



CLASS 12 · CBSE PHYSICS (042)

Physics Solved Board Papers

Chapter-wise and year-wise CBSE board questions with complete step-by-step solutions

10 years · 2016–2026

- ✓ Part A: every question sorted chapter-wise, grouped by marks, with full solutions
- ✓ Part B: 17 complete board papers, each followed by its solutions
- ✓ Board weightage table and most-asked topics for every chapter
- ✓ Derivations, numericals and ray/circuit diagrams worked the way the board awards marks
- ✓ Only the 2026-27 syllabus: questions on deleted topics are flagged

WHAT YOU GET

10 years of CBSE Physics papers. Every question solved. Sorted chapter-wise.

17

board papers

551

solved questions

10

years · 2016–26

14

chapters

149

diagrams

X Questions scattered across years



✓ All in one place, chapter-wise

X Don't know what to study first



✓ Weightage + most-asked topics

X One-line answers online



✓ Full solutions, board-style

X Old books carry deleted topics



✓ Only the 2026-27 syllabus

PART A**Chapter-wise****A**

- ✓ Weightage table
- ✓ Most-asked topics
- ✓ Every question + solution

PART B**Full papers****B**

- ✓ Exactly as set by CBSE
- ✓ Solutions after each paper
- ✓ Timed 3-hour practice

2026 · 55/1/1

2026 · 55/2/1

2025 · 55/1/1

2025 · 55/2/1

2024 · 55/1/1

2024 · 55/2/1

2023 · 55/1/1

2023 · 55/2/1

2022 · 55/1/1 · T2

2022 · 55/2/1 · T2

2020 · 55/1/1

2020 · 55/2/1

2019 · 55/1/1

2019 · 55/2/1

2018 · 55/1 · Set 1

2017 · 55/1 · Set 1

2016 · 55/1 · Set 1


Complete Notes · Solved PYQs

CLASS 6–12 · ALL SUBJECTS

100%
QUESTIONS
SOLVED
Made for **board toppers**

How to use this book

Part A puts every board question of a chapter together, from 1-mark MCQs to 5-mark long answers. Finish a chapter in your notes, then solve its Part A questions without looking at the solutions. Check your answer, mark the ones you got wrong, and repeat them a week later.

Each question shows where it was asked, for example **CBSE 2026 · 55/1/1 · Q13**. Use the weightage table and the most-asked topics chart at the start of each chapter to decide what to revise first.

Part B gives full papers. In the last month before the exam, sit with a clock and write one paper in 3 hours, then check it with the solutions that follow the paper.

Solutions are written the way the board awards marks: formula first, every step shown, units in the answer, and a labelled diagram wherever a derivation or ray diagram is asked. Write your answers the same way.

Contents

Part A · Chapter-wise questions with solutions

- | | |
|--|---|
| 1. Electric Charges and Fields 31 Qs | 8. Electromagnetic Waves 34 Qs |
| 2. Electrostatic Potential and Capacitance 36 Qs | 9. Ray Optics and Optical Instruments 70 Qs |
| 3. Current Electricity 51 Qs | 10. Wave Optics 42 Qs |
| 4. Moving Charges and Magnetism 55 Qs | 11. Dual Nature of Radiation and Matter 45 Qs |
| 5. Magnetism and Matter 14 Qs | 12. Atoms 38 Qs |
| 6. Electromagnetic Induction 26 Qs | 13. Nuclei 23 Qs |
| 7. Alternating Current 41 Qs | 14. Semiconductor Electronics 45 Qs |

Part B · Full board papers, each followed by its solutions

- | | |
|---------------------------------|---|
| 1. CBSE 2026 · 55/1/1 solutions | 9. CBSE 2022 · 55/1/1 · Term 2 solutions |
| 2. CBSE 2026 · 55/2/1 solutions | 10. CBSE 2022 · 55/2/1 · Term 2 solutions |
| 3. CBSE 2025 · 55/1/1 solutions | 11. CBSE 2020 · 55/1/1 solutions |
| 4. CBSE 2025 · 55/2/1 solutions | 12. CBSE 2020 · 55/2/1 solutions |
| 5. CBSE 2024 · 55/1/1 solutions | 13. CBSE 2019 · 55/1/1 solutions |
| 6. CBSE 2024 · 55/2/1 solutions | 14. CBSE 2019 · 55/2/1 solutions |
| 7. CBSE 2023 · 55/1/1 solutions | 15. CBSE 2018 · 55/1 · Set 1 solutions |
| 8. CBSE 2023 · 55/2/1 solutions | 16. CBSE 2017 · 55/1 · Set 1 solutions |
| | 17. CBSE 2016 · 55/1 · Set 1 solutions |

551 questions in all. Questions are taken from the CBSE Class 12 Physics board papers and the solutions are our own, checked against the official marking schemes. Questions on topics deleted from the current syllabus (communication systems, potentiometer and meter bridge, cyclotron, transistors and logic gates, polarisation, earth's magnetism and others) are left out of Part A and marked in Part B.

CHAPTER 1

Electric Charges and Fields**Board weightage 2016–2026**

Year	2016	2017	2018	2019	2020	2022	2023	2024	2025	2026
Questions	1	2	2	4	5	–	5	5	4	3
Marks	3	10	10	12	15	–	17	15	8	11

Most asked topics

Field of a plane sheet; two sheets	1
Electron beam between plates	1
Dipole field on equatorial line; dipole in uniform field	1
Coulomb force graph	1
Field of two negative charges	1
Electrostatic field is conservative	1
Open and closed surfaces; flux; Gauss's law	1
Field at the centre of a charged ring	1

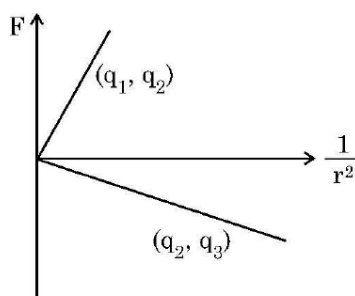
31 questions from 14 papers. Repeated questions are shown once with every year they were asked.

1 mark: MCQ and Assertion–Reason

CBSE 2025 · 55/1/1 · Q1

1 mark

Figure shows variation of Coulomb force (F) acting between two point charges with $\frac{1}{r^2}$, r being the separation between the two charges (q_1, q_2) and (q_2, q_3) . If q_2 is positive and least in magnitude, then the magnitudes of q_1 , q_2 and q_3 are such that



(A) $q_2 < q_3 < q_1$

(B) $q_3 < q_1 < q_2$

(C) $q_1 < q_2 < q_3$

(D) $q_2 < q_1 < q_3$

Solution

Answer: (A) $q_2 < q_3 < q_1$

$F = \frac{kq_a q_b}{r^2}$, so on an $F - \frac{1}{r^2}$ graph the slope is $kq_a q_b$. The (q_1, q_2) line is steeper (larger magnitude of slope) than the (q_2, q_3) line, so $|q_1 q_2| > |q_2 q_3|$, i.e. $|q_1| > |q_3|$. With q_2 the least: $q_2 < q_3 < q_1$. (The signs also tell us q_1 is positive, since F is repulsive, and q_3 is negative, since F is attractive.)

CBSE 2025 · 55/2/1 · Q1

1 mark

Two charges $-q$ each are placed at the vertices A and B of an equilateral triangle ABC. If M is the mid-point of AB, the net electric field at C will point along

- | | |
|--------|--------|
| (A) CA | (B) CB |
| (C) MC | (D) CM |

Solution**Answer: (D) CM**

The field of a negative charge points towards it, so at C the fields point along CA and CB, with equal magnitudes. Their components parallel to AB cancel, and the components along the bisector add. The resultant points from C towards M, i.e. along CM.

CBSE 2025 · 55/2/1 · Q8

1 mark

Which one of the following statements is correct? Electric field due to static charges is

- | | |
|--|---|
| (A) conservative and field lines do not form closed loops. | (B) conservative and field lines form closed loops. |
| (C) non-conservative and field lines do not form closed loops. | (D) non-conservative and field lines form closed loops. |

Solution**Answer: (A)**

The work done by an electrostatic field around any closed path is zero, so the field is conservative. Its lines start on positive charges and end on negative charges, so they never form closed loops.

CBSE 2024 · 55/1/1 · Q1

1 mark

A thin plastic rod is bent into a circular ring of radius R . It is uniformly charged with charge density λ . The magnitude of the electric field at its centre is

- | | |
|--|-------------------------------------|
| (A) $\frac{\lambda}{2\epsilon_0 R}$ | (B) Zero |
| (C) $\frac{\lambda}{4\pi\epsilon_0 R}$ | (D) $\frac{\lambda}{4\epsilon_0 R}$ |

Solution**Answer: (B) Zero**

For every small element of the ring there is an identical element diametrically opposite. Their fields at the centre are equal and opposite, so the net field at the centre is zero.

CBSE 2024 · 55/2/1 · Q1

1 mark

Two charged particles P and Q, having the same charge but different masses m_P and m_Q , start from rest and travel equal distances in a uniform electric field $\vec{E}$ in time t_P and t_Q respectively.

Neglecting the effect of gravity, the ratio $\left(\frac{t_P}{t_Q}\right)$ is

(A) $\frac{m_P}{m_Q}$
(C) $\sqrt{\frac{m_P}{m_Q}}$

(B) $\frac{m_Q}{m_P}$
(D) $\sqrt{\frac{m_Q}{m_P}}$

Solution**Answer: (C)** $\sqrt{\frac{m_P}{m_Q}}$

$a = \frac{qE}{m}$ and, from rest, $s = \frac{1}{2}at^2$, so $t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2sm}{qE}} \propto \sqrt{m}$ (same q, E and s).

CBSE 2023 · 55/1/1 · Q1

1 mark

A point charge situated at a distance 'r' from a short electric dipole on its axis, experiences a force $\vec{F}$. If the distance of the charge is '2r', the force on the charge will be

(a) $\frac{\vec{F}}{16}$
(c) $\frac{\vec{F}}{4}$

(b) $\frac{\vec{F}}{8}$
(d) $\frac{\vec{F}}{2}$

Solution**Answer: (b)** $\frac{\vec{F}}{8}$

On the axis of a short dipole $E = \frac{1}{4\pi\epsilon_0} \cdot \frac{2p}{r^3}$, so $F = qE \propto \frac{1}{r^3}$. Doubling r makes the force $\frac{1}{2^3} = \frac{1}{8}$ of its value.

CBSE 2023 · 55/2/1 · Q1

1 mark

The magnitude of the electric field due to a point charge object at a distance of 4.0 m is 9 N/C. From the same charged object the electric field of magnitude, 16 N/C will be at a distance of

(a) 1 m
(c) 3 m

(b) 2 m
(d) 6 m

Solution**Answer: (c) 3 m**

$E \propto \frac{1}{r^2}$: $\frac{16}{9} = \frac{4^2}{r^2}$, so $r^2 = 9$ and $r = 3$ m.

CBSE 2020 · 55/1/1 · Q1

1 mark

If the net electric flux through a closed surface is zero, then we can infer

- (A) no net charge is enclosed by the surface. (B) uniform electric field exists within the surface.
(C) electric potential varies from point to point inside the surface. (D) charge is present inside the surface.

Solution**Answer: (A) no net charge is enclosed by the surface.**

By Gauss's law $\Phi = \frac{q_{enc}}{\epsilon_0}$; zero flux means the net enclosed charge is zero (there may be equal positive and negative charges inside).

CBSE 2020 · 55/2/1 · Q11

1 mark

Fill in the blank: If the electric flux entering and leaving a closed surface in air are ϕ_1 and ϕ_2 respectively, the net electric charge enclosed within the surface is _____.

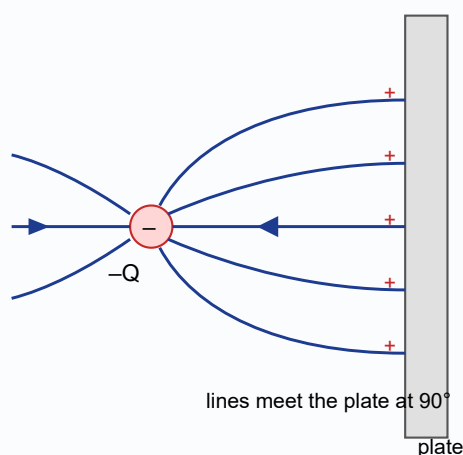
Solution**Answer: $(\phi_2 - \phi_1)\epsilon_0$**

Net outward flux = $\phi_2 - \phi_1 = \frac{q}{\epsilon_0}$.

CBSE 2019 · 55/1/1 · Q1

1 mark

Draw the pattern of electric field lines, when a point charge $-Q$ is kept near an uncharged conducting plate.

Solution

The field lines end on the charge $-Q$. They start on the induced positive charge on the near surface of the plate, and they meet the conducting surface at right angles (a conductor's surface is an equipotential).

3 marks: short answer

CBSE 2026 · 55/1/1 · Q22(a)

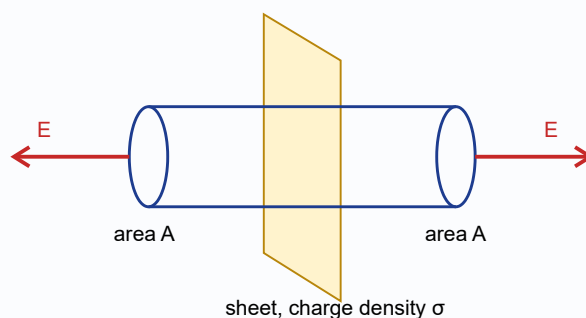
3 marks

- (a) Using Gauss's law, deduce an expression for electric field at a point due to a uniformly charged infinite plane thin sheet.
- (b) Two large thin plane sheets, each having surface charge density σ , are held close and parallel to each other in air. What is the net electric field at a point (i) inside and (ii) outside, the sheets?

