Unit 22 · Capacitors

ANSWER KEY · FOR TEACHERS

Full marks 37

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

1 Key words

1. capacitor
2. capacitance
3. farads
4. dielectric
5. permittivity
6. polarized
7. strength
8. electrolytic

K · 4

Each carries 0.5 mark.

2 Label the diagram

1. oxide layer: the dielectric
2. + foil
3. electrolyte
4. − foil

K · 2

Each carries 0.5 mark.

3 Multiple choice

i. **b.** 1 C/V — K · 1

C = Q/V: one coulomb per volt.

ii. **c.** stays the same — U · 1

C = ε_0A/d: halving A halves C, halving d doubles it; they cancel.

iii. **b.** 1 μF — A · 1

1/C = 1/2 + 1/3 + 1/6 = 1, so C = 1 μF, less than the smallest.

iv. **c.** rises — U · 1

The p.d. stays at the battery's voltage while C rises by ε_r, so the battery pushes more charge on: Q = CV rises.

v. **c.** 15 J — A · 1

E = ½CV^2 = 0.5 × 330 × 10^{-6} × 300^2 = 14.9 J.

4 Very short answers

a. MARKING SCHEME — K · 1

✓ 1 F: 1 C stored per 1 V across the plates.

b. MARKING SCHEME — U · 1

✓ Zero (+Q and −Q).

c. MARKING SCHEME — U · 1

✓ The oxide layer is kept only with the + foil at the higher potential; backwards it breaks down.

5 Short answers

a. MARKING SCHEME — U · 2

✓ No charge can cross the capacitor's insulating gap: charge only piles up on the plates.

✓ The growing p.d. across the plates pushes back until it equals the cell's e.m.f., and the current stops.

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b. MARKING SCHEME U · 2

- ✓ The dielectric is polarized: its faces carry charges opposite to the plates next to them, weakening the field between the plates.
- ✓ With a smaller field the p.d. V = Ed falls while Q stays the same, so C = Q/V rises (by ε_r).

c. MARKING SCHEME K · 2

- ✓ Any one, e.g. a camera's flash, a ceiling fan's starting capacitor.
- ✓ Any second, e.g. smoothing a power supply, tuning a radio, a defibrillator, keeping memory alive for a moment.

6 Long answer

ANSWER U · 4

While the capacitor charges, the p.d. across it grows in proportion to the charge, V = Q/C, so a graph of V against Q is a straight line through the origin. Moving a small charge ΔQ onto it at p.d. V takes work VΔQ, a thin strip under the graph; the total work is the area under the line up to Q: a triangle, ½QV. With Q = CV this is ½CV^2 (or $Q^2/2C$). It is not QV because the p.d. was not V all the time: it grew from zero, averaging V/2 during the charging.

MARKING SCHEME

- ✓ V = Q/C grows in proportion to Q (a straight line on a V–Q graph).
- ✓ Work to add ΔQ is VΔQ: the total is the area under the graph.
- ✓ Area = ½QV = ½CV^2.
- ✓ Not QV, since the p.d. rose from 0 to V (average V/2).

7 Numerical problems

a. ANSWER A · 3

$C = \varepsilon_r\varepsilon_0 A/d = 6.0 \times 8.85 \times 10^{-12} \times 0.040 \div 0.50 \times 10^{-3} =$ **4.2×10^{-9} F** (4.2 nF).
$Q = CV = 4.2 \times 10^{-9} \times 200 =$ **8.5×10^{-7} C**.

MARKING SCHEME

- ✓ $C = \varepsilon_r\varepsilon_0 A/d$.
- ✓ C = 4.2 nF.
- ✓ $Q = 8.5 \times 10^{-7}$ C.

b. ANSWER A · 4

i. Series pair: $C = (2 \times 3)/(2 + 3) = 1.2$ μF. With the 4 μF in parallel: $C = 1.2 + 4 =$ **5.2 μF**.
ii. The pair has 10 V across it: Q = 1.2 μF × 10 V = **12 μC**, the same on both capacitors in series. V = Q/C = 12 ÷ 2 = **6 V** across the 2 μF (and 4 V across the 3 μF).

MARKING SCHEME

- ✓ Series pair 1.2 μF.
- ✓ Total 5.2 μF.
- ✓ Charge on the 2 μF: 12 μC.
- ✓ p.d. across it: 6 V.

c. ANSWER A · 3

$E = ½CV^2$, so $V = \sqrt{(2E/C)} = \sqrt{(2 \times 200 \div 100 \times 10^{-6})} =$ **2,000 V**.
$Q = CV = 100 \times 10^{-6} \times 2000 =$ **0.20 C**.

MARKING SCHEME

- ✓ $V = \sqrt{(2E/C)}$.
- ✓ V = 2,000 V.
- ✓ Q = 0.20 C.

8 Think

ANSWER

In parallel, each capacitor sits across the same p.d., so it is as if their plates were laid side by side: the areas add, and since C ∝ A, the capacitances add. In series, the plates in the middle only pass charge along, so it is as if the gaps were stacked one after another: the gaps add, and since C ∝ 1/d, 1/C adds.

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A resistor's resistance grows with its length (series) and falls with its cross-section (parallel), so its rules are the other way round.

MARKING SCHEME

- ✓ Parallel is like adding plate area: C ∝ A, so C adds.
- ✓ Series is like adding gaps: C ∝ 1/d, so 1/C adds.
- ✓ For resistors R ∝ length/area, so the rules are reversed.

9 Activity: A capacitor from your kitchen (Activity 22.1)

(not marked)

WHAT STUDENTS SHOULD FIND

A few nanofarads. Pressing with a book squeezes out air and brings the foils closer (smaller d): C rises. Five sheets make d about five times larger: C falls to about a fifth. Half the overlap halves A: C about halves. C ∝ A/d explains each.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	10	12	12	3	**37**

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