AQA

SPECIMEN MATERIAL

A-level
PHYSICS
(7408/3A)

Paper 3 – Section A

Specimen 2014 Morning Time allowed: 2 hours

Materials
For this paper you must have:
- a pencil
- a ruler
- a calculator
- a data and formulae booklet
- a question paper / answer book for section B.

Instructions
- Answer **all** questions.
- Show all your working.
- The total time for both sections of this paper is 2 hours.

Information
- The maximum mark for this section is 45.

Please write clearly, in block capitals, to allow character computer recognition.

Centre number Candidate number

Surname

Forename(s)

Candidate signature

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ANSWER IN THE SPACES PROVIDED

Section A

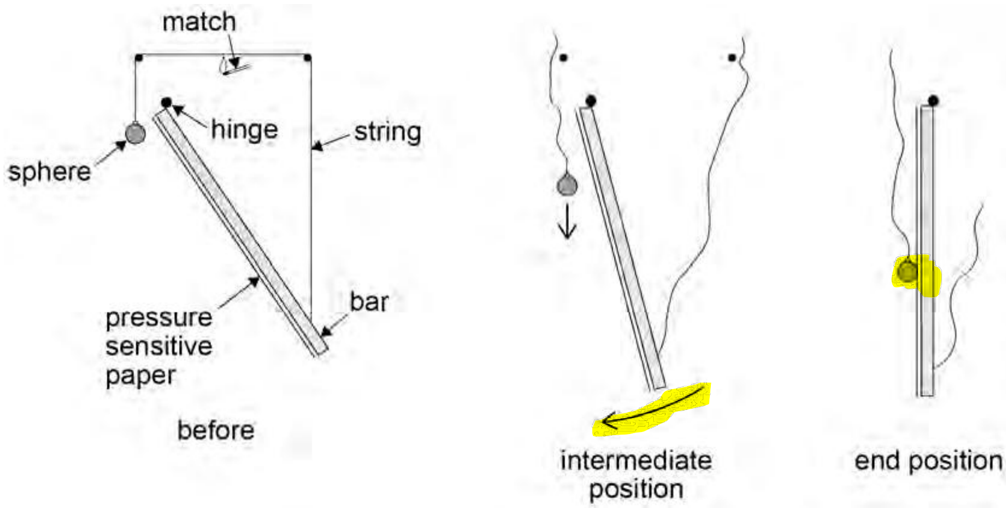
Answer **all** question(s) in this section.

0 1 This question is about measuring the acceleration of free fall g.

A student undertakes an experiment to measure the acceleration of free fall.

Figure 1 shows a steel sphere attached by a string to a steel bar. The bar is hinged at the top and acts as a pendulum. When the string is burnt through with a match, the sphere falls vertically from rest and the bar swings clockwise. As the bar reaches the vertical position, the sphere hits it and makes a mark on a sheet of pressure-sensitive paper that is attached to the bar.

Figure 1



The student needs to measure the distance d fallen by the sphere in the time t taken for the bar to reach the vertical position.

To measure d the student marks the initial position of the sphere on the paper. The student then measures the distance between the initial mark and the mark made by the sphere after falling.

To measure t the student sets the bar swinging without the string attached and determines the time for the bar to swing through 10 small-angle oscillations.

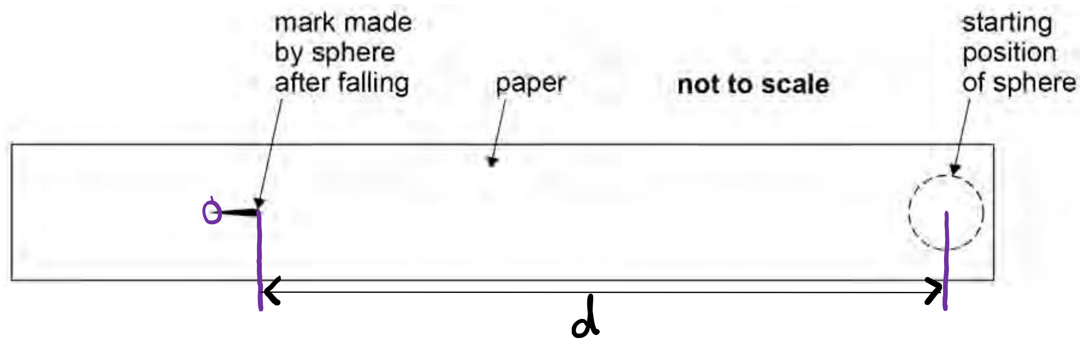
Question 1 continues on the next page

0 1 . 1 **Figure 2** shows the strip of paper after it has been removed from the bar. The initial position of the sphere and the final mark are shown.

