OXFORD CAMBRIDGE AND RSA EXAMINATIONS

A2 GCE

G494/01

PHYSICS B (ADVANCING PHYSICS)

Rise and Fall of the Clockwork Universe

WEDNESDAY 16 JANUARY 2013: Afternoon

DURATION: 1 hour 15 minutes
plus your additional time allowance

MODIFIED ENLARGED 18pt

Candidate forename		Candidate surname	

Centre number						Candidate number				

Candidates answer on the Question Paper.

OCR SUPPLIED MATERIALS:

Data, Formulae and Relationships Booklet
(sent with general stationery)

OTHER MATERIALS REQUIRED:

Electronic calculator
Ruler (cm/mm)

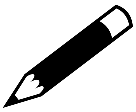
READ INSTRUCTIONS OVERLEAF

DC (NF/CGW) 1477691827 70694/2

INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the boxes on the first page. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer ALL the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the additional pages at the end of this booklet. The question number(s) must be clearly shown.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- The total number of marks for this paper is 60.
- You are advised to spend about 20 minutes on Section A and 55 minutes on Section B.
- The values of standard physical constants are given in the Data, Formulae and Relationships Booklet. Any additional data required are given in the appropriate question.
-  Where you see this icon you will be awarded marks for the quality of written communication in your answer.

  This means for example, you should
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that the meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.

Answer ALL the questions.

SECTION A

1 Here is a list of units.

N s

N m^{-2}

N m

N kg^{-1}

(a) Which one is a correct unit for pressure?

answer ______________________________ [1]

(b) Which one is a correct unit for kinetic energy?

answer ______________________________ [1]

2 Here are some observations about the Universe.

Put ticks (✓) in the boxes next to the TWO observations which provide evidence for a big bang at the start of the Universe.

Some nearby galaxies emit blue-shifted light. ☐

Microwave radiation is detected from all directions in space. ☐

X-rays from galaxies imply the presence of black holes at their core. ☐

The red-shift of light from most galaxies increases with increasing distance. ☐

Most of the visible matter in the Universe appears to be clumped in galaxies. ☐

[2]

3 **Scientists investigate contamination due to a radioactive isotope.**

Fig. 3.1 shows how the activity of the isotope changes with time.

FIG. 3.1

Use the graph to show that the decay constant of the isotope is about $4 \times 10^{-7}\,s^{-1}$.

1 day = 8.6×10^{4} s

[2]

4 The circuit diagram of Fig. 4.1 shows a 10 μF capacitor which is connected across a battery of e.m.f. 6.0 V in series with a 100 kΩ resistor and a switch.

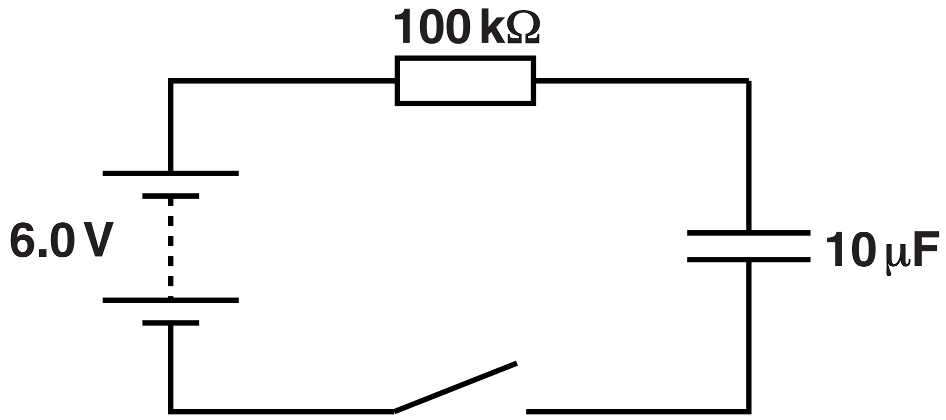


FIG. 4.1

The switch is closed.
Here are some statements about the circuit AFTER the switch has been closed.
Put ticks (✓) in the boxes next to the TWO correct statements.

