



Cambridge International AS & A Level

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PHYSICS

9702/21

Paper 2 AS Level Structured Questions

October/November 2025

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [].

This document has **16** pages. Any blank pages are indicated.



Data

acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$
speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
unified atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
hydrostatic pressure	$\Delta p = \rho g \Delta h$
upthrust	$F = \rho g V$
Doppler effect for sound waves	$f_o = \frac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$





1 (a) Define acceleration.

.....
 [1]

(b) A rocket is launched vertically from the surface of the Earth.

Fig. 1.1 shows the variation of the velocity of the rocket with time for the first 20 s after its launch.

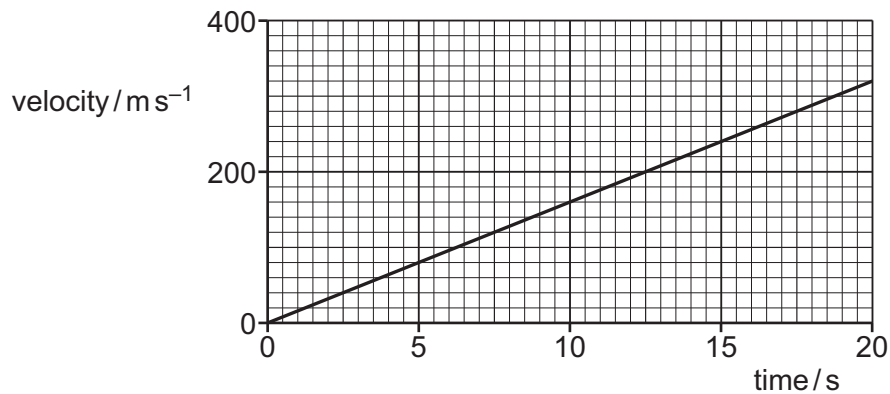


Fig. 1.1

(i) Determine the acceleration of the rocket.

acceleration = ... m s^{-2} [1]

(ii) Show that the height of the rocket above the surface of the Earth at a time of 20 s after launch is 3.2 km.

[2]



- (c) The mass of the rocket in (b) is $2.9 \times 10^6 \text{ kg}$. Assume that this mass remains constant.

For this rocket, from launch to its height at a time of 20 s after launch:

- (i) calculate the gain in gravitational potential energy ΔE_p

$$\Delta E_p = \dots\dots\dots \text{ J [2]}$$

- (ii) calculate the gain in kinetic energy ΔE_k

$$\Delta E_k = \dots\dots\dots \text{ J [2]}$$

- (iii) determine the average power output of the rocket engines. Assume that resistive forces are negligible.

$$\text{power} = \dots\dots\dots \text{ W [2]}$$

[Total: 10]



2 (a) (i) Define pressure.

.....
 [1]

(ii) Explain how hydrostatic pressure results in an upthrust force acting on a solid object immersed in a liquid.

.....

 [2]

(b) A small steel ball of radius r and mass m falls vertically at terminal speed v through oil.

The viscous drag force D that acts on the ball is given by

$$D = 6\pi\eta rv$$

where η is a property of the oil called its viscosity.

(i) On Fig. 2.1, draw labelled arrows from the ball to show the directions of the **three** forces that act on the ball as it falls.



Fig. 2.1

[3]





(ii) Determine the SI base units of η .

base units [2]

(c) The oil in (b) has a density of 920 kg m^{-3} and a viscosity of 4.7 in SI units.

The steel ball has a mass of $2.4 \times 10^{-3} \text{ kg}$ and a radius of $4.2 \times 10^{-3} \text{ m}$.

(i) Show that the upthrust force acting on the ball is $2.8 \times 10^{-3} \text{ N}$.

[1]

(ii) Determine the terminal speed v of the ball.

$v = \dots \text{ m s}^{-1}$ [3]

[Total: 12]



- 3 A wire has length L and cross-sectional area A . The wire is made from a metal that has Young modulus E and resistivity ρ .

(a) Define the Young modulus of a material.

.....
 [1]

- (b) (i) State an expression, in terms of some or all of L , A , E and ρ , for the resistance R_0 of the wire.

$R_0 =$ [1]

- (ii) Show that the spring constant k_0 of the wire is given by

$$k_0 = \frac{EA}{L}.$$

[2]

- (c) The wire is stretched, within the limit of proportionality, by a tensile force F . Assume that any changes in the cross-sectional area of the wire are negligible.

- (i) On Fig. 3.1, sketch the variation with F of the resistance R of the wire.



Fig. 3.1

[1]



- (ii) On Fig. 3.2, sketch the variation with F of the spring constant k of the wire.



Fig. 3.2

[1]

- (d) Copper has a resistivity of $1.8 \times 10^{-8} \Omega \text{ m}$ and a Young modulus of $1.3 \times 10^{11} \text{ Pa}$.

A copper wire of diameter 1.6 mm has a resistance of 0.034Ω .

- (i) Show that the length of the wire is 3.8 m.

[1]

- (ii) Use the equation in (b)(ii) to determine the spring constant of the wire.

spring constant = ... N m^{-1} [2]

[Total: 9]



- 4 (a) State what is meant by diffraction of a wave.

.....

.....

..... [2]

- (b) A beam of vertically polarised light of wavelength 540 nm is incident normally on a diffraction grating, as shown in Fig. 4.1.

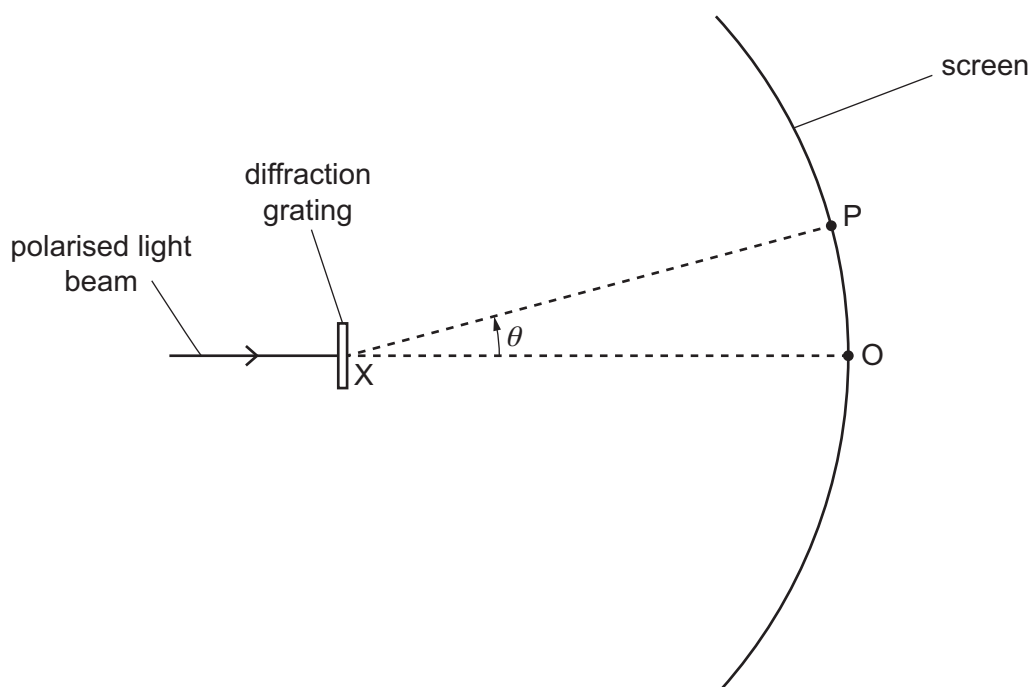


Fig. 4.1 (not to scale)

The diffraction grating has a line spacing of $5.0 \times 10^{-6}\text{ m}$.

The light transmitted by the diffraction grating illuminates a circular screen. The diffraction grating is at the centre X of the circle.

