1. Fig. 20.3 shows a capacitor-resistor circuit.

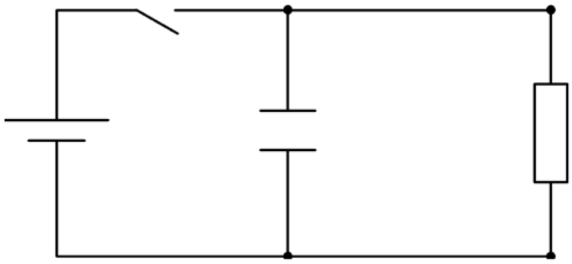

Fig. 20.3

Describe how the time constant of this circuit can be determined experimentally in the laboratory.

[3]

2. A student is carrying out an experiment in the laboratory to determine the capacitance C of a capacitor. Fig. 20.2 shows the circuit used by the student.

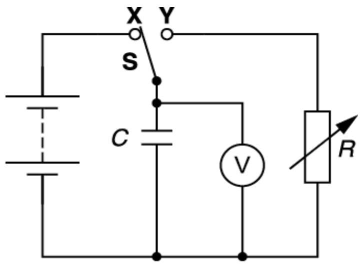

Fig. 20.2

The switch **S** is first connected to **X** to charge the capacitor. The switch is then moved to **Y** at time $t = 0$. The time T taken for the potential difference V across the capacitor to halve is determined for different values of resistance R.

i. Fig. 20.3 shows the graph of T against R as plotted by the student.

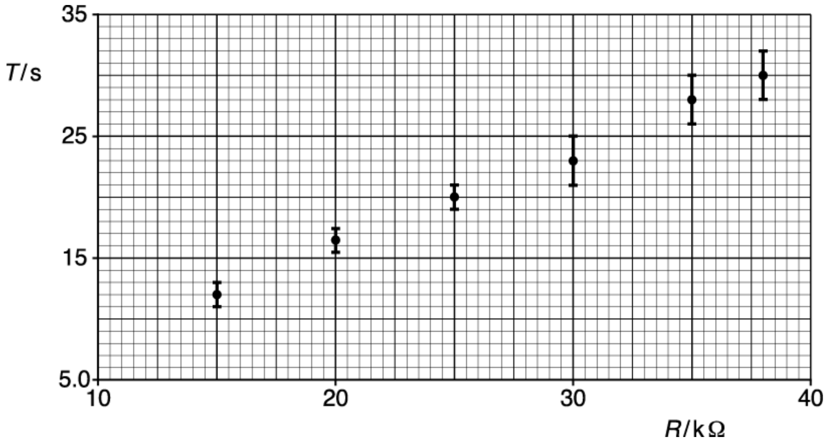

Fig. 20.3

1 Draw a straight line of best fit.

[1]

2 Use $V = V_0 e^{-t/CR}$ to show that $T = -\ln(0.5)CR$.

[2]

3 Determine a value for the capacitance *C*.

C = ... F **[3]**

ii. Describe, without doing any calculations, how you can use Fig. 20.3 to determine the percentage uncertainty in *C*.

---

[2]

3. This question is about investigating the charging and discharging of capacitors.

Two students are given the circuit shown in Fig. 6.1. It consists of two resistors and two uncharged capacitors, a 10 V supply and a two-way switch **S**.

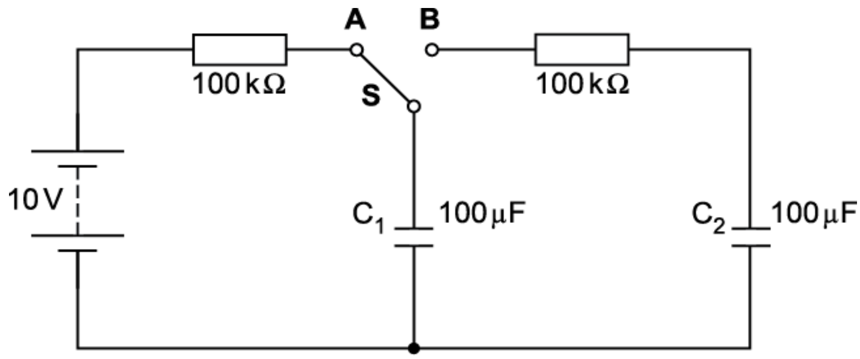

Fig. 6.1

The first student is asked to investigate the charging of the capacitor C_1 when **S** is connected to **A**. She selects an ammeter of range 0 to 100 μA reading to 2 μA and a stopwatch reading to 0.1 s.

Discuss whether she has made a sensible choice of equipment for this experiment.

....

....

....

....

....

....

....

.... **[4]**

4(a). A student is investigating how the discharge of a capacitor through a resistor depends on the resistance of the resistor.
The equipment is set up as shown in Fig. 3.1.

