Class 12 Physics · Chapter 1: Electric Charges and Fields

Answer key and marking scheme · 20 marks · about 40 minutes · based on NCERT

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1. Two equal point charges 10 cm apart in vacuum repel each other with a force of 0.9 N. (Take $1/4\pi\varepsilon_0 = 9 \times 10^9$ N m^2 C^{-2}.) The magnitude of each charge is [1]

(a) 0.10 μC (b) 10 μC
(c) 1.0 μC (d) 3.2 μC

Answer: (c) $q^2 = Fr^2/k = 0.9 \times (0.10)^2 / (9 \times 10^9) = 1.0 \times 10^{-12}$ C², so $q = 1.0 \times 10^{-6}$ C = 1.0 μC.

2. Four small bodies inside an insulated box carry charges +4 μC, −7 μC, +2 μC and −1 μC. The total charge of the system is [1]

(a) −6 μC (b) 2 μC
(c) 14 μC (d) −2 μC

Answer: (d) Charge is a scalar and adds algebraically: (+4) + (−7) + (+2) + (−1) = −2 μC. Adding magnitudes gives 14 μC, which ignores the signs.

3. A glass rod is rubbed with a silk cloth and the rod becomes positively charged. During the rubbing [1]

(a) electrons move from the rod to the silk (b) protons move from the silk to the rod
(c) electrons move from the silk to the rod (d) positive charge is created on the rod and destroyed on the silk

Answer: (a) In solids only some loosely bound electrons are transferred. The rod loses electrons to the silk, so the rod is left positive and the silk negative; no charge is created or destroyed.

4. Two identical small conducting spheres carry +12 μC and −4 μC and attract each other with a force F when their centres are r apart. They are made to touch and are then put back r apart. The force between them now is [1]

(a) F/3, repulsive (b) F/3, attractive
(c) 4F/3, repulsive (d) F/12, repulsive

Answer: (a) Total charge is conserved: +12 − 4 = +8 μC, shared equally by identical spheres, so each has +4 μC. $F \propto |q_1 q_2|$: before 12 × 4 = 48, after 4 × 4 = 16. New force = 16F/48 = F/3, and like charges repel.

5. Point charges +2 μC and +8 μC are fixed 12 cm apart in vacuum. A third charge placed on the line between them feels no net force. Its distance from the +2 μC charge is [1]

(a) 2.4 cm (b) 8 cm
(c) 6 cm (d) 4 cm

Answer: (d) The two forces cancel when $2/x^2 = 8/(12 - x)^2$, i.e. $(12 - x)/x = 2$, so x = 4 cm, nearer the smaller charge. 2.4 cm comes from dividing in the ratio of the charges instead of the square root of that ratio.

6. Starting from E = F/q, find the SI unit and the dimensions of electric field, and hence of electric flux. [2]

E = F/q: unit N C^{-1}; dimensions $[MLT^{-2}]/[AT] = [MLT^{-3}A^{-1}]$. Flux $\phi = E \cdot \Delta S$: unit N C^{-1} m^2 (equivalently V m); dimensions $[MLT^{-3}A^{-1}][L^2] = [ML^3T^{-3}A^{-1}]$.

- E: N C^{-1}, $[MLT^{-3}A^{-1}]$ (1)
- flux: N C^{-1} m^2, $[ML^3T^{-3}A^{-1}]$ (1)

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7. A very long straight wire carries a uniform linear charge density of +2.0 μC m^{-1}. Find the magnitude and direction of the force on an electron 10 cm from the wire. (Take $1/4\pi\varepsilon_0 = 9 \times 10^9$ N m^2 C^{-2} and $e = 1.6 \times 10^{-19}$ C.) [2]

$E = \lambda/(2\pi\varepsilon_0 r) = 2 \times (9 \times 10^9) \times (2.0 \times 10^{-6})/0.10 = 3.6 \times 10^5$ N C^{-1}, radially outward. $F = eE = 1.6 \times 10^{-19} \times 3.6 \times 10^5 = 5.76 \times 10^{-14}$ N $\approx 5.8 \times 10^{-14}$ N. The electron is negative, so the force is towards the wire.

