| Candidate forename | | Candidate surname | |
|---|---|---|---|

| Centre number | | | | | | Candidate number | | | | |
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# OXFORD CAMBRIDGE AND RSA EXAMINATIONS

**ADVANCED GCE**

# G494

# PHYSICS B (ADVANCING PHYSICS)

## Rise and Fall of the Clockwork Universe

**MONDAY 27 JUNE 2011: Morning**
**DURATION: 1 hour 15 minutes**

**SUITABLE FOR VISUALLY IMPAIRED CANDIDATES**

**Candidates answer on the question paper.**

**OCR SUPPLIED MATERIALS:**
**Data, Formulae and Relationships Booklet**

**OTHER MATERIALS REQUIRED:**
**Electronic calculator**
**Ruler (cm/mm)**

**READ INSTRUCTIONS OVERLEAF**

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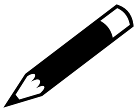
## INSTRUCTIONS TO CANDIDATES

- 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. Pencil may be used for graphs and diagrams only.
- 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. Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- Answer ALL the questions.
- Show clearly the working in all calculations, and give answers to only a justifiable number of significant figures.

## 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.
-  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.
- 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.

**Answer ALL the questions.**

## SECTION A

**1 Here is a list of units.**

$J\,m^{-1}$ $J\,kg^{-1}$ $N\,kg^{-1}$ $N\,m^{-1}$

**(a) Which is a correct unit for gravitational field strength?**

answer ____________________ [1]

**(b) Which has the same unit as force?**

answer ____________________ [1]

**2 A sample of radioactive material contains $1.2 \times 10^{23}$ unstable nuclei.**
**The activity of the sample is $4.8 \times 10^{4}$ Bq.**

**(a) Calculate the decay constant $\lambda$.**

$\lambda$ = ________________ $s^{-1}$ [1]

**(b) Calculate the number of unstable nuclei in the sample after a time interval of four half-lives.**

number = ____________________ [1]

**3** **Here are some statements about a mass on a spring in simple harmonic motion.**
**Only two of them are correct.**
**Put a tick (✓) in the box next to the TWO correct statements.**

| | |
|---|---|
| **The period is doubled as the amplitude is doubled.** | ☐ |
| **The force constant doubles as the mass is doubled.** | ☐ |
| **The force is doubled as the displacement is doubled.** | ☐ |
| **The total energy doubles as the amplitude is doubled.** | ☐ |
| **The force always acts towards the point of zero displacement.** | ☐ |
| **The velocity is always towards the point of zero displacement.** | ☐ |

**[2]**

**4** **A trolley of mass 2.5 kg moves at a speed of $0.84\ m\ s^{-1}$ towards a stationary trolley of mass 0.75 kg, as shown in Fig. 4.1. The trolleys collide and stick together.**

