1 (a) (i) Describe how you would make a direct measurement of the emf ε of a cell, stating the type of meter you would use.

___

___

(1)

(ii) Explain why this meter must have a very high resistance.

___

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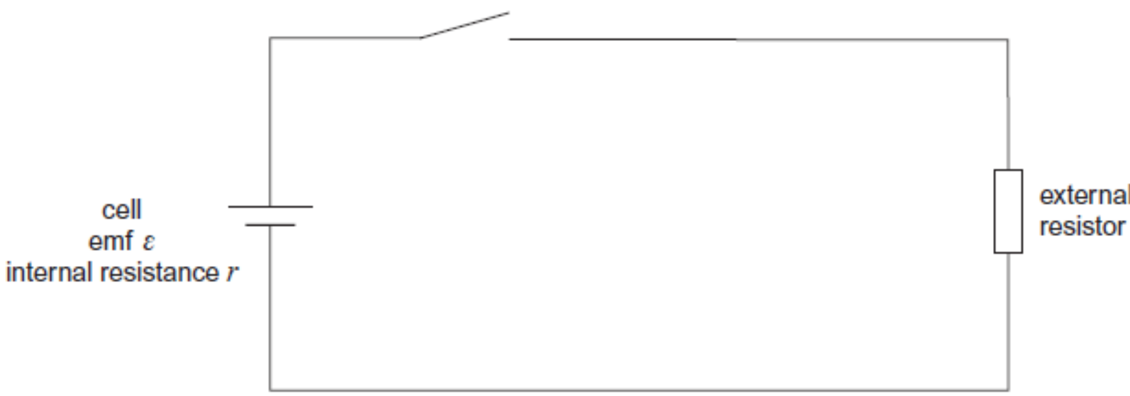
(1)

(b) A student is provided with the circuit shown in the diagram below.



The student wishes to determine the efficiency of this circuit.

In this circuit, useful power is dissipated in the external resistor. The total power input is the power produced by the battery.

$$\text{Efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

The efficiency can be determined using two readings from a voltmeter.

(i) Show that the efficiency = $\frac{V}{\varepsilon}$ where ε is the emf of the cell

and V is the potential difference across the external resistor.

(1)

(ii) Add a voltmeter to the diagram and explain how you would use this new circuit to take readings of ε and V.

(2)

(c) Describe how you would obtain a set of readings to investigate the relationship between efficiency and the resistance of the external resistor. State any precautions you would take to ensure your readings were reliable.

(2)

(d) State and explain how you would expect the efficiency to vary as the value of R is increased.

(2)
(Total 9 marks)

2 A student has a diffraction grating that is marked 3.5×10^3 lines per m.

(a) Calculate the percentage uncertainty in the number of lines per metre suggested by this marking.

percentage uncertainty = ____________________ %

(1)

(b) Determine the grating spacing.

grating spacing = ____________________ mm

(2)

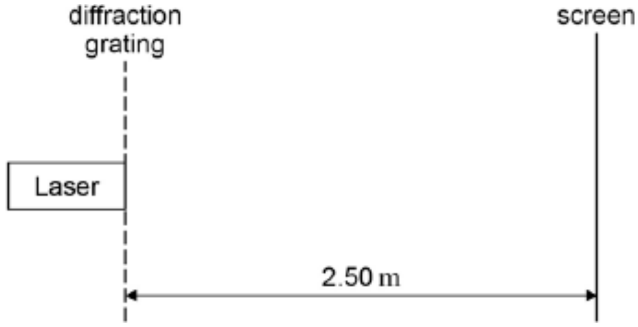
(c) State the absolute uncertainty in the value of the spacing.

absolute uncertainty = ____________________ mm

(1)

