CBSE EXAMINATION PAPER - 2024
Physics (Theory)
Class-12th
(Solved)
(Delhi & Outside Delhi Sets)

Time : 3 Hours **Max. Marks : 70**

General Instructions:

Read the following instructions carefully and follow them:

*(i) This question paper contains **33** questions. **All** questions are compulsory.*
*(ii) Question paper is divided into **FIVE** sections Section **A, B, C, D** and **E**.*
*(iii) In **Section A:** Question number **1** to **16** are Multiple Choice (MCQ) type questions carrying 1 mark each.*
*(iv) In **Section B:** Question number **17** to **21** are Very Short Answer (VSA) type questions carrying 2 marks each.*
*(v) In **Section C:** Question number **22** to **28** are Short Answer (SA) type questions carrying 3 marks each.*
*(vi) In **Section D:** Question number **29** & **30** are Long Answer (LA) type questions carrying 4 marks each.*
*(vii) In **Section E:** Question number **31** to **33** are Case-Based questions carrying 5 marks each.*
*(viii) There is no overall choice. However, an internal choice has been provided in 1 question in Section-**B**, 1 question in Section-**C**, 2 questions in Section-**D** and 3 questions in Section-**E**.*
(ix) Use of calculators is NOT allowed.

$c = 3 \times 10^8$ m/s
$h = 6.63 \times 10^{-34}$ Js
$e = 1.6 \times 10^{-19}$ C
$\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}
$\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}
$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N m^2 C^{-2}

Mass of electron (m_e) $= 9.1 \times 10^{-31}$ kg
Mass of neutron $= 1.675 \times 10^{-27}$ kg
Mass of proton $= 1.673 \times 10^{-27}$ kg
Avogadro's number $= 6.023 \times 10^{23}$ per gram mole
Boltzmann constant $= 1.38 \times 10^{-23}$ JK^{-1}

Delhi Set-1 **55/5/1**

SECTION A

1. A battery supplies 0.9 A current through a 2 Ω resistor and 0.3 A current through a 7 Ω resistor when connected one by one. The internal resistance of the battery is
(A) 2 Ω **(B)** 1.2 Ω
(C) 1 Ω **(D)** 0.5 Ω

2. A particle of mass *m* and charge *q* describes a circular path of radius *R* in a magnetic field. If its mass and charge were $2m$ and $\frac{q}{2}$ respectively, the radius of its path would be
(A) $\frac{R}{4}$ **(B)** $\frac{R}{2}$
(C) 2 R **(D)** 4 R

3. Which of the following pairs is that of paramagnetic materials?
(A) Copper and Aluminium
(B) Sodium and Calcium
(C) Lead and Iron
(D) Nickel and Cobalt

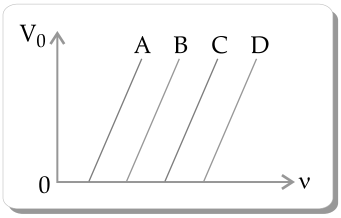
4. A galvanometer of resistance 50 Ω is converted into a voltmeter of range (0 – 2V) using a resistor of 1.0 k Ω. If it is to be converted into a voltmeter of range (0 – 10 V), the resistance required will be
(A) 4.8 kΩ **(B)** 5.0 kΩ
(C) 5.2 kΩ **(D)** 5.4 kΩ

5. Two coils are placed near each other. When the current in one coil is changed at the rate of 5 A/s, an emf of 2 mV is induced in the other. The mutual inductance of the two coils is
(A) 0.4 mH **(B)** 2.5 mH
(C) 10 mH **(D)** 2.5 H

6. The electromagnetic waves used to purify water are
(A) Infrared rays **(B)** Ultraviolet rays
(C) X-rays **(D)** Gamma rays

7. The focal lengths of the objective and the eyepiece of a compound microscope are 1 cm and 2 cm respectively. If the tube length of the microscope is 10 cm, the magnification obtained by the microscope for most suitable viewing by relaxed eye is
(A) 250 **(B)** 200
(C) 150 **(D)** 125

8. The variation of the stopping potential (V_0) with the frequency (ν) of the incident radiation for four metals A, B, C and D is shown in the figure. For the same frequency of incident radiation producing photo-electrons in all metals, the kinetic energy of photo-electrons will be maximum for metal



(A) A **(B)** B
(C) C **(D)** D

9. The energy of an electron in the ground state of hydrogen atom is –13.6 eV. The kinetic and potential energy of the electron in the first excited state will be

(A) –13.6 eV, 27.2 eV **(B)** –6.8 eV, 13.6 eV
(C) 3.4 eV, –6.8 eV **(D)** 6.8 eV, −3.4 eV

10. A Young's double-slit experimental set up is kept in a medium of refractive index $\left(\frac{4}{3}\right)$. Which maximum in this case will coincide with the 6th maximum obtained if the medium is replaced by air?

(A) 4th **(B)** 6th
(C) 8th **(D)** 10th

11. The potential energy between two nucleon's inside a nucleus is minimum at a distance of about

(A) 0.8 fm **(B)** 1.6 fm
(C) 2.0 fm **(D)** 2.8 fm

12. A pure Si crystal having 5×10^{28} atoms m^{-3} is dopped with 1 ppm concentration of antimony. If the concentration of holes in the doped crystal is found to be 4.5×10^9 m^{-3}, the concentration (in m^{-3}) of intrinsic charge carriers in Si crystal is about

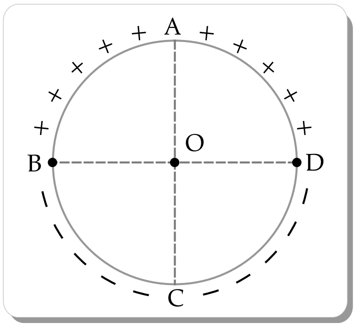
(A) 1.2×10^{15} **(B)** 1.5×10^{16}
(C) 3.0×10^{15} **(D)** 2.0×10^{16}

For Questions 13 to 16, two statements are given - one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the options as given below.

(A) If both Assertion (A) and Reason (R) are true and Reason (R) is correct explanation of Assertion (A).
(B) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).
(C) If Assertion (A) is true but Reason (R) is false.
(D) If both Assertion (A) and Reason (R) are false.

13. Assertion (A): Equal amount of positive and negative charges are distributed uniformly on two halves of a thin circular ring as shown in figure. The resultant electric field at the centre O of the ring is along OC.

Reason (R): It is so because the net potential at O is not zero.



14. Assertion (A): The energy of a charged particle moving in a magnetic field does not change.

Reason (R): It is because the work done by the magnetic force on the charge moving in a magnetic field is zero.

15. Assertion (A): In a Young's double-slit experiment, interference pattern is not observed when two coherent sources are infinitely close to each other.

Reason (R): The fringe width is proportional to the separation between the two sources.

16. Assertion (A): An alpha particle is moving towards a gold nucleus. The impact parameter is maximum for the scattering angle of 180°.

Reason (R): The impact parameter in an alpha particle scattering experiment does not depend upon the atomic number of the target nucleus.

SECTION B

17. (a) Four point charges of 1 μC, –2 μC, 1 μC and –2 μC are placed at the corners A, B, C and D respectively, of a square of side 30 cm. Find the net force acting on a charge of 4 μC placed at the centre of the square.

OR

(b) Three point charges, 1 pC each, are kept at the vertices of an equilateral triangle of side 10 cm. Find the net electric field at the centroid of triangle.

18. Derive an expression for magnetic force $\vec{F}$ acting on a straight conductor of length L carrying current I in an external magnetic field $\vec{B}$. Is it valid when the conductor is in zig-zag form? Justify.

19. A telescope has an objective lens of focal length 150 cm and an eyepiece of focal length 5 cm. Calculate its magnifying power in normal adjustment and the distance of the image formed by the objective.

20. (a) Two energy levels of an electron in hydrogen atom are separated by 2.55 eV. Find the wavelength of radiation emitted when the electron makes transition from the higher energy level to the lower energy level.

(b) In which series of hydrogen spectrum this line shall fall?

21. The earth revolves around the sun in an orbit of radius 1.5×10^{11} m with orbital speed 30 km/s. Find the quantum number that characterises its revolution using Bohr's model in this case (mass of earth = 6.0×10^{24} kg).

SECTION C

22. (a) Write Einstein's photoelectric equation. How did Millikan prove the validity of this equation?
 (b) Explain the existence of threshold frequency of incident radiation for photoelectric emission from a given surface.

23. (a) Define the term 'electric flux' and write its dimensions.
 (b) A plane surface, in shape of a square of side 1 cm is placed in an electric field $\vec{E} = \left(100\frac{N}{C}\right)\hat{i}$ such that the unit vector normal to the surface is given by $\hat{n} = 0.8\hat{i} + 0.6\hat{k}$. Find the electric flux through the surface.

24. (a) (i) State Lenz's Law. In a closed circuit, the induced current opposes the change in magnetic flux that produced it as per the law of conservation of energy. Justify.
 (ii) A metal rod of length 2 m is rotated with a frequency 60 rev/s about an axis passing through its centre and perpendicular to its length. A uniform magnetic field of 2T perpendicular to its plane of rotation is switched-on in the region. Calculate the e.m.f. induced between the centre and the end of the rod.

OR

 (b) (i) State and explain Ampere's circuital law.
 (ii) Two long straight parallel wires separated by 20 cm, carry 5 A and 10 A current respectively, in the same direction. Find the magnitude and direction of the net magnetic field at a point midway between them.

25. An electron moving with a velocity $\vec{v}$ = (1.0 × 10^7 m/s) $\hat{i}$ + (0.5 × 10^7 m/s) $\hat{j}$ enters a region of uniform magnetic field $\vec{B}$ = (0.5 mT) $\hat{j}$. Find the radius of the circular path described by it. While rotating; does the electron trace a linear path too? If so, calculate the linear distance covered by it during the period of one revolution.

26. (a) Name the parts of the electromagnetic spectrum which are (i) also known as heat waves' and (ii) absorbed by ozone layer in the atmosphere.
 (b) Write briefly one method each, of the production and detection of these radiations.

27. (a) Explain the characteristics of a *p-n* junction diode that makes it suitable for its use as a rectifier.
 (b) With the help of a circuit diagram, explain the working of a full wave rectifier.

28. Explain the following, giving reasons:
 (a) A doped semiconductor is electrically neutral.
 (b) In a *p-n* junction under equilibrium, there is no net current.
 (c) In a diode, the reverse current is practically not dependent on the applied voltage.

SECTION D

29. Dielectrics play an important role in design of capacitors. The molecules of a dielectric may be polar or non-polar. When a dielectric slab is placed in an external electric field, opposite charges appear on the two surfaces of the slab perpendicular to electric field. Due to this an electric field is established inside the dielectric.

The capacitance of a capacitor is determined by the dielectric constant of the material that fills the space between the plates. Consequently, the energy storage capacity of a capacitor is also affected. Like resistors, capacitors can also be arranged in series and/or parallel.

 (i) Which of the following is a polar molecule ?
 (A) O_2 (B) H_2
 (C) N_2 (D) HCl

 (ii) Which of the following statements about dielectrics is correct?
 (A) A polar dielectric has a net dipole moment in absence of an external electric field which gets modified due to the induced dipoles.
 (B) The net dipole moments of induced dipoles is along the direction of the applied electric field.
 (C) Dielectrics contain free charges.
 (D) The electric field produced due to induced surface charges inside a dielectric is along the external electric field.

 (iii) When a dielectric slab is inserted between the plates of an isolated charged capacitor, the energy stored in it
 (A) increases and the electric field inside it also increases.
 (B) decreases and the electric field also decreases.
 (C) decreases and the electric field increases.
 (D) increases and the electric field decreases.

 (iv) (a) An air-filled capacitor with plate area A and plate separation *d* has capacitance C_0. A slab of dielectric constant K, area A and thickness $\left(\frac{d}{5}\right)$ is inserted between the plates. The capacitance of the capacitor will become
 (A) $\left[\frac{4K}{5K+1}\right]C_0$ (B) $\left[\frac{K+5}{4}\right]C_0$
 (C) $\left[\frac{5K}{4K+1}\right]C_0$ (D) $\left[\frac{K+4}{5K}\right]C_0$

OR

 (b) Two capacitors of capacitances 2 C_0 and 6 C_0 are first connected in series and then in parallel across the same battery. The ratio of energies stored in series combination to that in parallel is
 (A) $\frac{1}{4}$ (B) $\frac{1}{6}$
 (C) $\frac{2}{15}$ (D) $\frac{3}{16}$

30. A prism is an optical medium bounded by three refracting plane surfaces. A ray of light suffers successive refractions on passing through its two surfaces and deviates by a certain angle from its original path. The refractive index of the material of the prism is given by $\mu = \sin\left(\frac{A+\delta_m}{2}\right) / \sin\frac{A}{2}$. If the angle of incidence on the second surface is greater than an angle called critical angle, the ray will not be refracted from the second surface and is totally internally reflected.

(i) The critical angle for glass is θ_1 and that for water is θ_2. The critical angle for glass-water surface would be (given ${}_a\mu_g = 1.5$, ${}_a\mu_w = 1.33$)

(A) less than θ_2 **(B)** between θ_1 and θ_2

(C) greater than θ_2 **(D)** less than θ_1

(ii) When a ray of light of wavelength λ and frequency υ is refracted into a denser medium

(A) λ and υ both increase.

(B) λ increases but υ is unchanged.

(C) λ decreases but υ is unchanged.

(D) λ and υ both decrease.

(iii) (a) The critical angle for a ray of light passing from glass to water is minimum for

(A) red colour **(B)** blue colour

(C) yellow colour **(D)** violet colour

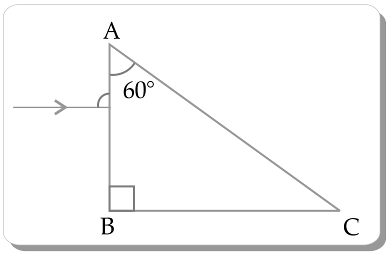
OR

(b) Three beams of red, yellow and violet colours are passed through a prism, one by one under the same condition. When the prism is in the position of minimum deviation, the angles of refraction from the second surface are r_R, r_Y and r_V respectively. Then

(A) $r_V < r_Y < r_R$ **(B)** $r_Y < r_R < r_V$

(C) $r_R < r_Y < r_V$ **(D)** $r_R = r_Y = r_V$

(iv) A ray of light is incident normally on a prism ABC of refractive index $\sqrt{2}$, as shown in figure. After it strikes face AC, it will



(A) go straight undeviated

(B) just graze along the face AC

(C) refract and go out of the prism

(D) undergo total internal reflection

SECTION E

31. (a) (i) Draw equipotential surfaces for an electric dipole.

(ii) Two point charges q_1 and q_2 are located at $\vec{r}_1$ and $\vec{r}_2$ respectively in an external electric field $\vec{E}$. Obtain an expression for the potential energy of the system.

(iii) The dipole moment of a molecule is 10^{-30} Cm. It is placed in an electric field $\vec{E}$ of 10^5 V/m such that its axis is along the electric field. The direction of $\vec{E}$ is suddenly changed by 60° at an instant. Find the change in the potential energy of the dipole, at that instant.

OR

(b) (i) A thin spherical shell of radius R has a uniform surface charge density σ. Using Gauss' law, deduce an expression for electric field (i) outside and (ii) inside the shell.

(ii) Two long straight thin wires AB and CD have linear charge densities 10 μC/m and –20 μC/m, respectively. They are kept parallel to each other at a distance 1 m. Find magnitude and direction of the net electric field at a point midway between them.

32. (a) (i) You are given three circuit elements X, Y and Z. They are connected one by one across a given ac source. It is found that V and I are in phase for element X. V leads I by $\left(\frac{\pi}{4}\right)$ for element Y while I leads V by $\left(\frac{\pi}{4}\right)$ for element Z. Identify elements X, Y and Z.

(ii) Establish the expression for impedance of circuit when elements X, Y and Z are connected in series to an ac source. Show the variation of current in the circuit with the frequency of the applied ac source.

(iii) In a series LCR circuit, obtain the conditions under which (i) impedance is minimum and (ii) wattless current flows in the circuit.

OR

(b) (i) Describe the construction and working of a transformer and hence obtain the relation for $\left(\frac{v_s}{v_p}\right)$ in terms of number of turns of primary and secondary.

(ii) Discuss four main causes of energy loss in a real transformer.

33. (a) (i) A plane light wave propagating from a rarer into a denser medium, is incident at an angle i on the surface separating two media. Using Huygen's principle, draw the refracted wave and hence verify Snell's law of refraction.

(ii) In a Young's double slit experiment, the slits are separated by 0.30 mm and the screen is kept 1.5 m away. The wavelength of light used is 600 nm. Calculate the distance between the central bright fringe and the 4^{th} dark fringe.

OR

(b) (i) Discuss briefly diffraction of light from a single slit and draw the shape of the diffraction pattern.

(ii) An object is placed between the pole and the focus of a concave mirror. Using mirror formula, prove mathematically that it produces a virtual and an enlarged image.

Delhi Set-2 **55/5/2**

Note: Except these, all other questions are available in Delhi Set-1

SECTION A

1. An ammeter and a voltmeter are connected in series to a battery. Their readings are noted as 'A' and 'V' respectively. If a resistor is connected in parallel with the voltmeter, then

(A) A will increase, V will decrease.

(B) A will decrease, V will increase.

(C) Both A and V will decrease.

(D) Both A and V will increase.

2. An ac voltage is applied across an ideal inductor. The current in it

(A) leads the voltage by $\left(\frac{1}{4}\right)$ cycle.

(B) lags the voltage by $\left(\frac{1}{4}\right)$ cycle.

(C) leads the voltage by $\left(\frac{1}{2}\right)$ cycle.

(D) lags the voltage by $\left(\frac{1}{2}\right)$ cycle.

3. An iron needle is kept near a strong bar magnet. It will experience

(A) a force of attraction and no torque.

(B) a force of attraction and a torque.

(C) a torque and no force.

(D) neither a force nor a torque.

4. A galvanometer shows full scale deflection for a current I_g. If a shunt of resistance S, is connected to the galvanometer, it gets converted into an ammeter of range (0 – I). When resistance of the shunt is made S_2, its range becomes (0 – 2I). Then $\left(\frac{S_1}{S_2}\right)$ is

(A) $\frac{I+I_g}{I-I_g}$ **(B)** $\frac{I-I_g}{I+I_g}$

(C) $\frac{2I-I_g}{I-I_g}$ **(D)** $\frac{I-I_g}{2I-I_g}$

5. A coil of area of cross-section 0.5 m^2 is placed in a magnetic field acting normally to its plane. The field varies as $B = 0.5t^2 + 2t$, where B is in tesla and t in seconds. The emf induced in the coil at $t = 1$s is

(A) 0.5 V **(B)** 1.0 V

(C) 1.5 V **(D)** 3.0 V

8. In a Young's double-slit experiment in air, the fringe width is found to be 0.44 mm. If the entire setup is immersed in water $\left(n=\frac{4}{3}\right)$, the fringe width will be

(A) 0.88 mm **(B)** 0.59 mm

(C) 0.33 mm **(D)** 0.44 mm

SECTION B

19. The radius of curvature of a convex mirror is 30 cm. It forms an image of an object which is half the size of the object. Find the separation between the object and the image.

20. Calculate the energy released/absorbed (in MeV) in the nuclear reaction:

$$^1_1H + {}^3_1H \rightarrow {}^2_1H + {}^2_1H$$

Given: $m\left({}^1_1H\right) = 1.007825\ \mu$

$m\left({}^2_1H\right) = 2.014102\ \mu$

$m\left({}^3_1H\right) = 3.016049\ \mu$

21. A proton of energy 1.6 MeV approaches a gold nucleus (Z = 79). Find the distance of its closest approach.

SECTION C

22. A photosensitive surface of work function 2.1 eV is irradiated by radiation of wavelength 150 nm. Calculate **(i)** the threshold wavelength, **(ii)** energy (in eV) of an incident photon and **(iii)** maximum kinetic energy of emitted photoelectron.

