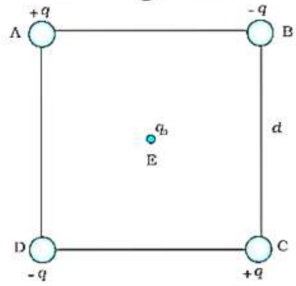
Section D

31. **[5]**
   i. Describe briefly the process of transferring the charge between the two plates of a parallel plate capacitor when connected to a battery. Derive an expression for the energy stored in a capacitor.
   ii. A parallel plate capacitor is charged by a battery to a potential difference V. It is disconnected from the battery and then connected to another uncharged capacitor

of the same capacitance. Calculate the ratio of the energy stored in the combination to the initial energy on the single capacitor.

OR

Four charges are arranged at the corners of a square ABCD of side d, as shown in fig.



a. Find the work required to put together this arrangement.

b. A charge q_0 is brought to the center E of the square, the four charges being held fixed at its corners. How much extra work is needed to do this?

32. Using Bohr's postulates, derive the expression for the frequency of radiation emitted when electron in hydrogen atom undergoes transition from higher energy state (quantum number n_i) to the lower state,(n_f). **[5]**

When electron in hydrogen atom jumps from energy state $n_i = 4$ to $n_f = 3, 2, 1$, identify the spectral series to which the emission lines belong.

OR

State any two postulates of Bohr's theory of hydrogen atom. What is the maximum possible number of spectral lines observed when the hydrogen atom is in its second excited state? Justify your answer.

Calculate the ratio of the maximum and minimum wavelengths of the radiations emitted in this process.

33. a. Derive the expression for the angle of deviation for a ray of light passing through an equilateral prism of refracting angle A. **[5]**

b. A prism is found to give a minimum deviation of 51°. The same prism gives a deviation of 62°48' for two values of the angles of incidence, namely, $46^\circ 6'$ and $82^\circ 42'$. Determine the refractive angle of the prism and the refractive index of its material.

OR

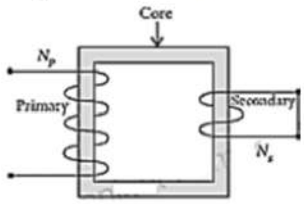
a. When a ray of light passes through a triangular glass prism, find out the relation for the total deviation, δ in terms of the angle of incidence, i and angle of emergence, e.

b. Plot a graph showing the variation of angle of deviation with the angle of incidence and obtain the condition for the angle of minimum deviation.

Section E

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

Step-down transformers are used to decrease or step-down voltages. These are used when voltages need to be lowered for use in homes and factories. A small town with a demand of 800 kW of electric power at 220 V is situated 15 km away from an electric plant generating power at 440 V. The resistance of the two wireline carrying power is 0.5 Ω per km. The town gets power from the line through a 4000-220 V step-down transformer at a sub-station in the town.



(i) What will be the value of the total resistance of the wires?

(ii) What will be the value of line power loss in the form of heat?

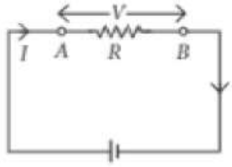
(iii) How much power must the plant supply, assuming there is negligible power loss due to leakage?

OR

What will be the voltage drop in the power line?

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

Whenever an electric current is passed through a conductor, it becomes hot after some time. The phenomenon of the production of heat in a resistor by the flow of an electric current through it is called heating effect of current or Joule heating. Thus, the electrical energy supplied by the source of emf is converted into heat. In purely resistive circuit, the energy expended by the source entirely appears as heat. But if the circuit has an active element like a motor, then a part of the energy supplied by the source goes to do useful work and the rest appears as heat. Joule's law of heating form the basis of various electrical appliances such as electric bulb, electric furnace, electric press etc.



(i) Which of the following is a correct statement?

a) Heat produced in a conductor is independent of the current flowing.

b) Heat produced in a conductor varies directly as the square of the current flowing.

c) Heat produced in a conductor varies inversely as the square of the current flowing.

d) Heat produced in a conductor varies inversely as the current flowing.

(ii) If the coil of a heater is cut to half, what would happen to heat produced?

a) Remains same

b) Halved

c) Remains same

d) Doubled

(iii) A 25 W and 100W are joined in series and connected to the mains. Which bulbs will glow brighter?

a) none will glow brighter

b) both bulbs will glow brighter

c) 100 W

d) 25 W

OR

A rigid container with thermally insulated wall contains a coil of resistance 100 Ω, carrying current 1A. Change in its internal energy after 5 min will be

a) 20 kJ

b) 0 kJ

c) 10 kJ

d) 30 kJ

SOLUTIONS

Section A

1. **(a)** Concave mirror
   Explanation: Concave mirror
2. **(a)** forbidden band being small and narrow
   Explanation: Ge acts as semiconductor as width of the forbidden band is small and it is narrow.
3. **(b)** 

