OXFORD
INTERNATIONAL AQA EXAMINATIONS

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname ____________________

Forename(s) ____________________

Candidate signature ____________________

INTERNATIONAL A-LEVEL
PHYSICS

Unit 5 Physics in practice

Friday 25 January 2019 07:00 GMT Time allowed: 2 hours

Materials
For this paper you must have:
- a Data and Formulae Booklet as a loose insert
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
TOTAL	

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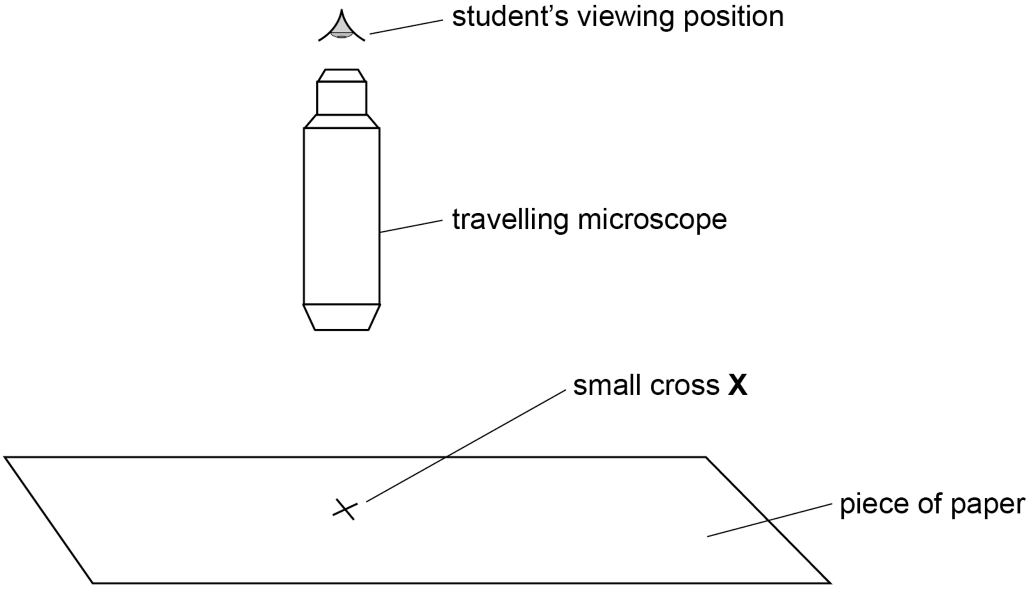
Section A

Answer **all** questions in this section.

0 1 This experiment is about measuring the refractive index of glass.

A student drew a small cross **X** on a piece of paper and viewed it from above through a travelling microscope as shown in **Figure 1**. A travelling microscope is used to measure the distance between the microscope and an object that it is focused on.

Figure 1



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0 1 . 1 The student looked at **X** through the microscope and adjusted the vertical position of the microscope until a focused image of **X** was seen. The vertical position h_1 of the microscope was measured 5 times and recorded in **Table 1**.

Table 1

h_1 / mm	First reading	Second reading	Third reading	Fourth reading	Fifth reading
	91.06	91.04	91.14	91.05	91.11

Calculate $\overline{h_1}$ the mean value of h_1 and its uncertainty $\Delta\overline{h_1}$.

[2 marks]

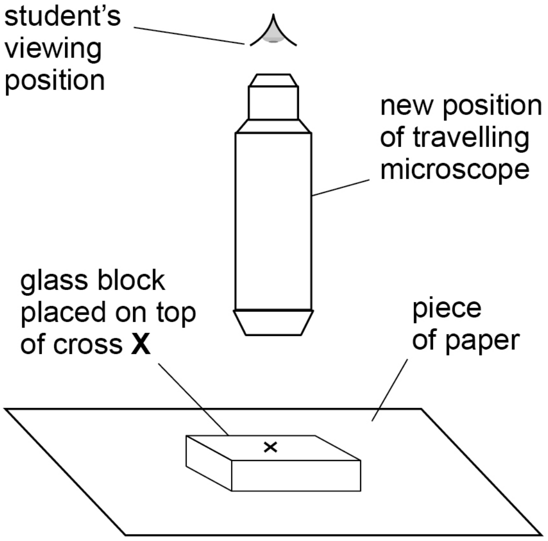
$\overline{h_1}$ = ____________________ mm

$\Delta\overline{h_1}$ = ± ____________________ mm

Question 1 continues on the next page

0 1 . 2 The student placed a glass block over **X** and adjusted the vertical position of the microscope until a focussed image of **X** was seen, as shown in **Figure 2**.

Figure 2



The new vertical position of the microscope h_2 was recorded, as shown in **Figure 3**. The measurements were repeated several times to find $\overline{h_2}$, the mean value of h_2, and $\Delta\overline{h_2}$, its uncertainty.