24. (i) Define 'temperature coefficient of resistance' of a metal.

(ii) Show the variation of resistivity of copper with rise in temperature.

(iii) The resistance of a wire is 10 Ω at 27 °C. Find its resistance at –73 °C. The temperature coefficient of resistance of the material of the wire is 1.70×10^{-4} °C^{-1}.

25. Name the part of the electromagnetic spectrum which are

(i) stopped by face mask worn by welders.

(ii) used in detectors in Earth satellites.

(iii) used in 'short-wave band' in communication.

Also write the order of wavelengths, in each case.

Delhi Set-3 **55/5/3**

Note: Except these, all other questions are available in Delhi Set-1 & 2

SECTION A

1. A heater coil rated as (P, V) is cut into two equal parts. One of the parts is then connected to a battery of V volt. The power consumed by it will be

(A) P **(B)** $\frac{P}{2}$

(C) $\frac{P}{4}$ **(D)** 2P

2. Two insulated concentric coils, each of radius R, placed at right angles to each other, carry currents I and √3 I respectively. The magnitude of the net magnetic field at their common centre will be

(A) $\frac{\mu_o I}{R}$ **(B)** $\frac{\mu_o I}{2R}$

(C) $\frac{\mu_o I}{4R}$ **(D)** $\frac{2\mu_o I}{R}$

3. Which of the following material has its magnetic susceptibility x in the range $0 < x < \varepsilon$, where ε is positive and small?

(A) Aluminium **(B)** Water

(C) Gadolinium **(D)** Bismuth

4. A galvanometer of resistance 100 Ω gives full scale deflection for a current of 1.0 mA. It is converted into an ammeter of range (0 – 1A). The resistance of the ammeter will be close to

(A) 0.1 Ω **(B)** 0.8 Ω

(C) 1.0 Ω **(D)** 10 Ω

5. The mutual inductance of two coils, in a given orientation is 50 mH. If the current in one of the coils changes as $i = 1.0 \sin\left(100\pi t + \frac{\pi}{3}\right)$ A, the peak value of emf (in volt) induced in the other coil will be

(A) $\frac{\pi}{5}$ **(B)** 5π

(C) 0.5π **(D)** 0.05π

12. A point object is kept 60 cm in front of a spherical convex surface (n = 1.5, radius of curvature 40 cm). The image formed is

(A) real, at a distance 1.8 m from the surface.

(B) virtual, at a distance 1.8 m from the surface.

(C) real, at a distance 3.6 m from the surface.

(D) virtual, at a distance 3.6 m from the surface.

SECTION B

19. A thin converging lens of focal length 10 cm is placed coaxially in contact with a thin diverging lens of focal length 15 cm. How will the combination behave? Justify your answer.

20. Deuterium undergoes the following fusion reaction:

$$^2_1H + ^2_1H \rightarrow ^3_2He + ^1_0n + 3.27 \text{ MeV}$$

How long an electric bulb of 200 W will glow by using the energy released in 2 g of deuterium ?

21. The electron in hydrogen atom is revolving with the speed of 2.2×10^6 m/s in an orbit of radius 0.53 Å. Calculate the initial frequency of light emitted by the electron using classical physics.

SECTION C

23. The threshold frequency for a metal is 3.0×10^{14} Hz. A beam of frequency 9.0×10^{14} Hz is incident on the metal. Calculate (i) the work function (in eV) of the metal and (ii) the maximum speed of photoelectrons.

27. An electron is moving with a velocity $\vec{v} = \left(3 \times 10^6 \frac{m}{s}\right)\hat{i}$. It enters a region of magnetic field $\vec{B} = (91 \text{ mT})\hat{k}$.

(a) Calculate the magnetic force $\vec{F}_B$ acting on electron and the radius of its path.

(b) Trace the path described by it.

28. A potential difference of 1.0 V is applied across a conductor of length 5.0 m and area of cross-section 1.0 mm^2. When current of 4.25 A is passed through the conductor, calculate **(i)** the drift speed and **(ii)** relaxation time, of electrons. (Given number density of electrons in the conductor, $n = 8.5 \times 10^{25}$ m^{-3}).

Outside Delhi Set-1 **55/4/1**

SECTION A

1. Two charges + q each are kept '2a' distance apart. A third charge – 2q is placed midway between them. The potential energy of the system is

(A) $\frac{q^2}{8\pi\varepsilon_0 a}$ **(B)** $-\frac{6q^2}{8\pi\varepsilon_0 a}$

(C) $\frac{-7q^2}{8\pi\varepsilon_0 a}$ **(D)** $\frac{9q^2}{8\pi\varepsilon_0 a}$

2. Two identical small conducting balls B_1 and B_2 are given –7 pC and + 4 pC charges respectively. They are brought in contact with a third identical ball B_3 and then separated. If the final charge on each ball is -2 pC, the initial charge on B_3 was

(A) –2 pC **(B)** –3 pC

(C) –5 pC **(D)** –15 pC

3. The quantum nature of light explains the observations on photoelectric effect as

(A) there is a minimum frequency of incident radiation below which no electrons are emitted.

(B) the maximum kinetic energy of photoelectrons depends only on the frequency of incident radiation.

(C) when the metal surface is illuminated, electrons are ejected from the surface after sometime.

(D) the photoelectric current is independent of the intensity of incident radiation.

4. The radius (r_n) of n^{th} orbit in Bohr model of hydrogen atom varies with n as

(A) $r_n \propto n$ **(B)** $r_n \propto \frac{1}{n}$

(C) $r_n \propto n^2$ **(D)** $r_n \propto \frac{1}{n^2}$

5. A straight wire is kept horizontally along east-west direction. If a steady current flows in wire from east to west, the magnetic field at a point above the wire will point towards

(A) East **(B)** West

(C) North **(D)** South

6. The magnetic susceptibility for a diamagnetic material is

(A) small and negative **(B)** small and positive.

(C) large and negative **(D)** large and positive

7. A galvanometer of resistance 100 Ω is converted into an ammeter of range (0 – 1 A) using a resistance of 0.1 Ω. The ammeter will show full scale deflection for a current of about

(A) 0.1 mA **(B)** 1 mA

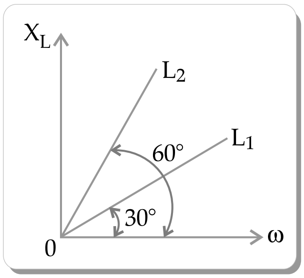
(C) 10 mA **(D)** 0.1 A

8. A circular loop A of radius R carries a current I. Another circular loop B of radius $r\left(=\frac{R}{20}\right)$ is placed concentrically in the plane of A. The magnetic flux linked with loop B is proportional to

(A) R **(B)** $\sqrt{R}$

(C) $R^{\frac{3}{2}}$ **(D)** R^2

9. Figure shows the variation of inductive reactance X_L of two ideal inductors of inductance L_1 and L_2 with angular frequency ω. The value of $\frac{L_1}{L_2}$ is



(A) $\sqrt{3}$ **(B)** $\frac{1}{\sqrt{3}}$

(C) 3 **(D)** $\frac{1}{3}$

10. The phase difference between electric field $\vec{E}$ and magnetic field $\vec{B}$ in an electromagnetic wave propagating along z-axis is

(A) zero **(B)** π

(C) $\frac{\pi}{2}$ **(D)** $\frac{\pi}{4}$

11. A coil of N turns is placed in a magnetic field $\vec{B}$ such that $\vec{B}$ is perpendicular to the plane of the coil. $\vec{B}$ changes with time as $B = B_0 \cos\left(\frac{2\pi}{T}t\right)$ where T is time period. The magnitude of emf induced in the coil will be maximum at

(A) $t = \frac{nT}{8}$ **(B)** $t = \frac{nT}{4}$

(C) $t = \frac{nT}{2}$ **(D)** $t = nT$

Here, n = 1, 2, 3, 4, ...

12. In Balmer series of hydrogen atom, as the wavelength of spectral lines decreases, they appear

(A) equally spaced and equally intense.

(B) further apart and stronger in intensity.

(C) closer together and stronger in intensity.

(D) closer together and weaker in intensity.

Note: For questions number 13 to 16, two statements are given — one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (A), (B), (C) and (D) as given below:

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

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

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

(D) If both Assertion (A) and Reason (R) are false.

13. Assertion (A): Electrons are ejected from the surface of zinc when it is irradiated by yellow light.

Reason (R): Energy associated with a photon of yellow light is more than the work function of zinc.

14. Assertion (A): The temperature coefficient of resistance is positive for metals and negative for *p*-type semiconductors.

Reason (R): The charge carriers in metals are negatively charged, whereas the majority charge carriers in *p*-type semiconductors are positively charged.

15. Assertion (A): When electrons drift in a conductor, it does not mean that all free electrons in the conductor are moving in the same direction.

Reason (R): The drift velocity is superposed over large random velocities of electrons.

16. Assertion (A): In interference and diffraction of light, light energy reduces in one region producing a dark fringe. It increases in another region and produces a bright fringe.

Reason (R): This happens because energy is not conserved in the phenomena of interference and diffraction.

SECTION B

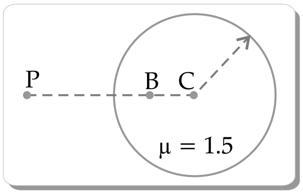
17. Draw the circuit diagram of a *p-n* junction diode in **(i)** forward biasing and **(ii)** reverse biasing. Also draw its I-V characteristics in the two cases.

18. A proton and α-particle are accelerated through different potentials V_1 and V_2 respectively so that they have the same de Broglie wavelengths. Find $\frac{V_1}{V_2}$.

19. A ray of light is incident normally on one face of an equilateral glass prism of refractive index μ. When the prism is completely immersed in a transparent medium, it is observed that the emergent ray just grazes the adjacent face. Find the refractive index of the medium.

20. Two electric heaters have power ratings P_1 and P_2, at voltage V. They are connected in series to a dc source of voltage V. Find the power consumed by the combination. Will they consume the same power if connected in parallel across the same source?

21. (a) An air bubble is trapped at point B ($CB = 20$ cm) in a glass sphere of radius 40 cm and refractive index 1.5 as shown in figure. Find the nature and position of the image of the bubble as seen by an observer at point P.



OR

(b) In normal adjustment, for a refracting telescope, the distance between objective and eye piece lens is 1.00 m. If the magnifying power of the telescope is 19, find the focal length of the objective and the eyepiece lens.

SECTION C

22. (a) Differentiate between nuclear fission and fusion.

(b) The fission properties of $_{94}Pu^{239}$ are very similar to those of $_{92}U^{235}$. How much energy (in MeV), is released if all the atoms in 1 g of pure $_{94}Pu^{239}$ undergo fission? The average energy released per fission is 180 MeV.

23. The electric field in a region is given by

$$\vec{E} = (10x + 4)\hat{i}$$

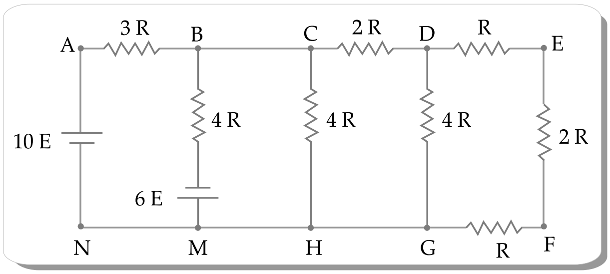
where x is in m and E is in N/C. Calculate the amount of work done in taking a unit charge from

(i) (5 m, 0) to (10 m, 0)

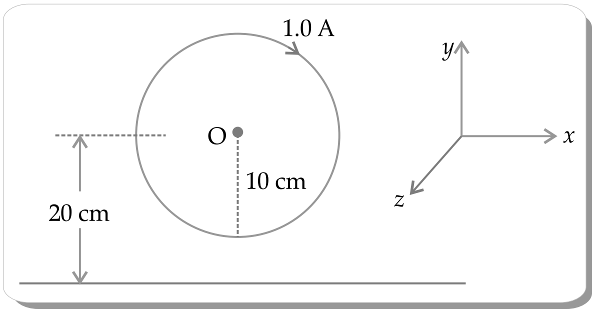
(ii) (5 m, 0) to (5 m, 10 m)

24. Draw the graph showing variation of scattered particles detected (N) with the scattering angle (θ) in Geiger-Marsden experiment. Write two conclusions that you can draw from this graph. Obtain the expression for the distance of closest approach in this experiment.

25. Find the current in branch BM in the network shown:



26. A circular loop of radius 10 cm carrying current of 1.0 A lies in x-y plane. A long straight wire lies in the same plane parallel to x-axis at a distance of 20 cm as shown in figure.



Find the direction and value of current that has to be maintained in the wire so that the net magnetic field at O is zero.

27. Name the electromagnetic waves with their wavelength range which are used for

(i) FM radio broadcast

(ii) detection of fracture in bones

(iii) treatment of muscular strain

28. (a) (i) Define mutual inductance. Write its SI unit.

(ii) Derive an expression for the mutual inductance of a system of two long coaxial solenoids of same length l, having turns N_1 and N_2 and of radii r_1 and r_2 ($>r_1$).

OR

(b) What are ferromagnetic materials? Explain ferromagnetism with the help of suitable diagrams, using the concept of magnetic domain.

SECTION D

Note: Questions number **29** to **30** are Case Study based questions. Read the following paragraph and answer the questions that follow.

29. A pure semiconductor like Ge or Si, when doped with a small amount of suitable impurity, becomes an extrinsic semiconductor. In thermal equilibrium, the electron and hole concentration in it are related to the concentration of intrinsic charge carriers. A p-type or n-type semiconductor can be converted into a p-n junction by doping it with suitable impurity. Two processes, diffusion and drift take place during formation of a p-n junction. A semiconductor diode is basically a p-n junction with metallic contacts provided at the ends for the application of an external voltage. A p-n junction diode allows currents to pass only in one direction when it is forward biased. Due to this property, a diode is widely used to rectify alternating voltages, in half-wave or full wave configuration.

(i) When Ge is doped with pentavalent impurity, the energy required to free the weakly bound electron from the dopant is about

(A) 0.001 eV **(B)** 0.01 eV

(C) 0.72 eV **(D)** 1.1 eV

(ii) At a given temperature, the number of intrinsic charge carriers in a semiconductor is 2.0×10^{10} cm^{-3}. It is doped with pentavalent impurity atoms. As a result, the number of holes in it becomes 8×10^3 cm^{-3}. The number of electrons in the semiconductor is

(A) 2×10^{24} m^{-3} **(B)** 4×10^{23} m^{-3}

(C) 1×10^{22} m^{-3} **(D)** 5×10^{22} m^{-3}

(iii) (a) During the formation of a p-n junction

(A) electrons diffuse from p-region into n-region and holes diffuse from n-region into p-region.

(B) both electrons and holes diffuse from n-region into p-region.

(C) electrons diffuse from n-region into p-region and holes diffuse from p-region into n-region.

(D) both electrons and holes diffuse from p-region into n-region.

OR

(b) Initially during the formation of a p-n junction

(A) diffusion current is large and drift current is small.

(B) diffusion current is small and drift current is large.

(C) both the diffusion and the drift currents are large.

(D) both the diffusion and the drift currents are small.

(iv) An ac voltage $V = 0.5 \sin (100\,\pi t)$ volt is applied, in turn, across n half-wave rectifier and a full-wave rectifier. The frequency of the output voltage across them respectively will be

(A) 25 Hz, 50 Hz **(B)** 25 Hz, 100 Hz

(C) 50 Hz, 50 Hz **(D)** 50 Hz, 100 Hz

30. A lens is a transparent optical medium bounded by two surfaces; at least one of which should be spherical. Applying the formula of image formation by a single spherical surface successively at the two surfaces of a thin lens, a formula known as lens maker's formula and hence the basic lens formula can be obtained. The focal length (or power) of a lens depends on the radii of its surfaces and the refractive index of its material with respect to the surrounding medium. The refractive index of a material depends on the wavelength of light used. Combination of lenses helps us to obtain diverging or converging lenses of desired power and magnification. **4×1=4**

(i) A thin converging lens of focal length 20 cm and a thin diverging lens of focal length 15 cm are placed coaxially in contact. The power of the combination is

(A) $\frac{-5}{6}D$ **(B)** $\frac{-5}{3}D$

(C) $\frac{4}{3}D$ **(D)** $\frac{3}{2}D$

(ii) The radii of curvature of two surfaces of a convex lens are R and 2R. If the focal length of this lens is (4/3)R, the refractive index of the material of the lens is

(A) $\frac{5}{3}$ **(B)** $\frac{4}{3}$

(C) $\frac{3}{2}$ **(D)** $\frac{7}{5}$

(iii) The focal length of an equiconvex lens

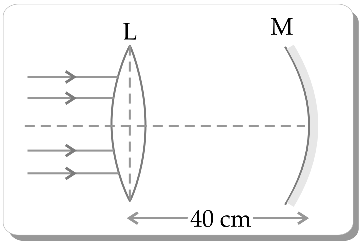
(A) increases when the lens is dipped in water.

(B) increases when the wavelength of incident light decreases.

(C) increases with decrease in radius of curvature of its surface.

(D) decreases when the lens is cut into two identical parts along its principal axis.

(iv) (a) A thin convex lens L of focal length 10 cm and a concave mirror M of focal length 15 cm are placed coaxially 40 cm apart as shown in figure. A beam of light coming parallel to the principal axis in incident on the lens. The final image will be formed at a distance of



(A) 10 cm, left of lens **(B)** 10 cm, right of lens

(C) 20 cm, left of lens **(D)** 20 cm, right of lens

OR

(b) A beam of light coming parallel to the principal axis of a convex lens L_1 of focal length 16 cm is incident on it. Another convex lens L_2 of focal length 12 cm is placed coaxially at a distance 40 cm from L_1. The nature and distance of the final image from L_2 will be

(A) real, 24 cm **(B)** virtual, 12 cm

(C) real, 32 cm **(D)** virtual, 18 cm

SECTION E

31. (a) (i) Draw a ray diagram for the formation of the image of an object by a convex mirror. Hence, obtain the mirror equation.

(ii) Why are multi-component lenses used for both the objective and the eyepiece in optical instruments ?

(iii) The magnification of a small object produced by a compound microscope is 200. The focal length of the eyepiece is 2 cm and the final image is formed at infinity. Find the magnification produced by the objective.

OR

(b) (i) Differentiate between a wavefront and a ray.

(ii) State Huygen's principle and verify laws of reflection using suitable diagram.

(iii) In Young's double slit experiment, the slits S_1 and S_2 are 3 mm apart and the screen is placed. 1.0 m away from the slits. It is observed that the fourth bright fringe is at a distance of 5 mm from the second dark fringe. Find the wavelength of light used.

32. (a) (i) A dielectric slab of dielectric constant K and thickness 't is inserted between plates of a parallel plate capacitor of plate separation d and plate area A. Obtain an expression for its capacitance.

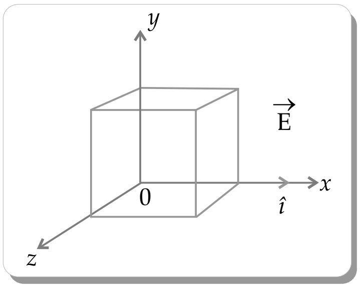
(ii) Two capacitors of different capacitances are connected first (1) in series and then (2) in parallel across a dc source of 100 V. If the total energy stored in the combination in the two cases are 40 mJ and 250 mJ respectively, find the capacitance of the capacitors.

OR

(b) (i) Using Gauss's law, show that the electric field $\vec{E}$ at a point due to a uniformly charged infinite plane sheet is given by $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$ where symbols have their usual meanings.