Solution

- (a)** Take a cylindrical Gaussian surface of end-area A , cutting the sheet perpendicularly.

Gaussian cylinder: flux passes only through the two flat ends



By symmetry $\vec{E}$ is normal to the sheet. There is no flux through the curved surface; through each flat end the flux is EA .

Total flux = $2EA$; charge enclosed = σA . Gauss's law:

$$2EA = \frac{\sigma A}{\epsilon_0} \Rightarrow E = \frac{\sigma}{2\epsilon_0}$$

directed away from the sheet if $\sigma > 0$; it does not depend on distance.

- (b)** Each sheet gives $\frac{\sigma}{2\epsilon_0}$.

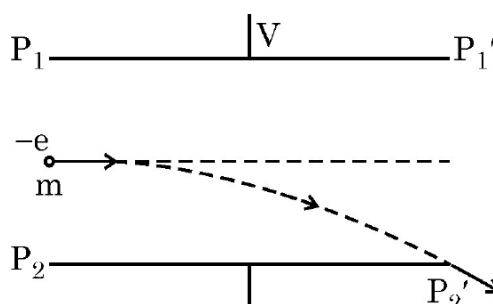
(i) Inside: the two fields are opposite, so $E = \frac{\sigma}{2\epsilon_0} - \frac{\sigma}{2\epsilon_0} = 0$.

(ii) Outside: the fields add, so $E = \frac{\sigma}{\epsilon_0}$, directed away from the sheets.

CBSE 2026 · 55/1/1 · Q24

3 marks

Figure shows a narrow beam of electrons entering with a velocity of 3×10^7 m/s, symmetrically through the space between two parallel horizontal plates P_1P_1' and P_2P_2' kept 2 cm apart. If each plate is 3 cm long, calculate the potential difference V applied between the plates so that the beam just strikes the end P_2' .



Solution

Field between plates $E = \frac{V}{d}$; acceleration of the electron $a = \frac{eE}{m} = \frac{eV}{md}$ (towards the positive plate).

Time to cross the plates: $t = \frac{L}{u}$.

To just strike the end, the deflection must be $y = \frac{d}{2} = 1 \text{ cm}$:

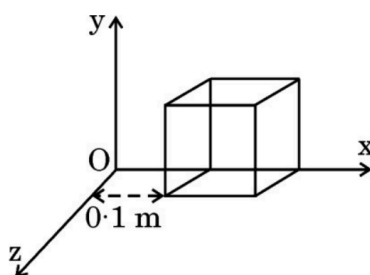
$$y = \frac{1}{2}at^2 = \frac{1}{2} \cdot \frac{eV}{md} \cdot \frac{L^2}{u^2} \Rightarrow V = \frac{2ymdu^2}{eL^2}$$

$$V = \frac{2 \times 0.01 \times 9.1 \times 10^{-31} \times 0.02 \times (3 \times 10^7)^2}{1.6 \times 10^{-19} \times (0.03)^2} = \frac{3.276 \times 10^{-19}}{1.44 \times 10^{-22}} \approx \mathbf{2275 \text{ V}}$$

CBSE 2024 · 55/1/1 · Q22

3 marks

A cube of side 0.1 m is placed, as shown in the figure, in a region where electric field $\vec{E} = 500x\hat{i}$ exists. Here x is in meters and E in N C^{-1} . Calculate: (a) the flux passing through the cube, and (b) the charge within the cube.

**Solution**

(a) $\vec{E}$ is along x , so only the two faces perpendicular to x carry flux. Area of each face $= (0.1)^2 = 0.01 \text{ m}^2$. The cube lies from $x = 0.1 \text{ m}$ to $x = 0.2 \text{ m}$.

Left face ($x = 0.1 \text{ m}$, area vector along $-x$): $\phi_L = -(500 \times 0.1)(0.01) = -0.5 \text{ N m}^2 \text{ C}^{-1}$.

Right face ($x = 0.2 \text{ m}$, area vector along $+x$): $\phi_R = (500 \times 0.2)(0.01) = +1.0 \text{ N m}^2 \text{ C}^{-1}$.

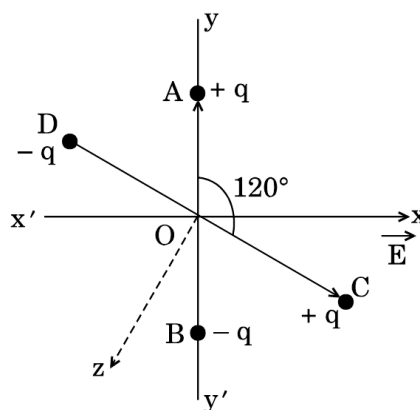
$$\phi = \phi_L + \phi_R = \mathbf{0.5 \text{ N m}^2 \text{ C}^{-1}}$$

(b) Gauss's law: $q = \epsilon_0 \phi = 8.854 \times 10^{-12} \times 0.5 \approx \mathbf{4.4 \times 10^{-12} \text{ C}}$.

CBSE 2020 · 55/2/1 · Q28(a)

3 marks

Two small identical electric dipoles AB and CD, each of dipole moment $\vec{p}$ are kept at an angle of 120° to each other in an external electric field $\vec{E}$ pointing along the x-axis as shown in the figure. Find the (a) dipole moment of the arrangement, and (b) magnitude and direction of the net torque acting on it.

**Solution**

(a) $\vec{p}_1$ (B $\rightarrow$ A) points along +y; $\vec{p}_2$ (D $\rightarrow$ C) points at 120° from it, i.e. 30° below the x-axis. The resultant of two equal vectors at 120° has magnitude

$$p_{net} = \sqrt{p^2 + p^2 + 2p^2 \cos 120^\circ} = p$$

along the bisector, i.e. at 60° to each, which is **30° above the x-axis**.

$$(b) \tau = p_{net} E \sin 30^\circ = \frac{pE}{2}.$$

$\vec{\tau} = \vec{p}_{net} \times \vec{E}$: with $\vec{p}_{net}$ at 30° above +x and $\vec{E}$ along +x, the torque points along the **-z direction**; it tends to rotate the arrangement clockwise (towards $\vec{E}$).

CBSE 2019 · 55/2/1 · Q17(a)

3 marks

Two large charged plane sheets of charge densities σ and -2σ C/m² are arranged vertically with a separation of d between them. Deduce expressions for the electric field at points (i) to the left of the first sheet, (ii) to the right of the second sheet, and (iii) between the two sheets.

Solution

Each sheet gives a field $\frac{|\sigma|}{2\epsilon_0}$: away from the positive sheet (σ), towards the negative sheet (-2σ), i.e. $\frac{\sigma}{2\epsilon_0}$ and $\frac{\sigma}{\epsilon_0}$. Take the σ sheet on the left.

(i) Left of the first sheet: σ -sheet field points left ($\frac{\sigma}{2\epsilon_0}$), -2σ -sheet field points right ($\frac{\sigma}{\epsilon_0}$):

$$E = \frac{\sigma}{\epsilon_0} - \frac{\sigma}{2\epsilon_0} = \frac{\sigma}{2\epsilon_0} \text{ towards the right}$$

(ii) Right of the second sheet: σ -sheet field points right, -2σ -sheet field points left:

$$E = \frac{\sigma}{2\epsilon_0} \text{ towards the left}$$

(iii) Between the sheets: both point right:

$$E = \frac{\sigma}{2\epsilon_0} + \frac{\sigma}{\epsilon_0} = \frac{3\sigma}{2\epsilon_0} \text{ towards the right (from } \sigma \text{ to } -2\sigma)$$

CBSE 2019 · 55/2/1 · Q17(b)

3 marks

A spherical conducting shell of inner radius r_1 and outer radius r_2 has a charge Q . (a) A charge q is placed at the centre of the shell. Find out the surface charge density on the inner and outer surfaces of the shell. (b) Is the electric field inside a cavity (with no charge) zero; independent of the fact whether the shell is spherical or not? Explain.

Solution

(a) The field inside the conducting material is zero, so a Gaussian surface within it encloses zero charge: the inner surface carries $-q$. The outer surface then carries $Q + q$.

$$\sigma_{in} = \frac{-q}{4\pi r_1^2}, \quad \sigma_{out} = \frac{Q + q}{4\pi r_2^2}$$

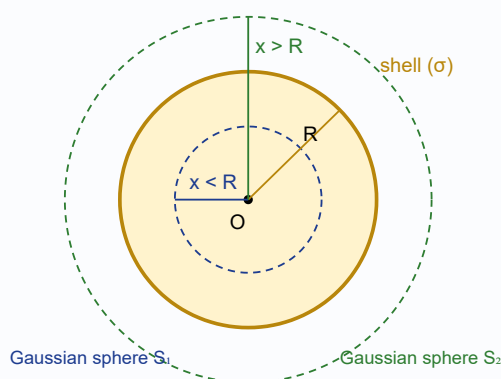
(b) **Yes.** For a cavity with no charge inside a conductor, the field in the cavity is zero whatever the shape of the conductor (electrostatic shielding). A Gaussian surface around the cavity inside the conductor encloses no charge, and any field lines inside would have to start and end on the cavity wall, which is an equipotential, giving zero work around a closed path, which is impossible unless $E = 0$.

CBSE 2016 · 55/1 · Set 1 · Q11

3 marks

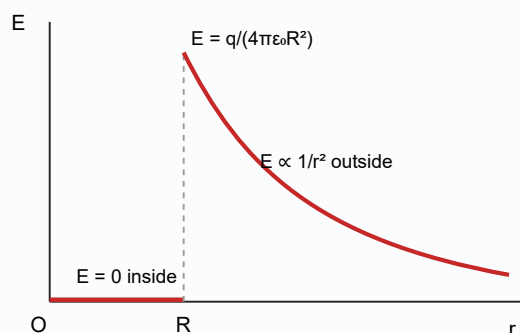
Find the electric field intensity due to a uniformly charged spherical shell at a point (i) outside the shell and (ii) inside the shell. Plot the graph of electric field with distance from the centre of the shell.

Solution



(i) Outside ($r > R$): Gaussian sphere of radius r encloses q : $E \cdot 4\pi r^2 = \frac{q}{\epsilon_0}$, so $E = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}$ (radial).

(ii) Inside ($r < R$): the Gaussian sphere encloses no charge, so $E = 0$.



5 marks: long answer

CBSE 2026 · 55/1/1 · Q31(a)

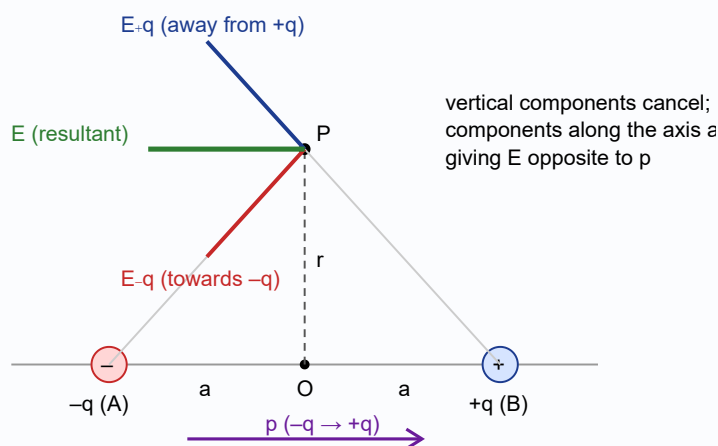
5 marks

(a) An electric dipole consists of two point charges q and $-q$ separated by a distance $2a$. Derive an expression for the electric field $\vec{E}$ due to this dipole at a point distant r from the centre of the dipole on the equatorial plane. Write the expression for the electric field at a far off point, i.e. $r \gg a$.

(b) A dipole is placed in x-y plane such that charges q and $-q$ are located at $x = a$ and $x = b$ respectively. There exists an electric field $\vec{E} = 2\hat{i}$ N/C in the region. Calculate the force $\vec{F}$ and torque $\vec{\tau}$ experienced by the dipole.

Solution

(a)



P is on the perpendicular bisector at distance r from the centre O. Distance of P from each charge $= \sqrt{r^2 + a^2}$, so

$$|\vec{E}_{+q}| = |\vec{E}_{-q}| = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2 + a^2}$$

Their components perpendicular to the axis cancel. The components parallel to the axis add, both pointing from $+q$ towards $-q$ (opposite to $\vec{p}$). If θ is the angle each field makes with the axis,

$$\cos \theta = \frac{a}{\sqrt{r^2 + a^2}}:$$

$$E = 2E_{+q} \cos \theta = \frac{1}{4\pi\epsilon_0} \cdot \frac{2qa}{(r^2 + a^2)^{3/2}}$$

With $\vec{p} = q(2a)\hat{p}$:

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

For a far-off point ($r \gg a$):

$$\vec{E} = -\frac{1}{4\pi\epsilon_0} \cdot \frac{\vec{p}}{r^3}$$

(b) The field is uniform, so the forces on $+q$ and $-q$ are $q\vec{E}$ and $-q\vec{E}$: net force $\vec{F} = q\vec{E} - q\vec{E} = \mathbf{0}$.

Dipole moment (from $-q$ to $+q$): $\vec{p} = q(a - b)\hat{i}$. Torque:

$$\vec{\tau} = \vec{p} \times \vec{E} = q(a - b)\hat{i} \times 2\hat{i} = \mathbf{0}$$

(the dipole lies along the field, so it is in equilibrium).