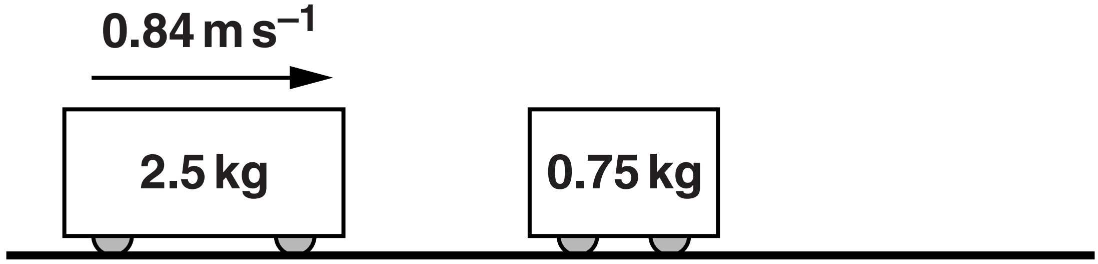



**Fig. 4.1**

**Use the conservation of momentum to calculate the speed *v* of the pair of trolleys after the collision.**

***v*** **= ______________ $m\ s^{-1}$ [2]**

5 Fig. 5.1 shows some equipotential surfaces drawn INSIDE the Earth at equal intervals of potential.

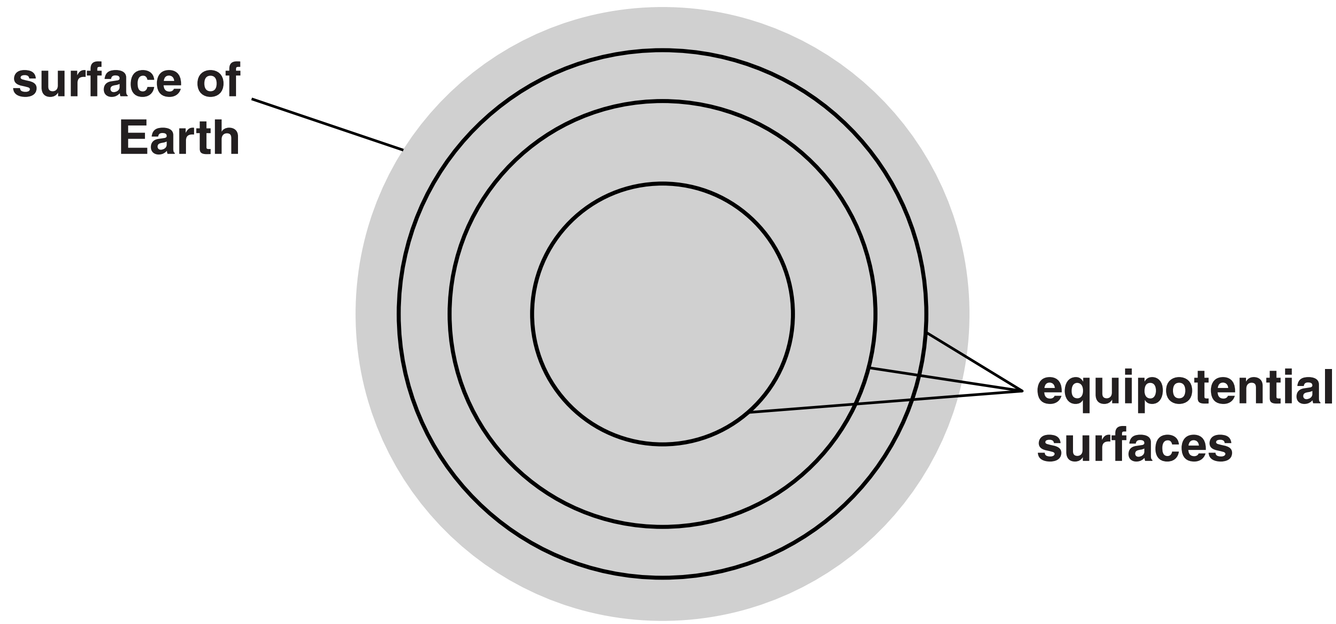



Fig. 5.1

State how the diagram shows that the gravitational field strength falls as you move from the surface towards the centre of the Earth.

[1]

**6** **An electronic watch contains a crystal which oscillates with a period of $3.1 \times 10^{-5}$ s.**
**The crystal can be modelled as a mass of $6.8 \times 10^{-7}$ kg held in place by a spring.**

