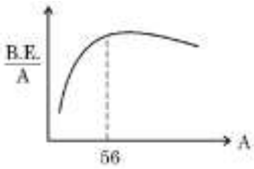
SECTION- A

1. **(a)** $q_2 < q_3 < q_1$
2. **(c)** $\frac{R}{8}$
3. **(b)** $(-3\hat{j} + 2\hat{k})\mu\text{N}$
4. **(b)** 0.30 C
5. **(b)** 2866
6. **(d)** $\frac{i_0 v_0}{2} \cos\phi$
7. **(a)** X- rays, Micro waves, UV radiation
8. **(b)** $\frac{3H}{4}$
9. **(c)** $\frac{h}{m}$
10. **(b)** $\lambda_e > \lambda_p > \lambda_d$
11. **(a)**



12. **(c)** The barrier height and the depletion layer width both decrease.
13. **(a)** Both Assertion (A)and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
14. **(a)** Both Assertion (A)and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
15. **(c)** Assertion (A)is true but Reason (R) is false.
16. **(d)** Assertion (A) is false and Reason (R) is also false.
17. $E = V + Ir$

In first case

$E = 5 + 2r$

In second case

$\text{E} = 4 + 4\text{r}$

After solving

$\text{E} = 6\text{ V}$

$\text{r} = 0.5\Omega$

18. **(a)** Condition for Minima $\text{a}\sin\theta = \text{n}\lambda$

For First Minima $\text{n} = 1$

$\text{a}\sin 30° = 600 \times 10^{-9}\text{ m}$

$$\text{a} \times \frac{1}{2} = 600 \times 10^{-9}\text{ m}$$

$$\text{a} = 1200 \times 10^{-9}\text{ m}$$

$$= 1.2 \times 10^{-6}\text{ m}$$

OR

(b) Phase difference $= \frac{2\pi}{\lambda} \times$ path difference

$$\Delta\phi = \frac{2\pi}{\lambda}\Delta x$$

$\Delta x = \frac{\lambda}{8}$ (given)

$$\Delta\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{8}$$

$$\Delta\phi = \frac{\pi}{4}$$

$$I = I_\circ + I_\circ + 2\sqrt{I_\circ I_\circ}\cos\frac{\pi}{4}$$

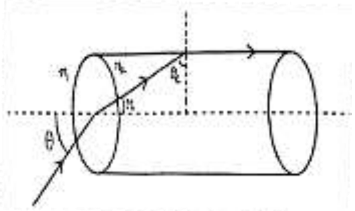
$$= 2I_\circ + 2I_\circ \times \frac{1}{\sqrt{2}}$$

$I = 2I_\circ\left(1+\frac{1}{\sqrt{2}}\right)$

$= I_\circ(2+\sqrt{2})$

$I = 3.414I^\circ$

19.



For critical Angle

$\frac{n_2}{n_1} = \frac{1}{\sin\theta_c}$

$n_1 = 1$ $n_2 = \frac{2}{\sqrt{3}}$ (given)

$\frac{2}{\sqrt{3}} = \frac{1}{\sin\theta_c}$

$\sin\theta_c = \frac{\sqrt{3}}{2}$

$\theta_c = 60^\circ$

$r = 90 - \theta_c$

$= 30^\circ$

From Snell's law at air rod interface

$n_1 \sin i = n_2 \sin r$

$n_2 = \frac{\sin\theta}{\sin r}$

$\frac{2}{\sqrt{3}} = \frac{\sin\theta}{\sin 30^\circ}$

$\frac{2}{\sqrt{3}} \times \frac{1}{2} = \sin\theta$

$\frac{1}{\sqrt{3}} = \sin\theta$

$\theta = \sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$

20. $T = \frac{2\Pi}{v}$ .... (1)

From Bohr's quantization condition

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

$v = \frac{nh}{2\pi mr}$ .... (2)

From (1) and (2)

$T = \frac{2\pi r}{\left(\frac{nh}{2\pi mr}\right)}$

$T = \frac{2\pi r(2\pi mr)}{nh}$

$T = \frac{4\pi^2 mr^2}{nh}$

From $r = \frac{n^2h^2}{4\pi^2mke^2}$

$T = \frac{4\pi^2\ m}{nh}\left(\frac{n^2\ h^2}{4\pi^2 mke^2}\right)^2$

$T = \frac{n^3\ h^3}{4\pi^2 mk^2e^4}$

$\Rightarrow T\alpha n^3$

21. 1 dopant atom for 5×10^7Si atoms

and number density of Si atoms $= 5 \times 10^{28} \frac{\text{atoms}}{\text{m}^3}$

No. of holes created per $\text{m}^3 = \frac{5\times10^{28}}{5\times10^7} = 10^{21}$ (given)

Number of holes created per cubic centimeter $= \frac{10^{21}}{10^6} = 10^{15}$

Any one example of dopant - Aluminium / Indium / Gallium

22. **(a)** (i) Because $E_{eq} = \frac{E_1r_2+E_2r_1}{r_1+r_2}$

$$E_{eq} = \frac{3 \times 0.4 + 6 \times 0.2}{0.6} = 4\text{ V}$$

(ii) $r_{eq} = \frac{r_1r_2}{r_1+r_2}$

$$r_{eq} = \frac{0.2 \times 0.4}{0.2 + 0.4} = 0.133\Omega$$

(iii) $I = \frac{E}{R+r_{eq}}$

$$I = \frac{4}{4 + 0.13} = \frac{4}{4.13}A$$

$I = 0.9A$

OR

(b) (i) $l' = 2l$

$Al = A'l' =$ volume of the wire

$Al = A'(2l)$

$\frac{A}{2} = A'$

$R = \frac{\rho l}{A}$

$R' = \frac{\rho l'}{A'}$

$R' = \frac{\rho(2l)}{A/2}$

$\frac{R'}{R} = 4$

(ii)$v_d = \frac{eE}{m}\tau$

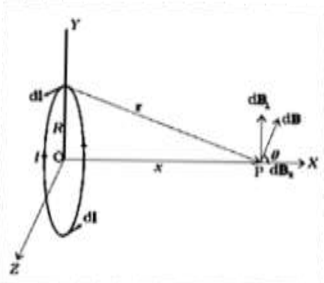
$v_d = \frac{eV}{ml}\tau$

$v'_d = \frac{eV}{ml'}\tau$

$\frac{v'_d}{v_d} = \frac{l}{l'} = \frac{1}{2}$

(ii)No

23.



From Biot Savart's Law

$$|d\vec{B}| = \frac{\mu_\circ}{4\pi}\frac{I|d\vec{l} \times \vec{r}|}{r^3}$$

Now $r^2 = x^2 + R^2$

Because $|d\vec{l}\times\vec{r}| = rdl$

$$dB = \frac{\mu_\circ}{4\pi}\frac{idl}{(x^2+R^2)}$$

$d\vec{B}$ has two components.

All the components perpendicular to x - axis are summed over and we obtain a null result.

Only x - components contribute. The net contribution along x – direction

$$dB_x = dB\cos\theta$$

$$\cos\theta = \frac{R}{(R^2+x^2)^{\frac{1}{2}}}$$

Thus: $dB_x = \frac{\mu_0 i}{4\pi} dl \frac{R}{(R^2+x^2)^{\frac{3}{2}}}$

Summing dB_x over the entire loop

$$\oint dl = 2\pi R$$

$$\vec{B} = B_x\hat{\imath} = \frac{\mu_0 i R^2}{2(x^2+R^2)^{\frac{3}{2}}}\hat{\imath}$$

Magnetic field at the centre of the loop-

Here x = 0

$$\vec{B} = \frac{\mu_0 i}{2R}\hat{\imath}$$

24. (a) Induced emf in an inductor $|\varepsilon| = L\frac{dI}{dt}$

Rate of work done at any instant $\frac{dW}{dt} = |\varepsilon| I$

Total Amount of work done in establishing current I

$$\mathrm{W} = \int dW = \int_0^I LIdI$$

Energy required to build up current I is $\mathrm{W} = 1/2\mathrm{LI}^2$

(b) The Magnetic Energy is

$$\mathrm{W} = \mathrm{U_B} = 1/2\mathrm{LI}^2$$

$$= 1/2\ \mathrm{L}\left(\frac{B}{n\mu_0}\right)^2 \quad \text{as} \quad \mathrm{B} = \mathrm{n}\mu_0\mathrm{I}$$

Using $\mathrm{L} = \mu_0 n^2 Al$

$$\mathrm{U_B} = \frac{1}{2}(\mu_0 n^2 Al)\left(\frac{B^2}{\mu_0^2 n^2}\right)$$

Energy density $= \frac{\mathrm{U_B}}{\text{volume}}$

$$\frac{\mathrm{U_B}}{\text{volume}} = \frac{1}{2}\times\mu_0\mathrm{n}^2\ Al\times\frac{\mathrm{B}^2}{\mu_0{}^2\mathrm{n}^2}\times\frac{1}{\mathrm{A}l}$$

$$= \frac{1}{2}\frac{\mathrm{B}^2}{\mu_0}$$

25. **(a)** Total current $\mathrm{I} = \mathrm{I_c} + \mathrm{I_d}$

outside the capacitor

$\mathrm{I_d} = 0$

$\therefore \mathrm{I} = \mathrm{I_c}$

Inside the capacitor $\mathrm{I_c} = 0$

$$\mathrm{I} = \mathrm{I_d} = \varepsilon_0\frac{d\phi_E}{dt}$$

$$= \varepsilon_0\frac{d}{dt}[EA]$$

$$= \varepsilon_0\frac{d}{dt}\left[\frac{\sigma}{\varepsilon_0}A\right]$$

$$= \frac{\varepsilon_0}{\varepsilon_0}A\frac{d}{dt}\left[\frac{Q}{A}\right]$$

$\mathrm{I}=\frac{dQ}{dt}=\mathrm{I_c}$

(b) Yes

Current entering the capacitor is ($\mathrm{I_c}$) and between the plates capacitor is ($\mathrm{I_d}$) $I_c=I_d$
which validates Kirchhoff's junction rule.

26. (a) When monochromatic light is incident on a metal surface then more/less tightly bound electrons will emerge with less/more kinetic energy. So all the photoelectrons do not eject with same kinetic energy.

(b) Maximum number of photoelectrons ejected per second (saturation current) is directly proportional to the Intensity of incident radiation Hence saturation current is different for different intensities.

(c) when λ increases, ν decreases and energy of incident photon ($h\nu$) also decreases. When $\lambda>\lambda_0, \nu<\nu_0$ (threshold frequency), no photoelectron is ejected. Emission of photoelectrons stop at $\lambda>\lambda_0$.

27. (a) Difference in the mass of the nucleus and its constituents is defined as mass defect. Binding Energy is the energy required to separate the nucleons from the nucleus. In Fission process a heavy nucleus splits into lighter nuclei and energy is released. As a result the Binding Energy per nucleon increases.

(b) $\Delta\mathrm{m}=\left(\mathrm{m_p}+\mathrm{m_n}\right)-\mathrm{m_d}$

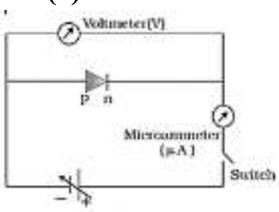
$\Delta\mathrm{m}=(1.007277+1.008665)-2.013553$

$\Delta\mathrm{m}=0.002389\mathrm{u}$

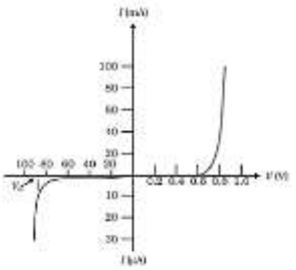
Energy released $=\Delta\mathrm{m}\times\mathrm{c}^2$

Energy released $=0.002389\times 931.5=2.2253\mathrm{MeV}\approx 2.22\mathrm{MeV}$

28. (a)



Circuit diagram for Reverse characteristics



(b)

Note : Please do not deduct marks for not writing values.

(c) Any two informations

Knee voltage / reverse saturation current / Breakdown voltage / very low resistance in forward biasing / very high resistance in Reverse biasing.

SECTION – D

29. (i) (b) 5 mC

(ii)(a) zero

(iii)(d) $[\mathrm{M^0\ L^0TA^0}]$

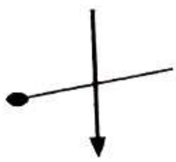
(iv) (a) $\frac{1}{2\sqrt{e}}mA$

Note: 1 mark for this part may be given to all the students who have attempted other parts of the question.

OR

(b) 0.5 mA

30. (i) (c)



(ii)(a) For a convex mirror magnification is always negative

(iii) (b) 2f

OR

(b) 12 cm

(iv) (c)$\sqrt{X_1X_2}$

SECTION – E

31. (i) $\vec{E} = \frac{3\times10^5}{r^2}\hat{r}$

$V = 3\times10^5/r$

(Given) $dV = -\vec{E}\cdot d\vec{r}$

Electrostatic energy of the system in the absence of the field $U_i = \frac{Kq_1q_2}{r_{12}}$

Electrostatic energy in the presence of the field

$U_f = \frac{Kq_1q_2}{r_{12}} + q_1V(\vec{r}_1) + q_2V(\vec{r}_2)$

$\Delta U = U_f - U_i = q_1V(\vec{r}_1) + q_2V(\vec{r}_2)$

$\Delta U = \frac{5\times10^{-6}\times3\times10^5}{3\times10^{-2}} - \frac{1\times10^{-6}\times3\times10^5}{3\times10^{-2}}$

=40 J

(ii)1) $C = \frac{Q}{V} = \frac{80}{16} = 5\mu$ F

(2) $C' = KC$

$=3\times5\mu \text{ F} = 15\mu$ F

$V' = \frac{Q}{C'} = \frac{80\mu C}{15\mu \text{ F}} = 5.33$ V

(3) No,

The capacitance of the system depends on its geometry.

OR

(b) Total charge for A = Total charge for B = Total charge for C = $_{+}4q$ As ,

$E = \frac{kQ}{r^2}$

Since $Q = 4q$ and $r = 3R$

$E = \frac{k(4q)}{9R^2} = \frac{4kq}{9R^2}$

$E_A = E_B = E_c$

(ii)$V_c = \left[\frac{k\times6\times10^{-6}}{5\times10^{-2}} - \frac{k\times6\times10^{-6}}{5\times10^{-2}}\right]$

$= 0$

$= \left[\frac{k\times6\times10^{-6}}{15\times10^{-2}} - \frac{k\times6\times10^{-6}}{5\times10^{-2}}\right]$

$V_A = \frac{k\times6\times10^{-6}}{10^{-2}}\left[\frac{1-3}{15}\right]$

$= -\frac{9\times10^9\times6\times10^{-6}\times2}{15\times10^{-2}}$

$= -7.2\times10^5$ V

$W = q[V_A - V_c]$

$W = 5\times10^{-6}[-7.2\times10^5 - 0]$

$W = -3.6$ J

32. (a) (i) Near point *P*

Magnetic field is acting into the plane of the paper as Force is acting upwards.

Near point Q

Magnetic field is into the plane of paper as force is acting upwards.

Near point R

Magnetic field is acting out of the plane of the paper as $\vec{F}$ is acting downwards.
Relative Magnitude of the Magnetic field.
As B $\alpha \frac{1}{r}$
Therefore,
Near point P , magnitude of B is small.
Near point Q, B is relatively smaller than point P.
Near point R, B is relatively larger than point P .
$\left(B_Q < B_P < B_R\right)$
(ii)Let r be the radius of the circular coil and I is the current in the coil then

$B = \frac{\mu_0 I}{2r}$ or $I = \frac{2Br}{\mu_0}$

$A = \pi r^2$ $r = \sqrt{\frac{A}{\pi}}$

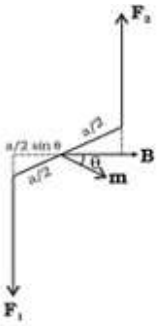
$M = IA$

$= \frac{2Br}{\mu_0} A$

$= \frac{2BA}{\mu_0}\sqrt{\frac{A}{\pi}}$

OR

(b)



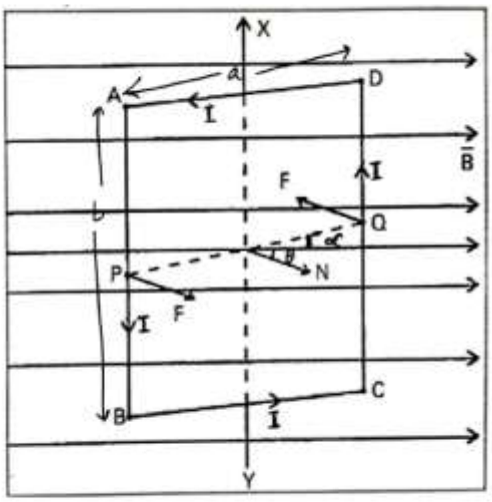
(i) $\vec{F}_1$ and $\vec{F}_2$ are the forces acting on two arms of the rectangular coil having sides a and b .
$|\vec{F}_1| = |\vec{F}_2| = IbB$
(b = length of the arm)
Forces constitute a couple. The magnitude of Torque on the loop is

$\tau = F_1 \frac{a}{2} \sin\theta + F_2 \frac{a}{2} \sin\theta$

$= IabB\sin\theta$

$= IAB\sin\theta$

$\vec{\tau} = I\vec{A} \times \vec{B}$



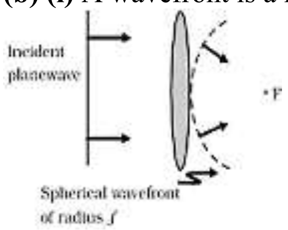
If the plane of the current carrying coil marks an angle $\propto$ with the magnetic field $\vec{F}_{DA} = -\vec{F}_{BC}$ (cancel each other).
Force on the arm DC is into the plane of the paper
$|F_{DC}| = IbB.$
Force on the arm AB is out of the plane of the paper.
$|F_{AB}| = IbB$
Both of them form a couple and Torque acting on the coil is $\tau =$ either force $\times$ perpendicular distance between the two forces.
$\tau = IbB \times a\cos\alpha$
$= IabB\cos\alpha$
$\tau = IAB\cos\alpha$
Let $\hat{n} =$ outward drawn normal to the plane of the coil.
$\theta + \alpha = 90^\circ$
$\alpha = 90^\circ - \theta$
$\tau = IAB\cos(90 - \theta)$
$= IAB\sin\theta$
$\vec{\tau} = I\vec{A} \times \vec{B}$
(ii) (1) $r = \frac{mv}{qB} = \frac{\sqrt{2mK}}{qB}$
$r \, \alpha \sqrt{K}$
$\frac{r'}{r} = \frac{\sqrt{\frac{K}{2}}}{\sqrt{K}} = \frac{1}{\sqrt{2}}$
$r' = \frac{r}{\sqrt{2}}$
(2) $T = \frac{2\pi m}{qB}$
Time period does not depend on Kinetic Energy $\therefore$ Time period will not change.

33. (a) (i) (1) If the phase difference between the displacement produced by each of the wave from two sources does not change with time then two sources are said to be coherent.
(2) Two independent sources will never be coherent because phase difference between them will not be constant.
(ii) (1) Distance between adjacent bright fringe = fringe width
$\beta = \frac{\lambda D}{d}$
$= \frac{600 \times 10^{-9} \times 1.2}{0.1 \times 10^{-3}} = 7.2 \text{ mm}$
(2)$\theta = \frac{\lambda}{d}$
$= \frac{600 \times 10^{-9}}{0.1 \times 10^{-3}} = 6 \times 10^{-3}\text{rad} = 0.34^\circ$

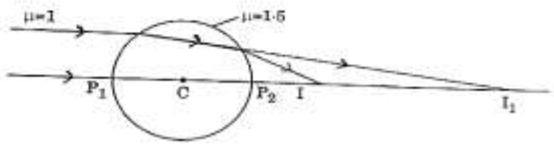
Give full marks if the student writes the answer in radians only.

OR

(b) (i) A wavefront is a locus of all the points which oscillate in phase.



(ii)



From Ist surface, Refraction is from rarer to denser medium and object is at ∞

$n_1 = 1, n_2 = 1.5, R = 15$ cm, $u = \infty$

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

$$\frac{1.5}{v} - \frac{1}{\infty} = \frac{1.5 - 1}{15}$$

$v = 45$ cm

From 2nd surface, Refraction is from denser to rarer medium and object is at 15 cm

$n_1 = 1, n_2 = 1.5, R = -15$ cm, $u = 15$ cm

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

$$\frac{1}{v} - \frac{1.5}{15} = \frac{1 - 1.5}{-15}$$

$v = 7.5$ cm

General Instructions: -

1. You are aware that evaluation is the most important process in the actual and correct assessment of the candidates. A small mistake in evaluation may lead to serious problems which may affect the future of the candidates, education system and teaching profession. To avoid mistakes, it is requested that before starting evaluation, you must read and understand the spot evaluation guidelines carefully.

2. "Evaluation policy is a confidential policy as it is related to the confidentiality of the examinations conducted, Evaluation done and several other aspects. Its' leakage to public in any manner could lead to derailment of the examination system and affect the life and future of millions of candidates. Sharing this policy/document to anyone, publishing in any magazine and printing in News Paper/Website etc may invite action under various rules of the Board and IPC."

3. Evaluation is to be done as per instructions provided in the Marking Scheme. It should not be done according to one's own interpretation or any other consideration. Marking Scheme should be strictly adhered to and religiously followed. However, while evaluating, answers which are based on latest information or knowledge and/or are innovative, they may be assessed for their correctness otherwise and due marks be awarded to them. In class - X, while evaluating two competency-based questions, please try to understand given answer and even if reply is not from marking scheme but correct competency is enumerated by the candidate, due marks should be awarded.

4. The Marking scheme carries only suggested value points for the answers These are in the nature of Guidelines only and do not constitute the complete answer. The students can have their own expression and if the expression is correct, the due marks should be awarded accordingly.

5. The Head-Examiner must go through the first five answer books evaluated by each evaluator on the first day, to ensure that evaluation has been carried out as per the instructions given in the Marking Scheme. If there is any variation, the same should be zero after delibration and discussion. The remaining answer books meant for evaluation shall be given only after ensuring that there is no significant variation in the marking of individual evaluators.

6. Evaluators will mark(√) wherever answer is correct. For wrong answer CROSS ' X " be marked. Evaluators will not put right (✓) while evaluating which gives an impression that answer is correct and no marks are awarded. This is most common mistake which evaluators are committing.
7. If a question has parts, please award marks on the right-hand side for each part. Marks awarded for different parts of the question should then be totaled up and written in the left-hand margin and encircled. This may be followed strictly.
8. If a question does not have any parts, marks must be awarded in the left-hand margin and encircled. This may also be followed strictly.
9. If a student has attempted an extra question, answer of the question deserving more marks should be retained and the other answer scored out with a note "Extra Question".
10. No marks to be deducted for the cumulative effect of an error. It should be penalized only once.
11. A full scale of marks _ 70 ___ (example 0 to 80/70/60/50/40/30 marks as given in Question Paper) has to be used. Please do not hesitate to award full marks if the answer deserves it.
12. Every examiner has to necessarily do evaluation work for full working hours i.e., 8 hours every day and evaluate 20 answer books per day in main subjects and 25 answer books per day in other subjects (Details are given in Spot Guidelines). This is in view of the reduced syllabus and number of questions in question paper.
13. Ensure that you do not make the following common types of errors committed by the Examiner in the past: -
• Leaving answer or part thereof unassessed in an answer book.
• Giving more marks for an answer than assigned to it.
• Wrong totaling of marks awarded on an answer.
• Wrong transfer of marks from the inside pages of the answer book to the title page.
• Wrong question wise totaling on the title page.
• Wrong totaling of marks of the two columns on the title page.
• Wrong grand total.
• Marks in words and figures not tallying/not same.
• Wrong transfer of marks from the answer book to online award list.
• Answers marked as correct, but marks not awarded. (Ensure that the right tick mark is correctly and clearly indicated. It should merely be a line. Same is with the X for incorrect answer.)
• Half or a part of answer marked correct and the rest as wrong, but no marks awarded.
14. While evaluating the answer books if the answer is found to be totally incorrect, it should be marked as cross (X) and awarded zero (0)Marks.
15. Any un assessed portion, non-carrying over of marks to the title page, or totaling error detected by the candidate shall damage the prestige of all the personnel engaged in the evaluation work as also of the Board. Hence, in order to uphold the prestige of all concerned, it is again reiterated that the instructions be followed meticulously and judiciously.
16. The Examiners should acquaint themselves with the guidelines given in the "Guidelines for spot Evaluation" before starting the actual evaluation.
17. Every Examiner shall also ensure that all the answers are evaluated, marks carried over to the title page, correctly totaled and written in figures and words.
18. The candidates are entitled to obtain photocopy of the Answer Book on request on payment of the prescribed processing fee. All Examiners/Additional Head Examiners/Head Examiners are once again reminded that they must ensure that evaluation is carried out strictly as per value points for each answer as given in the Marking Scheme.