The student then focussed the microscope on the upper surface of the glass block and recorded h_3, the new vertical position of the microscope, as shown in **Figure 3**. $\overline{h_3}$, the mean value of h_3, and $\Delta\overline{h_3}$, its uncertainty, were found.

Figure 3

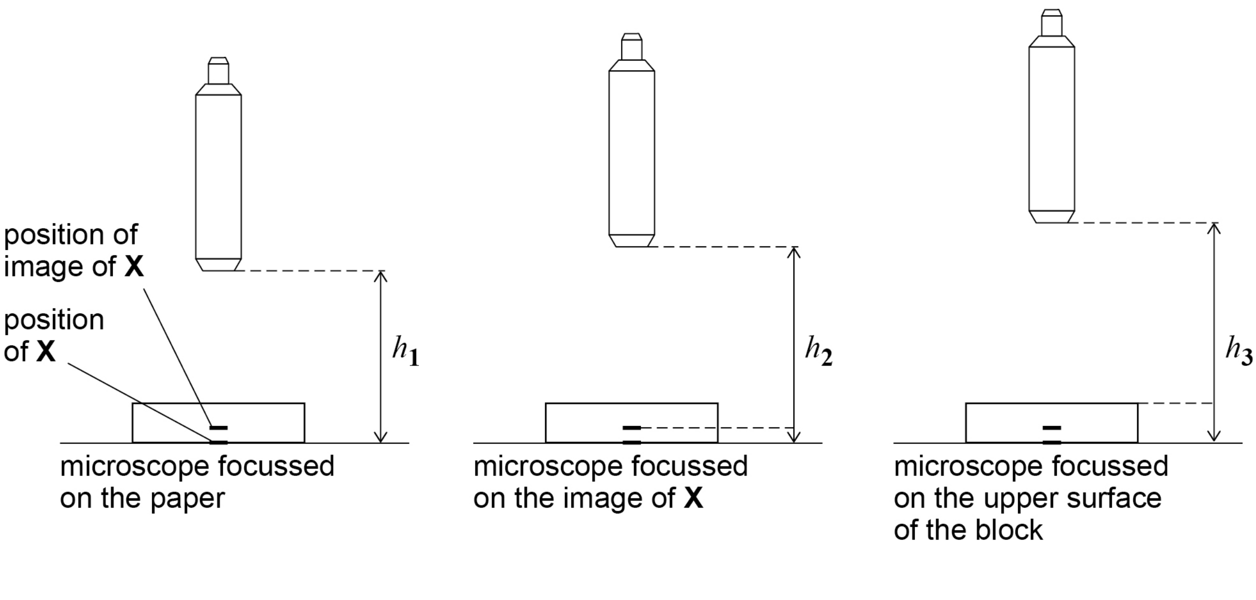


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Table 2 shows the measurements of $\overline{h_2}$, $\Delta\overline{h_2}$, $\overline{h_3}$ and $\Delta\overline{h_3}$.

Table 2

$\overline{h_2}$ / mm	$\Delta\overline{h_2}$ / mm	$\overline{h_3}$ / mm	$\Delta\overline{h_3}$ / mm
95.19	±0.04	103.09	±0.06

The thickness t of the glass block is $\overline{h_3} - \overline{h_1}$.

Calculate t and its uncertainty Δt.

[1 mark]

$t =$ ____________________ mm

$\Delta t = \pm$ ____________________ mm

0 1 . 3 The refractive index n of the glass can be calculated from

$$n = \frac{t}{\overline{h_3} - \overline{h_2}}$$

Calculate n.

[1 mark]