(ii) Electric field $\vec{E}$ in a region is given by $\vec{E} = (5x^2 + 2)\hat{i}$ where E is in N/C and x is in meters.

A cube of side 10 cm is placed in the region as shown in figure.



Calculate (1) the electric flux through the cube, and (2) the net charge enclosed by the cube.

33. (a) (i) Mention the factors on which the resonant frequency of a series LCR circuit depends. Plot a graph showing variation of impedance of a series LCR circuit with the frequency of the applied a.c. source.

(ii) With the help of a suitable diagram, explain the working of a step-up transformer.

(iii) Write two causes of energy loss in a real transformer.

OR

(b) (i) With the help of a diagram, briefly explain the construction and working of ac generator.

(ii) An electron is revolving around a proton in an orbit of radius r with a speed v. Obtain expression for magnetic moment associated with the electron.

Outside Delhi Set-2 **55/4/2**

Note: Except these, all other questions are available in Outside Delhi Set-1

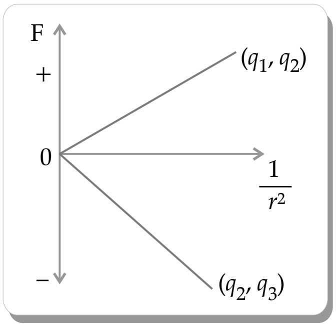
SECTION A

1. Three point charges, each of charge q are placed on vertices of a triangle ABC, with $AB = AC = 5L$, $BC = 6L$. The electrostatic potential at midpoint of side BC will be

(A) $\frac{11}{48}\frac{q}{\pi\varepsilon_0 L}$ **(B)** $\frac{8q}{36\pi\varepsilon_0 L}$

(C) $\frac{5q}{24\pi\varepsilon_0 L}$ **(D)** $\frac{1}{16}\frac{q}{\pi\varepsilon_0 L}$

2. The Coulomb force (F) versus ($1/r^2$) graphs for two pairs of point charges (q_1 and q_2) and (q_2 and q_3) are shown in figure. The charge q_2 is positive and has least magnitude. Then



(A) $q_1 > q_2 > q_3$ **(B)** $q_1 > q_3 > q_2$

(C) $q_3 > q_2 > q_1$ **(D)** $q_3 > q_1 > q_2$

5. A particle of mass m and charge q is moving with velocity $\vec{v} = v_x\hat{i} + v_y\hat{j}$. If it is subjected to a magnetic field $\vec{B} = B_0\hat{i}$, it will move in a –

(A) straight line path **(B)** circular path

(C) helical path **(D)** parabolic path

9. An ac source $V = 282 \sin(100\ t)$ volt is connected across a 1 μF capacitor. The rms value of current in the circuit will be (take $\sqrt{2} = 1.41$)

(A) 10 mA **(B)** 20 mA

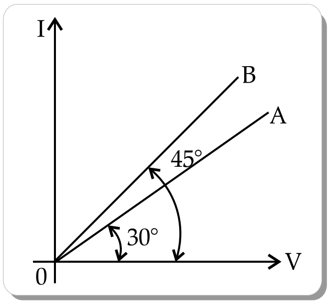
(C) 40 mA **(D)** 80 mA

SECTION B

20. Two wires A and B of different metals have their lengths in ratio 1 : 2 and their radii in ratio 2 : 1 respectively. I-V graphs for them is shown in the figure. Find the ratio of their

(i) Resistances (R_A/R_B) and

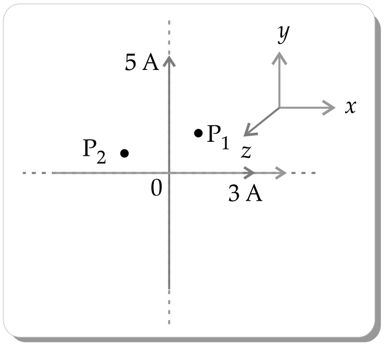
(ii) Resistivities (σ_A/σ_B)



SECTION C

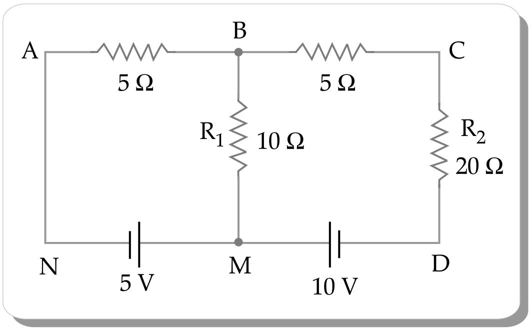
23. A thin spherical conducting shell of radius R has a charge q. A point charge Q is placed at the centre of the shell. Find **(i)** The charge density on the outer surface of the shell and **(ii)** the potential at a distance of (R/2) from the centre of the shell.

25. Two long insulated straight wires carrying currents of 3 A and 5 A are arranged in XY plane as shown in figure. Find the magnitude and direction of the net magnetic fields at points P_1 (2m, 2m) and P_2(–1m, 1m).



26. What is meant by displacement current? How is this current different from the conduction current? A capacitor is being charged by a source of emf. Justify the continuity of current in the circuit.

27. Find the currents flowing through the branches AB and BC in the network shown.



Outside Delhi Set-3 **55/4/3**

Note: Except these, all other questions are available in outside Delhi Set-1&2

SECTION A

1. An electric dipole of dipole moment $\vec{p}$ is kept in a uniform electric field $\vec{E}$. The amount of work done to rotate it from the position of stable equilibrium to that of unstable equilibrium will be

(A) 2 pE **(B)** –2 pE

(C) pE **(D)** zero

2. An infinite long straight wire having a charge density λ is kept along $y'y$ axis in x–y plane. The Coulomb force on a point charge q at a point P $(x, 0)$ will be

(A) attractive and $\dfrac{q\lambda}{2\pi\varepsilon_0 x}$

(B) repulsive and $\dfrac{q\lambda}{2\pi\varepsilon_0 x}$

(C) attractive and $\dfrac{q\lambda}{\pi\varepsilon_0 x}$

(D) repulsive and $\dfrac{q\lambda}{\pi\varepsilon_0 x}$

5. Two long straight parallel conductors A and B, kept at a distance r, carry current I in opposite directions. A third identical conductor C, kept at a distance $\left(\dfrac{r}{3}\right)$ from A carry current I_1 in the same direction as in A. The net magnetic force on unit length of C is

(A) towards A $\dfrac{3\mu_0 II_1}{2\pi r}$ **(B)** towards B $\dfrac{3\mu_0 II_1}{2\pi r}$

(C) towards A $\dfrac{3\mu_0 II_1}{4\pi r}$ **(D)** towards B $\dfrac{3\mu_0 II_1}{4\pi r}$

9. The r.m.s. value of a current given by $i = (i_1 \cos \omega t + i_2 \sin \omega t)$ is

(A) $\dfrac{1}{\sqrt{2}}(i_1 + i_2)$ **(B)** $\dfrac{1}{\sqrt{2}}(i_1 - i_2)$

(C) $\dfrac{1}{\sqrt{2}}\sqrt{(i_1^2 + i_2^2)}$ **(D)** $\dfrac{1}{\sqrt{2}}(i_1^2 + i_2^2)$

SECTION B

18. The ratio of de Broglie wavelengths of a proton and a deuteron accelerated by potential V_P and V_d respectively, $\left(\dfrac{\lambda_P}{\lambda_d}\right)$ is $\dfrac{1}{2}$. Find $\dfrac{V_P}{V_d}$.

20. Find the temperature at which the resistance of a conductor increases by 25% of its value at 27 °C. The temperature coefficient of resistance of the conductor is 2.0×10^{-4} °C^{-1}.

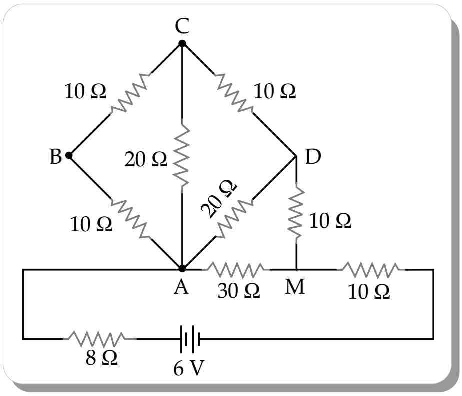
SECTION C

23. Two conducting spherical shells A and B of radii R and 2R are kept far apart and charged to the same charge density σ. They are connected by a wire. Obtain an expression for final potential of shell A.

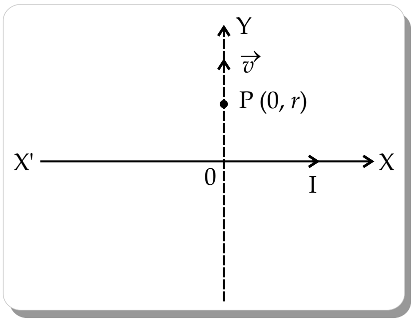
25. In the given network, calculate:

(i) effective resistance between points A and M, and

(ii) power supplied by the battery.



26. An infinite straight conductor is kept along X′X axis and carries a current as I. A charge q at point P(0, r) starts moving with velocity $\vec{v} = v_0\,\hat{j}$ shown in figure. Find the direction and magnitude of force initially experienced by the charge.



27. Explain the following giving reasons:

(i) 'Electromagnetic waves differ considerably in their mode of interaction with matter'.

(ii) 'Food items to be heated in microwave oven must contain water'.

(iii) 'Welders wear face mask with glasses during welding'.

■■

ANSWERS

Delhi Set-1 **55/5/1**

SECTION A

1. **Option (D) is correct.**

Explanation: Circuit current

$$I = \frac{E}{r+R} \Rightarrow E = I(r + R)$$

For 2 Ω, $E = 0.9(r + 2)$ ...(i)

For 7 Ω, $E = 0.3(r + 7)$ ...(ii)

From equations (i) & (ii),

$$0.9(r + 2) = 0.3(r + 7)$$

$$r = 0.5\ \Omega$$

2. **Option (D) is correct.**

Explanation: Since,

Magnetic force = centripetal force

$$qvB = \frac{mv^2}{R}$$

$$qB = \frac{mv}{R} \Rightarrow R = \frac{mv}{qB}$$

For $m = 2m$ and $q' = \frac{q}{2}$

$$\frac{q}{2}B = \frac{2mv}{R'}$$

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

3. **Option (B) is correct.**

Explanation: Paramagnetic are the materials that are feebly attracted to an external magnetic field. If a magnet is brought near these materials, these materials will get feebly magnetise towards it. Sodium and Calcium are paramagnetic materials.

4. **Option (C) is correct.**

Explanation: $V = I_g(G + R)$

I-Case: $2 = I_g(50 + 1000)$

$$I_g = \frac{2}{1050}\text{A}$$

II-Case: $10 = I_g(50 + R)$

$$10 = \frac{2}{1050}(50 + R)$$

$$R = \frac{10(1050)}{2} - 50$$

$$R = 5.2\ \text{k}\Omega$$

5. **Option (A) is correct.**

Explanation: By Mutual Inductance

$$\varepsilon_2 = -M\frac{dI}{dt}$$

$$2 \times 10^{-3} = -M(5)$$

$$M = -0.4\ \text{mH}$$

Negative sign shows that the mutual inductance is opposite to the induced emf.

6. **Option (B) is correct.**

Explanation: Ultraviolet rays are used to purify water and eye surgery.

7. **Option (D) is correct.**

Explanation: For the eyepiece:

$$\frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{u_e}$$

$$\Rightarrow \frac{1}{2} = \frac{1}{(-25)} - \frac{1}{u_e}$$

$$\Rightarrow u_e = -1.85\ \text{cm}$$

Since, the length of pipe is 10 cm.

So, $|v_o| + |u_e| = 10$ cm

$\Rightarrow |v_o| = 10 - 1.85 = 8.15$ cm

For the objective lens:

$$\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$$

$$\Rightarrow \frac{1}{1} = \frac{1}{8.15} - \frac{1}{u_o}$$

$$\Rightarrow u_o = -0.877\ \text{cm}$$

Now, magnification,

$$m = \frac{v_o}{|u_o|}\left(1 + \frac{D}{f_e}\right)$$

$$m = \frac{8.15}{0.877}\left(1 + \frac{25}{2}\right)$$

$$m = 125.46 \simeq 125$$

8. **Option (A) is correct.**

Explanation: Since, the threshold frequency is lesser for metal A. Hence, for the same frequency of incident radiation producing photoelectrons in the metals, the kinetic energy ($KE = hv - hv_0$) will be maximum for metal A.

9. **Option (C) is correct.**

Explanation: For first excited state, $n = 2$

$$E_1 = \frac{-13.6}{n^2} = \frac{-13.6}{(2)^2} = \frac{-13.6}{4}$$

$$E_1 = -3.4\ \text{eV}$$

Now, $K = -E = -(-3.4) = 3.4$ eV

$U = 2E = 2(-3.4) = -6.8$ eV

10. Option (C) is correct.

Explanation: Position of n^{th} bright fringe,

$$x_n = \frac{n\lambda D}{\mu d}$$

For 6^{th} maximum in air, ($\mu = 1$)

$$x_6 = \frac{6\lambda D}{d}$$

For n^{th} maximum in medium, $\left(\mu = \frac{4}{3}\right)$

$$x_n' = \frac{3n\lambda D}{4d}$$

Now, $x_n' = x_6$

$$\frac{3n\lambda D}{4d} = \frac{6\lambda D}{d}$$

$\Rightarrow$ $n = 8$

11. Option (A) is correct.

Explanation: the potential energy between two nucleons inside a nucleus is minimum at a distance of about 0.8 fm. If the distance reduces, the force becomes repulsive.

12. Option (B) is correct.

Explanation: 1 atom of Si doped out of 10^6 atom (1 ppm)

$\Rightarrow$ In 5×10^{28} atoms, net doped $= \frac{5\times10^{28}}{10^6}$

$= 5 \times 10^{22}$ atoms

1 Antimony creates 1 excess electron

$\Rightarrow$ Number of excess electrons $= n_e = 5 \times 10^{22}$

Also, $n_i^2 = n_e n_h$

$n_i^2 = (5 \times 10^{22})(4.5 \times 10^9)$

$\Rightarrow$ $n_i = 1.5 \times 10^{16}$

13. Option(C) is correct.

Explanation: Electric field is from positive charge to negative charge, hence the direction of electric field will be along OC. Also, the net potential at O is zero. Hence, assertion is true and reason is false.

14. Option (A) is correct.

Explanation: As the velocity and applied magnetic field are perpendicular to each other, hence, the work done by a magnetic force on a charge moving in a magnetic field is zero. This also means that the energy of the particle will not change. So, both the assertion and reason are true and reason correctly explains the assertion.

15. Option (C) is correct.

Explanation: As the fringe width is inversely proportional to the separation between two sources, so, there will be no pattern when the two sources are infinitely close to each other. So, the assertion is true but the reason is false.

16. Option (D) is correct.

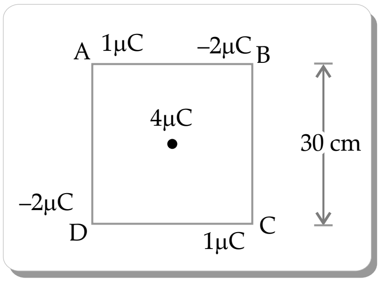
Explanation: Impact parameter, $b = \frac{Ze^2 \cot\left(\frac{\theta}{2}\right)}{4\pi\varepsilon_0 E}$

So, it depends upon the atomic number of target nucleus and its value is 0 when scattering angle is 180°. Therefore, both assertion and reason are false.

SECTION B

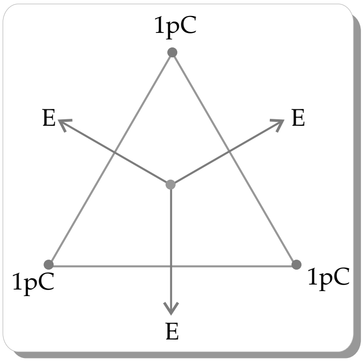
17. (a) The force of repulsion on charge 4μC due to charge 1μC at A and C are equal and opposite. Hence, they cancel each other.

Similarly, the force of attraction on charge 4μC due to charge –2μC at B and D are equal and opposite. Hence, they also cancel each other. So, the net force acting on the charge at the centre is zero.



OR

(b) The electric field at the centre of triangle due to all the three charges is zero as it is balanced from all the sides.



18. Since, the force on an individual charge moving at the drift velocity v_d,

$$F = qv_d B \sin\theta$$

For N charge carriers

$$F = (qv_d B \sin\theta)(N)$$

where, $N = nV = nAL$

$\Rightarrow \quad F = qv_d B \sin\theta \, nAL$

$F = nq Av_d B \sin\theta L$

$F = ILB \sin\theta \quad [\because I = nq Av_d]$

$\vec{F} = I(\vec{L} \times \vec{B})$

Yes, it is valid even when the conductor is in zig-zag form as then also the length of the wire will remain at the same angle with the magnetic field as before.

19. Given, $f_o = 150$ cm

$f_e = 5$ cm

In normal adjustment,

$$m = -\frac{f_o}{f_e} = -\frac{150}{5} = -30$$

For objective lens,

$$\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$$

$$\frac{1}{150} = \frac{1}{v_o} - \frac{1}{\infty}$$

$[\because u_o = \infty$, as object is at infinity]

$v_0 = 150$ cm

20. (a) Given, $E = 2.55 \text{ eV} = 2.55 \times 1.6 \times 10^{-19}$ J

$E = 4.08 \times 10^{-19}$ J

Since, $E = \frac{hc}{\lambda}$

$$\Rightarrow \quad 4.08 \times 10^{-19} = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{\lambda}$$

$\Rightarrow \quad \lambda = 4872$ Å

(b) This line falls in Balmer series of hydrogen spectrum.

21. Given, $r = 1.5 \times 10^{11}$ m

$v = 3 \times 10^4$ m/s

$m = 6.0 \times 10^{24}$ kg

According to Bohr's model, angular momentum is given as,

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

$$\Rightarrow \quad n = \frac{mvr2\pi}{h}$$

$$= \frac{6 \times 10^{24} \times 3 \times 10^4 \times 1.5 \times 10^{11} \times 2 \times 3.14}{6.626 \times 10^{-34}}$$

$\Rightarrow \quad n \simeq 3.0 \times 10^{74}$

SECTION C

22. (a) Einstein's photoelectric equation is,

$hv - hv_0 = KE$

Through a series of experiments, Millikan determined the slope $\frac{h}{e}$, of the $V_0 \rightarrow v$ graph. He calculated the known value of Planck's constant, $h = 6.626 \times 10^{-34}$ J-s, using the slope and electron charge values. Millikan conducted an experiment using a variety of alkali metals for a wide range of incident radiation, and he accurately verified the photoelectric equation.

(b) The threshold frequency is the frequency of incident radiation below which the photoelectric effect does not occur. At the threshold frequency, the electron is just ejected but does not have any kinetic energy to it. And when the energy with frequency more than the threshold frequency is incident on the surface, the electron gets ejected with a kinetic energy.

23. (a) The total number of electric field lines passing through an area per unit time is defined as electric flux. It is represented by ϕ.

$$\phi = \vec{E}.\vec{A}$$

Its dimensions are,

$\phi = [MLT^{-3}I^{-1}].[L^2]$

$\phi = [ML^3T^{-3}I^{-1}]$

(b) $\vec{E} = 100\frac{\text{N}}{\text{C}}\hat{i}$

side = 1 cm = 0.01 m

Surface area, $A = (0.01)^2 = 1 \times 10^{-4}$ m^2

Normal unit vector, $\hat{n} = 0.8\hat{i} + 0.6\hat{k}$

Angle, $\theta = \tan^{-1}\left(\frac{0.6}{0.8}\right) = 36.87°$

Now, $\phi = EA\cos\theta$

$\phi = 100(1 \times 10^{-4}) \cos 36.87$

$\phi = 10^{-2} \times 0.8$

$\phi = 8 \times 10^{-3}$ Nm^2/C

24. (a) (i) Lenz's law states that the direction of the induced current is such that the magnetic flux produced will oppose the change in flux which induced in the EMF in the first place.