**Calculate the force constant $k$ of the spring.**

**$k$ = ____________ $N\,m^{-1}$ [3]**

7 The graph of Fig. 7.1 shows how the displacement of a pendulum varies with time.

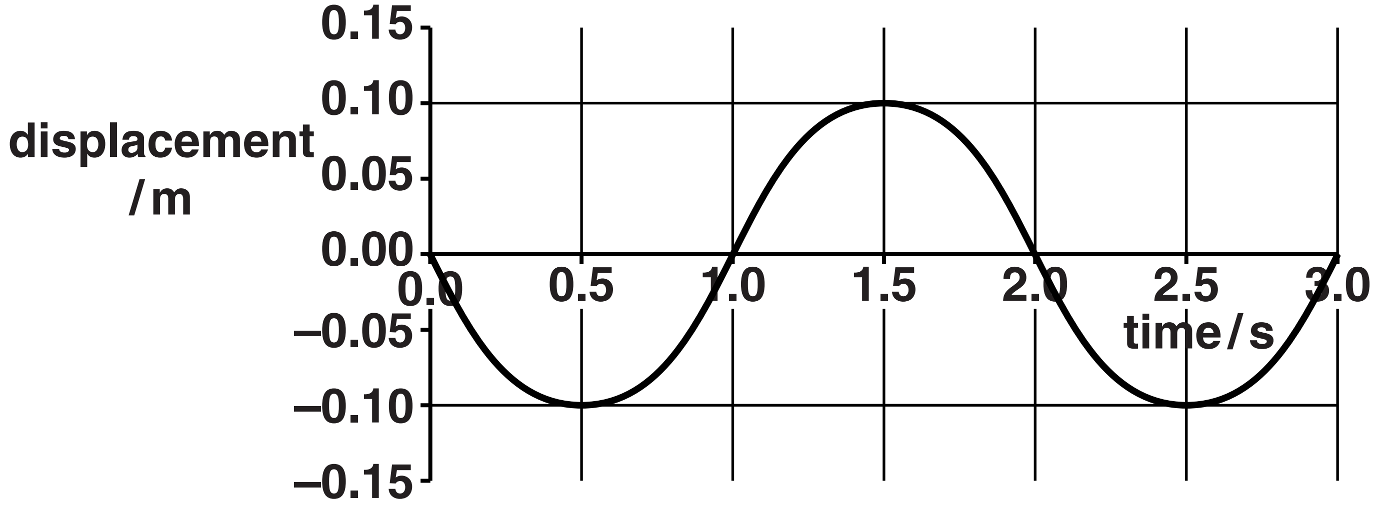



Fig. 7.1

(a) Which of the following equations describes how the displacement, $x$, varies with time, $t$? Put a ring around the correct equation.

$x = -0.1 \sin(\pi t)$  $x = -0.2 \cos(\pi t)$

$x = +0.1 \sin(\pi t)$  $x = +0.2 \cos(\pi t)$

[1]

(b) State one time when the magnitude of the ACCELERATION of the pendulum is a maximum.

______________ s [1]

**8** **A satellite in orbit around Mars uses pulses of light to map the surface of the planet.**

**(a)** **The satellite emits a brief pulse of light towards the surface.**
**The satellite detects a reflected pulse after a time delay of 840 μs.**

**Calculate the distance *d* of the planet surface below the satellite.**

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

$d$ = ______________ **m [1]**

**(b)** **State an assumption you have made in your calculation in (a).**

**[1]**

**(c)** **Suggest how the satellite could use the pulses of light to check whether the altitude of its orbit was decreasing gradually.**

**[1]**

9 A sealed glass bottle has a volume of $7.6 \times 10^{-4}\,m^3$.

(a) The bottle contains air at a pressure of $1.2 \times 10^5\,Pa$ at a temperature of 15 °C.

Calculate the number of particles in the bottle.

Boltzmann constant $k = 1.4 \times 10^{-23}\,J\,K^{-1}$

$N =$ ______________________ [2]

(b) On the axes of Fig. 9.1, sketch a graph to show how the pressure $P$ of the gas in the bottle varies with kelvin temperature $T$. Assume the air behaves as an ideal gas. [1]


Fig. 9.1

[Section A Total: 20]

## SECTION B

10 This question is about using the Moon as a source of raw materials for use on the Earth.
It has been proposed to launch metal extracted from ores on the Moon's surface towards the Earth by a cannon.

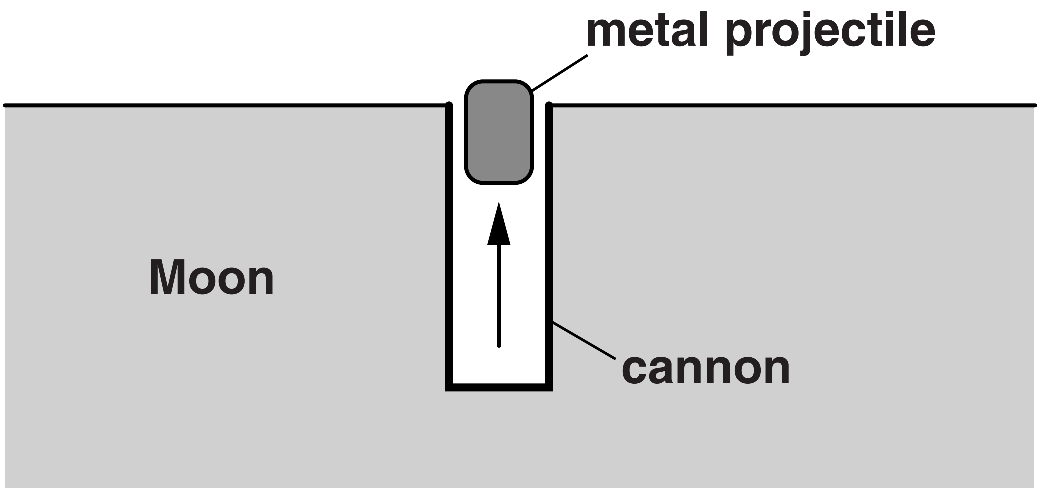



Fig. 10.1

(a) The metal projectile is subjected to a steady resultant force of $5.80 \times 10^7$ N for a time of 0.100 s by the cannon, starting from rest.
The mass of the projectile is $2.50 \times 10^3$ kg.

