Rewarding Learning

Centre Number

71	

Candidate Number

ADVANCED
General Certificate of Education
2013

Physics

Assessment Unit A2 1

assessing

Momentum, Thermal Physics, Circular Motion, Oscillations and Atomic and Nuclear Physics

[AY211]

MONDAY 20 MAY, AFTERNOON

AY211

TIME

1 hour 30 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
Answer **all eight** questions.
Write your answers in the spaces provided in this question paper.

INFORMATION FOR CANDIDATES

The total mark for this paper is 90.
Quality of written communication will be assessed in Question **5(a)**.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question.
Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.
You may use an electronic calculator.
Question **8** contributes to the synoptic assessment required of the specification.

For Examiner's use only	
Question Number	Marks
1	
2	
3	
4	
5	
6	
7	
8	
Total Marks	

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If you need the values of physical constants to answer any questions in this paper they may be found in the Data and Formulae Sheet.

Answer **all eight** questions

1 A trolley of mass 0.75 kg is running along a frictionless track at a constant speed of $0.7\,\mathrm{m\,s^{-1}}$ as shown in **Fig 1.1**.

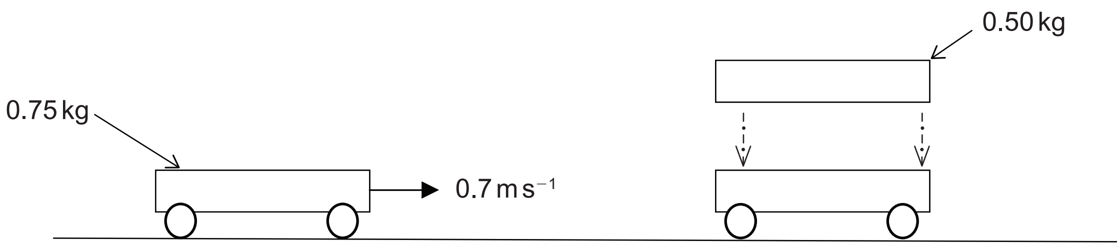

Fig. 1.1

As the trolley passes below a mass of 0.50 kg, the mass drops a short vertical distance onto the trolley.

(a) Calculate the new velocity of the trolley plus mass after the 0.50 kg mass has been added.

Assume that the 0.50 kg mass has no horizontal velocity when it lands on the trolley.

Velocity = ____________________ $\mathrm{m\,s^{-1}}$ [2]

(b) Calculate the percentage loss of the original kinetic energy after the mass has landed on the trolley.

Loss of ke = __________ % [3]

Examiner Only
Marks | Remark

2 (a) Boyle's Law relates the pressure of a gas to its volume.

State Boyle's Law.

____

____

____ [2]

(b) Describe an experiment that could be performed in a school laboratory to verify Boyle's Law.

Your description should include:

(i) a labelled diagram of the apparatus to be used.

[1]

(ii) a description of the method used to obtain an accurate set of results.

____

____

____

____

____ [2]

Examiner Only	
Marks	Remark

(iii) The results of the experiment can be used to plot a graph that will confirm the relationship. Complete **Fig. 2.1** by labelling the axes and sketching the best-fit line expected.

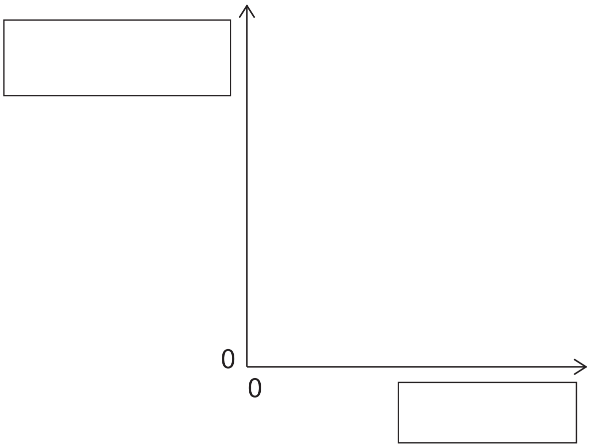

Fig. 2.1 [2]

(c) Why is it important that the tube containing the air in the above experiment should be of a constant diameter?

