Examiner only

**Your task is to carry out an investigation to determine the value of an unknown capacitor by using the method of capacitor discharge.**

**Time Allowed:** You should spend up to **15 minutes** to answer part *(a)* during which time you will have access to the equipment but should not start to set it up or to start taking measurements until you have finished part *(a)*. The total time for the task is **1¼ hours**.

You are provided with the following equipment

9 V d.c. power supply
Voltmeter (or multimeter set on d.c. voltage range)
Stopwatch
4 mm leads
Switch or switches
100 kΩ resistor
Unknown capacitor

The equation for the discharge of a capacitor is given by:

$$V = V_o e^{\left(-\frac{t}{RC}\right)}$$

where $V_o$ is the initial potential difference across the capacitor, $V$ is the potential difference across the capacitor, $C$, after a time $t$ and $R$ is the value of the resistor.

*(a)* (i) Draw a circuit diagram (or circuit diagrams) to show how you charge a capacitor and then discharge through the resistor $R$. [2]

*If you are unsure how to construct the circuit then ask your supervisor for information sheet 1(a). You will be deducted 2 marks for this.*

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| For supervisor's use only [Tick one box (✓)] | |
|---|---|
| Yes information sheet **needed** | |
| No information sheet **not** needed | |

Examiner only

(ii) Write a plan and describe how you would use your circuit to investigate the relationship between $V$, potential difference and $t$, time. [3]

*After designing the circuit, if you are still unsure how to proceed then ask your supervisor for information sheet 1(b). You will be deducted 2 marks for this.*

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| For supervisor's use only [Tick one box (✓)] | |
|---|---|
| Yes information sheet **needed** | |
| No information sheet **not** needed | |

*(b)* Set up your circuit. Before starting to take readings ask your supervisor to check your circuit. [1]

| For supervisor's use only [Tick one box (✓)] | |
|---|---|
| Help needed | |
| Help **not** needed | |

Examiner only

*(c)* Tabulate your results and include the resolution of the apparatus you have used. [4]

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*(d)* By taking logs re-arrange the equation $V = V_0 e^{\left(-\frac{t}{RC}\right)}$ into the form $y = mx + c$ and explain which graph should be plotted to determine $C$. [3]

*If you are unsure how to do this, ask your supervisor for information sheet 2. You will be deducted 3 marks for this.*