Mark on **Figure 2** the distance that the student should measure in order to determine d.

[1 mark]

Figure 2



0 1 . 2 The student repeats the procedure several times.

Data for the experiment is shown in **Table 1**.

Table 1

d / m
0.752
0.758
0.746
0.701
0.772
0.769

$$\frac{0.752+0.758+0.746+0.772+0.769}{5}$$

$= 0.759$ m

Time for bar to swing through 10 oscillations as measured by a stop clock = 15.7 s

Calculate the time for one oscillation and hence the time t for the bar to reach the vertical position.

[1 mark]

$$\frac{15.7}{10} = 1.57\text{ s}$$

$$\frac{1.57}{4} = 0.3925\text{ s}$$

$\simeq 0.393$ s

time 0.393 s

0 1 . 3 Determine the percentage uncertainty in the time t suggested by the precision of the recorded data.

[2 marks]

15.7s absolute uncertainty = 0.1s

$\frac{0.1}{15.7} = 0.00637 = 0.64\%$ ✓, this is the same as that for the time for the bar to fall ✓

uncertainty = 0.64 %

0 1 . 4 Use the data from **Table 1** to calculate a value for d.

[2 marks]

Exclude 0.701m as anomalous ✓

Mean = 0.759m ✓

d = 0.759 m

0 1 . 5 Calculate the absolute uncertainty in your value of d.

[1 mark]

0.772 − 0.746
= 0.026m

Absolute uncertainty = 0.013m

uncertainty = 0.013 m

0 1 . 6 Determine a value for g and the absolute uncertainty in g.

[3 marks]

When raising a value to a power, its % uncertainty must be multiplied by that power.

$s = ut + \frac{1}{2}at^2 = \frac{1}{2}at^2 \Rightarrow a = \frac{2s}{t^2} = \frac{2(0.759)}{0.393^2} = 9.83ms^{-2}$

(s: displacement, u: initial velocity, a: acceleration, t: time)

$\frac{0.013}{0.759} = 0.017 = 1.7\%$ ✓

$1.7 + (2 \times 0.64) = 3.0\%$

$0.03 \times 9.83 = 0.30ms^{-2}$ ($g = 10.0 \pm 0.3\ ms^{-2}$)

g = $9.83ms^{-2}$ ✓ m s^{-2}

uncertainty = 0.30 ✓ m s^{-2}

0 1 . 7 Discuss **one** change that could be made to reduce the uncertainty in the experiment.

[2 marks]

Change ✓	Use a pointed mass	Larger number of swings	Longer/heavier bar
Reason ✓	Uncertainty is most affected by measurement of d	% uncertainty is reduced (even though absolute uncertainty is constant)	% uncertainty is reduced, as time measurement is larger

0 1 . 8 The student modifies the experiment by progressively shortening the bar so that the time for an oscillation becomes shorter. The student collects data of distance fallen s and corresponding times t over a range of times.

Suggest, giving a clear explanation, how these data should be analysed to obtain a value for g.

[3 marks]

$s = \frac{1}{2}at^2$

Plot a graph of s against t^2 ✓

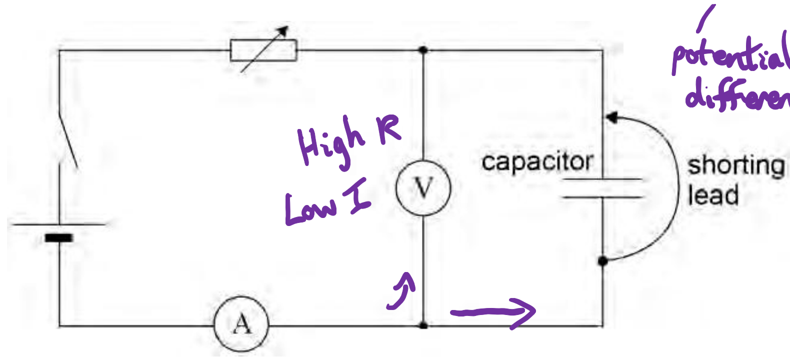
Find gradient of graph ✓

Gradient $= \frac{1}{2}a = \frac{1}{2}g$ ✓

0 2 This question is about capacitor charging and discharging.

A student designs an experiment to charge a capacitor using a constant current. **Figure 3** shows the circuit the student designed to allow charge to flow onto a capacitor that has been initially discharged.

Figure 3



The student begins the experiment with the shorting lead connected across the capacitor as in **Figure 3**. 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.