CBSE 2025 · 55/2/1 · Q31(b)

5 marks

- (i) What is difference between an open surface and a closed surface? Draw elementary surface vector $d\vec{S}$ for a spherical surface S .
- (ii) Define electric flux through a surface. Give the significance of a Gaussian surface. A charge outside a Gaussian surface does not contribute to total electric flux through the surface. Why?
- (iii) A small spherical shell S_1 has point charges $q_1 = -3 \mu\text{C}$, $q_2 = -2 \mu\text{C}$ and $q_3 = 9 \mu\text{C}$ inside it. This shell is enclosed by another big spherical shell S_2 . A point charge Q is placed in between the two surfaces S_1 and S_2 . If the electric flux through the surface S_2 is four times the flux through surface S_1 , find charge Q .

Solution

(i) An open surface (like a disc or a hemisphere) has a boundary and does not enclose a volume; a closed surface (like a sphere) encloses a volume and has no boundary. For a closed surface, the area vector $d\vec{S}$ of every small element points along the outward normal: on a sphere, radially outward from the centre.

(ii) Electric flux through a surface is $\Phi_E = \oint \vec{E} \cdot d\vec{S}$ (for a uniform field $E A \cos \theta$): a measure of the number of field lines crossing the surface. Its SI unit is $\text{N m}^2 \text{C}^{-1}$.

A Gaussian surface is a closed surface, chosen to fit the symmetry, through which the flux is $\frac{q_{\text{enc}}}{\epsilon_0}$; it makes the field easy to calculate.

A charge outside the surface contributes nothing because every field line from it that enters the surface also leaves it, so its inward and outward flux cancel.

(iii) Charge inside S_1 : $-3 - 2 + 9 = 4 \mu\text{C}$, so $\Phi_1 = \frac{4 \mu\text{C}}{\epsilon_0}$.

Charge inside S_2 : $(Q + 4) \mu\text{C}$, so $\Phi_2 = \frac{Q + 4 \mu\text{C}}{\epsilon_0}$.

$$\Phi_2 = 4\Phi_1 \Rightarrow Q + 4 = 16 \Rightarrow Q = 12 \mu\text{C}$$

CBSE 2024 · 55/1/1 · Q31(a)

5 marks

- (i) Derive an expression for potential energy of an electric dipole $\vec{p}$ in an external uniform electric field $\vec{E}$. When is the potential energy of the dipole (1) maximum, and (2) minimum?
- (ii) An electric dipole consists of point charges -1.0 pC and $+1.0$ pC located at $(0, 0)$ and $(3 \text{ mm}, 4 \text{ mm})$ respectively in $x - y$ plane. An electric field $\vec{E} = \left(\frac{1000 \text{ V}}{\text{m}}\right) \hat{i}$ is switched on in the region. Find the torque $\vec{\tau}$ acting on the dipole.

Solution

(i) A dipole at angle θ with $\vec{E}$ experiences a torque $\tau = pE \sin \theta$ that tends to align it with the field. Work done in rotating it slowly from θ_0 to θ against this torque:

$$W = \int_{\theta_0}^{\theta} pE \sin \theta d\theta = pE(\cos \theta_0 - \cos \theta)$$

This work is stored as potential energy. Taking $U = 0$ at $\theta_0 = 90^\circ$:

$$U(\theta) = -pE \cos \theta = -\vec{p} \cdot \vec{E}$$

(1) Maximum, $U = +pE$, when $\theta = 180^\circ$ ($\vec{p}$ antiparallel to $\vec{E}$, unstable equilibrium).

(2) Minimum, $U = -pE$, when $\theta = 0^\circ$ ($\vec{p}$ parallel to $\vec{E}$, stable equilibrium).

(ii) $\vec{p}$ points from $-q$ to $+q$: $\vec{p} = q\vec{r} = 1.0 \times 10^{-12} \times (3\hat{i} + 4\hat{j}) \times 10^{-3} \text{ C m} = (3\hat{i} + 4\hat{j}) \times 10^{-15} \text{ C m}$.

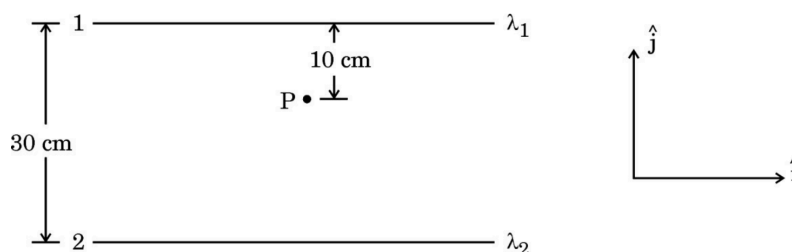
$$\vec{\tau} = \vec{p} \times \vec{E} = (3\hat{i} + 4\hat{j}) \times 10^{-15} \times 1000 \hat{i} = 4 \times 10^{-12} (\hat{j} \times \hat{i}) = -4 \times 10^{-12} \hat{k} \text{ N m}$$

(magnitude $4 \times 10^{-12} \text{ N m}$, along $-z$).

CBSE 2024 · 55/2/1 · Q31(b)

5 marks

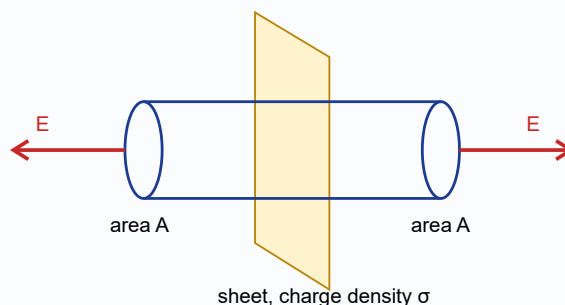
- (i) State Gauss's Law in electrostatics. Apply this to obtain the electric field $\vec{E}$ at a point near a uniformly charged infinite plane sheet.
- (ii) Two long straight wires 1 and 2 are kept as shown in the figure. The linear charge density of the two wires are $\lambda_1 = 10 \text{ } \mu\text{C/m}$ and $\lambda_2 = -20 \text{ } \mu\text{C/m}$. Find the net force $\vec{F}$ experienced by an electron held at point P.



Solution

(i) **Gauss's law:** the total electric flux through any closed surface equals $\frac{1}{\epsilon_0}$ times the net charge enclosed by it: $\oint \vec{E} \cdot d\vec{S} = \frac{q_{enc}}{\epsilon_0}$.

Gaussian cylinder: flux passes only through the two flat ends



Take a cylinder of end-area A crossing the sheet (surface charge density σ). By symmetry $\vec{E}$ is normal to the sheet: no flux through the curved surface, flux EA through each end. Total flux $2EA$; charge enclosed σA :

$$2EA = \frac{\sigma A}{\epsilon_0} \Rightarrow E = \frac{\sigma}{2\epsilon_0}$$

directed away from the sheet (for $\sigma > 0$), independent of distance.

(ii) Field of a long line charge: $E = \frac{\lambda}{2\pi\epsilon_0 r} = \frac{2k\lambda}{r}$.

P is 10 cm below wire 1 and 20 cm above wire 2.

Wire 1 (positive): $E_1 = \frac{2 \times 9 \times 10^9 \times 10 \times 10^{-6}}{0.10} = 1.8 \times 10^6 \text{ N/C}$, away from wire 1, i.e. along $-\hat{j}$.

Wire 2 (negative): $E_2 = \frac{2 \times 9 \times 10^9 \times 20 \times 10^{-6}}{0.20} = 1.8 \times 10^6 \text{ N/C}$, towards wire 2, i.e. along $-\hat{j}$.

Net field: $\vec{E} = -3.6 \times 10^6 \hat{j} \text{ N/C}$.

Force on the electron (charge $-e$):

$$\vec{F} = -e\vec{E} = 1.6 \times 10^{-19} \times 3.6 \times 10^6 \hat{j} = 5.76 \times 10^{-13} \hat{j} \text{ N}$$

(towards wire 1).

CBSE 2023 · 55/1/1 · Q31(a)

5 marks

- (i) State Coulomb's law in electrostatics and write it in vector form, for two charges.
- (ii) 'Gauss's law is based on the inverse-square dependence on distance contained in the Coulomb's law.' Explain.
- (iii) Two charges A (charge q) and B (charge $2q$) are located at points $(0, 0)$ and (a, a) respectively. Let $\hat{i}$ and $\hat{j}$ be the unit vectors along x-axis and y-axis respectively. Find the force exerted by A on B, in terms of $\hat{i}$ and $\hat{j}$.

Solution

(i) The force between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them, and acts along the line joining them:

$$\vec{F}_{21} = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1 q_2}{r_{21}^2} \hat{r}_{21}$$

where $\vec{F}_{21}$ is the force on q_2 due to q_1 and $\hat{r}_{21}$ is the unit vector from q_1 to q_2 .

(ii) For a point charge q at the centre of a sphere of radius r , $E = \frac{q}{4\pi\epsilon_0 r^2}$ and the area is $4\pi r^2$, so the flux $\Phi = E \cdot 4\pi r^2 = \frac{q}{\epsilon_0}$ does not depend on r . This is so only because E falls as $\frac{1}{r^2}$ while the area grows as r^2 . If the force law were any other power of r , the flux through a closed surface would depend on its size, and Gauss's law $\oint \vec{E} \cdot d\vec{S} = \frac{q}{\epsilon_0}$ would not hold.

(iii) $\vec{r}_{BA} = (a\hat{i} + a\hat{j})$, $r = a\sqrt{2}$, $\hat{r} = \frac{\hat{i} + \hat{j}}{\sqrt{2}}$.

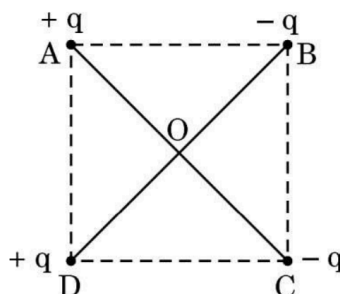
$$\vec{F} = \frac{1}{4\pi\epsilon_0} \cdot \frac{q(2q)}{2a^2} \cdot \frac{\hat{i} + \hat{j}}{\sqrt{2}} = \frac{1}{4\pi\epsilon_0} \cdot \frac{q^2}{\sqrt{2}a^2} (\hat{i} + \hat{j})$$

(repulsive, along AB produced).

CBSE 2023 · 55/1/1 · Q31(b)

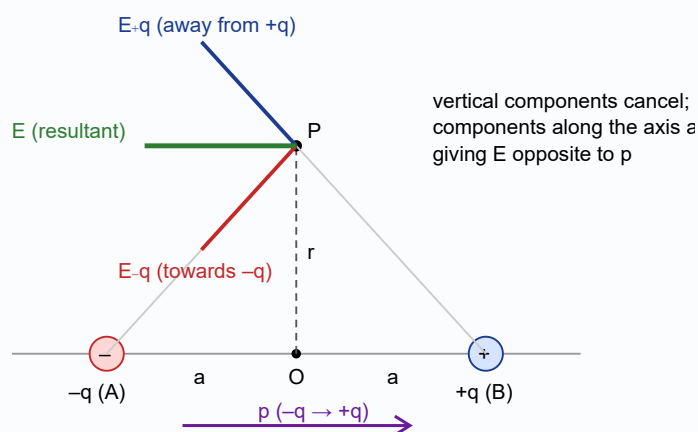
5 marks

- (i) Derive an expression for the electric field at a point on the equatorial plane of an electric dipole consisting of charges q and $-q$ separated by a distance $2a$.
- (ii) The distance of a far off point on the equatorial plane of an electric dipole is halved. How will the electric field be affected for the dipole?
- (iii) Two identical electric dipoles are placed along the diagonals of a square ABCD of side $\sqrt{2}$ m as shown in the figure. Obtain the magnitude and direction of the net electric field at the centre (O) of the square.



Solution

(i)



The point P is at distance r from the centre on the perpendicular bisector; each charge is at distance $\sqrt{r^2 + a^2}$:

$$E_{+q} = E_{-q} = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2 + a^2}$$

The components perpendicular to the axis cancel; the components along the axis add, pointing from +q towards -q:

$$E = 2E_{+q} \cos \theta = 2 \cdot \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2 + a^2} \cdot \frac{a}{\sqrt{r^2 + a^2}} = \frac{1}{4\pi\epsilon_0} \cdot \frac{p}{(r^2 + a^2)^{3/2}}$$

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

(ii) For a far point $E \propto \frac{1}{r^3}$; halving r makes the field **8 times**.

(iii) The diagonal of the square is $\sqrt{2} \times \sqrt{2} = 2$ m, so each charge is 1 m from O. Each charge produces a field of magnitude kq at O.

Dipole A(+q)–C(–q): both fields point from A towards C, total $2kq$ along AC.

Dipole D(+q)–B(–q): both fields point from D towards B, total $2kq$ along DB.

AC and DB are perpendicular, and their bisector is parallel to DC (AB). Each makes 45° with it, so the components perpendicular to DC cancel:

$$E = 2 \times 2kq \cos 45^\circ = 2\sqrt{2} kq = \frac{2\sqrt{2} q}{4\pi\epsilon_0} \text{ N/C}$$

directed parallel to DC (from the AD side towards the BC side).