____

____

____ [2]

(d) The four disc brakes in a Formula 1 racing car are made from carbon fibre composite. **Each** disc in the car has a mass of 1.5 kg and the total mass of the car and driver is 640 kg. The braking system of the car brings it to rest from a speed of 83.3 $m s^{-1}$. Calculate the specific heat capacity of the carbon fibre composite if the temperature of each disc rises by 970 °C during the braking process.

Specific heat capacity = ____________________ $J kg^{-1} °C^{-1}$ [3]

3 The bob of a conical pendulum describes a circle with a period of 0.64 s. A strong light source in front of the conical pendulum causes a shadow of the bob to be cast on a screen behind the conical pendulum as shown in **Fig. 3.1**.

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Marks	Remark

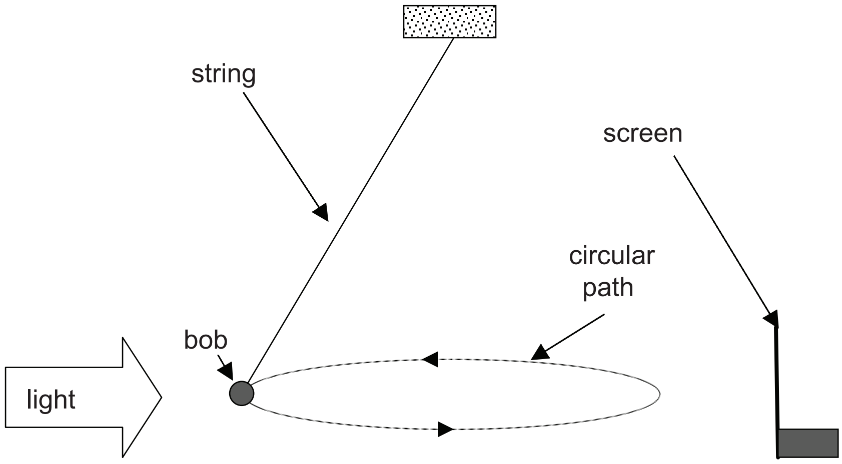

Fig. 3.1

(a) The pendulum bob, of mass 24 g, moves in a circle of diameter 30 cm with a periodic time of 0.64 s.

(i) Calculate the angular velocity, ω, of the bob.

$\omega =$ ____________________ rad s^{-1} [2]

(ii) Calculate the centripetal force acting on the bob.

Force = ____________________ N [3]

(iii) Consider **Fig. 3.1** and identify the source of the centripetal force acting on the bob.

____

____ [1]

(b) The shadow of the bob oscillates in a straight line with simple harmonic motion between two positions on the screen that are 30 cm apart, as shown in **Fig. 3.2**.

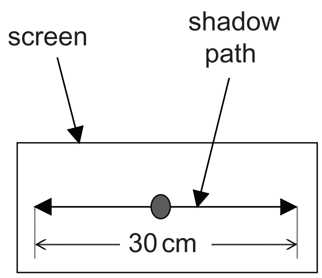

Fig. 3.2

(i) State the periodic time, T, of the simple harmonic oscillation.

T = __________ s [1]

(ii) Timing started when the shadow of the bob was at the extreme left hand position. Calculate the displacement, *d*, of the shadow, relative to the extreme left hand position, after 0.40 s.

d = __________________ cm [3]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

4 After Geiger and Marsden performed the alpha particle scattering experiment, Rutherford came to the following conclusions.

1. Most of the atom was empty space.
2. The atom had a central nucleus which was positively charged.

(a) (i) Which observation made during the experiment strongly suggested that most of the atom was empty space? Explain your answer.

____

____

____ [2]

(ii) Which observation made during the experiment strongly suggested that the atom had a central nucleus which was positive? Explain your answer.

____

____

____ [2]

(iii) J. J. Thomson had proposed a model of the atom in which the positive charge was distributed uniformly over the volume of the atom. The electrons were embedded in the atom like the currants in a cake. If Thompson's model of the atom was correct, what would have happened to the alpha particles?

____

____

____ [2]

(b) Rutherford was able to estimate the radius of the nucleus for many different types of atom and he found that the radius was related to the mass number of the nucleus.

(i) On **Fig. 4.1** sketch a graph to show this relationship.

Fig. 4.1 [2]

(ii) Given that the radius of a nucleus of mass number 1 is 1.2 fm, find the radius of a $^{27}_{13}Al$ nucleus.

Radius = ____________________ m [2]

Examiner Only

Marks	Remark

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In part (a) of this question you will be assessed on the quality of your written communication. Where appropriate you should answer in continuous prose.