   Explanation: The p-side is at higher potential (0 V) and n-side is at lower potential (-2 V). So the diode is forward biased.
4. **(b)** If both Assertion and Reason are false statements
   Explanation: If both Assertion and Reason are false statements.
5. **(b)** 50 Vm^{-1}
   Explanation: $I = \frac{P}{4\pi r^2}$
   Also $I = c\varepsilon_0 E^2$
   Hence, $\frac{P}{4\pi r^2} = c\varepsilon_0 E^2$
   or $E = \sqrt{\frac{P}{4\pi r^2 c\varepsilon_0}}$
   or $E = \sqrt{\frac{250}{4(3.14)(1.8)^2(3\times 10^8)(8.85\times 19^{-12})}}$
   $= 48.1\ Vm^{-1} = 50\ Vm^{-1}$
6. **(d)** $\frac{I}{2}$
   Explanation: Charge on capacitor plates at time t is q = It
   Electric field between the plates at this instant,
   $E = \frac{q}{A\varepsilon_0} = \frac{It}{A\varepsilon_0}$
   Electric flux through the given area,
   $\phi_E = \left(\frac{A}{2}\right)E = \frac{It}{2\varepsilon_0}$
   Therefore, displacement current,
   $I_d = \varepsilon_0 \frac{d\Phi_E}{dt} = \varepsilon_0 \frac{d}{dt}\left(\frac{It}{2\varepsilon_0}\right) = \frac{I}{2}$
7. **(b)** $\frac{24hR}{25m}$
   Explanation: $\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right) = R\left(\frac{1}{1^2} - \frac{1}{5^2}\right) = \frac{24}{25}R$
   $p = \frac{h}{\lambda}$
   $\therefore mv = h \times \frac{24}{25}R \Rightarrow v = \frac{24hR}{25m}$
8. **(c)** $M = \sqrt{L_1 L_2}$
   Explanation: For the first solenoid:
   $L_1 = \frac{\mu_0 N_1^2 A}{l}$ ...(i)
   For the second solenoid:
   $L_2 = \frac{\mu_0 N_2^2 A}{l}$ ...(ii)
   However, mutual inductance M is given by:
   $M = \frac{\mu_0 N_1 N_2 A}{l}$ ...(iii)

Multiplying equation (i) with equation (ii), we get;

$L_1L_2 = \frac{\mu_0^2 N_1^2 N_2^2 A^2}{l^2}$ ...(iv)

Squaring equation (iii), we get;

$M^2 = \frac{\mu_0^2 N_1^2 N_2^2 A^2}{l^2}$ ...(v)

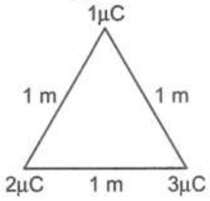
Combining equation (iv) and (v), we get;

$M^2 = L_1L_2$ or $M = \sqrt{L_1 L_2}$

9. **(a)** 0.01 J

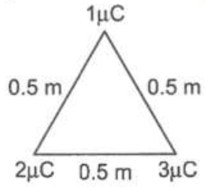
Explanation:

When charges are placed at vertices of an equilateral triangle of side 1 m, then potential energy of the combination is,



$U_1 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{1 \times 2 \times 10^{-12}}{(1)} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{2 \times 3 \times 10^{-12}}{(1)} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{3 \times 1 \times 10^{-12}}{(1)} = 11 \times \frac{1}{4\pi\varepsilon_0} \times 10^{-12} J$

When charges are placed at the vertices of an equilateral triangle of side 0.5 m, then the potential energy of the combination is,



$U_2 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{1 \times 2 \times 10^{-12}}{(0.5)} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{2 \times 3 \times 10^{-12}}{(0.5)} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{3 \times 1 \times 10^{-12}}{(0.5)} = 22 \times \frac{1}{4\pi\varepsilon_0} \times 10^{-12} J$

Work done = $\Delta U = U_2 - U_1$

$= 22 \times \frac{1}{4\pi\varepsilon_0} \times 10^{-12} J - 11 \times \frac{1}{4\pi\varepsilon_0} \times 10^{-12} J$

$= 11 \times \frac{1}{4\pi\varepsilon_0} \times 10^{-12}$

$= 11 \times 9 \times 10^9 \times 10^{-12}$

$= 99 \times 10^{-3} = 0.099$ J = 0.10 J

10. **(a)** 9 : 1

Explanation: As we know that,

$\frac{I_{max}}{I_{min}} = \frac{(a+b)^2}{(a-b)^2}$

$\therefore \frac{4}{1} = \frac{(a+b)^2}{(a-b)^2}$

or $\frac{2}{1} = \frac{a+b}{a-b}$

or a = 3b

$\Rightarrow \frac{a}{b} = 3$

$\therefore \frac{I_1}{I_2} = \frac{a^2}{b^2} = \frac{9}{1}$

11. **(b)** it has large cohesive energy

Explanation: Diamond is very hard because it has a large cohesive energy.

12. **(a)** $-\frac{4q}{9}, \frac{d}{3}$

Explanation: The position of the charge is given by:

$x = \frac{d}{\sqrt{q_2/q_1} + 1} = \frac{d}{2+1} = \frac{d}{3}$

Thus, the charge Q must be placed at a distance of $\frac{d}{3}$ from q. For the force on every charge to be zero, Q must be negative in sign. For force on the charge 4q to be zero,

$F = \frac{1}{4\pi\varepsilon_0}\frac{q \times 4q}{d^2} - \frac{1}{4\pi\varepsilon_0}\frac{Q4q}{(\frac{2d}{3})^2} = 0$

$Q = (\frac{4q}{9})$

Thus, a charge of $(\frac{4q}{9})$ must be placed at a distance of $(\frac{d}{3})$ from the charge q, for the system to be in equilibrium.