The central bright fringe is formed at point O on the screen and has intensity I_0 .

P is a point on the screen where the line XP is at a variable angle θ to the line XO. The intensity I of light on the screen at P varies with θ .

- (i) Show that the angle θ at which the first-order bright fringe is formed is 6.2° .

[2]



- (ii) Determine the value of θ at which the second-order bright fringe is formed.

$$\theta = \dots\dots\dots^\circ \quad [1]$$

- (iii) On Fig. 4.2, sketch the variation of the intensity I with θ for values of θ from -15° to $+15^\circ$.

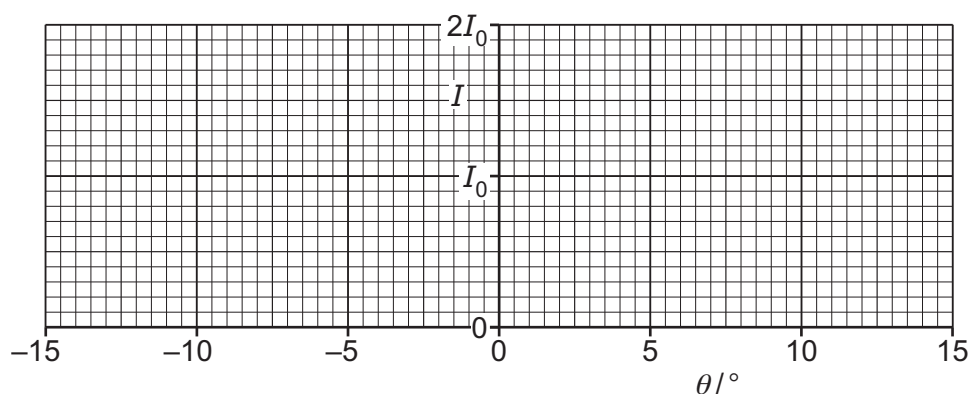


Fig. 4.2

[3]

- (c) A polarising filter is placed in the path of the light beam that is incident on the diffraction grating in Fig. 4.1. The transmission axis of the filter is at 45° to the vertical.

Suggest how the variation of intensity with θ for the light on the screen compares with the answer in (b)(iii).

.....

 [2]

[Total: 10]



5 (a) State Kirchhoff's first law.

.....
 [1]

(b) Fig. 5.1 shows a circuit containing a thermistor T that has a negative temperature coefficient.

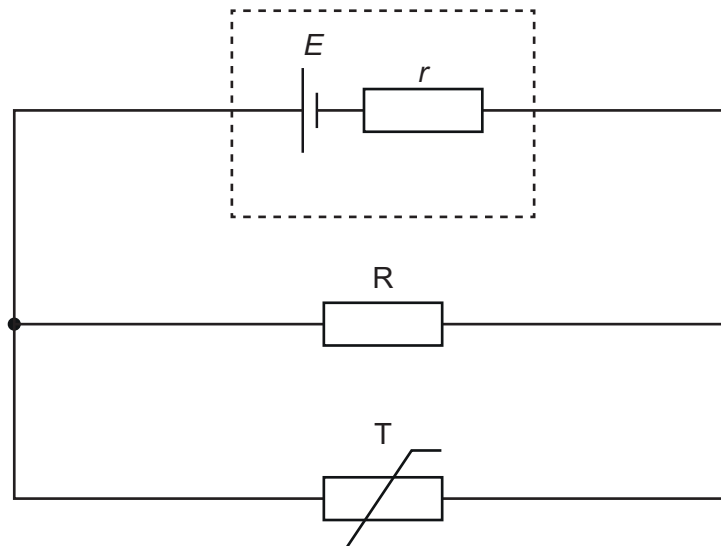


Fig. 5.1

(i) The thermistor has resistance R_0 at a temperature of 0°C .

On Fig. 5.2, sketch a possible variation of the resistance of the thermistor with temperature between 0°C and 100°C .

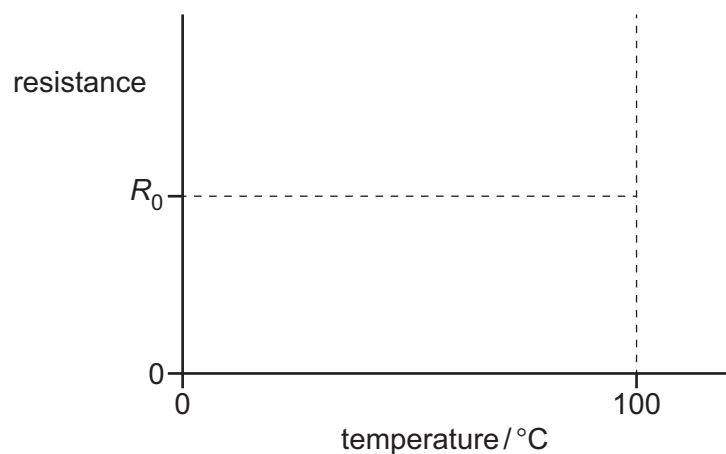


Fig. 5.2



- (ii) With reference to the current in the cell, explain why the current in **resistor R** decreases with increasing temperature of the thermistor.

.....

.....

.....

.....

..... [3]

- (c) The electromotive force (e.m.f.) E of the cell in Fig. 5.1 is 1.50 V. The internal resistance r of the cell is $0.12\ \Omega$.

Resistor R has a resistance of $6.00\ \Omega$.

At a particular temperature of the thermistor, the current in R is 0.200 A.

For this temperature of the thermistor, determine:

- (i) the current in the cell

current = ... A [2]

- (ii) the resistance of the thermistor.

resistance = ... Ω [2]

[Total: 10]



6 The nuclide ${}^3_1\text{H}$ is an isotope of hydrogen that is called tritium.

(a) (i) Determine the numbers of protons, neutrons and electrons in a neutral atom of tritium.

number of protons = ...

number of neutrons = ...

number of electrons = ...

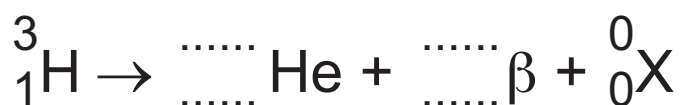
[2]

(ii) Draw a labelled diagram to represent a simple model of the arrangement of the protons, neutrons and electrons in a tritium atom.

[2]

(b) Tritium is radioactive and undergoes β^- decay to form an isotope of helium (He). Gamma radiation is not emitted during this decay.

(i) Complete the equation to represent the radioactive decay of tritium.



[2]

(ii) State the name of particle X.

..... [1]





(c) Determine the quark composition of a tritium nucleus.

.....

..... [2]

[Total: 9]





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- 1 Scientists are investigating the variation in air pressure at different locations on a mountain.

- (a) The scientists take measurements of several physical quantities at each location.

Complete Table 1.1 by stating the SI base unit for each quantity and identifying with a tick (✓) whether each quantity is a scalar or a vector. Use the space for any working.

Table 1.1

quantity measured	SI base unit	scalar	vector
air temperature			
air pressure			

[2]

- (b) (i) At one location, the density of the air is 1.1 kg m^{-3} . A spherical weather balloon is filled with a gas and released from rest. The balloon has radius 0.90 m.

Calculate the upthrust acting on the balloon when it is released.

upthrust = ... N [2]

- (ii) Explain why an upthrust acts on the balloon.

.....

 [2]



(iii) The balloon has weight 19 N.

Calculate the magnitude of the initial acceleration of the balloon.

acceleration = ... ms^{-2} [3]

- (c) A quantity c relating to the motion of the balloon is calculated from three measured quantities k , F and v using the formula

$$c = \frac{2kF}{v^2}.$$

The percentage uncertainties in the measured quantities are given in Table 1.2.

Table 1.2

measured quantity	percentage uncertainty
k	5%
F	3%
v	4%

The calculated value of c is 1.8.