Examiner Only	
Marks	Remark

5 **(a)** Describe an experiment to measure the half-life of a suitable radioisotope.

(i) Draw a labelled diagram of the apparatus.

[1]

(ii) Outline the method used to obtain the experimental data.

____

____

____

____

____ [2]

(iii) State the characteristic of the isotope that makes it suitable.

____

____ [1]

Quality of written communication [2]

(b) The results from such an experiment are displayed in two ways, as shown in **Fig. 5.1** and **Fig. 5.2**.
Both graphs are based on the exponential decay of radioactivity given by **Equation 5.1**.

$$A = A_0 e^{-\lambda t} \qquad \textbf{Equation 5.1}$$

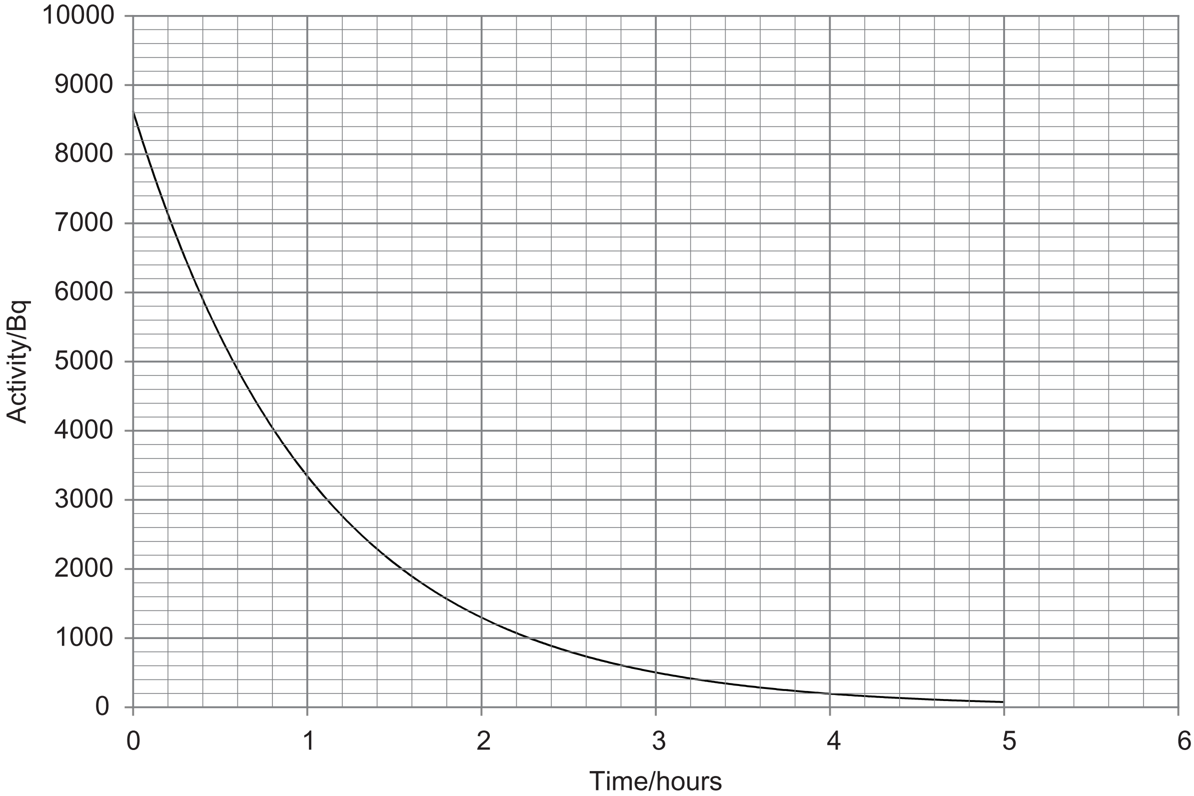

Fig. 5.1

Examiner Only	
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(i) Determine the half-life of the radioisotope, in minutes, from **Fig. 5.1**.