SECTION A

34. **(c)**

35. **(b)** Using a wire of same radius and half length.

36. **(b)** $(-3\hat{j}+2\hat{k})\mu\text{N}$

37. **(c)** 2

38. **(b)** 2866

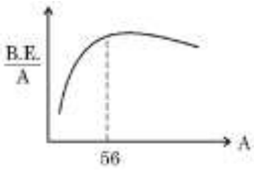
39. **(d)** $\frac{i_0 v_0}{2}\cos\phi$

40. **(b)** Speed Wavelength Frequency Remains same Decreases Increases

41. **(a)** medium ' 1 ' and at an angle greater that $\sin^{-1}\left(\frac{v_1}{v_2}\right)$

42. **(a)** 10^{16}

43. (a)



44. (c) The barrier height and the depletion layer width both decrease.

45. (b) $\lambda_e > \lambda_p > \lambda_d$

46. (d) Assertion (A) is false and Reason (R) is also false.

47. (c) Assertion (A) is true but Reason (R) is false.

48. (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion(A).

49. (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion(A).

50. $\vec{E} = \rho\vec{j}$

$\frac{V}{l} = \rho\frac{I}{A}$

$\frac{V}{I} = \rho\frac{l}{A} =$ constant (Ohm's Law)

Condition for non- validity of Ohm's Law

High temperature / in semiconductor

51. (a) Condition for Minima a $\sin\theta = n\lambda$

For First Minima n = 1

$a\sin 30^\circ = 600 \times 10^{-9}$ m

$a \times \frac{1}{2} = 600 \times 10^{-9}$ m

$a = 1200 \times 10^{-9}$ m

$= 1.2 \times 10^{-6}$ m

OR

(b) Phase difference $= \frac{2\pi}{\lambda} \times$ path difference

$\Delta\phi = \frac{2\pi}{\lambda}\Delta x$

$\Delta x = \frac{\lambda}{8}$ (given) $\Delta\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{8}$

$\Delta\phi = \frac{\pi}{4}$

$I = I_\circ + I_\circ + 2\sqrt{I_\circ I_\circ}\cos\frac{\pi}{4}$

$= 2I_\circ + 2I_\circ \times \frac{1}{\sqrt{2}}\, I = 2I_\circ\left(1 + \frac{1}{\sqrt{2}}\right)$

$= I_\circ(2 + \sqrt{2})$

$I = 3.414 I^\circ$

52. Refraction from rarer to denser medium

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

$u = -\frac{R}{2}, n_1 = 1, n_2 = 1.5$

$\frac{2}{R} + \frac{1.5}{v} = \frac{1.5 - 1}{R}$

$\frac{1.5}{v} = \frac{0.5}{R} - \frac{2}{R}$

$\frac{1.5}{v} = -\frac{1.5}{R}$

$v = -R$

The image is virtual in air at distance R.

53. $E_n = -\frac{13.6}{n^2}eV$

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

$n = 2$
Angular momentum
$$L = \frac{nh}{2\pi}$$
$$L = \frac{h}{\pi} = \frac{6.63 \times 10^{-34}}{3.14} = 2.11 \times 10^{-34} \text{Js}$$

54. 1 dopant atom for 5×10^{7} Si atoms

and number density of Si atoms $= 5 \times 10^{28} \frac{\text{atoms}}{\text{m}^3}$

No. of holes created per m^3 $= \frac{5\times10^{28}}{5\times10^{7}} = 10^{21}$ (given)

Number of holes created per cubic centimeter
$$= \frac{10^{21}}{10^{6}} = 10^{15}$$
Any one example of dopant - Aluminium / Indium / Gallium

55. **(a)** (i) Because $E_{\text{eq}} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$
$$E_{eq} = \frac{3 \times 0.4 + 6 \times 0.2}{0.6} = 4\ \text{V}$$
(ii)
$$r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$
$$r_{eq} = \frac{0.2 \times 0.4}{0.2 + 0.4} = 0.133\Omega$$
(iii)
$$I = \frac{E}{R + r_{eq}}$$
$$I = \frac{4}{4 + 0.13} = \frac{4}{4.13} A$$
$$I = 0.9A$$

OR

(b) (i) $l' = 2l$

$Al = A'l' =$ volume of the wire
$$Al = A'(2l)$$
$$\frac{A}{2} = A'$$
$$R = \frac{\rho l}{A}$$
$$R' = \frac{\rho l'}{A'}$$
$$R' = \frac{\rho(2l)}{A/2}$$
$$\frac{R'}{R} = 4$$
(ii) $v_d = \frac{eE}{m}\tau$
$$v_d = \frac{eV}{ml}\tau$$
$$v_d' = \frac{eV}{ml'}\tau$$
$$\frac{v_d'}{v_d} = \frac{l}{l'} = \frac{1}{2}$$
(ii) No

56. **(a)** Magnetic moment of a current carrying coil is defined as the product of
current flowing through the coil and Area of the coil.
Alternatively
$$\vec{M} = I\vec{A}$$

S.I. unit is Am^2

(b) $\tau = \text{NIAB} \sin\theta$

$\tau_1 = 0.12 = 60 \times 2 \times 1.5 \times 10^{-3} \times B\sin\theta$

$B\sin\theta = \dfrac{2}{3}$

$\tau_2 = 0.05 = 60 \times 2 \times 1.5 \times 10^{-3} \times \text{B}\cos\theta$

$\text{B}\cos\theta = \dfrac{5}{18}$

$\text{B} = \sqrt{\text{B}^2\sin^2\theta + \text{B}^2\cos^2\theta}$

$= \sqrt{\left(\dfrac{2}{3}\right)^2 + \left(\dfrac{5}{18}\right)^2} = \dfrac{13}{18}\ \text{T}$

SECTION A

57. (d) CM

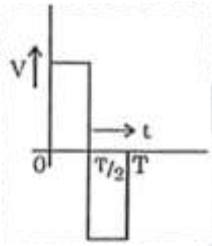
58. (c) two resistors in series and then this combination in parallel with the third resistor.

59. (c) $\frac{5.0}{\sqrt{2}} \times 10^{-10}\hat{\text{k}}\text{T}$

60. (a) $\frac{\mu_0}{4\pi} \times \frac{2\text{M}}{\text{r}^3}$

61. (b) Z to Y and then Y to Z

62.(c)



63.(d) 6750

64. (a) conservative and field lines do not from closed loops

65. (a) $1.6 \times 10^8\ \text{ms}^{-1}$

66. (c) Lyman series

67. (d) 5

68. (a) (A) resistor / (C) capacitor

69. (a) If both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).

70. (c) If Assertion (A) is true and Reason (R) is false.

71. (c) If Assertion (A) is true and Reason (R) is false.

72. (b) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).

SECTION B

73. (a) $\text{R} = \frac{\rho l_1}{\text{A}}; \text{R}_2 = \frac{\rho l_2}{\text{A}}$

$\dfrac{l_1}{l_2} = \dfrac{2}{3} \Rightarrow \dfrac{\text{R}_1}{\text{R}_2} = \dfrac{2}{3}$

$\text{I}\alpha\dfrac{1}{\text{R}}$

$\Rightarrow \dfrac{I_1}{I_2} = \dfrac{3}{2}$

$\text{I}_1 = \dfrac{3}{5} \times 15 = 9\ \text{A}$

$\Rightarrow \text{I}_2 = \dfrac{2}{5} \times 15 = 6\ \text{A}$

OR

(b) In steady state,

$2V - V = i(2R + R)$

$i = \frac{V}{3R}$

(i) $V_p - V_Q = -V - iR$

$= -V - \frac{V}{3}$

$V_p - V_Q = -\frac{4\ V}{3}$

(ii) $V_p - V_Q = -V + V_c$

$-\frac{4\ V}{3} = -V + V_c$

$V_c = -\frac{V}{3}$

74. Phase difference for 6^{th} dark fringe $= 11\pi$

Phase difference for 8^{th} bright fringe $= 16\pi$

$\Delta\phi + \phi_6 = \phi_8$

$2\pi(n-1)\frac{t}{\lambda} + 11\pi = 16\pi$

$t = \frac{5\lambda}{2(n-1)}$

75. For the first lens: -

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

$\frac{1}{v_1} + \frac{1}{4} = -\frac{1}{8}$

$v_1 = -\frac{8}{3}$ cm

For the second lens: -

$u_2 = -16 - \frac{8}{3} = -\frac{56}{3}$ cm

$\frac{1}{v_2} - \left(-\frac{3}{56}\right) = -\frac{1}{8}$

$v_2 = -5.6$ cm

Image is virtual.

76. $hv = \phi_0 + K_{max}$

$\frac{hc}{\lambda} = \phi_0 + \frac{1}{2}mv_{max}^2$

$\frac{6.63 \times 10^{-34} \times 3 \times 10^8}{4 \times 10^{-7}} = 3 \times 10^{-19} + \frac{1}{2}mv_{max}^2$

$\frac{19.89}{4} \times 10^{-19} = 3 \times 10^{-19} + \frac{1}{2}mv_{max}^2$

$\frac{4 \times 10^{-19}}{9 \times 10^{-31}} = v_{max}^2$

$v_{max} = \frac{2}{3} \times 10^6$ m/s

77. $V - V_o = IR$

$V - 0.7 = (15 \times 10^{-3}) \times 1000$

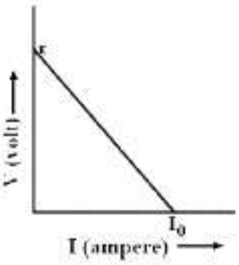
$V = 15.7$ volt

SECTION C

78. (a) Current drawn from the cell $(I) = \frac{E}{r+R}$

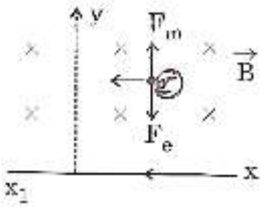
Potential difference (V) = IR

$V = \frac{ER}{r+R}$



(b)
Slope of the graph is equal to internal resistance of the cell.
The intercept on Y -axis gives the emf of the cell.

79. **(a) (i)**



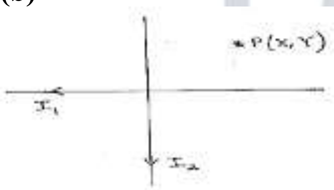
(ii) Electric force
Magnetic force
(iii) ev_o B = Ee

$$v_o x \left[\frac{\mu_o I}{2\pi\ d}\right] = E$$

$$v_o = \frac{(2\pi\ d)E}{\mu_o I}$$

OR

(b)



Magnetic field due to conductor carrying current $I_1\left(\overrightarrow{B_1}\right) = \frac{\mu_0 I_1}{2\pi Y}(-\hat{k})$

Magnetic field due to conductor Carrying current $I_2\left(\overrightarrow{B_2}\right) = \frac{\mu_0 I_2}{2\pi X}(\hat{k})$

$\vec{B}_P = \vec{B}_1 + \vec{B}_2$

$$\overrightarrow{B}_p = \frac{\mu_0}{2\pi}\left[\frac{I_2}{X} - \frac{I_1}{Y}\right]\hat{k}$$

Direction will be along the Z -axis.

80. **(a)** Lenz's law- The polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produced it.

(b) (i) AC generator

(ii) P - Slip rings

Q - Carbon brushes

R- Armature coil

(iii) Left side of the magnet is North & right side is South or vice-versa.

(iv) (Any two)

-By increasing the number of turns in the armature coil.

-By increasing the speed of rotation of the armature coil.

-By increasing the strength of the magnetic field B.

81. **(a)** Magnetic field oscillates in the east-west direction as it is mutually perpendicular to the direction of electric field.

(b) Wavelength of the radiowaves and microwaves is longer than visible light.

(c) (i) Use of infrared waves: -

(Any one)

- Used for physical therapy.
- Used for maintaining average temperature of the earth.
- Used in Earth satellites for military purposes & to observe growth of crops.
- Used in remote control

(ii) Use of Gamma rays: -

(Any one)

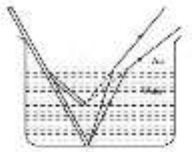
- Used in treatment of cancer.
- Used in diagnostic imaging.
- Used to sterilize medical equipment

82. **(a)** Width of the parallel beam of light increases in water.

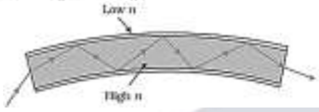
Alternatively: -

If a student explains using diagram, full credit to be given.

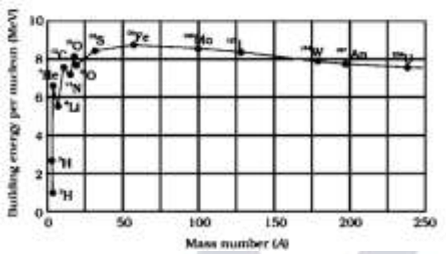
(b) Due to refraction of light, the image of the portion immersed in water appears to be raised.



(c)



83. **(a)**



Full credit to be given even if the values are not shown.

Significance of the binding energy curve -

(Anyone)

- Why lighter nuclei undergo fusion and heavier nuclei undergo fission.
- Nuclear forces are short ranged.
- Energy is released in both nuclear fission and nuclear fusion.

(b) (i) Nuclear fusion

(ii) Decreases

(iii) Energy is produced

84. **(a)** In an extrinsic semiconductor, the charge carriers whose number density is large are known as majority charge carriers.

In an extrinsic semiconductor, the charge carriers whose number density is small are known as minority charge carriers.

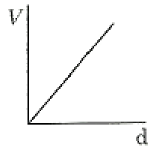
(b) Due to the applied forward voltage, electrons from n-side cross the depletion region and reach p-side. Similarly, holes from p-side cross the junction and reach the n-side. Due to the movement of these charge carriers current is produced.

(c) At $V = -0.6$ volt, $I = 0$, so dynamic resistance is infinite.

SECTION D

85.(i) (c) $\frac{E}{4}$

(ii) (d)



(iii) (c)

(iv) (a) $(\vec{E}_1 + \vec{E}_2) \cdot \vec{d}$

OR

(c) CK

86. (i) (b) are parallel to each other.

(ii) (c) me

(iii) Full 1 mark to be awarded to all the students who have attempted this part of the question.

OR

(b) $\frac{1}{2}, \frac{1}{2}$

(iv) (d) 13.3μ m

87. (a) (i) Potential on sphere A $= \mathrm{V} = \frac{\mathrm{Q}}{4\pi\varepsilon_0 \mathrm{r}}$

Charge on sphere A $= 4\pi\varepsilon_0 \mathrm{rV}$

The charge is transferred to shell B.

Potential on shell B $= \frac{1}{4\pi\varepsilon_0} \times \frac{4\pi\varepsilon_0 \mathrm{rV}}{\mathrm{R}}$

Potential on shell B $= \frac{rV}{R}$

Potential on sphere $A =$ Potential on shell B

(ii) Characteristics of equipotential surfaces: -

(Any two)

- Potential at all points on the surface is same.
- Equipotential surface is normal to the direction of the electric field.
- The work done in moving a charge on an equipotential surface is zero.

$V_0 - V = Ed = 50 \times 4$

$V_0 - V = 200V$

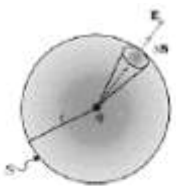
$V = 220V - 200V$

$V = 20V$

OR

(b) (i) Open Surface - A surface which does not enclose a volume.

Closed Surface - A surface which does enclose a volume.



(ii) Electric flux is defined as the number of electric field lines crossing an area normally.

(iii) Total charge enclosed by $\mathrm{S}_1 = (-3 - 2 + 9)\mu\mathrm{C} = 4\mu\mathrm{C}$

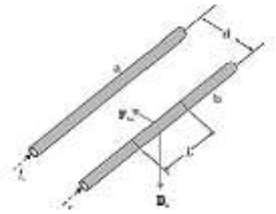
Total charge enclosed by $\mathrm{S}_2 = \mathrm{Q} + 4\mu\mathrm{C}$

$\phi_{s_2} = 4\phi_{s_1}$

$$\frac{Q + 4\mu C}{\varepsilon_0} = 4\left(\frac{4\mu C}{\varepsilon_0}\right)$$

$Q = 12\mu C$

88. **(a)** Reason - **(i)** The source of force is the interaction between the field produced by the current carrying conductor and the external field in which it is placed.



Two long parallel conductors a& b, separated by a distance d, carrying currents I_a and I_b, respectively.
The magnetic field due to a,

$B_a = \frac{\mu_0 I_a}{2\pi\ d}$

The force F_{ba}, is the force on a segment L of ' b ' due to ' a '.

$F_{ba} = I_b L B_a$

$= \frac{\mu_0 I_a I_b}{2\pi\ d}\ L$

Definition -
The 'ampere' is that value of steady current which, when maintained in each of the two very long, straight, parallel conductors of negligible cross-section, and
placed one metre apart in vacuum, would produce on each of these conductors a force equal to 2×10^{-7} newton per metre of length.

(ii) Work done by the magnetic force on the charge is zero as force is perpendicular to $\vec{v}$.

(iii) The velocity $(\vec{v})$ is at an arbitrary angle θ w.r.t the magnetic field $(\vec{B})$.

OR

(b)(i) The two faces of a current carrying loop behave like two poles of a magnet therefore can be considered as a magnetic dipole placed along its axis.

(ii) Magnetic moment (M) α Current (I)
α Area (A)
$\vec{M} = IA$
Direction is same as the area vector.

(iii) Net force acting on the coil is zero.
The potential energy (U_B) of a current carrying loop in an external magnetic field =-M.B
For the coil to be in stable equilibrium U_B should be minimum so $\theta = 0°$.
Therefore, magnetic flux (ϕ) due to the total field = (B_{coil} + B_{ext})A, which is its maximum value.

89. **(a)** **(i)** As the pencil lies between f and $2f$ such that one end of the pencil coincides with 2 f .

Position of the other end $(u) = -\left(2f - \frac{f}{4}\right) = -\frac{7f}{4}$

Magnification$(m)\ = \frac{f}{f-u}$

$= \frac{-f}{-f-\left(-\frac{7f}{4}\right)}$

$m = -\frac{4}{3}$

Alternatively: -
As the pencil lies between f and $2f$ such that one end of the pencil coincides with 2f.

Position of the other end $(u) = -\left(2f - \frac{f}{4}\right) = -\frac{7f}{4}$

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

$\frac{1}{v} - \frac{4}{7f} = -\frac{1}{f}$

$\frac{1}{v} = -\frac{1}{f} + \frac{4}{7f}$

$v = -\frac{7f}{3}$

$m = -\frac{v}{u} = -\frac{4}{3}$

(ii) For prism;

$i + e = A + \delta$

$45^\circ + e = 30^\circ + 15^\circ$

$e = 0^\circ$

Hence, $r_2 = 0^\circ$

Emergent ray is perpendicular to face AC.

Alternatively: - If the same is shown using diagram full credit to be given.

$r_1 + r_2 = A$

As $r_2 = 0$, hence $r_1 = 30^\circ$

Refractive index(n) $= \frac{\sin i}{\sin r}$

$= \frac{\sin 45^\circ}{\sin 30^\circ}$

$n = \sqrt{2}$

OR

(b) (i) (1) Calculating distance of the third bright fringe from central maximum 1

(2) Finding the least distance 1

(ii) (1) Diagram showing variation of intensity with angle of diffraction 1

Writing expression for value of angle corresponding to zero intensity 1

(2) Difference between diffraction of light and sound waves 1

(i) (1) Distance of the nth bright fringe from the central maximum $(x_n) = \frac{n\lambda D}{d}$

For n = 3

$X_3 = \frac{3 \times 600 \times 10^{-9} \times 1}{1 \times 10^{-9}}$

$= 1800$ m

(2) $n_1\lambda_1 = n_2\lambda_2$

$n_1 \times 600 = n_2 \times 480$

$\frac{n_1}{n_2} = \frac{480}{600}$

$\frac{n_1}{n_2} = \frac{4}{5}$

Position of the 4^{th} bright fringe of 600 nm $= 4 \times 600 = 2400$ m

Alternatively: -

Position of the 5^{th} bright fringe of 480 nm $= 5 \times 480 = 2400$ m

Alternatively: -

$(n-1)\lambda_1 = n\lambda_2$

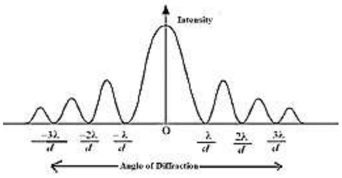
$(n-1) \times 600 = n \times 450$

on solving n = 4

Position of the 4^{th} bright fringe of 600 nm $= 4 \times 600 = 2400$ m

Position of the 5^{th} bright fringe of 480 nm $= 5 \times 480 = 2400$ m

(ii) (1)



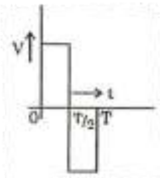
Angle of diffraction for zero intensity, $\theta = \frac{n\lambda}{a}$; n = 0,1,2, ...

(2) Diffraction of the light waves is not generally seen as compared to diffraction of sound waves as light waves have low wavelength.

SECTION A

90. **(d)** Zero

91. **(a)** 1.05



92. (c)

93. (d) repelled by north pole as well as by south pole

94.(a) $\frac{n_1}{n_2}$

95. (c) $\frac{5.0}{\sqrt{2}} \times 10^{-10}\hat{k}T$

96. (c) 0.63V

97. (c) Lyman series

98. (d) f

99. (a) conservative and field lines do not form closed loops.

100. **(a)** resistor / **(c)** capacitor

101. **(d) 5**

102. **(c)** If Assertion (A) is true but Reason (R) is false.

103. **(b)** If both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A).

104. **(c)** If Assertion (A) is true but Reason (R) is false.

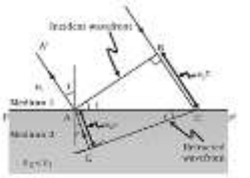
105. **(a)** If both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).

106. $V - V_o = IR$

$V - 0.7 = (15 \times 10^{-3}) \times 1000$

$V = 15.7$ volt

107.