(i) By calculating the momentum of the projectile as it leaves the cannon, show that the projectile has a kinetic energy of $6.73 \times 10^9$ J as it leaves the cannon.

[3]

**(ii) By calculating the gravitational potential energy of the projectile at the surface of the Moon show that the TOTAL energy of the projectile as it leaves the cannon is about $-6 \times 10^{8}$ J.**
**Ignore the effect of the Earth.**

**mass of Moon = $7.4 \times 10^{22}$ kg**

**radius of Moon = $1.7 \times 10^{6}$ m**

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

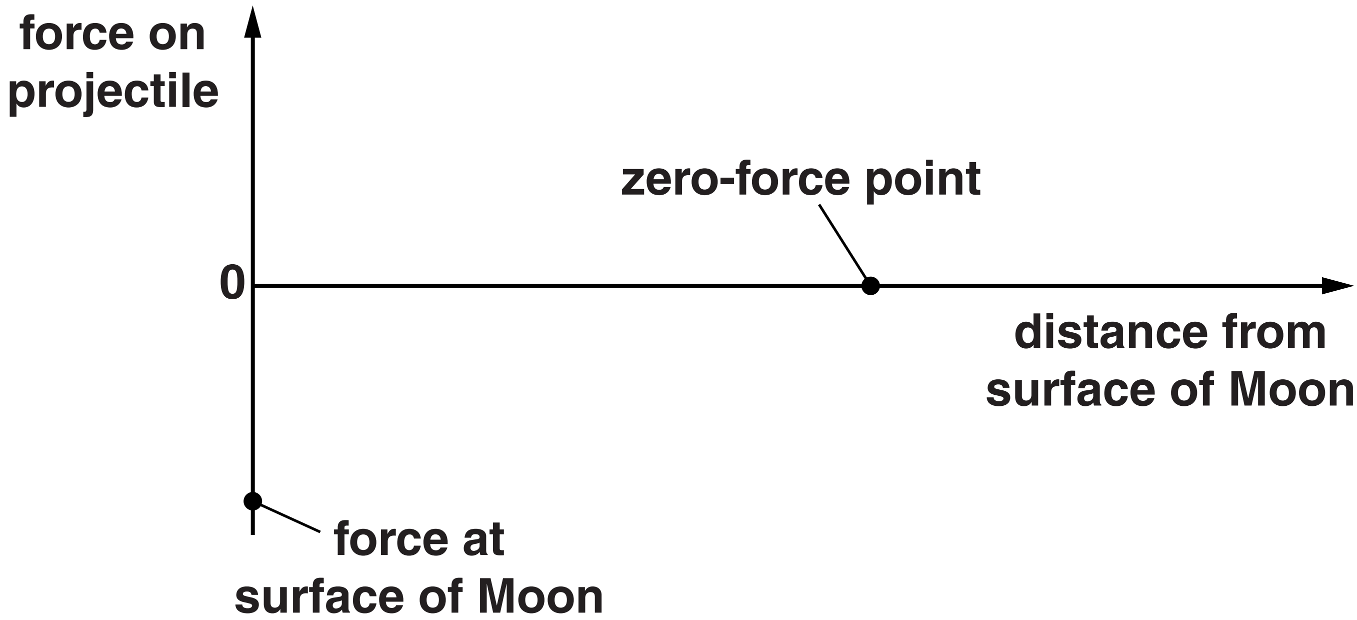
**[2]**

(b) The projectile is just able to reach the ZERO-FORCE POINT between the Moon and the Earth. This is where the gravitational force of the Earth is equal and opposite to that of the Moon.

(i) At the zero-force point, the gravitational force of the Moon on the projectile is 9.0 N. Calculate the distance of the zero-force point from the centre of the Moon.

distance = ______________ m [2]

(ii) On the axes of Fig. 10.2, sketch how the gravitational force on the projectile varies as the projectile moves from the surface of the Moon towards the Earth.