$n =$ ____________________

Question 1 continues on the next page

Turn over ►

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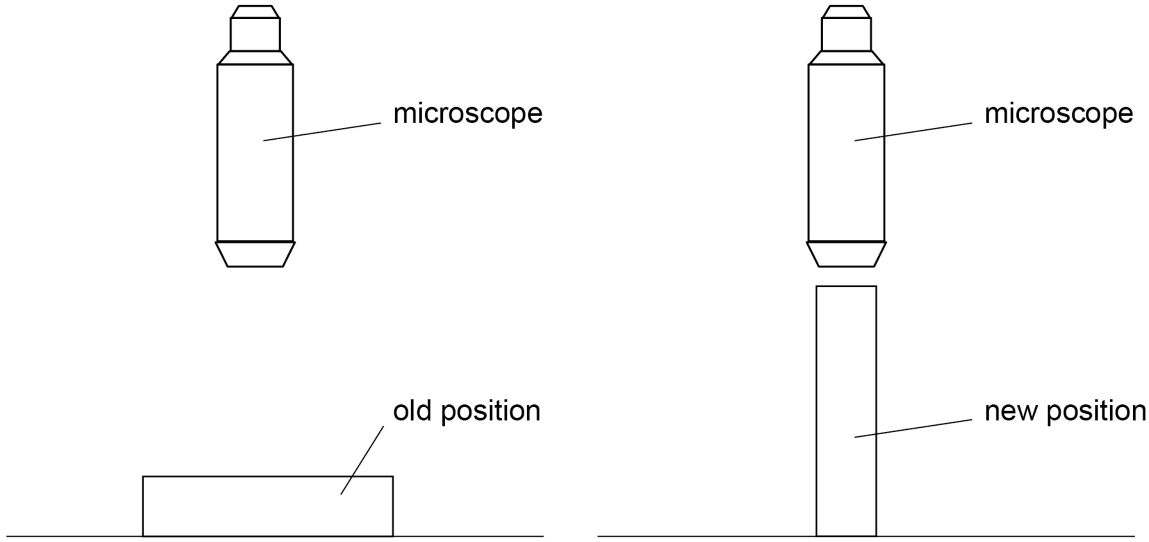
0 1 . 4 Calculate the percentage uncertainty in your value for n.

[2 marks]

percentage uncertainty in $n = \pm$ ____________________

0 1 . 5 The student changed the position of the block as shown in **Figure 4**.

Figure 4



Suggest how the percentage uncertainty in n is reduced by this change.

[2 marks]

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8

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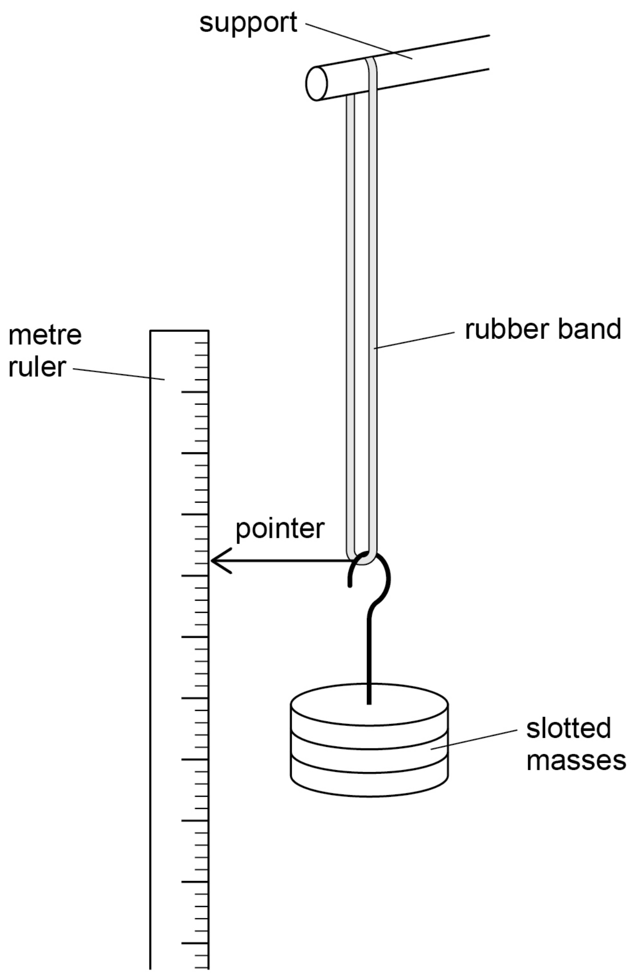
0 2 A student investigated the extension ΔL of a rubber band when the tensile force F acting on the rubber band was increased.

Figure 5 shows the apparatus used.