Determine the absolute uncertainty in c .

absolute uncertainty = ... [2]

[Total: 11]



- 2 A spacecraft in deep space uses jets of hot gas from its thrusters to change its velocity. Fig. 2.1 shows a side view of the spacecraft and some of its thrusters.

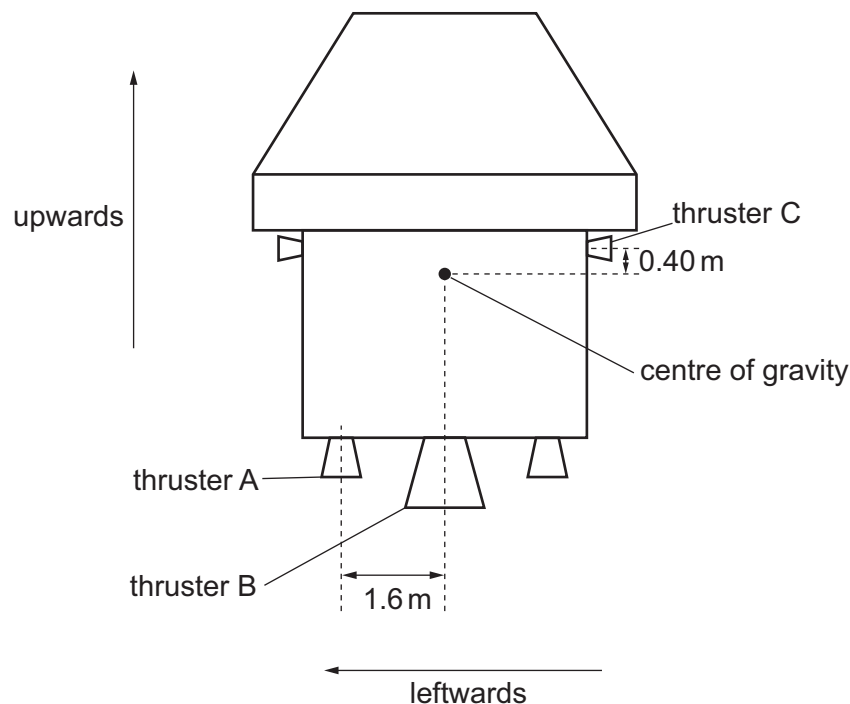


Fig. 2.1 (not to scale)

Thruster A is a distance of 1.6 m leftwards from the centre of gravity of the spacecraft. Thruster C is a distance of 0.40 m upwards from the centre of gravity of the spacecraft.

Thrusters A and B can produce forces on the spacecraft in the upwards direction only.

Thruster C can produce a force on the spacecraft in the leftwards direction only.

All the thrusters shown produce forces entirely in the same plane as the centre of gravity.

- (a) (i) Thruster A is activated, producing a force of 60 N upwards on the spacecraft. Thruster C is also activated, producing a force of 220 N in the leftwards direction on the spacecraft.

Calculate the resultant moment due to these forces about the centre of gravity.

resultant moment = ... N m [2]

- (ii) State and explain whether the forces from A and C are a couple.

.....

 [1]



- (b) Thrusters A and C are now switched off and the spacecraft is stationary. Thruster B is activated at time t_1 , producing a constant force on the spacecraft until the fuel runs out at time t_2 . As the fuel is used, the total mass of the spacecraft decreases.

On Fig. 2.2, sketch the variation of speed of the spacecraft with time from t_1 to t_2 .

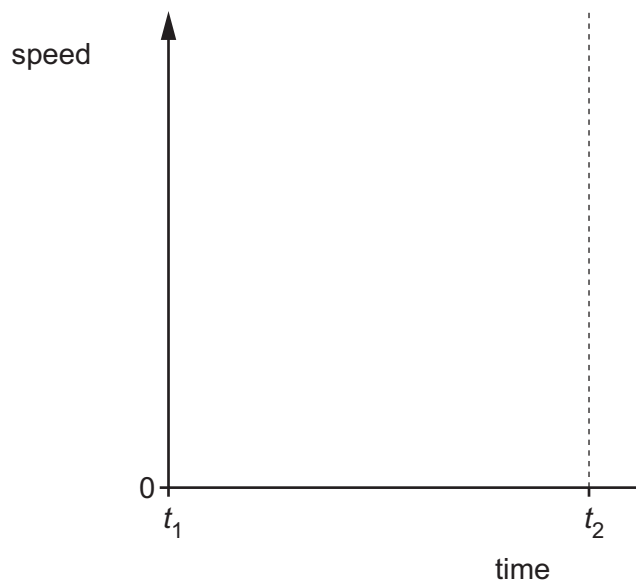


Fig. 2.2

[2]



(c) The spacecraft now splits apart into a carrier and a payload as shown in Fig. 2.3.

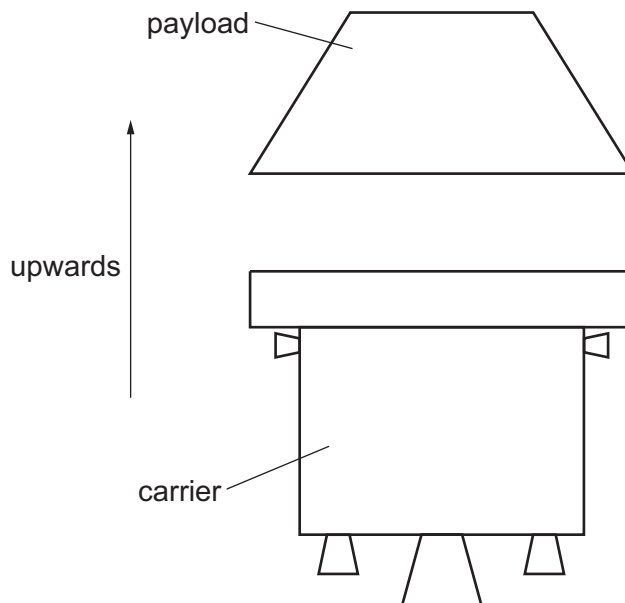


Fig. 2.3

During the split, an average force of 5500 N acts on the payload for a time of 0.36 s. The velocity of the payload increases by 8.5 m s^{-1} in the upwards direction.

The combined mass of the carrier and payload is $2.5 \times 10^3 \text{ kg}$.

(i) State the principle of conservation of momentum.

.....

 [2]

(ii) Show that the mass of the payload is 230 kg.

[2]



(iii) Calculate the magnitude of the change in velocity of the carrier.

change in velocity = ... ms^{-1} [3]

[Total: 12]



- 3 A spring is fixed at one end and attached to the frame of a pulley at the other end. A cable is passed around the wheel of the pulley. The spring is stretched to a fixed length using the cable and pulley.

Fig. 3.1 shows the view from above of the spring, cable and pulley.

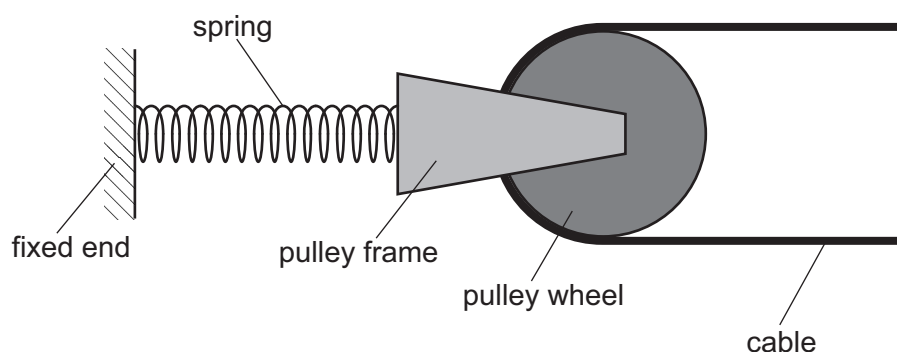


Fig. 3.1

The spring obeys Hooke's law and has a spring constant k of 250 N m^{-1} . A force F acts on the spring. The tension in the cable is T . The pulley is in equilibrium.