Consider the triangles ABC and AEC,

$\text{Sini} = \frac{\text{BC}}{\text{AC}} = \frac{\text{v}_1\tau}{\text{AC}} \ldots\ldots\ldots\ldots \text{(i)}$

$\text{Sinr} = \frac{\text{AE}}{\text{AC}} = \frac{\text{v}_2\tau}{\text{AC}} \ldots\ldots\ldots\ldots \text{(ii)}$

Divide eq. (i) & (ii): -

$\frac{Sini}{Sinr} = \frac{v_1}{v_2}.$ ……(iii)

Refractive index of medium 1,

$\text{n}_1 = \frac{\text{c}}{\text{v}_1}.$ ……. (iv)

Refractive index of medium 2,

$\text{n}_2 = \frac{\text{c}}{\text{v}_2}$ ………(v)

From eq. (iii); (iv) & (v): -

$\frac{\text{n}_2}{\text{n}_1} = \frac{\text{Sini}}{\text{Sinr}}$

108. For the first lens: -

$\frac{1}{\text{v}_1} - \frac{1}{\text{u}_1} = \frac{1}{\text{f}_1}$

$\frac{1}{\text{v}_1} + \frac{1}{30} = \frac{1}{10}$

$\text{v}_1 = 15$ cm

For the second lens: -

$u_2 = -20 - (-15) = -5$ cm

$\frac{1}{v_2} - \left(-\frac{1}{5}\right) = \frac{1}{10}$

On solving: -

$v_2 = -10$ cm

Image is virtual.

109. $hv = \phi_0 + K_{max}$

For radiation having photons of energy 2.5 eV

$2.5eV = 2eV + \frac{1}{2}mv_1^2$

$0.5eV = \frac{1}{2}mv_1^2 \dots\dots\dots\dots (i)$

For radiation having photons of energy 4.5 eV

$4.5eV = 2eV + \frac{1}{2}mv_2^2$

$2.5eV = \frac{1}{2}mv_2^2 \dots\dots\dots (ii)$

Dividing eq. (i) by (ii): -

$\frac{v_1}{v_2} = \sqrt{\frac{1}{5}}$

OR

$\frac{v_2}{v_1} = \sqrt{5}$

110. **(a)** $R_1 = \frac{\rho l_1}{A}$; $R_2 = \frac{\rho l_2}{A}$

$\frac{l_1}{l_2} = \frac{2}{3} => \frac{R_1}{R_2} = \frac{2}{3}$

$I\alpha\frac{1}{R}$

$\Rightarrow \frac{I_1}{I_2} = \frac{3}{2}$

$\Rightarrow I_1 = \frac{3}{5} \times 15 = 9$ A

$\Rightarrow I_2 = \frac{2}{5} \times 15 = 6$ A

OR

(b) In steady state,

(i) $2V - V = i(2R + R)$

$i = \frac{V}{3R}$

(ii) $V_p - V_Q = -V - iR$

$= -V - \frac{V}{3}$

$V_P - V_Q$

$= -\frac{4\,V}{3}$

$V_p - V_Q = -V + V_R$

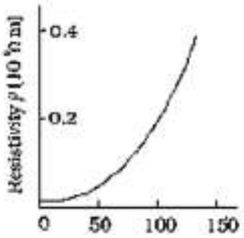
$-\frac{4V}{3} = -V + V_C$

$V_C = -\frac{V}{3}$

SECTION C

111. **(a)** Resistivity is the resistance of a material of unit length having unit area of cross-section.

On increasing the temperature of a conductor, the resistivity increases.



Full credit to be given if values are not shown on the graph.

(b) (i) A low internal resistance allows large current to be drawn even at a low voltage.

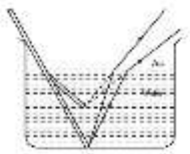
(ii) To limit the current.

112. **(a)** Width of the parallel beam of light increases in water.

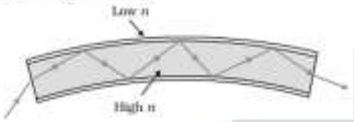
Alternatively: -

If a student explains using diagram, full credit to be given.

(b) Due to refraction of light, the image of the portion immersed in water appears to be raised.



(c)



113. Peak value is the maximum value of the alternating current.

rms current is the equivalent dc current that would produce the same average power loss as the alternating current.

$I_{\text{mms}} = \dfrac{I_0}{\sqrt{2}}$

Alternatively: -

$I_{\text{rms}} = 0.707 I_o$

The instantaneous power dissipated in the resistor is $P = i^2 R = i_m^2 R \sin^2 \omega t$

The average power over a cycle is: -

$\overline{P} = \langle i^2 R \rangle = \langle i_m^2 R \sin^2 \omega t \rangle$

$\langle \sin^2 \omega t \rangle = \dfrac{1}{2}$

$\overline{P} = \dfrac{1}{2} i_m^2 R = I_{ms}^2 R$

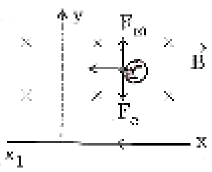
$I_{\text{rms}} = \sqrt{\dfrac{i_m^2}{2}} = \dfrac{i_m}{\sqrt{2}}$

114. **(a)** Electromagnetic waves are produced by accelerating / oscillating charges.

(b) South direction

(c) $\dfrac{\text{Shortest wavelength of radio waves}}{\text{Longest wavelength of gamma waves}} = \dfrac{0.1}{10^{-12}} = 10^{11}$

115. **(a)**



(i)

(ii) Electric force

Magnetic force

Alternatively: -

$F_E = eE$

$F_B = evB$

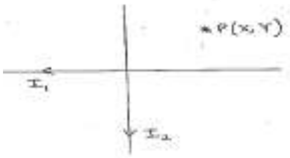
(iii) $e v_o B = Ee$

$$v_o x\left[\frac{\mu_o I}{2\pi\ d}\right] = E$$

$$v_o = \frac{(2\pi\ d)E}{\mu_o I}$$

OR

(b)



Magnetic field due to conductor carrying current $I_1(\vec{B}_1) = \frac{\mu_0 I_1}{2\pi Y}(-\hat{k})$

Magnetic field due to conductor Carrying current $I_2(\vec{B}_2) = \frac{\mu_0 I_2}{2\pi X}(\hat{k})$

$$\vec{B}_P = \vec{B}_1 + \vec{B}_2$$

$$\vec{B}_p = \frac{\mu_0}{2\pi}\left[\frac{I_2}{X} - \frac{I_1}{Y}\right]\hat{k}$$

Direction will be along the Z -axis.

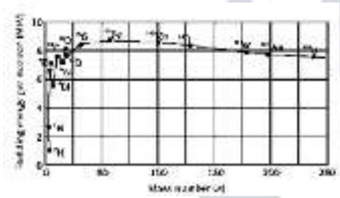
116. **(a)** In an extrinsic semiconductor, the charge carriers whose number density is large are known as majority charge carriers.

In an extrinsic semiconductor, the charge carriers whose number density is small are known as minority charge carriers.

(b) Due to the applied forward voltage, electrons from n-side cross the depletion region and reach p-side. Similarly, holes from p-side cross the junction and reach the n-side. Due to the movement of these charge carriers current is produced.

(c) At $V = -0.6$ volt, $I = 0$, so dynamic resistance is infinite.

117. **(a)**



Full credit to be given even if the values are not shown.

Significance of the binding energy curve -

(Anyone)

- Why lighter nuclei undergo fusion and heavier nuclei undergo fission.
- Nuclear forces are short ranged.
- Energy is released in both nuclear fission and nuclear fusion.

(b) **(i)** Nuclear fusion

(ii) Decreases

(iii) Energy is produced

SECTION -D

118. **(i)** (b) are parallel to each other.

(ii) (c) me

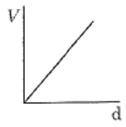
(iii) (b) Full 1 mark to be awarded to all the students who have attempted this part of the question.

OR

(c) $\frac{1}{2}, \frac{1}{2}$

(iv) (d) 13.3μ m

119. **(i)** (c) $\frac{E}{4}$

(ii) (d) 

(iii) (c) 

(iv) (a) $\left(\vec{E}_1 + \vec{E}_2\right) \cdot \vec{d}$

OR

(c) CK

120. **(a) (i)** As the pencil lies between f and $2f$ such that one end of the pencil coincides with 2 f .

Position of the other end $(u) = -\left(2f - \frac{f}{4}\right) = -\frac{7f}{4}$

Magnification$(m) = \dfrac{f}{f-u}$

$$= \frac{-f}{-f - \left(-\frac{7f}{4}\right)}$$

$m = -\dfrac{4}{3}$

(ii) For prism;

$i + e = A + \delta$

$45^\circ + e = 30^\circ + 15^\circ$

$e = 0^\circ$

Hence, $r_2 = 0^\circ$

Emergent ray is perpendicular to face AC.

If the same is shown using diagram full credit to be given.

$r_1 + r_2 = A$

As $r_2 = 0$, hence $r_1 = 30^\circ$

Refractive index(n) $= \frac{\sin i}{\sin r}$

$$= \frac{\sin 45^\circ}{\sin 30^\circ}$$

$n = \sqrt{2}$

OR

(b) (i) (1) Distance of the nth bright fringe from the central maximum $(x_n) = \frac{n\lambda D}{d}$

For $n = 3$

$$X_3 = \frac{3 \times 600 \times 10^{-9} \times 1}{1 \times 10^{-9}}$$

$= 1800$ m

(2)

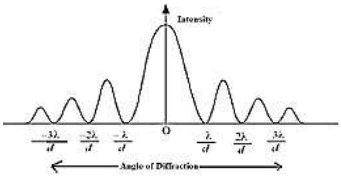
$n_1\lambda_1 = n_2\lambda_2$

$n_1 \times 600 = n_2 \times 480$

$$\frac{n_1}{n_2} = \frac{480}{600}$$

$$\frac{n_1}{n_2} = \frac{4}{5}$$

Position of the 4^{th} bright fringe of 600 nm $= 4 \times 600 = 2400$ m



(ii) (1)

Angle of diffraction for zero intensity, $\theta = \frac{n\lambda}{a}$; n = 0,1,2, ...

(2) Diffraction of the light waves is not generally seen as compared to diffraction of sound waves as light waves have low wavelength.

121. **(a)** (i) Potential on sphere A $= V = \frac{Q}{4\pi\varepsilon_0 r}$

Charge on sphere A $= 4\pi\varepsilon_0 rV$

The charge is transferred to shell B.

Potential on shell B $= \frac{1}{4\pi\varepsilon_0} \times \frac{4\pi\varepsilon_0 rV}{R}$

Potential on shell B $= \frac{rV}{R}$

Potential on sphere A = Potential on shell B

(ii) Characteristics of equipotential surfaces: -

(Any two)

- Potential at all points on the surface is same.
- Equipotential surface is normal to the direction of the electric field.
- The work done in moving a charge on an equipotential surface is zero.

$V_0 - V = Ed = 50 \times 4$

$V_0 - V = 200V$

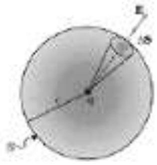
$V = 220V - 200V$

$V = 20V$

OR

(b) (i) Open Surface - A surface which does not enclose a volume.

Closed Surface - A surface which does enclose a volume.



(ii) Electric flux is defined as the number of electric field lines crossing an area normally.

$\phi = EA\cos\theta$

Significance of Gaussian Surface: -

It helps in finding the electric field in a simpler way.

Reason: -

Because any electric field line from the charge which enters the surface at one

(iii) Total charge enclosed by $S_1 = (-3 - 2 + 9)\mu C = 4\mu C$

Total charge enclosed by $S_2 = Q + 4\mu C$

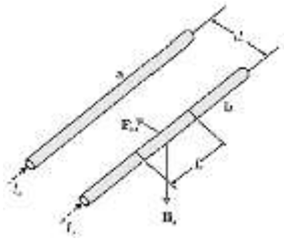
$\phi_{s_2} = 4\phi_{s_1}$

$$\frac{Q + 4\mu C}{\varepsilon_0} = 4\left(\frac{4\mu C}{\varepsilon_0}\right)$$

$Q = 12\mu C$

122. **(a).** Reason -

(i) The source of force is the interaction between the field produced by the current carrying conductor and the external field in which it is placed.



Two long parallel conductors a& b, separated by a distance d, carrying currents I_a and I_b, respectively.
The magnetic field due to a,

$$B_a = \frac{\mu_0 I_a}{2\pi d}$$

The force F_{ba}, is the force on a segment L of ' b ' due to ' a '.

$$F_{ba} = I_b L B_a$$
$$= \frac{\mu_0 I_a I_b}{2\pi d} L$$

Definition -
The 'ampere' is that value of steady current which, when maintained in each of the two very long, straight, parallel conductors of negligible cross-section, and
placed one metre apart in vacuum, would produce on each of these conductors a force equal to 2×10^{-7} newton per metre of length.
(ii) Work done by the magnetic force on the charge is zero as force is perpendicular to $\vec{v}$.
(iii) The velocity ($\vec{v}$) is at an arbitrary angle θ w.r.t the magnetic field ($\vec{B}$).

OR

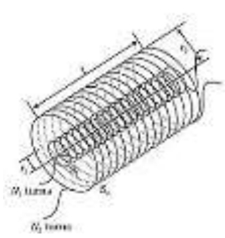
(b) (i) The two faces of a current carrying loop behave like two poles of a magnet therefore can be considered as a magnetic dipole placed along its axis.
(ii) Magnetic moment (M) α Current (I)
α Area (A)
$\vec{M} = IA$
Direction is same as the area vector.
(iii) Net force acting on the coil is zero.
The potential energy (U_B) of a current carrying loop in an external magnetic field =-M.B
For the coil to be in stable equilibrium U_B should be minimum so $\theta = 0°$.
Therefore, magnetic flux (ϕ) due to the total field = $(B_{coil} + B_{ext})$A, which is its maximum value.

SECTION A

123. **(c)** $qa(\hat{i} + \hat{j})$

124. **(d)** 12 V, 0.5 A

125.



Let N_1 and N_2 be the total number of turns of coils S_1 and S_2 respectively. When current I_2 is set up in S_2, flux linkage with solenoid S_1 is –

$N_1\phi_1 = M_{12}I_2$ .... (i)

$N_1\phi_1 = (n_1 l)(\pi r_1^2)(\mu_0 n_2 I_2)$

$N_1\phi_1 = \mu_0 n_1 n_2 \pi r_1^2 l I_2$ .... (ii)

From (i) and (ii)

$M_{12} = \mu_0 n_1 n_2 \pi r_1^2 l$

Considering Reverse case, when I_1 current is set up in S_1, flux linkage with S_2 is –

$N_2\phi_2 = M_{21}I_1$

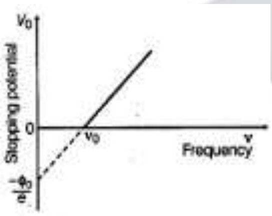
$N_2\phi_2 = (n_2 l)(\pi r_1^2)(\mu_0 n_1 I_1)$

From (iii) and (iv)

$M_{21} = n_1 n_2 \pi r_1^2 l$
$M_{12} = M_{21}$

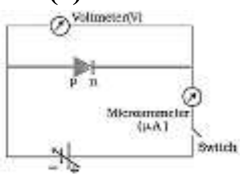
126. **(a)** Total current $I = I_c + I_d$
outside the capacitor
$I_d = 0$
$I = I_c$
Inside the capacity or
$I_c = 0$
$I = I_d = \varepsilon_0 \dfrac{d\phi_E}{dt}$
$= \varepsilon_0 \dfrac{d}{dt}[EA]$
$= \varepsilon_0 \dfrac{d}{dt}\left[\dfrac{\sigma}{\varepsilon_0} A\right]$
$= \dfrac{\varepsilon_0}{\varepsilon_0} A \dfrac{d}{dt}\left[\dfrac{Q}{A}\right]$
$I = \dfrac{dQ}{dt} = I_c$
(b) Yes
Current entering the capacitor is (I_c) and between the plates capacitor is (I_d)
$I_c = I_d$
which validates Kirchhoff's junction rule.

127. **(a)**

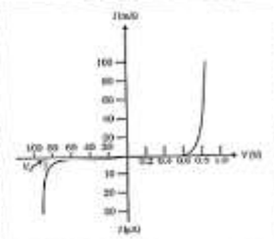


Value of work function can be obtained from intercept.
(b) (i)
$p = \sqrt{2mK}$
$= \sqrt{2 \times 9.1 \times 10^{-31} \times 80 \times 1.6 \times 10^{-19}}$
$= 4.8 \times 10^{-24}$ kg m/s
(ii) $\lambda = \frac{h}{p} = \frac{6.63 \times 10^{-34}}{4.8 \times 10^{-25}} = 1.38 \times 10^{-9}$ m

128. **(a)**



Circuit diagram for Reverse characteristics



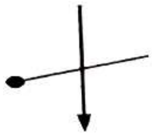
(b)
Please do not deduct marks for not writing values.
(c) Any two informations
Knee voltage / reverse saturation current / Breakdown voltage / very low resistance in forward biasing / very high resistance in Reverse biasing.

129. **(a)** Difference in the mass of the nucleus and its constituents is defined as mass defect. Binding Energy is the energy required to separate the nucleons from the nucleus. In Fission process a heavy nucleus splits into lighter nuclei and energy is released. As a result the Binding Energy per nucleon increases.

(b) $\Delta m = \left(m_p + m_n\right) - m_d$
$\Delta m = (1.007277 + 1.008665) - 2.013553$
$\Delta m = 0.002389u$
Energy released $= \Delta m \times c^2$
Energy released $= 0.002389 \times 931.5 = 2.2253\text{MeV} \approx 2.22\text{MeV}$

SECTION – D

130. **(i)** (c)



(ii) (a)For a convex mirror magnification is always negative
(iii) (b)2f

OR

(b) 12 cm
(iv) (c) $\sqrt{X_1 X_2}$

131. **(i)** (b) 5 mC
(ii) (a) zero
(iii) (d) $[M^0\ L^0 T A^0]$
(iv) (a) $\frac{1}{2\sqrt{e}} mA$
1 mark for this part may be given to all the students who have attempted other parts of the question.

OR

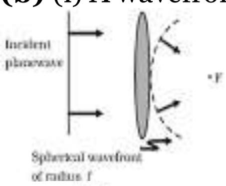
(b) 0.5 mA

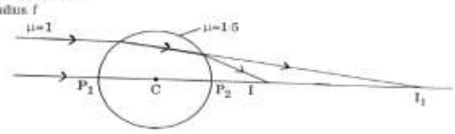
132. **(a)** (i) (1) If the phase difference between the displacement produced by each of the wave from two sources does not change with time then two sources are said to be coherent.
(2) Two independent sources will never be coherent because phase difference between them will not be constant.
(ii) (1) Distance between adjacent bright fringe = fringe width

$$\beta = \frac{\lambda D}{d}$$
$$= \frac{600 \times 10^{-9} \times 1.2}{0.1 \times 10^{-3}} = 7.2 \text{ mm}$$
(2) $\theta = \frac{\lambda}{d}$
$$= \frac{600 \times 10^{-9}}{0.1 \times 10^{-3}} = 6 \times 10^{-3}\text{rad} = 0.34°$$
Give full marks if the student writes the answer in radians only.

OR

(b) (i) A wavefront is a locus of all the points which oscillate in phase.





(ii)
From Ist surface, Refraction is from rarer to denser medium and object is at ∞
$n_1 = 1, n_2 = 1.5, R = 15 \text{ cm}, u = \infty$

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

$\frac{1.5}{v} - \frac{1}{\infty} = \frac{1.5 - 1}{15}$

$v = 45 \text{ cm}$

From 2^{nd} surface, Refraction is from denser to rarer medium and object is at 15 cm

$n_1 = 1, n_2 = 1.5, R = -15 \text{ cm}, u = 15 \text{ cm}$

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

$\frac{1}{v} - \frac{1.5}{15} = \frac{1 - 1.5}{-15}$

$v = 7.5 \text{ cm}$

133. **(a)** (i) $\vec{E} = \frac{3\times10^5}{r^2}\hat{r}$

(Given) $dV = -\vec{E}\cdot d\vec{r}$

$V = 3 \times 10^5/r$

Electrostatic energy of the system in the absence of the field $U_i = \frac{Kq_1q_2}{r_{12}}$

Electrostatic energy in the presence of the field

$U_f = \frac{Kq_1q_2}{r_{12}} + q_1V(\vec{r}_1) + q_2V(\vec{r}_2)$

$\Delta U = U_f - U_i = q_1V(\vec{r}_1) + q_2V(\vec{r}_2)$

$\Delta U = \frac{5 \times 10^{-6} \times 3 \times 10^5}{3 \times 10^{-2}} - \frac{1 \times 10^{-6} \times 3 \times 10^5}{3 \times 10^{-2}}$

$= 40 \text{ J}$

(ii)(1) $C = \frac{Q}{V} = \frac{80}{16} = 5\mu \text{ F}$

(2) $C' = KC$

$= 3 \times 5\mu \text{ F} = 15\mu \text{ F}$

$V' = \frac{Q}{C'} = \frac{80\mu C}{15\mu \text{ F}} = 5.33 \text{ V}$

(3) No,

The capacitance of the system depends on its geometry.

OR

(b) Total charge for A = Total charge for B = Total charge for C = $_{+}4q$ As ,

$E = \frac{kQ}{r^2}$

Since $Q = 4q$ and $r = 3R$

$E = \frac{k(4q)}{9R^2} = \frac{4kq}{9R^2}$

$E_A = E_B = E_c$

(ii)$V_c = \left[\frac{k\times6\times10^{-6}}{5\times10^{-2}} - \frac{k\times6\times10^{-6}}{5\times10^{-2}}\right]$

$= 0$

$= \left[\frac{k \times 6 \times 10^{-6}}{15 \times 10^{-2}} - \frac{k \times 6 \times 10^{-6}}{5 \times 10^{-2}}\right]$

$V_A = \frac{k \times 6 \times 10^{-6}}{10^{-2}}\left[\frac{1-3}{15}\right]$

$= -\frac{9 \times 10^9 \times 6 \times 10^{-6} \times 2}{15 \times 10^{-2}}$

$= -7.2 \times 10^5 \text{ V}$

$W = q[V_A - V_c]$

$W = 5 \times 10^{-6}[-7.2 \times 10^5 - 0]$

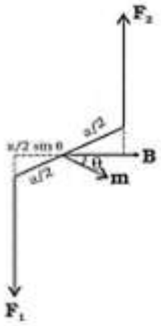
$W = -3.6 \text{ J}$

134. **(a)** (i) Near point *P*

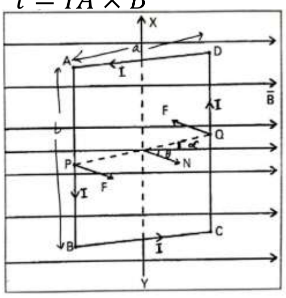
Magnetic field is acting into the plane of the paper as Force is acting upwards.
Near point Q
Magnetic field is into the plane of paper as force is acting upwards.
Near point R
Magnetic field is acting out of the plane of the paper as $\vec{F}$ is acting downwards.
Relative Magnitude of the Magnetic field.
As B $\alpha \frac{1}{r}$
Therefore,
Near point P , magnitude of B is small.
Near point Q, B is relatively smaller than point P.
Near point R, B is relatively larger than point P .
$\left(B_Q < B_P < B_R\right)$
(ii)Let r be the radius of the circular coil and I is the current in the coil then
$B = \frac{\mu_0 I}{2r}$ or $I = \frac{2Br}{\mu_0}$
$A = \pi r^2$ $r = \sqrt{\frac{A}{\pi}}$
$M = IA$
$= \frac{2Br}{\mu_0} A$
$= \frac{2BA}{\mu_0}\sqrt{\frac{A}{\pi}}$

OR

(b)



(i)
$\vec{F}_1$ and $\vec{F}_2$ are the forces acting on two arms of the rectangular coil having sides a and b .
$|\vec{F}_1| = |\vec{F}_2| = IbB$
(b = length of the arm)
Forces constitute a couple. The magnitude of Torque on the loop is
$\tau = F_1 \frac{a}{2}\sin\theta + F_2 \frac{a}{2}\sin\theta$
$= IabB\sin\theta$
$= IAB\sin\theta$
$\vec{\tau} = I\vec{A} \times \vec{B}$



If the plane of the current carrying coil marks an angle $\propto$ with the magnetic field $\vec{F}_{DA} = -\vec{F}_{BC}$ (cancel each other).
Force on the arm DC is into the plane of the paper
$|F_{DC}| = IbB.$
Force on the arm AB is out of the plane of the paper.
$|F_{AB}| = IbB$
Both of them form a couple and Torque acting on the coil is $\tau =$ either force $\times$ perpendicular distance between the two forces.

$$\tau = IbB \times a\cos\alpha$$
$$= IabB\cos\alpha$$
$$\tau = IAB\cos\alpha$$

Let $\hat{n}$ = outward drawn normal to the plane of the coil.

$$\theta + \alpha = 90^\circ$$
$$\alpha = 90^\circ - \theta$$
$$\tau = IAB\cos(90 - \theta)$$
$$= IAB\sin\theta$$
$$\vec{\tau} = I\vec{A} \times \vec{B}$$

(ii) (1) $r = \frac{mv}{qB} = \frac{\sqrt{2mK}}{qB}$

$$r \alpha \sqrt{K}$$
$$\frac{r'}{r} = \frac{\sqrt{\frac{K}{2}}}{\sqrt{K}} = \frac{1}{\sqrt{2}}$$
$$r' = \frac{r}{\sqrt{2}}$$

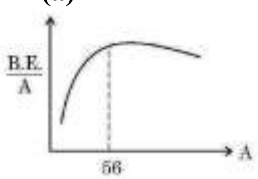
(2) $T = \frac{2\pi m}{qB}$

Time period does not depend on Kinetic Energy $\therefore$ Time period will not change.