Figure 5



Question 2 continues on the next page

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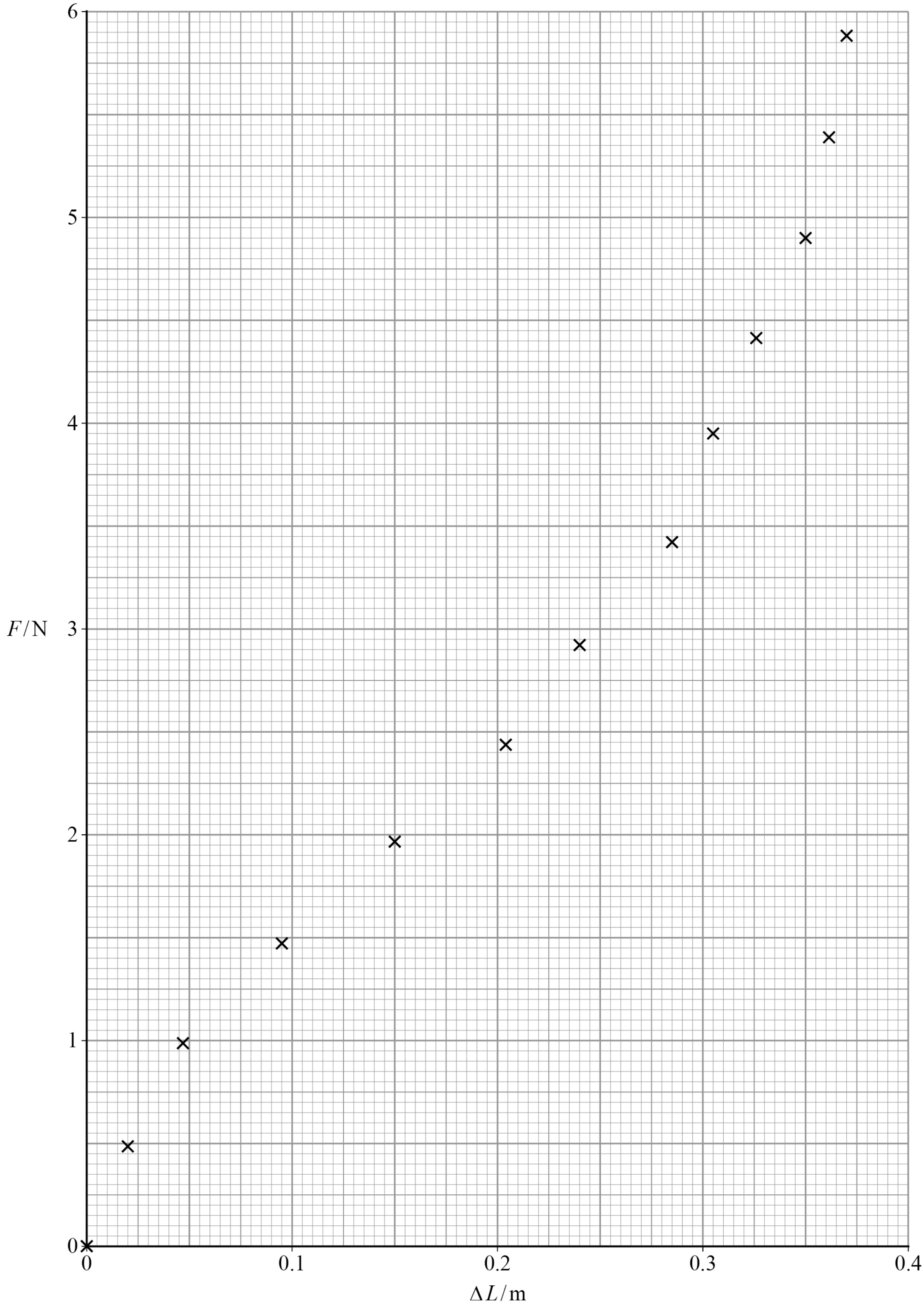
Figure 6



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0 2 . 1 **Figure 6** shows data from the experiment plotted on a graph.

Draw a best fit line.

[1 mark]

0 2 . 2 The graph is approximately linear between $\Delta L = 0.10$ m and $\Delta L = 0.25$ m.

Determine the stiffness of the rubber band in this range.

[2 marks]

stiffness = ____________________ $\mathrm{N\ m^{-1}}$

0 2 . 3 Determine the work done in stretching the rubber band between $\Delta L = 0.10$ m and $\Delta L = 0.25$ m.

[2 marks]

work done = ____________________ J

5

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0 3 . 1 Draw a diagram of a circuit that you would use to determine $\mathcal{E}$ the emf and r the internal resistance of a cell.

[1 mark]

0 3 . 2 Describe how you would use the circuit to determine accurate values of $\mathcal{E}$ and r.

You should include the following details in your description:

- the measurements you would make
- the range of values of the independent variable
- how you would process and analyse your results to determine $\mathcal{E}$ and r
- how you would ensure the accuracy of your values of $\mathcal{E}$ and r.

[5 marks]

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0 3 . 3 A battery can be made from a number n of identical cells connected **in parallel**.

A student uses the method you have described in question **03.2** to investigate how $\mathcal{E}$ and r vary with n.

Explain what you would expect the results to show.

[2 marks]

8

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0 4 An experiment was performed to investigate how the resistance R of a thermistor varied with absolute temperature T. **Table 3** shows the results.

Table 3

T / K	$\frac{1}{T}$ / × 10^{-3} K^{-1}	R / Ω	ln(R / Ω)
258		146	
273		97	
288		64	
303		46	
318		31	
333		24	

0 4 . 1 The relationship between R and T is:

$R = Ae^{\frac{B}{T}}$ where A and B are constants.

Show that $\ln R = \frac{B}{T} + \ln A$.

[1 mark]

0 4 . 2 Complete **Table 3** by calculating values for $\frac{1}{T}$ and $\ln R$.