Lenz's law is based upon the law of conservation of energy. Lenz law states that the induced current always tends to oppose the cause which produce it. So, in order to do work against opposing force we have to put extra effort. This extra work leads to periodic change in magnetic flux hence more current is induced. Thus, the extra effort is just transformed into electrical energy which is law of conservation of energy.

(ii) Given, $l = 2$ m

$\omega = 60$ rev/s

$B = 2T$

We know, $\varepsilon = \frac{1}{2}Bl^2w$

$\varepsilon = \frac{1}{2}(2)(2)^2(60)$

$\varepsilon = 4 \times 60$

$\varepsilon = 240$ V

OR

24. (b) (i) Ampere's circuit law state that the line integral of the magnetic field r around a closed path is equal to the product of magnetic permeability of that space and the current through the area bounded by the path.

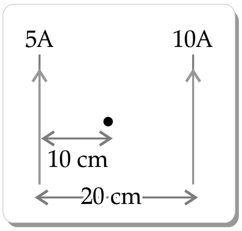
That is $\oint \vec{B}.\vec{dl} = \mu_0 I$

Where B is the magnetic field , μ_0 the magnetic permeability and I is the current through the area bounded by the path .

For its explanation, we can say that, Ampere's circuit law is the generalization of Biot-Savart's law. It is used to determine the magnetic field at any point due to distribution of current.

(ii) Given, $I_1 = 5A$

$I_2 = 10A$



We know, $B = \frac{\mu_0}{4\pi}\frac{2I}{d}$

So, $B_1 = \frac{\mu_0}{4\pi}\frac{10}{(0.01)} \otimes$

$B_2 = \frac{\mu_0}{4\pi}\frac{20}{(0.01)} \odot$

Thus, $B = B_2 - B_1$

$B = \frac{\mu_0}{4\pi(0.01)}(20-10)$

$B = \frac{10^{-7} \times 10}{0.01}$

$B = 10^{-4}$ T(outward direction)

25. Given, $\vec{v} = (1.0 \times 10^7 \text{ m/s})\hat{i} + (0.5 \times 10^7 \text{ m/s})\hat{j}$

$\vec{B} = (0.5 \text{ mT})\hat{j}$

Since, $\frac{mv^2}{r} = qvB$

$\Rightarrow r = \frac{mv_x}{qB} = \frac{(9.10 \times 10^{-31} \times 1.0 \times 10^7)}{(1.6 \times 10^{-19} \times 0.5 \times 10^{-3})}$

$r = 11.3875 \times 10^{-2}$ m

$r = 11.39$ cm

Now, $T = \frac{2\pi r}{v} = \frac{2\pi m}{qB}$

$T = \frac{2 \times 3.14 \times 9.11 \times 10^{-31}}{1.6 \times 10^{-19} \times 0.5 \times 10^{-3}}$

$T = 71.51 \times 10^{-9}$ s

$T = 71.51$ ns

The electron traces a linear path too. For one revolution pitch,

$T \times v_y = 71.51 \times 10^{-9} \times 0.5 \times 10^7$

$= 35.75 \times 10^{-2}$ m

$= 35.75$ cm

26. (a) (i) Infrared

(ii) Ultraviolet

(b) Production:

(1) Heated bodies radiate infrared rays.

(2) Ultraviolet rays are produced when electric current passed through gaseous medium known as gas discharge.

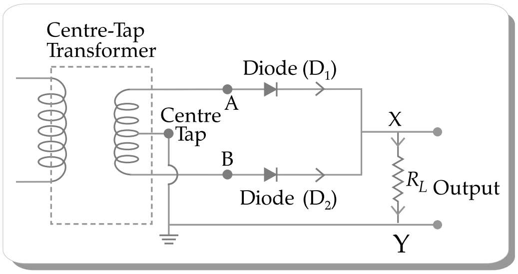
Detection:

(1) Infrared rays are detected using the point contact diodes.

(2) Ultraviolet light is detected using the specialised UV detectors.

27. (a) If an alternating voltage is applied across a junction diode, then the current will only in the part where it is forward biased. This property of junction diode can be used to rectify alternating current. The circuit used for this purpose is a rectifier.

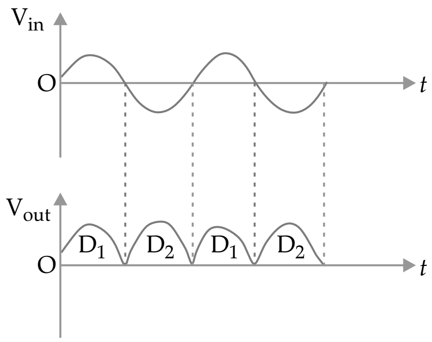
(b)



A full wave rectifier consists of two diodes connected in parallel across the ends of secondary winding of a centre tapped step down transformer. The load resistance R_L is connected across secondary winding and the diodes between A and B as shown in the circuit.

During positive half cycle of input a.c., end A of the secondary winding becomes positive and end B negative. Thus, diode D_1 becomes forward biased, whereas diode D_2 reverse biased. So, diode D_1 allows the current to flow through it, while diode D_2 does not, and current in the circuit flows from D_1 and through load R_L from X to Y.

During negative half cycle of input a.c., end A of the secondary winding becomes negative and end B positive, thus diode D_1 becomes reverse biased, whereas diode D_2 forward biased. So, diode D_1 does not allow the current to flow through it but diode D_2 does, and current in the circuit flows from D_2 and through load R_L from X to Y.



Input-Output waveforms

Since, in both the half cycles of input a.c., electric current through load R_L flows in the same direction, so d.c. is obtained across R_L. Although the direction of electric current through R_L remains same, but its magnitude changes with time, so it is called pulsating d.c.

28. (a) An intrinsic semiconductor has no fixed charges; instead, every electron comes from a broken bond that also leaves a hole in it. There are no fixed charges in this instance, and the number of positive and negative mobile charges is equal. As a result, an electrically neutral semiconductor is always uniformly doped.

(b) At equilibrium, the *p-n* junction has the same number of majority and minority carriers moving in opposite directions. The net current is the sum of drift current and diffusion current. So, the net current will be zero as diffusion and drift currents are equal and opposite.

(c) Since the current in a reverse-biased diode is caused by the minority charge carriers drifting from one area to another through the junction, the reverse current is essentially independent of the critical voltage. Therefore, a modest voltage is sufficient to continue sweeping the minority charge carriers.

SECTION D

29 (i) Option (D) is correct.

Explanation: HCl is a polar molecule because Chlorine atom in HCl is electronegative while Hydrogen is electropositive and they do not share the bonding electrons equally.

(ii) Option (B) is correct.

Explanation: The dipole moment is from negative charge to positive charge. So, when an external electric field is applied, the net dipole moments of induced dipoles is along the direction of the applied electric field.

(iii) Option (B) is correct.

Explanation: When a dielectric slab is inserted between the plates of an isolated charged capacitor, the capacitance increases. We know, $Q = CV$, so, for an isolated capacitor, the potential difference decreases which also concludes that the electric field decreases. Also the energy stored will decrease as the capacitance increases.

(iv) (a) Option (C) is correct.

Explanation: Since,

$$C_o = \frac{A\varepsilon_o}{d}$$

Now,

$$C = \frac{A\varepsilon_o}{d - t + \frac{t}{K}}$$

$$C = \frac{A\varepsilon_o}{d - \frac{d}{5} + \frac{d}{5K}} \qquad \left[\because t = \frac{q}{2}\right]$$

$$C = \frac{A\varepsilon_o}{d}\left[\frac{1}{1 - \frac{1}{5} + \frac{1}{5K}}\right]$$

$$C = \left[\frac{5K}{1+4K}\right]C_o$$

OR

(iv) (b) Option (D) is correct.

Explanation: For series combination,

$$\frac{1}{C_S} = \frac{1}{2C_o} + \frac{1}{6C_0}$$

$$\frac{1}{C_S} = \frac{3+1}{6C_o}$$

$$\Rightarrow \qquad C_S = \frac{3C_o}{2}$$

Energy stored, $U_S = \frac{1}{2}C_S V^2$

$$U_S = \frac{1}{2}\left(\frac{3C_o}{2}\right)V^2$$

For parallel combination,

$$C_P = 2C_o + 6C_o$$

$$C_P = 8C_o$$

Energy stored, $U_P = \frac{1}{2}C_P V^2$

$$U_P = \frac{1}{2}(8C_o)V^2$$

Now, $\frac{U_S}{U_P} = \frac{\frac{3}{2}C_o}{8C_o}$

$$\frac{U_S}{U_P} = \frac{3}{16}$$

30. (i) Option (C) is correct.

Explanation: $\sin\theta_1 = \frac{1}{\mu_g}$; $\sin\theta_2 = \frac{1}{\mu_w}$

since, $\mu_g > \mu_w$, $\theta_1 < \theta_2$

Critical angle θ between glass and water will be given by, $\sin\theta = \frac{\mu_w}{\mu_g} \Rightarrow \theta > \theta_2$

(ii) Option (C) is correct.

Explanation: When a ray of light is refracted into a denser medium, the frequency remains same but the wavelength decreases.

We know, $\mu = \frac{v_{rarer}}{v_{denser}} > 1$

$\Rightarrow \quad v_{rarer} > v_{denser}$

$\Rightarrow \quad \lambda_1 v_1 > \lambda_2 v_2 \quad$ [as $v_1 = v_2$]

$\Rightarrow \quad \lambda_1 > \lambda_2$

(iii) (a) Option (D) is correct.

Explanation: The critical angle is least for violet colour because its refractive index is the highest.

OR

(b) Option (D) is correct.

Explanation: In the case of minimum deviation, the refraction from the second surface for all the three rays are equal. For minimum deviation, the ray should be parallel to the base of the prism.

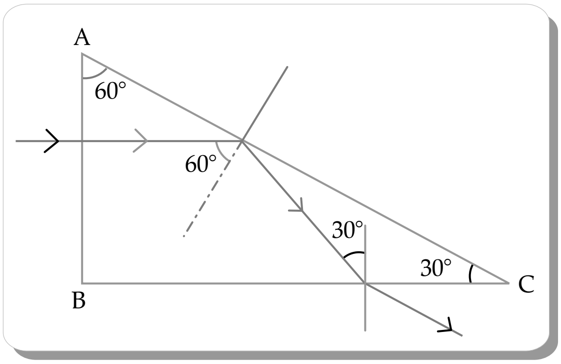
(iv) Option (D) is correct.

Explanation: $\mu = \sqrt{2}$

$\Rightarrow \quad \sin i_c = \frac{1}{\mu} = \frac{1}{\sqrt{2}}$

$$i_c = 45°$$

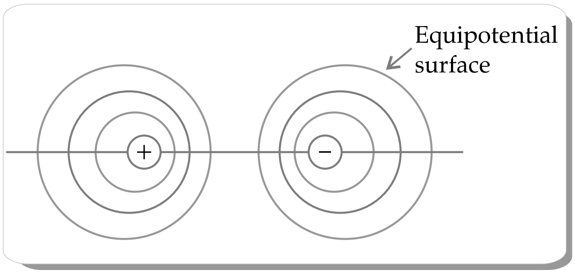
Now,



As the incident angle is greater than the critical angle, the ray will undergo total internal reflection.

SECTION E

31. (a) (i)



(ii) Work done is bringing the charge q_1 from infinity to the position r_1,

$$W_1 = q_1 V(r_1)$$

Work done in bringing the charge q_2 to the position r_2

$$W_2 = q_2 V(r_2) + \frac{q_1 q_2}{4\pi\varepsilon_o r_2}$$

Hence, total potential energy of system,

$$U = W_1 + W_2$$

$$U = q_2 V(r_1) + q_2 V(r_2) + \frac{q_1 q_2}{4\pi\varepsilon_o r_2}$$

(iii) Given, $P = 10^{-30}$ cm

$$E = 10^5 \text{ V/m}$$

$$\Delta U = -PE(\cos\theta_2 - \cos\theta_1)$$

$$\Delta U = -10^{-30} \times 10^5(\cos 60° - \cos 0°)$$

$$\Delta U = -10^{-30} \times 10^5\left(-\frac{1}{2}\right)$$

$$\Delta U = 10^{-25} \text{ J}$$

OR

(b) (i) (i) Outside the shell:

Let $\vec{E}$ be the electric field at P. The electric field through an elemental surface $\vec{dS}$ is, $d\phi = \vec{E}.\vec{dS}$

Total electric flux through the gaussian surface is

$$\phi = \oint_S EdS = E\oint_S dS = E(4\pi r^2)$$

Also, $\phi = \frac{q}{\varepsilon_o}$

$\Rightarrow \quad E(4\pi r^2) = \frac{q}{\varepsilon_o}$

$\Rightarrow \quad E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} \quad$ (for $r > R$)

(ii) Inside the shell:

$\Rightarrow \quad E(4\pi r^2) = 0$

$$E = 0$$

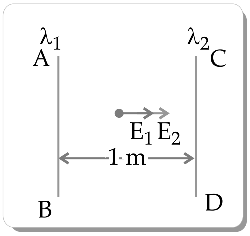
(ii) Given, $\lambda_1 = 10\mu$ C/m

$$\lambda_2 = -20\mu \text{ C/m}$$

$$d = 1 \text{ m}$$

For a point at a distance from linear charge,

$$E = \frac{\lambda}{2\pi\varepsilon_o r}$$



Total electric field,

$$E = E_1 + E_2$$

$$E = \frac{\lambda_1}{2\pi\varepsilon_o r} + \frac{\lambda_2}{2\pi\varepsilon_o r}$$

$$E = \frac{2}{4\pi\varepsilon_o r}(\lambda_1 + \lambda_2)$$

$$E = \frac{2 \times 10^9 \times 9}{0.5}(10 \times 10^{-6} - 20 \times 10^{-6})$$

$$E = -36 \times 10^9 \times 10^{-5}$$

$$E = -3.6 \times 10^5 \text{ N/C}$$

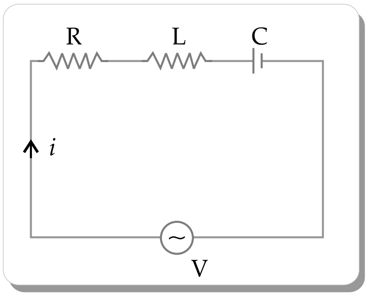
The direction of electric field is towards wire CD.

32. (a) (i) Since, the phase difference between V and I is zero, hence, the element X is a resistor.

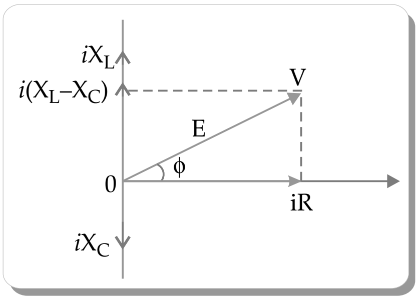
Since, the voltage leads the current by $\frac{\pi}{4}$, hence, the element Y is an inductor.

And, since, the current leads the voltage by $\frac{\pi}{4}$, hence, the element Z is a capacitor.

(ii)



Circuit diagram



Phasor diagram

Now,

$$V_R = i_o R$$

$$V_L = i_o X_L$$

$$V_C = i_o X_C$$

$$\Rightarrow \quad V^2 = VR^2 + (V_L - V_C)^2$$

$$V^2 = i^2(R^2 + (X_L - X_C)^2)$$

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

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

When $X_L = X_C$

$$\omega_r L = \frac{1}{\omega_r C}$$

$$\Rightarrow \quad \omega_r = \frac{1}{\sqrt{LC}}$$

$$2\pi\nu_r = \frac{1}{\sqrt{LC}}$$

$$\nu_r = \frac{1}{2\pi\sqrt{LC}}$$

At this frequency ν_r, as $X_L = X_C$

$$\Rightarrow \quad Z = R \rightarrow \text{minimum}$$

From the above relation, for frequencies greater than or less than ω_r, the values of current are less than the maximum value (I_0).

(iii) (i) When, $X_L = X_C$

$\therefore \quad Z = R$

So, the impedance is minimum when $X_L = X_C$.

(ii) $P = VI \cos\phi$

When $\phi = \frac{\pi}{2}$

$$P = 0$$

Therefore, wattless current flows when the impedance of the circuit is purely inductive or purely capacitive, i.e., $R = 0$.

OR

(b) (i) Transformer: A transformer is a device that can be used to increase or decrease an alternating voltage to any desired level. Step down transformers are the first kind of transformers that produce an output voltage that is lower than the input voltage. Step up transformers are the second kind of transformers that provide an output voltage that is higher than the input voltage.

Principle: When the current in a nearby coil varies, an e.m.f. is induced in the secondary coil.

Construction: The figure depicts a basic transformer. It is composed of two coils with varying turns wound around a closed, laminated soft iron core. Insulated wire is used to create the coils. The primary coil is the one to which the AC input voltage is applied, and the secondary coil is the one across which the AC output voltage is measured.

Working: When the primary is subjected to an alternating voltage, the resulting current creates an alternating magnetic flux that connects the secondary and causes an electromagnetic field (emf) in it. The number of turns determines this emf's value.

Let ϕ be flux in each turn in the core at time t due to current in primary when a voltage V_P is applied to it.

So, $$\varepsilon_S = -N_S \frac{d\phi}{dt}$$

Also, $$\varepsilon_P = -N_P \frac{d\phi}{dt}$$

But $\varepsilon_P = V_P$ and for small current $\varepsilon_S = V_S$

$$\Rightarrow \quad \frac{V_S}{V_P} = \frac{N_S}{N_P}$$

(ii) 1. Copper loss

(1) Heat energy lost as a result of the resistance of the copper coils used in a transformer's windings is known as copper loss.

(2) Using wire with a large cross-sectional area in the coils can reduce copper loss.

2. Hysteresis loss

(1) Hysteresis loss is the term for energy lost as a result of the transformer's constant magnetization and demagnetization.

(2) Soft magnetic core materials, such as silicon iron or permalloy, can reduce hysteresis loss in transformers.

3. Flux loss

(1) Poor coupling between the primary and secondary coils results in flux loss.

(2) Winding a transformer's primary and secondary coils one over the other will lower flux loss.

4. Eddy current loss

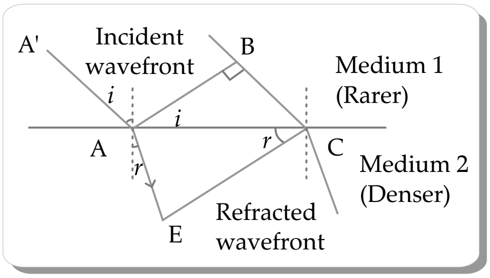
(1) Eddy current loss results from energy loss in a metallic plate kept in a time-varying magnetic field.

(2) It can be reduced by using a transformer with a laminated iron core.

33. (a) (i) Here, v_1 and v_2 are speeds of light in medium 1 and 2 as shown $BC = vt$ to get the shape of wave front draw an arc of radius v_2t form A towards medium 2.

If CE is tangent plane then $AE = v_2t$,

CE represents refracted wave front



In ΔABC, $$\sin i = \frac{BC}{AC} = \frac{v_1t}{AC}$$

In ΔAEC, $$\sin r = \frac{AE}{AC} = \frac{v_2t}{AC}$$

$$\Rightarrow \quad \frac{\sin i}{\sin r} = \frac{v_1}{v_2} \quad \text{...(i)}$$

Also, $\mu_1 = \frac{C}{v_1}$; $\mu_2 = \frac{C}{v_2}$

$$\Rightarrow \quad \frac{\mu_2}{\mu_1} = \frac{v_1}{v_2} \quad \text{...(ii)}$$

From (i) & (ii)

$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$$

This is snell's is law of refraction.