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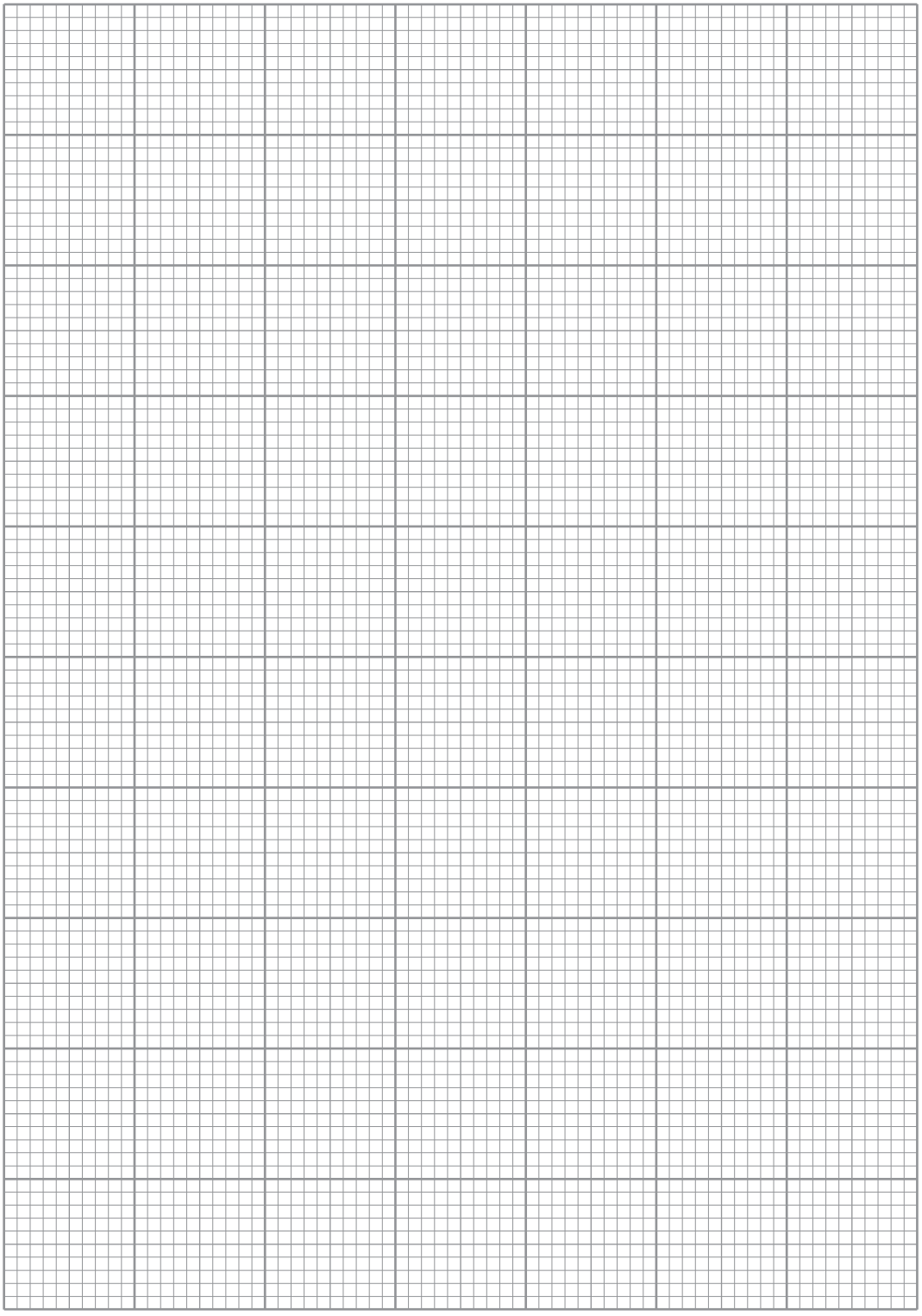
| For supervisor's use only [Tick one box (✓)] | |
|---|---|
| Yes information sheet **needed** | |
| No information sheet **not** needed | |

Examiner only

*(e)* Plot your data on a suitable graph. **Error bars are not required on the graph**. [5]



Examiner only

*(f)* (i) Determine the gradient of your graph. [1]

(ii) Hence determine a value for capacitance $C$ from your graph. You are not expected to calculate any uncertainty in $C$. [4]

*(g)* The manufacturers' value of the capacitance $C$ is 1000 μF and has a claimed tolerance of 5%. Comment on the value that you have obtained from the experimental data. [2]

## B. Specific Instructions

Details of the apparatus and materials required for the tests follow.

**If any difficulty is experienced in providing the apparatus, the WJEC should be informed as soon as possible.**

**Contacts: Subject Officer Gareth Kelly, 029 2026 5081, gareth.kelly@wjec.co.uk**
**Subject Support Officer Rhian Naish, 029 2026 5140, rhian.naish@wjec.co.uk**

**The numerical values for the various components are intended as a guide only and supervisors may use their discretion if these sizes are not readily available.**

### Apparatus Required

### Test 1

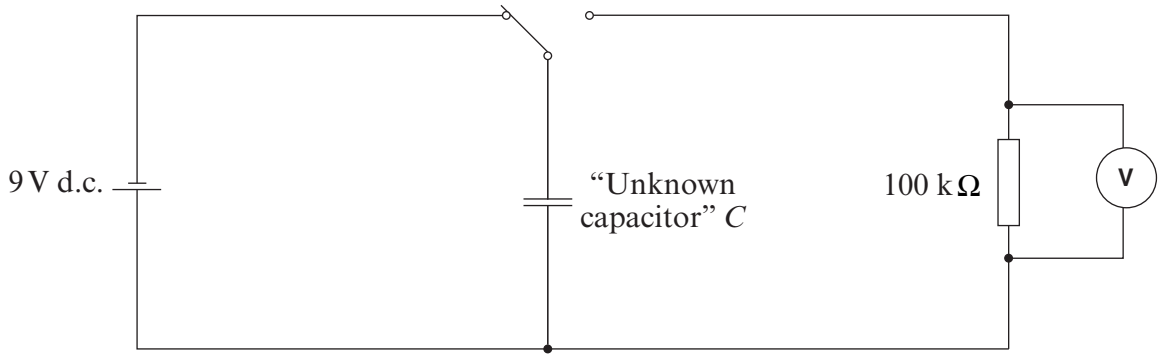
The candidates will be expected to investigate the decay of a capacitor through a resistor.