[2 marks]

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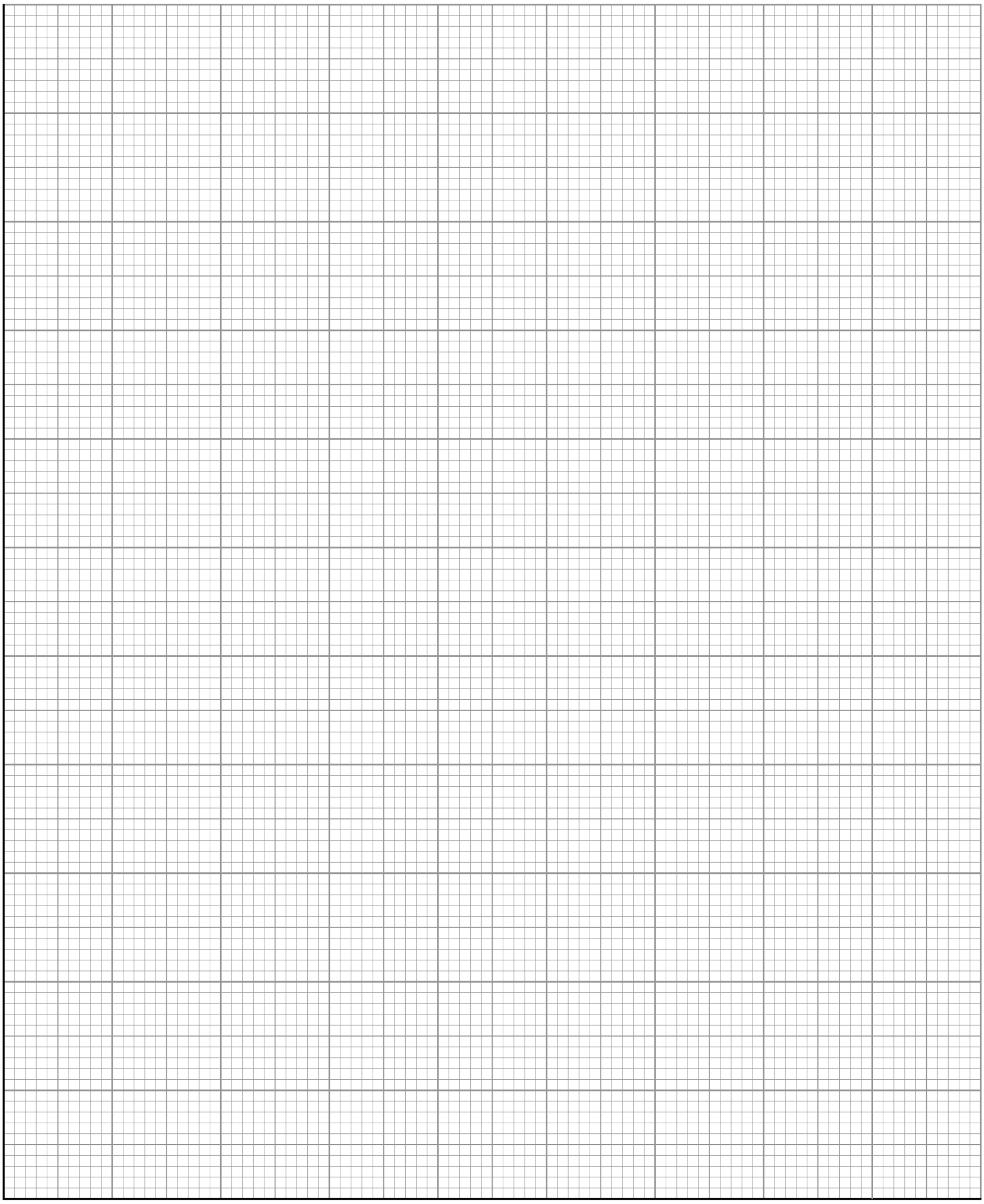
0 4 . 3 Draw on **Figure 7** a graph of $\ln R$ against $\frac{1}{T}$.

[4 marks]

Figure 7



Question 4 continues on the next page

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0 4 . 4 Determine, from your graph, a value for B.
State an appropriate unit for your answer.

[3 marks]

$B =$ ____________________

unit for $B =$ ____________________

0 4 . 5 Determine, using your graph, the average change in resistance per degree for temperatures between $280\ \mathrm{K}$ and $300\ \mathrm{K}$.

[3 marks]

average change in resistance per degree = ____________________ $\Omega\ \mathrm{K}^{-1}$

0 4 . 6 Discuss whether or not this thermistor would be suitable for use as a temperature sensor in the controls of an air-conditioning system in an office building.

[2 marks]

15

Turn over for the next question

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Section B

Answer **all** questions in this section.