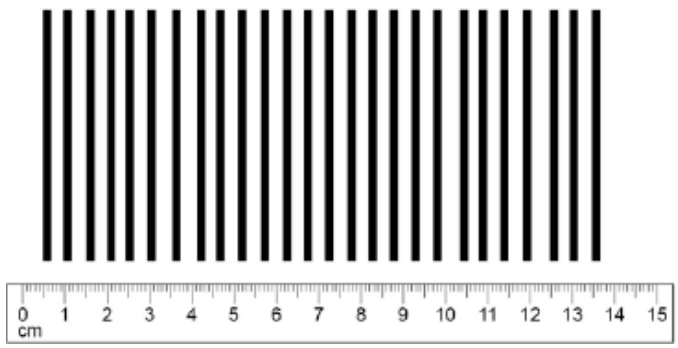
(d) The student sets up the apparatus shown in **Figure 1** in an experiment to confirm the value marked on the diffraction grating.

Figure 1



The laser has a wavelength of 628 nm. **Figure 2** shows part of the interference pattern that appears on the screen. A ruler gives the scale.

Figure 2



Use **Figure 2** to determine the spacing between two adjacent maxima in the interference pattern. Show all your working clearly.

spacing = ____________________ mm

(1)

(e) Calculate the number of lines per metre on the grating.

number of lines = ____________________

(2)

(f) State and explain whether the value for the number of lines per m obtained in part (e) is in agreement with the value stated on the grating.

____

____

____

(2)

(g) State **one** safety precaution that you would take if you were to carry out the experiment that was performed by the student.

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(1)

(Total 10 marks)

3

Data analysis question

Capillary action can cause a liquid to rise up a hollow tube. **Figure 1** shows water that has risen to a height h in a narrow glass tube because of capillary action.

Figure 1

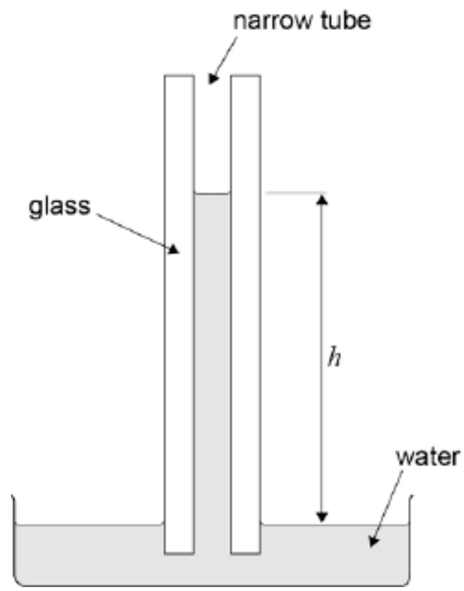
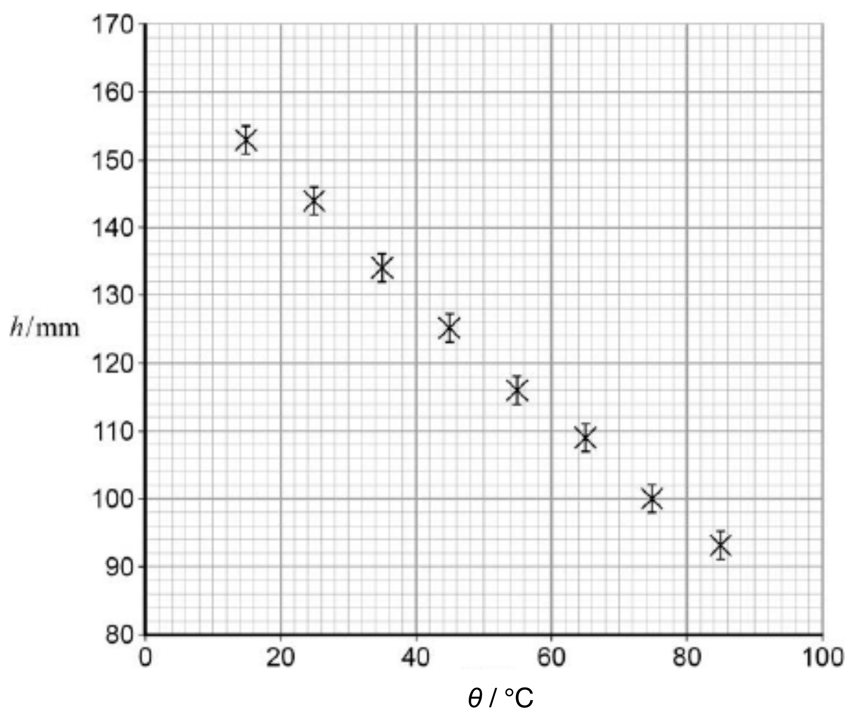


Figure 2 shows the variation of h with temperature θ for this particular tube.