CBSE 2023 · 55/2/1 · Q31(a)

5 marks

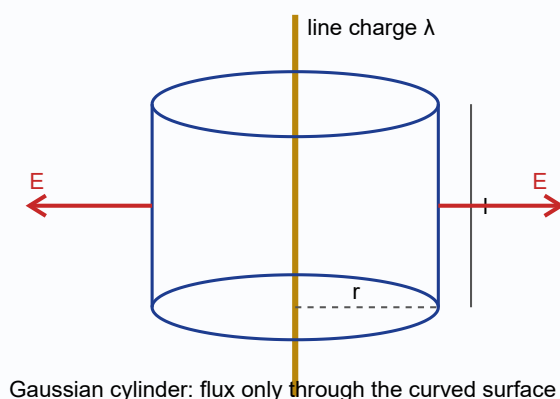
(i) Use Gauss' law to obtain an expression for the electric field due to an infinitely long thin straight wire with uniform linear charge density λ .

(ii) An infinitely long positively charged straight wire has a linear charge density λ . An electron is revolving in a circle with a constant speed v such that the wire passes through the centre, and is perpendicular to the plane, of the circle. Find the kinetic energy of the electron in terms of magnitudes of its charge and linear charge density λ on the wire.

(iii) Draw a graph of kinetic energy as a function of linear charge density λ .

Solution

(i)



Take a coaxial cylinder of radius r and length l as the Gaussian surface. By symmetry $\vec{E}$ is radial and has the same magnitude on the curved surface. The flux through the flat ends is zero ($\vec{E} \perp d\vec{S}$ there).

Flux = $E(2\pi rl)$; charge enclosed = λl :

$$E \cdot 2\pi rl = \frac{\lambda l}{\epsilon_0} \Rightarrow E = \frac{\lambda}{2\pi\epsilon_0 r}$$

directed radially outward for $\lambda > 0$.

(ii) The electrostatic attraction provides the centripetal force:

$$\frac{mv^2}{r} = eE = \frac{e\lambda}{2\pi\epsilon_0 r} \Rightarrow mv^2 = \frac{e\lambda}{2\pi\epsilon_0}$$

$$K = \frac{1}{2}mv^2 = \frac{e\lambda}{4\pi\epsilon_0}$$

(independent of the radius of the orbit).

(iii) $K \propto \lambda$: a straight line through the origin (slope $\frac{e}{4\pi\epsilon_0}$).

CBSE 2020 · 55/1/1 · Q35(a)

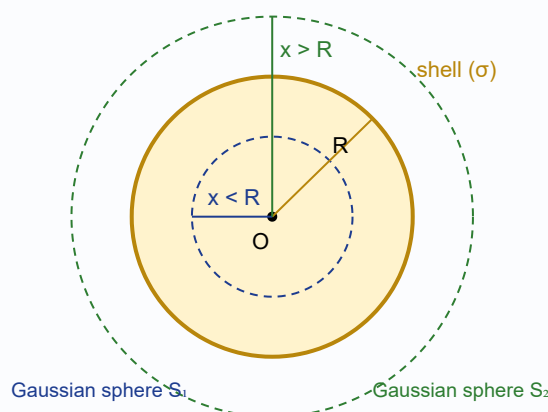
5 marks

(a) Using Gauss law, derive expression for electric field due to a spherical shell of uniform charge distribution σ and radius R at a point lying at a distance x from the centre of shell, such that (i) $0 < x < R$, and (ii) $x > R$.

(b) An electric field is uniform and acts along $+x$ direction in the region of positive x . It is also uniform with the same magnitude but acts in $-x$ direction in the region of negative x . The value of the field is $E = 200 \text{ N/C}$ for $x > 0$ and $E = -200 \text{ N/C}$ for $x < 0$. A right circular cylinder of length 20 cm and radius 5 cm has its centre at the origin and its axis along the x -axis so that one flat face is at $x = +10 \text{ cm}$ and the other is at $x = -10 \text{ cm}$. Find: (i) The net outward flux through the cylinder. (ii) The net charge present inside the cylinder.

Solution

(a)



By symmetry $\vec{E}$ is radial and has the same magnitude at all points at distance x .

(i) Inside ($x < R$): a Gaussian sphere of radius x encloses no charge, so $E \cdot 4\pi x^2 = 0$ and $\mathbf{E} = \mathbf{0}$.

(ii) Outside ($x > R$): the sphere encloses $q = \sigma \cdot 4\pi R^2$:

$$E \cdot 4\pi x^2 = \frac{\sigma 4\pi R^2}{\epsilon_0} \Rightarrow E = \frac{\sigma R^2}{\epsilon_0 x^2} = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{x^2}$$

directed radially outward (for $\sigma > 0$).

(b) (i) On both flat faces the field points outward (along $+x$ at $x = +10$ cm, along $-x$ at $x = -10$ cm); there is no flux through the curved surface. Area of each face $A = \pi(0.05)^2 = 7.85 \times 10^{-3} \text{ m}^2$.

$$\phi = EA + EA = 2 \times 200 \times 7.85 \times 10^{-3} \approx 3.14 \text{ N m}^2 \text{ C}^{-1}$$

$$(ii) q = \epsilon_0 \phi = 8.854 \times 10^{-12} \times 3.14 \approx 2.78 \times 10^{-11} \text{ C}.$$

CBSE 2020 · 55/2/1 · Q35(a)

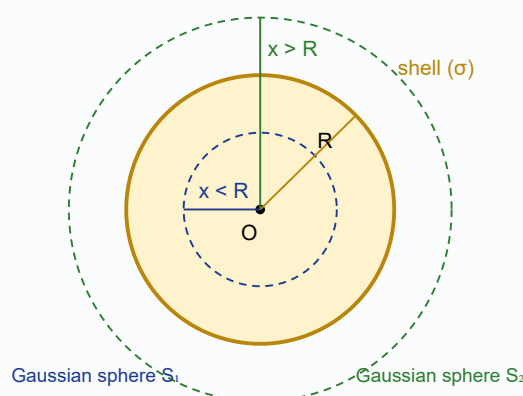
5 marks

(a) Use Gauss's law to show that due to a uniformly charged spherical shell of radius R , the electric field at any point situated outside the shell at a distance r from its centre is equal to the electric field at the same point, when the entire charge on the shell were concentrated at its centre. Also plot the graph showing the variation of electric field with r , for $r \leq R$ and $r \geq R$.

(b) Two point charges of $+1 \mu\text{C}$ and $+4 \mu\text{C}$ are kept 30 cm apart. How far from the $+1 \mu\text{C}$ charge on the line joining the two charges, will the net electric field be zero?

Solution

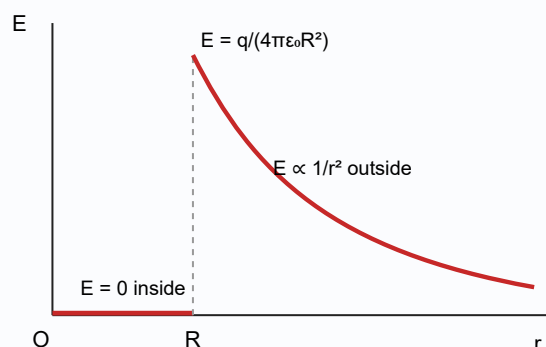
(a)



Take a concentric Gaussian sphere of radius $r > R$. By symmetry $\vec{E}$ is radial with the same magnitude everywhere on it:

$$E \cdot 4\pi r^2 = \frac{q}{\epsilon_0} \Rightarrow E = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}$$

This is exactly the field of a point charge q at the centre. Inside ($r < R$) the Gaussian sphere encloses no charge, so $E = 0$.



(b) Let the point be x from $+1 \mu\text{C}$ (between the charges, since both are positive):

$$\frac{k(1)}{x^2} = \frac{k(4)}{(0.3 - x)^2} \Rightarrow 0.3 - x = 2x \Rightarrow x = 0.1 \text{ m} = 10 \text{ cm}$$

from the $+1 \mu\text{C}$ charge.

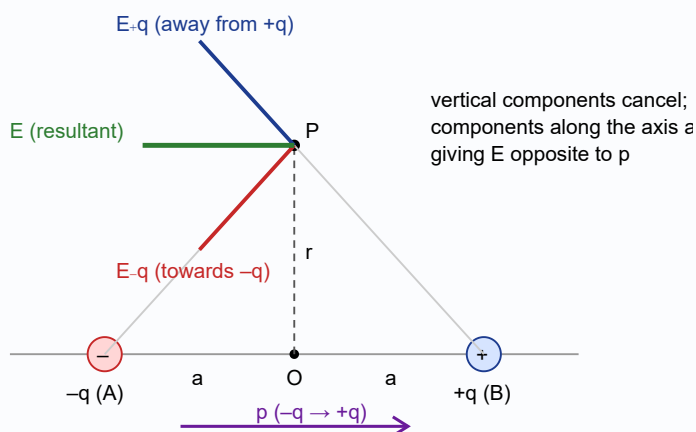
CBSE 2019 · 55/1/1 · Q27(b)

5 marks

(a) Derive an expression for the electric field at any point on the equatorial line of an electric dipole. (b) Two identical point charges, q each, are kept 2m apart in air. A third point charge Q of unknown magnitude and sign is placed on the line joining the charges such that the system remains in equilibrium. Find the position and nature of Q .

Solution

(a)



At P on the perpendicular bisector (distance r from the centre), each charge is at distance $\sqrt{r^2 + a^2}$ and produces $\frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2 + a^2}$. Components perpendicular to the axis cancel; those along the axis add (from $+q$ towards $-q$):

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

For $r \gg a$: $E = \frac{1}{4\pi\epsilon_0} \cdot \frac{p}{r^3}$.

(b) For Q to be in equilibrium between two equal charges, it must be at the **midpoint**, 1 m from each (the two forces on it balance there).

For each q to be in equilibrium, the attraction by Q must balance the repulsion of the other q :

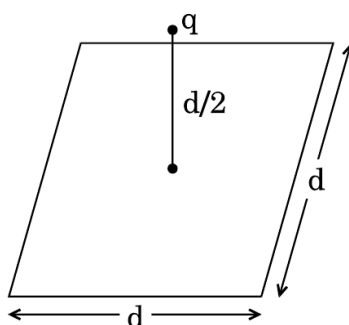
$$\frac{kq|Q|}{1^2} = \frac{kq^2}{2^2} \Rightarrow |Q| = \frac{q}{4}$$

Q must attract q, so it is **negative**: $Q = -\frac{q}{4}$, placed at the midpoint.

CBSE 2018 · 55/1 · Set 1 · Q24(a)

5 marks

(a) Define electric flux. Is it a scalar or a vector quantity? A point charge q is at a distance of $d/2$ directly above the centre of a square of side d, as shown in the figure. Use Gauss' law to obtain the expression for the electric flux through the square. (b) If the point charge is now moved to a distance 'd' from the centre of the square and the side of the square is doubled, explain how the electric flux will be affected.

**Solution**

(a) Electric flux through a surface is $\phi = \int \vec{E} \cdot d\vec{S}$, the number of field lines crossing it. It is a **scalar**.

Imagine a cube of side d with the charge at its centre: the square is one face of this cube (the charge is d/2 from it). By Gauss's law the total flux through the cube is $\frac{q}{\epsilon_0}$, shared equally by the six faces:

$$\phi = \frac{q}{6\epsilon_0}$$

(b) Now the charge is at distance d from a square of side 2d: it is again at the centre of a cube (side 2d) of which the square is a face. So the flux remains $\frac{q}{6\epsilon_0}$: **unchanged**.

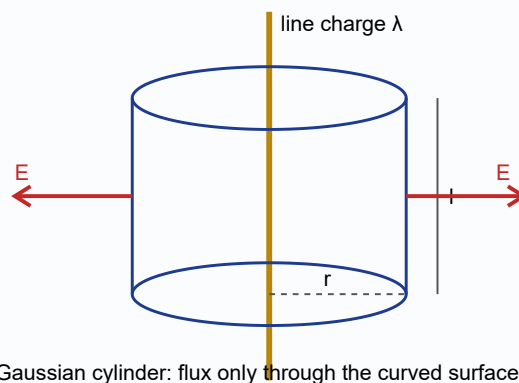
CBSE 2018 · 55/1 · Set 1 · Q24(b)

5 marks

(a) Use Gauss' law to derive the expression for the electric field ($\vec{E}$) due to a straight uniformly charged infinite line of charge density λ C/m. (b) Draw a graph to show the variation of E with perpendicular distance r from the line of charge. (c) Find the work done in bringing a charge q from perpendicular distance r_1 to r_2 ($r_2 > r_1$).

Solution

(a)



Take a coaxial cylinder of radius r and length l . E is radial, so flux passes only through the curved surface: $E(2\pi rl) = \frac{\lambda l}{\epsilon_0}$

$$E = \frac{\lambda}{2\pi\epsilon_0 r}, \text{ radially outward } (\lambda > 0)$$

(b) $E \propto \frac{1}{r}$: a rectangular hyperbola, decreasing with r .

(c) Work done by the field as q moves from r_1 to r_2 :

$$W = \int_{r_1}^{r_2} qE dr = \frac{q\lambda}{2\pi\epsilon_0} \ln \frac{r_2}{r_1}$$

(The work done by an external agent is the negative of this.)

CBSE 2017 · 55/1 · Set 1 · Q24(a)

5 marks

(a) Derive an expression for the electric field E due to a dipole of length ' $2a$ ' at a point distant r from the centre of the dipole on the axial line. (b) Draw a graph of E versus r for $r \gg a$. (c) If this dipole were kept in a uniform external electric field E_0 , diagrammatically represent the position of the dipole in stable and unstable equilibrium and write the expressions for the torque acting on the dipole in both the cases.