0 5 Gravitational waves can be produced when black holes collide. The length of structures can change as gravitational waves pass the Earth.

Figure 8 is a plan view of a gravitational wave detector called the Laser Interferometer Gravitational-Wave Observatory (LIGO).

Laser light is split to produce two separate beams. Each beam travels down a different tube before reflecting from mirror **P** or **Q**. The two tubes are over $4\ \text{km}$ long and are at $90°$ to each other. Partially-reflecting mirrors **R** and **S** make each light beam travel backwards and forwards along the tubes **280 times** before the light beams finally meet at the detector.

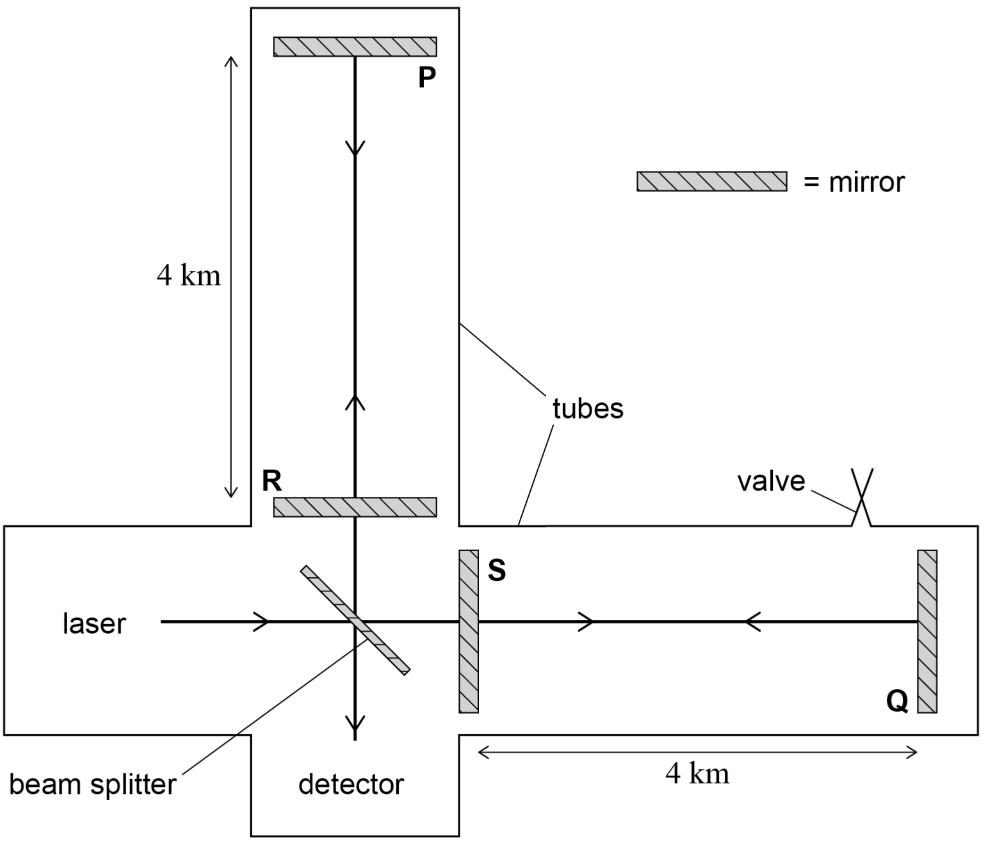
When distances **PR** and **QS** are exactly the same, the beams produce destructive interference when they meet at the detector.

When a gravitational wave changes the length of one tube, the path difference between the beams changes, creating an interference pattern. This allows small changes in **PR** and **QS** to be measured.

The interior of the LIGO is maintained at a very low pressure to prevent any disturbance to the mirrors. There are also damping systems that reduce unwanted vibrations from local industry, traffic and seismic activity.

Figure 8

not to scale



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0 5 . 1 The internal gas pressure is reduced by heating the LIGO from its normal temperature of 20 °C to 160 °C.
A valve is opened to allow some of the gas to escape.

Use the first law of thermodynamics to explain what happens to the internal energy of the gas that is heated and escapes through the valve.

[3 marks]

0 5 . 2 The valve is then closed and the LIGO cools to 20 °C. The pressure in the LIGO is further reduced by another method until it is 1.33×10^{-7} Pa. The volume of the LIGO is 1.00×10^{4} m^3.

Calculate the number of gas molecules remaining in the LIGO.

[3 marks]

number of gas molecules = ____________________

Question 5 continues on the next page

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0 5 . 3 State **one** assumption made in your calculation in question **05.2**.

[1 mark]

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0 5 . 4 In order to measure very small changes in length, it is important that the LIGO's mirrors are not disturbed at all.

Suggest **two** reasons why removing the air from the LIGO tubes would reduce disturbance to the mirrors.