The following apparatus is required for each candidate:

- 9 V d.c. power supply
- D.C voltmeter [or digital multimeter set to a voltage range] – resolution ± 0.01 V
- Stopwatch – Resolution - either ±1 s or ±0.01 s
- 4 mm leads
- Two way switch or suitable switches
- 1000 µF capacitor, labelled "Unknown *C*" [e.g. Rapid Electronics – Order Code 11-2953]. The value of the capacitor should be concealed.
- 100 k Ω(*R*) Resistor [e.g. Rapid Electronics – Order Code 63-2426].



A possible circuit is as follows.



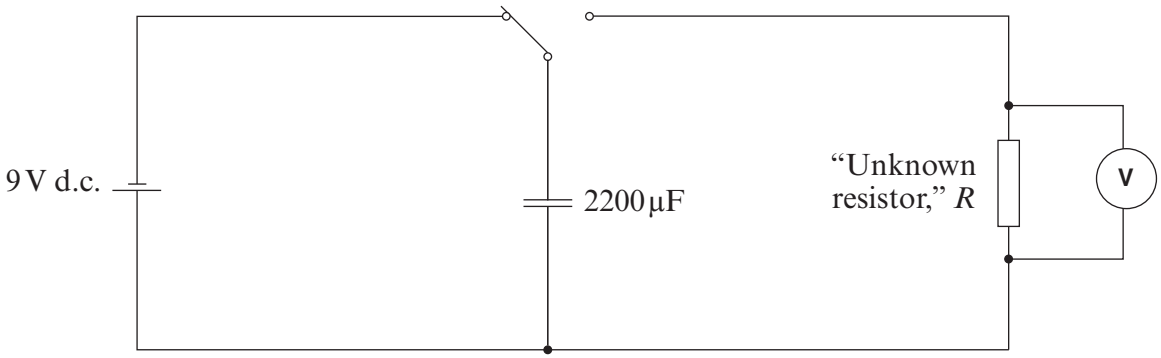

The apparatus should not be assembled for the candidates as this forms part of the task. The candidates will be expected to take pd and time readings.

**Test 2**

The apparatus is as for Test 1 except that:

- a 2200 μF capacitor is used [e.g. Rapid Electronics 11-2955]
- a 47 kΩ resistor is used [e.g. Rapid Electronics 63-2421]
- the capacitor should be labelled with its value
- the value of the resistor should be concealed.

A possible circuit is as follows.



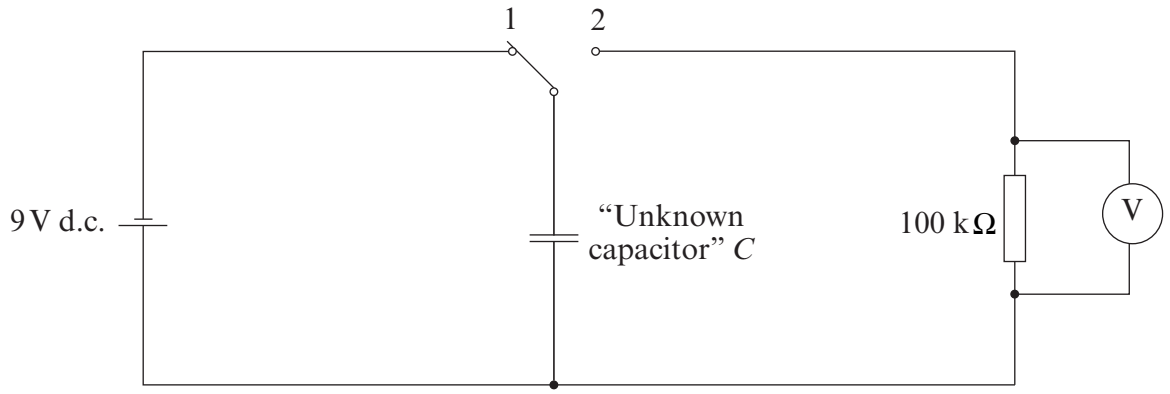
## INFORMATION SHEETS FOR TEST 1

**Sufficient copies of these information sheets should be made in advance.**

The **Information sheet 1(a)** required depends upon the apparatus available:
If candidates are to use a two way switch, the following information sheet is appropriate:

**INFORMATION SHEET 1(a):** **Test 1**

The circuit should be set up as follows:



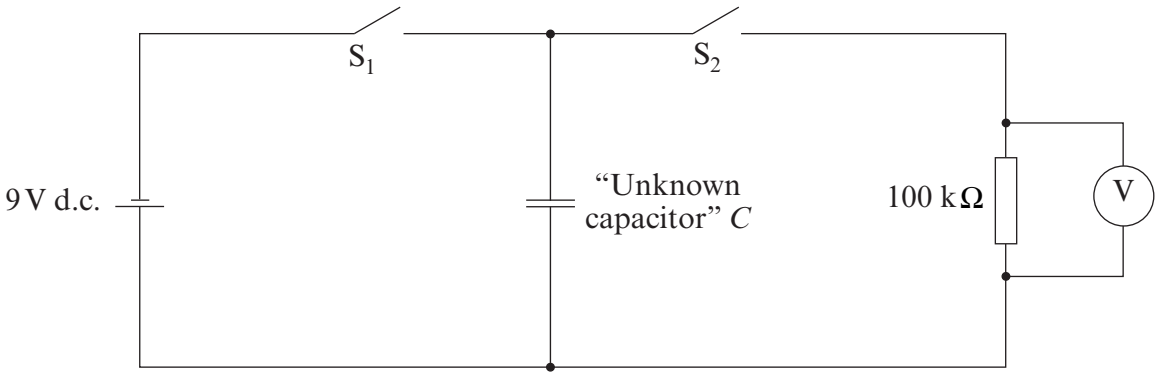

When the switch is in position 1, the capacitor charges. By switching to position 2, the capacitor discharges through the resistor.



If candidates are provided with two press-to-make switches, the following information sheet may be used:

**INFORMATION SHEET 1(a):** **Test 1**

The circuit should be set up as follows:

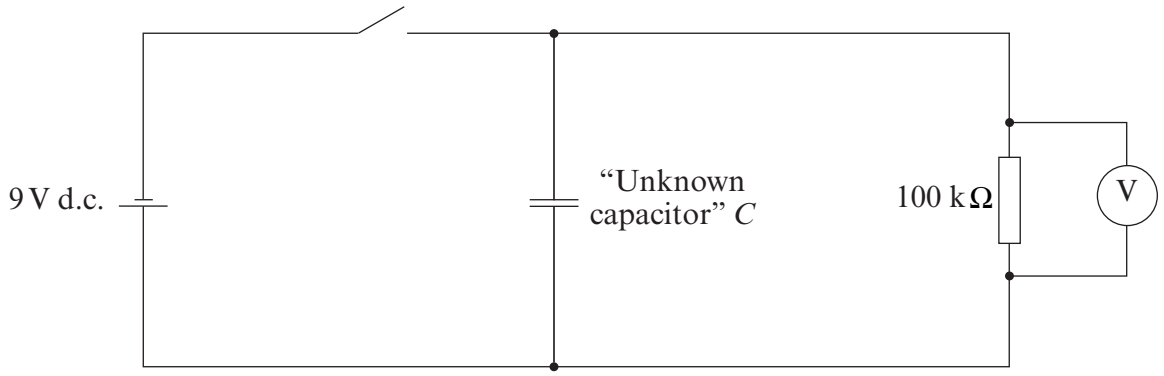



When switch $S_1$ is pressed, the capacitor charges. When $S_1$ is released and $S_2$ is pressed the capacitor discharges through the resistor

If candidates are provided with one press-to-make switch, the following information sheet may be used:

**INFORMATION SHEET 1(a):** **Test 1**

The circuit should be set up as follows:




When the switch is pressed, the capacitor charges up. When the switch is released, the capacitor discharges through the resistor.

**In the event that a different variant of Information Sheet 1(a) is required, centres should produce there own with the same level of information and provide a copy with the moderation sample.**

**INFORMATION SHEET 1(b):**

You need to measure the value of the p.d. across R at suitable time intervals and record your results in a table.