(ii) Given, $d = 0.30 \text{ mm} = 0.30 \times 10^{-3}$ m

$D = 1.5$ m

$\lambda = 600 \text{ nm} = 600 \times 10^{-9}$ m

For dark fringe,

$$x_n = \frac{(2n-1)}{2}\frac{\lambda D}{d}$$

When $n = 4$

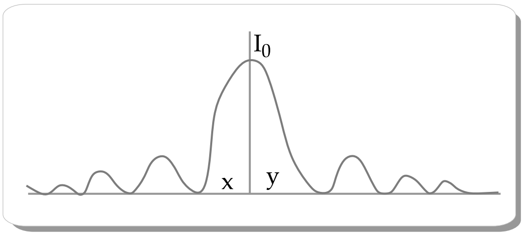
$$x_4 = \frac{(8-1)}{2}\frac{600 \times 10^{-9} \times 1.5}{0.30 \times 10^{-3}}$$

$$x_4 = \frac{7}{2}\frac{600 \times 10^{-9} \times 1.5}{0.30 \times 10^{-9}}$$

$$x_4 = 1.05 \text{ cm}$$

OR

(b) (i) Diffraction of light from a single slit: When monochromatic light is incident on a single slit, it diffracts light at that location. Behind the slit, on a screen, is the diffraction pattern. There are both dark and bright bands in the diffraction pattern. The central band reaches its peak intensity and then continues to decrease on either side.



(ii) Apply mirror's focal length formula.

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

for concave mirror, $f < 0$ & $u < 0$

$$\Rightarrow \quad \frac{1}{v} = \frac{1}{f}-\frac{1}{u}\text{; since } u < f < 0$$

$$\Rightarrow \quad \frac{1}{f}-\frac{1}{u} > 0$$

or $\quad \frac{1}{v} > 0$

$\Rightarrow \quad v > 0$

This shows that image is an right side of concave mirror.

Now, $\quad m = \frac{-v}{u}$

$\because \quad v > 0$ & $u < 0$

$\Rightarrow \quad m > 0$

Therefore, virtual and enlarged image is obtained.

Delhi Set-2 **55/5/2**

SECTION A

1. **Option (C) is correct.**

Explanation: When a resistance is joined in parallel, the effective resistance of the circuit will reduce. Thus, current will increase and voltage will decrease being low resistance.

2. **Option (B) is correct.**

Explanation: In the purely inductive circuit, Voltage leads the current by 90°.

3. **Option (B) is correct.**

Explanation: A magnetised needle in a uniform magnetic field experiences a torque but no net force. An iron nail near a bar magnet, however, experiences a force of attraction in addition to a torque.

4. **Option (C) is correct.**

Explanation: Since,

$$S = \frac{I_g G}{(I-I_g)}$$

Case-1 $\quad S_1 = \frac{i_g G}{(I-i_g)}$

Case-2 $\quad S_2 = \frac{i_g G}{2I-i_g}$

Now, $\quad \frac{S_1}{S_2} = \frac{2I-i_g}{I-i_g}$

5. **Option (D) is correct.**

Explanation: The magnetic flux Φ through the coil is given by the product of the magnetic field strength and the area of the coil:

$$\Phi = \vec{B}.\vec{A}$$

Given the magnetic field equation $B = 0.5t^2 + 2t$ and the area $A = 0.5 \text{ m}^2$, we can calculate the flux Φ at $t = 1$ second:

$$\Phi = (0.5\cdot(1)^2 + 2\cdot1) \times 0.5$$

$$\Phi = (0.5+2)\times0.5$$

$$\Phi = (2.5)\times0.5$$

$$\Phi = 1.25 \text{ Wb}$$

Now, we find the rate of change of magnetic flux $\frac{d\Phi}{dt}$ by differentiating the magnetic flux equation with respect to time:

$$\frac{d\Phi}{dt} = \frac{d}{dt}(0.5t^2 + 2t)$$

$$\frac{d\Phi}{dt} = 0.5(2t) + 2$$

$$\frac{d\Phi}{dt} = t + 2$$

Now, we can find the emf induced in the coil at $t = 1$ second using Faraday's law:

$$e_{emf} = \frac{d\Phi}{dt}$$

$$e_{emf} = -(1 + 2)$$

$$e_{emf} = -3 \text{ V}$$

Since, emf is induced in the coil, it's given by the negative of the rate of change of flux. So, the induced emf at $t = 1$ second is $e_{emf} = 3$ V.

Therefore, the correct answer is option (D) 3.0 V.

8. **Option (C) is correct.**

Explanation: The formula for the fringe width is :

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

$\therefore \quad B \propto \lambda$

We also know that the wavelength is inversely proportional to the refractive index of the medium.

So, $\quad \lambda' = \frac{\lambda}{\mu}$

So, $\quad \lambda' = \frac{3\lambda}{4}$

So, the ratio can be obtained as:

$$\frac{\beta'}{\beta} = \frac{\lambda'}{\lambda}$$

$$\beta' = \frac{0.44}{\frac{4}{3}}$$

$$\Rightarrow \quad \beta' = 0.33 \text{ mm}$$

19. $R = 2f = 30$ cm

$\Rightarrow$ $f = 15$ cm

$f = 15$ cm (convex mirror)

Convex mirror $\Rightarrow$ erect image $\Rightarrow m > 0$

$$m = \frac{1}{2} = \frac{-v}{u}$$

$$\Rightarrow v = \frac{-u}{2}$$

$$\Rightarrow u = -2v$$

By mirror formula,

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

$$\frac{1}{v}-\frac{1}{2v} = \frac{1}{15}$$

$$\Rightarrow \frac{1}{2v} = \frac{1}{15}$$

$$v = 7.5 \text{ cm}, u = -2v = -15 \text{ cm}$$

Distance between image & object

$= 7.5 + 15$

$= 22.5$ cm

20. ${}_1^1H + {}_1^3H \rightarrow {}_1^2H + {}_1^2H$

Mass lost $\times c^2$ = Energy released

$M_{LHS} = 10.07825 + 3.016049$

$= 4.023874u$

$M_{RHS} = 2 \times 2.014102$

$= 4.028204u$

$M_{RHS} > M_{LHS} \rightarrow$ Energy absorbed

$\Delta M = 0.00433u$

$\therefore$ $E = \Delta Mc^2$

$= (0.00433u) \times (931.5 \text{ MeV/c}^2)$

$= 4.00545$ MeV

21. To find the distance of closest approach for a proton approaching a gold nucleus, we can use the Rutherford scattering formula. Rutherford scattering describes the deflection of charged particles (such as alpha particles or protons) as they pass near a nucleus.

The Rutherford scattering formula for the distance of closest approach (r_{min}) for an incident particle with charge q and kinetic energy E approaching a nucleus with charge Ze and radius R is given by:

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

Where:

- K is the kinetic energy of the incident particle (in joules),
- Z is the atomic number of the nucleus (number of protons), and
- e is the elementary charge(1.6×10^{-19} C).

Given that the energy of the proton is 1.6 MeV,

$\because$ $1 \text{ MeV} = 1.6 \times 10^{-13}$ J

$\therefore$ $1.6 \text{ MeV} = 1.6 \times 1.6 \times 10^{-13}$ J

$= 2.56 \times 10^{-13}$ J

Now,

$$r_{min} = 9.0\times10^9 \times \frac{2\times79\times(1.6\times10^{-19})}{2.56\times10^{-13}}$$

$= 1422 \times 10^{-16}$ m

$r_{min} \approx 1.42 \times 10^{-13}$ m

So, the distance of closest approach is approximately 1.42×10^{-13} m.

22. (i) Here, $\Phi_0 = 2.1$ eV

$= 2.0 \times 1.6 \times 10^{-19}$ J

$\lambda = 150 \times 10^{-9}$ m

As, $$\Phi_0 = \frac{hc}{\lambda_0}$$

or $$\lambda_0 = \frac{hc}{\Phi_0}$$

$$= \frac{(6.63\times10^{-34})\times(3\times10^8)}{2.1\times1.6\times10^{-19}}$$

$= 6.187 \times 10^{-7}$ m

$= 6187.5$ Å

(ii) Max. kinetic energy of photoelectron is

$$K_{max} = \frac{hc}{\lambda} - \phi_0$$

$$= \frac{(6.63\times10^{-34})\times(3\times10^8)}{(150\times10^{-9})\times(1.6\times10^{-19})} - 2.0$$

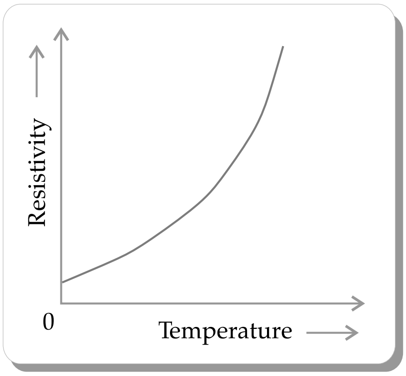
$= 7.42 - 2.1 = 5.32$ eV

(iii) Stopping potential $V_0 = \frac{K_{max}}{e} = \frac{5.32 \text{ eV}}{e}$

$= 5.32$V

24. (i) The temperature coefficient of resistance is generally defined as the change in electrical resistance of a substance with respect to per degree change in temperature.

(ii) The variation of resistivity of copper with temperature is parabolic in nature. From the graph it is understood that the resistivity of copper increases with the rise in temperature. It is also understood that, whatever the temperature is, the copper has a certain resistivity.



(iii) We can use the formula for the change in resistance due to temperature:

$$\Delta R = R_0 \alpha \Delta T$$
$$\Delta R = 1.70 \times 10^{-4}\ \Omega$$

Now, to find the resistance at – 73°C, we add the change in resistance to the initial resistance:

$$R_{-73} = R_0 + \Delta R$$
$$R_{-73} = 10\ \Omega + 1.70 \times 10^{-4}\ \Omega$$
$$R_{-73} = 10.00017\ \Omega$$

Therefore, the resistance of the wire at – 73°C is approximately 10.00017 Ω.

25. **(i)** The part of the electromagnetic spectrum that is stopped by face masks or welders is the infrared region. The order of wavelengths in the infrared region is approximately from 700 nanometers to 1 millimeter.

(ii) The part of the electromagnetic spectrum used in detectors in Earth satellites is the microwave region. The order of wavelengths in the microwave region is approximately from 1 millimeter to 1 meter.

(iii) The part of the electromagnetic spectrum used in short-wave hand in communication is the shortwave radio region. The order of wavelengths in the shortwave radio region is approximately from 10 meters to 100 meters.

Delhi Set-3 **55/5/3**

SECTION A

1. Option (D) is correct.

Explanation: Resistance of coil $R = +\dfrac{l}{A}$

$$R \propto l$$

Heater coil cut into two parts i.e., $l = \dfrac{l}{2}$

$$R = \frac{R}{2}$$

$$\text{Power} = \frac{V^2}{R} = \frac{V^2}{\frac{R}{2}}$$

$$= \frac{2V^2}{R} = 2P$$

2. Option (A) is correct.

Explanation: Magnetic field due to circular coil B

$$= \frac{\mu_0 I}{2r}$$

$$B_1 = \frac{\mu_0 I}{2R},\ B_2 = \frac{\mu_0 \sqrt{3} I}{2R}$$

Net $$M.F|B| = \sqrt{B_1^2 + B_2^2 + 2B_1B_2\cos 90°}$$

[As coils placed at right angle θ = 90°, cos 90° ≈ 0]

$$|B| = \sqrt{B_1^2 + B_2^2}$$

$$= \sqrt{\left(\frac{\mu_0 I}{2R}\right)^2 + \left(\frac{\mu_0\sqrt{3}I}{2R}\right)^2}$$

$$= \frac{\mu_0 I}{2R}\sqrt{1+3}$$

$$= \frac{\mu_0 I}{2R} \times 2 = \frac{\mu_0 I}{R}$$

3. Option (A) is correct.

Explanation: Ferromagnetic material have high susceptibility. Paramagnetic substance have small and +ve susceptibility. Aluminium is a paramagnetic. Water, bismuth is a diamagnetic. Gadolinium is ferromagnetic and considered as paramagnetic at room temperature.

4. Option (A) is correct.

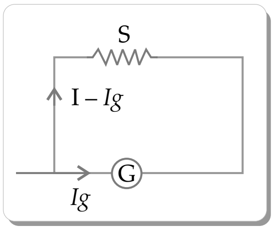
Explanation: $R_G = 100\ \Omega$, $I_g = 1.0$ mA $= 10^{-3}$A

$$I_g R_G = (I - I_g) R_S$$

$$R_S = \frac{I_g R_G}{I - I_g}$$

$$= \frac{10^{-3} \times 100}{(1 - 0.001)}$$

$$= \frac{0.1}{0.999} = 0.1\ \Omega$$



5. Option (B) is correct.

Explanation: $M = 50$ mH $= 50 \times 10^{-3}$H

$$i = 1.0 \sin\left(100\pi t + \frac{\pi}{3}\right) \text{A}$$

$$e = -M\frac{di}{dt}$$

$$= -50 \times 10^{-3} \frac{d}{dt}\left(1.0 \sin\left(100\pi t + \frac{\pi}{3}\right)\right)$$

$$= -50 \times 10^{-3} \times 1.0 \times 100\pi \cos\left(100\pi t + \frac{\pi}{3}\right)$$

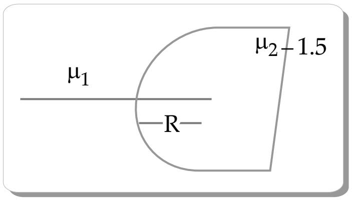
Peak emf $= |-50 \times 10^{-3} \times 1 \times 100\pi| = 5\pi$

Peak emf $= 5\pi$

12. Option (D) is correct.

Explanation: Refraction at convex spherical surfaces

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



R = 40 cm, μ_2 = 1.5

Object distance (u) = 60 cm

$$\frac{1.5}{v} - \frac{1}{(-60)} = \frac{1.5-1}{40}$$

$$\frac{1.5}{v} = \frac{0.5}{40} - \frac{1}{60}$$

$$= \frac{1}{80} - \frac{1}{60} = \frac{3-4}{240}$$

$$\frac{1.5}{v} = \frac{-1}{240}$$

$$v = -240 \times \frac{15}{10}$$

$$= -360 \text{ cm} = -3.6 \text{ m}$$

(– ve) sign so virtual.

SECTION B

19. f_1 = 10 cm, f_2 = – 15 cm

$$\text{Focal length } \frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{10} - \frac{1}{15}$$

$$\frac{1}{f} = \frac{15-10}{150} = \frac{5}{150} = \frac{1}{30}$$

$$f = 30 \text{ cm}$$

Combination will behave as converging lens of focal length f = 30 cm.

20. Deuterium $_1H^2$

Given mass = 2g

Atomic weight = 2

Number of atom in 2g of deuterium

$$= \frac{6.023 \times 10^{23} \times 2}{2}$$

$$= 6.023 \times 10^{23}$$

Energy released in 2g Deuterium = 3.27 MeV

$$\text{Total energy} = \frac{3.27}{2} \times 6.023 \times 10^{23} \text{ MeV}$$

$$= \frac{3.27}{2} \times 6.023 \times 10^{23} \times 10^6 \times 1.6 \times 10^{-19} \text{ J}$$

$$= 15.75 \times 10^{10} \text{ J}$$

Power consumed by bulb = 200 W

$$\text{Time for bulb glow} = \frac{15.75 \times 10^{10}}{200}$$

$$= 7.87 \times 10^8 \text{ s}$$

$$= \frac{7.87 \times 10^8}{365 \times 24 \times 60 \times 60} \text{ year}$$

$$= 24.95 \text{ year}$$

21. $V = 2.2 \times 10^6$ m/s, r = 0.53 Å = 0.53×10^{-10} m

$$f = \frac{1}{T}$$

$$\text{Time} = \frac{\text{distance}}{\text{Speed}} = \frac{d}{V} = \frac{2\pi r}{V}$$

$$= \frac{V}{d} = \frac{V}{2\pi r}$$

$$= \frac{2.2 \times 10^6}{2 \times 3.14 \times 0.53 \times 10^{-10}}$$

$$= \frac{2.2}{3.32} \times 10^{16}$$

$$f = 6.6 \times 10^{15} \text{ Hz}$$

23. Threshold frequency (V_0) = 3.0×10^{14} Hz

Incident frequency (ν) = 9.0×10^{14} Hz

(i) Work function (ϕ) = $h\nu_0$

$$h = 6.63 \times 10^{34} \text{ Js}$$

$$\phi = 6.63 \times 10^{-34} \times 3 \times 10^{14} \text{ Hz}$$

$$= 1.98 \times 10^{-19} \text{ J}, 1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$$

$$\phi(\text{in eV}) = \frac{1.98 \times 10^{-19}}{1.6 \times 10^{-19} \text{ J/eV}} = 1.24 \text{ eV}$$

(ii)

$$E = \phi + K.E$$

$$h\nu = \phi + K.E$$

$$K.E = h\nu - \phi$$

$$= 6.63 \times 10^{-34} \times 9 \times 10^{14} - 1.98 \times 10^{-19}$$

$$= 5.96 \times 10^{-19} \text{ J} - 1.98 \times 10^{-19}$$

$$= 3.98 \times 10^{-19}$$

$$K.E = \frac{1}{2} m V^2_{\text{max}}$$

$$V^2_{\text{max}} = \frac{2 \times K.E}{m} = \frac{2 \times 3.98 \times 10^{-19}}{9.1 \times 10^{-31}}$$

$$= \frac{7.96}{9.1} \times 10^{12}$$

$$V^2 = 87.4 \times 10^{10}$$

$$V = \sqrt{87.4 \times 10^8} = 9.3 \times 10^5 \text{ m/s}$$

27. $V = 3 \times 10^6 \text{ m/s } \hat{i}, \ \vec{B} = (91 \text{ mT})\hat{k}, = = 91 \times 10^{-3} \text{T } \hat{k}$

(a)

$$F = q(\vec{V} \times \vec{B})$$

$$= -(1.6 \times 10^{-19})[3 \times 10^6 \hat{i} \times 91 \times 10^{-3} \hat{k})$$

$$= 436.8 \times 10^{-16} (\hat{i} \times \hat{k})$$

$= -436.8 \times 10^{-16}\,\text{N}(-\hat{j})$

$= 436.8 \times 10^{-16}\,\text{N in } \hat{j}$ direction

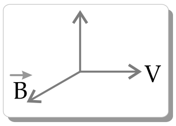
Since, $r = \dfrac{mv}{qB}$

$= \dfrac{9.1\times10^{-31}\times3\times10^{6}}{1.6\times10^{-19}\times91\times10^{-3}}$

$= \dfrac{27.3\times10^{-25}}{145.6\times10^{-22}}$

$= = 0.188 \times 10^{-3}\text{m}$

(b) $V = \hat{i},\ B = \hat{k},\ F = \hat{j}$



V, B and Force are mutually ⊥ to each other

28. $V = 1.0$ V, $l = 5$ m

$A = 1.0\ \text{mm}^2 = 1 \times 10^{-3}\ \text{m}^2$

$n = 8.5 \times 10^{28}$

$I = 4.25$ A

(i) $I = V_d enA$

$V_d = \dfrac{I}{enA}$

$= \dfrac{4.25}{1.6\times10^{-19}\times8.5\times10^{28}\times1\times10^{-3}}$

$= \dfrac{4.25}{13.6}\times10^{-6}$

$= 0.31 \times 10^{-6}$ m/s

(ii) $V_d = \dfrac{-eE}{m}\tau,\ E = \dfrac{V}{l}$

$V_d = \dfrac{-eV}{ml}\tau$

$\tau = \dfrac{V_d ml}{eV}$

$= \dfrac{0.31\times10^{-6}\times9.1\times10^{-31}\times5}{1.6\times10^{-19}\times1}$

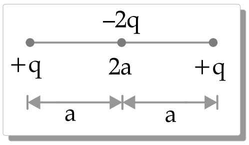
$\tau = 8.81\times10^{-18}$ s

Outside Delhi Set-1 **55/4/1**

SECTION A

1. Option (C) is correct.

***Explanation*:**



Potential energy of the system

$$U = \frac{kq^2}{2a} - \frac{-k2q^2}{a}\times2$$

$$\Rightarrow \quad U = \frac{kq^2 - 8kq^2}{2a} = \frac{-7kq^2}{2a}$$

So, $$U = \frac{-7q^2}{8\pi\varepsilon_0 a}$$

2. Option (B) is correct.

***Explanation*:** According to the law of conservation of charge, $-7 + 4 +$ charge on $B_3 = -6$

⇒ charge on $B_3 = -6 + 7 - 4 = -3pC$.