- (a) On Fig. 3.2, draw labelled arrows to show the directions of the forces acting on the pulley.

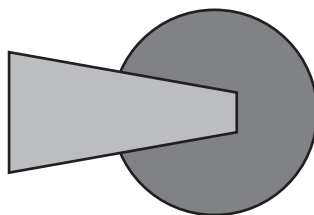


Fig. 3.2

[2]

- (b) The force F is 110 N .

- (i) Determine T .

$T = \dots\dots\dots \text{ N [1]}$



- (ii) Calculate the extension of the spring.

extension = ... m [2]

- (c) A second identical spring with the same spring constant of 250 N m^{-1} is now also connected to the pulley, as shown in Fig. 3.3.

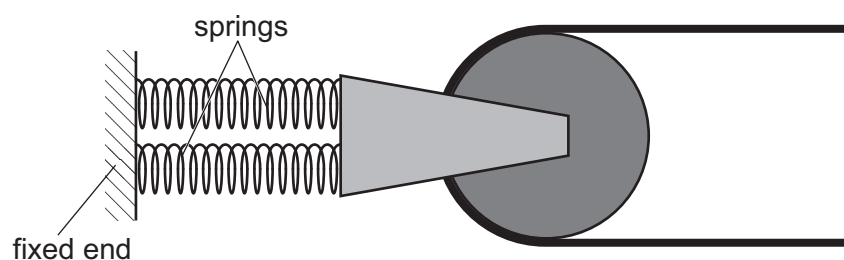


Fig. 3.3

The tension in the cable is kept the same. The pulley is again in equilibrium.

- (i) Determine the extension of the springs.

extension = ... m [2]

- (ii) The elastic potential energy stored in the spring in Fig. 3.1 is E_1 . The **total** elastic potential energy stored in the two springs in Fig. 3.3 is E_2 .

Calculate the ratio $\frac{E_1}{E_2}$.

ratio = ... [2]

[Total: 9]



- 4 A laser emits visible light of a single frequency in a vacuum. The light is incident normally on a double slit and then forms a pattern of bright and dark fringes on a screen, as shown in Fig. 4.1.

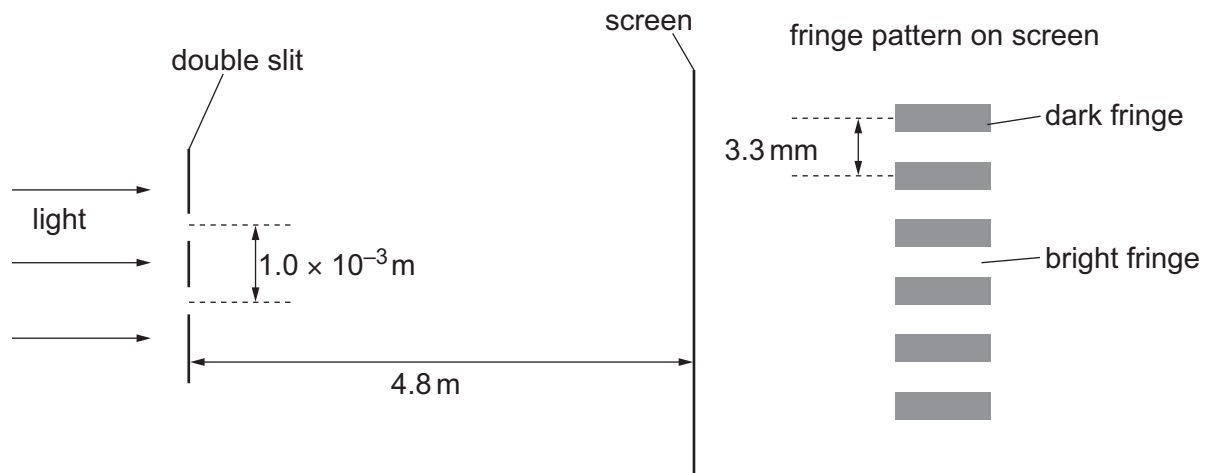


Fig. 4.1 (not to scale)

The separation of the slits is $1.0 \times 10^{-3} \text{ m}$. The distance from the slits to the screen is 4.8 m . The distance between the centres of adjacent dark fringes on the screen is 3.3 mm .

- (a) Explain how the pattern of bright and dark fringes is formed.

.....

.....

.....

.....

..... [3]

- (b) Calculate the frequency of the light emitted by the laser.

frequency = ... Hz [4]



- (c) The double slit is removed. A second laser is placed beside the first laser. The second laser produces visible light of a different frequency from that of the first laser. The beams of light from the two lasers overlap on the screen.

Explain why a steady pattern of bright and dark fringes is **not** formed on the screen.

.....
..... [1]

[Total: 8]



- 5 Fig. 5.1 shows a circuit containing a battery, two fixed resistors X and Y, and a light-dependent resistor (LDR) Z.

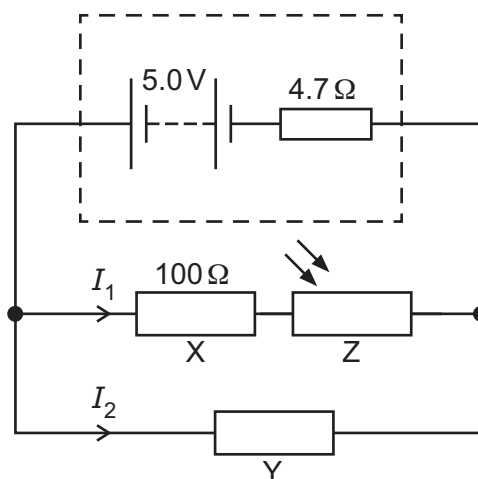


Fig. 5.1

The battery has electromotive force (e.m.f.) 5.0 V and internal resistance 4.7 Ω. The current in X is I_1 and the current in Y is I_2 .

The resistance of X is 100 Ω. The resistance of Z varies with the intensity of light incident on it as shown in Fig. 5.2.

