Rewarding Learning

**ADVANCED**
**General Certificate of Education**
**2017**

Centre Number

Candidate Number

# Physics

## Assessment Unit A2 1

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

**[AY211]**

*AY211*

**WEDNESDAY 21 JUNE, MORNING**

**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.
**You must answer the questions in the spaces provided.**
**Do not write outside the boxed area on each page or on blank pages.**
Complete in black ink only. **Do not write with a gel pen.**
Answer **all eight** questions.

**INFORMATION FOR CANDIDATES**

The total mark for this paper is 90.
Quality of written communication will be assessed in Question **2(b)(i)**.
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.

**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.**

**1** The pressure law relates the pressure of a gas to its temperature.

**(a)** State the pressure law.

______________________________________________________________

______________________________________________________________ [2]

**(b)** The results from an experiment to investigate this law are shown in the graph of pressure p against temperature θ in **Fig. 1.1**.

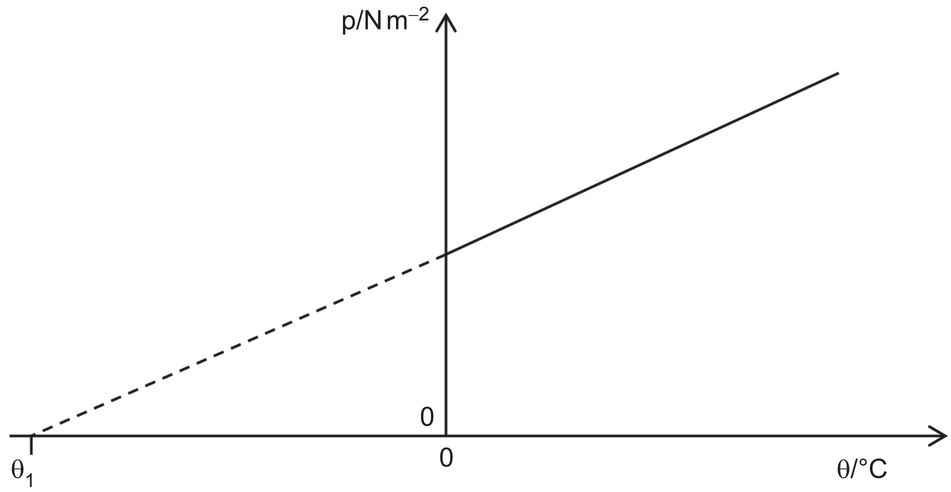


**Fig. 1.1**

Assume the gas behaves ideally.

**(i)** State the numerical value of $\theta_1$.

$\theta_1$ = ______________ °C [1]

**(ii)** State the name given to this value of temperature and describe the motion of the molecules within the gas at this temperature.

______________________________________________________________

______________________________________________________________

______________________________________________________________ [2]

**(c)** A bubble of air rises from the bottom of a lake, where the temperature is 3 °C, to the top of the lake, where the temperature is 12 °C. The pressure at the bottom of the lake is four times the pressure at the top of the lake.

Calculate the percentage increase in the volume of the bubble as it rises from the bottom to the top of the lake.

Percentage increase in volume ________________ % [4]

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

**2** **(a)** The specific heat capacity of aluminium is 900 J kg$^{-1}$ K$^{-1}$. Explain the meaning of this statement.

_______________________________________________________________

_____________________________________________________________ [1]

**(b)** A student carries out an experiment to determine the specific heat capacity of aluminium by an electrical method. The student sets up the apparatus shown in **Fig. 2.1**.

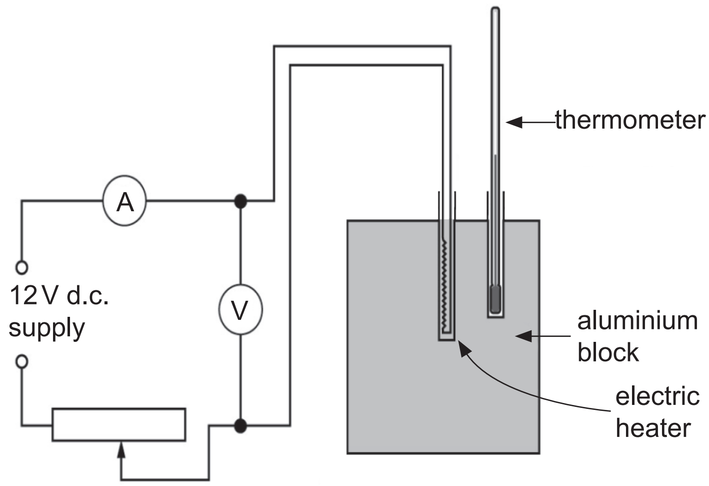


**Fig. 2.1**

**(i)** Outline the procedure the student should employ and explain how the results taken are used to determine the specific heat capacity of the aluminium block.