13. **(b)** 5.8

Explanation: 5.8

14. **(c)** 1.73×10^6 m/s

Explanation: As we know that,

$hv = h\upsilon_0 + E_k$

$6.6 \times 10^{-34} \times 3 \times 10^{15} = 4 \times 1.6 \times 10^{-19} + E_k$

$19.8 \times 10^{-19} - 6.4 \times 10^{-19} = E_k$

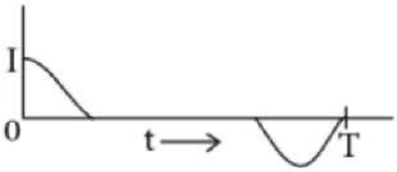
$E_k = 13.4 \times 10^{-19}$ J

$\Rightarrow \frac{1}{2}mv_{\max}^2 = 13.4 \times 10^{-19}$

$v_{max} = \sqrt{\frac{2\times13.4\times10^{-19}}{m}}$

$= \sqrt{\frac{2\times13.4\times10^{-19}}{9\times10^{-31}}}$

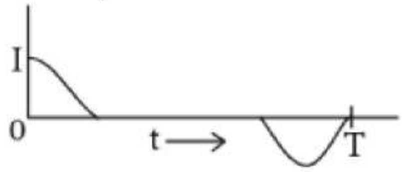
$= 1.73 \times 10^6$ m/s

15. **(a)** 

Explanation:

i. When the ring is just entering the magnetic field, emf is induced and the current flows in one direction.
ii. When the whole ring is surrounding the flux inside, there is no change in the flux. Induced emf = 0, current is zero.
iii. When the ring just goes out of the region of flux, a pulse of current is produced which is opposite to that of (i) given above.

Hence,



is the only figure that describes this.

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

Explanation: Time taken for the light emission from an atom $\approx 10^{-8}$ s

Time taken for release of energy in fission $\approx 10^{-6}$

Required ratio $= \frac{10^{-8}}{10^{-6}} = \frac{1}{100} = 1 : 100$

Both assertion and reason are true.

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

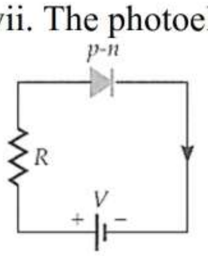
Explanation: Both A and R are true and R is the correct explanation of A.

18. **(c)** A is true but R is false.
Explanation: Due to the change of flux, the anticlockwise current is induced in the coil which opposes the motion of the magnet and so a < g.

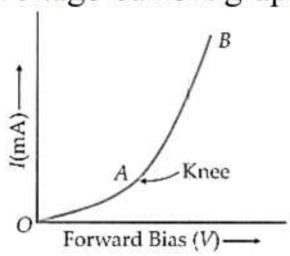
Section B

19. When two nuclei of deuterium fuse together,
Energy released = 3.2 MeV
Number of deuterium atoms in 2 kg
$= \frac{6.023 \times 10^{23}}{2} \times 2000 = 6.023 \times 10^{26}$
When 6.023×10^{26} nuclei of deuterium fuse together, energy released
$= \frac{3.2}{2} \times 6.023 \times 10^{26} MeV$
$= \frac{3.2}{2} \times 6.023 \times 10^{26} \times 1.6 \times 10^{-13} J$
$= 1.54 \times 10^{14} J$ or Ws
Power of electric lamp = 100 W
If the lamp glows for time t, then the electrical energy consumed by the lamp is 100 t.
$\therefore 100t = 1.54 \times 10^{14}$ or $t = 1.54 \times 10^{12} s$
$= \frac{1.54 \times 10^{12}}{3.154 \times 10^{7}} years$
$= 4.88 \times 10^{4} years$

20. i. For every metal there is a certain minimum frequency (threshold frequency) below which no photoelectrons are emitted, however high is the intensity of incident radiation.
ii. Photoelectric current is directly proportional to the intensity of incident radiation.
iii. The photoelectric current becomes zero at a certain value of negative potential (stopping potential) applied at the anode.
iv. The value of stopping potential increases with the increase in the frequency of incident radiation.
v. The maximum K.E. of photoelectrons is directly proportional to the frequency of incident radiation.
vi. The maximum K.E. of photoelectron is independent of the incident radiation.
vii. The photoelectric emission is an instantaneous process.

21. 

The figure shows a forward-biased p-n junction diode in which p-side is connected to the +ve terminal and n-side is connected to the -ve terminal of the battery and shows its voltage-current graph.



22. $\mathbf{F} = I\mathbf{L} \times \mathbf{B}$
$F = IBL\sin\theta$
The force per unit length is
$f = \frac{F}{L} = I B \sin\theta$
a. When the current is flowing from east to west,
$\theta = 90°$

Hence, sin 90° = 1

thus the force per unit length is given by f = I B

$= 1 \times 3 \times 10^{-5} = 3 \times 10^{-5}$ N m^{-1}

This is larger than the value 2×10^{-7} Nm^{-1} quoted in the definition of the ampere. Hence it is important to eliminate the effect of the earth's magnetic field and other stray fields while standardizing the ampere. The direction of the force is downwards. This direction may be obtained by the directional property of cross product of vectors.

b. When the current is flowing from south to north,

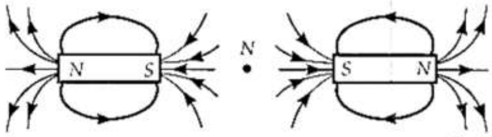
$\theta = 0^{0}$ and $\sin 0^{0} = 0$

f = 0

Hence there is no force on the conductor.