[2 marks]

Reason 1 ____

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Reason 2 ____

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0 5 . 5 A gravitational wave goes through the LIGO. It causes the tube containing mirrors **P** and **R** to change in length. This change in length results in the light beams meeting at the detector to produce constructive interference.
Assume that only the distance **PR** changes.

Explain how an increase in distance **PR** causes constructive interference at the detector.

[3 marks]

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0 5 . 6 The LIGO uses infrared radiation of wavelength 1.06×10^{-6} m.

Calculate the minimum increase in distance **PR** that would cause constructive interference to occur at the detector.
Assume the distance **QS** does not change.

[2 marks]

minimum increase in **PR** = ______________________ m

0 5 . 7 Damping systems are used to reduce disturbance of the LIGO due to vibrations (lines 16–17 on page 16).

Explain what is meant by damping.

[2 marks]

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0 5 . 8 There are two LIGOs, 3000 km apart in the USA.

Suggest how measurements from the two LIGOs could help to improve the validity of measurements when a gravitational wave passes the Earth.

[2 marks]

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18

0 6 **Figure 9** shows a tidal turbine generator (TTG). The TTG operates in a similar way to a wind turbine generator (WTG). A fluid moves over the turbine blades, making them rotate. The turbine extracts some of the kinetic energy from the fluid.

Figure 9

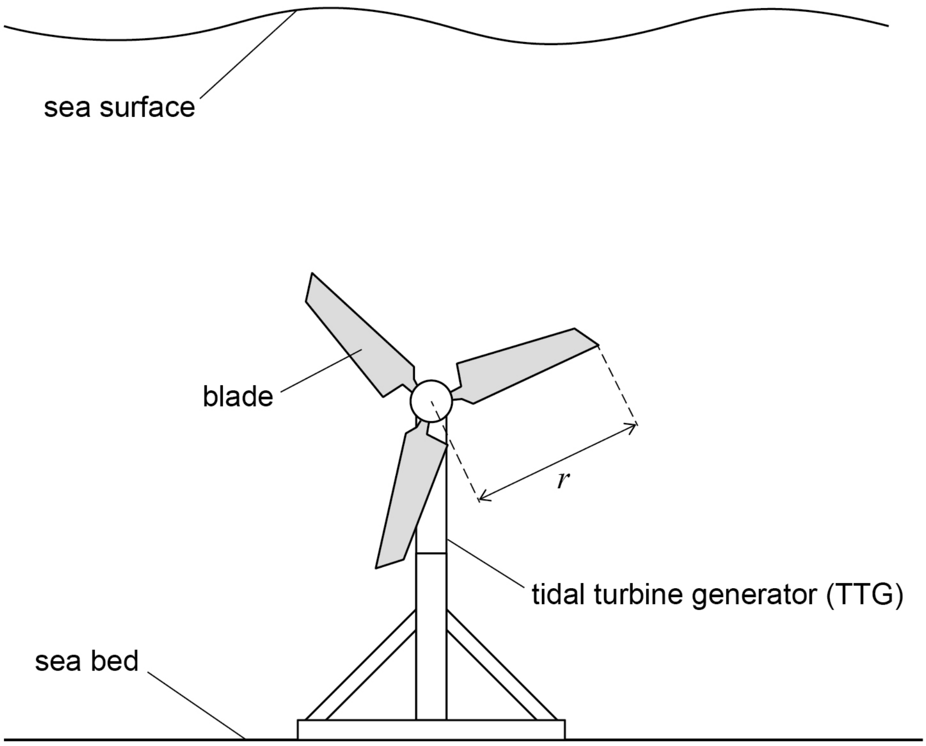

Table 4 shows data for a TTG and a WTG.

Table 4

	TTG	**WTG**
Fluid	seawater	air
Density of fluid, ρ / kg m^{-3}	1030	1.23
Blade length, r / m	8	50
Mean speed of fluid, v / m s^{-1}	3.8	8.5
Mean number of hours per day of operation	20	18

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0 6 . 1 The power P available to a TTG or WTG from the moving fluid is given by:

$$P = \frac{1}{2}\pi r^2 \rho v^3$$

In practice, no more than $\frac{16}{27}P$ can be extracted from the fluid by a turbine.

Explain why not all of the kinetic energy of a moving fluid can be extracted by a turbine.

[2 marks]

0 6 . 2 Compare the total energy that can be extracted from the moving fluid in one day by the TTG and the WTG.

Use data from **Table 4**.

[4 marks]

Question 6 continues on the next page

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0 6 . 3 Tides happen because of the gravitational effect of the Moon.
The radius R of the Moon's orbit around the Earth is 3.85×10^{8} m.
High tides in the Earth's oceans exert a force on the Moon that causes R to increase by 3.8 cm in one year.