SECTION A

135. **(a)**

136. **(a)** 2
137. **(b)** $(-3\hat{j} + 2\hat{k})\mu$N
138. **(d)** 0.1 A
139. **(b)** 2866
140. **(d)** $\frac{i_0 v_0}{2}\cos\phi$
141. **(b)** have wavelength smaller than that of ultraviolet radiation
142. **(b)** $\frac{\pi H^2}{(n^2-1)}$
143. **(c)** 2.5e V
144. **(c)** The barrier height and the depletion layer width both decrease.
145. **(b)** $\lambda_e > \lambda_p > \lambda_d$
146. **(a)**



147. **(c)** Assertion (A) is true but Reason (R) is false.
148. **(d)** Assertion (A) is false and Reason (R) is also false.
149. **(a)** Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion(A).

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

151. Net e.m. f $= (n-4)E$

$I = \frac{(n-4)E}{nr}$

Potential difference across' X '

$V = E + Ir$

152. **(a)** Condition for Minima $a \sin\theta = n\lambda$

For First Minima $n = 1$

$a\sin 30^\circ = 600 \times 10^{-9}$ m

$a \times \frac{1}{2} = 600 \times 10^{-9}$ m

$a = 1200 \times 10^{-9}$ m

$= 1.2 \times 10^{-6}$ m

OR

(b) Phase difference $= \frac{2\pi}{\lambda} \times$ path difference

$\Delta\phi = \frac{2\pi}{\lambda}\Delta x$

$\Delta x = \frac{\lambda}{8}$ (given) $\Delta\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{8}$

$\Delta\phi = \frac{\pi}{4}$

$I = I_\circ + I_\circ + 2\sqrt{I_\circ I_\circ}\cos\frac{\pi}{4}$

$= 2I_\circ + 2I_\circ \times \frac{1}{\sqrt{2}}$ $I = 2I_\circ\left(1 + \frac{1}{\sqrt{2}}\right)$

$= I_\circ(2 + \sqrt{2})$

$I = 3.414 I^\circ$

153. $\frac{1}{f} = \left(\frac{n_g}{n_w} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

For double convex lens $R_1 = R$ and $R_2 = -R$

$\frac{1}{f} = \left(\frac{1.5}{1.33} - 1\right)\left(\frac{2}{R}\right)$

$= \left(\frac{1.5 - 1.33}{1.33}\right)\left(\frac{2}{17}\right)$

$f = 66.5$ cm

154. $E_n = \frac{-13.6}{n^2}$ eV

For $E_n = -1.51$eV

$-1.51 = \frac{-13.6}{n^2}$

$n = 3$

For $E_n = -3.40$eV

$-3.40 = \frac{-13.6}{n^2}$

$n = 2$

$r = 0.53 n^2$ Å

change in radius

$\Delta r = 0.53[3^2 - 2^2]$

$= 0.53 \times 5$

$= 2.65$ A

155. 1 dopant atom for 5×10^7 Si atoms

and number density of Si atoms $= 5 \times 10^{28} \frac{\text{atoms}}{\text{m}^3}$

No. of holes created per $m^3 = \frac{5\times10^{28}}{5\times10^7} = 10^{21}$ (given)

Number of holes created per cubic centimeter $= \frac{10^{21}}{10^6} = 10^{15}$

SECTION - C

156. **(a) (i)** Because $E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$

$$E_{eq} = \frac{3 \times 0.4 + 6 \times 0.2}{0.6} = 4\text{ V}$$

(ii) $r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$

$$r_{eq} = \frac{0.2 \times 0.4}{0.2 + 0.4} = 0.133\Omega$$

(iii) $I = \frac{E}{R + r_{eq}}$

$$I = \frac{4}{4 + 0.13} = \frac{4}{4.13}A$$

$$I = 0.9A$$

OR

(b) (i) $l' = 2l$

$Al = A'l' =$ volume of the wire

$$Al = A'(2l)$$

$$\frac{A}{2} = A'$$

$$\mathrm{R} = \frac{\rho l}{A}$$

$$R' = \frac{\rho l'}{A'}$$

$$R' = \frac{\rho(2l)}{A/2}$$

$$\frac{R'}{R} = 4$$

(ii) $\mathrm{v_d} = \frac{\mathrm{eE}}{\mathrm{m}}\tau$

$$\mathrm{v_d} = \frac{\mathrm{eV}}{\mathrm{ml}}\tau$$

$$\mathrm{v'_d} = \frac{\mathrm{eV}}{\mathrm{ml'}}\tau$$

$$\frac{\mathrm{v'_d}}{\mathrm{v_d}} = \frac{l}{l'} = \frac{1}{2}$$

(ii) No

157. **(a)** $\vec{\mathrm{B}} = \frac{\mu_s \mathrm{I}}{2\pi\,\mathrm{d}}(-\hat{\mathrm{K}})$

(b) $\vec{\mathrm{F}}_\mathrm{B} = \mathrm{q}(\vec{\mathrm{v}} \times \vec{\mathrm{B}}) = \frac{\mathrm{qv}\mu_s \mathrm{I}}{2\pi\,\mathrm{d}}(-\hat{\mathrm{j}})$

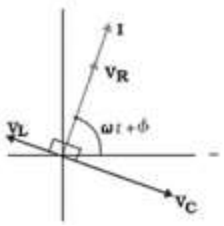
(c) $\mathrm{q}\vec{\mathrm{F}}_\mathrm{e} = -\vec{\mathrm{F}}_\mathrm{B}$ (For undeviation of charge particle)

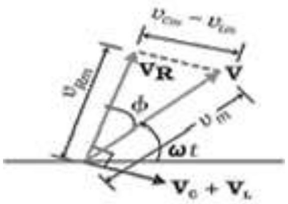
$$\vec{\mathrm{F}}_\mathrm{e} = \frac{\mathrm{qv}\mu_o \mathrm{I}}{2\pi\,\mathrm{d}}(\hat{\mathrm{j}})$$

$$\vec{\mathrm{F}}_\mathrm{e} = \mathrm{q}\vec{\mathrm{E}}\vec{\mathrm{E}}$$

$$\vec{\mathrm{E}} = \frac{\mu_o \mathrm{vI}}{2\pi\,\mathrm{d}}\hat{\mathrm{j}}$$

158. **(a)**





(b)
$V_{Rm} = i_m R, V_{Cm} = i_m X_c, V_{Lm} = i_m X_L$
From Phasor diagram
$V_m^2 = V_{Rm}^2 + (V_{Cm} - V_{Lm})^2$
$V_m^2 = (i_m R)^2 + (i_m X_c - i_m X_L)^2$
$= (i_m)^2[R^2 + (X_c - X_L)^2]$

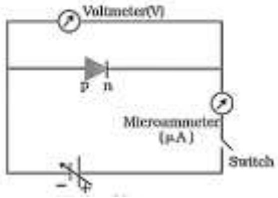
Or

$$i_m = \frac{V_m}{\sqrt{R^2 + (X_c - X_L)^2}}$$
$$i_m = \frac{V_m}{Z}$$
$$Z = \sqrt{R^2 + (X_c - X_L)^2}$$
From phasor diagram
$$\tan\theta = \frac{V_{Cm} - V_{Lm}}{V_{Rm}}$$
$$= \frac{X_c - X_L}{R}$$
$$\theta = \tan^{-1}\left(\frac{X_c - X_L}{R}\right)$$

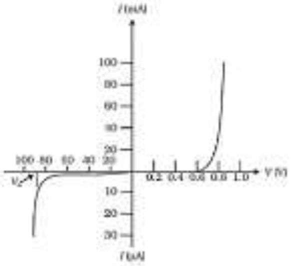
159. **(a)** Total current $I = I_c + I_d$
outside the capacitor
$I_d = 0$
$I = I_c$
Inside the capacitor
$I_c = 0$
$$I = I_d = \varepsilon_0 \frac{d\phi_E}{dt}$$
$$= \varepsilon_0 \frac{d}{dt}[EA]$$
$$= \varepsilon_0 \frac{d}{dt}\left[\frac{\sigma}{\varepsilon_0} A\right]$$
$$= \frac{\varepsilon_0}{\varepsilon_0} A \frac{d}{dt}\left[\frac{Q}{A}\right]$$
$$I = \frac{dQ}{dt} = I_c$$
(b) Yes
Current entering the capacitor is (I_c) and between the plates capacitor is (I_d)
$I_c = I_d$
which validates Kirchhoff's junction rule.

160. **(a)** Three features
(i) The existence of threshold frequency (v_0)
(ii) Maximum Kinetic energy of photoelectrons is independent of intensity of incident radiation.
(iii) Instantaneous nature of photoelectric effect.
(b) slope $= \frac{h}{e}$
$h = e \times$ slope
$= 1.6 \times 10^{-19} \times 4.12 \times 10^{-15}$
$= 6.6 \times 10^{-34}$Js

161. **(a)**



Circuit diagram for Reverse characteristics



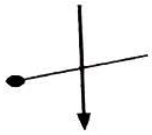
(b)
Please do not deduct marks for not writing values.
(c) Any two informations
Knee voltage / reverse saturation current / Breakdown voltage / very low resistance in forward biasing / very high resistance in Reverse biasing.

162. **(a)** Difference in the mass of the nucleus and its constituents is defined as mass defect. Binding Energy is the energy required to separate the nucleons from the nucleus. In Fission process a heavy nucleus splits into lighter nuclei and energy is released. As a result the Binding Energy per nucleon increases.

(b) $\Delta m = \left(m_p + m_n\right) - m_d$
$\Delta m = (1.007277 + 1.008665) - 2.013553$
$\Delta m = 0.002389u$
Energy released $= \Delta m \times c^2$
Energy released $= 0.002389 \times 931.5 = 2.2253 MeV \approx 2.22 MeV$

SECTION – D

163. **(i) (c)**



(ii) (a) For a convex mirror magnification is always negative
(iii) (b)2f

OR

(b) 12 cm
(iv) (c)$\sqrt{X_1 X_2}$

164. **(i) (b)** 5 mC
(ii)(a) zero
(iii)(d) $[M^0\ L^0 T A^0]$
(iv) (a) $\frac{1}{2\sqrt{e}} mA$
1 mark for this part may be given to all the students who have attempted other parts of the question.

OR

(b) 0.5 mA

165. **(a) (i)** (1) If the phase difference between the displacement produced by each of the wave from two sources does not change with time then two sources are said to be coherent.
(2) Two independent sources will never be coherent because phase difference between them will not be constant.
(ii) (1) Distance between adjacent bright fringe = fringe width

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

$$= \frac{600 \times 10^{-9} \times 1.2}{0.1 \times 10^{-3}} = 7.2 \text{ mm}$$

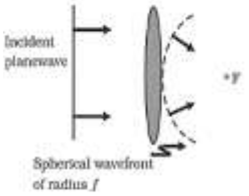
(2) $\theta = \frac{\lambda}{d}$

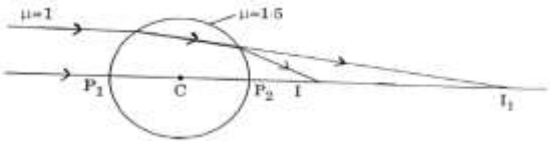
$= \frac{600 \times 10^{-9}}{0.1 \times 10^{-3}} = 6 \times 10^{-3}\text{rad} = 0.34^\circ$

Give full marks if the student writes the answer in radians only.

OR

(b) (i) A wave front is a locus of all the points which oscillate in phase.





(ii)

From I^{st} surface, Refraction is from rarer to denser medium and object is at ∞

$n_1 = 1, n_2 = 1.5, R = 15 \text{ cm}, u = \infty$

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

$\frac{1.5}{v} - \frac{1}{\infty} = \frac{1.5 - 1}{15}$

$v = 45 \text{ cm}$

From 2^{nd} surface, Refraction is from denser to rarer medium and object is at 15 cm

$n_1 = 1, n_2 = 1.5, R = -15 \text{ cm}, u = 15 \text{ cm}$

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

$\frac{1}{v} - \frac{1.5}{15} = \frac{1 - 1.5}{-15}$

$v = 7.5 \text{ cm}$

166. **(a) (i)** $\vec{E} = \frac{3\times10^5}{r^2}\hat{r}$

$V = 3 \times 10^5/r$

(Given) $dV = -\vec{E} \cdot d\vec{r}$

Electrostatic energy of the system in the absence of the field $U_i = \frac{Kq_1q_2}{r_{12}}$

Electrostatic energy in the presence of the field

$U_f = \frac{Kq_1q_2}{r_{12}} + q_1V(\vec{r}_1) + q_2V(\vec{r}_2)$

$\Delta U = U_f - U_i = q_1V(\vec{r}_1) + q_2V(\vec{r}_2)$

$\Delta U = \frac{5\times10^{-6}\times3\times10^5}{3\times10^{-2}} - \frac{1\times10^{-6}\times3\times10^5}{3\times10^{-2}}$

= 40 J

(ii) 1) $C = \frac{Q}{V} = \frac{80}{16} = 5\mu \text{ F}$

(2) $C' = KC$

$= 3 \times 5\mu \text{ F} = 15\mu \text{ F}$

$V' = \frac{Q}{C'} = \frac{80\mu C}{15\mu \text{ F}} = 5.33 \text{ V}$

(3) No,

The capacitance of the system depends on its geometry.

OR

(b) Total charge for A = Total charge for B = Total charge for C = $_{+}4q$ As ,

$E = \frac{kQ}{r^2}$

Since $Q = 4q$ and $r = 3R$

$E = \frac{k(4q)}{9R^2} = \frac{4kq}{9R^2}$

$E_A = E_B = E_c$

(ii) $V_c = \left[\frac{k\times6\times10^{-6}}{5\times10^{-2}} - \frac{k\times6\times10^{-6}}{5\times10^{-2}}\right]$

$= 0$

$= \left[\frac{k\times6\times10^{-6}}{15\times10^{-2}} - \frac{k\times6\times10^{-6}}{5\times10^{-2}}\right]$

$V_A = \frac{k\times6\times10^{-6}}{10^{-2}}\left[\frac{1-3}{15}\right]$

$= -\frac{9\times10^{9}\times6\times10^{-6}\times2}{15\times10^{-2}}$

$= -7.2\times10^{5}$ V

$W = q[V_A - V_c]$

$W = 5\times10^{-6}[-7.2\times10^{5} - 0]$

$W = -3.6$ J

167. **(a) (i)** Near point P

Magnetic field is acting into the plane of the paper as Force is acting upwards.

Near point Q

Magnetic field is into the plane of paper as force is acting upwards.

Near point R

Magnetic field is acting out of the plane of the paper as $\vec{F}$ is acting downwards.

Relative Magnitude of the Magnetic field.

As $B \, \alpha \frac{1}{r}$

Therefore,

Near point P , magnitude of B is small.

Near point Q, B is relatively smaller than point P.

Near point R, B is relatively larger than point P .

$(B_Q < B_P < B_R)$

(ii) Let r be the radius of the circular coil and I is the current in the coil then

$B = \frac{\mu_0 I}{2r}$ or $I = \frac{2Br}{\mu_0}$

$A = \pi r^2 \; r = \sqrt{\frac{A}{\pi}}$

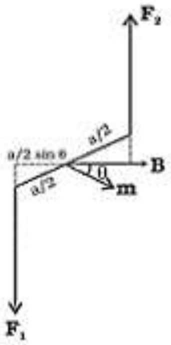
$M = IA$

$= \frac{2Br}{\mu_0}A$

$= \frac{2BA}{\mu_0}\sqrt{\frac{A}{\pi}}$

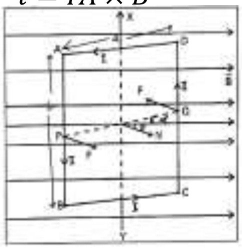
OR

(b)



(i) $\vec{F}_1$ and $\vec{F}_2$ are the forces acting on two arms of the rectangular coil having sides a and b .
$|\vec{F}_1| = |\vec{F}_2| = IbB$
(b = length of the arm)
Forces constitute a couple. The magnitude of Torque on the loop is

$$\tau = F_1 \frac{a}{2} \sin\theta + F_2 \frac{a}{2} \sin\theta$$
$$= IabB\sin\theta$$
$$= IAB\sin\theta$$
$$\vec{\tau} = I\vec{A} \times \vec{B}$$



If the plane of the current carrying coil marks an angle $\propto$ with the magnetic field $\vec{F}_{DA} = -\vec{F}_{BC}$ (cancel each other).
Force on the arm DC is into the plane of the paper
$|F_{DC}| = IbB.$
Force on the arm AB is out of the plane of the paper.
$|F_{AB}| = IbB$
Both of them form a couple and Torque acting on the coil is $\tau =$ either force $\times$ perpendicular distance between the two forces.

$$\tau = IbB \times a\cos\alpha$$
$$= IabB\cos\alpha$$
$$\tau = IAB\cos\alpha$$

Let $\hat{n}$ = outward drawn normal to the plane of the coil.

$$\theta + \alpha = 90^\circ$$
$$\alpha = 90^\circ - \theta$$
$$\tau = IAB\cos(90 - \theta)$$
$$= IAB\sin\theta$$
$$\vec{\tau} = I\vec{A} \times \vec{B}$$

(ii) (1) $r = \frac{mv}{qB} = \frac{\sqrt{2mK}}{qB}$

$r \, \alpha \sqrt{K}$

$$\frac{r'}{r} = \frac{\sqrt{\frac{K}{2}}}{\sqrt{K}} = \frac{1}{\sqrt{2}}$$
$$r' = \frac{r}{\sqrt{2}}$$

(2) $T = \frac{2\pi m}{qB}$

Time period does not depend on Kinetic Energy ∴ Time period will not change.

168. **(a)** conservative and field lines do not form closed loops.

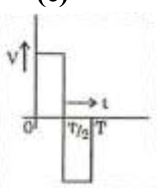
169. **(b)** diamagnetic

170. **(b)** anticlockwise current

171. **(c)** $\frac{5.0}{\sqrt{2}} \times 10^{-10}\hat{k}$T

172. **(d)** P and S

173. **(c)**



174. **(d)** $\frac{R}{2(n-1)}$
175. **(A)** resistor / **(C)** capacitor
176. **(c)** Lyman series
177. **(d)** 5
178. **(b)** If both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A).
179. **(c)** If Assertion (A) is true but Reason (R) is false.
180. **(a)** If both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
181. **(c)** If Assertion (A) is true but Reason (R) is false.

SECTION -B

182. $V - V_o = IR$

$V - 0.7 = (15 \times 10^{-3}) \times 1000$

$V = 15.7$ volt

183. Angular width $(\theta) = \frac{\lambda}{d}$

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

$$= \frac{500 \times 10^{-9}}{0.2 \times \frac{\pi}{180}}$$

$$d = \frac{45}{\pi} \times 10^{-5} \text{ m}$$

$= 0.14$ mm

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

$$\frac{1}{v} = -\frac{1}{15} + \frac{1}{10}$$

On solving: -

v = 30 cm

Magnitude of $OO' = 30 - 10 = 20$ cm

Direction is away from the lens.

185. **(i)** $\phi = \frac{hc}{\lambda_o}$

$$\phi = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{450 \times 10^{-9} \times 1.6 \times 10^{-19}}$$

$\phi = 2.76$eV

(ii) $K_{max} = h\upsilon - \phi$

$$h\upsilon = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{250 \times 10^{-9} \times 1.6 \times 10^{-19}} = 4.97\text{eV}$$

$K_{max} = 4.97 - 2.76$

$K_{max} = 2.21$eV

186. **(a)** $R_1 = \frac{\rho l_1}{A}; R_2 = \frac{\rho l_2}{A}$

$$\frac{l_1}{l_2} = \frac{2}{3} => \frac{R_1}{R_2} = \frac{2}{3}$$

$$I \alpha \frac{1}{R}$$

$$\Rightarrow \frac{I_1}{I_2} = \frac{3}{2}$$

$$\Rightarrow I_1 = \frac{3}{5} \times 15 = 9 \text{ A}$$

$$I_2 = \frac{2}{5} \times 15 = 6 \text{ A}$$

OR

(b) In steady state,

$2V - V = i(2R + R)$

$i = \frac{V}{3R}$

(i) $V_P - V_Q = -V - iR$

$= -V - \frac{V}{3}$

$V_P - V_Q = -\frac{4V}{3}$

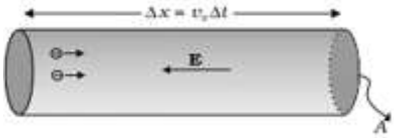
(ii) $V_P - V_Q = -V + V_C$

$-\frac{4V}{3} = -V + V_C$

$V_C = -\frac{V}{3}$

SECTION C

187. **(a)** Electrical conductivity: - It is the reciprocal of the resistivity.



$I\Delta t = +neA|\vec{v}_d|\Delta t$

Substituting $|\vec{v}_d| = \frac{e|\vec{E}|}{m}\tau$

$I\Delta t = \frac{e^2 A}{m}\tau n\Delta t|\vec{E}|$

$I = |\vec{j}|A$

$\Rightarrow |\vec{j}| = \frac{ne^2}{m}\tau|\vec{E}|$ .... (1)

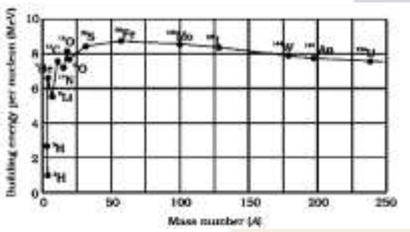
$\vec{j} = \sigma\vec{E}$ .... (2)

Comparing eq.(1) & (2):-

$\sigma = \frac{ne^2}{m}\tau$

(b) On increasing the temperature, the value of τ decreases as a consequence conductivity decreases and hence resistivity increases.

188. **(a)**



Full credit to be given even if the values are not shown.