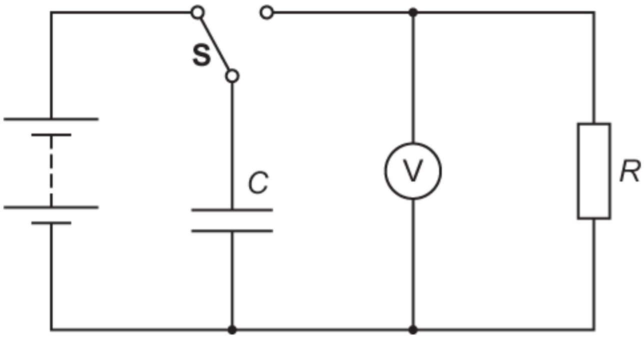

Fig. 3.1

The student charges the capacitor of capacitance *C* and then discharges it through a resistor of resistance *R* using switch **S**. After a time t = 15.0 s the student records the potential difference *V* across the capacitor. The student repeats this procedure for different values of *R*.

It is suggested that *V* and *R* are related by the equation

$$V = V_0 e^{-\frac{t}{CR}}$$

where V_0 is the initial potential difference across the capacitor and t is the time over which the capacitor has discharged.

The student decides to plot a graph of ln (V / V) on the y-axis against $\frac{1}{R}$ on the x-axis to obtain a straight line graph. Show that the magnitude of the gradient is equal to $\frac{15}{C}$.

[2]

(b). Values of *R* and *V* at *t* = 15.0 s are given in the table below.

R / kΩ	*V* / V	$\left(\frac{1}{R}\right)$ / 10^{-6} Ω^{-1}	ln (*V* / V)
56	3.0 ± 0.2	18	
68	3.7 ± 0.2	15	1.31 ± 0.06
100	5.0 ± 0.2	10	1.61 ± 0.04
150	6.4 ± 0.2	6.7	1.86 ± 0.03
220	7.3 ± 0.2	4.5	1.99 ± 0.03
330	8.1 ± 0.2	3.0	2.09 ± 0.03

i. Complete the missing value of ln (*V* / V) and its absolute uncertainty in the table above. **[1]**

ii. Use the data to complete the graph of Fig. 3.2. Four of the six points have been plotted for you. **[2]**

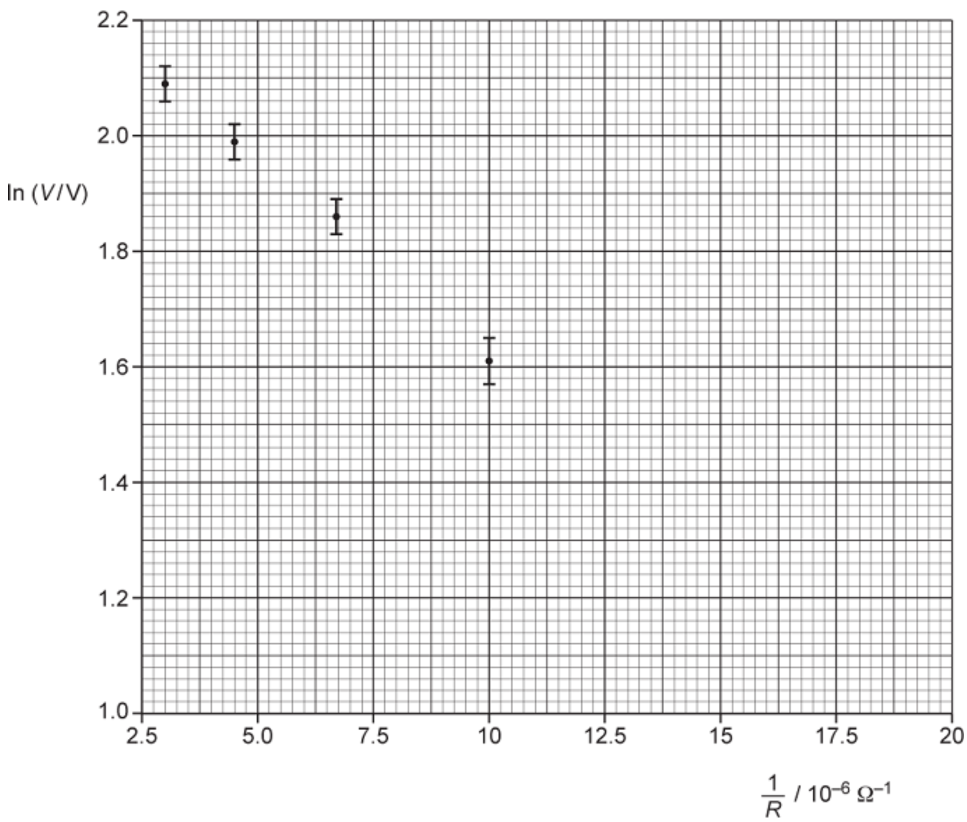

Fig. 3.2

iii. Use the graph to determine a value for *C*. Include the absolute uncertainty and an appropriate unit in your answer.