[2]

Fig. 10.2

**(c) The calculations in (a) which ignore the presence of the Earth suggest that the projectile does not have enough kinetic energy to reach the zero-force point. Explain how the presence of the Earth does allow the projectile to reach the zero-force point.**

**[2]**

**[Total: 11]**

**11** This question is about modelling exponential decays.

Fig. 11.1 shows a circuit used for investigating capacitor discharge. The switch is moved from position 1 to position 2 and the p.d. readings obtained at 20 s intervals are recorded in the table.

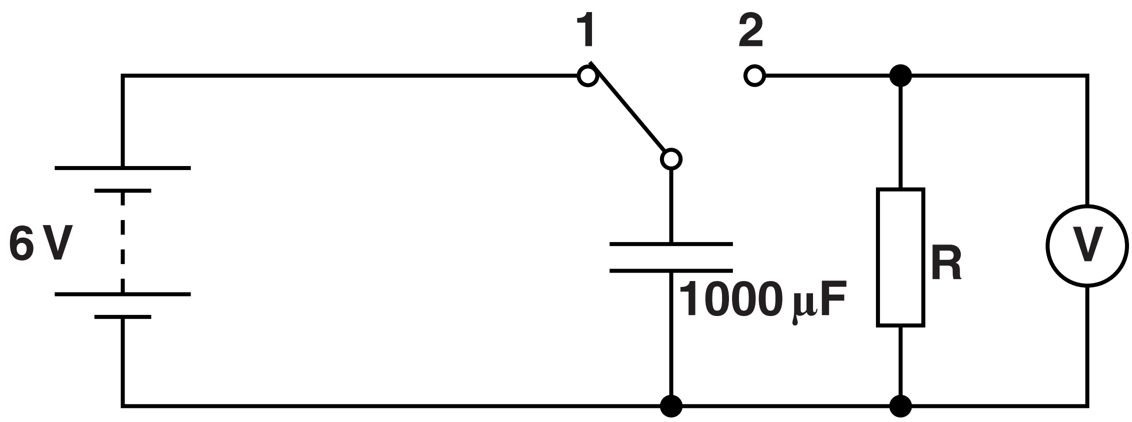
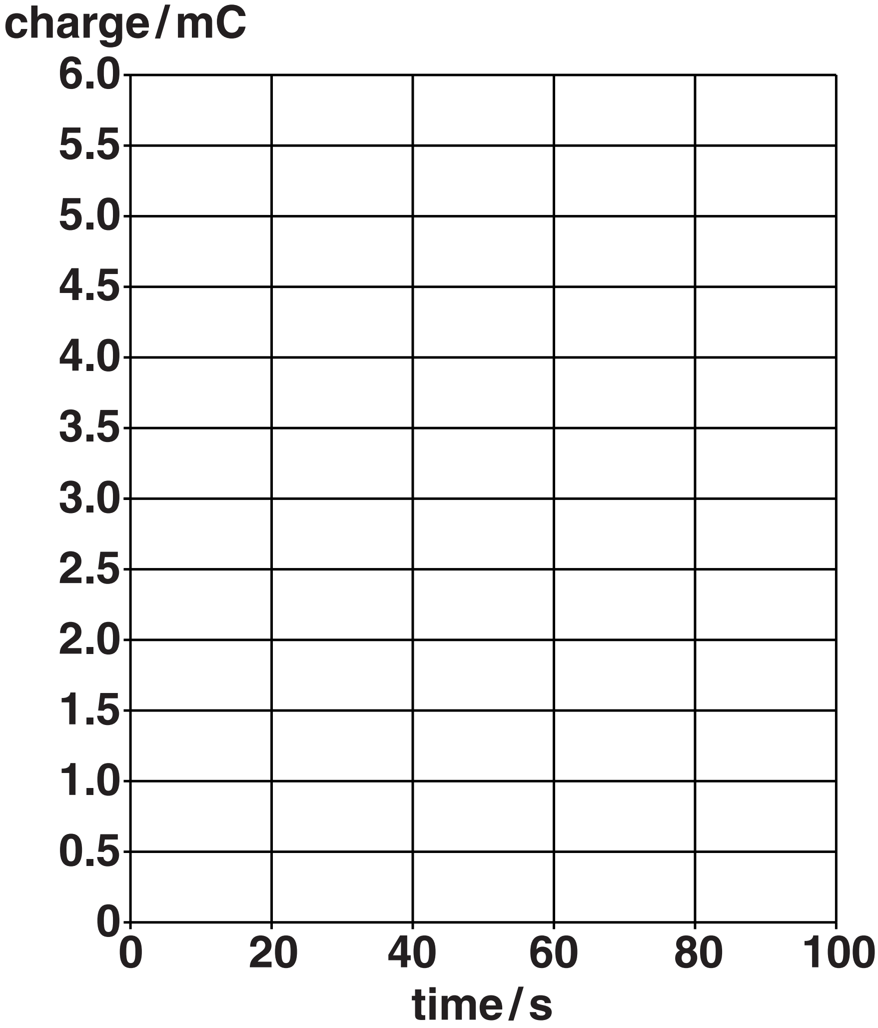