_______________________________________________ [3]

Quality of written communication [2]

**(ii)** Comment on whether the result obtained for the specific heat capacity of aluminium, using the equipment in **Fig. 2.1**, would be higher or lower than the actual value of 900 J $kg^{-1}$ $K^{-1}$. Explain your answer fully.

_______________________________________________ [2]

**(c)** **(i)** A man hiking in the countryside stops to have a drink of coffee in a metal mug. The mug has a mass of 120 g and is made from aluminium. He pours 250 g of hot coffee, at a temperature of 72.0 °C, from a flask into the mug. What is the highest temperature reached by the mug?
The mug is initially at a temperature of 14.2 °C and the specific heat capacity of coffee can be assumed to be 4190 J $kg^{-1}$ $K^{-1}$.
(The specific heat capacity of aluminium is 900 J $kg^{-1}$ $K^{-1}$)

Highest temperature reached by mug ______________________ °C [3]

**(ii)** Explain why the correct answer to **(c)(i)** is closer to the initial temperature of the coffee (72.0 °C) than the initial temperature of the mug (14.2 °C).

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

_______________________________________________________________ [2]

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3 (a) **Fig. 3.1** shows an object being forced to move in a horizontal circle with constant linear speed.

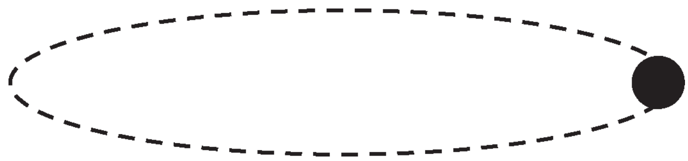

**Fig. 3.1**

Explain why the object accelerates although moving with a constant linear speed.

______________________________________________

______________________________________________

______________________________________________ [2]

**(b)** A pilot of mass 90 kg flies a light aircraft of mass 735 kg. The two forces acting on the aircraft are the weight W and the lift force L as shown in **Fig. 3.2**. The pilot must fly the aircraft at an angle of 60°, at a constant linear speed of 56 m $s^{-1}$, in order to gain the lift required to fly in a horizontal circle of radius R metres.

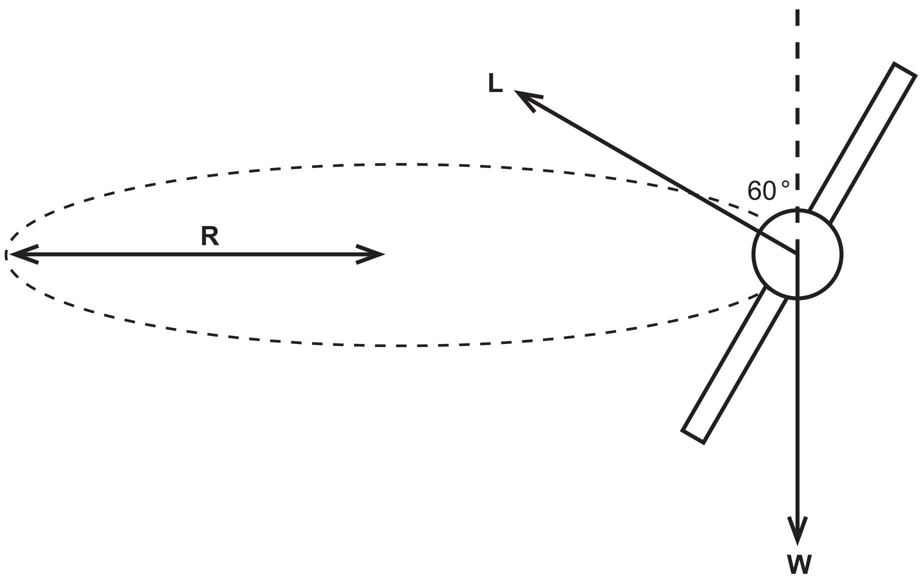


**Fig. 3.2**

**(i)** Determine the lift force L acting on the aircraft.

L = ______________ N [2]

**(ii)** Hence determine the acceleration of the aircraft towards the centre of the circle.

Acceleration = ______________ m s$^{-2}$ [3]

**(iii)** Calculate the radius R of the path of the aircraft.

R = ______________ m [2]

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**4** **(a)** Define simple harmonic motion.