OR

The magnetic lines of force of two magnets placed with their S-poles facing each other are shown in the figure. Here N is the neutral point.



23. Lorentz magnetic force, $F = q(v \times B) \Rightarrow F = qvB\sin\theta$

where, θ is the angle between v and B.

$\Rightarrow \quad B = F/qv\sin\theta$

If q = 1 C, v = 1 ms^{-1}, $\theta = 90^\circ$

Thus the magnetic field is,

$B = \frac{1N}{(1C)(1ms^{-1})\ \sin\ 90^o} = 1\ Ns/Cm\ = 1T$

So, SI unit of magnetic field is Tesla (T).

Thus, the magnitude of magnetic field at a point is said to be one Tesla, if a charge of one Coulomb moving at a right angle to a magnetic field B with a velocity of 1ms^{-1} experiences a force of one Newton.

OR

Shunt resistance, $R_8 = \frac{I_8 \times R_8}{I - I_g}$

Clearly, the shunt needed to convert galvanometer into a milliammeter has a larger value than that required to convert into an ammeter. As the shunt resistance is connected in parallei with the galvanometer, so the milliammeter will have a higher resistance than the ammeter.

24. Here $\mu = \frac{4}{3}$, i = 45^{0}, λ = 6000 $\mathring{A}$ = 6×10^{-7}m

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

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

cos r = $\sqrt{1 - \sin^2 r} = \sqrt{1 - \frac{9}{32}} = \sqrt{\frac{23}{32}}$ = 0.8478

For a bright fringe in transmitted light,

2 μt cos r = $n\lambda$

For minimum thickness, n = 1

$\therefore$ 2 μt cos r = λ

or t = $\frac{\lambda}{2\mu\cos r} = \frac{6\times10^{-7}}{2\times\frac{4}{3}\times0.8478}$ = 2.6×10^{-7}m

25. **Advantages:**

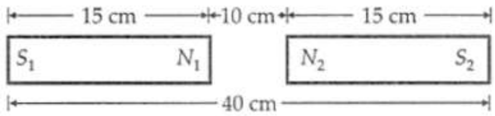
- As semiconductor devices have no filaments, hence no power is needed to heat them to cause the emission of electrons. Since no heating is required, semiconductor devices are set into operation as soon as the circuit is switched on.
- During operation, semiconductor devices do not produce any humming noise. Semiconductor devices require low voltages for their operation as compared to vacuum tubes.

Disadvantages:

- Ordinary semiconductor devices cannot handle as much power as ordinary vacuum tubes can do. In high frequency range, they have poor response.
- The semiconductor devices are temperature-sensitive. The maximum temperature, the semiconductor devices can withstand, is very low

Section C

26. The situation is shown in the figure. Here $q_{m_1} = q_{m_2} = 80$ Am



Force of repulsion between poles N_1 and N_2 is

$F_1 = \frac{\mu_0}{4\pi} \cdot \frac{q_{m_1} q_{m_2}}{r^2} = \frac{10^{-7} \times 80 \times 80}{(0.10)^2} = 0.064$ N

Force of repulsion between poles S_1 and S_2 is

$F_2 = \frac{10^{-7} \times 80 \times 80}{(0.40)^2} = 0.004$ N

Force of attraction between N_1 and S_2 is

$F_3 = \frac{10^{-7} \times 80 \times 80}{(0.25)^2} = 0.010$ N

Force of attraction between N_2 and S_1 is

$F_4 = F_3 = 0.010$ N

Resultant force between the two magnets is

$F = F_1 + F_2 - F_3 - F_4$

$= 0.064 + 0.004 - 0.010 - 0.010$

$= 0.048$ N (repulsive)

27. i. Relation between diffraction from each slit to the interference pattern in a double slit experiment:

(a) If slit width in interference pattern is reduced to the size of wavelength of light used the diffraction will also take place along with interference.

(b) The diffraction pattern is itself due to the interference of wavelength belonging to same.

ii. Given that, wavelength of the light beam,

$\lambda_1 = 590\text{nm} = 5.9 \times 10^{-7}\text{m}$

Wavelength of another light beam, $\lambda_2 = 596\text{nm} = 5.96 \times 10^{-7}\text{m}$

Distance of the slit from the screen, D = 1.5 m

Aperture of the slit = $d = 2 \times 10^{-4}\text{m}$

For the first secondary maxima,

o $x_1 = \frac{3\lambda_1 D}{2d}$ and for the second wavelength, $x_2 = \frac{3\lambda_2 D}{2d}$

$\therefore$ Spacing between the positions of first secondary maxima of two sodium lines

$x_2 - x_1 = \frac{3D}{2d}(\lambda_2 - \lambda_1)$

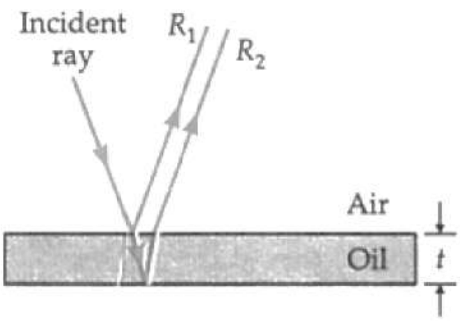
Substituting the value of all elements

$= \frac{3\times1.5}{2\times2\times10^{-4}}(5.96 - 5.9)\times10^{-7}$

$= 6.75\times10^{-5}$m

OR

Fig. shows the rays reflected from the upper and lower surfaces of a thin film of thickness t for almost normal incidence.