In the first 10 s the capacitor gains 180 μJ of energy.	☐
In the first 10 s the voltage across the capacitor rises to 3.0 V.	☐
The current in the resistor is a constant 60 μA.	☐
The capacitor becomes fully charged after 1.0 s.	☐
The charges on the plates are equal and opposite.	☐

[2]

5 A student measures the extension of a spring for various weights hung from one end.
Her results are shown in Fig. 5.1.

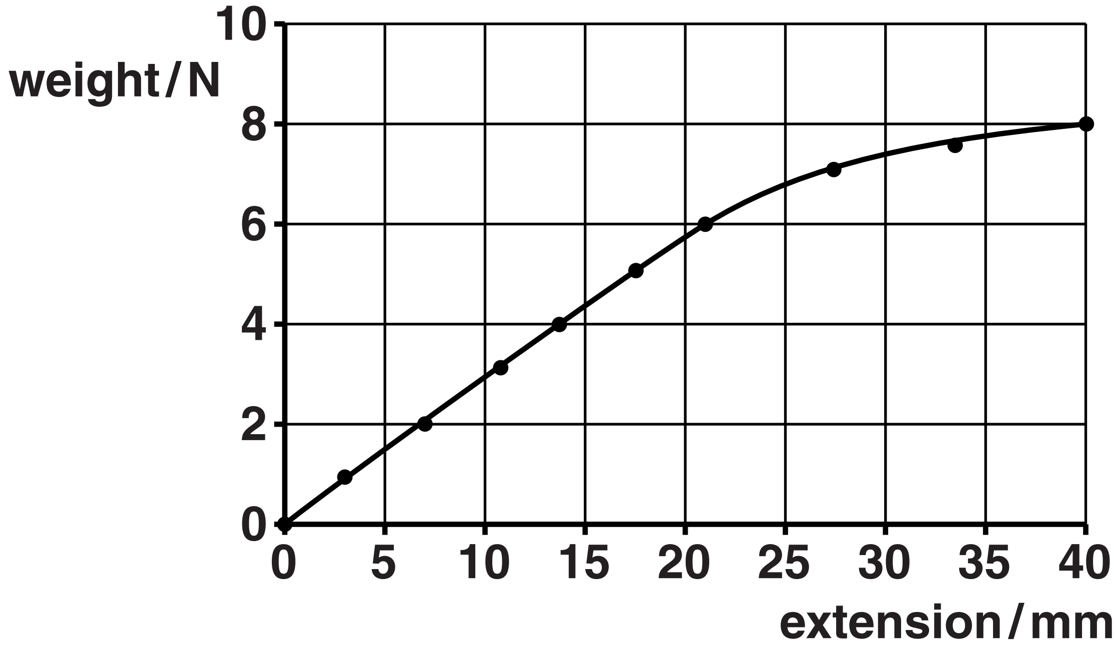


FIG. 5.1

(a) Calculate the energy stored in the spring when it supports a weight of 6.0 N.

energy = ______________________________ J [2]

(b) The 6.0 N weight is displaced vertically from its equilibrium position by 15 mm.
When released, it oscillates.
Suggest why the oscillations are NOT exactly simple harmonic.

[1]

6 **The graph of Fig. 6.1 shows how the gravitational field strength *g* of a uniform sphere of radius *R* varies with the distance *r* from the centre of the sphere.**