Significance of the binding energy curve -

(Anyone)

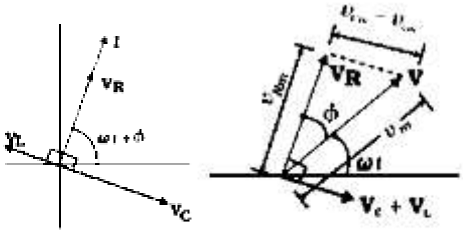
- Why lighter nuclei undergo fusion and heavier nuclei undergo fission.
- Nuclear forces are short ranged.
- Energy is released in both nuclear fission and nuclear fusion.

(b) **(i)** Nuclear fusion

(ii) Decreases

(iii) Energy is produced

189. **(a)**

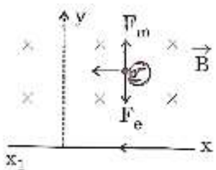


$\vec{V}_L + \vec{V}_R + \vec{V}_C = \vec{V}$
$v_m^2 = v_{Rm}^2 + (v_{Cm} - v_{im})^2$
$= (i_m R)^2 + (i_m X_C - i_m X_L)^2$
$v_m^2 = i_m^2 [R^2 + (X_C - X_L)^2]$
$i_m = \dfrac{v_m}{\sqrt{R^2 + (X_C - X_L)^2}}$
$=> Z = \sqrt{R^2 + (X_C - X_L)^2}$
(b) When $X_L = X_C$, the impedance of the series LCR circuit is minimum and the current flowing through it is maximum.
$\omega_0 = \dfrac{1}{\sqrt{LC}}$

190. **(a)** Intensity (I) α (amplitude)
$=> m = n^2$
(b) (i) White surface
As white surface will reflect maximum light falling on it, the change in momentum of light will be maximum and as a consequence the pressure exerted by the light will be maximum.
(ii) Black surface
As black surface absorbs maximum light falling on it, the change in momentum of light will be minimum and as a consequence the pressure exerted by the light will be minimum.

191. **(a)** In an extrinsic semiconductor, the charge carriers whose number density is large are known as majority charge carriers.
In an extrinsic semiconductor, the charge carriers whose number density is small are known as minority charge carriers.
(b) Due to the applied forward voltage, electrons from n-side cross the depletion region and reach p-side. Similarly, holes from p-side cross the junction and reach the n-side. Due to the movement of these charge carriers current is produced.
(c) At V = −0.6 volt, I = 0, so dynamic resistance is infinite.

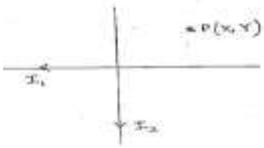
192. **(i)**



(ii) Electric force
Magnetic force
Alternatively: -
$F_E = eE$
$F_B = evB$
(iii) ev_o B = Ee
$v_o \text{x} \left[\dfrac{\mu_o \text{I}}{2\pi \text{ d}}\right] = \text{E}$
$v_o = \dfrac{(2\pi \text{ d})\text{E}}{\mu_o \text{I}}$

OR

(b)



Magnetic field due to conductor carrying current $I_1 (\vec{B}_1) = \frac{\mu_0 I_1}{2\pi Y}(-\hat{k})$

Magnetic field due to conductor Carrying current $I_2 (\vec{B}_2) = \frac{\mu_0 I_2}{2\pi X}(\hat{k})$

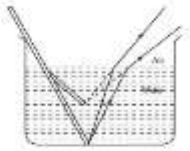
$$\vec{B}_P = \vec{B}_1 + \vec{B}_2$$

$$\vec{B}_p = \frac{\mu_0}{2\pi}\left[\frac{I_2}{X} - \frac{I_1}{Y}\right]\hat{k}$$

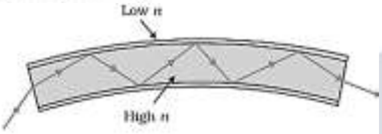
Direction will be along the Z -axis.

193. **(a)** Width of the parallel beam of light increases in water.

(b) Due to refraction of light, the image of the portion immersed in water appears to be raised.



(c)



SECTION D

194. **(i) (b)** are parallel to each other.

(ii) (c) me

(iii) Full 1 mark to be awarded to all the students who have attempted this part of the question.

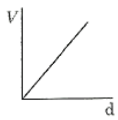
OR

(b) $\frac{1}{2}, \frac{1}{2}$

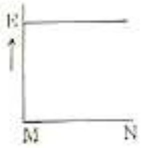
(iv) (d) 13.3μ m

195. **(i) (c)** $\frac{E}{4}$

(ii) (d)



(iii) (c)



(iv) (a) $(\vec{E}_1 + \vec{E}_2) \cdot \vec{d}$

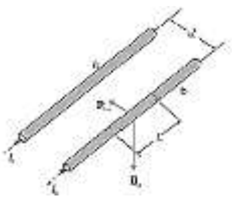
OR

(c) CK

SECTION E

196. **(a)** Reason -

(i) The source of force is the interaction between the field produced by the current carrying conductor and the external field in which it is placed.



Two long parallel conductors a& b, separated by a distance d, carrying currents I_a and I_b, respectively.
The magnetic field due to a,

$$B_a = \frac{\mu_0 I_a}{2\pi d}$$

The force F_{ba}, is the force on a segment L of ' b ' due to ' a '.

$$F_{ba} = I_b L B_a$$
$$= \frac{\mu_0 I_a I_b}{2\pi d} L$$

Definition -
The 'ampere' is that value of steady current which, when maintained in each of the two very long, straight, parallel conductors of negligible cross-section, and
placed one metre apart in vacuum, would produce on each of these conductors a force equal to 2×10^{-7} newton per metre of length.

(ii) Work done by the magnetic force on the charge is zero as force is perpendicular to $\vec{v}$.

(iii) The velocity ($\vec{v}$) is at an arbitrary angle θ w.r.t the magnetic field ($\vec{B}$).

OR

(b) (i) The two faces of a current carrying loop behave like two poles of a magnet therefore can be considered as a magnetic dipole placed along its axis.

(ii) Magnetic moment (M) α Current (I)
α Area (A)
$\vec{M} = IA$
Direction is same as the area vector.

(iii) Net force acting on the coil is zero.
The potential energy (U_B) of a current carrying loop in an external magnetic field =-M.B
For the coil to be in stable equilibrium U_B should be minimum so $\theta = 0°$.
Therefore, magnetic flux (ϕ) due to the total field = (B_{coil} + B_{ext})A, which is its maximum value.

197. **(i)** As the pencil lies between f and $2f$ such that one end of the pencil coincides with 2 f .

Position of the other end $(u) = -\left(2f - \frac{f}{4}\right) = -\frac{7f}{4}$

$$\text{Magnification}(m) = \frac{f}{f-u}$$

$$= \frac{-f}{-f - \left(-\frac{7f}{4}\right)}$$

$m = -\frac{4}{3}$

(ii) For prism;

$$i + e = A + \delta$$
$$45° + e = 30° + 15°$$
$$e = 0°$$

Hence, $r_2 = 0°$
Emergent ray is perpendicular to face AC.

OR

(b) (i)

(1) Distance of the nth bright fringe from the central maximum $(x_n) = \frac{n\lambda D}{d}$

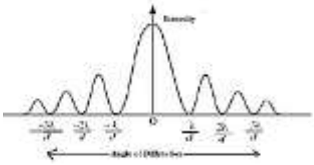
For n = 3

$$X_3 = \frac{3 \times 600 \times 10^{-9} \times 1}{1 \times 10^{-9}}$$
$$= 1800 \text{ m}$$

(2) $n_1 \lambda_1 = n_2 \lambda_2$

$$n_1 \times 600 = n_2 \times 480$$
$$\frac{n_1}{n_2} = \frac{480}{600}$$
$$\frac{n_1}{n_2} = \frac{4}{5}$$

Position of the 4^{th} bright fringe of 600 nm $= 4 \times 600 = 2400$ m



(ii) (1)

Angle of diffraction for zero intensity, $\theta = \frac{n\lambda}{a}$; n = 0,1,2, … … ….

(2) Diffraction of the light waves is not generally seen as compared to diffraction of sound waves as light waves have low wavelength.

198. **(a) (i)** Potential on sphere A $= V = \frac{Q}{4\pi\varepsilon_0 r}$

Charge on sphere A $= 4\pi\varepsilon_0 rV$

The charge is transferred to shell B.

Potential on shell B $= \frac{1}{4\pi\varepsilon_0} \times \frac{4\pi\varepsilon_0 rV}{R}$

Potential on shell B $= \frac{rV}{R}$

Potential on sphere A = Potential on shell B

(ii) Characteristics of equipotential surfaces: -

(Any two)

- Potential at all points on the surface is same.
- Equipotential surface is normal to the direction of the electric field.
- The work done in moving a charge on an equipotential surface is zero.

$V_0 - V = Ed = 50 \times 4$

$V_0 - V = 200V$

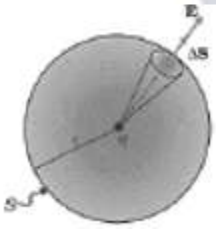
$V = 220V - 200V$

$V = 20V$

OR

(b) (i) Open Surface - A surface which does not enclose a volume.

Closed Surface - A surface which does enclose a volume.



(ii) Electric flux is defined as the number of electric field lines crossing an area normally.

Reason: -

Because any electric field line from the charge which enters the surface at one

(iii) Total charge enclosed by $S_1 = (-3 - 2 + 9)\mu C = 4\mu C$

Total charge enclosed by $S_2 = Q + 4\mu C$

$\phi_{s_2} = 4\phi_{s_1}$

$$\frac{Q + 4\mu C}{\varepsilon_0} = 4\left(\frac{4\mu C}{\varepsilon_0}\right)$$

$Q = 12\mu C$

SECTION A

199. **(c)** decreases by 4.55×10^{-23} kg

200. **(c)** R^3

201. **(b)** a semicircular path in XY plane

202. **(c)** 60°

203. **(b)** Sodium Chloride

204. **(a)** $10\sqrt{2}$ A

205. **(d)** 3.33×10^{-6} T

206. **(b)** Concave and real

207. **(c)** Photons of light and electrons both exhibit dual nature Photons of light and electrons both exhibit dual nature

208. **(b)** The red beam has more numbers of photons than the blue beam

209. **(a)** Sn

210. **(c)** Concentric horizontal circles around the wire

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

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

213. **(c)** Assertion (A) is true but Reason (R) is false.

214. **(b)** Both Assertion (A) and Reason (R) are true but reason (R) is not the correct explanation of the Assertion (A)

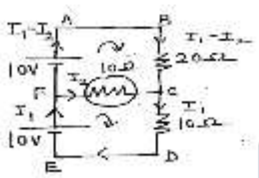
SECTION B

215. **(a) (i)** Brightness of the bulb ' S ' will be more than bulbs ' P ' and ' Q ' The current flowing through the bulb ' S ' is twice of the current in bulbs ' P ' and ' Q '.

(ii) Brightness of the bulb ' S ' and ' Q 'will be same The current flowing through both bulbs is same.

OR

(ii)



By applying Kirchhoff 's loop rule to closed loops ABCFA and FCDEF

$2I_1 - 3I_2 = 1 - -(1)$

$I_1 + I_2 = 1 - - - (2)$

On solving,

Current through the bulb,

$I_2 = \frac{1}{5}A$

216. $\theta = (2n+1)\frac{\lambda}{2a}$

For first secondary maxima n = 1

$\theta = \frac{3\lambda}{2a}$

$\theta = \frac{3 \times 550 \times 10^{-9}}{2 \times 0.55 \times 10^{-3}}$

$\theta = 1.5 \times 10^{-3}$ radian $= 0.086$ degree

217. $\frac{1}{f} = (n_{21} - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

$R_1 = R$ and $R_2 = -R$

$\frac{1}{15} = (1.55 - 1)\left[\frac{2}{R}\right]$

$R = 16.5$ cm

218. $\mathrm{lu} = \frac{1}{12}$ mass of carbon atom $= \frac{1.9926 \times 10^{-26}\ \mathrm{kg}}{12} = 1.66 \times 10^{-27}$ kg

mass of an electron $= 9.1 \times 10^{-31}$ kg

mass of two electrons $= \frac{2 \times 9.1 \times 10^{-31}}{1.66 \times 10^{-27}}$

$= 0.00109638\mathrm{u}$

mass of α-particle = mass of the normal helium atom - mass of two electrons

$= 4.0026030 - 0.00109638$

$= 4.00150662\mathrm{u}$

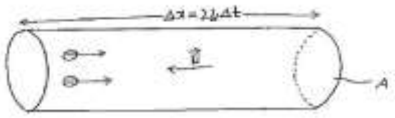
219. **(a) (i)** Trivalent

(ii) p - type semi conductor

(b) Electron concentration

$$n_e = \frac{n_i^2}{n_h}$$
$$n_e = \frac{(5 \times 10^8)^2}{8 \times 10^{12}}$$
$$n_e = 3.125 \times 10^4 \text{ m}^{-3}$$

220. **(a)(i)**



Total charge transported along E is

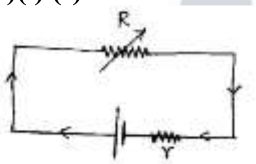
$$I\Delta t = \frac{e^2 A}{m} \tau n \Delta t E$$
$$\frac{I}{A} = \frac{ne^2}{m}\tau E$$
$$J = \frac{1}{\rho}E$$
$$\rho = \frac{m}{ne^2\tau}$$

(ii) From given graph

$$\frac{Q_1}{Q_2} = \frac{A_1 \text{ (Area of rectangle)}}{A_2 \text{ (Area of triangle)}}$$
$$\frac{Q_1}{Q_2} = \frac{2}{3/2}$$
$$Q_1 > Q_2$$

OR

(b)(i) (I)



$$V = E - Ir$$
$$IR = E - Ir$$
$$I = \frac{E}{R + r}$$

For maximum value of current $R = 0$

$$I_{\text{max}} = \frac{E}{r}$$

(II)

$$V = V_+ + V_- - Ir$$
$$V = E - Ir$$
$$V_{\text{max}} = E, \text{ when } I = 0$$

(ii)

$$I_1R_1 + I_1 r = I_2R_2$$
$$r = \frac{I_2R_2 - I_1R_1}{I_1 - I_2}$$

221. **(a)** $d\vec{B} = \frac{\mu_0}{4\pi}\frac{I(\vec{dl} \times \vec{r})}{r^3}$

(b) As $B = \frac{\mu_0}{4\pi}\frac{2I}{a}$

B_1 = Magnetic field due to current carrying wire along XX'

$\vec{B}_1 = \frac{\mu_0}{4\pi}\frac{2I}{a} = \frac{2 \times 2 \times 10^{-7}}{5} = (8 \times 10^{-8}\ T)(\hat{k})$

B_2 = Magnetic field due to current carrying wire along YY'

$\vec{B}_2 = \frac{\mu_0}{4\pi}\frac{2I}{a} = \frac{2 \times 2 \times 10^{-7}}{4} = 10 \times 10^{-8}\ T(-\hat{k})$

$\vec{B}_{net} = \vec{B}_2 + \vec{B}_1$

$= 2 \times 10^{-8}\ T(-\hat{k})$

Direction of resultant magnetic field along -Z axis.

222. **(a)** Induced current will be clockwise.

Due to the direction flow of current in coil 2, the face approaching to coil 1 behaves like south pole. Induced polarity on coil 1 viewed from the side of coil 2 will be south pole

(b) Induced current will be Anticlockwise Due to direction of flow of current in coil 2, face going away from coil 1 behaves like south pole. Induced polarity on coil 1 viewed from the side of coil 2, will be north pole.

(c) Induced current will be Anticlockwise

Till the resistance in coil 2 is increasing, the magnetic flux associated with coil 1 is decreasing. Hence according to Lenz's law current will induce in coil 1, momentarily and after that no induced current in coil

223. **(a)** (Any three)

• Electromagnetic wave carries energy.
• Electromagnetic wave carries momentum.
• Electromagnetic wave moves with velocity of light in vacuum.
• In electromagnetic wave, electric field vector, magnetic field vector
and direction of propagation, all are mutually perpendicular.
• Electromagnetic waves are transverse in nature.
• Electromagnetic waves do not require a physical medium to propagate and can travel through a vacuum.
• Electromagnetic waves consist of oscillating electric and magnetic fields.

(b)

• During charging of capacitor, time varying electric field / electric flux between the plates of capacitor induces the displacement current.
• Displacement current exists between the plates of capacitor.

224. **(a)**

• Speed of light will decrease
• Frequency remains unaffected
• Wavelength decreases

(b)

• Fringe width decreases
• Shapes does not change
• Position of central maxima does not change.

225. **(a)** Einstein Photo electric equation

$h\nu = h\nu_o + K_{max}$

$K_{max} = h(\nu - \nu_o)$

For $\nu < \nu_o$, K_{max} will be negative

Hence, Photoelectric emission is not possible.

(b) According to Einstein Photoelectric equation

$K_{max} = h(\nu - \nu_o)$

Hence $K_{max} \alpha \nu$

It shows K_{max} depends upon frequency only and not depends upon intensity.

(c) $eV_o = h\nu - h\nu_o$

$V_o = \frac{h}{e}\nu - \frac{h}{e}\nu_o$

This equation represents the equation of straight line $(y = mx + c)$ with the slope $\frac{h}{e}$.

226. **(a)** In p-type semiconductor

Majority charge carriers - holes
Minority charge carriers - electrons
In n-type semiconductors
Majority charge carriers - electrons
Minority charge carriers - holes
(b) Diffusion current - during the formation of p n junction, and due to the concentration gradient across p and n - sides, holes diffuse from p side to n
side ($p \rightarrow n$) and electrons diffuse from $n -$ side to $p -$ side ($n \rightarrow p$). This motion of charge carriers gives rise to diffusion current across the junction.
Drift current -Due to electric field at junction, an electron on $p -$ side of the junction moves to n - side and a hole on n - side of the junction moves to p side. This motion of charge carriers due to electric field gives drift current.

SECTION D

227. **(i) (c)** $\frac{2\varepsilon_0 KL^2}{d}$

(ii) (b) $\frac{\varepsilon_0 VKL^2}{d}$

(iii) (a) $\frac{V}{d}$

(iv) (a)

(c) $\frac{d}{2K}$ OR

(b) (d) Zero

228. **(i) (c)** $\sqrt{\frac{Ke^2}{mr}}$

(ii) (b) $\frac{-Ke^2}{2r}$

(iii) (c) $-2.48, 2.48$

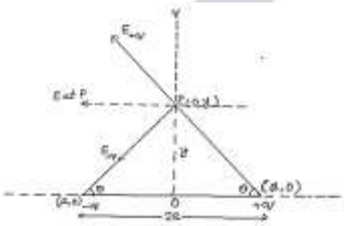
(iv) (a)

(d) $\frac{1}{n^3}$

OR

(b)
(c) 1.59Å

229. **(a)**



Magnitude of electric field due to the two charges $+q$ and $-q$ are given by

$$E_{+q} = \frac{q}{4\pi\varepsilon_0} \frac{1}{y^2 + a^2}$$

$$E_{-q} = \frac{q}{4\pi\varepsilon_0} \frac{1}{y^2 + a^2}$$

Components normal to the dipole axis cancel out.
The components along the dipole axis add up.
The total electric field is opposite to the dipole moment will be given by-

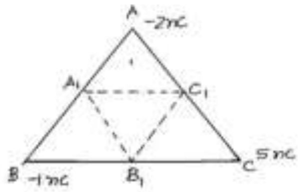
$$\vec{E} = -(E_{+q} + E_{-q}) \cos\theta \hat{p}$$

$$= -\frac{2qa}{4\pi\varepsilon_0 (y^2 + a^2)^{3/2}} \hat{p}$$

($\hat{p}$ is a unit vector along dipole moment)
At large distance ($y \gg a$)

$$E = \frac{-2qa}{4\pi\varepsilon_0 y^3} \hat{p}$$

(ii)



Initial electrostatic potential energy of the system

$U_1 = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_A q_B}{AB} + \frac{q_C q_A}{AC} + \frac{q_C q_B}{BC}\right)$

$= \frac{9\times10^9}{0.2}[(-2\times-1)+(-2\times5)+(-1\times5)]\times10^{-18}$

$U_1 = -5.85\times10^{-7}$ J

$U_2 = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_{A_1} q_{B_1}}{A_1\,B_1} + \frac{q_{C_1} q_{A_1}}{A_1 C_1} + \frac{q_{C_1} q_{B_1}}{B_1 C_1}\right)$

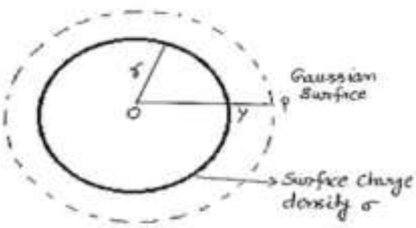
$U_2 = -11.7\times10^{-7}$ J

$W = U_2 - U_1 = -5.85\times10^{-7}$ J

OR

(b) (i) Gauss's theorem is based on the inverse square dependence on distance contained in the coulomb's law.

(I) For $y > r$



(i)

Electric flux through Gaussian surface $E \times 4\pi y^2$

The charge enclosed by the surface $\sigma \times 4\pi r^2$

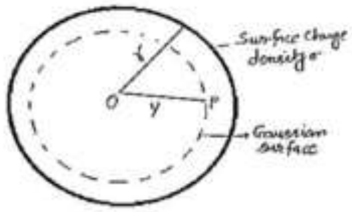
Using Gauss theorem

$E(4\pi y^2) = \frac{\sigma 4\pi r^2}{\varepsilon_0}$

$\vec{E} = \frac{q}{4\pi\varepsilon_0 y^2}\hat{r}$

(II) For $y < r$

(ii)



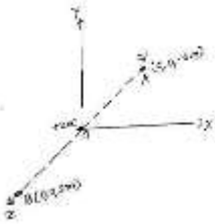
The charge enclosed by Gaussian surface $= 0$

Using Gauss theorem

Electric flux $= E(4\pi y^2) = 0$

i.e. $E = 0\ (y < r)$

(ii)



Let the charge is kept at A be q

Potential at point B due to charge at the origin O and charge (q) at A

$V = V_1 + V_2$

$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{2\times10^{-9}}{2} + \frac{q}{6+2}\right]$

$\frac{1}{4\pi\varepsilon_0}\left[10^{-9} + \frac{q}{8}\right] = 0$

$q = -8 \times 10^{-9} C$

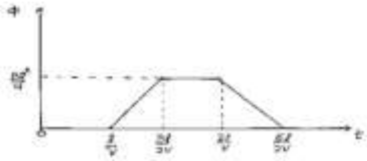
230. **(a)** Lenz's law - Polarity of the induced emf is such that it tends to produce a current, which opposes the change in magnetic flux that produces it.

When magnet is moved closer/ away from the loop, same/ opposite pole is developed on the approaching face of the loop. So mechanical work is required to move a magnet which gets converted into electrical energy which is consistent with the law of conservation of energy.

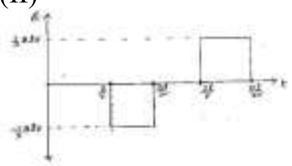
(ii) (I)

• Anticlockwise

• Clockwise



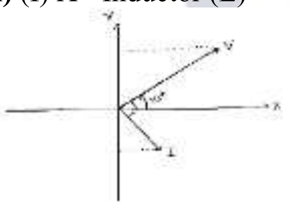
(II)



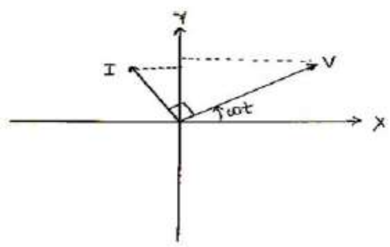
OR

(b) (i) Peak value - It is the maximum value of Alternating current. rms value - It is the equivalent dc current that would produce the same average power loss as alternating current.