3. Option (A) is correct.

***Explanation*:** The quantum nature of light explains the photoelectric effect by stating that there is a minimum frequency of incident radiation below which no electrons are emitted. The minimum frequency is called the threshold frequency.

4. Option (C) is correct.

***Explanation*:** In Bohr's model of H-atom, the radius of n^{th} orbit is given by.

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

So, $r_n \propto n^2$

5. Option (C) is correct.

***Explanation*:** Right hand thumb rule states that point your thumb in the direction of current, and your curled fingers show the direction of the magnetic field.

6. Option (A) is correct.

***Explanation*:** The magnetic susceptibility of a diamagnetic material is small and negative. Diamagnetic materials are weakly repelled by magnetic fields. When placed in a magnetic field, they create a magnetic field in the opposite direction, due to the orbital motion of electrons within their atoms.

7. Option (B) is correct.

***Explanation*:** $I_g G = (I - I_g)S$

$\Rightarrow \quad I_g \times 100 = (1 - I_g) \times 0.1$

$\Rightarrow \quad I_g \times 1000 = 1 - I_g$

$\Rightarrow \quad 1001\, I_g = 1$

$\Rightarrow \quad I_g = \dfrac{1}{1001} \approx 1$ mA

8. Option (A) is correct.

***Explanation*:** Magnetic flux linked with Loop B,

$$\phi = \frac{I_{10}I}{2R}\times\pi\left(\frac{R}{20}\right)^2$$

$$\Rightarrow \qquad \phi = \frac{l_{10}I}{2R}\pi\frac{R^2}{400}$$

$$\Rightarrow \qquad \phi \propto R$$

9. Option (D) is correct.

Explanation: $$\frac{L_1}{L_2} = \frac{\tan 30^\circ}{\tan 60^\circ}$$

$$= \frac{1}{\sqrt{3}\times\sqrt{3}} = \frac{1}{3}$$

10. Option (A) is correct.

Explanation: The variations in electric and magnetic fields are in same phase, i.e., both attain their maxima and minima at the same instant and at the same place.

11. None of the option is correct

Explanation: $$\in = \frac{-d\phi}{dt}$$

$$= -\frac{d}{dt}B_0\cos\left(\frac{2\pi}{T}t\right)NA$$

$$= NAB_0\sin\left(\frac{2\pi}{T}t\right)\times\frac{2\pi}{T}$$

$$= \frac{NAB_0 2\pi}{T}\sin\left(\frac{2\pi}{T}t\right)$$

For emf to be maximum,

$$\sin\left(\frac{2\pi}{T}t\right) = \pm 1$$

$$\Rightarrow \qquad \frac{2\pi}{T}t = (2n-1)\frac{\pi}{2}$$

$$\Rightarrow \qquad t = (2n-1)\frac{T}{4}$$

12. Option (D) is correct.

Explanation: In Balmer series of *H*-atom, as the wavelength of spectral lines decreases, they appear closer together and weaker in intensity due to reduced transition probability.

13. Option (A) is correct.

Explanation: The photons transfer their energy to electrons allowing them to overcome the work function and escape from the surface of the material.

14. Option (B) is correct.

Explanation: The behaviour of temperature coefficient of resistance is directly related to the change in carrier concentration with temperature in these materials, rather than the polarity of charge carriers.

15. Option (A) is correct.

Explanation: When electrons drift in a conductor, it doesn't mean that all free electrons in the conductor are moving in the same direction. this is because the drift velocity, which constitutes the net flow of electrons, is superposed over large random velocities of electrons within the conductor.

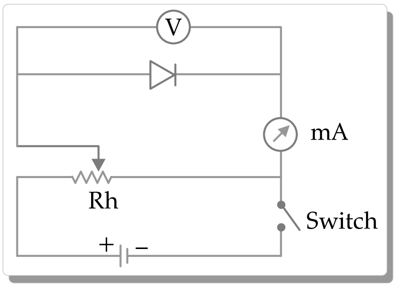
16. Option (C) is correct.

Explanation: Energy is conserved in interference and diffraction phenomena.

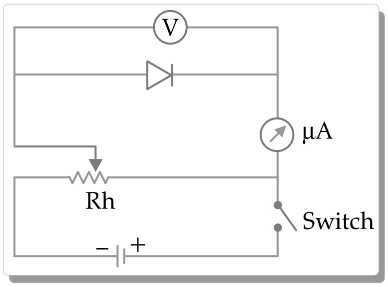
SECTION B

17. Circuit diagram of a *p-n* junction diode

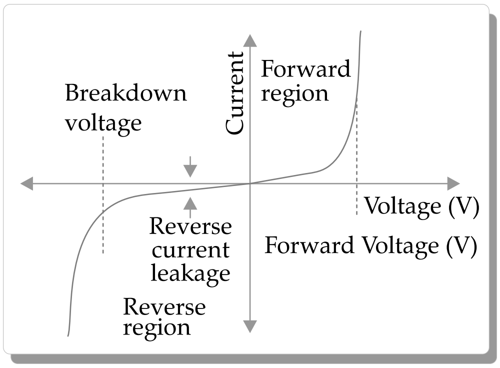
(i) In forward biasing



(ii) In reverse biasing



$V \sim I$ characteristics



18. De-Broglie wavelength is given by

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

According to the question,

$$\frac{h}{\sqrt{2m_p q_p V_1}} = \frac{h}{\sqrt{2m_d q_d V_2}}$$

$$\Rightarrow \qquad m_d q_d V_2 = m_p q_p V_1$$

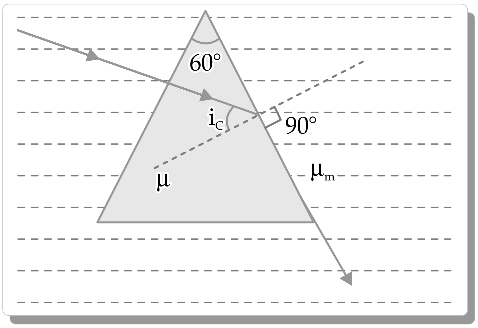
$$\Rightarrow \qquad 4m_p \times 2q_p \times V_2 = m_p q_p V_1$$

[As $m_d = 4m_p$ and $q_d = 2q_p$]

$$\Rightarrow \qquad 8V_2 = V_1$$

$$\Rightarrow \qquad \frac{V_1}{V_2} = 8$$

19.



For a prism we have

$$r_1 + r_2 = A$$

Here $r_1 = 0$

$\Rightarrow$ $r_2 = A$

Applying Snell's law

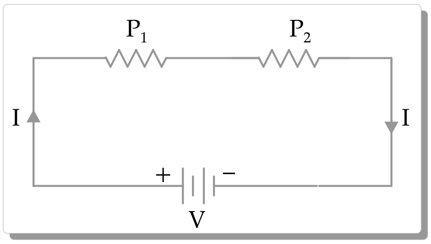
$$\mu \sin r_2 = \mu_m \sin 90°$$

$$\mu \sin A = \mu_m$$

$\Rightarrow$ $\mu \sin 60° = \mu_m$

$\Rightarrow$ $\mu_m = \frac{\sqrt{3}}{2}\mu$

20. (i) When the, heaters are connected in series:



The resistance of these heaters are

$$R_1 = \frac{V^2}{P_1} \text{ and } R_2 = \frac{V^2}{P_2}$$

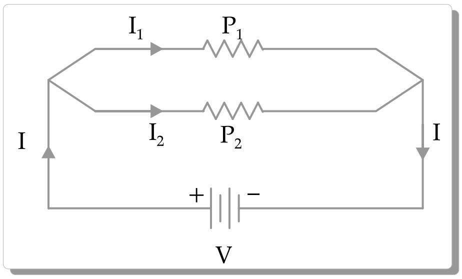
Here, $R = R_1 + R_2$

It P is the effective power of the combination,

then $\frac{V^2}{P} = \frac{V^2}{P_1} + \frac{V^2}{P_2}$

$\Rightarrow$ $\frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2}$

(ii) When the heaters are connected in parallel:



Again the resistances of these heaters are

$$R_1 = \frac{V^2}{P_1} \text{ and } R_2 = \frac{V^2}{P_2}$$

Here, $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

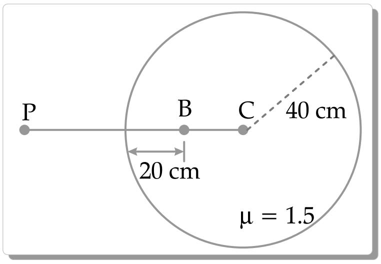
Multiplying both sides by V^2,

$$\frac{V^2}{R} = \frac{V^2}{R_1} + \frac{V^2}{R_2}$$

$\Rightarrow$ $P = P_1 + P_2$

Therefore, they will consume different powers if connected in series and in parallel across the same source.

21. (a) From refraction at curved surfaces,



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

$\Rightarrow$ $\frac{1}{v} - \frac{1.5}{-20} = \frac{1-1.5}{-40}$

$\Rightarrow$ $\frac{1}{v} + \frac{1.5}{20} = \frac{-0.5}{-40}$

$\Rightarrow$ $\frac{1}{v} + \frac{3}{40} = \frac{1}{80}$

$\Rightarrow$ $\frac{1}{v} = \frac{1}{80} - \frac{3}{40}$

$\Rightarrow$ $\frac{1}{v} = \frac{1-6}{80} = \frac{-5}{80} = -\frac{1}{16}$

$\Rightarrow$ $v = -16$ cm

So, the image formed is virtual.

OR

(b) Given $f_o + f_e = 100$ cm ...(i)

and magnifying power

$$= \frac{f_o}{f_e} = 19$$

$\Rightarrow$ $f_o = 19f_e$

From eqn (i), $19f_e + f_e = 100$

$\Rightarrow$ $f_e = 5$ cm

So $f_o = 95$ cm

SECTION C

22. (a)

	Nuclear fission	Nuclear fusion
(i)	When a heavy nucleus is excited, it gets split up into two smaller nuclei of nearly comparable masses.	Here two lighter nuclei fuse together to form a heavier nucleus.
(ii)	The conditions of high temperature and pressure are not necessary for its occurrence.	The conditions of extremely high pressure and temperature are necessary for its occurrence.
(iii)	Neutrons are the link particles.	Protons are the link particles.
(iv)	${}^{235}_{92}U + {}_0{}'n \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3{}^{1}_{0}n + Q$	${}^{1}_{1}H + {}^{1}_{1}H \rightarrow {}^{2}_{1}H + e^{+} + \nu + 0.42$ MeV

(b) Number of atoms in 1g of ${}_{94}Pu^{239}$

$$= \frac{\text{Avogodro's number}}{\text{Mass number}}$$

$$= \frac{6.023 \times 10^{23}}{239}$$

Energy released per fission = 180 MeV.

Energy released by fission of 1g of ${}_{94}Pu^{239}$

$$= \frac{6.023 \times 10^{23}}{239} \times 180$$

$$= 0.025 \times 10^{23} \text{ MeV}$$

23. $\vec{E} = (10x + 4)\hat{i}$

We have $W = Vq$

$\Rightarrow$ $V = \frac{W}{q} = \frac{W}{1} = W$

Now applying $V = -\int E dx$

(i) $W = V = -\int_5^{10} (10x + 4) dx$

$= -\left[5x^2 + 4x\right]_5^{10}$

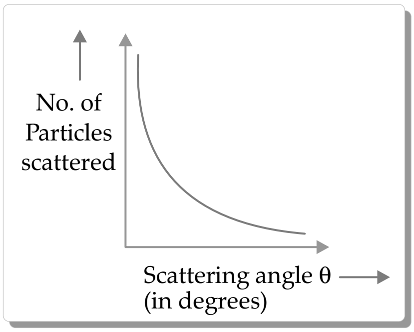
$= -[5 \times (100 - 25) + 4(10 - 5)]$

$= -(5 \times 75 + 4 \times 5)$

$= -395$ J

(ii) No work is done in moving the unit positive charge from $(5m, 0)$ to $(5m, 10)$, because the displacement of the charge is perpendicular to the field.

24.



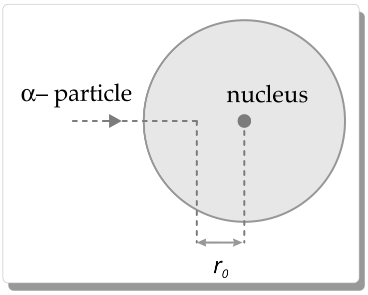
Two conclusion from the graph:

(i) Most of the α-particles pass straight through the gold foil or suffer only small deflections.

(ii) A few α-particles, about 1 in 8000, get deflected through 90° or more.

(iii) Occasionally, an α-particle gets rebounded from the gold foil, suffering a deflection of nearly 180°.

Expression for the distance of closest approach:



The distance of closest approach is defined as the distance of the charged particle from the centre of the nucleus, at which the whole of the initial *k*E of the charged particle gets converted into electric *p*E of the system.

Charge on the α-particle $q_1 = +2e$

Charge on the nucleus $q_2 = +Ze$

Initial *k*E of the α-particle $k_\alpha = \frac{1}{2}mv^2$

Electrostatic *p*E of α-particle and nucleus at r_0,

$$U = k\frac{q_1 q_2}{r_0} = k\frac{2e.Ze}{r_0}$$

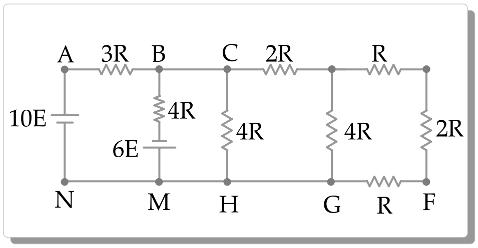
Now $k_\alpha = U$

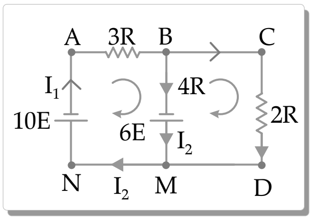
$\Rightarrow$ $\frac{1}{2}mv^2 = k\frac{2Ze^2}{r_0}$

$\Rightarrow$ $r_0 = \frac{2kZe^2}{k_\alpha} = \frac{4kZe^2}{mv^2}$

Where $k = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ NM^{2}C^{-2}

25.





In ABMNA Loop

$$3RI_1 + 4RI_2 - 6E - 10E = 0$$

$$\Rightarrow \quad 3RI_1 + 4RI_2 = 16E \qquad \text{...(i)}$$

In BCDMB Loop

$$(I_1 - I_2)2R + 6E - I_2 4R = 0$$

$$\Rightarrow \quad 2RI_1 - 6RI_2 = -6E \qquad \text{...(ii)}$$

Upon solving $26RI_2 = 50E$

$$\Rightarrow \quad I_2 = \frac{1.923}{R}$$

26. Magnetic field due to the current carrying loop,

$$B_1 = \frac{\mu_0 I}{2R} \qquad \text{(at its centre)}$$

$$\Rightarrow \quad B_1 = \frac{\mu_0 \times 1}{2 \times 10 \times 10^{-2}}$$

(into the plane of the paper)

Magnetic field due to the current carrying wire,

$$B_2 = \frac{\mu_0 I}{2\pi r}$$

$$\Rightarrow \quad B_2 = \frac{\mu_0 \times I}{2\pi \times 20 \times 10^{-2}} \ T$$

Now according to the question,

$$B_1 = B_2$$

So, $$\frac{\mu_0}{2 \times 10 \times 10^{-2}} = \frac{\mu_0 I}{2\pi \times 20 \times 10^{-2}}$$

$$\Rightarrow \quad I = 2\pi \text{ A}$$

$$\Rightarrow \quad I = 6.28 \text{ A}$$

And the direction of current is in the $+x$ direction as the magnetic field to be produced should be outward from the plane of the paper to make the net magnetic field zero at 0.

27. (i) Radio waves

Wavelength range 600 m to 0.1 m

(ii) *X*-rays

Wavelength range 100 Å to 0.1 Å

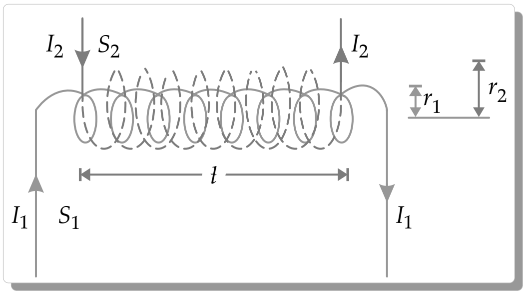
(iii) Infrared waves

Wavelength range 5×10^{-3} m to 10^{-6} m

28. (a) (i) Mutual induction is the phenomenon of production of induced emf in one coil due to a change of current in the neighbouring coil.

SI unit = henry (*H*)

(ii)



Consider two co-axial long Solenoids S_1 and S_2

Let l = length of each solenoid.

r_1, r_2 = radii of two solenoids

$A = \pi r_1^2$

= area of cross section of S_1

N_1, N_2 = no. of turns in S_1 and S_2 respectively

Let I_2, a time varying current is passed through S_2.

So magnetic field $B_2 = \mu_0 n_2 I_2$; $n_2 = \dfrac{N_2}{l}$

Total magnetic flux linked with S_1 is,

$$\phi_1 = B_2 A N_1 = \mu_0 n_2 I_2 . A N_1$$

$\therefore$ Mutual inductance of coil – 1 w.r.t coil – 2 is

$$M_{12} = \frac{\phi_1}{I_2} = \mu_0 n_2 A N_1$$

$$= \frac{\mu_0 N_1 N_2 A}{l}$$

Similarly flux linked with the outer solenoid S_2 due to current I_1 in S_1,

$$\phi_2 = B_1 A N_2 = \mu_0 n_1 I_1 . A N_2$$

$$\Rightarrow \quad \phi_2 = \frac{\mu_0 N_1 N_2 A I_1}{l}$$

Now mutual inductance of coil – 2 w.r.t coil – 1 is

$$M_{21} = \frac{\phi_2}{I_1} = \frac{\mu_0 N_1 N_2 A}{l}$$

So, $$M_{12} = M_{21} = M(\text{Let})$$

$$\therefore \quad M = \frac{\mu_0 N_1 N_2 A}{l}$$

$$= \mu_0 n_1 n_2 A l = \mu_0 n_1 n_2 \pi r_1^2 l$$

OR

(b) Ferromagnetic substances are those which develop strong magnetisation in the direction of the magnetising field. They are strongly attracted by magnets.

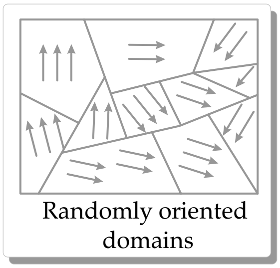
Ferromagnetism on the basis of domain theory:

⇒ In ferromagnetic materials, the individual atoms are associated with large magnetic moments.