Half-life = ___________ minutes [3]

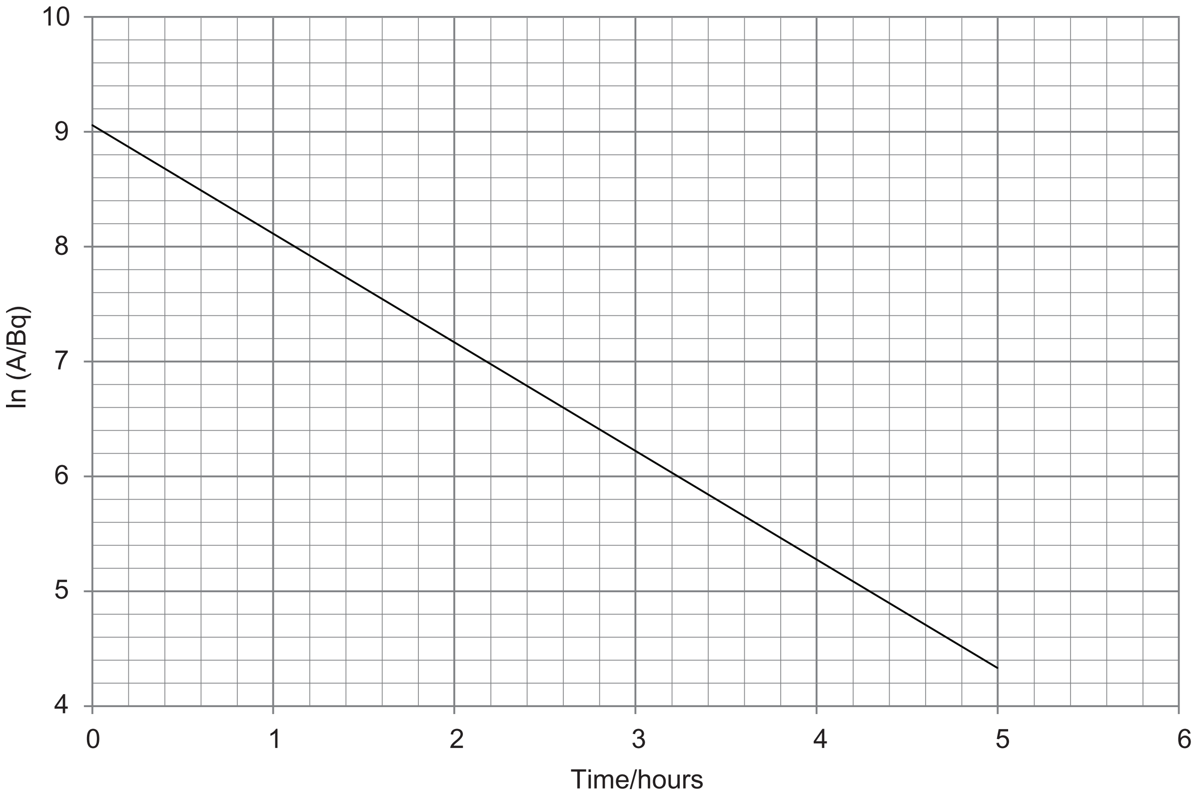

Fig. 5.2

Examiner Only

Marks | Remark

(ii) Determine the half-life of the radioisotope, in minutes, from **Fig. 5.2**.

Half-life = ___________ minutes [3]

Examiner Only	
Marks	Remark

(c) Technetium-99 (Tc-99) is a radioisotope tracer with a decay constant, λ, of 0.12 hr^{-1}. It emits 140 keV gamma photons and is commonly used in nuclear medicine to study the functionality of body organs and systems. A patient undergoing a bone scan is injected with Tc-99 with activity 800 MBq. After how long will the total amount of gamma energy emitted from the patient every second fall to 1.0 μJ?

Time = __________

Unit = __________ [4]

6 **(a)** In 1905, Albert Einstein made the important assertion that

$$E = \Delta mc^2 \qquad \textbf{Equation 6.1}$$

Complete **Table 6.1** to identify each symbol and its appropriate unit.

Table 6.1

Symbol	Quantity	Unit
E		
Δm		
c		

[2]

(b) A sodium-24 nucleus $\left({}^{24}_{11}\text{Na}\right)$ has a mass of 23.99096 u.
Determine the binding energy per nucleon in MeV of sodium-24 if a proton has mass 1.00728 u and a neutron has mass 1.00867 u.

Binding energy per nucleon = ____________________ MeV [4]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

7 **(a)** **(i)** As a result of the massive earthquake in Japan in 2011, the nuclear reactor at Fukushima was "**shut down**". Explain how "**shut down**" can be achieved in a nuclear fission reactor and describe the physical process involved.