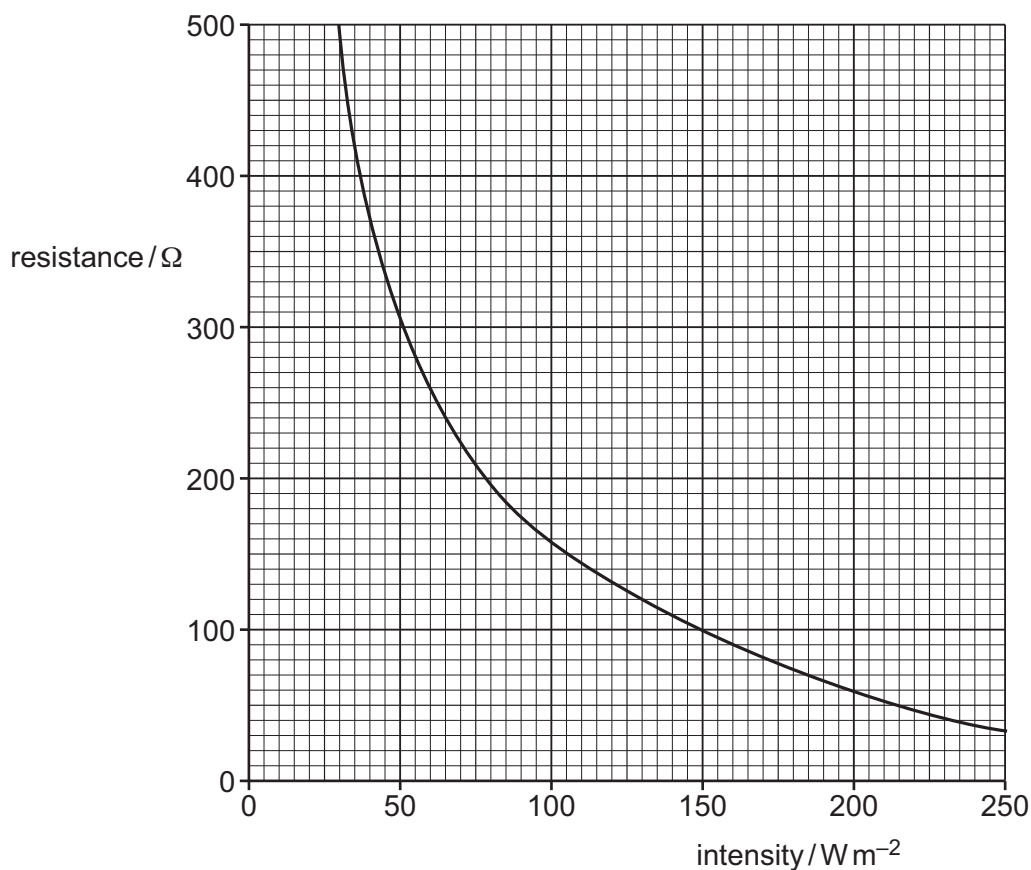


Fig. 5.2



(a) State Kirchhoff's first law.

.....
 [1]

(b) The intensity of light incident on Z is 130 W m^{-2} . The current in the battery is 38 mA.

(i) Show that the terminal potential difference of the battery is 4.8 V.

[2]

(ii) Calculate the current I_2 in Y.

$I_2 = \dots\dots\dots \text{ A}$ [3]

(iii) Calculate the power dissipated in Y.

power = $\dots\dots\dots \text{ W}$ [2]

(iv) The intensity of the light incident on Z decreases.

State and explain the effect on the terminal potential difference of the battery.

.....

 [3]

[Total: 11]



- 6 (a) State what is meant by a fundamental particle.

.....
 [1]

- (b) (i) Particle Q is a meson with a charge of 0.

Determine a possible quark composition for Q.

..... [2]

- (ii) Particle Q has a mass of 0.67 u and a kinetic energy of 2.1×10^{-16} J.

Calculate the speed of particle Q.

speed = ... m s^{-1} [3]

- (c) Radium-228 ($^{228}_{88}\text{Ra}$) is a radioactive nuclide.

- (i) State the number of electrons in a neutral atom of radium-228.

number of electrons = ... [1]

- (ii) A nucleus of radium-228 undergoes a series of decays to form nucleus X.
 During the process, 5 α -particles and 4 β^- particles are emitted.

Determine the number of protons and the number of neutrons in nucleus X.

number of protons = ...

number of neutrons = ...

[2]

[Total: 9]





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- 1 (a) Define acceleration.

.....
 [1]

- (b) A rocket is launched vertically from the surface of the Earth.

Fig. 1.1 shows the variation of the velocity of the rocket with time for the first 20 s after its launch.

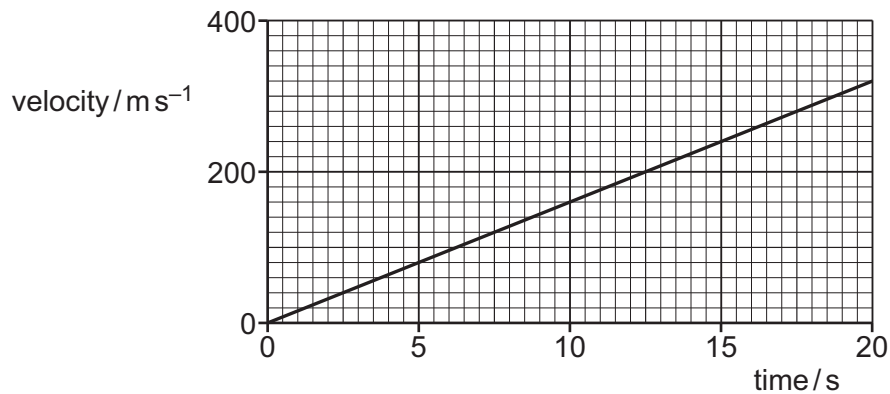


Fig. 1.1

- (i) Determine the acceleration of the rocket.

acceleration = ... m s^{-2} [1]

- (ii) Show that the height of the rocket above the surface of the Earth at a time of 20 s after launch is 3.2 km.

[2]



- (c) The mass of the rocket in (b) is $2.9 \times 10^6 \text{ kg}$. Assume that this mass remains constant.

For this rocket, from launch to its height at a time of 20 s after launch:

- (i) calculate the gain in gravitational potential energy ΔE_p

$$\Delta E_p = \dots\dots\dots \text{ J [2]}$$

- (ii) calculate the gain in kinetic energy ΔE_k

$$\Delta E_k = \dots\dots\dots \text{ J [2]}$$

- (iii) determine the average power output of the rocket engines. Assume that resistive forces are negligible.

$$\text{power} = \dots\dots\dots \text{ W [2]}$$

[Total: 10]



2 (a) (i) Define pressure.

.....
 [1]

(ii) Explain how hydrostatic pressure results in an upthrust force acting on a solid object immersed in a liquid.

.....

 [2]

(b) A small steel ball of radius r and mass m falls vertically at terminal speed v through oil.

The viscous drag force D that acts on the ball is given by

$$D = 6\pi\eta rv$$

where η is a property of the oil called its viscosity.

(i) On Fig. 2.1, draw labelled arrows from the ball to show the directions of the **three** forces that act on the ball as it falls.



Fig. 2.1

[3]





(ii) Determine the SI base units of η .

base units [2]

(c) The oil in (b) has a density of 920 kg m^{-3} and a viscosity of 4.7 in SI units.

The steel ball has a mass of $2.4 \times 10^{-3} \text{ kg}$ and a radius of $4.2 \times 10^{-3} \text{ m}$.

(i) Show that the upthrust force acting on the ball is $2.8 \times 10^{-3} \text{ N}$.

[1]

(ii) Determine the terminal speed v of the ball.

$v = \dots \text{ m s}^{-1}$ [3]

[Total: 12]



- 3 A wire has length L and cross-sectional area A . The wire is made from a metal that has Young modulus E and resistivity ρ .

(a) Define the Young modulus of a material.

.....
 [1]

- (b) (i) State an expression, in terms of some or all of L , A , E and ρ , for the resistance R_0 of the wire.

$$R_0 = \dots\dots\dots [1]$$

- (ii) Show that the spring constant k_0 of the wire is given by

$$k_0 = \frac{EA}{L}.$$

[2]

- (c) The wire is stretched, within the limit of proportionality, by a tensile force F . Assume that any changes in the cross-sectional area of the wire are negligible.

- (i) On Fig. 3.1, sketch the variation with F of the resistance R of the wire.



Fig. 3.1

[1]



(ii) On Fig. 3.2, sketch the variation with F of the spring constant k of the wire.



Fig. 3.2

[1]

(d) Copper has a resistivity of $1.8 \times 10^{-8} \Omega \text{ m}$ and a Young modulus of $1.3 \times 10^{11} \text{ Pa}$.

A copper wire of diameter 1.6 mm has a resistance of 0.034Ω .

(i) Show that the length of the wire is 3.8 m.

[1]

(ii) Use the equation in (b)(ii) to determine the spring constant of the wire.

spring constant = ... N m^{-1} [2]

[Total: 9]



- 4 (a) State what is meant by diffraction of a wave.

.....

.....

..... [2]

- (b) A beam of vertically polarised light of wavelength 540 nm is incident normally on a diffraction grating, as shown in Fig. 4.1.