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________ [2]

**(b)** Tidal motion can be considered as simple harmonic. The port where a ship must dock has a depth of 15 m at high tide, which occurs at 10.00 am and a depth of 6 m at low tide, which occurs at 4.00 pm. The minimum depth required for the ship to dock is 11 m. The situation is illustrated in **Fig. 4.1**.

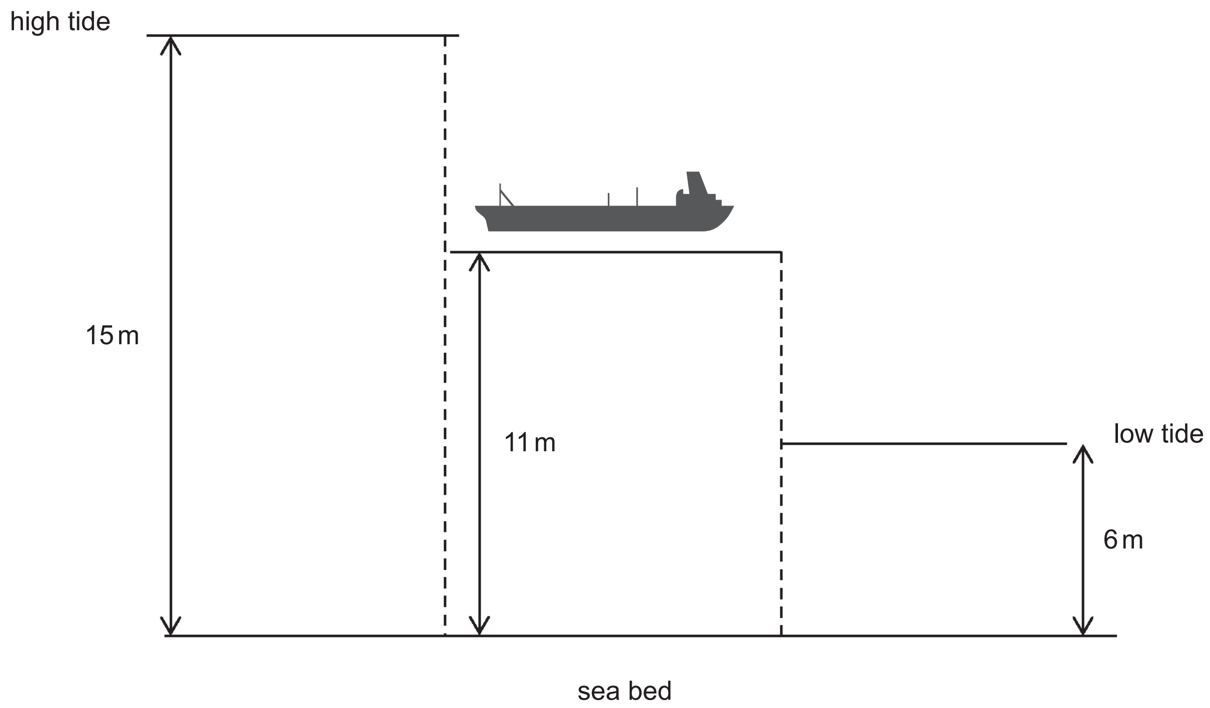


**Fig. 4.1**

What is the latest time that a ship requiring a depth of 11 m can dock?

Latest time ________________ [7]

[Turn over

**5 (a)** A stationary radioactive isotope of bismuth, mass 210 u, decays by the emission of an alpha particle of mass 4 u. The emitted alpha particle has a kinetic energy of $1.30 \times 10^{-12}$ J.

Determine the recoil velocity of the radioactive nucleus.

Recoil velocity ________________ m $s^{-1}$ [4]

**(b)** Alpha particles were used in an experiment carried out by Geiger and Marsden in 1909 to establish the nuclear model of the atom.

