Unit 22 · Capacitors

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 28

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Spot the error

ANSWER U · 3

That is the rule for resistors in series, or capacitors in **parallel**. For capacitors in series the reciprocals add: $1/C = 1/6 + 1/12 = 3/12$, so **$C = 4\ \mu F$**, less than the smaller capacitor.

MARKING SCHEME

- ✓ The error: in series, $1/C = 1/C_1 + 1/C_2$ (adding is for parallel).
- ✓ $1/C = 1/6 + 1/12$.
- ✓ $C = 4\ \mu F$.

2 Check the readings

ANSWER HA · 3

Q/V for each: 47, 47, 47, 42.5, 47 μF. The capacitance is **47 μF**; the reading at **8 V** is wrong. It should be $47 \times 8 =$ **376 μC**.

MARKING SCHEME

- ✓ Q/V worked out for each reading: $C = 47\ \mu F$.
- ✓ The 8 V reading doesn't fit.
- ✓ It should be 376 μC.

3 What if?

ANSWER HA · 4

i. Charge is conserved: $Q = 4.0 \times 12 = 48\ \mu C$, shared by 6.0 μF in parallel: $V = 48 \div 6.0 =$ **8.0 V**.

ii. Before: $\frac{1}{2} \times 4.0 \times 10^{-6} \times 12^2 =$ **288 μJ**. After: $\frac{1}{2} \times 6.0 \times 10^{-6} \times 8.0^2 =$ **192 μJ**.

iii. 96 μJ, a third, was turned into **heat** in the wires (and a little as a spark and radio waves) while the charge rushed across.

MARKING SCHEME

- ✓ 48 μC shared over 6.0 μF: $V = 8.0$ V.
- ✓ 288 μJ before.
- ✓ 192 μJ after.
- ✓ The 96 μJ lost becomes heat (and a spark) in the connecting wires.

4 Design it

MARKING SCHEME A · 3

- ✓ Two in series give 2 μF and share the p.d. (200 V each, under 250 V).
- ✓ Three such pairs in parallel give 6 μF.
- ✓ Six capacitors in all.

5 Estimate it

ANSWER A · 2

$A = Cd/\varepsilon_0 = 1 \times 1.0 \times 10^{-3} \div 8.85 \times 10^{-12} =$ **$1.1 \times 10^8\ m^2$**, a square about **11 km** on each side, larger than Kathmandu's ring road encloses. This is why a farad is a huge capacitance.

MARKING SCHEME

- ✓ $A = Cd/\varepsilon_0 = 1.1 \times 10^8\ m^2$.
- ✓ About 11 km × 11 km, a city's size.

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6 Predict, then explain

ANSWER HA · 3

The **charge stays the same** (disconnected). $C = \varepsilon_0 A/d$ halves, so **$V = Q/C$ doubles**, and the energy $Q^2/2C$ **doubles**. The extra energy comes from the **work done pulling the plates apart** against their attraction (+Q and −Q).

MARKING SCHEME

- ✓ Charge unchanged.
- ✓ C halves, so V doubles.
- ✓ Energy $Q^2/2C$ doubles; the extra comes from the work done separating the attracting plates.

7 Reading a graph

MARKING SCHEME A · 3

- ✓ C = 20 μF.
- ✓ E = area = 6.25 mJ.
- ✓ 18.75 mJ more (25 mJ in all).

8 Correct the misconceptions

ANSWER U · 3

1. A capacitor **separates** charge: one plate +Q, the other −Q, total **zero**.
2. Capacitance depends only on how it is built (A, d, ε_r): raising V raises Q, but **Q/V stays the same**.
3. **No charge crosses** the insulating dielectric: electrons flow round the outside circuit from one plate to the other.

MARKING SCHEME

- ✓ The total charge is zero (+Q and −Q).
- ✓ C depends only on its build, not on V.
- ✓ No current crosses the dielectric; charge moves round the outside circuit.

9 Think

ANSWER HA · 2

The field across it, E = V/d, grows as d shrinks. Past the dielectric strength the insulator breaks down and conducts, destroying the capacitor. So a thin dielectric means a low voltage rating: a designer trades capacitance against the highest safe voltage, with a margin for thin spots and spikes.

MARKING SCHEME

- ✓ A thinner dielectric means a larger field E = V/d at the same p.d.
- ✓ Above the dielectric strength it breaks down: the voltage rating limits how thin it can be.

10 Make your own

ANSWER HA · 2

For example two 6 μF in series (3 μF), or a 2 μF in parallel with two 2 μF in series (2 + 1 = 3 μF). Any combination whose series and parallel rules give 3 μF is right.

MARKING SCHEME

- ✓ A combination drawn with its capacitors.
- ✓ Worked to 3 μF with the series and parallel rules.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	6	8	14	**28**

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