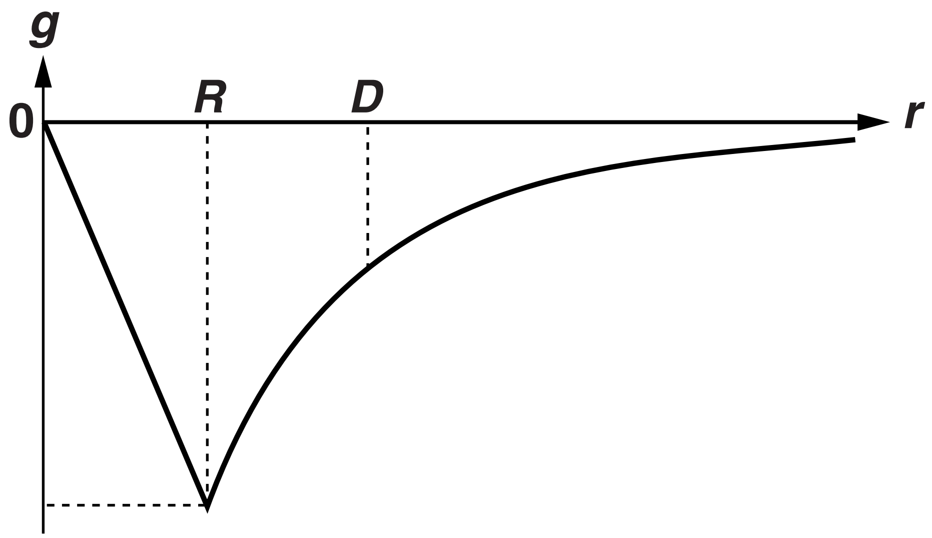


FIG. 6.1

(a) **Shade the area of the graph which could be used to estimate the gravitational potential at a distance *D* from the centre of the sphere.** **[1]**

(b) **Here are some deductions from the graph about the gravitational field.**
Put a tick (✓) next to the ONE correct deduction.

The field strength can never be zero. ☐

The field changes direction at the surface of the sphere. ☐

The field direction is always towards the centre of the sphere. ☐

[1]

7 64 mol of an ideal gas is placed in a container of volume $0.75\,m^3$ at a temperature of $36\,°C$.

(a) Calculate the pressure p of the gas in the container.

$R = 8.3\,J\,mol^{-1}\,K^{-1}$

p = ______________________________ Pa [2]

(b) On the axes of Fig. 7.1, sketch a graph to show how the pressure of an ideal gas varies with its volume at a constant temperature. [2]

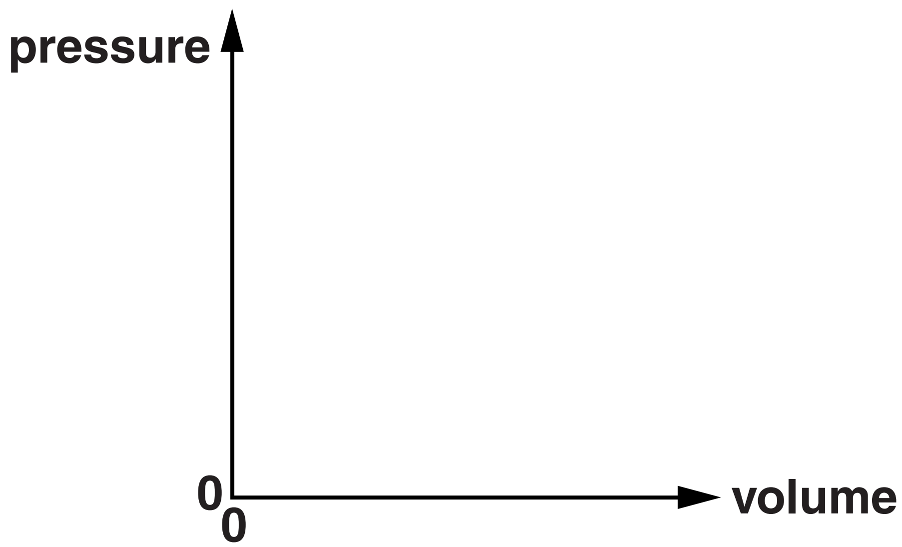


FIG. 7.1

8 **A student uses the apparatus shown in Fig. 8.1 to measure the specific thermal capacity *c* of a block of copper.**