0 2 . 1 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.

[1 mark]

We don't want to lose any charge through the voltmeter.

Question 2 continues on page 9

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0 2 . 2 Suggest **one** advantage of using an analogue ammeter rather than a digital ammeter for this experiment.

[1 mark]

Markings can be made on a scale, which can be read off later.

0 2 . 3 Suggest a suitable full scale deflection for an analogue ammeter to be used in the experiment.

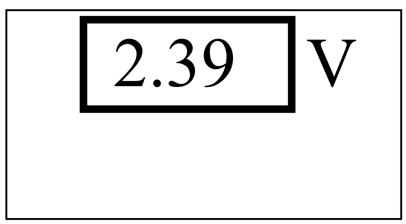
[2 marks]

$I = \frac{V}{R} = \frac{6}{100{,}000} = 6 \times 10^{-5}\,\text{A}$

$\simeq 60.0\,\mu\text{A}$ ✓

full scale deflection = $100\,\mu\text{A}$ ✓

0 2 . 4 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.

[1 mark]

$0.02 \times 2.39 = 0.0478\,\text{V}$

$\simeq 0.05\,\text{V}$

uncertainty = 0.05 V

Question 2 continues on the next page

0 2 . 5 Determine the number of different readings the student will be able to take before the capacitor becomes fully charged.

[3 marks]

$Q = CV = 6.8\times10^{-4} \times 6.0 = 4.08\times10^{-3}\,C$ ✓

$Q = It \Rightarrow t = \frac{Q}{I} = \frac{4.08\times10^{-3}}{6\times10^{-5}} = 68\,s$ ✓

$\frac{68}{10} = 6$, remainder 8

number = 6 ✓

0 2 . 6 The experiment is performed with a capacitor of nominal value 680 μF and a manufacturing tolerance of $\pm$ 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.

[2 marks]

$65\mu A = 65\mu C s^{-1}$, $98 mV s^{-1}$

$Q = CV \quad C = \frac{Qt}{Vt} = \frac{Q}{t} \div \frac{V}{t} = (65\times10^{-6}) \div (98\times10^{-3})$ ✓

capacitance = 660 ✓ μF

0 2 . 7 Deduce whether the capacitor is within the manufacturer's tolerance.

[1 mark]

$0.05 \times 680 = 34\mu F$

$\Rightarrow 680 \pm 34 = 646\mu F \leq C \leq 714\mu F$

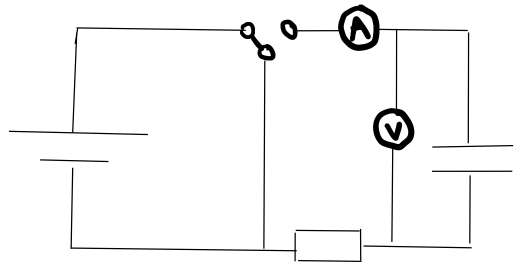
$\therefore$ Yes it is

0 2 . 8 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 marks]