Solution

(a) Charges $-q$ at A and $+q$ at B, P on the axis at distance r from the centre, nearer to $+q$.

$$E_{+q} = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{(r-a)^2}, \quad E_{-q} = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{(r+a)^2} \text{ (opposite)}$$

$$E = \frac{q}{4\pi\epsilon_0} \left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2} \right] = \frac{1}{4\pi\epsilon_0} \cdot \frac{4qar}{(r^2 - a^2)^2}$$

along $\vec{p}$. For $r \gg a$: $E = \frac{1}{4\pi\epsilon_0} \cdot \frac{2p}{r^3}$.

(b) For $r \gg a$, $E \propto \frac{1}{r^3}$: a curve falling steeply with r .

(c) Stable equilibrium: $\vec{p}$ parallel to $\vec{E}_0$ ($\theta = 0$). Unstable equilibrium: $\vec{p}$ antiparallel ($\theta = 180^\circ$). In both, $\tau = pE_0 \sin \theta = 0$.

CBSE 2017 · 55/1 · Set 1 · Q24(b)

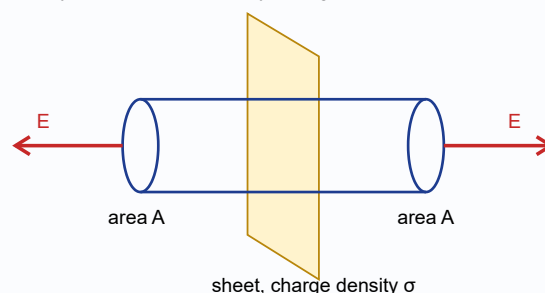
5 marks

(a) Use Gauss's theorem to find the electric field due to a uniformly charged infinitely large plane thin sheet with surface charge density σ . (b) An infinitely large thin plane sheet has a uniform surface charge density $+\sigma$. Obtain the expression for the amount of work done in bringing a point charge q from infinity to a point, distance r , in front of the charged plane sheet.

Solution

(a)

Gaussian cylinder: flux passes only through the two flat ends



Cylindrical Gaussian surface crossing the sheet: flux $2EA$, charge enclosed σA : $E = \frac{\sigma}{2\epsilon_0}$, normal to the sheet.

(b) The field is uniform and does not fall off with distance, so the potential (and work from infinity) is not finite: work done in bringing q from infinity is infinite. The work in moving q from a distance r_1 to r (towards the sheet) is

$$W = \frac{q\sigma}{2\epsilon_0}(r_1 - r)$$

(The board accepted the expression $V = V_0 - \frac{\sigma}{2\epsilon_0}r$ relative to the sheet.)

CBSE BOARD PAPER

2026 · Q.P. Code 55/1/1

Time: 3 hours

Maximum marks: 70

Section A · Multiple choice and Assertion–Reason (1 mark each)

1. In a region, the electric potential varies as $V = 10 - 50x$, where V is in volts and x in meters. The electric field in the region is 1
 - (A) 10 N/C along $+x$
 - (B) 10 N/C along $-x$
 - (C) 50 N/C along $+x$
 - (D) 50 N/C along $-x$
2. A conducting wire connects two charged metallic spheres A and B of radii r_1 and r_2 respectively. The distance between the spheres is very large compared to their radii. The ratio of electric fields (E_A/E_B) at the surfaces of spheres A and B will be 1
 - (A) $\frac{r_1}{r_2}$
 - (B) $\frac{r_2}{r_1}$
 - (C) $\frac{r_1^2}{r_2^2}$
 - (D) $\frac{r_2^2}{r_1^2}$
3. A long straight wire of circular cross-section (radius a) carries a steady current I . The current is uniformly distributed across this cross-section. The magnitude of the magnetic field produced at a point at a distance ($a/2$) from the axis of the wire will be 1
 - (A) Zero
 - (B) $\frac{\mu_0 I}{2\pi a}$
 - (C) $\frac{\mu_0 I}{4\pi a}$
 - (D) $\frac{\mu_0 I}{6\pi a}$
4. The shape of the interference fringes in Young's double-slit experiment, when the distance between the slit and the screen is very large as compared to the slit-separation, is nearly 1
 - (A) straight
 - (B) parabolic
 - (C) circular
 - (D) hyperbolic
5. An electromagnetic wave passes from vacuum into a dielectric medium with relative electrical permittivity ($3/2$) and relative magnetic permeability ($8/3$). Then, its 1
 - (A) wavelength is doubled and frequency remains unchanged.
 - (B) wavelength is doubled and frequency is halved.
 - (C) wavelength is halved and frequency remains unchanged.
 - (D) wavelength and frequency both will remain unchanged.
6. In a series LCR circuit, the voltage across the resistor, capacitor and inductor is 10 V each. If the capacitor is short circuited, the voltage across the inductor will be 1
 - (A) 10 V
 - (B) $5\sqrt{2}$ V
 - (C) $\frac{5}{\sqrt{2}}$ V
 - (D) $10\sqrt{2}$ V

7. Electromagnetic waves used in a diagnostic tool in medicine have a wavelength range 1
 (A) 1 nm to 10^{-3} nm (B) 400 nm to 1 nm
 (C) 1 mm to 700 nm (D) 0.1 m to 1 mm
8. The 'distance of closest approach' of an alpha-particle is 'd' when it moves with a velocity v head-on towards the target nucleus. If the velocity of alpha particle is halved, the new 'distance of closest approach' will be 1
 (A) $\frac{d}{2}$ (B) $2d$
 (C) $\frac{d}{4}$ (D) $4d$
9. A concave lens of focal length 10 cm is cut into two identical plano-concave lenses. The focal length of each lens will be 1
 (A) 20 cm (B) 30 cm
 (C) 40 cm (D) 5 cm
10. Four independent waves are expressed as (i) $y_1 = A_1 \sin \omega t$ (ii) $y_2 = A_2 \sin 2\omega t$ (iii) $y_3 = A_3 \cos \omega t$ (iv) $y_4 = A_4 \sin(\omega t + \pi/3)$. The interference between two of these waves is possible in 1
 (A) (i) and (iii) only (B) (iii) and (iv) only
 (C) (i), (iii) and (iv) only (D) All of them
11. Two heaters rated as (P_1, V) and (P_2, V) are connected in series across a dc source of $\frac{V}{2}$ volt. The power consumed by the combination will be 1
 (A) $(P_1 + P_2)$ (B) $\frac{P_1 + P_2}{2}$
 (C) $\frac{P_1 P_2}{2(P_1 + P_2)}$ (D) $\frac{P_1 P_2}{4(P_1 + P_2)}$
12. In an unbiased p-n junction, at equilibrium, which of the following statements is true? 1
 (A) Diffusion current is zero but drift current exists. (B) Diffusion current exists but drift current is zero.
 (C) Diffusion and drift currents are equal (D) Both the diffusion and drift currents exist but are unequal.
13. Assertion (A): All atoms have a net magnetic moment. 1
 Reason (R): A current loop does not always behave as a magnetic dipole.
 (A) Both A and R are true and R is the correct explanation of A. (B) Both A and R are true but R is not the correct explanation of A. (C) A is true but R is false. (D) A is false but R is true.
14. Assertion (A): If accelerated electrons are passed through a narrow slit, a diffraction pattern is observed. 1
 Reason (R): Electrons behave as both particles and waves.
 (A) Both A and R are true and R is the correct explanation of A. (B) Both A and R are true but R is not the correct explanation of A. (C) A is true but R is false. (D) A is false but R is true.

15. Assertion (A): The mass of a nucleus is less than the sum of the masses of the constituent nucleons. 1
Reason (R): Energy is absorbed when the nucleons are bound together to form a nucleus.
(A) Both A and R are true and R is the correct explanation of A. (B) Both A and R are true but R is not the correct explanation of A. (C) A is true but R is false. (D) A is false but R is true.
16. Assertion (A): In Bohr model of hydrogen atom, the energy levels are discrete and quantised. 1
Reason (R): In a hydrogen atom, the electrostatic force on the electron provides the necessary centripetal force to it to revolve around the nucleus.
(A) Both A and R are true and R is the correct explanation of A. (B) Both A and R are true but R is not the correct explanation of A. (C) A is true but R is false. (D) A is false but R is true.

Section B · Very short answer (2 marks each)

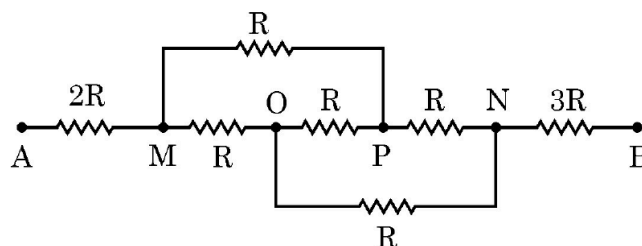
17. In a photoelectric experiment, the emitter plate is irradiated with radiation of 200 nm. The photocurrent becomes zero when the collector plate potential is -0.80 V. Calculate the work function (in eV) of the emitter. 2
18. (a) A beam of light consisting of two wavelengths 400 nm and 600 nm is used to illuminate a single slit of width 1 mm. Find the least distance of the point from the central maximum where the dark fringes due to both wavelengths coincide on the screen placed 1.5 m from the slit. 2
- OR**
- (b) In a Young's double-slit experimental set-up with slit separation 0.6 mm a beam of light consisting of two wavelengths 440 nm and 660 nm is used to obtain interference pattern on a screen kept 1.5 m in front of the slits. Find the least distance of the point from the central maximum where the bright fringes due to both the wavelengths coincide. 2
19. A wire of length L is bent round into (i) a square coil having N turns and (ii) a circular coil having N turns. The coil in both cases is free to turn about a vertical axis coinciding with the plane of the coil, in a uniform, horizontal magnetic field and carry the same currents. Find the ratio of the maximum value of the torque acting on the square coil to that on the circular coil. 2
20. What is the order of magnitude of drift velocity of electrons in a conductor? Deduce the relation between the current flowing through a conductor and drift velocity of electrons in it. 2
21. Draw the plot of potential energy of a pair of nucleons as a function of their separation. Write two important conclusions that can be drawn from this plot. 2

Section C · Short answer (3 marks each)

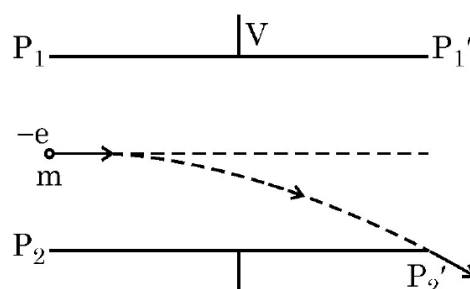
22. (a) Using Gauss's law, deduce an expression for electric field at a point due to a uniformly charged infinite plane thin sheet. 3
(b) Two large thin plane sheets, each having surface charge density σ , are held close and parallel to each other in air. What is the net electric field at a point (i) inside and (ii) outside, the sheets?

OR

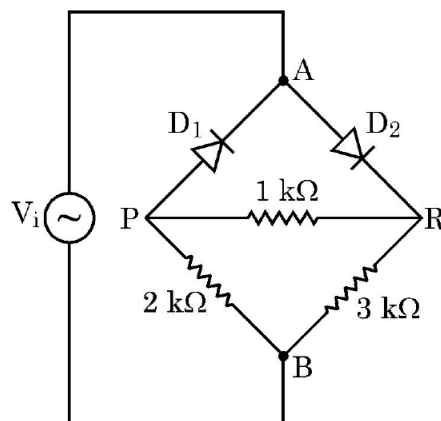
- (b) (a) Obtain the condition of balance of a Wheatstone bridge.
(b) Find net resistance of the network of resistors connected between A and B, as shown in figure.



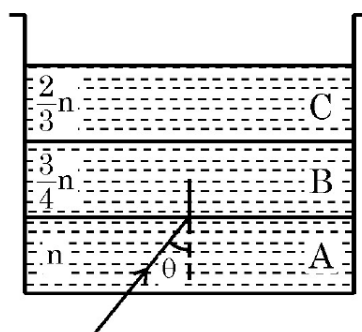
23. A parallel plate capacitor of capacitance C has a dielectric slab between its plates. It is charged to a potential difference V by connecting it across a battery. The battery is then disconnected. If the dielectric slab is now withdrawn from the capacitor, how will the following be affected? (a) Capacitance of the capacitor, (b) Energy stored in the capacitor, and (c) The potential difference between the plates of the capacitor. Justify your answer in each case.
24. Figure shows a narrow beam of electrons entering with a velocity of 3×10^7 m/s, symmetrically through the space between two parallel horizontal plates P_1P_1' and P_2P_2' kept 2 cm apart. If each plate is 3 cm long, calculate the potential difference V applied between the plates so that the beam just strikes the end P_2' .



25. An ac voltage $V_i = 12 \sin(100\pi t)$ V is applied between points A and B in a network of two ideal diodes and three resistors as shown in figure. During the positive half-cycle of the input voltage V_i supplied to the network, (a) Identify which of the two diodes will conduct and why?
(b) Redraw an equivalent circuit diagram to show the flow of current.
(c) Calculate the output voltage drops V_0 across the three resistors when the input voltage attains its peak value.