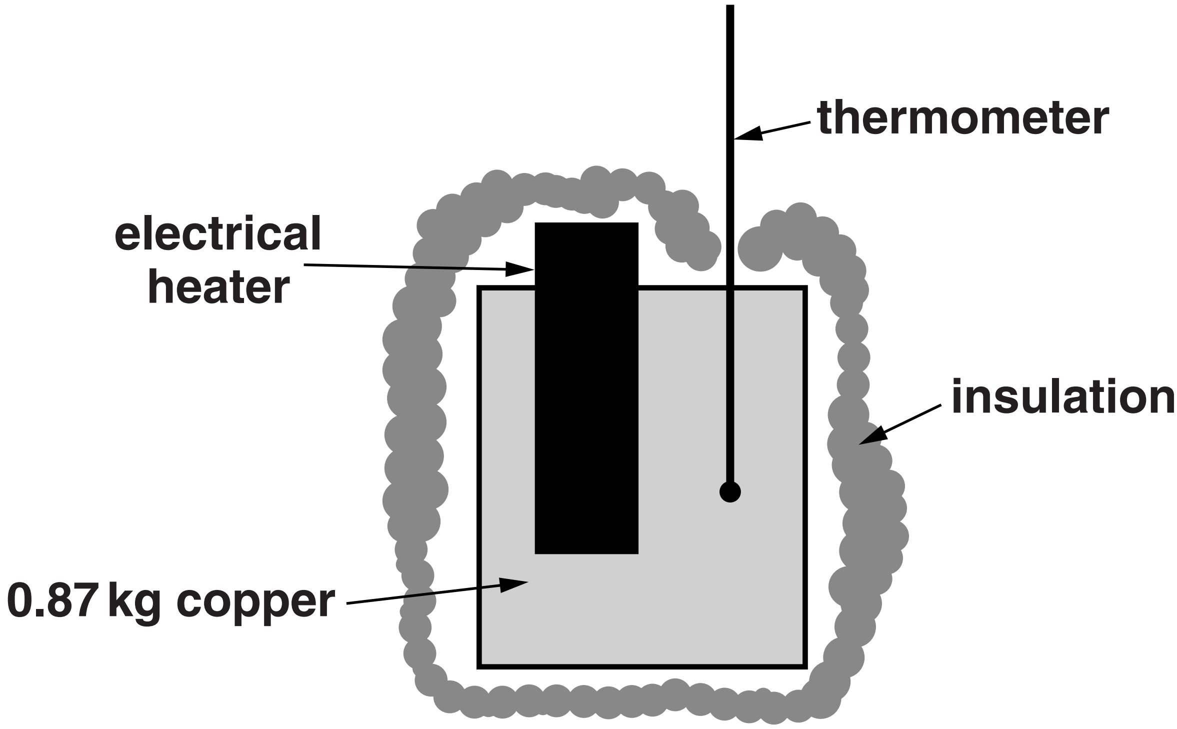


FIG. 8.1

The temperature of the block of mass 0.87 kg rises from room temperature 294 K to 308 K when 5000 J is transferred from the electrical heater.

(a) Calculate a value for the specific thermal capacity *c* of the block.

***c* = ______________________________ J kg^{-1} K^{-1} [1]**

(b) Suggest why the presence of the heater and thermometer means that your answer to (a) is only an approximation.

[1]

9 Charged pions at rest in the laboratory have a measured half-life of 18 ns.
A beam of high-speed charged pions passes through the laboratory.
The half-life of these pions is measured in the laboratory as 54 ns.

(a) Calculate the value of the relativistic factor γ for the charged pions in the beam.

γ = ______________________________ [1]

(b) Calculate the speed *v* of the charged pions in the beam relative to the laboratory. Show your working.

$c = 3.0 \times 10^{8}\,\mathrm{m\,s^{-1}}$

v = ______________________________ $\mathrm{m\,s^{-1}}$ [2]

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SECTION B

10 **This question is about the gravitational field around the Earth, shown in Fig. 10.1.**

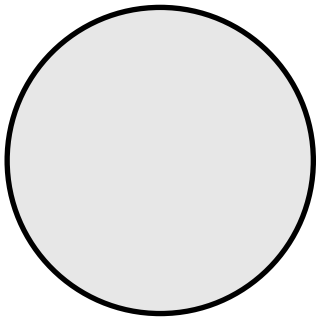

FIG. 10.1

(a) **Draw four arrowed lines on Fig. 10.1 to represent the gravitational field above the Earth's surface.** **[2]**

(b) The gravitational field strength at the Earth's surface, 6.4×10^6 m from its centre, is $9.8\,N\,kg^{-1}$. Show that the mass of the Earth is about 6×10^{24} kg.

$G = 6.7 \times 10^{-11}\,N\,m^2\,kg^{-2}$

[2]

(c) The Moon orbits the Earth, moving in a circle of radius 3.8×10^8 m.