(ii) (I) X - Inductor (L)



Y- Capacitor (C)



(II) Impedance of the circuit

$Z = (X_L - X_C)$

At resonance $Z = 0$

$X_L = X_C$

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

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

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

Impedance at resonance

$Z = 0$

231. **(a)** For real image form by Convex lens

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

$$\frac{1}{10} = \frac{1}{v_1} - \frac{1}{(-30)}$$

$$v_1 = 15 \text{ cm}$$

For Combination of lenses, let the focal length of combination of lens is f_3

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

$$\frac{1}{f_3} = \frac{1}{(15+45)} + \frac{1}{30}$$

$$f_3 = 20 \text{ cm}$$

Let the focal length of concave lens is f_2

$$\frac{1}{f_3} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\frac{1}{f_2} = \frac{1}{20} - \frac{1}{10}$$

$$f_2 = -20 \text{ cm}$$

(ii) Angle of minimum deviation

$$\mu = \frac{\text{Sin}\frac{(A+\delta_m)}{2}}{\text{Sin}\frac{A}{2}}$$

$$\sqrt{3} = \frac{\text{Sin}\frac{(60^\circ+\delta_m)}{2}}{\text{Sin}30}$$

$$\frac{\sqrt{3}}{2} = \text{Sin}\frac{(A+\delta_m)}{2}$$

$$60^\circ = \frac{(A+\delta_m)}{2}$$

$$\delta_m = 60^\circ$$

Angle of incidence

$$i + e = A + \delta$$

$$2i = A + \delta_m$$

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

$$i = 60^\circ$$

OR

(b) (i)

(I) Slit separation

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

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

$$= \frac{633 \times 10^{-9} \times 5}{5 \times 10^{-3}}$$

$$= 633 \times 10^{-6} \text{ m}$$

$$= 633\mu \text{ m}$$

(II) Distance of first minimum from central maximum

$$x_n = \frac{(2n-1)\lambda D}{2d}$$

$$n = 1$$

$$x = \frac{633 \times 10^{-9} \times 5}{2 \times 5 \times 10^{-3}}$$

$x = 316.5 \times 10^{-6}$ m
$x = 316.5\mu$ m
(ii) Distance between first order minima on both the side
$W = \frac{2D\lambda}{d}$
$= \frac{2 \times 650 \times 10^{-9}}{0.6 \times 10^{-3}} \times 60 \times 10^{-2}$
$= 1.3 \times 10^{-3}$ m

SECTION A

232. **(b)** becomes greater than C
233. **(a)** $\frac{\alpha}{r}$
234. **(d)** $\frac{4R}{3}$
235. **(b)** 5cm
236. **(c)** $0.196 \mathrm{Am}^2$
237. **(d)** 69 V
238. **(a)** Infrared rays
239. **(b)** $[M^0 L^2 T^{-2}]$
240. **(a)** X rays
241. **(a)** f_0 and f_e small, and $f_e > f_0$
242. **(b)** 0 and $4a^2$
243. **(c)** $\frac{1}{4}$
244. **(b)** Both Assertion (A) and Reason (R) are true, but Reason (R) is the not the correct explanation of the Assertion (A)
245. **(c)** Assertion (A) is true, but Reason (R) is false
246. **(d)** Both Assertion (A) and reason (R) are false
247. **(a)** Both assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the assertion (A).

SECTION – B

248. $eV_0 = h(v - v_0)$
$V_0 = \frac{6.63 \times 10^{-34} \times (6.8 - 3.6) \times 10^{14}}{1.6 \times 10^{-19}}$
$= 1.33$ V

249. **(a)** For refraction at convex surface
$\frac{n_1}{-u} + \frac{n_2}{v} = \frac{n_2 - n_1}{R}$
$\frac{n}{v} = \frac{[n - 1 - 3]}{R}$
$v = \frac{nR}{n - 4}$
For all values of $n < 4$, the value of v is negative and greater than R Therefore the nature of image is virtual and is formed in front of convex surface.

OR

(b) $\phi = \frac{2\pi}{\lambda} \times \Delta x$
$= \frac{2\pi}{\lambda} \times \frac{\lambda}{3}$
$= \frac{2\pi}{3}$
$I' = 4I\cos^2 \phi/2$ Given $4I = I_0$
$= I_0 \cos^2 2\pi/6$
$= \frac{I_0}{4}$
If a student attempt by using $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$, award full credit for correct answer.

250. $\mathrm{I} = \frac{V}{R}$

$= \frac{25}{1000}$

$= 25 \times 10^{-3}$ A

Resistance to be connected to voltmeter

$\mathrm{R}' = \frac{\mathrm{V}'}{\mathrm{I}} - R$

$= \frac{250}{25 \times 10^{-3}} - 1000$

$= 9000\Omega$

This 9000Ω is in series with voltmeter.

251. ${}^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{192}_{54}\mathrm{Xe} + {}^{94}_{38}\mathrm{Sr} + 2({}^{1}_{0}n)$

$\Delta \mathrm{m} = \mathrm{m}({}^{1}_{0}n) = \mathrm{m}({}^{235}_{92}\mathrm{U}) - (\mathrm{m}({}^{140}_{54}\mathrm{Xe}) + \mathrm{m}({}^{94}_{38}\mathrm{Sr}) + 2 \times \mathrm{m}({}^{1}_{0}\mathrm{n}))$

$= 0.00866 + 235.04393 - 139.92164 - 93.91536 - 2 \times 1.00866$

$= 0.19827\, u$

Energy released $= \Delta\mathrm{m} \times 931\mathrm{MeV}$

$= 0.19827 \times 931\mathrm{MeV}$

$= 184.59\mathrm{MeV}$

252. **(i)** $\mathrm{R}_2 = \mathrm{R}_1(1 + \alpha(\mathrm{t}_2 - \mathrm{t}_1))$

$10.5 = 10(1 + \alpha \times 100)$

$\alpha = 5 \times 10^{-4} / {}^\circ\mathrm{C}$

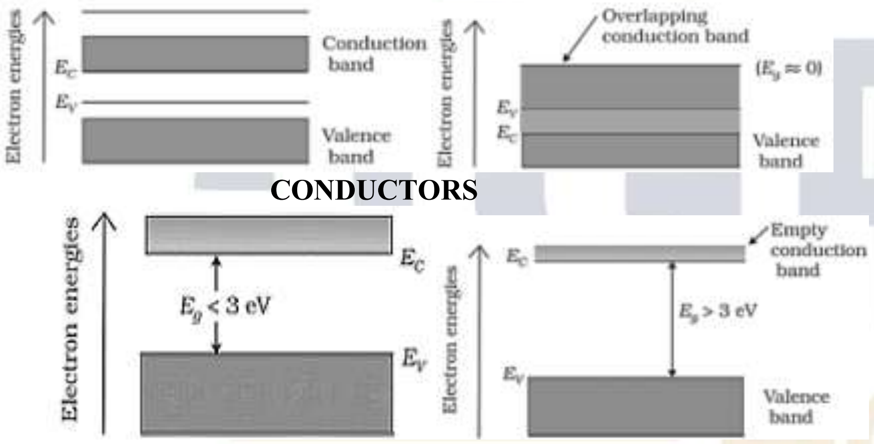
(ii) $R_{425} = R_{25}(1 + \alpha(425 - 25))$

$= 10(1 + 5 \times 10^{-4} \times 400)$

$= 12\Omega$

SECTION C

253. **(a)**



SEMICONDUCTORS **INSULATORS**

At room temperature, thermal energy is sufficient for electrons to make them free from the bonds and create a vacancy called hole. Hence electron hole pair is formed.

(b) The valence electron in carbon and silicon lie in the second and third orbit respectively. So, the energy required to take out an electron will be less for silicon as compared to carbon. Hence number of free electrons for conduction in silicon are significant but negligibly small for carbon.

254. **(a)** $\frac{1}{C} = \frac{1}{K\left(\frac{\varepsilon_0 A}{d/2}\right)} + \frac{1}{\frac{\varepsilon_0 A}{d/2}}$

$\frac{1}{C} = \frac{d}{2K\varepsilon_0 A} + \frac{d}{2\varepsilon_0 A}$

$= \left(\frac{1}{K} + 1\right)\frac{d}{2\varepsilon_0 A}$

$C = \left(\frac{2K}{K+1}\right)\frac{\varepsilon_0 A}{d}$

(b) $C = \frac{\varepsilon_0 AK}{2d} + \frac{\varepsilon_0 A}{2d}$

$= \left(\frac{K+1}{2}\right)\frac{\varepsilon_0 A}{d}$

255. **(a)** Distance $= \frac{n\lambda_1 D}{d} - \frac{n\lambda_2 D}{d}$

For $n = 1$

Distance $= \frac{(600-500)\times 10^{-9}\times 1}{10^{-3}}$

$= 10^{-4}$ m

(b) $n\lambda_1 \frac{D}{d} = (n+1)\lambda_2 \frac{D}{d} n\lambda_1 \frac{D}{d} = (n+1)\lambda_2 \frac{D}{d}$

$n \times 600 \times 10^{-9} = (n+1) \times 500 \times 10^{-9}$

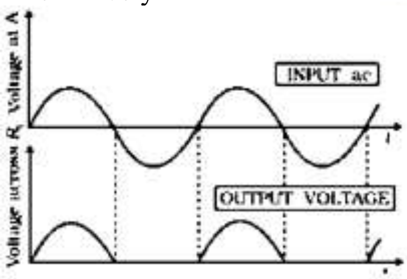
$n = 5$

$x = 5 \times \frac{\lambda_1 D}{d}$

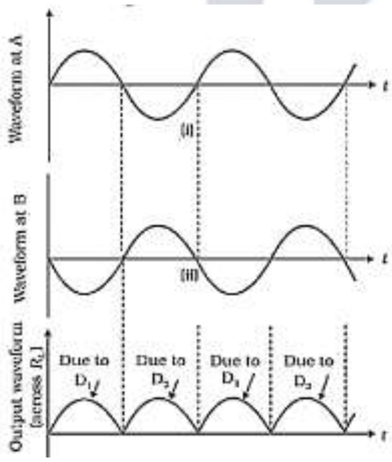
$= \frac{5 \times 600 \times 10^{-9} \times 1}{10^{-3}} = 3$ mm

256. In half wave rectification there is output in one half of input cycle, whereas in full wave rectification, output is obtained for both half cycles of input (positive and negative)

Alternatively

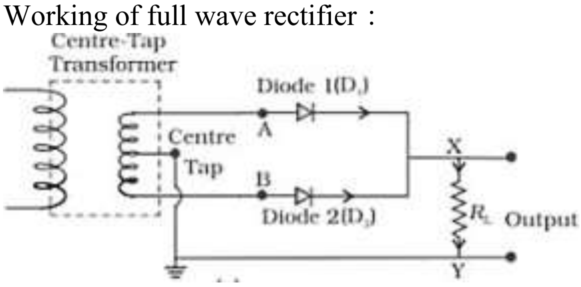


Half wave Rectification



Full wave Rectification

Working of full wave rectifier :



Suppose the input voltage to A with respect to the Centre - tap at any instant is positive At that instant, voltage at B being out of phase will be negative. So, diode D_1 gets forward biased and conducts(while D_2 being reverse biased is not conducting). Hence, during this positive half cycle we get an output current (and output voltage across the load resistor R_L). In the course of ac cycle when the voltage at A becomes negative with respect to centre tap, the voltage at B would be positive. In this part of the cycle diode D_1 would not conduct but diode D_2 would, giving an output current and output voltage (across R_L) during the negative half cycle of the input ac.

257. **(a)** $\mu = IA$

$= \frac{e}{T} \times A$

$= \frac{e}{\frac{2\pi r}{v}} \times \pi r^2$

$= \frac{1}{2}\text{evr}$

(b) $\text{L} = \text{mvr}$

$\mu = \frac{\text{evr} \times \text{m}}{2 \times \text{m}}$

$= \left(\frac{e}{2m}\right) L$

Direction of $\vec{\mu}$ is opposite to that of $\vec{\text{L}}$

$\vec{\mu} = -\left(\frac{\text{e}}{2\text{ m}}\right)\vec{\text{L}}$

258. For glass- liquid interface

$\sin \text{i}_c = \frac{1}{\text{n}_{21}}$

$= \frac{1.25}{1.5}$

$= \frac{5}{6}$

$i_c + r = 90^\circ$

$\sin r = \sqrt{1 - \cos^2 r} = \frac{\sqrt{11}}{6}$

Since

$\frac{\text{Sini}}{\text{Sinr}} = n$

Therefore, $\text{Sin}i = \frac{\sqrt{11}}{4}$ or $i = \text{Sin}^{-1}\frac{\sqrt{11}}{4}$

259. **(a)** For ball A

$\text{q}_1 = 2\sigma \times 4\pi\text{R}^2$

$= 8\pi\text{R}^2\sigma$

For ball B

$\text{q}_2 = 3\sigma \times 4\pi(2\text{R})^2$

$= 48\pi\text{R}^2\sigma$

Total charge $(\text{Q}) = \text{q}_1 + \text{q}_2$

$= 56\pi\text{R}^2\sigma$

When balls A and B are connected by a wire, their potentials will be equal Let q be the charge on ball A and $(Q - q)$ be the charge on the ball B after connecting wire.

$\frac{Kq}{R} = \frac{K(Q-q)}{2R}$

$2q = Q - q$

$q = \frac{Q}{3}$

$= \frac{56\pi R^2\sigma}{3}$

$Q - \frac{Q}{3} = \frac{112\pi R^2\sigma}{3}$

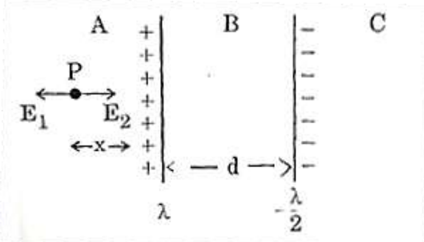
$\sigma_A = \frac{\frac{56\pi R^2\sigma}{3}}{4\pi R^2}$

$= \frac{14}{3}\sigma$

$$\sigma_B = \frac{\frac{112\pi R^2\sigma}{3}}{4\pi(2R)^2}$$
$$= \frac{7}{3}\sigma$$

OR

(b)



Electric field due to wire 1 and wire 2 at point P

$$E_1 = \frac{\lambda}{2\pi\varepsilon_0 x}$$
$$E_2 = \frac{\lambda/2}{2\pi\varepsilon_0(x+d)}$$

At P, Net electric field is zero

$$E_1 = E_2$$
$$\frac{\lambda}{2\pi\varepsilon_0 x} = \frac{\lambda}{2\times 2\pi\varepsilon_0(x+d)}$$
$$x = -2\,d$$

Negative sign indicates that point lies in the region C.

At a distance 2d from wire 1 electric field is zero.

SECTION D

260. **(i) (b)** $\frac{NBA}{K}$

(ii) (a) 0.25Ω

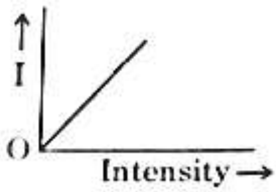
(iii) (b) 0.24Ω

(iv) (a) (A) $(R_2 - 2R_1)$

OR

(b) (B) 1.8×10^{-4}Nm

261. **(i) (c)**



(ii) (d) Remains the same

(iii) (c) cut-off potential versus frequency of incident light

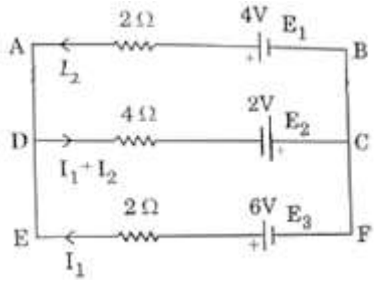
(iv) (a) (C) $K_B > K_Y > K_B$

OR

(b) (a) Caesium

SECTION- E

262. **(a) (i)**



In closed loop ABCD, using Kirchhoff's loop law

$4I_1 + 6I_2 = 6$ .... (1)

Similarly In closed loop CDFE

$6I_1 + 4I_2 = 8$ .... (2)

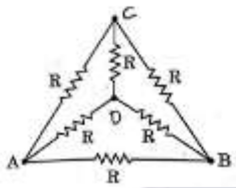
Solving eqn. (1) and (2)

$$I_2 = \frac{1}{5}A$$

$$I_1 = \frac{6}{5}A$$

$$I_1 + I_2 = \frac{7}{5}A$$

(ii)



Resistances R_{AC}, R_{CB}, R_{AD}, and R_{DB} form a balanced Wheatstone bridge Hence current through R_{CD} is zero and will not contribute to equivalent resistance.

The equivalent resistance of bridge is R, is in parallel with R_{AB} Series combinations of R_{AC}&R_{CB} and R_{AD}&R_{DB} is in parallel with R_{AB}

$$\frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{R}$$

$$R_{eq} = \frac{R}{2}$$

Given $R = 10\Omega$, Therefore $R_{eq} = 5\Omega$

OR

(b) (i)(I) $\vec{j} = \sigma\vec{E}$

$$\frac{j_A}{j_B} = \frac{E_A}{E_B}$$

$$= \frac{I/A_A}{I/A_B}$$

$$= \frac{A_B}{A_A}$$

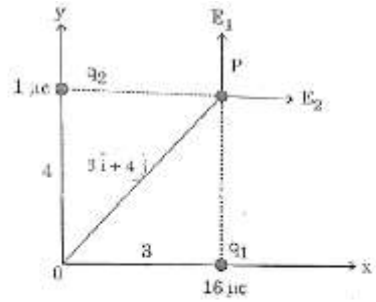
$$= \frac{2}{1}$$

(II) $v_d = \frac{I}{neA}$

$$= \frac{1}{8.5\times10^{28}\times1.6\times10^{-19}\times2\times10^{-7}}$$

$= 3.6 \times 10^{-4}$ m/s

(ii) $\vec{E} = \frac{Kq}{r^2}\hat{r}$



$\vec{E}_1 = \frac{9\times10^9\times16\times10^{-6}}{(4)^2}\hat{j}$

$= 9\times10^3\hat{j}$

$\vec{E}_2 = \frac{9\times10^9\times1\times10^{-6}}{(3)^2}\hat{\imath}$

$= 10^3\hat{\imath}$

$\vec{E}_{net} = (\hat{\imath}+9\hat{j})10^3 N/C$

263. Self Inductance is magnetic flux linked with a coil when the current through the coil is unity.

To maintain growth of current, power has to be supplied from external source.

$P = |e||I|$

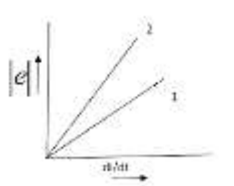
$= \frac{dW}{dt} = LI\frac{dI}{dt}$

$dW = LIdI$

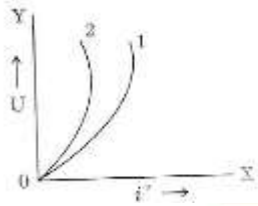
$W = \int LIdI$

$= \frac{1}{2}LI^2$

(I) $E = -L\frac{dI}{dt}$



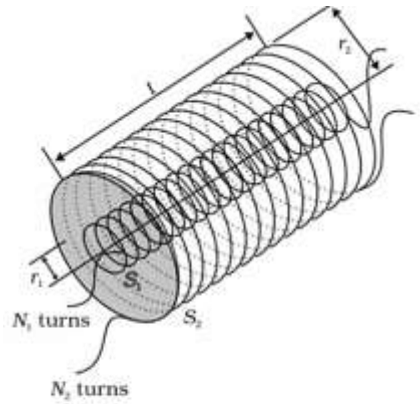
(II) $U = \frac{1}{2}LI^2$ Parabolic graph obtained.



(1 indicates 10 mH)&(2 indicates 20 mH)

OR

(a)(i) Mutual inductance is defined as the magnetic flux linked with the primary coil when the current in secondary coil is unity.



Consider two long co-axial solenoids each of length 1. Radius of inner solenoid S_1 is r_1 and number of turns per unit length is n_1.
The corresponding quantities for outer solenoid S_2 are r_2 and n_2 respectively. Let N_1 and N_2 be the total number of turns of coils S_1 and S_2 respectively.
When a current I_2 is set up through S_2, it sets up magnetic flux through S_1.

$N_1\phi_1 = M_{12}I_2$

$= (n_1 l) \times (\pi r_1^2) \times (\mu_0 n_2 I_2)$

$= \mu_0 n_1 n_2 \pi r_1^2 l I_2$

$M_{12} = \mu_0 n_1 n_2 \pi r_1^2 l = M_{21}$

(ii)

$|e| = L\frac{dI}{dt}$

$L = \frac{e}{dI/dt}$

$= \frac{5 \times 10^{-3}}{2/40}$

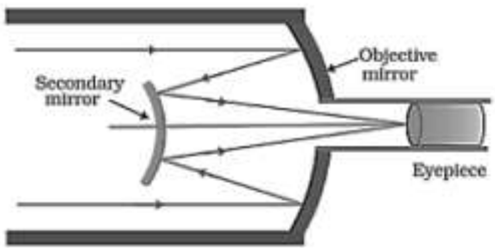
$= 0.1H$

$\phi = LI$

$= 0.1 \times \frac{2}{40} \times 10$

$= 0.05$ Wb

264. **(a) (i)**



The parallel rays from a distant object are reflected by a large concave mirror. These rays are then reflected by a convex mirror placed just before the focus of concave mirror and are converged to a point outside the hole. The final image is viewed through eye piece.
Advantages (any two)
1. No chromatic aberration.
2. Less spherical aberration
3. Less mechanical support required
4. Brighter Image
5. High resolving power.
6. High magnifying power

(ii) For image at infinity

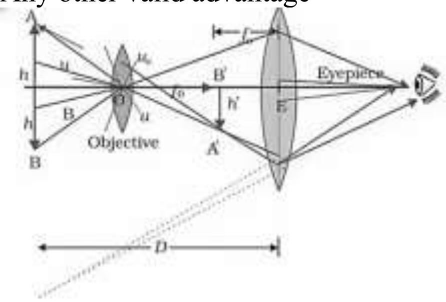
$|f_0| + |f_0| = L$

According to question

$f_0 = 50 \times f_s$
$f_s + 50fe = 102$
$f_o = 2$ cm
$f_0 = 100$ cm

OR

(b) (i) Advantages (any two)
1. Larger magnification
2. Brighter image
Any other valid advantage



(deduct 1/2 mark for not showing arrow for ray diagram)
The lens nearest the object, called the objective, forms a real, inverted, magnified image of the object. This serves as the object for the second lens, the eye piece, functions like a simple microscope and produces final image which is enlarged and virtual.

(ii) Power of plano concave lens $= P_1 = \frac{-(n_1-1)}{R}$

$= P_2 = (n_2 - 1)\left(\frac{2}{R}\right)$

$P = P_1 + P_2$

Power of convex lens $= \dfrac{(2n_2 - n_1 - 1)}{R}$

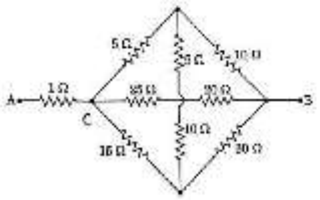
SECTION A

265. **(d)** $T_1 < T_2$
266. **(c)** $\left[\frac{n^2-1}{n}\right] R$
267. **(c)** $\frac{\mu_0 I}{4R}$
268. **(d)** does not move at all
269. **(c)** small resistance in parallel
270. **(b)** $\frac{1}{2}$
271. **(c)** g
272. **(a)** 10 V
273. **(c)** $2I_0$
274. **(a)** Red Light
275. **(b)** 1.326×10^{-27}
276. **(d)** $F_{pp} = F_{pn} = F_{nn}$
277. **(a)** Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A)
278. **(c)** Assertion (A) is true, But Reason (R) is false.
279. **(d)** Both Assertion (A) and Reason (R) are false.
280. **(c)** Assertion (A) is true, But Reason (R) is false.

