A-LEVEL PHYSICS • EXERCISE SHEET

19.1 Capacitors and capacitance

Name: _____ Class: _____ Date: _____ **Total: 24 marks**

KEY WORDS capacitance 电容 • capacitor 电容器 • potential difference 电势差 • resistor 电阻器 • farad 法拉

Objective

Build the skills to answer exam questions on **capacitance** — $C = Q/V$ and combining capacitors.

You must be able to:

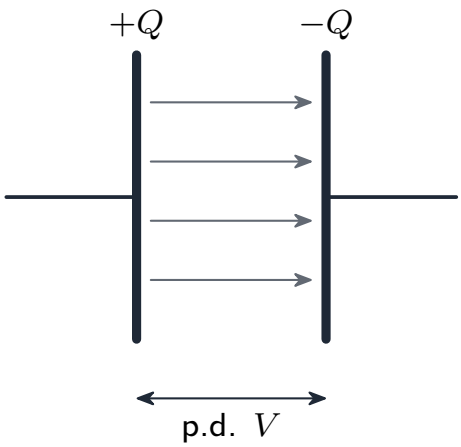
- define **capacitance** and use $C = Q/V$
- combine capacitors in **series** and **parallel**

1 Worked examples

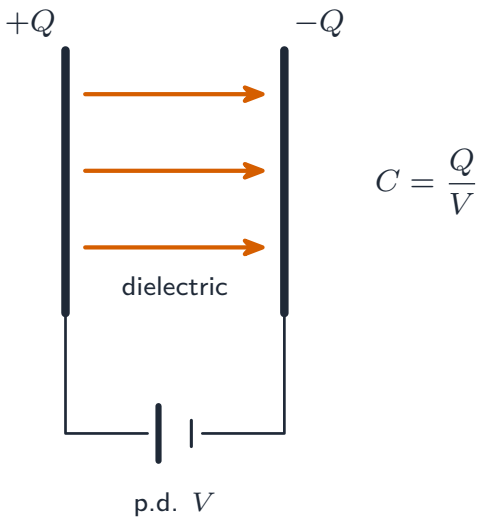
Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

Capacitance

A **capacitor** stores charge: $+Q$ on one plate, $-Q$ on the other, with p.d. V across the gap:



$$C = Q/V$$



$$C = \frac{Q}{V}$$

A parallel-plate capacitor

$$C = \frac{Q}{V} \quad \text{(farad, F} = \text{C V}^{-1}\text{)}.$$

■ **Combining capacitors (opposite to resistors)**

- **parallel:** $C = C_1 + C_2 + \dots$
- **series:** $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$

2 Practice

Now apply the methods above.

2.1 Define **capacitance**. [1]

2.2 State the **unit** of capacitance. [1]

2.3 A capacitor holds 60 μC of charge at 12 V. Find its **capacitance**. [2]

2.4 Write the formula for capacitors in **parallel**. [1]

3 Exam-style questions

3.1 The unit of capacitance is the: [1]

- **A** coulomb
- **B** farad
- **C** volt
- **D** ohm

3.2 A 100 μF capacitor is charged to 9.0 V. Calculate the **charge** stored. [2]

3.3 A 4.0 μF and a 2.0 μF capacitor are connected in **series**. Calculate the combined capacitance. [3]

3.4 Write the formula for capacitors in **series**. [1]

3.5 Three capacitors are available: $C_1 = 120$ μF, $C_2 = 180$ μF and $C_3 = 220$ μF.

(a) C_1 and C_2 are connected in **series** across a supply. **Complete** the table to show how the charge on each and the p.d. across each relate to the total charge Q_S and the supply p.d. V_S. [2]

quantity	relationship
charges Q_1, Q_2 and Q_S	_____
p.d.s V_1, V_2 and V_S	_____

(b) **Determine** the combined capacitance of C_1 and C_2 in series. [2]

(c) The supply provides 12 V. **Calculate** the charge stored by that series combination, and the p.d. across C_1. [3]

(d) C_3 is now connected in **parallel** with the series pair. **Determine** the total capacitance of the whole network, and the total charge it now stores at 12 V. [3]

(e) **State and explain** which single capacitor in the network stores the **most** charge. [2]

Solutions

2.1 The **charge stored per unit potential difference** ($C = Q/V$).

2.2 The **farad** (F).

2.3 $C = Q/V = (60 \times 10^{-6})/12 = 5.0\ \mu\text{F}$.

2.4 $C = C_1 + C_2 + \ldots$.

3.1 **B** — farad.

3.2 $Q = CV = (100 \times 10^{-6})(9.0) = 9.0 \times 10^{-4}$ C.

3.3 $\dfrac{1}{C} = \dfrac{1}{4.0} + \dfrac{1}{2.0} = \dfrac{3}{4.0}$; $C = 1.3\ \mu\text{F}$.

3.4 $\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \ldots$.

3.5 (a) Charges: $Q_1 = Q_2 = Q_\text{S}$ — the same charge passes through every capacitor in a series chain. P.d.s: $V_1 + V_2 = V_\text{S}$.
(b) $\dfrac{1}{C} = \dfrac{1}{120} + \dfrac{1}{180}$, so $C = \dfrac{120 \times 180}{300} = 72\ \mu\text{F}$.
(c) $Q = CV = 72 \times 10^{-6} \times 12 = 8.6 \times 10^{-4}$ C; $V_1 = \dfrac{Q}{C_1} = \dfrac{8.64 \times 10^{-4}}{120 \times 10^{-6}} = 7.2$ V. (The **smaller** capacitor takes the larger share of the p.d.)
(d) Capacitors in parallel add: $C_\text{total} = 72 + 220 = 292\ \mu\text{F}$; $Q_\text{total} = 292 \times 10^{-6} \times 12 = 3.5 \times 10^{-3}$ C.
(e) C_3 — it has the full 12 V across it and the largest capacitance, so $Q = CV$ is largest; the series pair shares the same p.d. between two capacitors and behaves as only 72 μF.