26. Briefly explain the two important processes that occur during the formation of a p-n junction.
27. (a) Draw the ray diagram to show the image formation by a refracting telescope and write the expression for angular magnification for the telescope in normal adjustment.
(b) Give two reasons to explain why a reflecting telescope is preferred over a refracting telescope.
28. (a) State the two conditions under which total internal reflection occurs.
(b) A transparent container contains layers of three immiscible transparent liquids A, B and C of refractive indices n , $\frac{3}{4}n$ and $\frac{2}{3}n$, respectively. A laser beam is incident at the interface between A and B at an angle θ as shown in figure. Prove that the beam does not enter region C at all for $\sin \theta \geq \frac{2}{3}$.



Section D · Case-based (4 marks each)

29. A galvanometer is used to detect or/and measure small currents in an electrical circuit. It essentially works on the fact that a current-carrying coil experiences a deflecting torque when placed in a magnetic field. This deflection in the coil can be measured and it is related to the current flowing in the coil, the number of turns in the coil, area of the coil and the magnetic field. A hair spring attached to the coil provides a counter torque and helps in measuring the deflection. A galvanometer can be converted to an ammeter or a voltmeter of desired range by using suitable resistances.

(I) The torque on the coil remains constant irrespective of the coil's orientation during rotation due to

- | | |
|--|--|
| (A) use of soft iron core which increases the magnetic field | (B) radial magnetic field |
| (C) hair spring which provides the counter torque | (D) eddy current in the iron core which causes damping |

(II) The best way to increase current sensitivity of a galvanometer is by

- | | |
|---|---|
| (A) increasing number of turns of the coil | (B) increasing area of coil and magnetic field strength |
| (C) decreasing area of coil and magnetic field strength | (D) increasing torsional constant of the hair spring |

(III) A moving coil galvanometer has a coil with area of cross-section $4.0 \times 10^{-3} \text{ m}^2$ and number of turns 50. The coil is rotating in a magnetic field of 0.25 T. The torque acting on the coil when a current of 5 A passes through it is

- | | |
|--------------|--------------|
| (A) 1.0 N m | (B) 2.0 N m |
| (C) 0.50 N m | (D) 0.25 N m |

OR

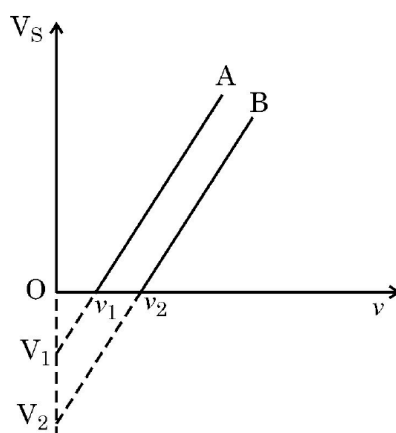
A galvanometer coil has a resistance of 15Ω and the meter shows full scale deflection for a current of 3 mA. The value of resistance required to convert it into a voltmeter of range (0 – 12 V) is

- | | |
|-------------------|-------------------|
| (A) 4015Ω | (B) 3985Ω |
| (C) 415Ω | (D) 385Ω |

(IV) A galvanometer with coil of resistance 20Ω shows full scale deflection for a current of 5 mA. To convert it into an ammeter of range (0 – 10 A), a resistance of

- | | |
|---|---|
| (A) 0.05Ω should be connected in series with it | (B) 0.05Ω should be connected in parallel with it |
| (C) 0.01Ω should be connected in parallel with it | (D) 0.01Ω should be connected in series with it |

30. A researcher performs an experiment on photo-electric effect using two metals A and B with unknown work functions. She illuminates the surfaces of A and B with monochromatic radiation of various frequencies and records the value of corresponding stopping potentials (V_s). The graph shows the variation of stopping potential (V_s) with the frequency of incident radiation (ν) for metals A and B.



(I) From the graph, the work functions of A and B are (h is Planck's constant and e value of charge on an electron)

(A) ν_1 and ν_2

(B) V_1 and V_2

(C) $h\nu_1$ and $h\nu_2$

(D) $\frac{h\nu_1}{e}$ and $\frac{h\nu_2}{e}$

(II) For radiation of frequency $\nu > \nu_2$ incident on the surfaces of A and B, the maximum kinetic energy of ejected electron is

(A) greater for metal A because it has a smaller work function

(B) greater for metal B because it has a larger work function

(C) greater for metal B because it has higher threshold frequency

(D) the same for both metal A and metal B because it is independent of work functions of metals

(III) If the intensity of the incident radiation for both metals A and B, is doubled keeping its frequency constant, then

(A) the slope of the parallel lines will increase

(B) the slope of the parallel lines will decrease

(C) the threshold frequencies for both A and B will decrease

(D) the slope of the parallel lines will not change but more electrons will be emitted per second

(IV) The threshold frequency for a metal surface is ν_0 . If the radiation of frequency $3\nu_0$ illuminates the surface, the maximum kinetic energy (KE) of photoelectrons is E_1 . If the frequency were increased to $6\nu_0$, the maximum KE of the photoelectrons becomes E_2 . Then

$\left(\frac{E_1}{E_2}\right)$ equals

(A) $1/3$

(B) $1/2$

(C) $2/5$

(D) $3/4$

OR

Let m be the slope of the graph line for metal B. If e is the value of electron charge, then Planck's constant ' h ' is given by

(A) me (B) $\frac{1}{me}$ (C) $\frac{m}{e}$ (D) $\frac{e}{m}$

Section E · Long answer (5 marks each)

31. (a) An electric dipole consists of two point charges q and $-q$ separated by a distance $2a$. Derive an expression for the electric field $\vec{E}$ due to this dipole at a point distant r from the centre of the dipole on the equatorial plane. Write the expression for the electric field at a far off point, i.e. $r \gg a$. 5
- (b) A dipole is placed in x - y plane such that charges q and $-q$ are located at $x = a$ and $x = b$ respectively. There exists an electric field $\vec{E} = 2\hat{i}$ N/C in the region. Calculate the force $\vec{F}$ and torque $\vec{\tau}$ experienced by the dipole.

OR

- (b) (a) Two cells of emf E_1 and E_2 with internal resistances r_1 and r_2 respectively, are connected in parallel by connecting their positive terminals together and negative terminals together. Deduce an expression for equivalent emf and equivalent internal resistance of the combination. 5
- (b) A parallel combination, as stated in (a) above, of two cells of emfs E and $3E$ and internal resistances R each is connected across a resistance $2R$. Find the current that flows through resistance $2R$.
32. (a) Using the relation for refraction at a curved spherical surface, derive the expression for lens maker's formula. 5
- (b) Three lenses L_1 , L_2 and L_3 , each of focal length 40 cm, are placed coaxially. The distance between L_1 and L_2 and between L_2 and L_3 are 120 cm and 20 cm respectively. An object is kept at a distance of 80 cm to the left of lens L_1 . Find the distance of the final image formed from the object.

OR

- (b) (a) Draw a ray diagram to show the image formation by a concave mirror when the object is kept between its focus and the centre of curvature. Using this diagram, derive the mirror formula. 5
- (b) A concave mirror produces a two times magnified virtual image of an object kept 10 cm in front of it. Calculate the focal length of the mirror.
33. (a) State Faraday's law of electromagnetic induction. 5
- (b) Derive an expression for the self-inductance of an air-filled long solenoid of length l and cross-sectional area A having N turns.
- (c) A conducting rod of length 50 cm, with one end pivoted, is rotated with angular speed of 60 rpm in a uniform magnetic field of 4.0 mT directed perpendicular to the plane of rotation of rod. Find the emf induced in the rod.

OR

(b) (a) Draw a labelled diagram of a step-up transformer. State the principle on which it works and obtain the ratio of secondary voltage to primary voltage in terms of number of turns and currents in the two coils.

(b) The ratio of the number of turns in the primary to the secondary of an ideal transformer is 1 : 5. If 5 kW power at 200 V is supplied to the primary, find (i) current in the primary, and (ii) output voltage.

Solutions · CBSE 2026 · 55/11

Q1 Answer: (C) 50 N/C along $+x$

$$E_x = -\frac{dV}{dx} = -\frac{d}{dx}(10 - 50x) = +50 \text{ V/m} = 50 \text{ N/C}$$

The positive sign means the field points along $+x$ (the direction in which V decreases).

Q2 Answer: (B) $\frac{r_2}{r_1}$

Connected spheres are at the same potential: $\frac{kq_1}{r_1} = \frac{kq_2}{r_2}$, so $\frac{q_1}{q_2} = \frac{r_1}{r_2}$.

$$\frac{E_A}{E_B} = \frac{kq_1/r_1^2}{kq_2/r_2^2} = \frac{q_1}{q_2} \cdot \frac{r_2^2}{r_1^2} = \frac{r_1}{r_2} \cdot \frac{r_2^2}{r_1^2} = \frac{r_2}{r_1}$$

Q3 Answer: (C) $\frac{\mu_0 I}{4\pi a}$

Inside the wire ($r < a$), Ampere's law with the enclosed current $I \frac{r^2}{a^2}$ gives $B = \frac{\mu_0 I r}{2\pi a^2}$. At $r = a/2$:

$$B = \frac{\mu_0 I (a/2)}{2\pi a^2} = \frac{\mu_0 I}{4\pi a}$$

Q4 Answer: (A) straight

The fringes are strictly hyperbolic, but when $D \gg d$ the part of each hyperbola on the screen is practically a straight line, so the fringes appear as straight bright and dark bands.

Q5 Answer: (C) wavelength is halved and frequency remains unchanged.

$$v = \frac{c}{\sqrt{\epsilon_r \mu_r}} = \frac{c}{\sqrt{\frac{3}{2} \times \frac{8}{3}}} = \frac{c}{\sqrt{4}} = \frac{c}{2}.$$

Frequency is set by the source and does not change; $\lambda = v/\nu$, so the wavelength becomes half.

Q6 Answer: (B) $5\sqrt{2} \text{ V}$

$V_L = V_C$, so the circuit is at resonance and the supply voltage is $V = V_R = 10 \text{ V}$. Also $IR = IX_L$, so $X_L = R$.

With C shorted: $Z = \sqrt{R^2 + X_L^2} = \sqrt{2} R$, $I' = \frac{10}{\sqrt{2}R}$, and

$$V_L = I'X_L = \frac{10}{\sqrt{2}R} \times R = \frac{10}{\sqrt{2}} = 5\sqrt{2} \text{ V}$$

Q7 **Answer: (A) 1 nm to 10^{-3} nm**

X-rays are used as a diagnostic tool in medicine; their wavelengths lie roughly between 10 nm and 10^{-4} nm, so the range 1 nm to 10^{-3} nm fits.

Q8 **Answer: (D) 4d**

At closest approach all kinetic energy becomes potential energy: $\frac{1}{2}mv^2 = \frac{k(2e)(Ze)}{d}$, so $d \propto \frac{1}{v^2}$.

Halving v makes v^2 one-fourth, so $d' = 4d$.

Q9 **Answer: (A) 20 cm**

For the equi-concave lens, $\frac{1}{f} = (n - 1) \left(-\frac{2}{R} \right)$, so $|f| = \frac{R}{2(n - 1)} = 10 \text{ cm}$.

Each plano-concave half has one curved surface: $\frac{1}{f'} = (n - 1) \left(-\frac{1}{R} \right)$, so $|f'| = \frac{R}{n - 1} = 2 \times 10 = 20 \text{ cm}$.

Q10 **Answer: (C) (i), (iii) and (iv) only**

Sustained interference needs the same frequency and a constant phase difference. Waves (i), (iii) and (iv) all have angular frequency ω with fixed phase differences ($\pi/2$ and $\pi/3$). Wave (ii) has frequency 2ω , so it cannot interfere steadily with the others.

Q11

Answer: (D) $\frac{P_1 P_2}{4(P_1 + P_2)}$

$R_1 = \frac{V^2}{P_1}$, $R_2 = \frac{V^2}{P_2}$, so in series $R = V^2 \left(\frac{1}{P_1} + \frac{1}{P_2} \right) = \frac{V^2(P_1 + P_2)}{P_1 P_2}$.

$$P = \frac{(V/2)^2}{R} = \frac{V^2}{4} \cdot \frac{P_1 P_2}{V^2(P_1 + P_2)} = \frac{P_1 P_2}{4(P_1 + P_2)}$$

Q12 **Answer: (C) Diffusion and drift currents are equal and opposite.**

At equilibrium both currents flow, but they balance exactly, so the net current through an unbiased junction is zero.

Q13 **Answer: (D) Both Assertion (A) and Reason (R) are false.**

Atoms of diamagnetic substances have zero net magnetic moment (the moments of their electrons cancel), so A is false. A current loop always behaves as a magnetic dipole of moment $\vec{m} = I\vec{A}$, so R is also false.

Q14 **Answer: (A) Both A and R are true and R is the correct explanation of A.**

Moving electrons have a de Broglie wavelength $\lambda = h/p$. This wave nature makes them diffract at a narrow slit (as in the Davisson–Germer experiment), so R explains A.

Q15 **Answer: (C) Assertion (A) is true, but Reason (R) is false.**

The nucleus has a mass defect Δm , so A is true. When nucleons combine, energy $\Delta m c^2$ (the binding energy) is **released**, not absorbed, so R is false.

Q16 **Answer: (B) Both A and R are true, but R is not the correct explanation of A.**

The energy levels are discrete because of Bohr's quantum condition $mvr = \frac{nh}{2\pi}$. The electrostatic force acting as centripetal force is true, but on its own it allows any orbit; it does not explain quantisation.