Clearly, the path difference between the reflected rays R_1 and R_2

$\approx$ 2 t in oil = 2 μt

But ray R_1 suffers an extra path difference of $\frac{\lambda}{2}$ due to its reflection from the upper denser surface of oil, so the net path difference between R_1 and R_2 is

$p = 2\mu t + \frac{\lambda}{2}$

For a dark fringe,

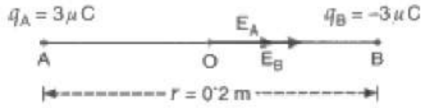
$p = 2\mu t + \frac{\lambda}{2} = (2n+1)\frac{\lambda}{2}$ or $2\mu t = n\lambda$

This is the required condition for a dark fringe.

28. Here, $q_A = 3\mu C = 3\times10^{-6}$ C ;

$q_B = -3\mu C = -3\times10^{-6}$ C and r = 20 cm = 0·2 m

Let O be the mid-point of the line AB as shown in Fig.



Then, $OA = OB = \frac{r}{2} = \frac{0\cdot2}{2} = 0\cdot1$ m

a. The electric field at point O due to q_A

$E_A = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_A}{(OA)^2} = 9\times10^9\times\frac{3\times10^{-6}}{(0\cdot1)^2}$

$= 2\cdot7\times10^6$ NC^{-1} (along OB)

The electric field at point O due to q_B,

$E_B = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_A}{(OB)^2} = 9\times10^9\times\frac{3\times10^{-6}}{(0-1)^2}$

$= 2\cdot7\times10^6$ NC^{-1} (along OB)

Therefore, net electric field at point O due to the charges q_A and q_B,

$E = E_A + E_B = 2\cdot7\times10^6 + 2\cdot7\times10^6$

$= 5\cdot4\times10^6$ N C^{-1} (along OB)

b. Force on a negative charge of magnitude $1\cdot5\times10^{-9}$ C placed at point O,

$F = qE = 1\cdot5\times10^{-9}\times5\cdot4\times10^6$

$= 8\cdot1\times10^{-3}$ N (along OA)

The force on the negative charge acts in a direction opposite to that of the electric field.

29. Given N = 100, r = 8 cm = 0.08 m, I = 0.40 A

$\therefore \quad B=\frac{\mu_0 NI}{2r}=\frac{4\pi\times10^{-7}\times100\times0.40}{2\times0.08}$

$=\pi\times10^{-4}=3.1\times10^{-4}$ T

30. Given equation is:

$B_y=(8\times10^{-6})\sin[2\times10^{11}t+300\pi x]T$

i. Comparing the given equation with the equation of magnetic field varying sinusoidally with x and t,

$B_y=B_0\sin\left(\frac{2\pi x}{\lambda}+\frac{2\pi t}{T}\right)$, we get

$\frac{2\pi}{\lambda}=300\pi$

Thus, the wavelength of the electromagnetic wave is,

$\lambda=\frac{2}{300}=0.0067m$

ii. $B_0=8\times10^{-6}T$

$E_0=cB_0=3\times10^8\times8\times10^{-6}$

$=24\times10^2=2400Vm^{-1}$

$\therefore$ The required expression for the oscillating electric field is,

$E_z=E_0\sin\left(\frac{2\pi x}{\lambda}+\frac{2\pi t}{T}\right)$

$=2400\sin(300\pi x+2\times10^{11}t)V/m$

OR

i. It absorbs ultraviolet radiation from the sun and prevents them from reaching on the earth's surface causing damage to life. In the electromagnetic spectrum, ultraviolet radiations occur in between visible light and x-rays.

Identification: Ultraviolet radiations

application: Ultraviolet radiations are used to destroy the harmful bacteria and for sterilizing the surgical instruments.

ii. Water molecules present in most materials readily absorb infrared waves. Hence, their thermal motion increases, therefore, they heat their surroundings.

They are produced by hot bodies and molecules. Incoming visible light is absorbed by the earth's surface and radiated as infrared radiations. These radiations are trapped by greenhouse gases.

Section D

31. i. Consider a parallel plate capacitor which is connected across a battery. The electrons are transferred from the negative terminal of the battery to the metallic plate connected to the negative terminal and acquires a negative charge. Similarly, the electrons move from the second plate to the positive terminal of the battery and acquire a positive charge. This process continues until the potential difference between the two plates becomes equal to the potential difference between the terminals of the battery. Thus, the charge is developed on the capacitor.

Let ‘dW’ be the work done by the battery in increasing the charge on the capacitor is given by, having the charge q and potential V is:

dW = V dq

where V = $\frac{q}{C}$

$\therefore$ dW = $\frac{q}{C}$dq

Total work done in charging up the capacitor is given by,

W = $\int$ dW = $\int_0^Q \frac{q}{c}$dq

$\therefore$ W = $\frac{Q^2}{2C}$

Hence total energy stored in the plates of the capacitor is given by, W = $\frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$

ii. Charge on the plates of the capacitor is given by q = CV
When uncharged capacitor of same capacitance is connected to the charged capacitor, sharing of charges takes place between the two capacitors till both the capacitors acquire same potential $\frac{V}{2}$
Energy stored in the combination of capacitors is given by,
$U_2 = \frac{1}{2}C(\frac{V}{2})^2 + \frac{1}{2}C(\frac{V}{2})^2 = \frac{CV^2}{4}$
Energy stored by a single capacitor before connecting is given by, $U_1 = \frac{1}{2}CV^2$
Ratio of energy stored in the combination to that in the single capacitor is given by,
$\frac{U_2}{U_1} = \frac{CV^2/4}{CV^2/2} = 1 : 2$, Hence these are required results.