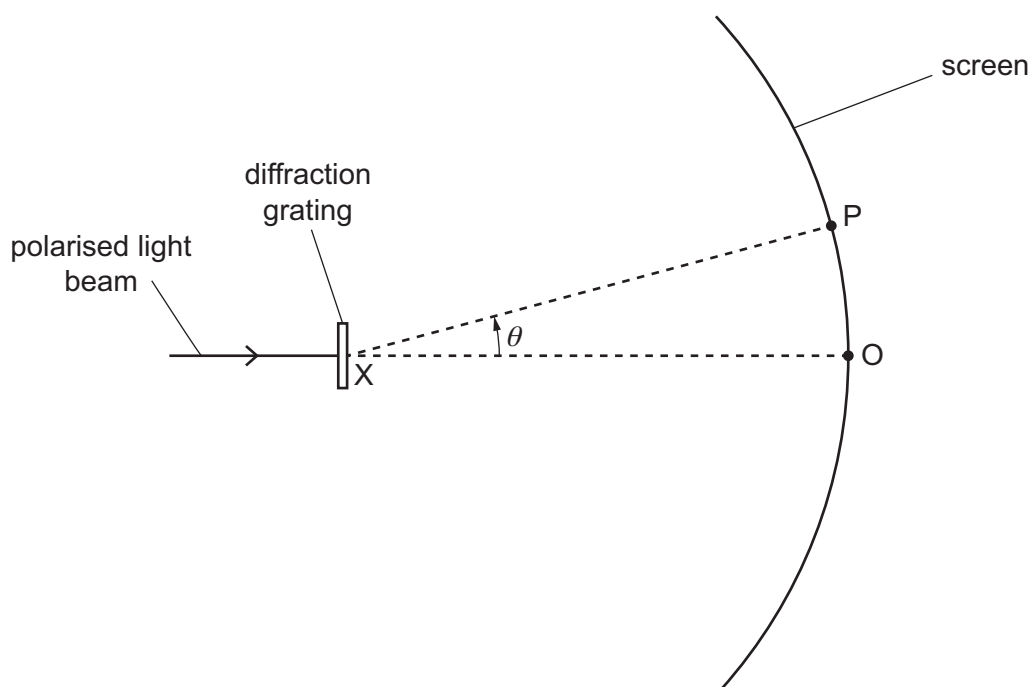


Fig. 4.1 (not to scale)

The diffraction grating has a line spacing of $5.0 \times 10^{-6}\text{ m}$.

The light transmitted by the diffraction grating illuminates a circular screen. The diffraction grating is at the centre X of the circle.

The central bright fringe is formed at point O on the screen and has intensity I_0 .

P is a point on the screen where the line XP is at a variable angle θ to the line XO. The intensity I of light on the screen at P varies with θ .

- (i) Show that the angle θ at which the first-order bright fringe is formed is 6.2° .

[2]



- (ii) Determine the value of θ at which the second-order bright fringe is formed.

$$\theta = \dots\dots\dots^\circ \quad [1]$$

- (iii) On Fig. 4.2, sketch the variation of the intensity I with θ for values of θ from -15° to $+15^\circ$.

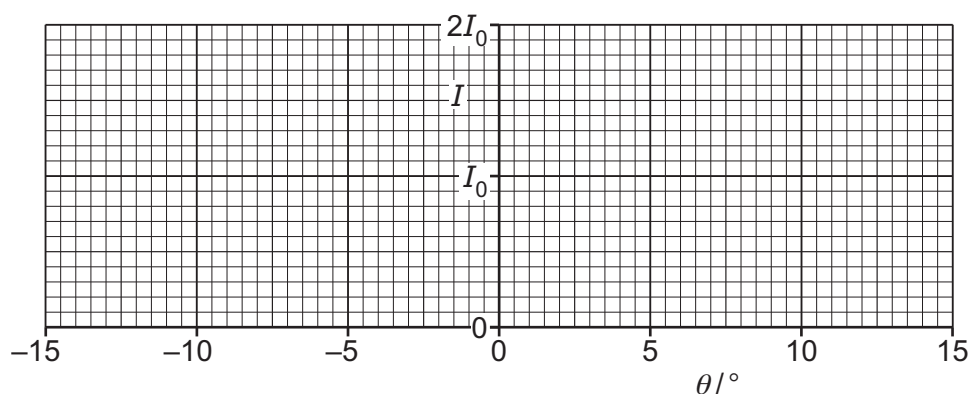


Fig. 4.2

[3]

- (c) A polarising filter is placed in the path of the light beam that is incident on the diffraction grating in Fig. 4.1. The transmission axis of the filter is at 45° to the vertical.

Suggest how the variation of intensity with θ for the light on the screen compares with the answer in (b)(iii).

.....

 [2]

[Total: 10]



5 (a) State Kirchhoff's first law.

.....
 [1]

(b) Fig. 5.1 shows a circuit containing a thermistor T that has a negative temperature coefficient.

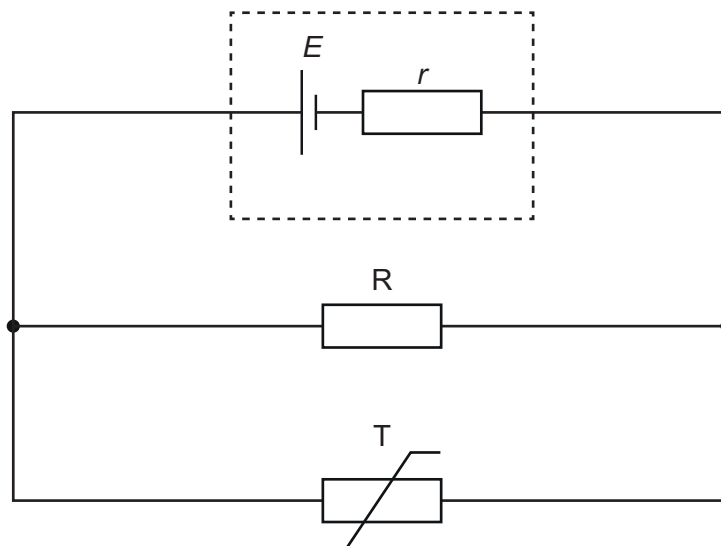


Fig. 5.1

(i) The thermistor has resistance R_0 at a temperature of 0°C .

On Fig. 5.2, sketch a possible variation of the resistance of the thermistor with temperature between 0°C and 100°C .

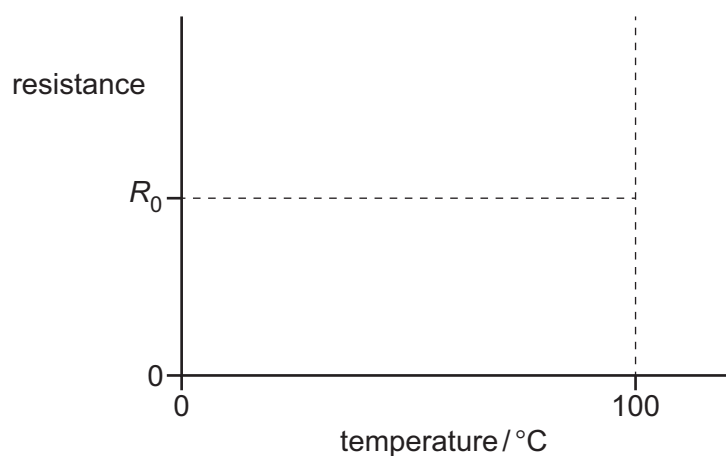


Fig. 5.2

[2]



- (ii) With reference to the current in the cell, explain why the current in **resistor R** decreases with increasing temperature of the thermistor.

.....

.....

.....

.....

..... [3]

- (c) The electromotive force (e.m.f.) E of the cell in Fig. 5.1 is 1.50 V. The internal resistance r of the cell is $0.12\ \Omega$.

Resistor R has a resistance of $6.00\ \Omega$.

At a particular temperature of the thermistor, the current in R is 0.200 A.