**(i)** Correctly label the diagram in **Fig. 5.1** as required in boxes 1, 2, 3 and 4.

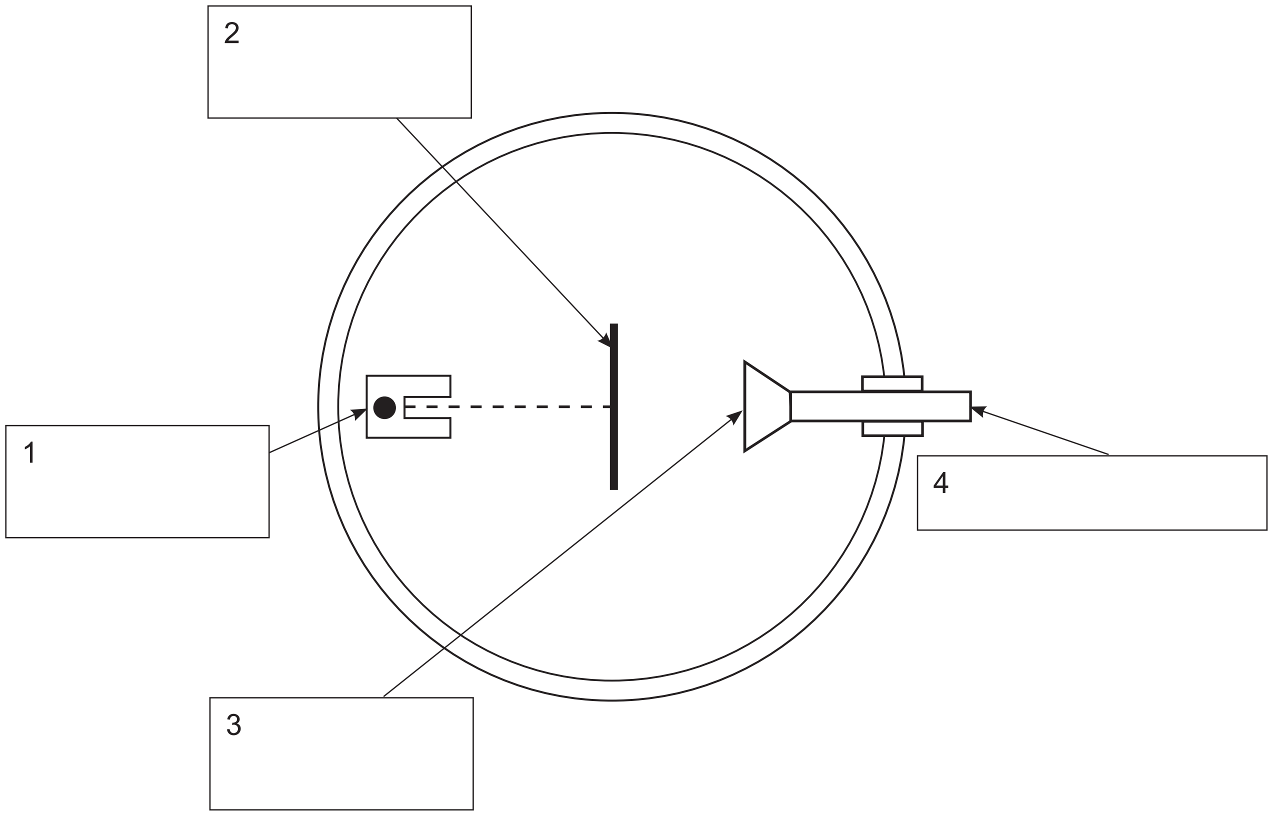


**Fig. 5.1**

[2]

**(ii)** One of the observations from the experiment was that very few alpha particles (1 in 8000) were backscattered. State fully the conclusions to which this observation led.

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

____________________________________________________________________ [2]

**[Turn over**

**6 (a) (i)** What is meant by the radioactive decay of a nucleus?

______________________________________________

______________________________________________ [1]

**(ii)** Radioactive isotopes decay according to **Equation 6.1** and **Equation 6.2** which are stated in your Data and Formulae Sheet.

$$A = A_0\, e^{-\lambda t} \qquad \textbf{Equation 6.1}$$

$$A = \lambda N \qquad \textbf{Equation 6.2}$$

Complete **Table 6.1**, identifying the symbols and stating their S.I. unit where appropriate.

**Table 6.1**

| Symbol | Quantity | S.I. Unit |
|---|---|---|
| A | | |
| $\lambda$ | | |
| N | | |

[3]

**(iii)** On **Fig. 6.1** sketch the graph you would expect to obtain if the value of **A** was plotted against time **t** for any isotope obeying **Equation 6.1**.