OR

a. Since the work done depends on the final arrangement of the charges, and not on how they are put together, we calculate work needed for one way of putting the charges at A, B, C and D. Suppose, first the charge +q is brought to A, and then the charges –q, +q, and -q are brought to B, C, and D, respectively. The total work needed can be calculated in steps:
   i. Work needed to bring charge +q to A when no charge is present elsewhere: this is zero.
   ii. Work needed to bring –q to B when +q is at A. This is given by (charge at B) × (electrostatic potential at B due to charge +q at A)
   $= -q \times \left(\frac{q}{4\pi\varepsilon_0 d}\right) = -\frac{q^2}{4\pi\varepsilon_0 d}$
   iii. Work needed to bring charge +q to C when +q is at A and -q is at B. This is given by (charge at C) × (potential at C due to charges at A and B
   $= +q\left(\frac{+q}{4\pi\varepsilon_0 d\sqrt{2}} + \frac{-q}{4\pi\varepsilon_0 d}\right)$
   $= \frac{-q^2}{4\pi\varepsilon_0 d}\left(1 - \frac{1}{\sqrt{2}}\right)$
   iv. Work needed to bring -q to D when +q at A, -q at B, and +q at C. This is given by (charge at D) × (potential at D due to charges at A, B, and C)
   $= -q\left(\frac{+q}{4\pi\varepsilon_0 d} + \frac{-q}{4\pi\varepsilon_0 d\sqrt{2}} + \frac{q}{4\pi\varepsilon_0 d}\right)$
   $= \frac{-q^2}{4\pi\varepsilon_0 d}\left(2 - \frac{1}{\sqrt{2}}\right)$
   Add the work done in steps (i), (ii), (iii), and (iv). The total work required is
   $= \frac{-q^2}{4\pi\varepsilon_0 d}\left\{(0) + (1) + \left(1 - \frac{1}{\sqrt{2}}\right) + \left(2 - \frac{1}{\sqrt{2}}\right)\right\}$
   $= \frac{-q^2}{4\pi\varepsilon_0 d}(4 - \sqrt{2})$
   The work done depends only on the arrangement of the charges, and not how they are assembled. By definition, this is the total electrostatic energy of the charges.

b. The extra work necessary to bring a charge q_0 to point E when the four charges are at A, B, C, and D is q_0 × (electrostatic potential at E due to the charges at A, B, C, and D).
The electrostatic potential at E is clearly zero since potential due to A and C is cancelled by that due to B and D. Hence, no work is required to bring any charge to point E. Also, it can be said that the work done over a closed surface is zero. (charges are opposite in corners so work done during one cycle cancel out by another cycle) hence work done is zero.

32. Suppose m be the mass of an electron and v be its speed in nth orbit of radius r. The centripetal force for revolution is produced by electrostatic attraction between electron and nucleus.

$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(e)}{r^2}$

or, $mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r}$ .....(i)

So, Kinetic energy [K] = $\frac{1}{2}mv^2$

K = $\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2r}$

Potential energy = $\frac{1}{4\pi\varepsilon_0}\frac{(Ze)(-e)}{r} = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r}$

Total energy,

E = KE + PE = $\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2r} + \left(-\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r}\right)$

E = $-\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2r}$

So, $E_n = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2r_n}$ ......(ii)

Again from Bohr's postulate for quantization of angular momentum,

velocity, v = $\frac{nh}{2\pi mr}$

Substituting this value of v in equation (i), we get

$m(\frac{nh}{2\pi mr})^2 = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r}$

or, r = $\frac{\varepsilon_0 h^2 n^2}{\pi m Ze^2}$ or $r_n = \frac{\varepsilon_0 h^2 n^2}{\pi m Ze^2}$ ....(iii)

Substituting this value of r_n in equation (ii), we get

$E_n = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2\left(\frac{\varepsilon_0 h^2 n^2}{\pi m Ze^2}\right)} = -\frac{mZ^2e^4}{8\varepsilon_0^2 h^2 n^2}$

or, $E_n = -\frac{Z^2Rhc}{n^2}$, where R = $\frac{me^4}{8\varepsilon_0^2 ch^3}$

where R is called Rydberg constant.

For hydrogen atom, Z = 1, so

$E_n = \frac{-Rch}{n^2}$

If n_i and n_f are the quantum numbers of initial and final states and E_i & E_f are energies of electron in H-atom in an initial and final state, we have

$E_i = \frac{-Rhc}{n_i^2}$ and $E_f = \frac{-Rhc}{n_f^2}$

If ν is the frequency of emitted radiation, we get

$\nu = \frac{E_i - E_f}{h}$

$\nu = \frac{-Rch}{n_i^2}$ - $\left(\frac{-Rch}{n_f^2}\right)$ = Rch$\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right] = \frac{me^4}{8\varepsilon_0^2 h^2}\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$

This is the required expression.

If electron jumps from n_i = 4 to n_f = 3, 2, 1, radiation belongs to Paschen, Balmer and Lyman series.