For this temperature of the thermistor, determine:

- (i) the current in the cell

current = ... A [2]

- (ii) the resistance of the thermistor.

resistance = ... Ω [2]

[Total: 10]



6 The nuclide ${}^3_1\text{H}$ is an isotope of hydrogen that is called tritium.

(a) (i) Determine the numbers of protons, neutrons and electrons in a neutral atom of tritium.

number of protons = ...

number of neutrons = ...

number of electrons = ...

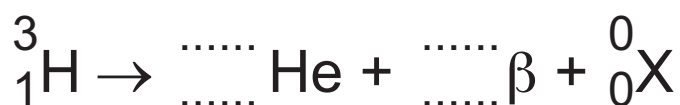
[2]

(ii) Draw a labelled diagram to represent a simple model of the arrangement of the protons, neutrons and electrons in a tritium atom.

[2]

(b) Tritium is radioactive and undergoes β^- decay to form an isotope of helium (He). Gamma radiation is not emitted during this decay.

(i) Complete the equation to represent the radioactive decay of tritium.



[2]

(ii) State the name of particle X.

..... [1]





(c) Determine the quark composition of a tritium nucleus.

.....

..... [2]

[Total: 9]





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PHYSICS

9702/24

Paper 2 AS Level Structured Questions

October/November 2025

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [].

This document has **16** pages. Any blank pages are indicated.



Data

acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$
speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
unified atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
hydrostatic pressure	$\Delta p = \rho g \Delta h$
upthrust	$F = \rho g V$
Doppler effect for sound waves	$f_o = \frac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$





- 1 A child kicks a ball so that it leaves horizontal ground with a velocity of 28 m s^{-1} at an angle of 34° to the horizontal, as shown in Fig. 1.1.

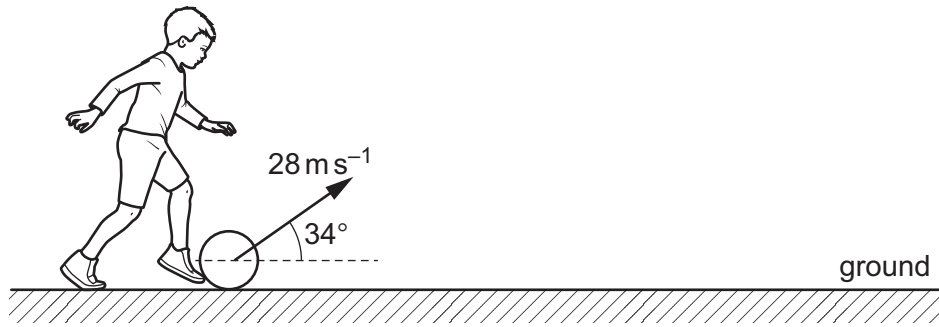


Fig. 1.1

Air resistance is negligible. The ball leaves the ground at time $t = 0$.

- (a) (i) Calculate the horizontal component v_H and the vertical component v_V of the velocity of the ball immediately after it has left the ground.

$$v_H = \dots\dots\dots \text{ m s}^{-1}$$

$$v_V = \dots\dots\dots \text{ m s}^{-1}$$

[2]

- (ii) Show that the ball reaches its maximum height at time $t = 1.6 \text{ s}$.

[1]



- (iii) On Fig. 1.2, sketch the variation of v_H with time t between $t = 0$ and $t = 3.2$ s. Label your line H.

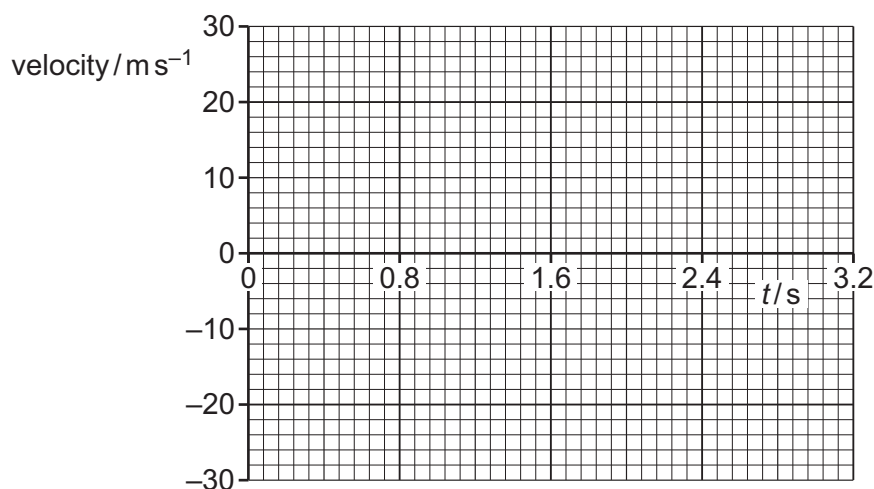


Fig. 1.2

[1]

- (iv) On Fig. 1.2, sketch the variation of v_V with time t between $t = 0$ and $t = 3.2$ s. Assume that velocity in the upward direction is positive. Label your line V. [3]
- (b) The total change in momentum of the ball between leaving the ground at $t = 0$ and landing on the ground at $t = 3.2$ s is 13 kg ms^{-1} .

- (i) Define momentum.

.....
 [1]

- (ii) Calculate the force that acts on the ball while it is in the air.

force = ... N [2]

- (iii) Determine the mass of the ball.

mass = ... kg [1]

[Total: 11]

[Turn over]



- 2 Fig. 2.1 shows a square metal sheet of non-uniform density, with a thin wooden rod fixed at its centre. One of the corners of the sheet is labelled X.

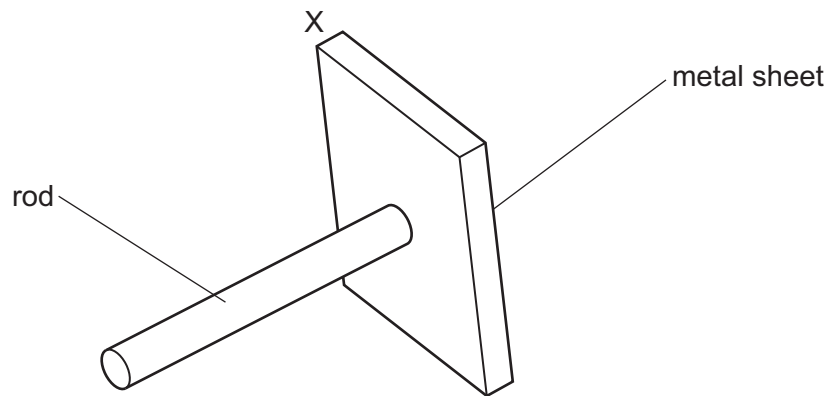


Fig. 2.1

The rod has negligible mass. The mass of the metal sheet is 2.8 kg.
The rod is supported so that the rod is horizontal and the metal sheet is vertical.

- (a) Define the torque of a couple.

.....

.....

..... [2]

- (b) When the rod is supported in such a way that it can rotate freely within its support, the sheet hangs in equilibrium with point X vertically above the rod, as shown in Fig. 2.2.