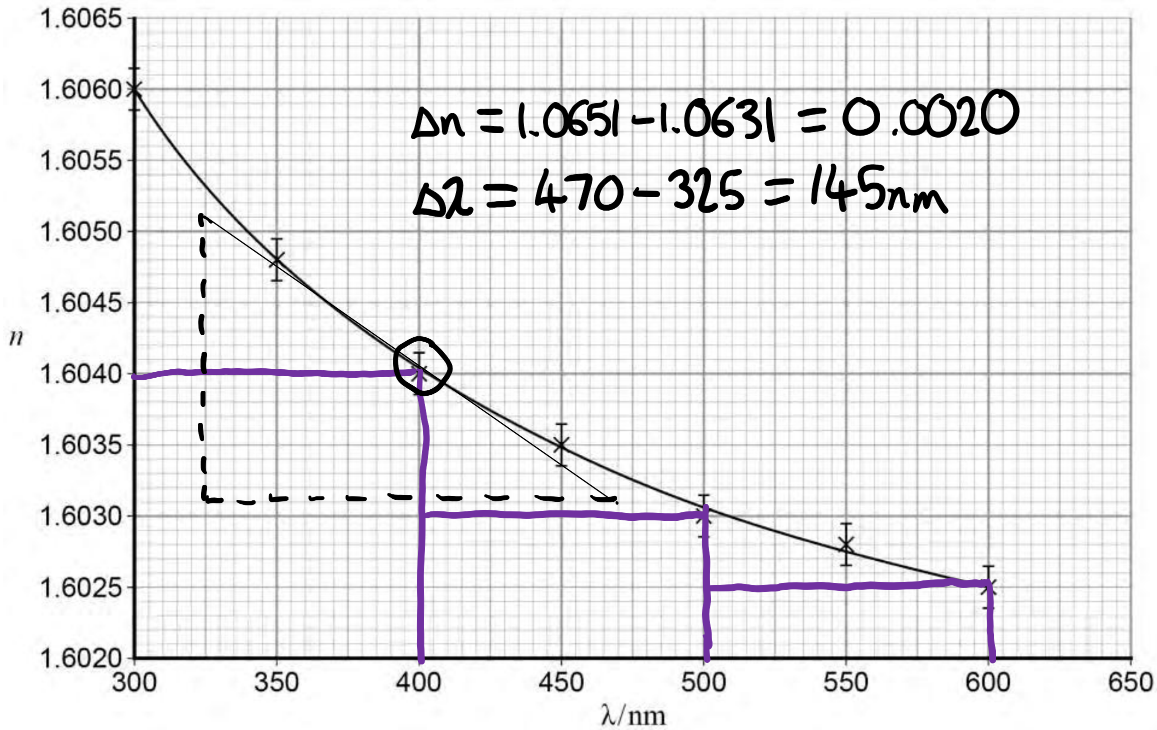


Method

- Charge the capacitor fully, and then discharge it through the resistor, at intervals of 10 seconds.
- Plot a graph of V against time
- Gradient = $1/RC$
- Work out time for V to halve ($t_{1/2}$)
- $\frac{1}{RC} = \frac{\ln 2}{t_{1/2}}$
- Plot graph of V against time
- Find time for V to fall to $\frac{1}{e}$ of its initial value

0 3 **Figure 4** shows how the refractive index n of a type of glass varies with the wavelength of light λ passing through the glass. The data for plotting the graph were determined by experiment.

Figure 4



0 3 . 1 A student says that **Figure 4** resembles that of the decay of radioactive atomic nuclei with time and that it shows half-life behaviour.

$n = \frac{c}{v}$, $v = f\lambda$

Comment on whether the student is correct.

$n = \frac{c}{f\lambda}$

[1 mark]

The value of n drops by 20 small squares, then 10, then 5 every 100nm

0 3 . 2 The dispersion D of glass is defined as the rate of change of its refractive index with wavelength. At a particular wavelength $D = \frac{\Delta n}{\Delta \lambda}$.

Determine D at a wavelength of 400 nm. State an appropriate unit for your answer.

[3 marks]

$\Delta n = 0.0020, \quad \Delta\lambda = 145 \text{ nm} = 1.45 \times 10^{-7} \text{ m}$

$D = \frac{\Delta n}{\Delta \lambda} = \frac{0.0020}{1.45 \times 10^{-7}} = 1.38 \times 10^{4} \text{ m}^{-1}$ ✓

Tangent + triangle ✓

D 1.38×10^{4} unit m^{-1} ✓

0 3 . 3 It is suggested that the relationship between n and λ is of the form

$$n = a + \frac{b}{\lambda^2}$$

where a and b are constants. The data plotted in **Figure 4** are given in **Table 2**.

Table 2

λ / nm	n	λ / m	$1/\lambda^2$ / m^{-2}	
300	1.6060	3.0×10^{-7}	11.1×10^{-12}	
350	1.6048	3.5×10^{-7}	8.16×10^{-12}	
400	1.6040	4.0×10^{-7}	6.25×10^{-12}	
450	1.6035	4.5×10^{-7}	4.94×10^{-12}	
500	1.6030	5.0×10^{-7}	4.00×10^{-12}	
550	1.6028	5.5×10^{-7}	3.31×10^{-12}	
600	1.6025	6.0×10^{-7}	2.78×10^{-12}	

You are to determine *a* using a graph of n against $\frac{1}{\lambda^2}$.