Figure 2



The uncertainty in the measurement of h is shown by the error bars. Uncertainties in the measurements of temperature are negligible.

(a) Draw a best-fit straight line for these data **(Figure 2)**.

(1)

(b) It is suggested that the relationship between h and θ is

$$h = h_0 - (h_0 k)\theta$$

where h_0 and k are constants.
Determine h_0.

h_0 = = ______________________ mm

(1)

(c) Show that the value of h_0k is about 0.9 mm K^{-1}.

(3)

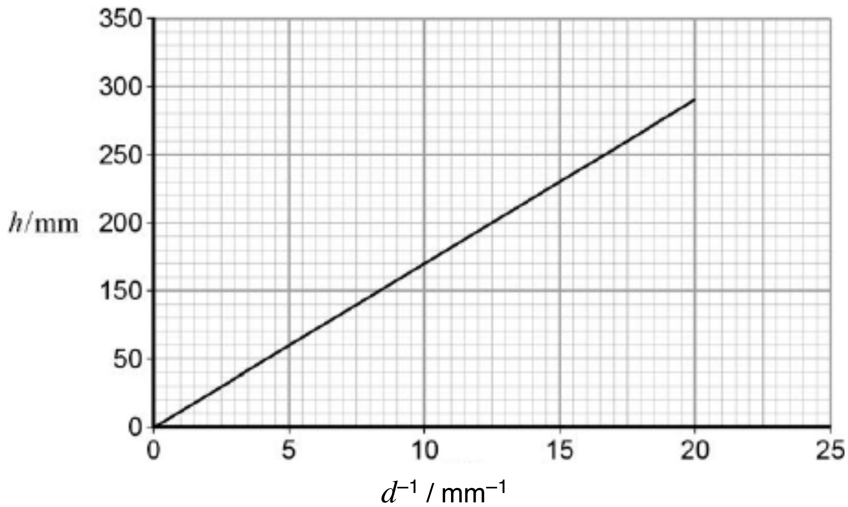
(d) Determine k. State a unit for your answer.

k = ______________________ unit = ___________

(2)

(e) A similar experiment is carried out at constant temperature with tubes of varying internal diameter d. **Figure 3** shows the variation of h with $\frac{1}{d}$ at a constant temperature.

Figure 3



It is suggested that capillary action moves water from the roots of a tree to its leaves.

The gradient of **Figure 3** is 14.5 mm^2.

The distance from the roots to the top leaves of the tree is 8.0 m.

Calculate the internal diameter of the tubes required to move water from the roots to the top leaves by capillary action.

(2)

(f) Comment on the accuracy of your answer for the internal tube diameter in part (v).

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(1)
(Total 10 marks)

4 **Figure 1** shows an arrangement used to investigate double slit interference using microwaves. **Figure 2** shows the view from above.