OR

Two postulates of Bohr's theory of hydrogen atom are

i. Every atom consists of small and massive central core, known as nucleus around which electron revolve. The necessary centripetal force is provided by electrostatic force of attraction between positively charged nucleus and negatively charged electrons.
ii. The electrons revolved around the nucleus in only those circular orbits which satisfy the quantum condition, that the angular momentum of electrons is equal to integral multiple

of $\frac{h}{2\pi}$ where, h is Planck's constant. Thus, for any stationary orbit,

$mvr = \frac{nh}{2\pi}$

where, n = 1, 2, 3,...

In second excited state i.e., n = 3, two spectral lines namely Lyman series and Balmer series can be obtained corresponding to transition of electron from n = 3 to n = 1 and n = 3 to n = 2, respectively.

For Lyman series, n = 3 to n = 1, for minimum wavelength

$\frac{1}{\lambda_{\min}} = R\left[\frac{1}{1^2} - \frac{1}{3^2}\right] = \frac{8R}{9}$ ....(i)

For Balmer series (maximum wavelength),

$\frac{1}{\lambda_{\max}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$

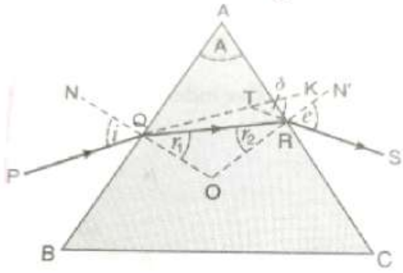
$= \left(\frac{9-4}{36}\right) R = \frac{5R}{36}$ ....(ii)

On dividing Eq. (i) by Eq. (ii), we get

$\frac{\lambda_{\max}}{\lambda_{\min}} = \frac{8R/9}{5R/36} = \frac{8R}{9} \times \frac{36}{5R} = \frac{32}{5}$

$\Rightarrow \lambda_{\max} : \lambda_{\min} = 32 : 5$

33. a. Consider that a ray of light PQ is incident on the refracting face AB of the prism at point Q as shown in figure. When light passes through a prism refraction takes place at both the surfaces of the prism.



In figure, i and e are the angle of incidence and emergence respectively. Angles r_1 and r_2 are angle of refraction at both the surfaces of the prism. A is the angle of prism and δ be the angle of deviation.

The rays PQ, QR and RS are called incident ray, refracted ray and emergent ray respectively. Produce SR backwards, so as to meet the ray PQ at point T, when produced. Then, KTS = δ is called the angle of deviation.

Since $\angle$ TQO = i and $\angle$RQO = r_1, we have

$\angle TQR = i - r_1$

Also, $\angle$TRO = e and $\angle$QRO = r_2. Therefore,

$\angle TRQ = e - r_2$

Now, in triangle TQR, the side QT has been produced outwards. Therefore,

$\delta = \angle TQR + \angle TRQ = (i - r_1) + (e - r_2)$

or $\delta = (i + e) - (r_1 + r_2)$ ....(i)

In triangle QRO, the sum of the angles is 180^o. Therefore,

$r_1 + r_2 + \angle QOR = 180^o$ ...(ii)

In quadrilateral AQOR, each of the angles AQO and ARO is 90^o. Since the sum of the four angles of a quadrilateral is four angles, the sum of the remaining two angles should be 180^o i.e.

$A + \angle QOR = 180^o$ ....(iii)

From the equation (ii) and (iii), we have

$r_1 + r_2 = A$ ...(iv)

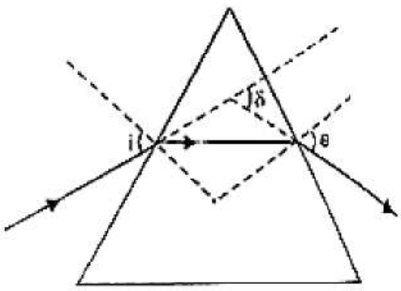
In the equation (i), substituting for $(r_1 + r_2)$ we have

$\delta = (i + e) - A$

or $A + \delta = i + e$

Hence, $\delta = (i + e) - A$

b. The incident ray is deviated through $\delta = 62^\circ 48'$ when angle $i = 40^\circ 6'$. From the principle of reversibility of light, it is clear from the figure that the emergent ray (for which angle $e = 82^\circ 42'$) is also deviated through the same angle δ. Now,



$\delta = (i + e) - A$

or $A = (i + e) - \delta$

$= 40^\circ 6' + 82^\circ 42' - 62^\circ 48'$

or $A = 60^\circ$

which is the refractive angle of the prism.

For minimum deviation, $i = e$

Hence, $\delta_{\min} = 2i - A$

or $i = \left(\frac{\delta_{\min} + A}{2}\right)$

$= \frac{(51^\circ + 60^\circ)}{2} = 55^\circ 30'$

which is the angle of incidence at minimum deviation? The refractive index of the material of the prism is given by

$\mu = \frac{\sin \frac{(\delta_{\min} + A)}{2}}{\sin \frac{A}{2}}$

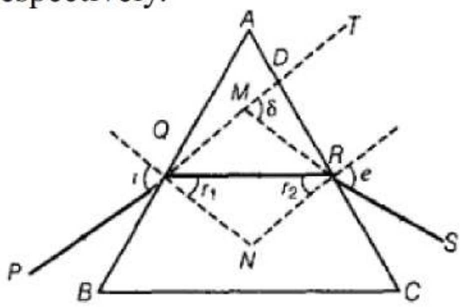
or $\mu = \frac{\sin\left(\frac{51^\circ + 60^\circ}{2}\right)}{\sin \frac{60^\circ}{2}}$

or $\mu = 1.648$

OR

a. Let PQ and RS are incident and emergent rays. Let incident ray get deviated by δ by the prism. i.e. $\angle TMS = \delta$

Let δ_1 and δ_2 are deviation produced at refractions taking place at AB and AC, respectively.



