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WORKSHEETS
ATTEMPT | CHECK | CORRECT | IMPROVE

Capacitors 2

Discharge time constants and changing current

35–40 minutes independent work + 15–20 minutes review

OCR A H556 and AQA 7408 | A-level physics

Specification and route

OCR A H556: 6.1.1(a)–(b), 6.1.1(e)(i), 6.1.2(b), 6.1.3(a)–(c) and (e), selected discharge content.

AQA 7408: 3.7.4.1, 3.7.4.3 and 3.7.4.4, selected discharge content. Practical preparation supports RP9 / OCR PAG9.

A-level only. Charging algebra and ln graphs are developed in Capacitors 3.

22 core parts | 41 marks

A moving lunar-lander museum exhibit uses a capacitor timer to delay its reset after a visitor's command. A high-input-resistance controller resets the exhibit when the capacitor p.d. falls to a threshold. A separate supply powers the controller and the mechanism.

Show your working, include units and justify decisions using the information given.

The exhibit timer

In Figure 1 the switch is first held at A until C reaches 9.0 V. It is then moved to B. The charging supply is ideal. During discharge, C = 470 μF and R = 68.0 kΩ. Treat meter/controller loading and leakage as negligible unless told otherwise.

The arrow I defines positive current into the upper capacitor plate during charging. In calculation questions asking for magnitude, give a positive value. In signed-current sketches, use this printed reference direction.

For discharge use $V = V_0 \exp(-t/RC)$, $Q = CV$ and $|I| = V/R$. Here t is elapsed time since moving to B. You may use the half-time $t_{1/2} = 0.693RC$.

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1 Explain and establish the starting values

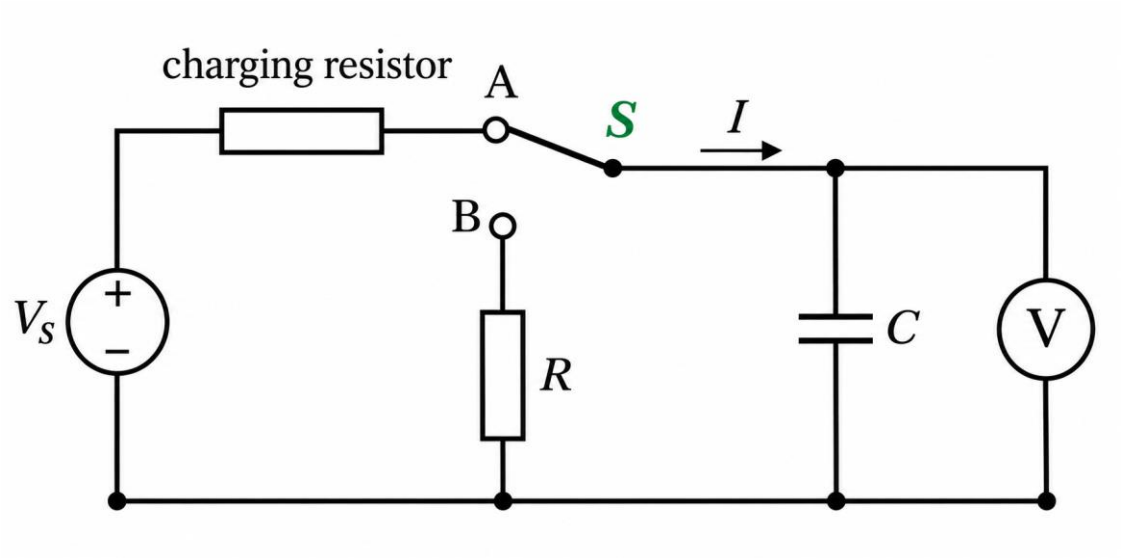


Figure 1 The switch is shown at A. At B the capacitor discharges through R. V represents a high-resistance voltmeter or voltage logger.

1(a) When the switch moves to B, identify the complete discharge path and explain why the charging supply does not drive this current. **[2 marks]**

1(b) Explain why the discharge current magnitude is largest initially and then decreases non-linearly, although R stays constant. **[2 marks]**

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2 Establish the discharge values

2(a) Calculate the initial charge magnitude on either plate. **[1 mark]**

2(b) Calculate the initial discharge current magnitude. **[1 mark]**

2(c) Calculate RC and state the physical meaning of this time constant during discharge. **[2 marks]**

2(d) Determine the p.d. and charge magnitude after one time constant. **[2 marks]**

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3 Calculate and check the measured data

The switch moved to B when the logger clock read 18.0 s. The table gives rounded p.d. readings during that discharge. Use these exact table values for calculations.