C =..................± .... unit .... **[4]**

(c). Determine the value of *R*, in kΩ, for which the capacitor discharges to 10% of its original potential difference in 15.0 s. Show your working.

R = ... kΩ **[2]**

5. A student wishes to determine the permittivity *ε* of paper using a capacitor made in the laboratory.

The capacitor consists of two large parallel aluminium plates separated by a very thin sheet of paper.

The capacitor is initially charged to a potential difference V_0 using a battery. The capacitor is then discharged through a fixed resistor of resistance 1.0 MΩ.

The potential difference *V* across the capacitor after a time *t* is recorded by a data-logger. The student uses the data to draw the ln*V* against *t* graph shown in Fig. 22.

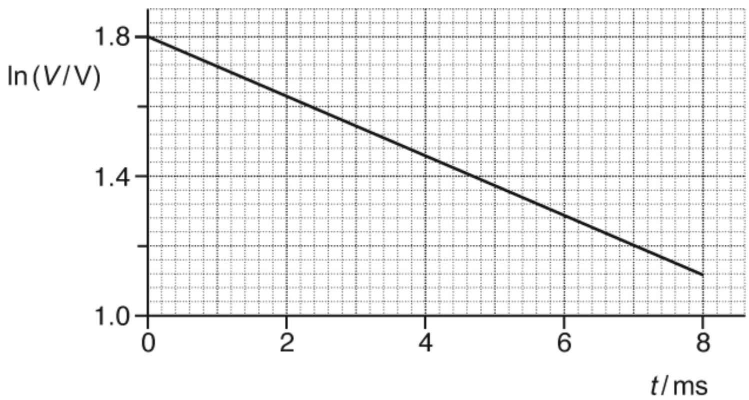

Fig. 22

Use Fig. 22 to determine the capacitance *C* of the capacitor. Describe how the student can then use this value of *C* to determine a value for *ε*.
In your description, mention any additional measurements required on the capacitor.

[6]

6. A student sets up the circuit shown in Fig. 9.1 with an old capacitor.

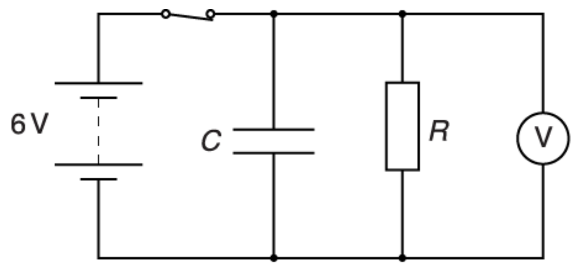

Fig. 9.1

The p.d. across the capacitor in the circuit is measured after the switch has been opened. The results are shown in the graph of Fig. 9.2.

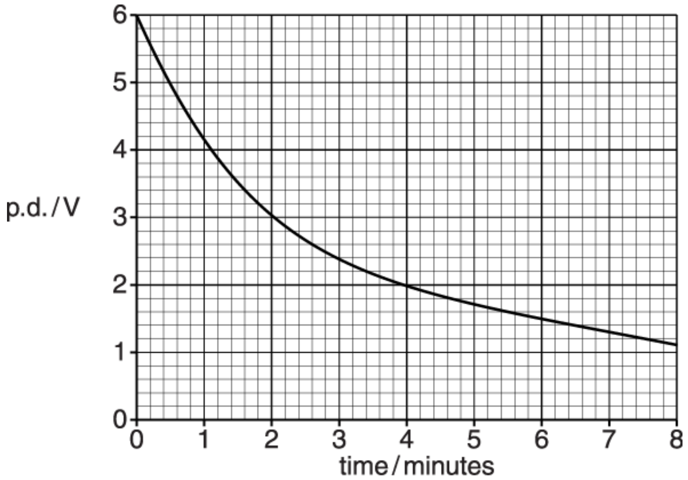

Fig. 9.2

The student expects the graph to show exponential decay, but it does not.
Use data from the graph to show that the graph does **not** show exponential decay.

