ANSWER KEY & MARKING SCHEME · CBSE CLASS 12

Electrostatic Potential and Capacitance

Physics · Chapter 2 · Use this with the Board Paper · Companion to Quick Drill

HOW TO USE

Attempt the Board Paper first (closed-book, full time). Then come here. For 2-mark+ questions, compare your answer to the model. For 3-4 mark questions, also consult the **Topper Templates** below — these show the exact step-by-step structure that scores full marks per CBSE marking-scheme conventions.

MODEL ANSWERS · BOARD PAPER

Section A — MCQ (1 mark each, 6 Qs)

Q1. SI unit of electric potential is ____ . ***[1 mark]***

Ans: Volt = Joule/Coulomb.

Q2. Relationship between E and V: E = ____ . ***[1 mark]***

Ans: $-dV/dr$ (the minus sign captures direction: E points from high V to low V).

Q3. Equipotential surfaces are always ___ to electric field lines. ***[1 mark]***

Ans: Perpendicular.

Q4. Capacitance of parallel-plate capacitor with dielectric K is: C = ____ . ***[1 mark]***

Ans: $C = K\varepsilon_0 A/d$.

Q5. Energy stored in capacitor: U = ____ (in terms of Q and C). ***[1 mark]***

Ans: $U = \frac{1}{2} Q^2/C$ (also $\frac{1}{2} CV^2$ and $\frac{1}{2} QV$).

Q6. Series of two equal capacitors C gives C_eq = ____ . ***[1 mark]***

Ans: C/2.

Section B — Very Short Answer (2 marks each, 4 Qs)

Q7. State any two properties of equipotential surfaces. ***[2 marks]***

Ans: (1) Always perpendicular to electric field lines. (2) Work done in moving charge ON the surface = 0 (because $\Delta V = 0$). Additional: surfaces never intersect; closer-spaced surfaces indicate stronger field.

Q8. Find V at the centre of a square of side 2a, with charges +q, +q, −q, −q at the four corners (alternating). ***[2 marks]***

Ans: All four charges at distance $r = a\sqrt{2}$ from centre. $V = k(q+q-q-q)/(a\sqrt{2}) = 0$. (Cancellation by symmetry.)

Q9. Two capacitors $C_1 = 6\mu F$ and $C_2 = 12\mu F$ are connected in series. Find C_eq. ***[2 marks]***

Ans: 1/C_eq = 1/6 + 1/12 = 3/12 = 1/4. C_eq = 4 μF.

Q10. What is the effect on capacitance and stored energy if a dielectric of constant K is inserted in an ISOLATED charged capacitor? ***[2 marks]***

Ans: Isolated capacitor → Q constant. C increases by K times ($K\varepsilon_0 A/d$). Voltage V = Q/C decreases by K times. Energy $U = Q^2/(2C)$ decreases by K times. (Energy stored decreases — energy was used to draw dielectric in.)

Section C — Short Answer (3 marks each, 3 Qs)

Q11. Derive an expression for the energy stored in a charged capacitor. ***[3 marks]***

Ans: During charging, when capacitor has charge q, voltage = q/C. Work to add infinitesimal dq is dW = (q/C)dq. Total work $W = \int_0^Q (q/C)\, dq = [q^2/2C]_0^Q = Q^2/(2C)$. This is the stored energy: $U = \frac{1}{2} Q^2/C$. Substituting Q = CV: $U = \frac{1}{2} CV^2$. Substituting V = Q/C: $U = \frac{1}{2} QV$. Three equivalent forms.

Q12. What is meant by an equipotential surface? Show that the work done in moving a charge on such a surface is zero. ***[3 marks]***

Ans: An equipotential surface is a surface on which the electric potential V is constant (same V at every point). The work done in moving a charge q between two points A and B is $W = q(V_A - V_B)$. For two points on the SAME equipotential surface, $V_A = V_B$, so $W = q \times 0 = 0$. Hence work done in moving a charge on an equipotential surface is always zero, regardless of path.