Figure 1

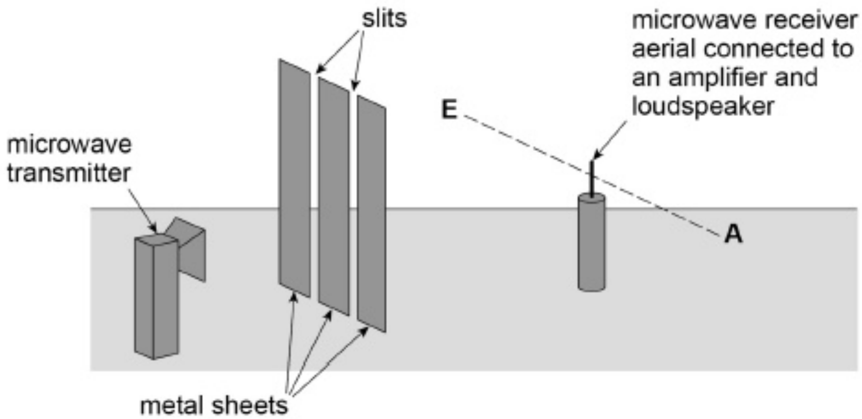
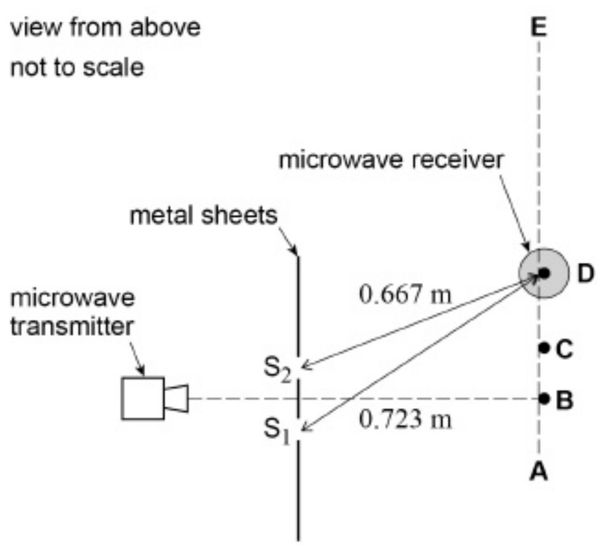


Figure 2



The microwaves from the transmitter are polarised. These waves are detected by the aerial in the microwave receiver (probe). The aerial is a vertical metal rod.

The receiver is moved along the dotted line **AE**. As it is moved, maximum and minimum signals are detected. Maximum signals are first detected at points **B** and **C**. The next maximum signal is detected at the position **D** shown in **Figure 2**.

Figure 2 shows the distances between each of the two slits, S_1 and S_2, and the microwave receiver when the aerial is in position **D**.
S_1D is 0.723 m and S_2D is 0.667 m.

(a) Explain why the signal strength falls to a minimum between **B** and **C**, and between **C** and **D**.

(3)

(b) Determine the frequency of the microwaves that are transmitted.

frequency = ______________________________ Hz

(3)

(c) The intensity of the waves passing through each slit is the same.

Explain why the minimum intensity between **C** and **D** is not zero.

(2)

(d) The vertical aerial is placed at position **B** and is rotated slowly through 90° until it lies along the direction **AE**.

State and explain the effect on the signal strength as it is rotated.

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(3)

(Total 11 marks)

5 A student performs an experiment to find the acceleration due to gravity. The student measures the time t for a spherical object to fall freely through measured vertical distances s. The time is measured electronically. The results are shown in the table below.

s/**m**	t_1/s	t_2/s	t_3/s	**mean time** t_m/s	t_m^2/s^2
0.300	0.245	0.246	0.244	0.245	0.0600
0.400	0.285	0.286	0.286	0.286	0.0818
0.500	0.319	0.321	0.318	0.319	0.102
0.600	0.349	0.351	0.348	0.349	0.122
0.700	0.378	0.380	0.378	0.379	0.144
0.800	0.403	0.406	0.404		
0.900	0.428	0.428	0.430		

(a) Complete the table by entering the missing values for t_m and t_m^2

(1)

(b) Complete the graph below by plotting the remaining two points and draw a line of best fit.

(2)

(c) Determine the gradient of the graph.