[2]

END OF QUESTION PAPER

Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1			Connect a voltmeter or data-logger or oscilloscope across the resistor (or capacitor) or an ammeter in series with the resistor.	B1	
			A stopwatch is started when the switch is opened and stopped when the p.d. or the current to decreases to 37% of its initial value.	B1	
			The time constant is the time taken for the p.d. or the current to decreases to 37% of its initial value.	B1	
			Total	**3**	
2		i	**1** A straight line of best-fit drawn passing through all error bars.	B1	
			2 $V = V_0e^{-t/CR}$, therefore $½ = e^{-T/CR}$	M1	
			$\ln(0.5) = -T/CR$	M1	
			$T = -\ln(0.5)CR$	A0	
			3 gradient = $(-)\ \ln(0.5)C$	C1	
			gradient determined using a 'large triangle' and equal to $(-)\ 7.7 \times 10^{-4}$ (s Ω^{-1})	C1	**Allow** gradient in the range 7.5 to 8.0×10^{-4}
			C = gradient/ln(0.5) = $(-)\ 7.7 \times 10^{-4}/\ln(0.5)$ $C = 1.1 \times 10^{-3}$ (F)	A1	Possible ECF from value of gradient
		ii	Draw a worst-fit straight line through the error bars.	M1	

			Correct description of how to determine the % uncertainty in *C*.	A1	**Allow**: $\frac{\text{difference between worst and best - fit gradients}}{\text{value of best gradient from } \textbf{(i)3}} \times 100$
			Total	**8**	
3			Time constant of charging = 10 s	B1	**allow** alternative but equivalent statements
			maximum current = 10/100k = 100 μA	B1	**e.g.** current falls to 37 mA in 10 s
			statements about adequate sensitivity of meter and stopwatch	B1 B1	**e.g.** readings can be taken every 3 to 5 s so can collect at least 8 sets of values before approaching change of less than 2 μA; sensitivity of 0.5 s adequate
			Total	**4**	
4	a		Take In to give In$V = -(t / C).1/R$ + In V_0 gradient (m) = (−) t / C where t = 15	M1 A1	**allow** In $(V / V_0) = -(t / C).1/R$
	b	i	1.10 ± 0.07	B1	value plus uncertainty required for the mark
		ii	two points plotted correctly to within ½ small square on x-axis; line of best fit	B1 B1	**ignore** accuracy of length of error bar; **ecf bi** value **or both** worst acceptable lines drawn
		iii	gradient (= 15/C) = 6.6 (× 10^4); C = 15 / 6.6 × 10^4 = 2.3 × 10^{-4} (F) worst acceptable straight line drawn (C) ± 0.3 × 10^{-4} F	C1 A1 B1 B1	**accept** 6.4 to 6.8 **ignore** power of 10 **accept** 2.3 ± 0.1 × 10^{-4} **allow ecf** for the point calculated incorrectly in **b(ii);** steepest or shallowest possible line that passes through all the error bars; should pass from top of top error bar to bottom of bottom error bar **or** bottom of top error bar to top of bottom error bar **allow** e.g. (C) ± 0.2 × 10^{-4}; **allow** value of C to 4 SF **but N.B.** the uncertainty and the value of C **must be** to the same number of decimal places **allow** 230 ± 30 μF etc **allow** equivalent unit including s Ω^{-1}, C V^{-1}, A s V^{-1}

	c		ln(0.1) = −15/RC **or** R = −15/C ln(0.1) **or** R = 0.65/C R = 0.65/2.3 × 10^{-4} giving R = 28 kΩ	C1 A1	ln(0.1) = −2.30 **ecf (b)(iii)**
			Total	**11**	
5			**Level 3 (5–6 marks)** Clear description **and** correct value of *C* *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Clear description **and** some correct working **OR** Some description **and** correct value for *C* *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Some description **OR** Some working *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit	B1 × 6	**Indicative scientific points may include:** **Description** • $C = \varepsilon A/d$ • *A* = area (of overlap) and *d* = separation. • Use ruler to measure the side / radius / diameter (andhence the area *A*) • Ensure total overlap of plates. • Measure the thickness / *d* of paper using micrometer /(vernier) caliper. • Take several readings of thickness and determine anaverage value for *d* **Calculation of capacitance** • gradient ≈ 85 • C ≈ 1.2 × 10^{-8} (F)
			Total	**6**	
6			A correct test clearly stated for [1];	1	e.g., ...

			Note: This could be implied in the comments made e.g., calculations for two gradients at two stated voltages, is followed by ... *the* $\frac{gradient}{voltage}$ *is NOT a constant value*.		• an exponential then should have a constant half-life (of 0.7*RC*); • The ratio of voltages in equal time intervals should be the same. • $\frac{\Delta Ln(V)}{\Delta t} = const$ • A plot of Ln(V) vs *t* would be a straight line. • • $\frac{gradient\ of\ curve}{voltage} = const$ • Correct use of $V = V_0 e^{-t/RC}$
			Evidence from graph that it isn't [1] e.g. 6 V to 3 V in 2 minutes, but 3 V to 1.5 V in 4 minutes;	1	There should be a minimum of two data points from the graph. An incorrect test would not allow this second mark to be obtained. Candidate must not simply state two pieces of data.
			Total	**2**	