SECTION B

281. Resistance between points C and B

$$\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}$$
$$\frac{1}{R}=\frac{1}{15}+\frac{1}{45}+\frac{1}{45}$$
$R = 9\Omega$



Equivalent resistance between points A and B
$R_{eq} = R_1 + R_2$
$R_{eq} = 1 + 9$
$= 10\Omega$

282. **(a) (i)** $\Delta\phi = \frac{2\pi}{\lambda}\cdot\Delta x$

$$\Delta\phi = \frac{2\pi}{\lambda}\cdot\frac{\lambda}{3} = \frac{2\pi}{3}$$
$$I = 4I_0\cos^2\frac{\phi}{2}$$
$$I = 4I_0\cos^2\frac{\pi}{3}$$
$I = I_0$

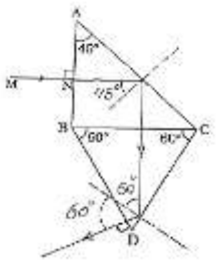
(ii)
$$\Delta\phi = \frac{2\pi}{\lambda}\cdot\frac{\lambda}{2} = \pi$$
$$I = 4I_0\cos^2\frac{\pi}{2}$$
$I = 0$

OR

(b) $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$
$$\frac{1.5}{v} - \frac{1}{(-12)} = \frac{1.5-1}{30}$$
$v = -22.5$ cm
Image is virtual and erect.

283. **(i)** $E = h\nu$
$= 6.63\times10^{-34}\times3.0\times10^{14}$
$= 1.99\times10^{-19}$ J
(ii) $N = \frac{P}{E}$
$$= \frac{9\times10^{-3}}{1.99\times10^{-19}}$$
$= 4.5\times10^{16}$

284.



Please deduct 1/2 mark for not showing arrows with the rays.

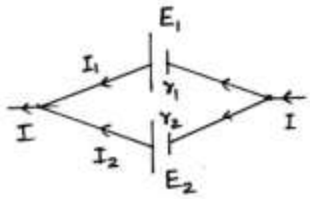
285. In a doped semiconductor the total number of conduction electrons is due to the electrons contributed by donors and those generated intrinsically, while the total number of holes is only due to the holes from the intrinsic sources.

SECTION-C

286. **1.** Potential difference between the terminals of a cell in open circuit is emf and in closed circuit it is terminal voltage.

2. An emf does not depend on the external resistance, while terminal voltage depends on external resistance.

3. emf is the cause and terminal voltage is the effect.



$V = E_1 - I_1 r_1$

$V = E_2 - I_2 r_2$

$I = I_1 + I_2$

$I = \left(\frac{E_1 - V}{r_1}\right) + \left(\frac{E_2 - V}{r_2}\right)$

On comparing above equation with $I = \frac{E_{eq} - V}{r_{eq}}$

$E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$

$r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$

287. **(i)** $\tau = mB\sin\theta$

As $\vec{m}$ and $\vec{B}$ are in same direction, $\theta = 0^0$

$\tau = 0$

(ii) $F = \frac{\mu_0 I_1 I_2 l}{2\pi r}$

$F_{net} = \frac{\mu_0 I_1 I_2 l}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$

$= \frac{4\pi \times 10^{-7} \times 2 \times 1 \times 5 \times 10^{-2}}{2\pi \times 10^{-2}}\left(1 - \frac{1}{2}\right)$

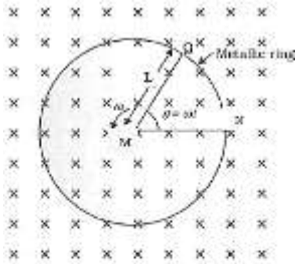
$F_{net} = 1 \times 10^{-6}$ N

Net force on the loop is towards the long straight wire.

288. **(a)** Lenz's law

The polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produced it.

Expression of induced emf



The magnitude of the emf generated across the length dr of the rod as it moves at right angles to the magnetic field is given by

$d\varepsilon = Bvdr$

$\varepsilon = \int d\varepsilon$

$= \int_0^L Bvdr$

$\varepsilon = \int_0^L B\omega rdr$

$\varepsilon = \frac{1}{2} BL^2\omega$

OR

(b) Self inductance of a coil is the ratio of the flux linkage to the current flowing in the coil.
Expression for self inductance of a long solenoid:
The magnetic field due to current flowing in the solenoid, B $= \mu_0 nI$
Total flux linked with the given solenoid

$N\phi_B = (nl)(\mu_0 nI)$A

$N\phi_B = \mu_0 n^2$ AlI

Self inductance

$L = \frac{N\phi_B}{I}$

$L = \mu_0 n^2$ Al

289. The electromagnetic waves used are

(i) Microwaves

(ii) Ultraviolet / Infrared

(iii) X-Rays

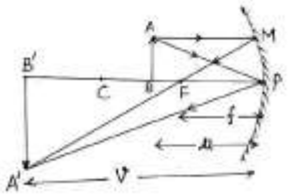
Wavelength range of electromagnetic waves used

(i) 0.1 m to 1 mm

(ii) 400 nm to 1 nm/1 mm to 700 nm

(iii) 1 nm to 10^{-3} nm

290.



Please deduct 1/2 mark of this diagram if not showing arrows with the rays.
In similar triangles

$\triangle A'B'F$ and $\triangle MPF$

$\frac{A'B'}{MP} = \frac{B'F}{FP}$

or $\frac{A'B'}{AB} = \frac{B'F}{FP}$ $(\because MP = AB)$ ……… (1)

In similar triangles $\triangle A'B'P$ and $\triangle ABP$

$\frac{A'B'}{AB} = \frac{PB'}{PB}$ ……………..(2)

from equation (1) and (2)

$\frac{B'F}{FP} = \frac{PB'}{PB}$

$\frac{PB' - PF}{FP} = \frac{PB'}{PB}$

$\frac{(-v) - (-f)}{(-f)} = \frac{(-v)}{(-u)}$

on solving we get

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

291. The electrostatic force of attraction between the electrons and the nucleus provides the necessary centripetal force required to an electron to revolve in the orbit.

$\frac{mv^2}{r} = \frac{e^2}{4\pi\varepsilon_0 r^2}$ ------(1) ($Z = 1$ for hydrogen atom)

Kinetic energy of the electron

$K = \frac{1}{2}mv^2$

$K = \frac{e^2}{8\pi\varepsilon_0 r}$ (from eq (1))

Potential energy of the electron

$U = \frac{-e^2}{4\pi\varepsilon_0 r}\left(\because U = \frac{q_1 q_2}{4\pi\varepsilon_0 r}\right)$

Total energy of the electron

$E = K + U$

$E = \frac{-e^2}{8\pi\varepsilon_0 r}$

Full credit of this part should be given if a student shows this derivation using alternative method

Negative sign signifies that electron is bound to the nucleus

OR force is attractive.

292. **(a)** $\Delta m = [m(^2_1H) + m(^3_1H)] - [m(^4_2He) + m(^1_0\text{n})]$

$= (2.014102 + 3.016049) - (4.002603 + 1.008665)$

$= 0.018883\text{u}$

$Q = \Delta m \times 931$

$= 0.018883 \times 931\text{MeV}$

$Q = 17.58\text{MeV}$

(b) Nuclear density $= \frac{\text{Mass of nucleus}}{\text{Volume of nucleus}}$

$\rho = \frac{mA}{\frac{4}{3}\pi R^3}$

$R = R_0 A^{\frac{1}{3}}$

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

Independent of mass number (A)

SECTION-D

293. **(i) (a)** $\left(\frac{C}{4}\right)$

(ii) (b) $\frac{\sigma}{\sigma - \sigma_p}$

(iii) (c) $\frac{1}{2}\varepsilon_0 E^2 V$

(iv) (a) (D) 6

OR

(b) (b) $\frac{2K}{K+1}$

294. **(i) (b)** Antimony

(ii) (c) 0.05 eV

(iii) (b) A layer of positive charge on n side and a layer of negative charge on p side appear

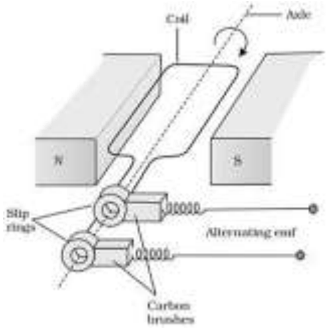
(iv) (a) B The applied voltage mostly drops across the depletion region

OR

(b) (c) 100 Hz

SECTION-E

295. **(a) (i)** Principle: It works on the principle of electromagnetic induction.



Working: The coil is mechanically rotated in the uniform magnetic field. The rotation of the coil causes the magnetic flux through it to change, so an emf is induced in the coil.

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

$= \sqrt{(400)^2 + \left(100\pi \times \frac{5}{\pi} - \frac{1}{100\pi \times \frac{50}{\pi} \times 10^{-6}}\right)^2}$

$= 500\Omega$

$I_{rms} = \frac{V_{rms}}{Z}$

$I_{rms} = \frac{140}{\sqrt{2} \times 500} = \frac{0.28}{\sqrt{2}}$ A

$(V_{rms})_R = I_{rms}R$

$= \frac{0.28}{\sqrt{2}} \times 400$

$= \frac{112}{\sqrt{2}} = 56\sqrt{2}$ V

$(V_{rms})_L = I_{rms}\omega$ L

$= \frac{0.28}{\sqrt{2}} \times 500$

$= \frac{140}{\sqrt{2}} = 70\sqrt{2}$ V

$(V_{rms})_C = I_{rms}\frac{1}{\omega C}$

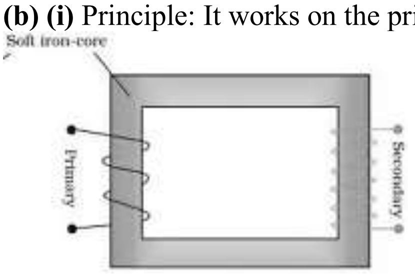
$= \frac{0.28}{\sqrt{2}} \times 200$

$= \frac{56}{\sqrt{2}} = 28\sqrt{2}$ V

The algebraic sum of voltages is more than the rms voltage of source because voltages across R, L and C are not in phase.

OR

(b) (i) Principle: It works on the principle of mutual induction.

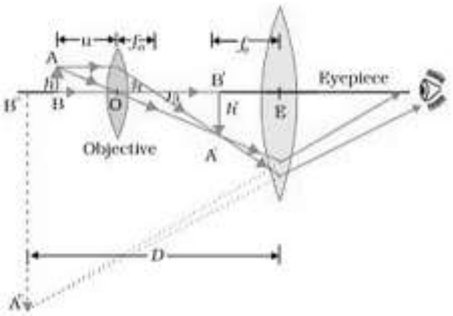


Working: When an alternating voltage is applied to the primary, the resulting current produces an alternating magnetic flux which links the secondary and induces an emf in it. Since the no. of turns are more in secondary windings an emf induced is proportional to the no. of turns. Therefore more emf is developed across the secondary windings.

(ii) $P_t = V_p I_p$

$$200 = \frac{20}{\sqrt{2}} I_p$$
$$I_p = 10\sqrt{2}\text{ A}$$
$$\frac{V_o}{V_t} = \frac{250}{50}$$
$$5 = \frac{V_o}{V_t}$$
$$V_o = 100\sin(100\pi)\text{tV}$$
$$P_o = (V_o)_{ms}(I_o)_{ms}$$
$$200 = \frac{100}{\sqrt{2}}(I_o)_{ms}$$
$$(I_o)_{ms} = 2\sqrt{2}\text{ A}$$
$$I_o = (2\sqrt{2})\sqrt{2}\sin(100\pi)\text{t}$$
$$I_o = 4\sin(100\pi)\text{tA}$$

296. **(a) (i)**



Deduct 1/2 mark for not showing arrows with the rays. Magnification produced by objective

$$m_0 = \frac{h'}{h} = \frac{L}{f_o}$$

Magnification produced by eye-piece

$$m_e = 1 + \frac{D}{f_e}$$

If the final image is formed at infinity

$$m_e = \frac{D}{f_e}$$

Total magnification

$$m = m_0 \times m_e$$
$$= \left(\frac{L}{f_o}\right)\left(\frac{D}{f_e}\right)$$

(ii)

$$\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_0}$$
$$\frac{1}{v_o} - \frac{1}{(-1.5)} = \frac{1}{1.25}$$
$$v_o = 7.5\text{ cm}$$

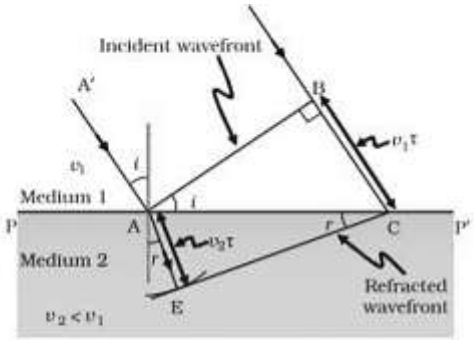
$L = |v_o| + |f_e|$ as final image is formed at infinity $(v_e = \infty, u_e = f_e)$

$L = 7.5 + 5$

$L = 12.5$ cm

OR

(b) (i)



$\sin i=\frac{BC}{AC}=\frac{v_1\tau}{AC}$

$\sin r=\frac{AE}{AC}=\frac{v_2\tau}{AC}$

$\frac{\sin i}{\sin r}=\frac{v_1}{v_2}$

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

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

(ii) $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

$u<0, f>0$

$\frac{1}{v}+\frac{1}{(-u)}=\frac{1}{f}$

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

$\frac{1}{V}$ is positive

v is positive ⇒ virtual image

297. (a) (i)

$V=-\int \vec{E}\cdot\overrightarrow{dr}$

$=-\int 40x\,dx$

$=-20x^2$

Potential at A $(0,3\text{ m}), V_A=0$

Potential at B $(5\text{ m}, 0), V_B=-500\text{ V}$

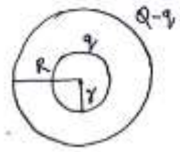
Work done in taking a unit positive charge from a point (0,3 m) to the point (5 m, 0)

$W=q(V_B-V_A)$

$=1(-500-0)$

$W=-500\text{ J}$

(ii) (I) Electric field at the common centre will be zero as the charge enclosed by the inner sphere is zero.



(II) ∵ Surface charge densities are equal

$\frac{q}{4\pi r^2}=\frac{Q-q}{4\pi R^2}$

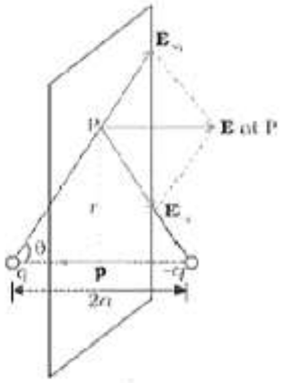
$q=\frac{Qr^2}{R^2+r^2}$

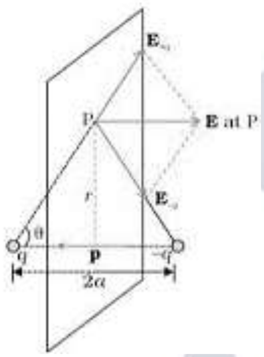
Potential at common centre

$$V=\frac{kq}{r}+\frac{k(Q-q)}{R}$$
$$V=\frac{k}{r}\frac{Qr^2}{(R^2+r^2)}+\frac{k}{R}\left[Q-\frac{Qr^2}{(R^2+r^2)}\right]$$
$$V=\frac{kQ(R+r)}{R^2+r^2}$$

OR

(b) (i)





The magnitudes of the electric field due to two charges +q and -q are

$$E_{+q}=\frac{q}{4\pi\varepsilon_0}\frac{1}{(r^2+a^2)}$$
$$E_{-q}=\frac{q}{4\pi\varepsilon_0}\frac{1}{(r^2+a^2)}$$

The total electric field

$$\vec{E}=-\left(E_{+q}+E_{-q}\right)\cos\theta\hat{p}$$
$$\vec{E}=-\frac{\vec{p}}{4\pi\varepsilon_0(r^2+a^2)^{3/2}}$$

Direction of electric field is opposite to dipole moment ($\vec{p}$)

(I) At centre of dipole, r = 0

$$\vec{E}=-\frac{-\vec{p}}{4\pi\varepsilon_0 a^3}$$

(II) At a point r ≫ a

$$\vec{E}=-\frac{-\vec{p}}{4\pi\varepsilon_0 r^3}$$

(ii) $\vec{E}=(10x+5)\hat{\imath}$ N/C

$$\phi_L=\int\vec{E}\cdot\overrightarrow{ds}$$
$$=-E_L(L^2)$$
$$=-5L^2$$
$$\phi_R=E_R(L^2)$$
$$=(10L+5)L^2$$
$$\phi_{\text{net}}=\phi_L+\phi_R$$

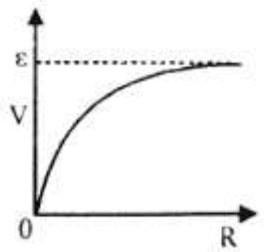
$= -5L^2 + (10L + 5)L^2$
$= 10L^3 \text{Nm}^2/\text{C}$

SECTION- A

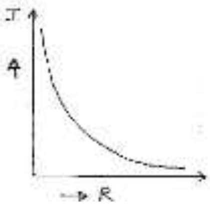
298. **(a)** 250 V
299. **(c)** $16/3\Omega$
300. **(a)** BAsin α
301. **(a)** $1/200$ s
302. **(c)** capacitive and inductive respectively
303. **(b)** 0.2 mV
304. **(d)** $[\text{ML}^2\ \text{T}^{-2}\ \text{A}^{-2}]$
305. **(b)** 3.20×10^{14} Hz
306. **(c)** holes and few electrons
307. **(a)** n = 4 to n = 3
308. **(a)** Both the potential barrier height and width of depletion layer decrease.
309. **(c)** Both the potential barrier height and width of depletion layer decrease.
310. **(d)** Both Assertion (A) and Reason (R) are false.
311. **(c)** Assertion(A) is true and Reason(R) is false.
312. **(b)** Both Assertion(A) and Reason (R) are true but Reason(R) is not the correct explanation of Assertion(A).
313. **(b)** Both Assertion(A) and Reason (R) are true but Reason(R) is not the correct explanation of Assertion(A).

SECTION- B

314. **(a)**



(b)



315. **(a)** Let, u = nf

From the Mirror formula

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

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

$$= \frac{1}{f} + \frac{1}{nf}$$

$$\text{v} = \frac{nf}{n+1}$$

$n = +ve \ \therefore v < f$

$$m = \frac{-v}{u} = \frac{1}{n+1}$$

m is always positive & less than 1 .

OR

(b) $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3}$

$$\frac{1}{12}=\frac{1}{10}-\frac{1}{15}+\frac{1}{f_3}$$
$$\frac{1}{f_3}=\frac{5-6+4}{60}$$
$$f_3 = 20 \text{ cm}$$

Nature: Convex

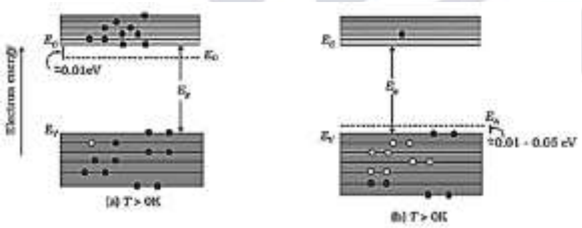
316.

Interference pattern		Diffraction pattern	
1.	The interference pattern has a number of equally spaced bright and dark bands.	1.	The diffraction pattern has a central bright maximum which is twice as wide as the other maxima.
2.	The interference pattern is obtained by superposing two waves originating from the two narrow slits.	2.	The diffraction pattern is obtained by superposition of a continuous family of waves originating from each point on a single slit.
3.	The maximas are of same intensity.	3.	The intensity falls as we go to successive maxima away from the centre, on either side.

(Any two differences)

The light wave coming out of two independent source of light will not have constant phase with time.

317.



318. Energy is produced in stars due to Nuclear fusion.

Two lighter nuclei fuse to form a heavier nucleus which is more stable, hence energy is released.

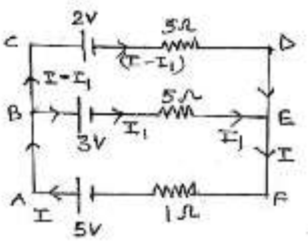
Hence energy is released.

$${}^{1}_{1}\text{H} + {}^{1}_{1}\text{H} \rightarrow {}^{2}_{1}\text{He} + e^{+} + \nu$$
$${}^{2}_{1}\text{H} + {}^{2}_{1}\text{H} \rightarrow {}^{3}_{2}\text{He} + {}^{1}_{0}\text{n}$$
$${}^{3}_{2}\text{He} + {}^{3}_{2}\text{He} \rightarrow {}^{4}_{2}\text{He} + {}^{1}_{1}\text{H} + {}^{1}_{1}\text{H}$$

Any two above equation.

SECTION- C

319.



In loop ABEFA,

$$5-3-5I_1-I=0$$

$2 = 5I_1 + I$ .... (1)
In loop CBEDC,
$2 - 3 - 5I_1 + 5I - 5I_1 = 0$
$-1 = 10I_1 - 5I$ .... (2)
Solving equation (1) and (2)
$I = \frac{5}{7}$ A in arm AF/through the cell of 5 V(A)
$I_1 = \frac{9}{35}$ A in arm BE/through the cell of 3 V(B)
$I - I_1 = \frac{16}{35}$ A in arm CD/through the cell of 2 V(C)

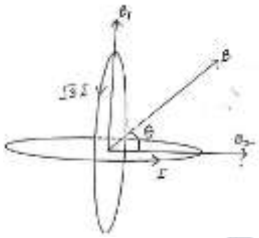
320. **(a) (i)** $\overrightarrow{dB} = \frac{\mu_0}{4\pi}\frac{I(\overrightarrow{dl}\times\vec{r})}{r^3}$

(ii) $B_1 = \frac{\mu_0 I}{2R}$

$$B_2 = \frac{\mu_0\sqrt{3}I}{2R}$$

$$B = \sqrt{B_1^2 + B_2^2}$$

$$B = \frac{\mu_0 I}{2R}\sqrt{1+3}$$



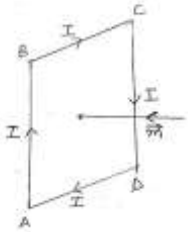
$$B = \frac{\mu_0 I}{R}$$

$$\tan\theta = \frac{B_1}{B_2} = \frac{1}{\sqrt{3}}$$

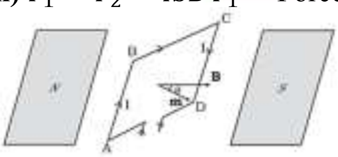
Direction of net magnetic field is 30° with direction of B2/60° with the direction of B_1.

OR

(b) (i) $\vec{m} = I\vec{A}$



(ii) $F_1 = F_2 = IbB$ F_1 = Force on AB into the plane F_2 = Forceon CD out of the plane



Since forces are equal & opposite so net force = 0
Both forces form a couple, magnitude of torque acting on the coil is

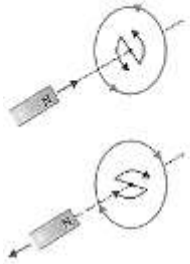
$$\tau = F_1\frac{l}{2}\sin\theta + F_2\frac{l}{2}\sin\theta$$
$$= Ib\,Bl\sin\theta$$
$$= IA\,B\sin\theta$$
$$= mB\sin\theta$$
$$\vec{\tau} = \vec{m}\times\vec{B}$$

321. **(a)** The magnitude of induced emf in a circuit is equal to the time rate of change of magnetic flux.