Q17 Einstein's equation: $h\nu = \phi_0 + eV_0$, so $\phi_0 = \frac{hc}{\lambda} - eV_0$.

$$\frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{200 \times 10^{-9}} \text{ J} = \frac{9.945 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ eV} \approx 6.2 \text{ eV}$$

Stopping potential $V_0 = 0.80 \text{ V}$, so $eV_0 = 0.80 \text{ eV}$.

$$\phi_0 = 6.2 - 0.8 = \mathbf{5.4 \text{ eV}}$$

Q18(a) Minima of a single slit: $a \sin \theta = n\lambda$, at $y = \frac{n\lambda D}{a}$.

For coincidence $n_1\lambda_1 = n_2\lambda_2$: $n_1 \times 400 = n_2 \times 600$. The smallest whole numbers are $n_1 = 3$, $n_2 = 2$.

$$y = \frac{n_2\lambda_2 D}{a} = \frac{2 \times 600 \times 10^{-9} \times 1.5}{1 \times 10^{-3}} = 1.8 \times 10^{-3} \text{ m} = \mathbf{1.8 \text{ mm}}$$

(Check: $3 \times 400 \times 10^{-9} \times 1.5/10^{-3} = 1.8 \text{ mm}$.)

Q18(b) Bright fringes: $y = \frac{n\lambda D}{d}$. For coincidence $n_1\lambda_1 = n_2\lambda_2$: $n_1 \times 440 = n_2 \times 660$, so $n_1 = 3$, $n_2 = 2$.

$$y = \frac{2 \times 660 \times 10^{-9} \times 1.5}{0.6 \times 10^{-3}} = 3.3 \times 10^{-3} \text{ m} = \mathbf{3.3 \text{ mm}}$$

Q19 Maximum torque $\tau_{max} = NIAB$, so $\frac{\tau_s}{\tau_c} = \frac{A_s}{A_c}$.

Square: perimeter of one turn $= \frac{L}{N} = 4a$, so $a = \frac{L}{4N}$ and $A_s = \frac{L^2}{16N^2}$.

Circle: $2\pi r = \frac{L}{N}$, so $r = \frac{L}{2\pi N}$ and $A_c = \pi r^2 = \frac{L^2}{4\pi N^2}$.

$$\frac{\tau_s}{\tau_c} = \frac{L^2/16N^2}{L^2/4\pi N^2} = \frac{4\pi}{16} = \frac{\pi}{4}$$

Ratio = $\pi : 4$.

Q20 Order of drift velocity: about 10^{-4} m/s (a fraction of a mm per second).

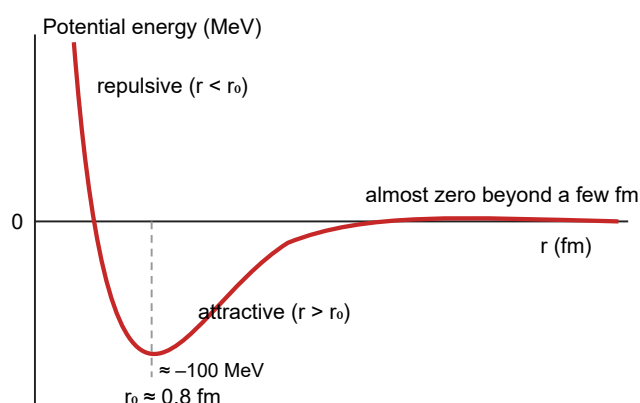
Relation: Take a conductor of cross-section A with n free electrons per unit volume, drifting with speed v_d .

In time Δt each electron moves $v_d \Delta t$, so all electrons in a length $v_d \Delta t$ cross a section: their number is $nA v_d \Delta t$.

Charge crossing: $\Delta Q = e n A v_d \Delta t$.

$$I = \frac{\Delta Q}{\Delta t} = n e A v_d$$

Q21

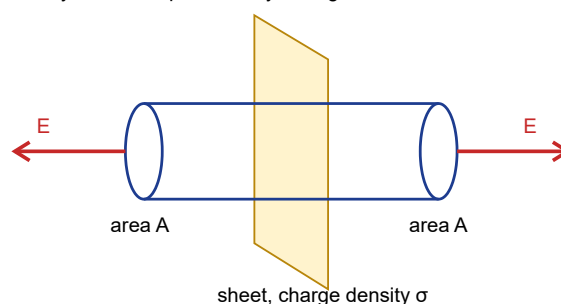


Conclusions (any two):

1. The potential energy is minimum at a separation $r_0 \approx 0.8$ fm.
2. For $r > r_0$ the nuclear force is attractive; for $r < r_0$ it is strongly repulsive.
3. The nuclear force is short range: it becomes negligible beyond a few femtometres.

Q22(a) (a) Take a cylindrical Gaussian surface of end-area A , cutting the sheet perpendicularly.

Gaussian cylinder: flux passes only through the two flat ends



By symmetry $\vec{E}$ is normal to the sheet. There is no flux through the curved surface; through each flat end the flux is EA .

Total flux = $2EA$; charge enclosed = σA . Gauss's law:

$$2EA = \frac{\sigma A}{\epsilon_0} \Rightarrow E = \frac{\sigma}{2\epsilon_0}$$

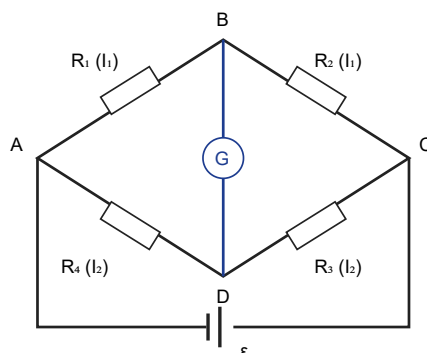
directed away from the sheet if $\sigma > 0$; it does not depend on distance.

(b) Each sheet gives $\frac{\sigma}{2\epsilon_0}$.

(i) Inside: the two fields are opposite, so $E = \frac{\sigma}{2\epsilon_0} - \frac{\sigma}{2\epsilon_0} = 0$.

(ii) Outside: the fields add, so $E = \frac{\sigma}{\epsilon_0}$, directed away from the sheets.

Q22(b) (a)



At balance no current flows through the galvanometer, so B and D are at the same potential. Then R_1 and R_2 carry the same current I_1 ; R_4 and R_3 carry I_2 .

Kirchhoff's loop rule:

Loop ABDA: $I_1 R_1 + 0 - I_2 R_4 = 0 \Rightarrow I_1 R_1 = I_2 R_4 \dots (1)$

Loop BCDB: $I_1 R_2 - I_2 R_3 - 0 = 0 \Rightarrow I_1 R_2 = I_2 R_3 \dots (2)$

Dividing (1) by (2):

$$\frac{R_1}{R_2} = \frac{R_4}{R_3}$$

(b) Between M and N, the resistors M-O (R), M-P (R , top), O-N (R , bottom), P-N (R) and O-P (R) form a Wheatstone bridge. Since $\frac{R}{R} = \frac{R}{R}$, it is balanced and O-P carries no current.

R_{MN} = two paths of $2R$ in parallel = R .

$$R_{AB} = 2R + R + 3R = 6R$$

Q23

With the battery disconnected, the charge $Q = CV$ stays constant. Let K be the dielectric constant.

(a) $C = \frac{K\epsilon_0 A}{d}$; without the slab $C' = \frac{\epsilon_0 A}{d} = \frac{C}{K}$. Capacitance **decreases** K times.

(b) $U = \frac{Q^2}{2C}$; $U' = \frac{Q^2}{2C'} = KU$. Energy **increases** K times (work is done in pulling the slab out).

(c) $V' = \frac{Q}{C'} = KV$. Potential difference **increases** K times.

Q24

Field between plates $E = \frac{V}{d}$; acceleration of the electron $a = \frac{eE}{m} = \frac{eV}{md}$ (towards the positive plate).

Time to cross the plates: $t = \frac{L}{u}$.

To just strike the end, the deflection must be $y = \frac{d}{2} = 1 \text{ cm}$:

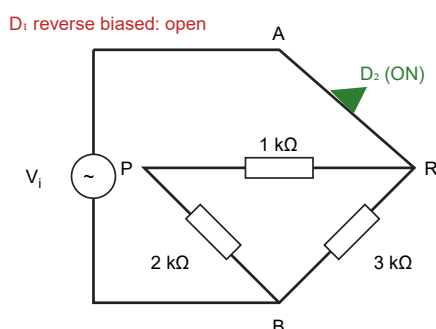
$$y = \frac{1}{2}at^2 = \frac{1}{2} \cdot \frac{eV}{md} \cdot \frac{L^2}{u^2} \Rightarrow V = \frac{2ymdu^2}{eL^2}$$

$$V = \frac{2 \times 0.01 \times 9.1 \times 10^{-31} \times 0.02 \times (3 \times 10^7)^2}{1.6 \times 10^{-19} \times (0.03)^2} = \frac{3.276 \times 10^{-19}}{1.44 \times 10^{-22}} \approx \mathbf{2275 \text{ V}}$$

Q25

(a) In the positive half-cycle A is at the higher potential. D_2 (pointing from A towards R) is forward biased and conducts; D_1 (pointing from P towards A) is reverse biased and does not conduct.

(b) Equivalent circuit (D_2 a closed switch, D_1 open):



From R the current divides: through 3 kΩ directly to B, and through 1 kΩ and 2 kΩ (via P) to B.

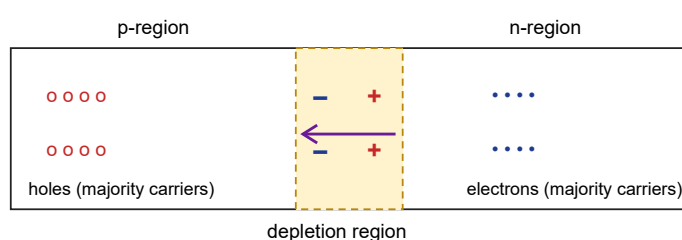
(c) The two branches are 3 kΩ and $(1 + 2) = 3 \text{ k}\Omega$, in parallel: $R = 1.5 \text{ k}\Omega$. At peak $V = 12 \text{ V}$:

$$I = \frac{12}{1.5 \times 10^3} = 8 \text{ mA}, \text{ which splits equally, } 4 \text{ mA in each branch.}$$

Drops: across 3 kΩ: $4 \text{ mA} \times 3 \text{ k}\Omega = \mathbf{12 \text{ V}}$; across 1 kΩ: $\mathbf{4 \text{ V}}$; across 2 kΩ: $\mathbf{8 \text{ V}}$.

Q26

The two processes are **diffusion** and **drift**.



Diffusion: holes $p \rightarrow n$, electrons $n \rightarrow p$ (concentration gradient)

Drift: barrier field ($n \rightarrow p$) pushes minority carriers back

1. **Diffusion:** the n-side has more electrons and the p-side more holes. Due to this concentration gradient, electrons diffuse from n to p and holes from p to n. This gives the diffusion current ($p \rightarrow n$). Electrons leaving the n-side leave behind positive donor ions, and holes leaving the p-side leave negative acceptor ions near the junction. This layer of immobile ions, free of charge carriers, is the **depletion region**.

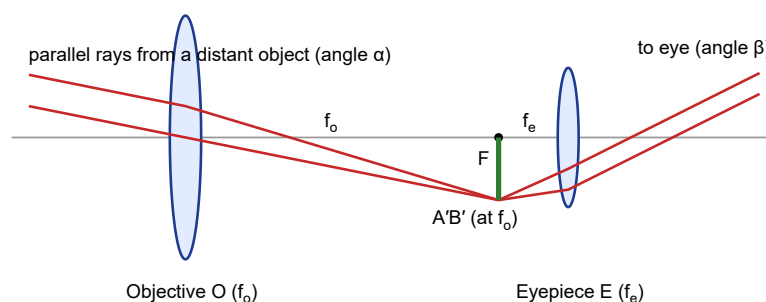
2. **Drift:** the ions in the depletion region set up an electric field from n to p (the barrier potential). This field pushes minority carriers across the junction (electrons $p \rightarrow n$, holes $n \rightarrow p$), giving a drift current opposite to the diffusion current.

At first the diffusion current is large; as the depletion layer widens the drift current grows. Equilibrium is reached when the two currents are equal, and no net current flows.

Q27

(a)

Refracting telescope: final image at infinity (normal adjustment)



In normal adjustment (final image at infinity):

$$m = \frac{\beta}{\alpha} = \frac{f_o}{f_e}$$

(the length of the tube is $f_o + f_e$).

(b) Any two:

1. A mirror has no chromatic aberration (no dispersion), and a parabolic mirror removes spherical aberration.
2. A large mirror is easier and cheaper to make and support (it can be supported over its whole back), whereas a large lens is heavy and sags.
3. The image is brighter, since a large aperture gathers more light.

Q28

- (a) 1. Light must travel from an optically denser medium to a rarer medium.
2. The angle of incidence must be greater than the critical angle for the pair of media.
- (b) At the A-B interface (Snell's law), with refraction angle θ_1 :

$$n \sin \theta = \frac{3}{4} n \sin \theta_1 \Rightarrow \sin \theta_1 = \frac{4}{3} \sin \theta \quad \dots (1)$$

At the B-C interface, with refraction angle r :

$$\frac{3}{4} n \sin \theta_1 = \frac{2}{3} n \sin r \quad \dots (2)$$

From (1) and (2): $n \sin \theta = \frac{2}{3} n \sin r$, so $\sin r = \frac{3}{2} \sin \theta$.

For $\sin \theta = \frac{2}{3}$: $\sin r = 1$, $r = 90^\circ$, and the ray grazes the B-C surface. For $\sin \theta > \frac{2}{3}$, $\sin r$ would exceed 1, which is impossible: the ray is totally internally reflected at the B-C interface. Hence for $\sin \theta \geq \frac{2}{3}$ the beam does not enter region C at all.

