



Attempt all questions before checking the answer key. Use $k = 9 \times 10^9 \text{ N m}^2/\text{C}^2$ and $\epsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$ where needed.

A. Very short answers - 1 mark each

1. State the quantisation of charge. Can an isolated body carry $2.4 \times 10^{-19} \text{ C}$?
2. Why do two electric field lines never intersect?
3. Define electric flux and give its SI unit.
4. What is the net electric flux through a closed surface enclosing an electric dipole?
5. A charge moves in a uniform electric field. Does the force depend on its velocity?

B. Short answers / practice - 2 marks each

6. Two charges of $+2 \mu\text{C}$ and $-3 \mu\text{C}$ are 0.30 m apart in vacuum. Calculate the force and specify its nature.
7. Explain charging by induction with a conductor and an earthing connection.
8. Can the electric field be non-zero everywhere on a closed surface whose net flux is zero? Give an example.
9. A plane of area 0.02 m^2 has its normal at 60° to a 500 N/C field. Calculate its flux.
10. Define electric dipole moment. State the direction of the field at an equatorial point relative to this moment.
11. Can electrostatic field lines form closed loops? Explain.
12. A $+3 \mu\text{C}$ charge experiences 0.06 N . Find the field magnitude.
13. Two equal charges repel with 9 N . Find force when their separation triples.
14. Find charge on a body that has lost 10^{12} electrons; $e = 1.6 \times 10^{-19} \text{ C}$.
15. Why does excess charge reside on a conductor's surface in electrostatic equilibrium?
16. Find flux through a closed surface enclosing $+3 \mu\text{C}$ and $-1 \mu\text{C}$.
17. Find dipole moment for charges $\pm 2 \mu\text{C}$ separated by 4 mm .
18. Does an electric dipole experience net force in every non-uniform field?
19. A dipole is released from rest at a small angle to a uniform field. Describe its initial motion.
20. State how force on a test charge changes when its magnitude doubles at a fixed point.

C. Short answers - 3 marks each

21. Charges $+4 \mu\text{C}$ and $+9 \mu\text{C}$ are 1 m apart. Locate the point on their joining line where the electric field vanishes.
22. Square ABCD has side a and charges $+q$ at A, $+q$ at B and $-q$ at C. Find the electric field at D; draw the labelled square and define your axes.
23. An electric dipole of moment $4 \times 10^{-8} \text{ C m}$ makes 30° with a uniform field of $2 \times 10^5 \text{ N/C}$. Find torque and net force.
24. A charge q is at the centre of a cube. Find the flux through one face. Explain what changes if the charge is displaced within the cube.
25. Sketch electric field against distance from the centre of a uniformly charged thin spherical shell. Explain its values inside, just outside and far away.

D. Long answers - 5 marks each

26. Derive the electric field on the axis of a dipole of charges $\pm q$ separated by $2a$. Obtain the short-dipole approximation and direction.
27. Derive the electric field on the equatorial line of an electric dipole. Compare its magnitude and direction with the axial field at a large equal distance.
28. State Gauss's law and use a suitable Gaussian surface to derive the field of an infinitely long uniformly charged straight wire.
29. Apply Gauss's law to a uniformly charged infinite plane sheet and a thin spherical shell. State the symmetry arguments used in each case.
30. Derive the torque on a dipole in a uniform electric field. Discuss stable and unstable orientations and explain why the net force is zero.

ANSWER KEY - Numerical / short answers

- 1) No; $q/e = 1.5$ is not an integer. 4) Zero. 5) No; $F = qE$. 6) 0.60 N , attractive. 8) Yes; a uniform field has zero net closed-surface flux but can be non-zero everywhere on the surface. 9) $5 \text{ N m}^2/\text{C}$. 11) No; the electrostatic field is conservative. 12) $2.0 \times 10^4 \text{ N/C}$. 13) 1 N . 14) $+1.6 \times 10^{-7} \text{ C}$. 16) $2 \times 10^{-6}/\epsilon_0 \approx 2.26 \times 10^5 \text{ N m}^2/\text{C}$. 17) $8 \times 10^{-9} \text{ C m}$, from negative to positive charge. 18) Not necessarily; it depends on the field variation and orientation. 20) It doubles; the source field is unchanged. 21) 0.40 m from $+4 \mu\text{C}$, between the charges. 22) Take $A(0,0)$, $B(a,0)$, $C(a,a)$, $D(0,a)$; $E = (kq/a^2)[(1 - 1/(2\sqrt{2}))i + (1 + 1/(2\sqrt{2}))j]$. 23) Torque = $4.0 \times 10^{-3} \text{ N m}$; net force = 0. 24) $q/(6\epsilon_0)$; after displacement, total remains q/ϵ_0 but individual face fluxes generally differ.