Q13. Two parallel-plate capacitors A (C = 3μF) and B (C = 6μF) are connected in parallel across a 12V battery. Find (i) charge on each, (ii) total energy stored. ***[3 marks]***

> **Ans:** In parallel, V same = 12V across each. Q_A = 3 × 12 = 36 μC. Q_B = 6 × 12 = 72 μC. Total Q = 108 μC. Total C_eq = 3 + 6 = 9 μF. Energy = ½ C_eq V^2 = ½ × 9×10^{-6} × 144 = 6.48 × 10^{-4} J = 648 μJ.

Section D — Long Answer (4 marks each, 2 Qs)

Q14. Derive an expression for the capacitance of a parallel-plate capacitor with a dielectric medium of dielectric constant K filling the space between the plates. ***[4 marks]***

> **Ans:** Setup: parallel plates area A, separation d, charge +Q on top, −Q on bottom. Surface density σ = Q/A. Step 1 — Field with vacuum: between plates (using Gauss), $E_0 = \sigma/\varepsilon_0 = Q/(\varepsilon_0 A)$. Step 2 — Voltage with vacuum: $V_0 = E_0 \times d = Qd/(\varepsilon_0 A)$. Step 3 — Capacitance vacuum: $C_0 = Q/V_0 = \varepsilon_0 A/d$. Step 4 — With dielectric K filling gap: polarisation reduces field by factor K, so $E = E_0/K = \sigma/(K\varepsilon_0)$. New voltage $V = E \times d = Qd/(K\varepsilon_0 A) = V_0/K$. New capacitance C = Q/V = $K\varepsilon_0 A/d$. RESULT: $C = K\varepsilon_0 A/d$. Capacitance increases by factor K. Physical reason: dielectric polarisation reduces internal field, lowering V for the same Q, raising C = Q/V.

Q15. Case study: A 4μF capacitor is charged to 100V and then connected in parallel with an UNCHARGED 6μF capacitor. Find (i) the common voltage after connection, (ii) total charge before and after, (iii) energy lost in the process. ***[3 marks]***

> **Ans:** (i) Initial Q on 4μF = 4×100 = 400 μC. After connection, total C = 10μF, total Q still 400 μC (conserved). Common V = 400/10 = 40 V. (ii) Total Q before = 400 μC; after = 400 μC (conserved — confirms Kirchhoff). (iii) Energy before = ½ × 4 × 100^2 = 20,000 μJ = 20 mJ. Energy after = ½ × 10 × 40^2 = 8,000 μJ = 8 mJ. ENERGY LOST = 20 − 8 = 12 mJ. Dissipated as heat in connecting wires + EM radiation. Key learning: charge is conserved, energy is NOT.

★ TOPPER ANSWER TEMPLATES

3 TEMPLATES · MEMORISE THE FORMAT

★ TOPPER TEMPLATE — 5-mark derivation: Capacitance of parallel-plate capacitor with dielectric slab of constant K

Annual

Step 1 *[1 mark]*	**Set up: parallel plates with vacuum first**	Two parallel plates of area A separated by distance d. Charge +Q on top, −Q on bottom. Vacuum between. Field E_0 between plates (uniform, ignoring edges) = $\sigma/\varepsilon_0 = Q/(\varepsilon_0 A)$.
Step 2 *[1 mark]*	**Compute V_0 and C_0 for vacuum case**	Potential difference $V_0 = E_0 \times d = Qd/(\varepsilon_0 A)$. Capacitance $C_0 = Q/V_0 = \varepsilon_0 A/d$. This is the vacuum case.
Step 3 *[2 marks]*	**Insert dielectric slab of constant K**	With dielectric K filling the gap fully, the field inside REDUCES to $E = E_0/K = \sigma/(K\varepsilon_0)$ (polarisation of dielectric reduces effective field). New voltage $V = E \times d = Qd/(K\varepsilon_0 A) = V_0/K$. New capacitance $C = Q/V = K\varepsilon_0 A/d = K \cdot C_0$.
Step 4 *[1 mark]*	**Result + interpretation**	$C = K\varepsilon_0 A/d$. Capacitance INCREASES by factor K with dielectric. Physical reason: polarisation of dielectric reduces internal field → lower V for same Q → higher C = Q/V.