____

____

____ [2]

(ii) The tsunami which followed the earthquake caused all the pumps used to circulate the water coolant to stop working resulting in the temperature of the reactor core rising sharply. Explain why heat is generated in the fission of uranium.

____

____

____ [1]

(iii) Each fuel rod in the core contains a mass of uranium which is subcritical. The high temperature in the core could result in the fuel rod containers melting. Why could this situation lead to an uncontrollable reaction?

____

____

____ [2]

(iv) After the tsunami it was suggested that the damaged reactor core be encased in concrete. Why would this be necessary?

____

____

____

____ [1]

(b) (i) A possible alternative source of energy production to nuclear fission is nuclear fusion. What is nuclear fusion?

____

____

____ [2]

(ii) Plasma confinement increases the probability of a fusion event occurring. What two conditions has plasma confinement achieved?

____

____ [2]

(c) (i) Part of the D-T reaction is given below. Complete the equation.

$$^{2}_{1}\text{D} + {}^{3}_{1}\text{T} \rightarrow$$

[1]

(ii) Explain why this reaction is the most suitable for terrestrial fusion.

____

____

____ [2]

Examiner Only	
Marks	Remark

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Examiner Only	
Marks	Remark

8 **Data Analysis Question**

This question contributes to the synoptic requirement of the specification. In your answer you will be expected to bring together and apply principles and concepts from different areas of physics, and to use the skills of physics in the particular situation described.

Fig. 8.1 shows a metre rule loaded at one end and clamped at the other.

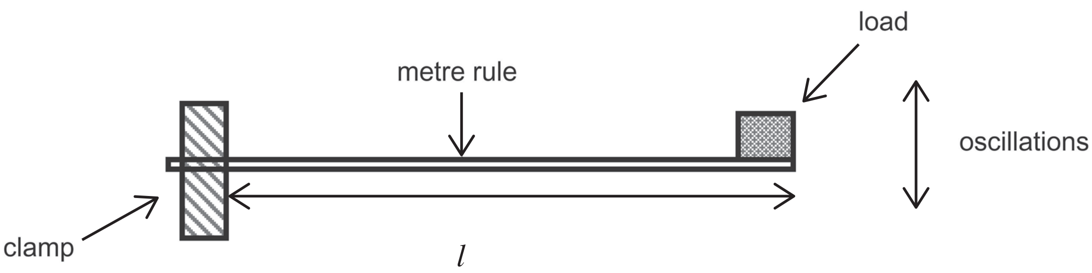

Fig. 8.1

By displacing the loaded end, the metre rule can be made to oscillate. The relationship between the period of oscillation, T, of the loaded end and l, the length of the metre rule from the clamp to the mass, is given by **Equation 8.1**

$$T = Al^n \qquad \textbf{Equation 8.1}$$

where A and n are constants.

(a) Show that a graph of lg T against lg l will give a straight line and explain how the values of n and A could be found.

[2]

Examiner Only	
Marks	Remark

The experiment is performed and values of l and corresponding times for 10 oscillations are obtained. These are shown in **Table 8.1** opposite.

(b) (i) The values obtained for the times at $l = 0.450\,\text{m}$ show increased variation. Suggest a reason for this.

____

____ [1]

(ii) What practical step could be taken to obtain more reliable results?

____

____ [1]

(c) Blank columns have been provided in **Table 8.1**. By heading the columns appropriately, record the further quantities, with units, which must be calculated in order to draw the straight line graph. [3]

(d) On the graph grid of **Fig. 8.2**, draw the graph. [4]

(e) Hence find the values of *A* and *n*.

Value of $n =$ ____________________

Value of $A =$ ____________________ [4]

Table 8.1

l/m	Time for 10 oscillations/s					
	t_1	t_2	t_{av}/s			
0.850	7.23	7.25	7.24			
0.750	5.89	5.93	5.91			
0.650	4.74	4.80	4.77			
0.550	3.65	3.77	3.71			
0.450	2.64	2.84	2.74			