**Fig. 11.1**

| *t* / s | p.d. / V | charge / mC |
|---|---|---|
| 0 | | |
| 20 | 3.5 | 3.5 |
| 40 | 2.1 | 2.1 |
| 60 | 1.2 | 1.2 |
| 80 | 0.7 | 0.7 |

**(a) (i)** Complete the table by filling in the values for p.d. and charge when $t = 0$ s. **[1]**

(ii) On the axes of Fig. 11.2, plot a graph of the data in the table.




[2]

Fig. 11.2

(iii) Use the data or graph to show that $R$ is 38 kΩ.

[2]

**(b)** **In an attempt to model the discharge of the capacitor, a student uses the equation**

$$\Delta Q = -\frac{Q}{RC}\Delta t.$$

**The equation allows a series of values of charge $Q$ to be calculated at equal time steps $\Delta t$.**

**(i)** **Use the equation to complete the table below. The value of the time step $\Delta t$ has been chosen as 20 s.**

| $t$ / s | $Q$ / mC | $\Delta Q = -\frac{Q}{RC}\Delta t$ / mC |
|---|---|---|
| 20 | 3.50 | –1.84 |
| 40 | 1.66 | |
| 60 | | |
| 80 | | |

**[2]**

**(ii) The values of charge calculated above are in poor agreement with the ones obtained from the experiment. Explain the cause of this discrepancy.**

***Your answer should clearly link the model to the discrepancy.***

**[3]**

**[Total: 10]**

12 This question is about deriving the equation

$PV = \frac{Nm}{3}\overline{c^2}$ for an ideal gas.

Although the usual model considers particles in a rectangular box, a student chooses to model an ideal gas as follows:

- the gas is in a spherical container of radius *r*
- each particle has mass *m* and speed *v*
- all particles move at right angles to the walls of the container

(a) Fig. 12.1 shows a single particle approaching the container wall.

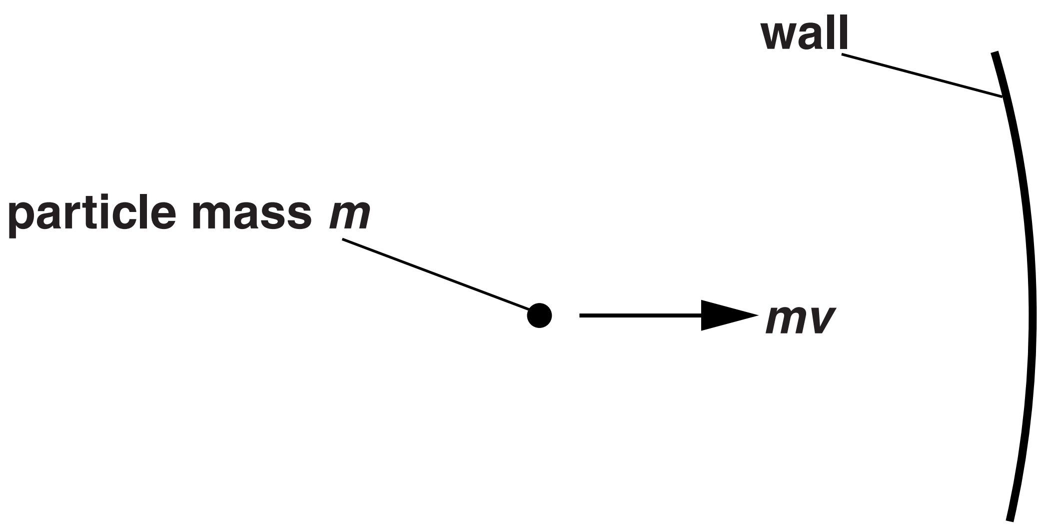



Fig. 12.1

(i) The arrow on Fig. 12.1 represents the momentum of the particle before it hits the wall. Draw another arrow to represent the momentum of the particle AFTER it has hit the wall. [1]