(i) Explain why the value of the centripetal acceleration of the Moon in its orbit is equal to the gravitational field strength of the Earth at that distance.

[2]

(ii) Use the centripetal acceleration of the Moon to calculate the speed of the Moon in its orbit.

speed = ______________________________ $m\,s^{-1}$ [3]

(d) Explain how you could use electromagnetic waves to verify that the radius of the Moon's circular orbit is 3.8×10^8 m.

Your answer should clearly explain how the radius is derived from the measurements.

[3]

[TOTAL: 12]

11 **This question is about the internal energy of steam in a power station.**

(a) **Steam is created in a power station by heating water in the boiler. This is effectively a box containing only liquid water and steam, as shown in Fig. 11.1.**

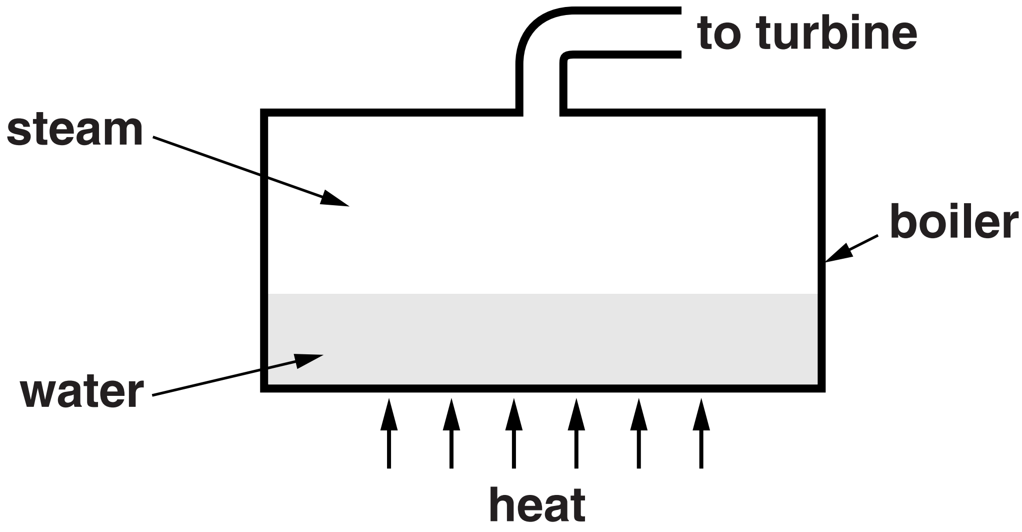

FIG. 11.1

(i) **Explain why the number of molecules N in the steam at temperature T is approximated by**

$$N \propto e^{-\varepsilon/kT}$$

where ε is the energy required to move a molecule from the water to the steam.

[2]

(ii) Show that the pressure *p* of the steam in the boiler at temperature *T* is given by

$$p = CTe^{-\varepsilon/kT}$$

where *C* is a constant. Assume that steam in the boiler behaves like an ideal gas with a constant volume *V*.

[2]

(b) Describe and explain how the energy of a water molecule in steam at a constant temperature changes with time.

Your answer should clearly explain the changes of energy of the water molecule.

[3]

(c) Assuming that steam behaves as an ideal gas, its ENERGY DENSITY, the internal energy E_{int} per unit volume V, is given by

$$\frac{E_{int}}{V} = 3p.$$

(i) Calculate the energy density of the steam as it leaves the boiler at a pressure of 2.2×10^7 Pa.

energy density = ____________________ $J\,m^{-3}$ [1]

(ii) Using (a)(ii) sketch a graph on the axes of Fig. 11.2 to show how the energy density of steam in the boiler varies with temperature.