- $E = \lambda/(2\pi\varepsilon_0 r) = 3.6 \times 10^5$ N C^{-1} (1)
- $F = eE \approx 5.8 \times 10^{-14}$ N, directed towards the wire (1)

8. A plastic comb run through dry hair attracts small bits of neutral paper. Explain why. [2]

The charged comb produces a field that polarises the paper: it induces a dipole moment in the paper along the field. The comb's field is non-uniform, stronger nearer the comb, so the induced dipole feels a net force towards the stronger field, and the paper moves towards the comb.

- the comb's field polarises the paper, inducing a dipole along the field (1)
- field is non-uniform, so a net force acts towards the comb (1)

9. Two free point charges +q and +4q are a distance L apart. A third charge Q is placed so that all three charges are in equilibrium. Find the position and the value of Q. [3]

Q must lie between the two charges (outside, the two forces on it point the same way). Let it be x from +q. Equilibrium of Q: $kqQ/x^2 = k(4q)Q/(L - x)^2$, so $(L - x) = 2x$ and $x = L/3$. Equilibrium of +q: the repulsion from +4q, $k \cdot 4q^2/L^2$, must be balanced by an attraction towards Q, so Q is negative with $kq|Q|/(L/3)^2 = 4kq^2/L^2$, giving $|Q| = 4q/9$. So $Q = -4q/9$ at L/3 from +q. (The charge +4q is then also in equilibrium, since the net force on the system is zero.)

- Q between the charges; x = L/3 from +q (1)
- balance on +q gives $|Q| = 4q/9$ (1)
- Q negative: $Q = -4q/9$ (1)

10. A closed surface encloses a small electric dipole of charges ±3.0 μC and a point charge of +4.0 μC. A charge of −6.0 μC lies outside the surface. (a) Find the net electric flux through the surface. (b) Does the −6.0 μC charge affect the electric field on the surface? Does it affect the flux? (Take $\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}.) [3]

(a) Charge enclosed = +3.0 − 3.0 + 4.0 = +4.0 μC. $\phi = q/\varepsilon_0 = 4.0 \times 10^{-6}/8.854 \times 10^{-12} = 4.5 \times 10^5$ N m^2 C^{-1}. (b) The field at each point of the surface is due to all charges, inside and outside, so the −6.0 μC charge changes it; but it encloses no part of the surface, so it adds no net flux: the flux counts only the charge inside.

- enclosed charge +4.0 μC (dipole contributes zero) (1)
- $\phi = q/\varepsilon_0 = 4.5 \times 10^5$ N m^2 C^{-1} (1)
- outside charge changes E but not the net flux (1)

11. Two large parallel plane sheets A and B carry uniform surface charge densities +2σ and −σ. Find the magnitude and direction of the electric field (a) to the left of A, (b) between A and B, (c) to the right of B. Take A on the left. [3]

Each sheet gives a field of (its σ)/$2\varepsilon_0$, away from a positive sheet and towards a negative one. A: $2\sigma/2\varepsilon_0 = \sigma/\varepsilon_0$, away from A. B: $\sigma/2\varepsilon_0$, towards B. (a) Left of A: A's field to the left, σ/ε_0; B's field to the right, $\sigma/2\varepsilon_0$. Net $\sigma/2\varepsilon_0$ to the left. (b) Between: A's field to the right, σ/ε_0; B's field to the right, $\sigma/2\varepsilon_0$. Net $3\sigma/2\varepsilon_0$ to the right. (c) Right of B: A's field to the right, σ/ε_0; B's to the left, $\sigma/2\varepsilon_0$. Net $\sigma/2\varepsilon_0$ to the right.

- left of A: $\sigma/2\varepsilon_0$, to the left (1)
- between: $3\sigma/2\varepsilon_0$, from A to B (1)
- right of B: $\sigma/2\varepsilon_0$, to the right (1)

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