

Exercise walk-through

4.4

Capacitors and RC circuits (statements 100–104, CP11)

Pearson Edexcel · International A-Level · Physics

Scattering links observation to a model

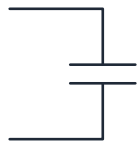
Observation / symbol	Supported conclusion
Most pass nearly straight	Most atomic volume is empty
Rare large deflections	Tiny, dense, positive nucleus
A_ZX	Proton number Z ; nucleon number A ; neutrons $A - Z$

The quark–lepton model organises particles

Family	Constituents / example
Baryon	Three quarks; proton uud
Meson	Quark + antiquark; pion
Lepton / antilepton	Electron / positron
Photon	Electromagnetic quantum

Exercise 2.1

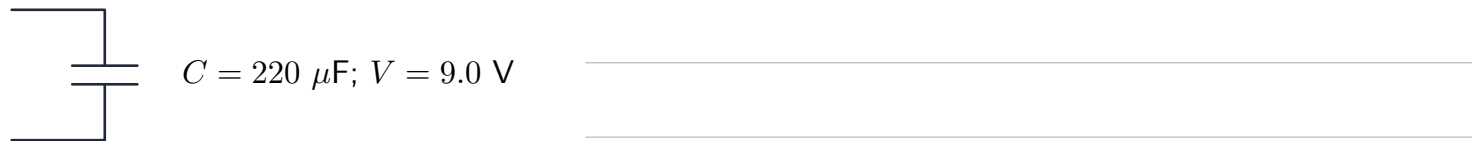
2.1 A $220\ \mu\text{F}$ capacitor is charged to $9.0\ \text{V}$. Calculate charge on either plate and stored energy. Explain why summing the magnitudes on both plates does not give the quoted capacitor charge. [5]



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2.1 Convert capacitance to farads and use $Q = CV$.

$$Q = CV = 220 \times 10^{-6}\ \text{F} \times 9.0\ \text{V} = 1.98 \times 10^{-3}\ \text{C}$$

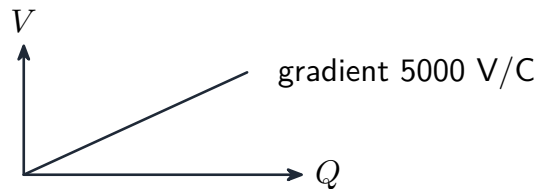
Charge magnitude. Use capacitor energy, not final QV .

$$W = \frac{1}{2}CV^2 = \frac{1}{2} \times 220 \times 10^{-6}\ \text{F} \times (9.0\ \text{V})^2 = 8.91 \times 10^{-3}\ \text{J}$$

Energy. Quoted Q is the separated-charge magnitude on either plate; the ideal plates have $+Q$ and $-Q$, not total stored charge $2Q$.

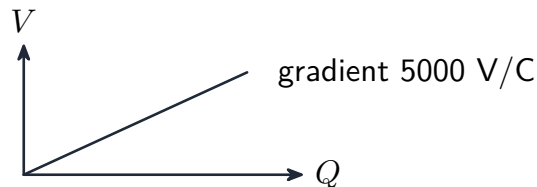
Exercise 2.2

2.2 A capacitor's V – Q graph is a straight line through the origin with gradient 5000 V C^{-1} . Find capacitance. Use the graph to derive the stored-energy formula. [4]



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2.2 The slope is $1/C$.

$$C = \frac{1}{\text{gradient}} = \frac{1}{5000 \text{ V C}^{-1}} = 2.00 \times 10^{-4} \text{ F}$$

Capacitance $200 \mu\text{F}$. Work is the area under V against charge added, a triangle:

$$W = \frac{1}{2}QV = \frac{1}{2}CV^2$$

The factor half follows from the voltage rising from zero.

Exercise 2.3

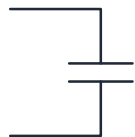
2.3 A $100\ \mu\text{F}$ capacitor discharges from $10.0\ \text{V}$ through $30.0\ \text{k}\Omega$. Calculate its time constant, p.d. and current magnitude after $6.0\ \text{s}$. [5]



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2.3 Use discharge time constant.

$$\tau = RC = 30.0 \times 10^3\ \Omega \times 100 \times 10^{-6}\ \text{F} = 3.00\ \text{s}$$

Time constant. Exponential discharge.

$$V = V_0 e^{-t/RC} = 10.0\ \text{V} \times e^{-6.0/3.00} = 1.35\ \text{V}$$

Voltage.

$$|I| = \frac{V}{R} = \frac{1.353\ \text{V}}{30.0 \times 10^3\ \Omega} = 4.51 \times 10^{-5}\ \text{A}$$

Current magnitude $45.1\ \mu\text{A}$.

Exercise 3.1

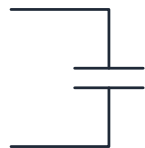
3.1 An initially uncharged capacitor charges through resistance R from supply V_s . Explain why current is initially maximum and decreases. Derive the time when resistor and capacitor p.d.s are equal. Explain why replacing the resistor with a smaller resistance worsens smoothing when the charged capacitor discharges into that load between supply peaks. [5]



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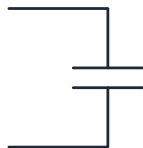
3.1 Initially $V_C = 0$, so the resistor has full supply p.d. and $I_0 = V_s/R$. As V_C rises, $V_R = V_s - V_C$ and current decrease. Equality gives $e^{-t/RC} = 1 - e^{-t/RC}$, hence:

$$t = RC \ln 2$$

Correct time. Smaller load resistance gives smaller RC , faster discharge between peaks and larger voltage ripple.

Exercise 3.2

3.2 A $470\ \mu\text{F}$ capacitor's p.d. falls from $8.0\ \text{V}$ to $3.0\ \text{V}$ in $4.0\ \text{s}$. Assume the stated capacitance is exact for this test. Determine the resistance and whether it lies within $10.0\ \text{k}\Omega \pm 10\%$. Calculate energy delivered to the resistance during this interval. [6]



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3.2 Divide the two exponential readings from one uninterrupted discharge.

$$R = -\frac{\Delta t}{C \ln(V_2/V_1)} = -\frac{4.0 \text{ s}}{470 \times 10^{-6} \text{ F} \times \ln(3.0/8.0)} = 8.68 \times 10^3 \Omega$$

Resistance. Allowed interval is $9.00\text{--}11.0 \text{ k}\Omega$, so it fails this test under the exact-capacitance assumption. Subtract stored energies.

Energy delivered.

Exercise 3.3

3.3 Plan a data-logger investigation of capacitor discharge that obtains RC from a log graph. Include the circuit, graph axes and gradient, repeats, sampling, input resistance and safety. Then state how instrument loading can affect the inferred time constant. [7]

data logger

capacitor discharge

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3.3 Charge from a low-voltage supply then isolate it and discharge through known R , sensing p.d. across C . Record voltage/time at intervals short compared with RC . Restore the same initial voltage before repeats and keep R , C and temperature steady. Plot $\ln(V/V_0)$ vertically against t horizontally; gradient is $-1/(RC)$, so $RC = -1/\text{gradient}$. Use a sensor input resistance much larger than R ; its parallel discharge path otherwise reduces effective resistance and measured time constant. Respect capacitor polarity/rating and discharge through a resistor before reconnecting; avoid logs near zero where relative uncertainty is large.