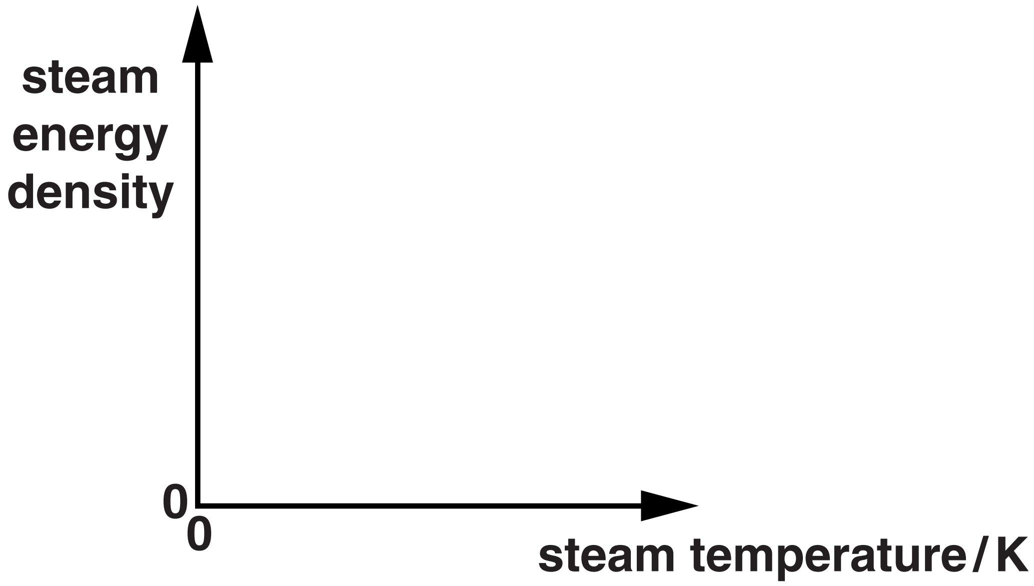

FIG. 11.2 [1]

[TOTAL: 9]

12 This question is about the launch of a rocket.

(a) (i) Use the principle of momentum conservation to explain how an engine ejecting exhaust gases in a downwards direction is able to accelerate a rocket upwards.

[3]

(ii) The rocket engines provide a constant thrust of 3.4×10^7 N. Exhaust gases are ejected downwards from the engines at a rate of 1.3×10^4 kg s^{-1}.

Calculate the speed relative to the engine of the exhaust gases.

speed = ______________________________ m s^{-1} [2]

(iii) The graph of Fig. 12.1 shows how the speed of the rocket changes in the first 150 s of flight.