**(ii) Explain why the change of momentum $\Delta p$ of the wall when the particle bounces off it is given by $\Delta p = 2mv$, towards the right.**

**[2]**

**(iii) Explain why the number of times $n$ that the particle bounces off the same point on the wall in each second is given by $n = \frac{v}{4r}$.**

**The radius of the sphere is $r$.**

**[1]**

**(b)** The force $F$ on the wall due to a single particle is given by

$$F = n\Delta p = \frac{mv^2}{2r}.$$

The student then considers the effect of all $N$ particles in the container, so that bounces are evenly spread over a hemisphere, as shown in Fig. 12.2.

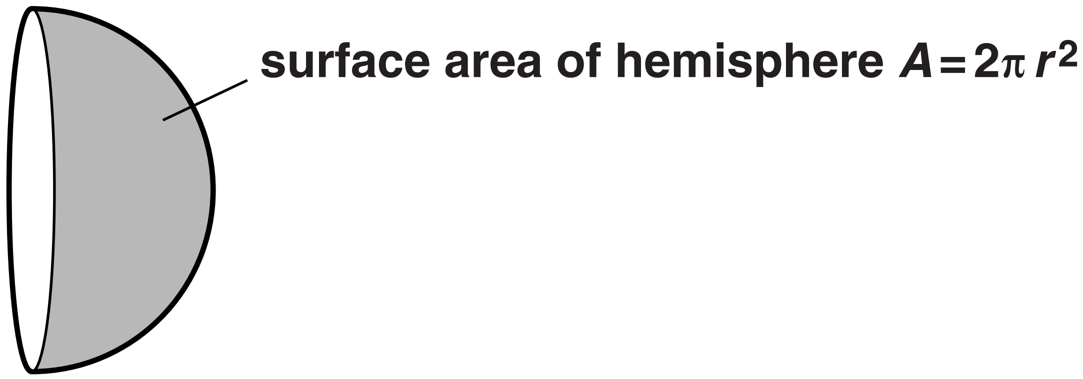



Fig. 12.2

**(i)** Show that the pressure $P$ on the wall of the container is given by

$$P = \frac{Nm}{3V} v^2$$

where $V = \frac{4}{3}\pi r^3$ is the volume of the spherical container.

**[3]**

**(ii) Although the student's model produces the correct relationship, many aspects of it are unrealistic. Describe three assumptions of this model that are unrealistic.**

***Your answer should have correct spelling, punctuation and grammar.***

**[3]**

**[Total: 10]**

**13** **This question is about using the Boltzmann factor to explain a property of liquid ethanol.**
**The fluidity $\phi$ of ethanol is a measure of how easily it flows.**
**The table shows how the fluidity of ethanol varies with temperature.**

| temperature / K | fluidity / $N^{-1}m^2s^{-1}$ |
|---|---|
| 273 | 530 |
| 298 | 920 |
| 323 | 1500 |
| 348 | 2200 |

**(a)** **Perform a test on the data in the table to show that the fluidity does NOT increase exponentially with temperature. Show your method clearly.**

**[2]**

**(b) Liquid ethanol can be modelled as particles very close to one another, with the liquid only able to change its shape when particles break free from their neighbours and move to a different place. This allows the variation of fluidity $\phi$ with temperature $T$ to be modelled with the Boltzmann factor, leading to the relationship**

$$\phi = \phi_0 e^{-\frac{\varepsilon}{kT}}.$$

**(i) In this model, what is the quantity $\varepsilon$ in the relationship $\phi = \phi_0 e^{-\frac{\varepsilon}{kT}}$?**

**[1]**

**(ii) In this model, what is the quantity $kT$ in the relationship $\phi = \phi_0 e^{-\frac{\varepsilon}{kT}}$?**

**[1]**

(iii) On the axes of Fig. 13.1, sketch a graph for

$\phi = \phi_0 e^{-\frac{\varepsilon}{kT}}$.


**[3]**

Fig. 13.1

(c) Explain how the Boltzmann factor accounts for the way that the fluidity of ethanol increases with temperature.

**[2]**

**[Total: 9]**

**[Section B Total: 40]**

**END OF QUESTION PAPER**

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