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:

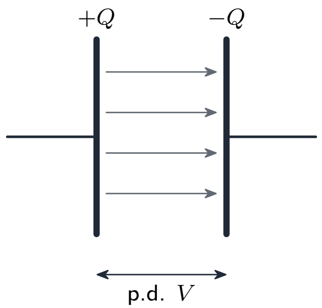
- define **capacitance** and use $C = Q/V$
- combine capacitors in **series** and **parallel**

1 Worked examples

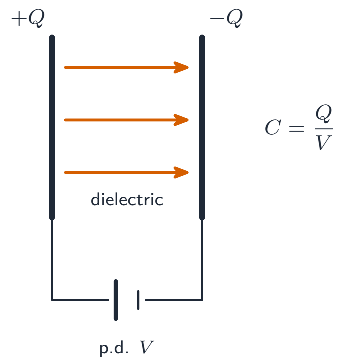
Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

Capacitance

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



$C = Q/V$



A parallel-plate capacitor

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

Combining capacitors (opposite to resistors)

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

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: $C_1 = 120\ \mu$F, $C_2 = 180\ \mu$F and $C_3 = 220\ \mu$F.

(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

Each answer shows the steps, then the **result**.

2.1

- the **charge stored per unit potential difference** ($C = Q/V$)

2.2

- the **farad** (F)

2.3

- $C = Q/V$

$$C = \frac{60 \times 10^{-6}\ \text{C}}{12\ \text{V}} = \mathbf{5.0}\ \mu\text{F}$$

2.4

- $C = C_1 + C_2 + \ldots$

3.1 B

- the SI unit of capacitance is the **farad**

3.2

- $Q = CV$

$$Q = (100 \times 10^{-6}\ \text{F})(9.0\ \text{V}) = \mathbf{9.0 \times 10^{-4}}\ \text{C}$$

3.3

- series: $1/C = 1/C_1 + 1/C_2$

$$\frac{1}{C} = \frac{1}{4.0\ \mu\text{F}} + \frac{1}{2.0\ \mu\text{F}} = \frac{3}{4.0\ \mu\text{F}}$$

- $C = \mathbf{1.3}\ \mu\text{F}$

3.4

- $1/C = 1/C_1 + 1/C_2 + \ldots$

3.5

(a) charges: $Q_1 = Q_2 = Q_S$ — the same charge passes through every capacitor in a series chain

- p.d.s: $V_1 + V_2 = V_S$

(b) $1/C = 1/120 + 1/180$

$$C = \frac{(120\ \mu\text{F})(180\ \mu\text{F})}{300\ \mu\text{F}} = \mathbf{72}\ \mu\text{F}$$

(c) $Q = CV$

$$Q = (72 \times 10^{-6}\ \text{F})(12\ \text{V}) = \mathbf{8.6 \times 10^{-4}}\ \text{C}$$

$$V_1 = \frac{Q}{C_1} = \frac{8.64 \times 10^{-4}\ \text{C}}{120 \times 10^{-6}\ \text{F}} = \mathbf{7.2}\ \text{V}$$

- the **smaller** capacitor takes the larger share of the p.d.

(d) capacitors in parallel add: $C_{\text{total}} = 72\ \mu\text{F} + 220\ \mu\text{F} = \mathbf{292}\ \mu\text{F}$

$$Q_{\text{total}} = (292 \times 10^{-6}\ \text{F})(12\ \text{V}) = \mathbf{3.5 \times 10^{-3}}\ \text{C}$$

(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. and behaves as only 72 μF