$\therefore \quad \delta = \delta_1 + \delta_2 = (i - r_1) + (e - r_2)$

$= (i + e) - (r_1 + r_2)$ ....(i)

But in $\triangle QNR$,

$\angle QNR + \angle RQN + \angle QRN = 180^\circ$

or $\angle QNR = 180^\circ - (r_1 + r_2)$ ....(ii)

In □QARN, ∠AQN and ∠ARN are right angles.

So, $\angle QNR = 180^\circ - A$ ......(iii)

where, A is angle of prism.

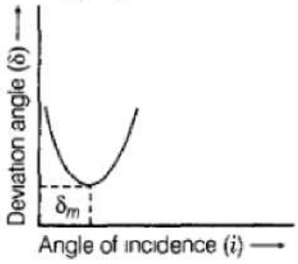
From Eqs. (ii) and (iii), we have

$A = r_1 + r_2$ ....(iv)

From Eqs. (i) and (iv), we have

$\delta = (i + e) - A$

b. $i - \delta$ graph is shown in the figure below:



The conditions for the angle of minimum deviation are given as below:

i. Angle of incidence (i) and angle of emergence (e) are equal, i.e. $\angle i = \angle e$

ii. In equilateral prism, the refracted ray is parallel to base of prism.

iii. The incident and emergent rays are bent on same angle from refracting surfaces of the prism, i.e. $\angle r_1 = \angle r_2$

For minimum deviation position,

Putting $r = r_1 = r_2$ in Eq. (iv), we get,

$2r = A \Rightarrow r = \frac{A}{2}$

Also, for minimum deviation, i = e,

Thus, $\delta_m = 2i - A$

$i = \frac{A + \delta_m}{2}$

∴ Refractive index of material of prism is

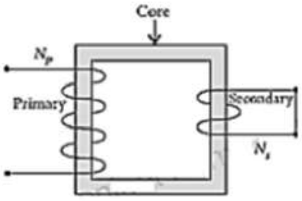
$\mu = \frac{\sin i}{\sin r}$

$\Rightarrow \quad \mu = \frac{\sin\left(\frac{A + \delta m}{2}\right)}{\sin \frac{A}{2}}$

Section E

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

Step-down transformers are used to decrease or step-down voltages. These are used when voltages need to be lowered for use in homes and factories. A small town with a demand of 800 kW of electric power at 220 V is situated 15 km away from an electric plant generating power at 440 V. The resistance of the two wireline carrying power is 0.5 Ω per km. The town gets power from the line through a 4000-220 V step-down transformer at a sub-station in the town.



(i) Resistance of the two wire lines carrying power = 0.5 Ω/km

Total resistance = (15 + 15)0.5 = 15 Ω

(ii) Linear power loss = $I^2 R$

RMS current in the coil, $I = \frac{P}{V_1} = \frac{800 \times 10^3}{4000}$ = 200 A

$\therefore$ Power loss = $(200)^2 \times 15$ = 600 kW

(iii)Assuming that the power loss is negligible due to the leakage of the current.

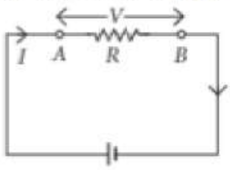
The total power supplied by the plant = 800 kW + 600 kW = 1400 kW

OR

Voltage drop in the power line = IR = 200 × 15 = 3000 V

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

Whenever an electric current is passed through a conductor, it becomes hot after some time. The phenomenon of the production of heat in a resistor by the flow of an electric current through it is called heating effect of current or Joule heating. Thus, the electrical energy supplied by the source of emf is converted into heat. In purely resistive circuit, the energy expended by the source entirely appears as heat. But if the circuit has an active element like a motor, then a part of the energy supplied by the source goes to do useful work and the rest appears as heat. Joule's law of heating form the basis of various electrical appliances such as electric bulb, electric furnace, electric press etc.



(i) **(b)** Heat produced in a conductor varies directly as the square of the current flowing.

Explanation: According to Joule's law of heating.

Heat produced in a conductor, $H = I^2 Rt$

where, I = Current flowing through the conductor

R = Resistance of the conductor

t = Time for which current flows through the conductor.

$\therefore H \propto I^2$

(ii) **(d)** Doubled

Explanation: If the coil is cut into half, its resistance is also halaved.

As $H = \frac{V^2}{R} t$

$\therefore$ H' = 2

(iii)**(d)** 25 W

Explanation: $P = \frac{V^2}{R}$ or $R = \frac{V^2}{P}$

The bulbs are joined in series. Current in both the bulbs will same.

$\therefore$ The heat produced in them is given by $H = I^2 Rt$

or $H \propto R \Rightarrow H \propto \frac{1}{P}$

Therefore the bulb with low wattage or high resistance will glow brighter or we can say the 25 W bulb will glow brighter than the 100 W bulb.

OR

(d) 30 kJ

Explanation: R = 100 Ω; I = 1A; t = 5 min = 5 × 60 = 300s

change in internal energy = heat generated in coil

$= I^2 Rt = ((1)^2 \times 100 \times 300)J$

$= 30000 \text{ J} = 30 \text{ kJ}$