Q29

(I) **(B) radial magnetic field.** In a radial field the plane of the coil is always parallel to $\vec{B}$, so $\sin \theta = 1$ and $\tau = NIAB$ at every position.

(II) **(A) increasing number of turns of the coil** (answer as per the CBSE marking scheme).

Current sensitivity $\frac{\phi}{I} = \frac{NAB}{k}$ increases with N .

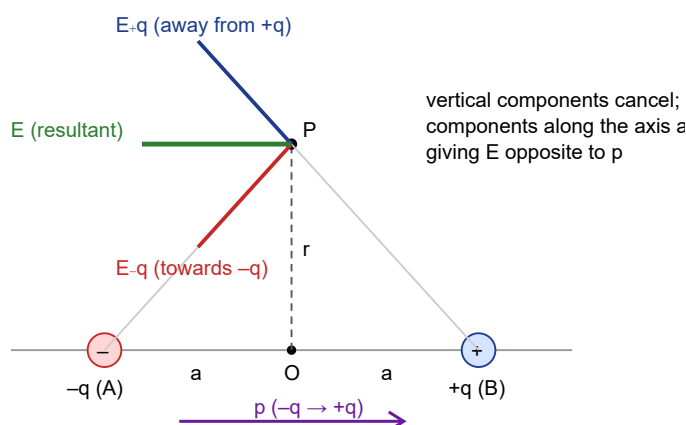
(III) **(D) 0.25 N m.** $\tau = NIAB = 50 \times 5 \times 4.0 \times 10^{-3} \times 0.25 = 0.25 \text{ N m}$.

OR **(B) 3985 Ω .** $R = \frac{V}{I_g} - G = \frac{12}{3 \times 10^{-3}} - 15 = 4000 - 15 = 3985 \Omega$, in series.

(IV) **(C) 0.01 Ω in parallel.** Shunt $S = \frac{I_g G}{I - I_g} = \frac{5 \times 10^{-3} \times 20}{10 - 0.005} \approx 0.01 \Omega$, connected in parallel.

- Q30** (I) **(C)** $h\nu_1$ and $h\nu_2$. The intercepts on the ν -axis are the threshold frequencies, and $\phi_0 = h\nu_0$.
 (II) **(A)** **greater for metal A because it has a smaller work function.** $K_{max} = h\nu - \phi_0$; for the same ν , the smaller ϕ_0 (metal A) gives the larger K_{max} .
 (III) **(D)** The slope h/e does not depend on intensity, and the threshold frequency does not change; higher intensity means more photons, so more electrons are emitted per second.
 (IV) **(C)** **2/5.** $E_1 = h(3\nu_0) - h\nu_0 = 2h\nu_0$; $E_2 = h(6\nu_0) - h\nu_0 = 5h\nu_0$; $\frac{E_1}{E_2} = \frac{2}{5}$.
 OR **(A)** **me.** $V_s = \frac{h}{e}\nu - \frac{\phi_0}{e}$, so the slope $m = \frac{h}{e}$ and $h = me$.

Q31(a) (a)



P is on the perpendicular bisector at distance r from the centre O. Distance of P from each charge $= \sqrt{r^2 + a^2}$, so

$$|\vec{E}_{+q}| = |\vec{E}_{-q}| = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2 + a^2}$$

Their components perpendicular to the axis cancel. The components parallel to the axis add, both pointing from $+q$ towards $-q$ (opposite to $\vec{p}$). If θ is the angle each field makes with the axis, $\cos \theta = \frac{a}{\sqrt{r^2 + a^2}}$:

$$E = 2E_{+q} \cos \theta = \frac{1}{4\pi\epsilon_0} \cdot \frac{2qa}{(r^2 + a^2)^{3/2}}$$

With $\vec{p} = q(2a)\hat{p}$:

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

For a far-off point ($r \gg a$):

$$\vec{E} = -\frac{1}{4\pi\epsilon_0} \cdot \frac{\vec{p}}{r^3}$$

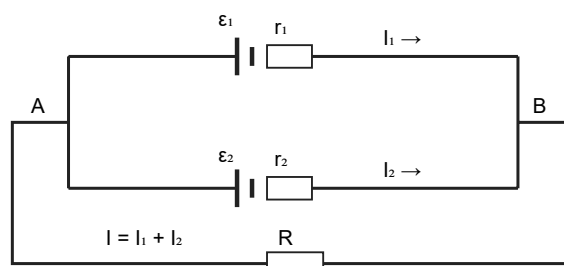
(b) The field is uniform, so the forces on $+q$ and $-q$ are $q\vec{E}$ and $-q\vec{E}$: net force $\vec{F} = q\vec{E} - q\vec{E} = \mathbf{0}$.

Dipole moment (from $-q$ to $+q$): $\vec{p} = q(a - b)\hat{i}$. Torque:

$$\vec{\tau} = \vec{p} \times \vec{E} = q(a - b)\hat{i} \times 2\hat{i} = \mathbf{0}$$

(the dipole lies along the field, so it is in equilibrium).

Q31(b) (a)



Let I_1 and I_2 leave the positive terminals; the external current is $I = I_1 + I_2$. The terminal voltage V is common:

$$V = E_1 - I_1 r_1 \Rightarrow I_1 = \frac{E_1 - V}{r_1}; V = E_2 - I_2 r_2 \Rightarrow I_2 = \frac{E_2 - V}{r_2}$$

$$I = \frac{E_1}{r_1} + \frac{E_2}{r_2} - V \left(\frac{1}{r_1} + \frac{1}{r_2} \right)$$

$$V = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2} - I \frac{r_1 r_2}{r_1 + r_2}$$

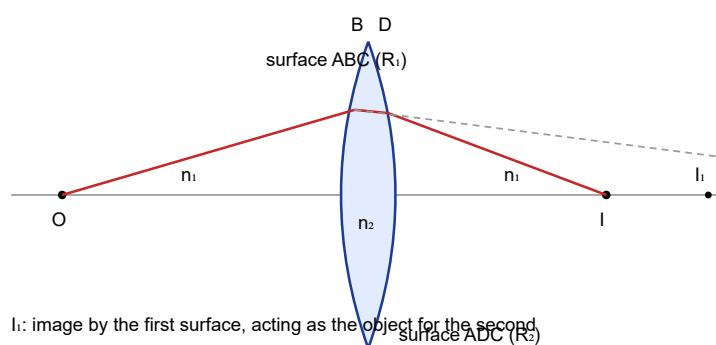
Comparing with $V = E_{eq} - I r_{eq}$:

$$E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}, \quad r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$

$$(b) E_{eq} = \frac{E \cdot R + 3E \cdot R}{R + R} = 2E; r_{eq} = \frac{R \cdot R}{2R} = \frac{R}{2}.$$

$$I = \frac{E_{eq}}{2R + r_{eq}} = \frac{2E}{2R + R/2} = \frac{4E}{5R}$$

Q32(a) (a)



A thin lens of refractive index n_2 in a medium n_1 has surfaces of radii R_1 and R_2 . Object O on the axis.

Refraction at the first surface ABC forms image I_1 :

$$\frac{n_2}{v_1} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1} \quad \dots (1)$$

I_1 acts as the object for the second surface ADC, which forms the final image I (light goes from n_2 to n_1):

$$\frac{n_1}{v} - \frac{n_2}{v_1} = \frac{n_1 - n_2}{R_2} \quad \dots (2)$$

Adding (1) and (2) (the lens is thin, so distances are from the optical centre):

$$\begin{aligned} \frac{n_1}{v} - \frac{n_1}{u} &= (n_2 - n_1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right) \\ \frac{1}{v} - \frac{1}{u} &= \left(\frac{n_2}{n_1} - 1 \right) \left(\frac{1}{R_1} - \frac{1}{R_2} \right) \end{aligned}$$

For an object at infinity, $v = f$:

$$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1 \right) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

This is the lens maker's formula (in air, $\frac{n_2}{n_1} = n$).

(b) Taking each lens as converging, $f = +40$ cm.

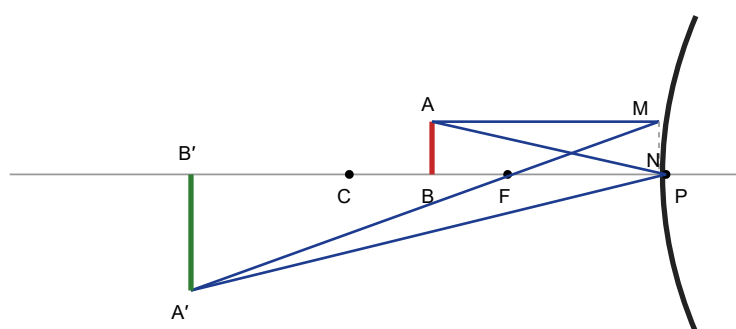
L_1 : $u = -80$ cm: $\frac{1}{v} = \frac{1}{40} - \frac{1}{80} = \frac{1}{80}$, so $v = 80$ cm (to the right of L_1).

L_2 is 120 cm from L_1 , so this image is 40 cm to the left of L_2 : $u = -40$ cm $= -f$, so the image is at infinity (rays leave L_2 parallel).

L_3 : parallel rays focus at $v = f = 40$ cm to the right of L_3 .

Distance of the final image from the object $= 80 + 120 + 20 + 40 = \mathbf{260 \text{ cm}}$.

Q32(b) (a)



Object between F and C: real, inverted, magnified image beyond C

Object AB between F and C; the ray parallel to the axis reflects through F, and the ray to the pole P reflects symmetrically. They meet at A' , giving a real, inverted image $A'B'$ beyond C. MN is the normal from M to the axis; for a small aperture, $MN \approx AB$ and $N \approx P$.

$\triangle A'B'F \sim \triangle MNF$ (approximately $\triangle MPF$):

$$\frac{A'B'}{AB} = \frac{B'F}{FP} \quad \dots (1)$$

$\triangle A'B'P \sim \triangle ABP$ (equal angles of incidence and reflection at P):

$$\frac{A'B'}{AB} = \frac{B'P}{BP} \quad \dots (2)$$

So $\frac{B'F}{FP} = \frac{B'P}{BP}$, i.e. $\frac{B'P - FP}{FP} = \frac{B'P}{BP}$.

Using the sign convention $B'P = -v$, $FP = -f$, $BP = -u$:

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

(b) Virtual image, $m = +2$; $u = -10$ cm.

$$m = -\frac{v}{u} \Rightarrow v = -mu = +20 \text{ cm (behind the mirror).}$$

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} = \frac{1}{20} - \frac{1}{10} = -\frac{1}{20}$$

$f = -20$ cm: the focal length is **20 cm** (concave).

Q33(a) (a) The magnitude of the emf induced in a circuit equals the time rate of change of magnetic flux through it: $\varepsilon = -\frac{d\Phi_B}{dt}$ (for N turns, $\varepsilon = -N\frac{d\Phi_B}{dt}$). The negative sign shows the induced emf opposes the change (Lenz's law).

(b) Turns per unit length $n = \frac{N}{l}$. A current I gives a field inside the solenoid

$$B = \mu_0 n I = \frac{\mu_0 N I}{l}$$

Total flux linkage: $N\Phi = N \cdot BA = \frac{\mu_0 N^2 A I}{l}$.

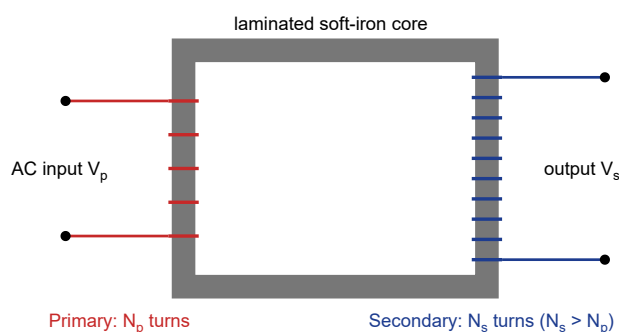
Since $N\Phi = LI$:

$$L = \frac{\mu_0 N^2 A}{l}$$

(c) $\omega = 60 \text{ rpm} = 1 \text{ rev/s} = 2\pi \text{ rad/s}$; $l = 0.5 \text{ m}$; $B = 4.0 \times 10^{-3} \text{ T}$.

$$\varepsilon = \frac{1}{2} B \omega l^2 = \frac{1}{2} \times 4.0 \times 10^{-3} \times 2\pi \times (0.5)^2 = \pi \times 10^{-3} \text{ V} \approx \mathbf{3.14 \text{ mV}}$$

Q33(b) (a)



Principle: mutual induction. An alternating current in the primary produces a changing flux in the core, which links the secondary and induces an emf in it.

If the flux in each turn is ϕ , and there is no flux leakage:

$$\varepsilon_s = -N_s \frac{d\phi}{dt} \text{ and } \varepsilon_p = -N_p \frac{d\phi}{dt}.$$

Taking $V_s \approx \varepsilon_s$ and $V_p \approx \varepsilon_p$ (negligible resistance):

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

For an ideal transformer (no losses), input power = output power: $V_p I_p = V_s I_s$, so

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$$

For a step-up transformer $N_s > N_p$, so $V_s > V_p$ and $I_s < I_p$.

(b) (i) $I_p = \frac{P}{V_p} = \frac{5000}{200} = \mathbf{25 \text{ A}}.$

(ii) $V_s = V_p \frac{N_s}{N_p} = 200 \times 5 = \mathbf{1000 \text{ V}}.$



All the best for your boards!

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