Logger clock / s	V / V
18	9
26	7.01
34	5.46
42	4.25
50	3.31
58	2.57
66	2
82	1.21
98	0.737

3(a) Use the exponential law to calculate the capacitor p.d. 16.0 s after switching to B, as a check on the table value. **[1 mark]**

3(b) At that same instant, calculate the charge magnitude and discharge current magnitude. **[2 marks]**

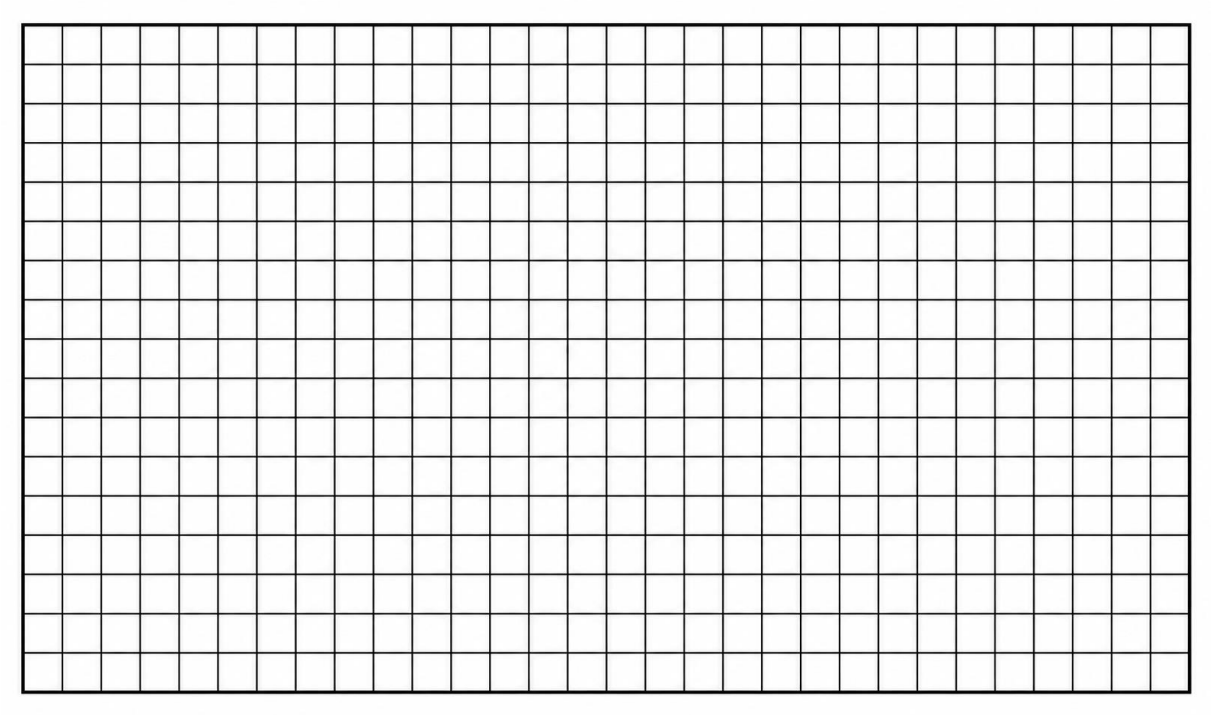
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3 Test the decay pattern

3(c) Use successive readings separated by 16 s to test whether the data are consistent with exponential decay. Show two ratios. **[2 marks]**

4 Construct the discharge graph

4(a) On the grid, plot V against logger clock time and draw a smooth curve. Choose labelled linear scales and use at least six readings. **[2 marks]**



Choose and label suitable linear scales. Plot from the exact data table.

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4 Extract time and current from your graph

Use your graph from 4(a). Show constructions on it where appropriate.

4(b) Determine RC from the graph using the time to fall from 9.00 V to 9.00/e V. Show how the logger readings give an elapsed time. **[2 marks]**

4(c) Draw a tangent at clock time 50 s. Estimate its gradient and hence the signed current I at that instant, using I = C × gradient of V against time. **[2 marks]**

4(d) Sketch the signed current I against elapsed discharge time. Label its initial value and the value after one RC. Show how it approaches zero. **[2 marks]**

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5 Set the reset delay

The controller resets at a capacitor p.d. of 2.25 V. The required delay is 42–47 s after switching to B. The controller draws negligible current from C.

5(a) Use the half-time relation to determine when the threshold is reached, and judge whether the delay is suitable. **[2 marks]**

5(b) Engineers can choose R = 56.0 kΩ, 68.0 kΩ or 82.0 kΩ with the same capacitor. Determine the threshold delay for each and select R. **[2 marks]**

5(c) Explain why this exponential model could not simply be applied to a real lamp or the exhibit motor in place of the fixed resistor. **[1 mark]**

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6 Change the settings

6(a) Compare doubling R with doubling C, starting each test at 9.0 V. State what happens to RC and to the initial current magnitude in each case. **[2 marks]**

6(b) Instead double the starting p.d., leaving R and C unchanged. The threshold is set to one quarter of this new starting p.d. State the effects on the initial current and threshold time. **[2 marks]**

6(c) For the original circuit, calculate the energy remaining after 16.0 s. Explain why the fraction of energy remaining is smaller than the fraction of p.d. remaining. **[2 marks]**

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7 Evaluate the timing test

7(a) An engineer says the capacitor is “empty after five RC”. Calculate the percentage of initial charge still present at that time and comment on this description. **[2 marks]**

7(b) A proposed investigation leaves the battery connected to the upper capacitor plate, uses a low-resistance voltmeter across C and takes only one late reading. Give three justified changes that would produce useful discharge data. **[3 marks]**

7(c) An unintended 68.0 kΩ resistor is connected in parallel with the original discharge resistor. Find the new RC and explain the effect on the reset delay. **[2 marks]**

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