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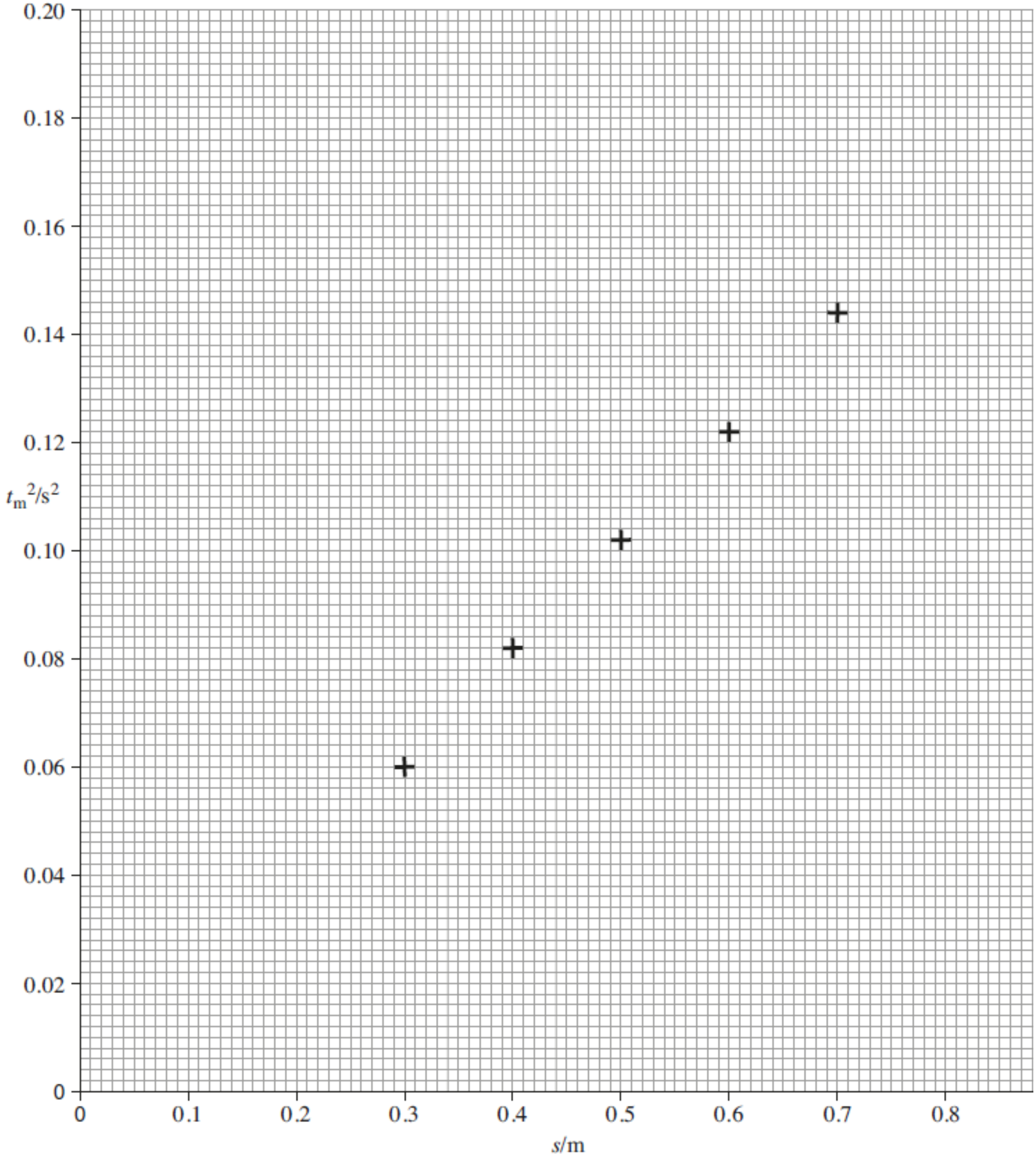
(3)


0.20
0.18
0.16
0.14
0.12
$t_m{}^2/s^2$
0.10
0.08
0.06
0.04
0.02
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
s/m

(d) Theory suggests that the equation for the line is $t^2 = \frac{2s}{g}$ where g is the acceleration due to gravity.

Calculate a value for g using the above equation and the gradient of your graph above.

(1)

(e) Calculate the percentage difference between your value for g and the accepted value of 9.81 m s $^{-2}$.