**Fig. 6.1**

[1]

**(b)** In the late 1940s, Willard Libby developed a method to determine the age of an object containing organic material. This method is known as carbon-14 dating and is based on the fact that all living organisms absorb carbon from the atmosphere. When the organism dies it stops absorbing carbon from the atmosphere and the amount of carbon-14 it contains starts to decrease as a result of the decay process.

The half-life of carbon-14 is approximately 5700 years and the activity per kg of living material containing carbon can be assumed to be 250 counts per second.

Estimate the age of a piece of wood, of mass 2.15 g, which has an activity of 136 counts per hour.

Age = ______________ years [4]

**7** **(a)** In 1905 Einstein put forward his theory of special relativity. According to his theory, mass and energy were equivalent as shown in the equation **E** = ∆**mc²**.

**(i)** Explain what is meant by the **mass defect, ∆m** of an atomic nucleus.

_______________________________________________

_______________________________________________ [1]

**(ii)** Explain what is meant by the **binding energy, E** of a nucleus.

_______________________________________________

_______________________________________________ [1]

**(iii)** Use the data in **Table 7.1** to determine the binding energy of the helium-4 nucleus ($^{4}_{2}He$).

**Table 7.1**

| | |
|---|---|
| Mass of helium nucleus | 4.00150 u |
| Mass of proton | 1.00728 u |
| Mass of neutron | 1.00867 u |

Binding energy = ______________ MeV [4]

**(b)** Nuclear fusion reactions occur in the Sun. The reactions that occur in the Sun can be summarised by **Equation 7.1**.

$$4\,{}^{1}_{1}\text{H} \rightarrow {}^{4}_{2}\text{He} + \text{other products} + \text{energy} \qquad \textbf{Equation 7.1}$$

**(i)** Explain what is meant by nuclear fusion and state the conditions required for this to occur.

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________ [3]

**(ii)** The mass of the Sun is $1.99 \times 10^{30}$ kg with a surface temperature of 5780 K. It radiates energy at a constant rate of $3.75 \times 10^{26}$ W due to the process of nuclear fusion.
Calculate how long it would take for 0.65% of its mass to be lost during this process.
(1 year = $3.16 \times 10^{7}$ s)

Time = ________________ years [3]

**[Turn over**

**(iii)** Show that the root mean square (r.m.s.) speed of a hydrogen atom on the surface of the sun is $1.2 \times 10^4\,\text{m s}^{-1}$.

(Atomic mass of hydrogen $= 1.67 \times 10^{-27}\,\text{kg}$).

[2]

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**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.**

## Atwood Machine

Mathematician, George Atwood, invented the Atwood machine in 1784. It is a simple machine used to verify Newton's second law of motion and consists of two different masses $\mathbf{m_1}$ and $\mathbf{m_2}$, where $\mathbf{m_2} > \mathbf{m_1}$, connected by a light inextensible string of negligible mass over a frictionless pulley. This is illustrated in **Fig. 8.1**.