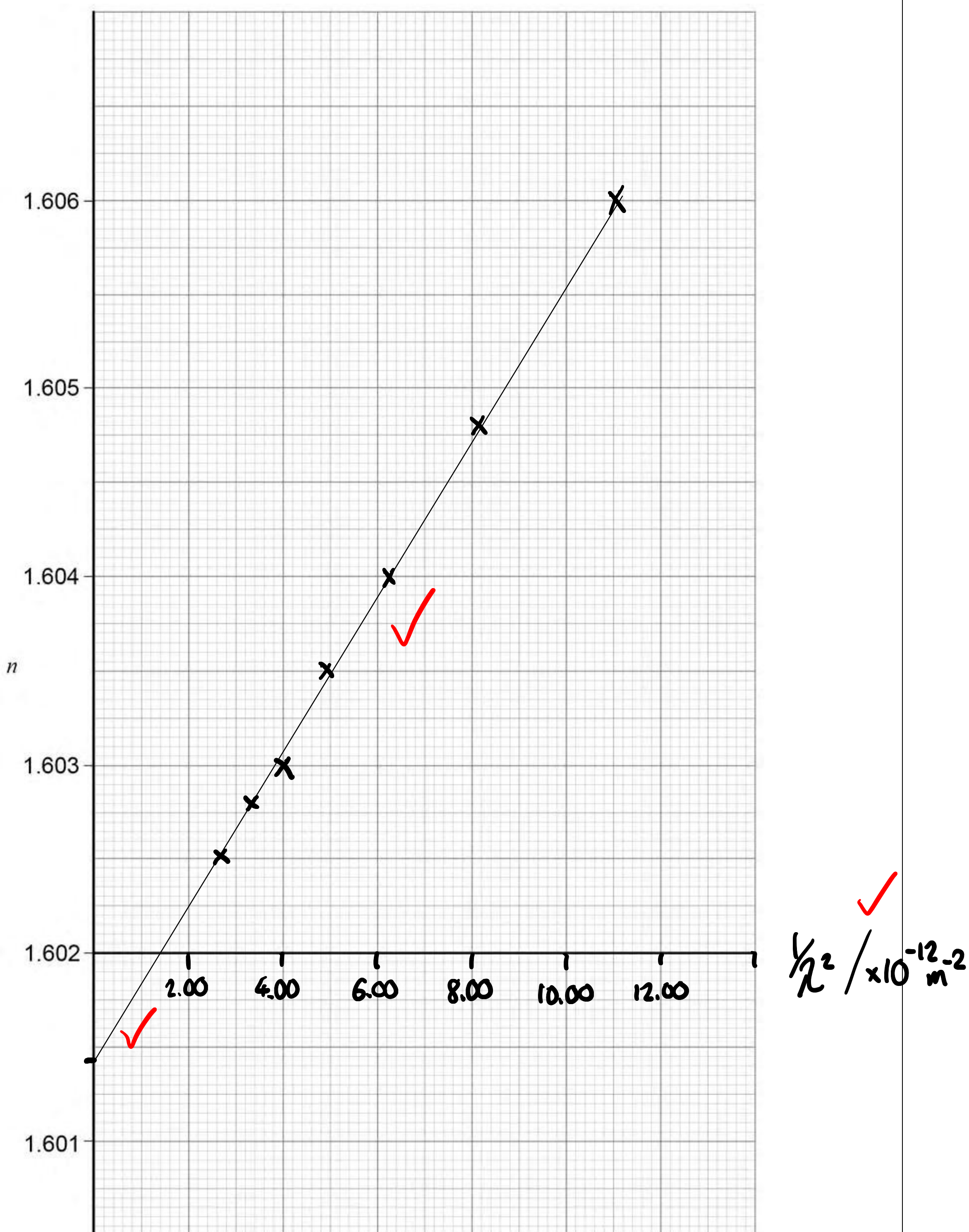
Make any calculations that you need to in order to plot your graph. The columns in **Table 2** are for you to use to calculate and tabulate the derived data that you need. You may not need all the columns.

[3 marks]

0 3 . 4 Plot your graph on **Figure 5**. The values of n are provided on the y-axis.

[3 marks]

Figure 5



0 3 . 5 Use your graph to determine a.

$n = a + \frac{b}{\lambda^2}$

$n = b\left(\frac{1}{\lambda^2}\right) + a$

$y = mx + c$

[1 mark]

0 3 . 6 State the significance of a.

[1 mark]

$a = a + 0$

$= a + \frac{b}{\lambda^2} = n$

• a is the value of n when $b/\lambda^2 = 0$

• i.e. when λ is infinite or at least very large ✓

0 3 . 7 Another suggestion for the relationship between n and λ is that

$$n = c\lambda^d$$

where c and d are constants.

Explain how d can be determined graphically. Do not attempt to carry out this analysis.

[3 marks]

Straight line graph: $y = mx + c$

$\log(n) = \log(c\lambda^d)$

$= \log(c) + \log(\lambda^d)$

$= \log(c) + d\log(\lambda)$

$\log(n) = d\log(\lambda) + \log(c)$ ✓

$y = m \quad x + c$

• Plot a graph of $\log(n)$ (y-axis) against $\log(\lambda)$ (x-axis) ✓

• The gradient of this graph is equal to d ✓