⇒ The magnetic moments of neighbouring atoms interact with each other and align themselves spontaneously in a common direction over macroscopic regions called domains.

⇒ Each domain has a typical size of about 1 mm and contains about 10^{11} atoms. So, each domain possesses a strong magnetic moment.

⇒ In the absence of any external magnetic field, these domains are randomly distributed, so that the net magnetic moment is zero.

⇒ 

Randomly oriented domains

⇒ When it is placed in a magnetic field, all the domains align themselves along the direction of the field.

⇒ This is why ferromagnetic materials are strongly attracted by the magnets.

⇒ The alignment of domains may occur in either of the two ways.

(i) By displacing the boundaries of domains.

(ii) By rotation of domains.

SECTION D

29. (i) Option (B) is correct.

Explanation: When Ge is doped with pentavalent impurity, it becomes a n-type semiconductor.

(ii) Option (D) is correct.

Explanation: $n_i^2 = n_e n_h$

⇒ $4 \times 10^{20} = n_e \times 8 \times 10^3$

$$n_e = \frac{4\times10^{20}}{8\times10^3} = 0.5\times10^{17}\,\text{cm}^{-3}$$

$= 0.5 \times 10^{17} \times (10^{-2}\text{m})^{-3}$

$= 0.5 \times 10^{17} \times 10^{6}\text{m}^{-3}$

$= 0.5 \times 10^{23}\ \text{m}^{-3}$

$= 5 \times 10^{22}\ \text{m}^{-3}$

(iii) (a) Option (C) is correct.

Explanation: During the formation of a p-n junction, electrons diffuse from n-region into p-region and holes diffuse from p-region to n-region.

OR

(b) Option (A) is correct.

Explanation: Initially during the formation of a p-n junction diffusion current is large and drift current is small.

(iv) Option (D) is correct.

Explanation: $V = 0.5 \sin(100\pi t)$

So, $\omega = 100\pi = 2\pi f$

⇒ $f = 50$ Hz

Therefore, the frequency of the output voltage across the full wave rectifier is 100 Hz

30. (i) Option (B) is correct.

Explanation: $$\frac{1}{f} = \frac{1}{f_1}+\frac{1}{f_2}$$

⇒ $$\frac{1}{f} = \frac{1}{20}-\frac{1}{15} = \frac{3-4}{60} = \frac{-1}{60}$$

⇒ $f = -60$ cm

So, $$\text{Power} = \frac{-100}{60} = \frac{-5}{3}D$$

(ii) Option (C) is correct.

Explanation: $$\frac{1}{f} = (\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

⇒ $$\frac{3}{4R} = (\mu-1)\left(\frac{1}{R}+\frac{1}{2R}\right)$$

⇒ $$\frac{3}{4R} = (\mu-1)\left(\frac{3}{2R}\right)$$

⇒ $$\mu-1 = \frac{1}{2}$$

⇒ $$\mu = \frac{3}{2}$$

(iii) Option (A) is correct.

Explanation: When an equiconvex lens is dipped in water its focal length increases due to change in refractive index between the lens material and water.

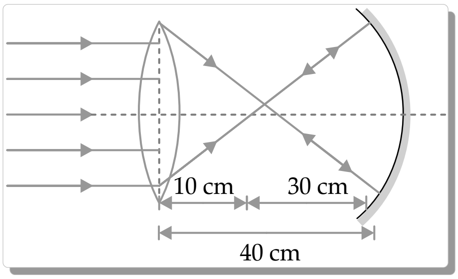
The focal length of an equiconvex lens is

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

⇒ $$f = \frac{R}{2(\mu-1)}$$

(iv) (a) Option (B) is correct.

Explanation:

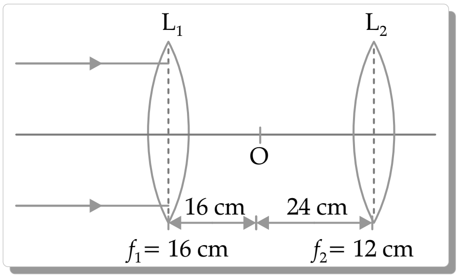


The image of the lens will be formed at point 'R' which is the centre of curvature of the mirror.

OR

(b) Option (A) is correct.

Explanation:



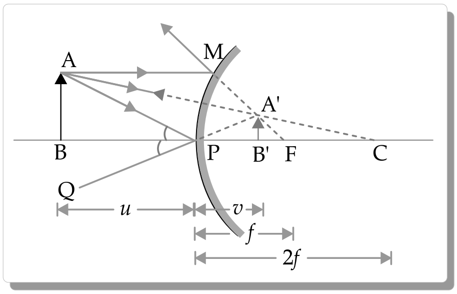
Object for L_2 is at 2F so the image will also be formed at 2F

The image of L_1 will be formed at point 'O' which is the centre of curvature of the lens L_2.

So the final image will be formed at 24 cm from the lens, and the nature is real.

SECTION E

31. (a) (i)



Using Cartesian sign convention, we find

Object distance, $BP = -u$

Image distance, $PB' = +v$

Focal length, $FP = +f$

Radius of curvature, $PC = +R = +2f$

Now $\Delta A'B'C \sim \Delta ABC$

$$\therefore \quad \frac{A'B'}{AB} = \frac{B'C}{BC}$$

$$= \frac{PC - PB'}{BP + PC} = \frac{R - v}{-u + R} \quad ...(i)$$

As $\angle A'PB' = \angle BPQ = \angle APB$

Therefore, $\Delta A'B'P \sim \Delta ABP$

$$\text{Consequently, } \frac{A'B'}{AB} = \frac{PB'}{BP} = \frac{v}{-u} \quad ...(ii)$$

From equations (i) and (ii), we get

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

or $-uR + uv = -uv + vR$

$vR + uR = 2uv$

Dividing both sides by uvR, we get

$$\frac{1}{u} + \frac{1}{v} = \frac{2}{R} \quad \text{But } R = 2f$$

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

This proves the mirror formula for a convex mirror.

(ii) Multi-component lenses are used for both the objective and eyepiece in optical instruments to achieve better image quality.

This can minimise the aberrations such as chromatic aberration and spherical aberration.

Multi-component lens allow for greater control over factors such as magnification, field of view and depth of field.

(iii) Angular magnification

$$= m_0 \times \frac{D}{f_e}$$

$$\Rightarrow \quad 200 = \frac{m_0 \times 25}{2}$$

$$\Rightarrow \quad 400 = m_0 \times 25$$

$$\Rightarrow \quad m_0 = \frac{400}{25} = 16.$$

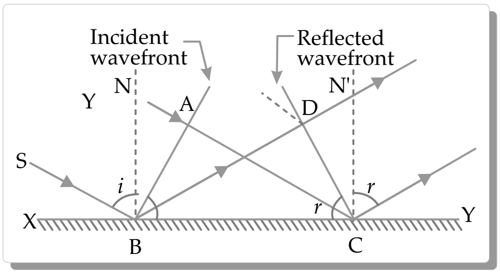
OR

(b) (i) A ray is a straight line representing the path along which light travels. It's used to simplify the description of light propagation, particularly in geometric optics.

A wavefront is a surface that represents points in a medium that are in phase (i.e., oscillating in synchrony) with each other. It's perpendicular to the direction of propagation of the wave.

(ii) Laws of reflection on the basis of Huygens' wave theory:

As shown in Fig., consider a plane wavefront AB incident on the plane reflecting surface XY, both the wavefront and the reflecting surface being perpendicular to the plane of paper.



First the wavefront touches the reflecting surface at B and then at the successive points towards C. In accordance with Huygens' principle, from each point on BC, secondary wavelets start growing with the speed c. During the time the disturbance from A reaches the point C, the secondary wavelets from D must have spread over a hemisphere of radius $BD = AC = C$, where t is the time taken by the disturbance to travel from A to C.

Let angles of incidence and reflection be i and r respectively. In ΔABC and ΔDCB, we have

$$\angle BAC = \angle CDB$$
$$BC = BC$$
$$AC = BD$$
$$\Delta ABC \cong \Delta DCB$$

Hence, $\angle ABC = \angle DCB$

or $\angle i = \angle r$

i.e., the angle of incidence is equal to the angle of reflection. This proves the first law of reflection.

Further, since the incident ray SB, the normal BN and the reflected ray BD are respectively perpendicular to the incident wavefront AB, the reflecting surface XY and the reflected wayefront CD (all of which are perpendicular to the plane of the paper), therefore, they all lie in the plane of the paper, i.e., in the same plane. This proves the second law of reflection.

(iii) Given $d = 3\text{ mm} = 3 \times 10^{-3}\text{ m}$, $D = 1.0\text{ m}$

According to the question,

$$\frac{5\beta}{2} = 5 \times 10^{-3}$$

$$\Rightarrow \quad \frac{5}{2} \times \frac{\lambda D}{d} = 5 \times 10^{-3}$$

$$\Rightarrow \quad \lambda = \frac{2d \times 10^{-3}}{D}$$

$$= \frac{2 \times 3 \times 10^{-3} \times 10^{-3}}{1}$$

$$\Rightarrow \quad \lambda = 6 \times 10^{-6}\text{ m}$$

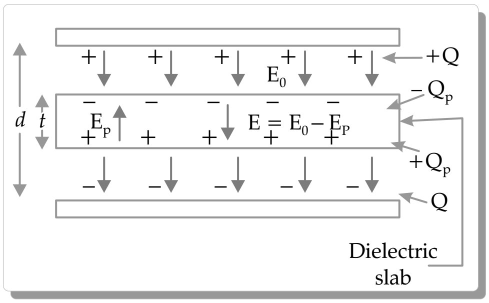
32. (a) (i) Capacitance of a parallel plate capacitor with a dielectric slab:

The capacitance of a parallel plate capacitor of plate area A and plate separation d with vacuum between its plates is given by

$$C_0 = \frac{\varepsilon_0 A}{d}$$

Suppose initially the charges on the capacitor plates are ±Q. Then the uniform electric field set up between the capacitor plates is

$$E_0 = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$$



When a dielectric slab of thickness $t < d$ is placed between the plates, the induced field is given by

$$E_p = \frac{\sigma_p}{\varepsilon_0} = \frac{P}{\varepsilon_0}$$

$$\left[\sigma_p = \frac{Q}{A} = P, \text{ polarisation density}\right]$$

The net field inside the dielectric is

$$E = E_0 - E_p = \frac{E_0}{\kappa} \quad \left[\because \frac{E_0}{E_0 - E_p} = \kappa\right]$$

where k is the dielectric constant of the slab. Hence, the potential difference between the capacitor plates is

$$V = E_0(d - t) + Et$$

$$= E_0(d-t) + \frac{E_0}{\kappa}t \left[\because \frac{E_0}{E} = \kappa\right]$$

$$= E_0\left(d - t + \frac{t}{\kappa}\right)$$

$$= \frac{Q}{\varepsilon_0 A}\left(d - t + \frac{t}{\kappa}\right)$$

The capacitance of the capacitor on introduction of dielectric slab becomes

$$C = \frac{Q}{V} = \frac{\varepsilon_0 A}{d - t + \frac{t}{\kappa}}.$$

(ii) For series combination,

$$V = \frac{1}{2}\frac{C_1C_2}{C_1 + C_2}V^2$$

$$\Rightarrow \quad 0.04 = \frac{1}{2}\frac{C_1C_2}{C_1 + C_2} \times (100)^2 \quad \text{...(i)}$$

For parallel combination,

$$U = \frac{1}{2}(C_1 + C_2)V^2$$

$$\Rightarrow \quad 0.25 = \frac{1}{2}(C_1 + C_2) \times (100)^2$$

or, $C_1 + C_2 = 0.5 \times 10^{-4}$ ...(ii)

from eq (i), $0.04 = \frac{1}{2} \times \frac{C_1C_2}{0.5 \times 10^{-4}} \times (100)^2$

$$\Rightarrow \quad C_1C_2 = 0.04 \times 10^{-8}$$

Now $(C_1 - C_2)^2 = (C_1 + C_2)^2 - 4C_1C_2$

$= (0.5 \times 10^{-4})^2 - 4 \times 0.04 \times 10^{-8}$

$= (0.25 - 0.16) \times 10^{-8}$

$= 0.09 \times 10^{-8}$

$C_1 - C_2 = 0.3 \times 10^{-4}$ ...(iii)

On solving (ii) and (iii)

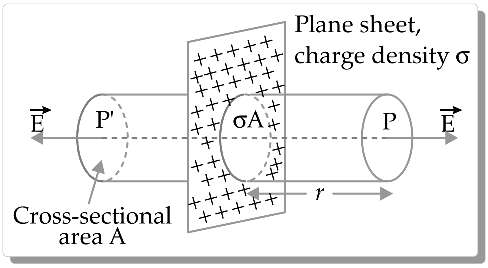
$C_1 = 0.4 \times 10^{-4}$ F

and $C_2 = 0.1 \times 10^{-4}$ F

OR

(b) (i) Consider a thin infinite plane sheet of charge with uniform surface charge density σ. We wish to calculate its electric field at a point P at distance *r* from it.

By symmetry, electric field E points outwards normal to the sheet. Also, it must have same magnitude and opposite direction at two points P and P' equidistant from the sheet and on opposite sides. We choose cylindrical Gaussian surface of cross-sectional area A and length 2*r* with its axis perpendicular to the sheet.



Here, the flux through the curved surface is zero. The flux through the plane-end faces of the cylinder is

$$\phi_E = EA + EA = 2EA$$

Charge enclosed by the Gaussian surface, $q = \sigma A$

According to Gauss's theorem,

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

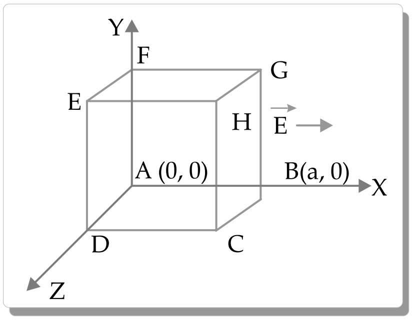
$$\therefore \quad 2EA = \frac{\sigma A}{\varepsilon_0}$$

$$E = \frac{\sigma}{2\varepsilon_0}$$

sssss $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$

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

(ii)



$$\vec{E} = (5x^2 + 2)\hat{i}$$

$$\phi_{BCHG} = (5a^2 + 2)\hat{i}.a^2\hat{i}$$

$$= 5a^4 + 2a^2$$

$$\phi_{AFED} = -2a^2$$

Flux for all the four surfaces = 0

So $\phi_{net} = 5a^4$

$= 5 \times (10 \times 10^{-2})^4$

$= 5 \times 10^{-4}$ weber.

33. (a) (i) The resonance frequency of a series LCR circuit is given by

$$\omega_r = 2\pi f_r = \frac{1}{\sqrt{LC}}$$

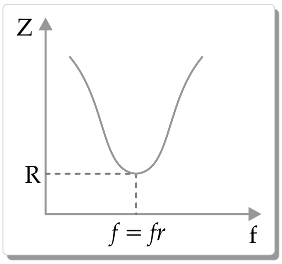
or $$f_r = \frac{1}{2\pi\sqrt{LC}}$$

So, it depends upon the values of inductance and capacitance of the circuit.

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

$$\Rightarrow \quad Z = \sqrt{R^2 + \left(2\pi fL - \frac{1}{2\pi fC}\right)^2}$$

At $f = f_r \Rightarrow X_L = X_C$



(ii) Let N_1 and N_2 be the number of turns in the primary and secondary respectively. Then

Induced emf in the primary coil, $\varepsilon_1 = -N_1\frac{d\phi}{dt}$

Induced emf in the secondary coil, $\varepsilon_2 = -N_2\frac{d\phi}{dt}$

where ϕ is the magnetic flux linked with each turn of the primary or secondary at any instant.

Thus $$\frac{\varepsilon_2}{\varepsilon_1} = \frac{N_2}{N_1}$$

Let ε be the emf applied to the primary. By Lenz's law, self-induced emf ε_1 opposes ε in the primary coil.

∴ Resultant emf in the primary = $\varepsilon - \varepsilon_1$

This emf sends current I_1, through the primary coil of resistance R.

$$\therefore \quad \varepsilon - \varepsilon_1 = RI_1$$

But R is very small, so the term RI_1 can be neglected. Then

$$\varepsilon = \varepsilon_1$$

Thus ε_1 may be regarded as input emf and ε_2 as the output emf.

$$\frac{\varepsilon_2}{\varepsilon_1} = \frac{\text{Output emf}}{\text{Input emf}} = \frac{N_2}{N_1}$$

The ratio $\frac{N_2}{N_1}$, of the number of turns in the secondary to that in the primary, is called the turns ratio of the transformer. It is also called transformation ratio.

In a step-up transformer, $N_2 > N_1$, i.e., the turns ratio is greater than 1 and therefore $\varepsilon_2 > \varepsilon_1$. The output voltage is greater than the input voltage.

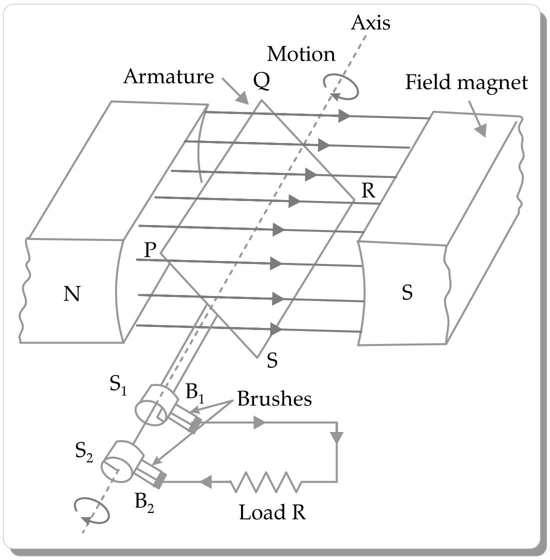
(iii) Copper loss: Some energy is lost due to heating of copper wires used in the primary and secondary windings.

Eddy current loss: The alternating magnetic flux induces eddy currents in the iron core which leads to some energy loss in the form of heat.

OR

(b) (i) An a.c. generator is a device which produces a current that alternates or changes its direction regularly after a fixed interval of time, i.e., it is a device which converts mechanical energy into alternating form of electrical energy.

Principle: The working of an a.c. generator is based on the principle of electromagnetic induction.



Construction:

(i) Field magnet: It is a permanent magnet of the horse shoe shape. It produces a strong magnetic field in the region between its pole-pieces.

(ii) Armature: It consists of a rectangular coil PQRS having a large number of turns of insulated copper wire wound on a soft iron cylindrical core. The core is laminated one to avoid losses due to eddy currents.

(iii) Slip rings: The two ends of the armature coil are connected to two coaxial brass rings S_1 and S_2 called slip rings. The rings are rigidly fixed to same shaft which is used to rotate the coil. The slips are insulated from each other as well as from the shaft.

(iv) Brushes: Two graphite or flexible metallic rods called brushes are lightly pressed against the two slip rings. The brushes B_1 and B_2 remain fixed in their position and maintain sliding contacts with the rotatable slip rings S_1 and S_2 respectively.

Working: As the armature coil rotates, the magnetic flux linked with it changes and so an induced-current flows through it.

Suppose initially the coil PQRS be in the vertical position and it is rotated in the clockwise direction. The side PQ moves downward and SR moves upward.

According to Fleming's right-hand rule, the induced current flows from Q to P and from S to R.

So, during the first half rotation of the coil, the induced current flows in the direction SRQP, with brush B_1 acting as positive terminal and brush B_2 as negative terminal. During the second half-rotation, the current flows along PQRS, so that the brush B_2 now functions as the positive terminal and brush B_1 as the negative terminal.

Thus, the direction of current in the external circuit is reversed after every half cycle.