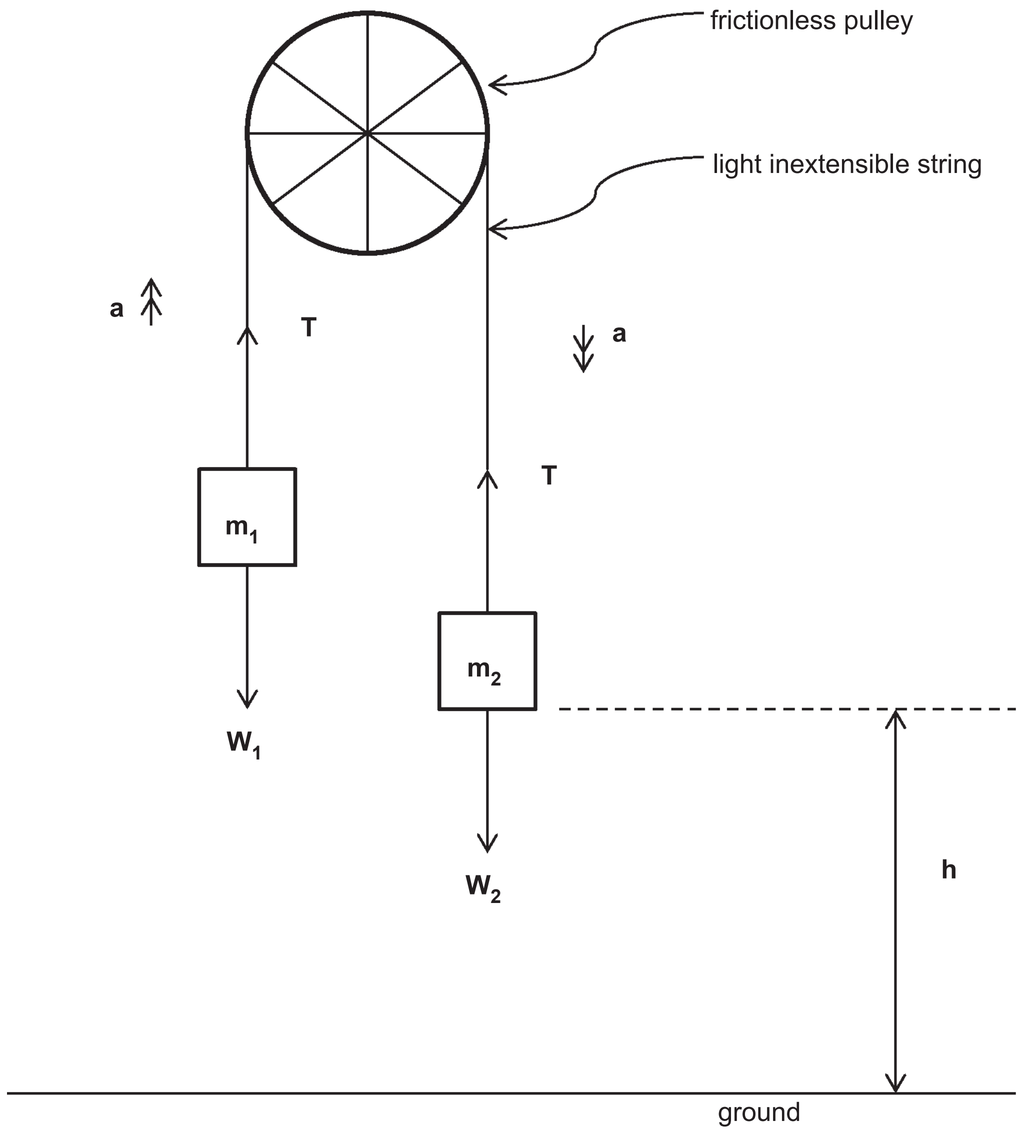



**Fig. 8.1**

The masses are released from **rest** and the acceleration **a** of both masses is determined by recording the time taken **t** for mass $\mathbf{m_2}$ to fall through a distance **h** to the ground. **h** is kept constant at **1.50 m** throughout the experiment. This is repeated three times to obtain an average time for each combination of masses. The sum of the masses $(\mathbf{m_1 + m_2})$ is kept constant but the difference $(\mathbf{m_2 - m_1})$ is varied. This is achieved by removing mass from $\mathbf{m_1}$ and adding it to $\mathbf{m_2}$ each time. The tension in the light inextensible string is **T** newtons.

The acceleration of the masses is given by **Equation 8.1**.

$$a = \frac{(m_2 - m_1)Q}{(m_1 + m_2)} \quad \textbf{Equation 8.1}$$

where **Q** is a constant.

**(a)** Apply Newton's second law in the form F = ma to each mass and show how **Equation 8.1** can be obtained. State the value of the constant **Q**.

**Q** = ______________ [4]

**[Turn over**

**(b)** **Table 8.1** gives a set of results for the time taken **t** for mass $\mathbf{m_2}$ to fall through distance **1.50 m**. The sum of the masses is kept constant at **500 g**.