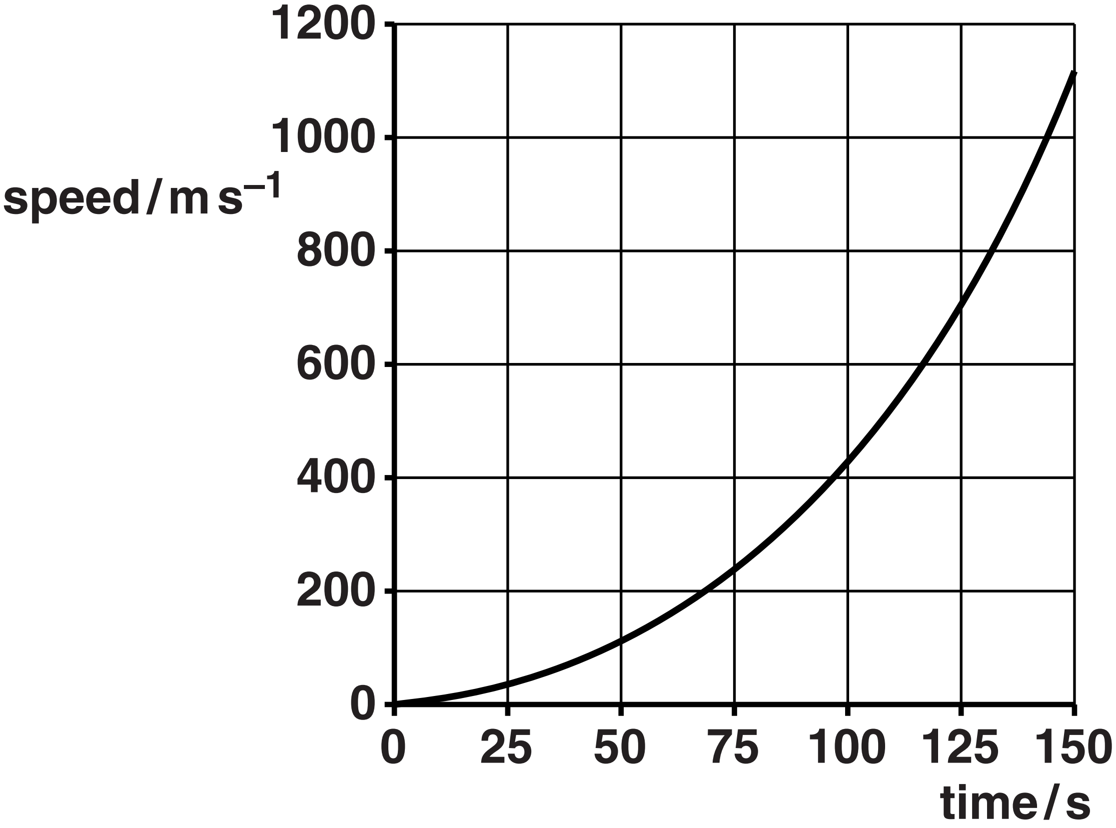

FIG. 12.1

Explain the shape of the graph.

[3]

(b) **Each of the rocket engines combines liquid oxygen and hydrogen in a combustion chamber to produce a gas of water particles at high temperature, as shown in Fig. 12.2.**

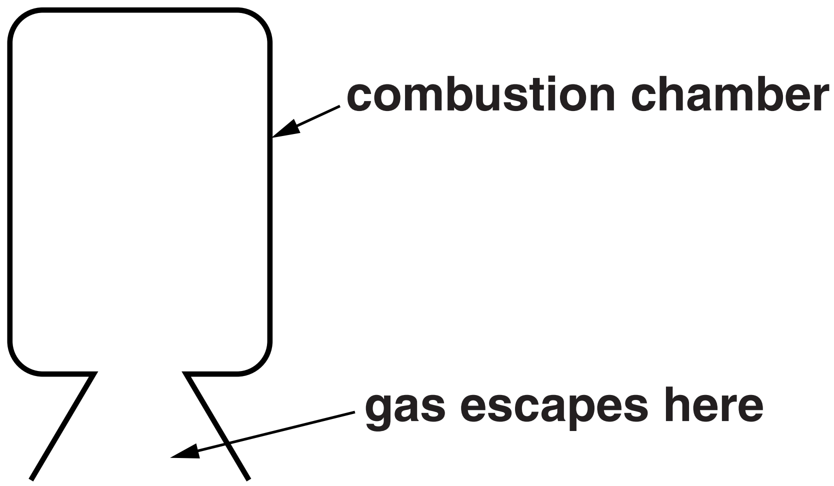

FIG. 12.2

Use kinetic theory to explain how the gas particles at high temperature push the combustion chamber upwards.

[2]

[TOTAL: 10]