COMMON LOSS OF MARKS:
- Confusing E with V (−1 mark).
- Wrong direction of dielectric effect on V or C (−2 marks).
- Missing the polarisation explanation (−1 mark).

★ TOPPER TEMPLATE — 5-mark question: Equivalent capacitance for series and parallel combinations + derivation

95% of years

Step 1 *[2 marks]*	**Series combination derivation**	n capacitors $C_1, C_2, ..., C_n$ in series. Same charge Q on each. Total $V = V_1 + V_2 + ... + V_n = Q/C_1 + Q/C_2 + ... + Q/C_n$. C_eq = Q/V → $1/C_{eq} = 1/C_1 + 1/C_2 + ... + 1/C_n$. Equivalent capacitance is LESS than the smallest individual capacitance.
Step 2 *[2 marks]*	**Parallel combination derivation**	n capacitors in parallel. Same V across each. Total $Q = Q_1 + Q_2 + ... + Q_n = C_1V + C_2V + ... + C_nV = (C_1+C_2+...+C_n)V$. $C_{eq} = Q/V = C_1 + C_2 + ... + C_n$. Equivalent capacitance is GREATER than the largest individual capacitance.
Step 3 *[1 mark]*	**Mnemonic + key contrast with resistors**	Memory: capacitors OPPOSITE to resistors. Resistors: series adds, parallel reciprocals. Capacitors: series reciprocals, parallel adds. Confusing these is the most common error in CBSE 5-mark questions on combination networks.

COMMON LOSS OF MARKS:
- Reversing series/parallel formulas (−2 marks).
- Missing the derivation logic + jumping to formula (−1 mark).

★ TOPPER TEMPLATE — 4-mark question: Energy stored in capacitor + redistribution on connection

70% of years

Step 1 *[1 mark]*	**Derive energy stored formula**	Building charge q on capacitor (instantaneous voltage = q/C). Work to add dq = (q/C)dq. Total $W = \int_0^Q (q/C)dq = Q^2/(2C)$. So $U = ½ Q^2/C = ½ CV^2 = ½ QV$ (three equivalent forms).
Step 2 *[2 marks]*	**Redistribution on parallel connection**	Capacitor C_1 charged to V_1 (charge $Q_1 = C_1V_1$) connected in parallel to uncharged C_2. New shared voltage $V = Q_1/(C_1+C_2)$. Final charges: $Q_1' = C_1V$, $Q_2' = C_2V$. Charge IS conserved. Energy initial = $½ C_1V_1^2$; final = $½(C_1+C_2)V^2$. Energy LOST = E_initial − E_final = $½ \times C_1C_2V_1^2/(C_1+C_2)$. Released as heat in wires + EM radiation.
Step 3 *[1 mark]*	**Key insight: charge conserved, energy NOT conserved**	Total CHARGE is always conserved (Kirchhoff). Energy is NOT — it dissipates as heat + radiation in the connecting process. This is a counter-intuitive but exam-tested fact. State both conservations explicitly.

COMMON LOSS OF MARKS:

- Claiming energy is conserved (−1 mark).
- Missing the heat/radiation loss mechanism (−1 mark).

MARKING SCHEME — GENERAL NOTES

- Derivation questions: step marks for setup, key equations, intermediate manipulation, final result with units.
- Numerical questions: units MUST be quoted (V, F, μF, J, μJ). Missing units = −0.5.
- Conceptual differentiation (V vs U, series vs parallel formulas) frequently mis-stated — read questions carefully.
- Energy-conservation claim on capacitor connection: ALWAYS WRONG. Charge conserved, energy NOT.