**Table 8.1**

| $m_2$/g | $m_1$/g | $(m_1 + m_2)$/g | $(m_2 - m_1)$/g | t/s | | | | $t^2$/__ | $2h/t^2$/__ |
|---|---|---|---|---|---|---|---|---|---|
| | | | | $t_1$ | $t_2$ | $t_3$ | $t_{av}$ | | |
| 310 | 190 | 500 | 120 | 1.13 | 1.13 | 1.11 | | | |
| 300 | 200 | 500 | 100 | 1.21 | 1.24 | 1.20 | | | |
| 290 | 210 | 500 | 80 | 1.37 | 1.39 | 1.36 | | | |
| 280 | 220 | 500 | 60 | 1.58 | 1.55 | 1.57 | | | |
| 270 | 230 | 500 | 40 | 1.94 | 2.00 | 1.96 | | | |
| 260 | 240 | 500 | 20 | 2.99 | 2.97 | 3.03 | | | |

**Equation 8.1** can be written in terms of **h** and **t**, as shown in **Equation 8.2**.

$$2\,(m_1 + m_2)\,h = (m_2 - m_1)\,Qt^2 \quad \textbf{Equation 8.2}$$

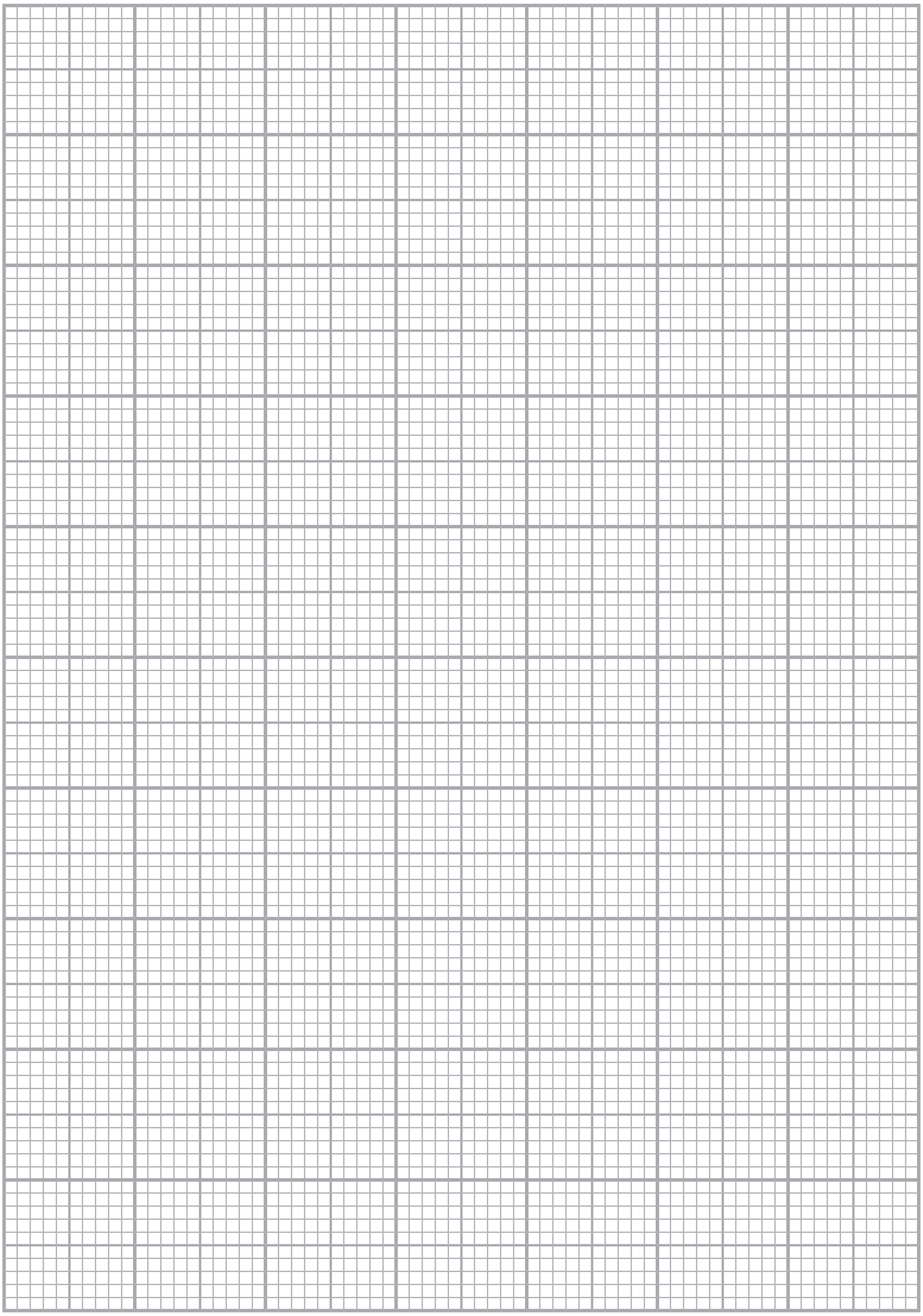
**(i)** By rearranging **Equation 8.2**, show that a graph of $\mathbf{2h/t^2}$ against $\mathbf{(m_2 - m_1)}$ will give a straight line through the origin.