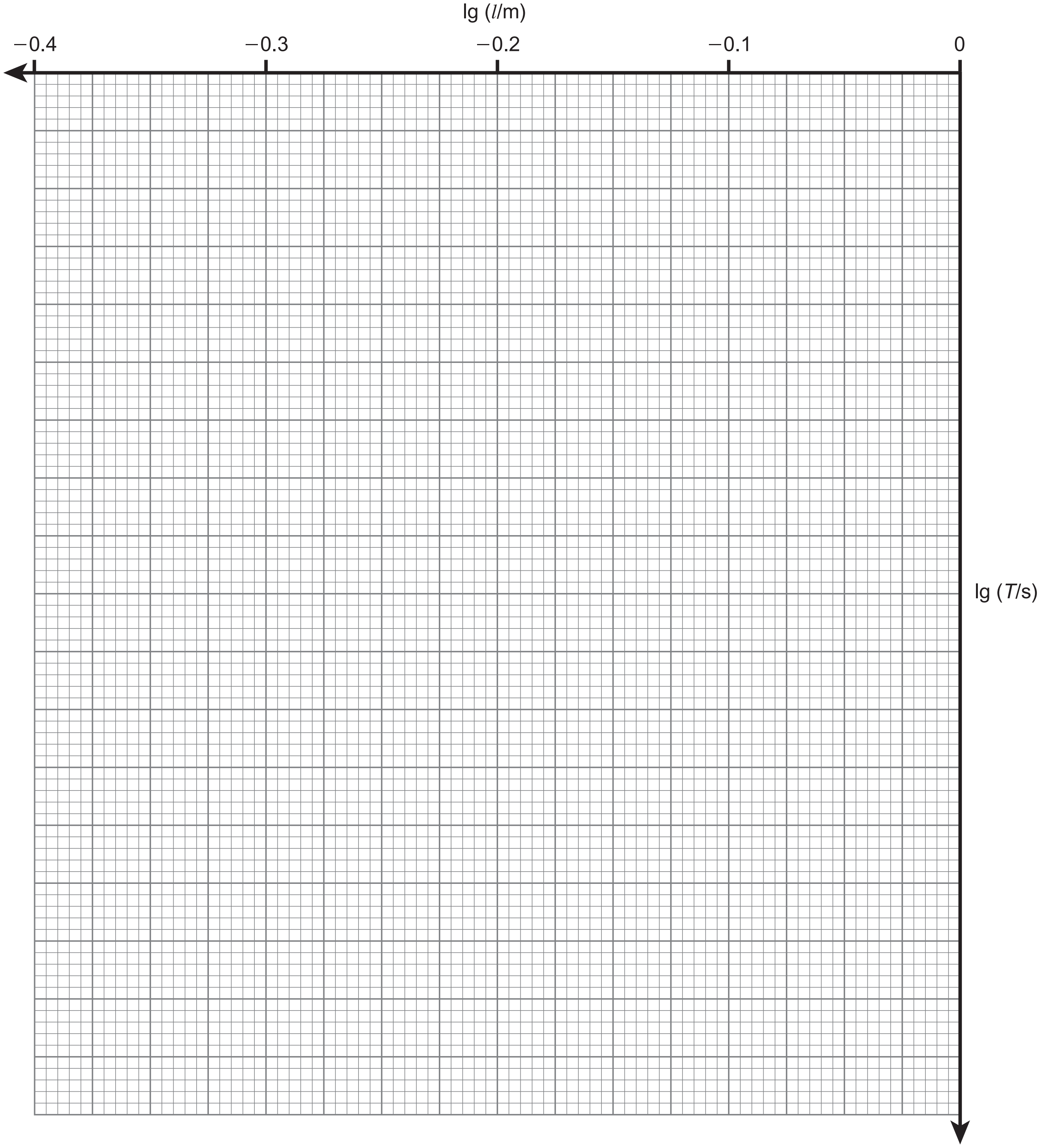

Fig. 8.2

(f) By further analysis it can be shown that

$$A = 2\pi\sqrt{\frac{4M}{Ebd^3}} \qquad \textbf{Equation 8.2}$$

where M is the mass clamped at the end of the metre rule, which is 300 g. E is the Young Modulus for the material of the metre rule, b is the width of the metre rule which is 25 mm and d is the thickness of the metre rule which is 5 mm. Use the value of A obtained in part **(e)** and the values of the other constants given to obtain a value for E the Young Modulus of the material from which the metre rule is made. You may assume the value for A in part **(e)** is in the appropriate S.I. unit form.

E = ____________________ Pa [3]

THIS IS THE END OF THE QUESTION PAPER

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Marks	Remark

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