Show that the work needed to increase R by 3.8 cm is approximately 8×10^{18} J.
For this calculation, assume that there is no change in the Moon's kinetic energy.

mass of the Moon = 7.35×10^{22} kg

[3 marks]

0 6 . 4 Explain the effect of an increase in R on the orbital period of the Moon.

[2 marks]

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0 6 . 5 The overall effect of increasing R is to increase the Moon's angular momentum.

Explain how this will affect the length of an Earth day.

[2 marks]

13

Turn over for the next question

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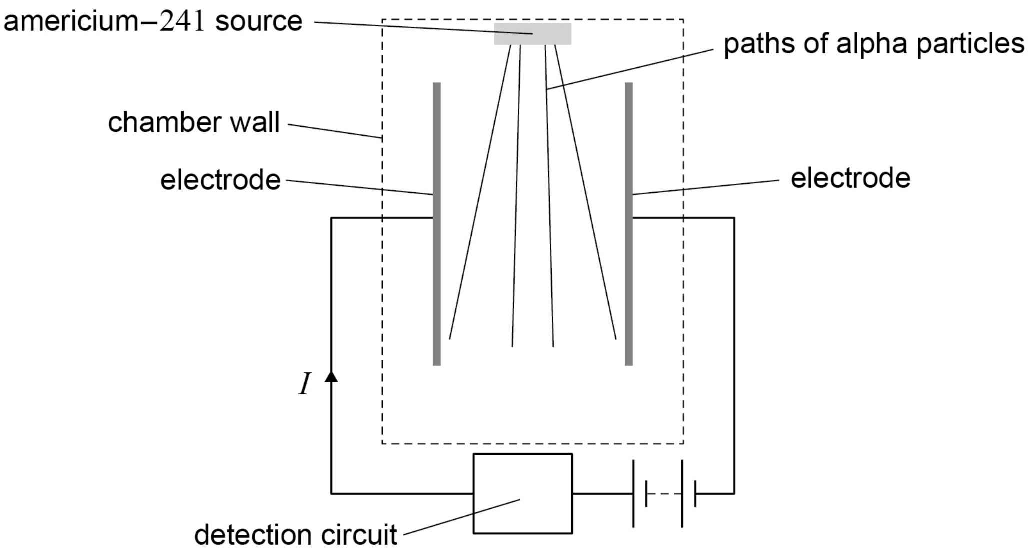
0 7 **Figure 10** shows an ionisation smoke detector. It has a small chamber containing two electrodes and a source of alpha particles.
The chamber walls have many small holes in them to allow air and smoke to pass through.

Figure 10



Alpha particles from the source ionise the air in the chamber. Each ionisation of an atom in the air produces a free electron and a positive ion. A free electron and positive ion produced in this way are called an ion pair. There is a current I in the detection circuit when both types of charge carrier move.

When there is a fire, smoke enters the chamber and many ions and free electrons become attached to the smoke particles. This reduces the number of available charge carriers. The reduction in I is detected and an alarm buzzer sounds.

The radioactive source is americium–241 with an initial activity of $38\ \text{kBq}$ and a decay constant of 1.60×10^{-3} year^{-1}. The americium–241 emits alpha particles each with a kinetic energy of $5.5\ \text{MeV}$.

The mean energy needed to ionise an atom in the air is $15\ \text{eV}$.

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0 7 . 1 Deduce whether the americium–241 source will need to be replaced during the life of the smoke detector.

[2 marks]

0 7 . 2 Explain why the radioactive source inside the smoke detector is considered to be non-hazardous.

[2 marks]

Question 7 continues on the next page

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0 7 . 3 Half of the alpha particles emitted from the source enter the chamber.

Show that approximately 7.0×10^9 ion pairs are produced in the chamber in one second when the activity of the source is 38 kBq.

[2 marks]

0 7 . 4 Calculate the maximum magnitude of the current I due to these ion pairs when there is no smoke in the chamber.

[2 marks]

$I =$ ______________________ A

0 7 . 5 An alpha particle produces 1.0×10^4 ions per mm of its path.

Deduce the total length of an alpha-particle path.

[1 mark]

length of path = ______________________ mm

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0 7 . 6 An americium–241 nucleus has 146 neutrons and decays into an isotope of neptunium (Np).

Complete the equation for the decay of americium–241.

[2 marks]

$$^{---}_{---}\text{Am} \longrightarrow \, ^{---}_{---}\text{Np} + \, ^{---}_{---}\alpha$$

0 7 . 7 The neptunium isotope formed by the decay of americium–241 is also an alpha emitter. Its decay constant is $1.02 \times 10^{-14}\ \text{s}^{-1}$.

Explain using an appropriate calculation whether the presence of neptunium will affect the magnitude of the current I.

[2 marks]

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13

END OF QUESTIONS

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