Expression for induced emf:

Let N = number of turns in the coil

A = face area of each turn

B = magnitude of the magnetic field

θ = angle which normal to the coil makes with field $\vec{B}$ at any instant t

ω = the angular velocity with which coil rotates

Then the magnetic flux linked with the coil at any instant t will be

$$\phi = NBA\cos\theta = NBA\cos\omega t$$

By Faraday's flux rule, the induced emf is given by

$$\varepsilon = -\frac{d\Phi}{dt} = -\frac{d}{dt}(NBA\cos\omega t)$$

$$= NBA\omega\sin\omega t$$

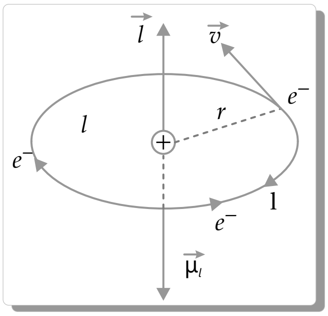
or $$\varepsilon = \varepsilon_0\sin\omega t$$

where $\varepsilon_0 = NBA\omega$. When a load of resistance R is connected across the terminals, a current I flows in the external circuit.

$$I = \frac{\varepsilon}{R} = \frac{\varepsilon_0\sin\omega t}{R} = I_0\sin\omega t$$

where $I_0 = \frac{\varepsilon_0}{R}$. Both current and voltage vary sinusoidally with time.

(ii) Consider an electron moving around a proton anticlockwise as shown in the figure,



Equivalent current,

$$I = \frac{\text{Charge}}{\text{Time}} = \frac{e}{T}$$

$$= \frac{e}{\frac{2\pi r}{v}} = \frac{ev}{2\pi r}$$

Area of the current loop, $A = \pi r^2$

Therefore, the orbital magnetic moment (magnetic moment due to orbital motion) of the electron is

$$\mu_l = IA = \frac{ev}{2\pi r}.\pi r^2$$

or $$\mu_l = \frac{evr}{2}$$

Outside Delhi Set-2 — 55/4/2

SECTION A

1. Option (A) is correct.

Explanation: Total potential $V_{net} = V_A + V_B + V_C$

$$V_{net} = \frac{Kq}{R} + \frac{Kq}{R} + \frac{Kq}{R}$$

$$V_{net} = \frac{Kq}{4L} + \frac{Kq}{3L} + \frac{Kq}{3L}$$

$$V_{net} = \frac{Kq}{4L} + \frac{2Kq}{3L}$$

$$V_{net} = \frac{11Kq}{12L} = \frac{11}{12L} \times \frac{q}{4\pi\varepsilon_0}$$

$$V_{net} = \frac{11}{48}\frac{q}{\pi\varepsilon_0 L}$$

2. Option (A) is correct.

Explanation: According to Coulomb's force (F)

$$= \frac{kq_1q_2}{r^2} \quad \text{...(i)}$$

Equation of straight line $(y) = mx$ ...(ii)

Comparing equation (i) and (ii)

Slope $(m) = k(q_1q_2)$

From the given figure:

For first pair of charges (q_1 and q_2)

Slope (m) = positive (q_1 and q_2 is positive) and has repulsive nature.

For second pair of charges (q_2 and q_3)

Slope (m) = negative (q_1 is positive and q_2 is negative) and has attractive nature.

So, $q_1 > q_2 > q_3$

5. Option (C) is correct.

Explanation: Helical path

We shall consider motion of a charged particle in a uniform magnetic field. If velocity has a component along B, this component remains unchanged as the motion along the magnetic field will not be affected by the magnetic field. The motion in a plane perpendicular to B is as before a circular one, thereby producing a helical motion

9. Option (B) is correct.

Explanation: $V = V_0 \sin \omega t = 282 \sin (100t)$

So, $V_0 = 282\ V$ and $\omega = 100$

Capacitance (C) = $1\mu F = 10^{-6}$ F

Capacitive reactance (XC) = $\frac{1}{\omega C} = 10^4$

$$I_0 = \frac{V_0}{X_C} = 282 \times 10^{-4}\ \text{A}$$

$$I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{282 \times 10^{-4}}{1.41}$$

$$= 20 \times 10^{-3}\ \text{A} = 20\ \text{mA}$$

20. Given, $L_1 : L_2 = 1 : 2$ and $r_1 : r_2 = 2 : 1$

Resistance = slope = tan (90 – θ) = cot θ.

From given figure, $R_A = \cot 30° = \sqrt{3}$

$R_B = \cot 45° = 1$

(i) Ratio of resistances $R_A : R_B = \sqrt{3} : 1$

(ii) Resistivity $(\sigma) = \frac{RA}{L} = \frac{R \times \pi r^2}{L}$

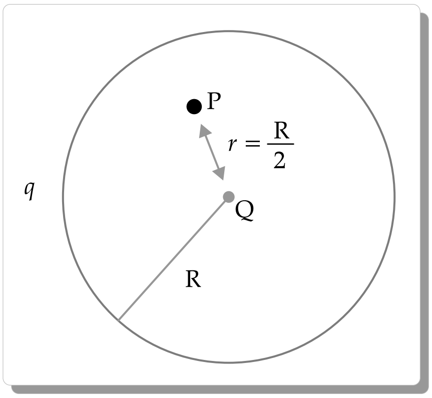
$$\frac{(\sigma_A)}{\sigma_B} = \frac{\frac{R_A \times r_1^2}{L_1}}{\frac{R_B \times r_2^2}{L_2}} = \left(\frac{R_A}{R_B}\right)\left(\frac{L_2}{L_1}\right)\left(\frac{r_1}{r_2}\right)^2$$

$$\frac{(\sigma_A)}{\sigma_B} = \left(\frac{\sqrt{3}}{1}\right)\left(\frac{2}{1}\right)\left(\frac{2}{1}\right)^2 = \frac{8\sqrt{3}}{1}$$

Ratio of resistivities $\sigma_A : \sigma_B = 8\sqrt{3} : 1$

23. **(i)** A charge of q is induced on the outer surface of the sphere. A charge of magnitude Q is placed on the outer surface of the sphere. Therefore, total charge on the outer surface of the sphere is Q-q. Surface charge density at the outer surface,

$$\sigma_{outer} = \frac{Q-q}{4\pi R^2}$$



(ii) Potential (V_1) at point P due to charge Q

$$V_1 = \frac{kQ}{r} = \frac{Q}{4\pi\varepsilon_0 r}$$

$$= \frac{2Q}{4\pi\varepsilon_0 R} \quad \text{....(i)}$$

Potential (V_2) at point P due to sphere (i.e., same at all points inside the shell)

$$V_2 = \frac{kQ}{r} = \frac{q}{4\pi\varepsilon_0 R} \quad \text{...(ii)}$$

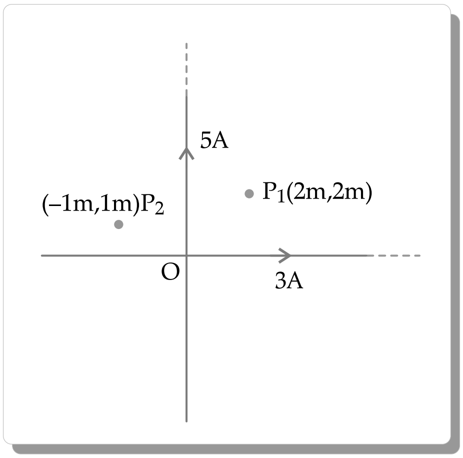
Total potential (V) = $V_1 + V_2$

From equation (i) & (ii),

$$V = \frac{2Q}{4\pi\varepsilon_0 R} + \frac{q}{4\pi\varepsilon_0 R}$$

$$V = \frac{1}{4\pi\varepsilon_0 R}(2Q+q)$$

25. For a current carrying wire, using the Biot-savart's law



Magnetic field at point P_1(2 m, 2 m):

$$B_1 = \frac{\mu_o I}{2\pi r_1} \text{ and } B_2 = \frac{\mu_o I}{2\pi r_2}$$

Distance $r_1 = \sqrt{8}$ and $r_2 = \sqrt{8}$

So, $$B_1 = \frac{\mu_o 3}{2\pi\sqrt{8}} \text{ and } B_2 = \frac{\mu_o 5}{2\pi\sqrt{8}}$$

$$B_{net} = \sqrt{B_1^2 + B_2^2}$$

$$= \sqrt{\left(\frac{\mu_o 3}{2\pi\sqrt{8}}\right)^2 + \left(\frac{\mu_o 5}{2\pi\sqrt{8}}\right)^2} = \frac{\mu_o\sqrt{17}}{4\pi}$$

Magnetic field at point P_2(– 1 m, 1 m):

$$B_1 = \frac{\mu_o I}{2\pi\sqrt{r_1}} \text{ and } B_2 = \frac{\mu_o I}{2\pi\sqrt{r_2}}$$

Distance $r_1 = \sqrt{2}$ and $r_2 = \sqrt{2}$

So, $$B_1 = \frac{\mu_o 3}{2\pi\sqrt{2}} \text{ and } B_2 = \frac{\mu_o 5}{2\pi\sqrt{2}}$$

$$B_{net} = \sqrt{B_1^2 + B_2^2} = \sqrt{\left(\frac{\mu_o 3}{2\pi\sqrt{2}}\right)^2 + \left(\frac{\mu_o 5}{2\pi\sqrt{2}}\right)^2}$$

$$= \frac{\mu_o\sqrt{17}}{2\pi}$$

26. Displacement current is a quantity appearing in Maxwell's equations that is defined in terms of the rate of change of electric flux having the units of electric current and has associated magnetic field similar as actual currents.

Displacement current is defined as:

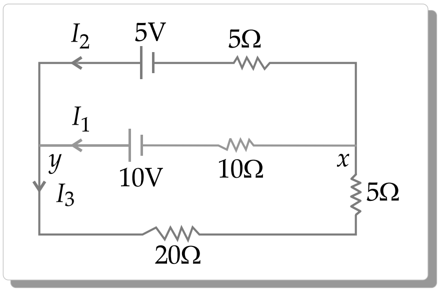
$$I_d = \varepsilon_0 \frac{d\phi_E}{dt}$$

$$I_d = \varepsilon_0 A \frac{dE}{dt}$$

Conduction current occurs due to the actual movement of the electrons, but in displacement current, no movement of electrons takes place, but occurs due to the variations of the electric field, almost equivalent to a flowing current.

The continuity of current in the circuit is because the magnitude of electric field and charge over an area of capacitor plates is constant.

27.



By using Kirchoff voltage law

$$\text{Potential } (V_x - V_y) = \frac{\frac{\varepsilon_1}{R_1} + \frac{\varepsilon_2}{R_2} + \frac{\varepsilon_3}{R_3}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

$$V_x - V_y = \frac{\frac{5}{5} + \frac{10}{10} + 0}{\frac{1}{5} + \frac{1}{10} + \frac{1}{20}}$$

$$= \frac{50}{17} = 2.94 \text{ V}$$

By using Kirchoff's current law

for current I_1: $I_1 = \frac{V}{R_1} = \frac{50}{17 \times 10} = \frac{5}{17} = 0.29\text{A}$

for current I_2: $I_2 = \frac{V}{R_2} = \frac{50}{17 \times 5} = \frac{10}{17} = 0.58\text{A}$

for current I_3: $I_1 + I_2 = 0.29 + 0.58 = 0.87$ A

Outside Delhi Set-3 **55/4/3**

SECTION A

1. **Option (A) is correct.**

Explanation: For stable equilibrium

$$\theta = 0° \Rightarrow U = -\vec{P}.\vec{E} = -PE$$

For unstable equilibrium

$$\theta = 180° \Rightarrow U = -\vec{P}.\vec{E} = +PE$$

So, $\Delta U = +2PE$

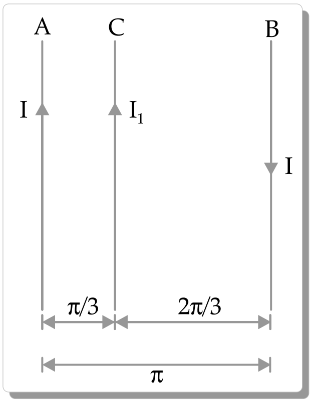
2. **Option (B) is correct.**

Explanation: $F = qE = q\left(\frac{2k\lambda}{x}\right)$

$$= 2q \times \left(\frac{1}{4\pi\varepsilon_0}\frac{\lambda}{x}\right)$$

5.

$$= \frac{q\lambda}{2\pi\varepsilon_0 x} \text{ and repulsive}$$



Force per unit length on C due to A,

$$\frac{\mu_0 I I_1}{2\pi \times \frac{r}{3}} = \frac{3\mu_0 I I_1}{2\pi r} \text{ "towards" } A$$

force per unit length on C due to B,

$$\frac{\mu_0 I I_1}{2\pi \times \frac{2r}{3}} = \frac{3\mu_0 I I_1}{4\pi r} \text{ "towards" } A$$

So total force per unit length

$$\frac{F}{l} = \frac{3\mu_0 I I_1}{2\pi r} + \frac{3\mu_0 I I_1}{4\pi r}$$

$$= \frac{6\mu_0 I I_1 + 3\mu_0 I I_1}{4\pi r}$$

$$= \frac{6\mu_0 I I_1 + 3\mu_0 I I_1}{4\pi r}$$

$$= \frac{9\mu_0 I I_1}{4\pi r} \text{ towards } A.$$

9. **Option (C) is correct.**

Explanation: $I = I_1 \cos \omega t + I_2 \sin \omega t$

$$\Rightarrow \quad I = I_1 \sin\left(\omega t + \frac{\pi}{2}\right) + I_2 \sin \omega t$$

So, $$I_0 = \left(I_1^2 + I_1^2\right)^{\frac{1}{2}}$$

$$\Rightarrow \quad I_{\text{rms}} = \frac{I_0}{\sqrt{2}} = \frac{1}{\sqrt{2}}\sqrt{I_1^2 + I_2^2}$$

SECTION B

18. De-Broglie wavelength is given by

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

now $$\frac{\lambda_p}{\lambda_d} = \frac{h}{\sqrt{2m_p q_p V_p}} \times \frac{\sqrt{2m_d q_d V_d}}{h}$$

$$\Rightarrow \quad \frac{\lambda_p}{\lambda_d} = \sqrt{\frac{m_p q_d V_d}{m_p q_p V_p}},$$

Squaring both sides

$$\Rightarrow \quad \frac{1}{4} = \frac{m_d q_d V_d}{m_p q_p V_p}$$

$$\Rightarrow \quad \frac{1}{4} = \frac{2m_p \times e \times V_d}{m_p \times e \times V_p}$$

$$\Rightarrow \quad 2\frac{V_d}{V_p} = \frac{1}{4}$$

$$\Rightarrow \quad V_P = 8\,V_d$$

$$\Rightarrow \quad \frac{V_p}{V_d} = 8$$

20. $R_{27} = R(\text{say})$

$$R_T = R + \frac{25}{100}R = 1.25R$$

$$T_1 = 27 + 273 = 300\text{ K}$$

from the relation, $\underline{R_T} = R_{27}\,[1 + \alpha(T_2 - 300)]$,

we have $1.25\,R = R\,[1 + 2\times 10^{-4}\,(T_2 - 300)]$

$$\Rightarrow 1 + 2\times 10^{-4}\,(T_2 - 300) = 1.25$$

$$\Rightarrow \quad 2\times 10^{-4}\,(T_2 - 300) = 0.25$$

$$\Rightarrow \quad T_2 - 300 = \frac{0.25}{2\times 10^{-4}} = 1250$$

$$\Rightarrow \quad T_2 = 1250 + 300$$

$$= 1550\text{ K}$$

23. According to the question,

$$\frac{Q_1}{4\pi R^2} = \frac{Q_2}{4\pi(2R)^2}$$

$$\Rightarrow \quad \frac{Q_1}{R^2} = \frac{Q_2}{4R^2}$$

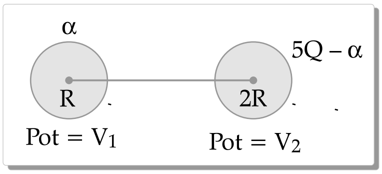
$$\Rightarrow \quad Q_1 = \frac{Q_2}{4}$$

$\Rightarrow \quad Q_2 = 4Q_1$; If $Q_1 = Q$ (say),

then $\quad Q_2 = 4Q$

So, the total charge $= 5Q$

When the two spherical shells are connected by a wire, after shifting of charge.



Now, $\quad V_1 = V_2$

$$\Rightarrow \quad \frac{k\alpha}{R} = \frac{k(5Q-\alpha)}{2R}$$

$$2\alpha = 5Q - \alpha$$

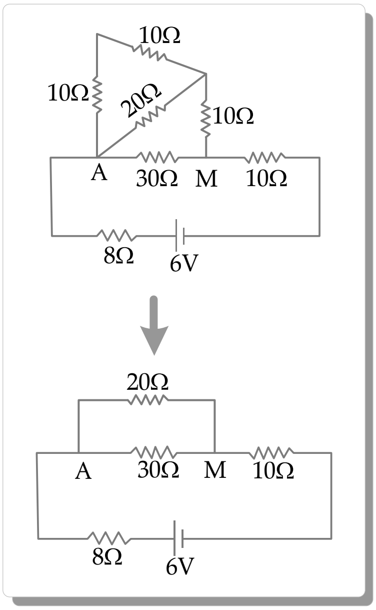
$$\Rightarrow \quad \alpha = \frac{5Q}{3}$$

$$= \frac{k}{R}\times\frac{5}{3}\times\sigma\times 4\pi R^2$$

$$= \frac{1}{4\pi\varepsilon_0 R}\times\frac{5}{3}\times\sigma\times 4\pi R^2$$

$$= \frac{5\sigma R}{3\varepsilon_0}$$

25. (i)



$$\text{So} \quad \frac{1}{R_{eq}} = \frac{1}{20} + \frac{1}{30}$$

$$= \frac{3+2}{60} = \frac{5}{60}$$

$$= \frac{1}{12}$$

$\Rightarrow \quad R_{eq} = 12\,\Omega$ [across A and M]

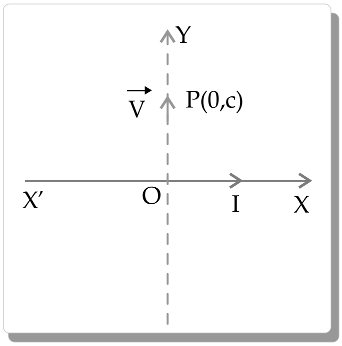
(ii) Now, the equivalent resistance

$$R_{eq} = 18 + \frac{30\times 20}{50} = 30\,\Omega$$

So, $\quad I = \frac{6}{30} = \frac{1}{5}A$

$$\Rightarrow \quad P = VI = 6\times\frac{1}{5} = \frac{6}{5}W = 1.2W$$

26.

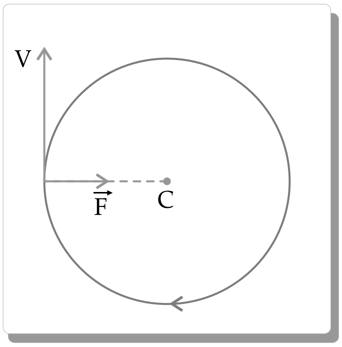


The magnetic field

$$B = \frac{\mu_0 I}{2\pi r}\ \text{(outward)}$$

Velocity is in the upward direction.

So, the motion of the particle will be in the x-y plane.



$$\text{Force} = qvB$$

$$\vec{F} = qv\frac{\mu_0 I}{2\pi r}\hat{i}$$

27. (i) Electromagnetic waves interact differently with matter due to variations in their wavelengths and energy levels.

(ii) Microwave ovens heat food by interacting primarily with water molecules present in the food.

(iii) Welders ear face masks with glasses to protect their eyes from intense light, harmful UV and IR radiation, and flying debris or sparks during welding.