13 Fig. 13.1 shows a device which could be used to measure the mass of an object in a zero-gravity environment.

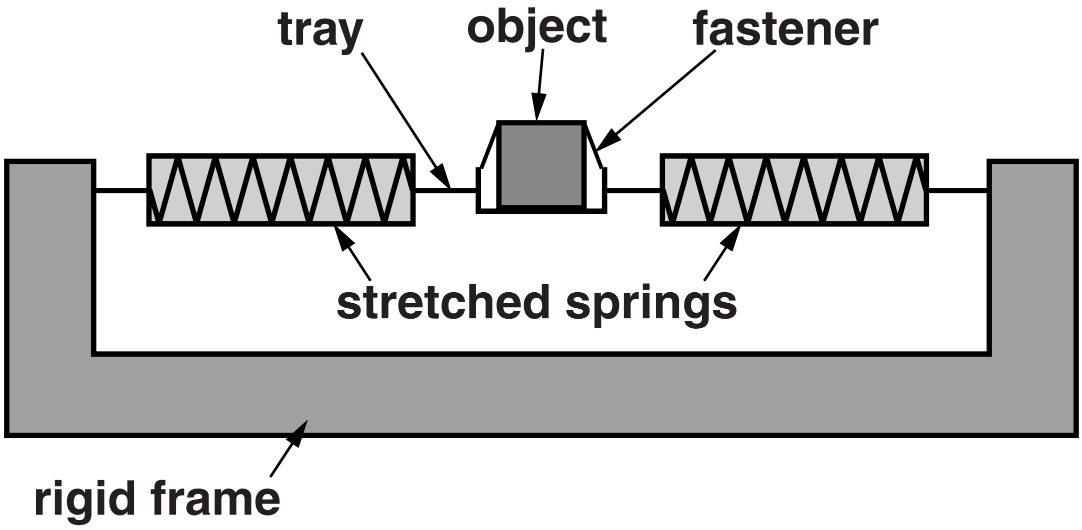

FIG. 13.1

The object is fastened to a tray which is suspended between a pair of identical stretched springs.
The period of sideways oscillation of the object can be used to measure its mass.

The tension T in each spring when the object is in equilibrium is given by

$T = ke$

where e is the equilibrium extension of the spring and k is its force constant.

The object is displaced to the right from equilibrium by a distance $+x$.

(a) By writing down expressions for the tension T_L of the left-hand spring and T_R of the right-hand spring, show that when the object is released its acceleration a is given by

$$a = -\frac{2k}{M}x$$

where M is the total mass of the object, fastener and tray.

[3]

(b) **A mass of 0.24 kg is fastened to the tray, displaced to the right and released.**
The period of subsequent oscillations is 1.6 s.
Show that the mass of the tray and fastener is 0.06 kg.

$k = 2.3\,\mathrm{N\,m^{-1}}$

[2]

(c) **The device is calibrated by measuring the period of oscillation for objects of known mass. On the axes of Fig. 13.2, sketch the expected shape of the calibration curve obtained from this procedure.**

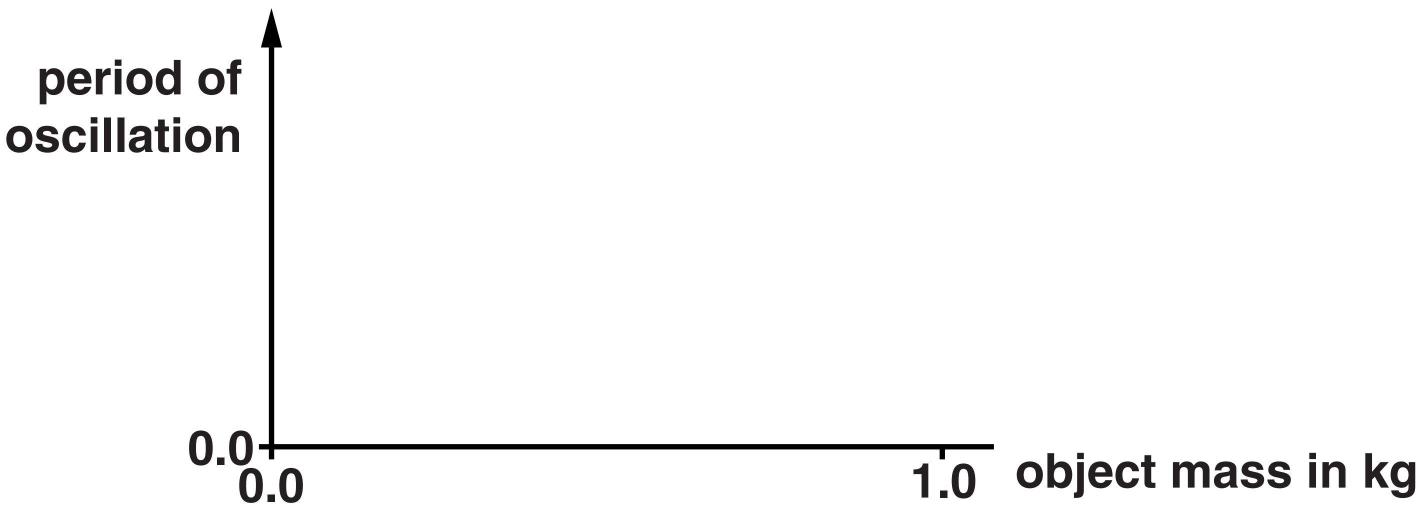

FIG. 13.2

[2]

[TOTAL: 7]

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional answer space is required, you should use the blank page(s) below. The question number(s) must be clearly shown.

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RECOGNISING ACHIEVEMENT