**INFORMATION SHEET 2.**

If we take logs [ln] of both sides of the equation

$$V = V_0 e^{\left(\frac{-t}{RC}\right)}$$

we get

$$\ln V = \ln V_0 - \frac{1}{RC} t$$

Compare this with

$$y = mx + c$$

the equation for a straight line graph.

You will need to plot a graph of ln $V$ on the $y$-axis against $t$ on the $x$-axis.

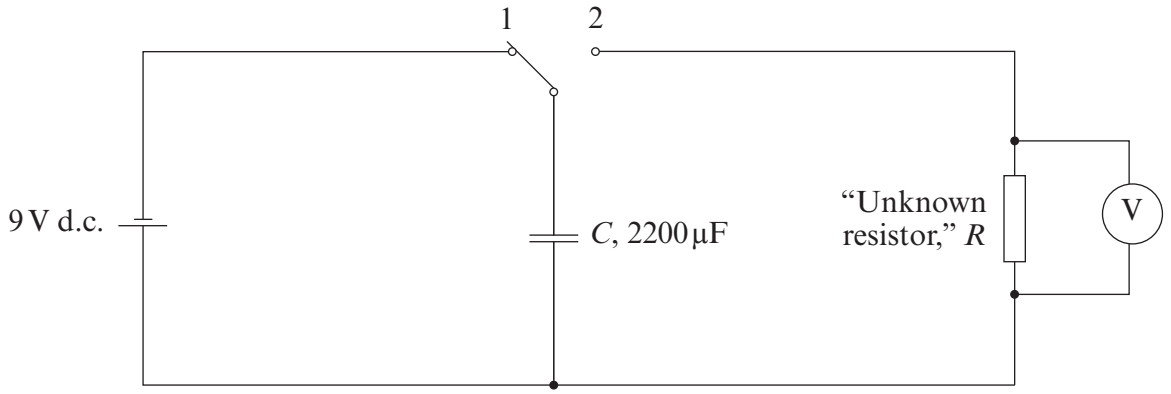
## INFORMATION SHEETS FOR TEST 2

**Sufficient copies of these information sheets should be made in advance.**

The **Information sheet 1(a)** required depends upon the apparatus available:
If candidates are to use a two way switch, the following information sheet is appropriate:

**INFORMATION SHEET 1(a):** **Test 2**

The circuit should be set up as follows:

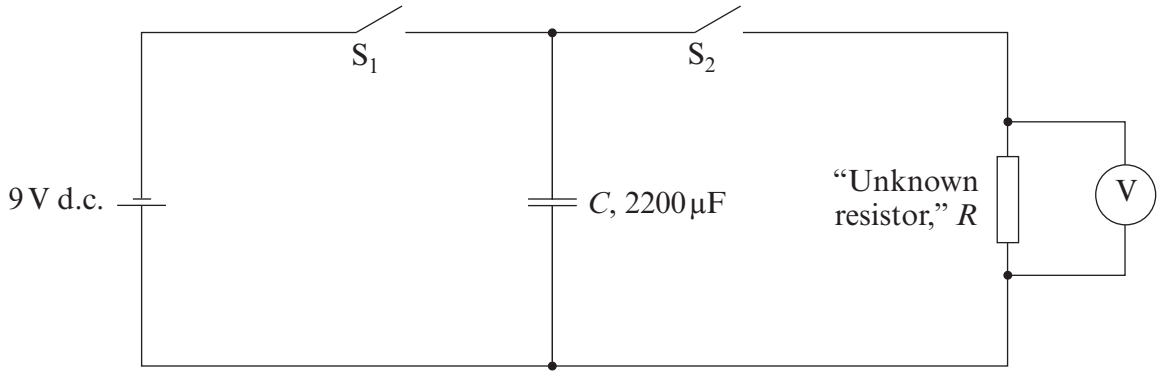



When the switch is in position 1, the capacitor is charging. By switching to position 2, the capacitor discharges through the resistor *R*.