(1)

(f) Calculate the uncertainty in the smallest value of t_m.

(1)

(g) Calculate the value of g which would be given from the smallest value of t_m and the corresponding value of s.

(3)

(h) The uncertainty in each value of s is ± 0.001 m.

Calculate the uncertainty in the value of g you calculated in part **(g)**.

You will need to use the uncertainty for t_m you calculated in part **(f)**.

(3)

(i) A student wishes to investigate the effect of changing the mass of the spherical object on the acceleration of free fall.

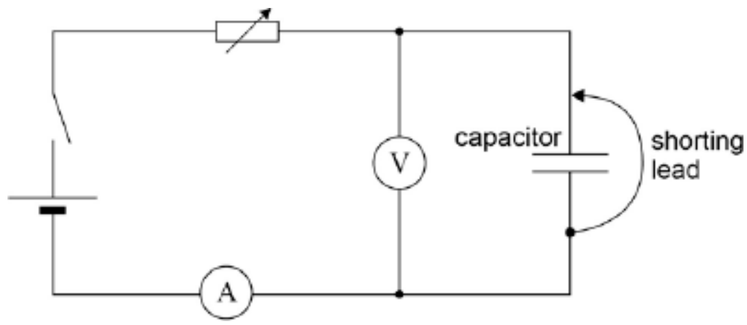
Explain how you would modify the experiment seen at the start of this question.

(3)

(Total 18 marks)

6 This question is about capacitor charging and discharging.

A student designs an experiment to charge a capacitor using a constant current. The figure below shows the circuit the student designed to allow charge to flow onto a capacitor that has been initially discharged.



The student begins the experiment with the shorting lead connected across the capacitor as in the figure above. The variable resistor is then adjusted to give a suitable ammeter reading. The shorting lead is removed so that the capacitor begins to charge. At the same instant, the stop clock is started.

The student intends to measure the potential difference (pd) across the capacitor at 10 s intervals while adjusting the variable resistor to keep the charging current constant.

The power supply has an emf of 6.0 V and negligible internal resistance. The capacitor has a capacitance of 680 μF. The variable resistor has a maximum resistance of 100 kΩ.

(a) The student chooses a digital voltmeter for the experiment. A digital voltmeter has a very high resistance.

Explain why it is important to use a voltmeter with very high resistance.

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(1)

(b) Suggest **one** advantage of using an analogue ammeter rather than a digital ammeter for this experiment.

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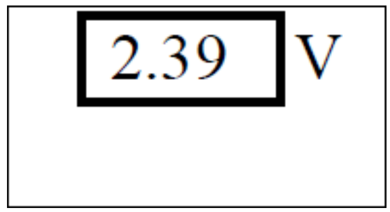
(1)

(c) Suggest a suitable full scale deflection for an analogue ammeter to be used in the experiment.

full scale deflection = ____________________

(2)

(d) The diagram shows the reading on the voltmeter at one instant during the experiment. The manufacturer gives the uncertainty in the meter reading as 2%.



Calculate the absolute uncertainty in this reading.

uncertainty = ____________________ V

(1)

(e) Determine the number of different readings the student will be able to take before the capacitor becomes fully charged.

number = ____________________

(3)

(f) The experiment is performed with a capacitor of nominal value 680 μF and a manufacturing tolerance of ± 5 %. In this experiment the charging current is maintained at 65 μA. The data from the experiment produces a straight-line graph for the variation of pd with time. This shows that the pd across the capacitor increases at a rate of 98 mV s^{-1}.

Calculate the capacitance of the capacitor.

capacitance = ____________________ μF

(2)

(g) Deduce whether the capacitor is within the manufacturer's tolerance.

____

____

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(1)

(h) The student decides to confirm the value of the capacitance by first determining the time constant of the circuit when the capacitor **discharges** through a **fixed** resistor.

Describe an experiment to do this. Include in your answer:

- a circuit diagram
- an outline of a procedure
- an explanation of how you would use the data to determine the time constant.

(4)

(Total 15 marks)