Mathematically, $e = -d\Phi/dt$

Negative sign indicates that the direction of induced emf and hence induced current in closed loop opposes its cause.

(b) When magnet is moved closer/away from the loop, same/ opposite pole is developed on the approaching face of the loop. So, mechanical work is required to move a magnet which gets converted into electrical energy which is consistent with law of conservation of energy.



322. **(a)** Similarity

Both give rise to magnetic field.

Dissimilarity(any one)

• Conduction current is due to flow of charges in the conductor.

• Displacement current arises due to change in electric field/ time varying electric flux.

(b) A magnetic field, changing with time, gives rise to an electric field. Then, an electric field changing with time gives rise to a magnetic field and is a consequence of the displacement current being a source of a magnetic field. Thus, time- dependent electric and magnetic fields give rise to each other and hence em wave is generated.

(Please award 1/2mark of this part if a child writes the expression only)

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 I_c + \mu_0 \varepsilon_0 \frac{d\Phi_e}{dt}$$

323. **(a)**Minimum energy required by an electron to escape from metal surface.

The intercept on the y axis for a graph between stopping potential & frequency gives ϕ_0/e.

$\phi_0 = e \times$ intercept on y -axis.

(b) $eV_0 = \frac{hc}{\lambda} - \phi_0$

$$0.6 = \frac{hc}{\lambda} - 2.4$$

$$3 = \frac{hc}{\lambda} \Rightarrow 3 \times 1.6 \times 10^{-19} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{\lambda}$$

$$\lambda = \frac{1241}{3} = 413.6 \text{ nm}$$

324. Mathematical form of postulates of Bohr's Theory

(i) $E_n = \frac{-13.6}{n^2} e\text{ V}$

Electron revolve in stable orbits with definite energy called stationary orbits.

(ii) $L = mvr = \frac{nh}{2\pi}$

(iii) $h\nu = E_f - E_i$

(a) $\frac{mv^2}{r} = \frac{Ze^2}{r^2}$ ....(1)

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

Solving (1) & (2)

$r = n^2 \left(\frac{h}{2\pi}\right)^2 \frac{4\pi\varepsilon_0}{me^2}$ .... (3)

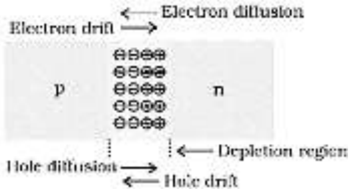
Since energy in the orbit $E_n = \frac{-e^2}{8\pi\varepsilon_0 r}$

Using eq (3) $E_n = \frac{-me^4}{8n^2\varepsilon_0{}^2 h^2}$

or $E_n \propto \frac{1}{n^2}$

(b) Total energy of the atom is proportional to $1/n^2$

325. When an electron diffuses from n-side to p-side, it leaves behind an ionized donor on n side.
Similarly when a hole diffuses from p -side to n -side, it leaves behind an ionized acceptor on p side.
This space charge region consisting of immobile ions on either side of the junction is known as depletion layer.
As diffusion process continues, width of depletion layer increases and consequently strength of electric field increases across the junction and thus the drift current.
The potential that prevents the movement of electron from n region into p region is called potential barrier.



Diode allows current to pass only when it is forward biased as resistance is small, whereas in reverse bias, its resistance is very large.

SECTION -D

326. **(i) (d)** 1

(ii) (c) 3.75×10^6

(iii) (b) $500^\circ C$

(iv) (a) (d) I decreases and II is almost constant

OR

(b) (d) All I, II and III change

327. **(i) (a)** $1/\sqrt{n^2-1}$

(ii) (a) (b) 1.4

OR

(b) (d) increase by 19%.

(iii) (c) First real and then virtual

(iv) (a) 10 cm

SECTION- E

328. **(a)** $C_0 = \frac{\varepsilon_0 A}{d}$

$$C = \frac{\varepsilon_0 A}{(d-t) + \frac{t}{K}}$$

$t = d/4$

$$\text{(i)} C = \frac{\varepsilon_0 A}{\left(d - \frac{d}{4}\right) + \frac{d}{4K}} = \frac{\varepsilon_0 A}{d\left(\frac{3}{4} + \frac{1}{4K}\right)}$$

$$= C_0 \frac{4K}{(3K+1)}$$

(ii) Each capacitance can withstand 200 V

No. of capacitors in each row $= \frac{1200}{200} = 6$

Net capacitance of each row $= 1/6\mu$ F

Number of rows = n

$C_{eq} = C_1 + C_2 + \cdots - - C_n$

$$C_{eq} = \frac{1}{6} + \frac{1}{6} + - - - - - n$$

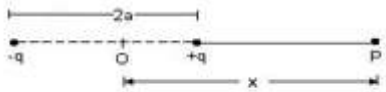
$$2 = \frac{n}{6}$$

$n = 12$

Total no. of capacitors in the arrangement $= 6 \times 12 = 72$

OR

(b) I. Along its axis



$V_- = \dfrac{-kq}{x+a}$

$V_+ = \dfrac{kq}{x-a}$

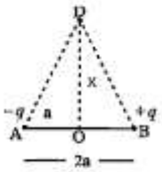
$V = V_- + V_+$

$= kq\left(\dfrac{-1}{x+a} + \dfrac{1}{x-a}\right)$

$= kq\dfrac{2a}{(x^2-a^2)} = \dfrac{kp}{x^2-a^2}$

$x \gg a \;\therefore V = \dfrac{kp}{x^2}$

II. Along the bisector line



$V_- = \dfrac{kq}{\sqrt{x^2+a^2}}$

$V_+ = \dfrac{-kq}{\sqrt{x^2+a^2}}$

$V = V_- + V_+$

$= 0$

(ii) $\vec{\tau} = \vec{p} \times \vec{E}$

$= (0.8\hat{\imath} + 0.6\hat{\jmath}) \times 10^{-29} \times (1 \times 10^7)\hat{k}$

$= [0.8(-\hat{\jmath}) + 0.6\hat{\imath}] \times 10^{-22}$

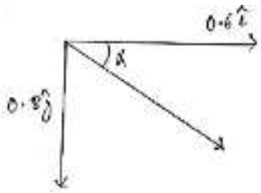
$\tau = \left[\sqrt{(0.8)^2 + (0.6)^2}\right] \times 10^{-22}$

$= 10^{-22}\text{Nm}$

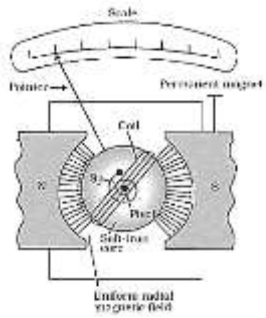
$\tan\alpha = \dfrac{|0.8|}{0.6}$

$\alpha = \tan^{-1}\left(\dfrac{4}{3}\right)$

$\alpha = 53°$



329. **(a)**



Principle: A current carrying coil placed in uniform magnetic field, experiences a torque.

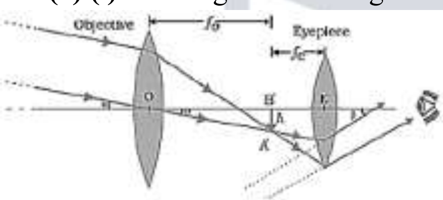
(i) Radial magnetic field makes the scale linear

(ii) Use of soft iron core is to increase the strength of magnetic field/ increase sensitivity of the galvanometer.
(ii) Current sensitivity is defined as deflection per unit current.
Alternatively:
$I_s = \frac{\Phi}{I} = \frac{NAB}{k}$
Voltage sensitivity $V_s = \frac{\Phi}{V} = \left(\frac{NAB}{k}\right)\frac{I}{V} = \left(\frac{NAB}{k}\right)\frac{1}{R}$
Increase in number of turns, increases the current sensitivity and resistance of the galvanometer in the same proportion of current sensitivity therefore Voltage sensitivity remains unchanged.

OR

(b) (i) (I) $\oint \vec{B} \cdot \vec{dl} = \mu_0 I_e$
I_e = Total current through the surface
B = Magnetic field
dl = length of small element
(II) As length of solenoid increases, it appears like a long cylindrical metal sheet, so field outside approaches zero.
(III) For a given perimeter, a circle encloses greater area than any other shape, which maximizes the flux.
(ii) $R_1 = \frac{V}{I_g} - G \Rightarrow \frac{V}{I_g} = R_1 + G$ ....(1)
$R_2 = \frac{V}{2I_g} - G \Rightarrow \frac{V}{2I_g} = R_2 + G$ .... (2)
Solving (1) & (2)
G= $R_1 - 2R_2$
$R_3 = \frac{2V}{I_g} - G$ .... (3)
Solving using eq (1) & (3)
$R_3 = 3R_1 - 2R_2$

330. **(a) (i)** Drawing labeled Diagram Explanation



Light from distant object enters the objective lens & forms a real image A'B' at f_o.
This image $A'B'$ acts as an object for eye piece and eye piece forms a magnified image at infinity.
Magnifying Power $= f_o/f_e$
(ii) Image is formed at least distance of distinct vision
$20 = m_o \times m_e$
$m_o = \frac{20}{5} = 4$
$m_e = 1 + \frac{D}{f_e}$
$f_e = \frac{25}{4}$ cm
$\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e}$
$\frac{1}{-25} - \frac{1}{u_e} = \frac{4}{25}$
$u_e = -5$ cm
$L = v_0 + |u_e|$
$v_0 = 9$ cm
Given, $\frac{v_0}{u_0} = 4$
$\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0}$
$\frac{1}{f_0} = \frac{1}{9} - \left(-\frac{4}{9}\right)$

$f_0 = \frac{9}{5}$ cm

(b) (i) $y_1 = a\cos\omega t$

$y_2 = a\cos(\omega t + \phi)$

According to Principle of Superposition

$y = y_1 + y_2$

$= a[\cos\omega t + \cos(\omega t + \phi)]$

$= 2a\cos\phi/2\cos(\omega t + \phi/2)$

$y = A\cos(\omega t + \phi/2)$

where, $A = 2a\cos\phi/2$

$I = kA^2$

$I = k(4a^2\cos^2\phi/2)$

$I = 4I_0\cos^2\phi/2$

(ii) (I) Position of first order minimum

$y = \frac{n\lambda D}{a}$

$y_1 = \frac{\lambda D}{a}$

$= \frac{600 \times 10^{-9} \times 1.5}{3 \times 10^{-3}} = 3 \times 10^{-4}$ m

(II) Position of second order maximum

$y_n = (2n + 1)\frac{\lambda D}{2a}$

$n = 2, y_2 = \frac{5\lambda D}{2a}$

$= \frac{5 \times 600 \times 10^{-9} \times 1.5}{2 \times 3 \times 10^{-3}} = 7.5 \times 10^{-4}$ m

SECTION A

331. **(b)** gain of 6.25×10^{12} electrons by the body
332. **(a)** $2 \times 10^{-4}\ {}^\circ C^{-1}$
333. **(c)** F
334. **(d)** 0.015 N
335. **(d)** increases the voltage to transmit power over long distance with minimum loss.
336. **(a)** 5 V
337. **(a)** Ultraviolet rays
338. **(b)** at a distance of 40 cm in front of the combination
339. **(b)** $\frac{m_p}{m_e}$
340. **(a)** n = 3 to n = 1
341. **(d)** before the the reverse saturation current.
342. **(d)** Boron
343. **(b)** Both Assertion (A) and Reason (R) are true, but Reason (R) is the not the correct explanation of the Assertion (A)
344. **(a)** Both assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the assertion (A).
345. **(d)** Both Assertion (A) and reason (R) are false
346. **(a)** Both assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the assertion (A).

SECTION -B

347. Drift velocity, $v_d = \frac{eE\tau}{m}$

using $E = \frac{V}{\ell}$ and $\tau = \frac{mv_d l}{eV}$

$\tau = \frac{0.8 \times 10^{-3} \times 9.1 \times 10^{-31} \times 0.20}{1.6 \times 10^{-19} \times 4}$

$\tau = 2.28 \times 10^{-16}$ s

348. **(a)** $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$

$u=-x, v=-2x$

$$\frac{1}{-10}=\frac{1}{-x}+\frac{1}{-2x}=-\frac{3}{2x}$$

$x=15$ cm

Distance between object and image,

$d=2x-x=30-15=15$ cm

OR

(b) $f=\frac{1}{P}=\frac{1}{4}=0.25$ m $=25$ cm

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

$$\frac{1}{25}=\frac{1}{v}-\left(\frac{1}{-150}\right)$$

On solving, $v=30$ cm

The image formed is real and inverted.

349. Angular width of central maxima $=\frac{2\lambda}{a}$

$$=\frac{2\times 700\times 10^{-9}}{2\times 10^{-4}} \text{ radian}$$

$=0.007$ radian

350. **(a)** $U=2E=2\times(-13.6)=-27.2eV$

(b) $K=-E=-(-13.6)eV=+13.6eV$

(c) $\frac{E}{K}=\frac{13.6eV}{13.6eV}=1$

351. Dynamic resistance $r_d=\frac{\Delta V}{\Delta I}$

$$r_d=\frac{0.95-0.90}{0.005}=\frac{0.05}{0.005}$$

$r_d=10\Omega$

SECTION - C

352. **(a)** emf- It is the potential difference across the terminal of the cell, when no current is being drawn from it.

Terminal Voltage - It is the potential difference between the terminals of the cell in a closed circuit.

OR

(b) Current density - It is defined as the current through unit area normal to the current.

$$\vec{J}=\frac{I}{\vec{A}}$$

S.I unit A/m^2

Derivation

$V=IR$

$$\vec{E}1=I\frac{\rho l}{\vec{A}}$$

$$\vec{E}=\vec{J}\rho$$

$$\vec{J}=\frac{I}{\rho}\vec{E}=\sigma\vec{E}$$

353. **(a)** Point of similarity(Any one)

(i) Both obey inverse square law.

(ii) Both are long range.

(iii) Superposition principle is applicable on both.

Point of difference (Any one)

(i) The electric field is produced by scalar source, the magnetic field is produced by vector source.

(ii) Electric field is radially out ward or inward towards the source charge, the magnetic field is perpendicular to plane.

(iii) electric field is due to static charge, magnetic field is due to moving charge.

(b) Magnetic field at the center of circular coil $B=\frac{N\mu_0 I}{2r}$

for coil 1, $l=2\pi r_1 \Rightarrow r_1=\frac{l}{2\pi}$

$$B_1=\frac{1\times\mu_0 I}{2\left(\frac{l}{2\pi}\right)}=\frac{\mu_0\pi I}{l}$$

for coil 2, $l=2\times 2\pi r_2 \Rightarrow r_2=\frac{l}{4\pi}$

$$B_2=\frac{2\times\mu_0 I}{2\times\left(\frac{l}{4\pi}\right)}=\frac{\mu_0 4\pi I}{l}$$

$$\frac{B_1}{B_2}=\frac{1}{4}$$

354. **(a) (i)** The ray of light should pass from a denser to a rarer medium

(b) (ii) The angle of incidence is greater than the critical angle for the pair of media.

(c) $n=\frac{\text{Real depth}}{\text{Apparent depth}}$

$$\text{Apparant depth}=\frac{\text{Real depth}}{n}$$

$$=\frac{3\text{ cm}}{1.5}=2\text{ cm}$$

The height through which the image of the dot raised (i.e. Normal shift)

= Real depth - Apparent depth

$=3-2=1$ cm

355. **(a)** $X_c=\frac{1}{\omega C}=\frac{1}{2\pi\nu C}$

$$X_c\propto\frac{1}{\nu}$$

If frequency increases, X_c decreases and vice- versa

$X_L=\omega L=2\pi\nu L$

$X_L\propto\nu$

If frequency increases, X_L increases and vice- versa

(b) $I_o=\frac{V_o}{2\pi\nu L}$

$$I_o=\frac{314}{2\times3.14\times50\times0.5}=2\text{ A}$$

356. **(a)** Characteristics of em waves(any two)

(i) Electromagnetic waves carries energy and momentum.

(ii) velocity of electromagnetic wave is same as velocity of light in vaccum.

(iii) In electromagnetic wave electric field vector $\vec{E}$, magnetic field vector $\vec{B}$ and direction of propagation, all are mutually perpendicular.

(b) Displacement current - It is defined as the current due to changing electric field and hence electric flux with time.

Alternatively

$$I_d=\epsilon_o\left(\frac{d\phi_E}{dt}\right)$$

During charging of capacitor, time varying electric field/ electric flux between the plates of capacitor induces the displacement current.

357. Bohr's Postulates

(i) an electron in an atom could revolve in certain stable orbits without the emission of radiant energy.

(ii) The electron revolves around the nucleus only in those orbits for which the angular momentum is some integral multiple of $\frac{h}{2\pi}$.

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

(iii) An electron might make a transition from one of its specified non radiating orbits to another of lower energy, if it does so a photon is emitted having energy equal to the energy difference between the intial and final states.

The frequency of emitted photon is then given by $E_i - E_f = hv$
From second postulates

$mv_n r_n = \frac{nh}{2\pi}$

$2\pi r_n = \frac{nh}{mv_n}$

$2\pi r_n = n\lambda$

358. **(a)** Resistivity - It is the property of material that measures how much it resists the flow of current .

(b) (i) As the temperature increases , Resistivity of metal increases.

$\rho = \frac{m}{ne^2\tau}$

Justification - As T increases , (τ) decreases

So, ρ increases $\left(\rho \propto \frac{1}{\tau}\right)$

(ii) As the temperature increases, resistivity of semiconductor decreases .

Justification

If T increases, n increases and (τ) decreases but the increase of n more than compensates the decrease in (τ), so (ρ) decreases.

359. **(i) (d)** Lesser in magnitude but in opposite direction.

(ii) (d) The potential increases in the direction of the electric field between the plates.

(iii) (c) $\sqrt{\frac{2ev}{m}}$

(iv) (a) (d) 1.0 V

OR

(b) (c) 3.2×10^{-17} N

360. **(i) (a)** Photon

(ii) (c) 1.1×10^{-27} kg m/s

(iii) (c) 1.0×10^{16}

(iv) (a) (d) 0.55×10^{-19} J

OR

(b) (c) 5.3×10^{14} Hz

SECTION – E

361. **(a)** (a) Expression for potential energy.

Work done in bringing the charge $q_{1,\text{ from }\infty}$ ∞ to $r_1, W_1 = q_1 V(\bar{f}_1)$

Work done in bringing the charge q_2, from ∞ to r_2 is not only against the external field but also against the field due to $q1$

$W_2 = q_2\ V(\bar{r}_2) + \frac{q_1 q_2}{4\pi\varepsilon_0 \vec{r}_{12}}$

Where r_{12} is the distance between q_1 and q_2

Thus, potential energy of the system = total work done in assembling the system

$U = q_1\ V(\vec{r}_1) + q_2\ V(\vec{r}_2) + \frac{q_1 q_2}{4\pi\varepsilon_o \vec{r}_{12}}$

(b) (i) Force becomes one forth

(ii) Force becomes four times

OR

Difference(Any three)

(i) Electrostatic force may be attractive or repulsive, while gravitational force is always attractive

(ii) Electrostatic force is stronger than gravitational force.

(iii) Electrostatic force depends on magnitude of two charge particles, and gravitational force depends on masses of two particles.

(iv) Electrostatic force depends on intervening medium between two charge particles, while gravitational force is independent of intervening medium between two bodies.

(B) (i) As charge particle at rest which emplies that electrostatic force balances the gravitational force.

So, nature of charge is negative.

(ii) $mg = qE = q\frac{V}{l}$

$q = \frac{4 \times 10^{-11} \times 10 \times 3 \times 10^{-2}}{480}$

$q = 2.5 \times 10^{-14} C$

362. **(a) (i)** Right hand thumb rule

When we hold a conductor in right hand in such a way that a thumb stretches in the direction of flow of current than the curled fingers shows the direction of magnetic field.

(ii) Magnetic field due to straight conductor at a distance r is given by

Since $B \propto \frac{1}{r}$ As r increases, B decreases

(iii) B depends on current ,nature of medium and angle θ between current element and displacement r.(any two factors)

(b) Explanation

(i) Stable equilibrium

When the magnetic dipole aligned along the direction of external magnetic field.

(ii) Unstable equilibrium

When the magnetic dipole align in opposite direction of external magnetic field.

OR

(b) (i) Radius of circular path in magnetic field is

$r = \frac{mv}{qB}$

$r \propto \frac{1}{B}$

If B decreases, r increases.

(ii) $r \propto V$

If v decreases, r decreases.

(iii) Under the influence of these two components the charge particle follow helical path.

(iv) The charge particle will move in the field undeviated.

(v) The charge particle will fly off tangently along the direction of velocity.

(b) Derivation of torque

The magnetic field exerts no force on two arms of length 'a' parallel to magnetic field.

The field exerts a force on two arm of length b perpendicular to magnetic field is,

$F_1 = F_2 = IbB$

F_1 is directed into the plane of the loop and F_2 is directed out of the plane of paper. Thus the net force on the loop is zero.

There is a torque on loop due to pair of force $\vec{F}_1$ and $\vec{F}_2$. The torque on the loop tends to rotate anticlockwise.

The magnitude of torque –

$\tau = F_1\frac{a}{2} + F_2\frac{a}{2}$

$= IbB\frac{a}{2} + IbB\frac{a}{2} = I(ab)B$

$\tau = IAB$

Where $A = ab$ is the area of rectangle?

363. **(a)** (A) The distance of n^{th} minima

$Y_n = \frac{(2n+1)\lambda D}{2d}, n = 0,1,2 - \cdots - -$

$Y_8 - Y_1 = \frac{15\lambda D}{2d} - \frac{\lambda D}{2d} = \frac{7\lambda D}{d}$

$\lambda = \frac{(Y_8 - Y_1) \times d}{7D}$

$\lambda = \frac{8 \times 10^{-2} \times 1.5 \times 2 \times 10^{-4}}{7 \times 3}$ m

$\lambda = 5.71 \times 10^{-7}$ m $= 571$ nm

(B) Intensity of resultant wave

$I \propto A^2$ (where A is amplitude of resultant wave)

$A = \sqrt{A_1^2 + A_1^2 + 2A_1A_2\cos\varphi}$

$A_{\max} = (A_1 + A_2)^2$

$A_{\min} = (A_1 - A_2)^2$

$\frac{I_{\min}}{I_{\max}} = \frac{(A_1 - A_2)^2}{(A_1 + A_2)^2}$

OR.

(b) (A) As refracted ray emerges normally from opposite face AC of the prism, So $r_2 = 0$

$r_1 + r_2 = A$

$r_1 = A$

$n = \frac{\mathrm{Sin} i_1}{\mathrm{Sin} r_1} = \frac{\mathrm{Sin} A/2}{\mathrm{Sin}\ A}$

$n = \frac{\mathrm{Sin} A/2}{2\mathrm{Sin}\ A/2\mathrm{Cos}\ A/2}$

$n = \frac{1}{2\cos\ A/2}$

(B) From lens maker formula

$\frac{1}{f} = ({}^1n_2 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$\frac{1}{f_{\text{air}}} = (1.5 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$\frac{1}{f_{\text{air}}} = 0.5\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$\frac{1}{f_{\text{liguid}}} = \left(\frac{1.5}{1.25} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$\frac{1}{f_{\text{liguid}}} = 0.2\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$\frac{f_l}{f_{\text{air}}} = \frac{5}{2}$

$f_l = \frac{5}{2} \times f_{\text{air}} = \frac{5}{2} \times 20 = 50\ \text{cm}$