[2]

**(ii)** Complete the three blank columns in the table. Include a unit for the columns headed $\mathbf{t^2}$ and $\mathbf{2h/t^2}$. Quote all values to 3 significant figures. [5]

**(iii)** Select suitable scales for the $\mathbf{2h/t^2}$ and $\mathbf{(m_2 - m_1)}$ axes for the graph on **Fig. 8.2**. Plot the points and draw the best-fit line. [3]

$\mathbf{2h/t^2}$
**/unit**



$\mathbf{(m_2 - m_1)/g}$

**Fig. 8.2**

**(iv)** Determine a value for the constant **Q** from your best-fit line.

State an appropriate unit for your value of **Q**.

**Q** = ______________

Unit: ______________ [3]

**(v)** The masses are changed so that the sum is now kept constant at 300 g. State how this would affect your graph if at all. Explain your answer.

______________________________________________

______________________________________________

______________________________________________ [1]

**(vi)** For larger values of ($m_2 - m_1$) there is a trend for the points to be further from the best-fit line. Explain why this trend occurs.

______________________________________________

______________________________________________

______________________________________________ [1]

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| For Examiner's use only | |
|---|---|
| **Question Number** | **Marks** |
| 1 | |
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| 6 | |
| 7 | |
| 8 | |

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| **Total Marks** | |

**Examiner Number**

# GCE Physics

## Data and Formulae Sheet for A2 1 and A2 2

### Values of constants

| | |
|---|---|
| speed of light in a vacuum | $c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$ |
| permittivity of a vacuum | $\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$ |
| | $\left(\dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \mathrm{F^{-1}m}\right)$ |
| elementary charge | $e = 1.60 \times 10^{-19}\ \mathrm{C}$ |
| the Planck constant | $h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$ |
| (unified) atomic mass unit | $1\ \mathrm{u} = 1.66 \times 10^{-27}\ \mathrm{kg}$ |
| mass of electron | $m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$ |
| mass of proton | $m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$ |
| molar gas constant | $R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$ |
| the Avogadro constant | $N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$ |
| the Boltzmann constant | $k = 1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$ |
| gravitational constant | $G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$ |
| acceleration of free fall on the Earth's surface | $g = 9.81\ \mathrm{m\,s^{-2}}$ |
| electron volt | $1\ \mathrm{eV} = 1.60 \times 10^{-19}\ \mathrm{J}$ |

The following equations may be useful in answering some of the questions in the examination:

**Mechanics**

| | | |
|---|---|---|
| Conservation of energy | $\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$ | for a constant force |
| Hooke's Law | $F = kx$ | (spring constant $k$) |

**Simple harmonic motion**

| | |
|---|---|
| Displacement | $x = A\cos\omega t$ |

**Sound**

| | |
|---|---|
| Sound intensity level/dB | $= 10\lg_{10}\frac{I}{I_0}$ |

**Waves**

| | |
|---|---|
| Two-source interference | $\lambda = \frac{ay}{d}$ |

**Thermal physics**

| | |
|---|---|
| Average kinetic energy of a molecule | $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$ |
| Kinetic theory | $pV = \frac{1}{3}Nm\langle c^2\rangle$ |
| Thermal energy | $Q = mc\Delta\theta$ |

**Capacitors**

| | |
|---|---|
| Capacitors in series | $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ |
| Capacitors in parallel | $C = C_1 + C_2 + C_3$ |
| Time constant | $\tau = RC$ |

## Light

Lens formula $$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$$

Magnification $$m=\frac{v}{u}$$

## Electricity

Terminal potential difference $V=E-Ir$ (e.m.f. $E$; Internal Resistance $r$)

Potential divider $$V_{out}=\frac{R_1 V_{in}}{R_1+R_2}$$

## Particles and photons

Radioactive decay $$A=\lambda N$$

$$A=A_0 e^{-\lambda t}$$

Half-life $$t_{\frac{1}{2}}=\frac{0.693}{\lambda}$$

de Broglie equation $$\lambda=\frac{h}{p}$$

## The nucleus

Nuclear radius $$r=r_0 A^{\frac{1}{3}}$$