If candidates are provided with two press-to-make switches, the following information sheet may be used:

**INFORMATION SHEET 1(a):** **Test 2**

The circuit should be set up as follows:

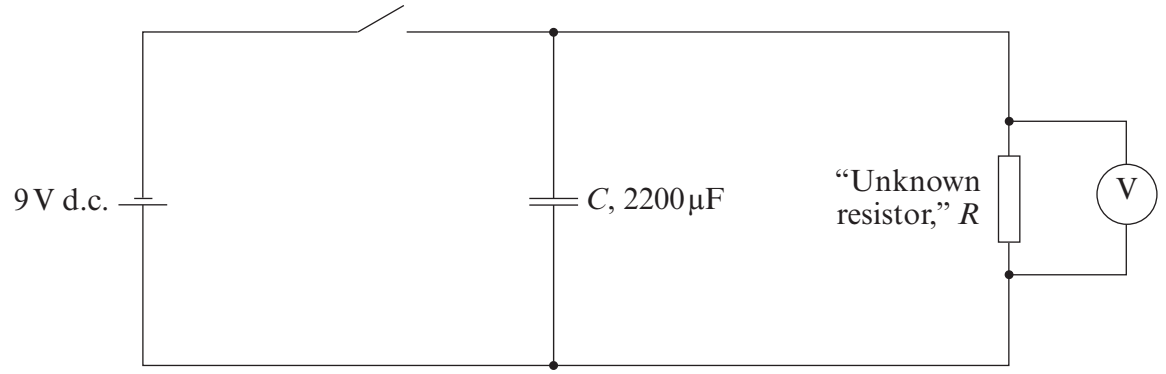



When switch $S_1$ is pressed, the capacitor charges. When $S_1$ is released and $S_2$ is pressed the capacitor discharges through the resistor

If candidates are provided with one press-to-make switch, the following information sheet may be used:

**INFORMATION SHEET 1(a):** **Test 2**

The circuit should be set up as follows:




When the switch is pressed, the capacitor charges up. When the switch is released, the capacitor discharges through the resistor.

**In the event that a different variant of Information Sheet 1(a) is required, centres should produce there own with the same level of information and provide a copy with the moderation sample.**

**Information sheets 1(b) and 2 are as for Test 1.**

# ASSESSMENT UNIT PH6B – EXPERIMENTAL TASK

## MARK SCHEME

## TEST 1

*(a)* (i) Correct diagram (2 marks with 1 mark penalty for incorrect symbols or incorrectly placed components) [see appropriate helper sheet 1*(a)*] [2]

(ii) Plan to charge and discharge the capacitor (1)
Plan to take at least 5 readings of voltage and time at equal intervals of voltage or time (1)
Repeat readings to be taken (1) [3]

*(b)* Circuit set up correctly [1]
[Assistance required → 0]

*(c)* Tabulation: Titles and units on all columns ($V$ and $t$) (1)
Repeat readings included and means calculated correctly (1)
Data given consistently to 3 sig figs (1)
Instrument resolution of stopwatch and voltmeter given (1) [4]

*(d)* Taking logs correctly (1)
Comparison with $y = mx + c$ (1)
Graph is ln $V$ against $t$ (1) [3]

*(e)* **Graph:** Graph of ln $V$ ($y$ – axis) against $t$ ($x$ – axis) plotted with axes labelled and correct units given (1)
Values of ln $V$ correctly calculated (allow $\log_{10} V$) (**anywhere in script**) (1)
Suitable scale chosen so that all data points occupy at least half the graph paper (1)
All points plotted correctly to within ± ½ division (1)
Line of best fit drawn (1)
[The first mark is not available for candidates who plot $V$ against $t$; the other marks are all available in principle] [5]

*(f)* (i) Gradient calculated correctly
[not available for candidates that have plotted $V$ against $t$] [1]

(ii) The value of the gradient, $m$, of the graph of ln $V$ against $t$ is [–] $\frac{1}{RC}$ (1)

Statement that $C = -\frac{1}{mR}$ (1)

[This mark also implies that the first mark can be given by implication]
$C$ calculated correctly (1)
$C$ given to 3 sig figs and correct unit [allow e.c.f. from a graph of $V$ against $t$ for 1 mark only] (1)
[NB For full marks there need to be a clear link between the graph and the calculated value of $C$] [4]

*(g)* [±] 50 μF stated (1)
Suitable comment on the comparison of candidates own value with the max/min values of $C$ (ecf on the maximum and minimum values of $C$ and value of $C$ from part *(f)*(ii)) (1)
[Alternatively – calculating % difference of own value from 1000 μF (1 mark)
Comparison with 5% (1 mark)] [2]