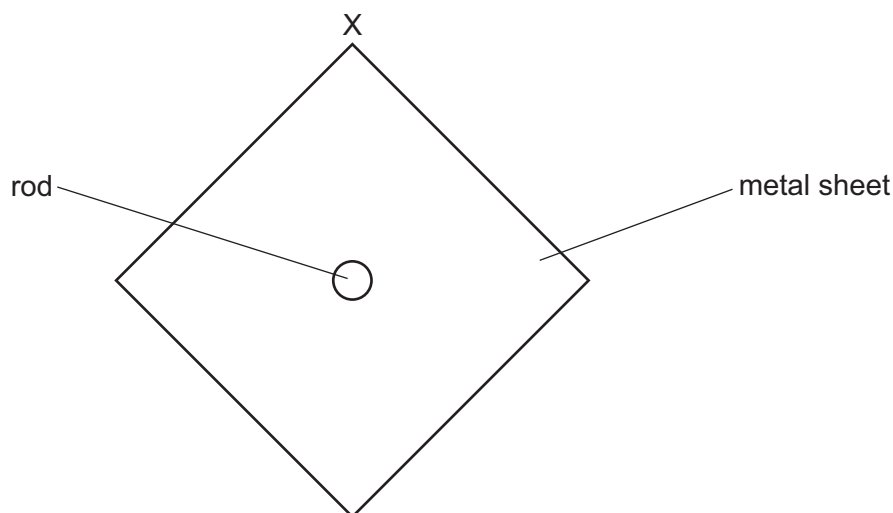


Fig. 2.2

On Fig. 2.2, draw a line to indicate the range of possible positions for the centre of gravity of the metal sheet. [1]



- (c) When a torque of 3.3 Nm is applied to the rod, the sheet is held in equilibrium with two of its edges horizontal, as shown in Fig. 2.3. Point X is at the top-left corner.

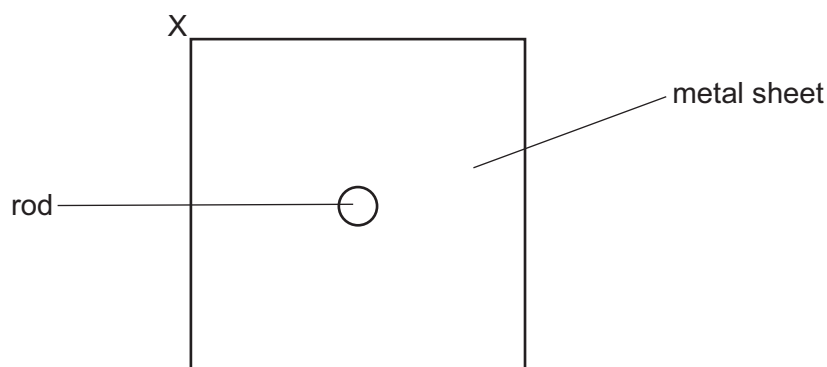


Fig. 2.3

- (i) Explain whether the torque applied to the rod to hold the sheet in equilibrium is clockwise or anticlockwise.

.....
 [1]

- (ii) Show that the centre of gravity of the sheet has a horizontal displacement of 0.12 m from the rod.

[1]

- (d) The square metal sheet has an average density of 3000 kg m^{-3} and a uniform thickness of 4.0 mm .

Show that the side length of the sheet is 0.48 m .

[3]

- (e) Use the answer in (b) and the information in (c) and (d) to determine the position of the centre of gravity of the sheet. Indicate this position on Fig. 2.3 with a point labelled Y. [2]

[Total: 10]



- 3 A bungee jumper of mass 64 kg secures one end of an elastic rope to a bridge. The other end is attached to the bungee jumper. The jumper falls from rest from the bridge and descends into the valley below, as shown in Fig. 3.1.

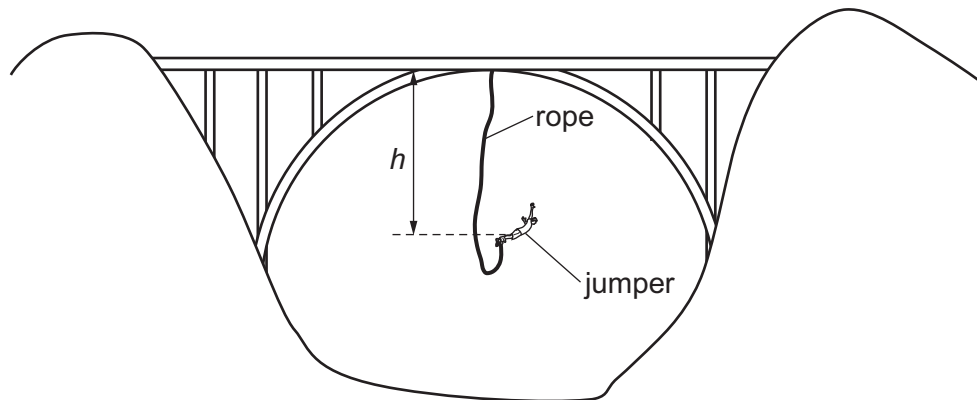


Fig. 3.1 (not to scale)

Fig. 3.2 shows the variation of the tension T in the rope with the vertical distance h of the jumper below the level of the bridge.

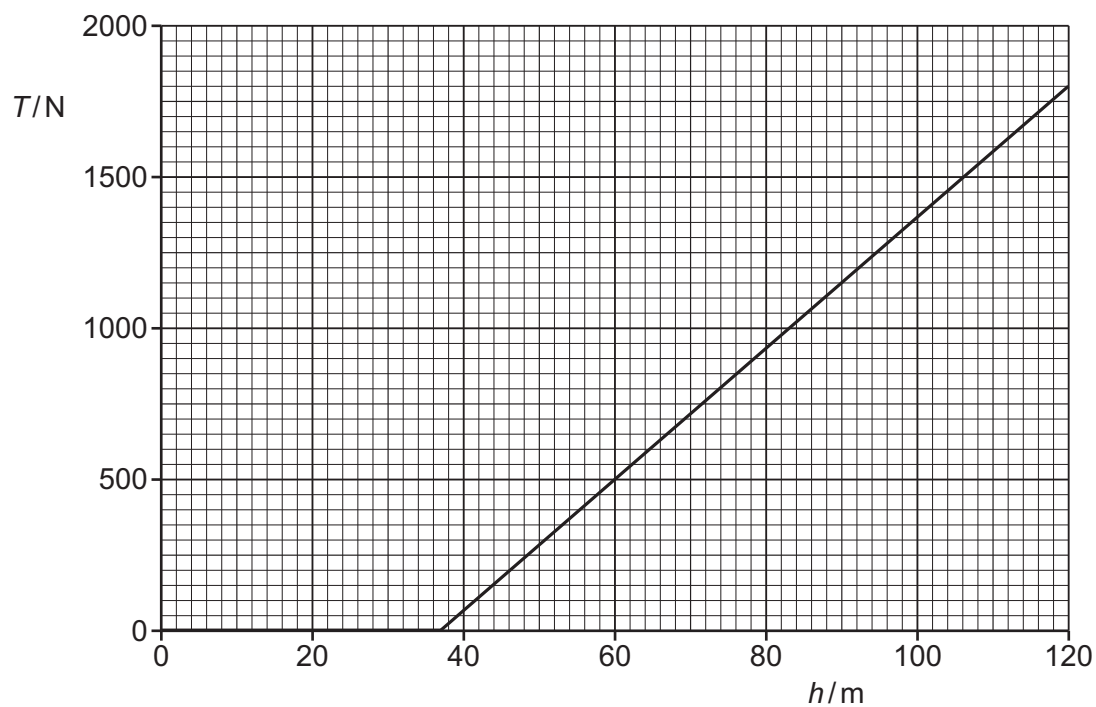


Fig. 3.2

- (a) The rope obeys Hooke's law.

State Hooke's law.

.....
 [1]



- (b) (i) Determine the unstretched length of the rope.

length = ... m [1]

- (ii) Determine the spring constant k of the rope.

$k = \dots\dots\dots \text{Nm}^{-1}$ [2]

- (c) For the position of the bungee jumper at a distance of 120 m below the bridge:

- (i) show that the loss of gravitational potential energy since leaving the bridge is 75 kJ

[2]

- (ii) show that the elastic potential energy in the rope is 75 kJ.

[2]

- (d) Explain what can be deduced from the information in (c) about the speed of the bungee jumper when at a distance of 120 m below the bridge.

.....

 [2]

[Total: 10]



- 4 (a) State the principle of superposition.

.....

.....

..... [2]

- (b) An electromagnetic wave of wavelength 0.026 m in free space is incident normally on an aluminium sheet, as shown in Fig. 4.1.

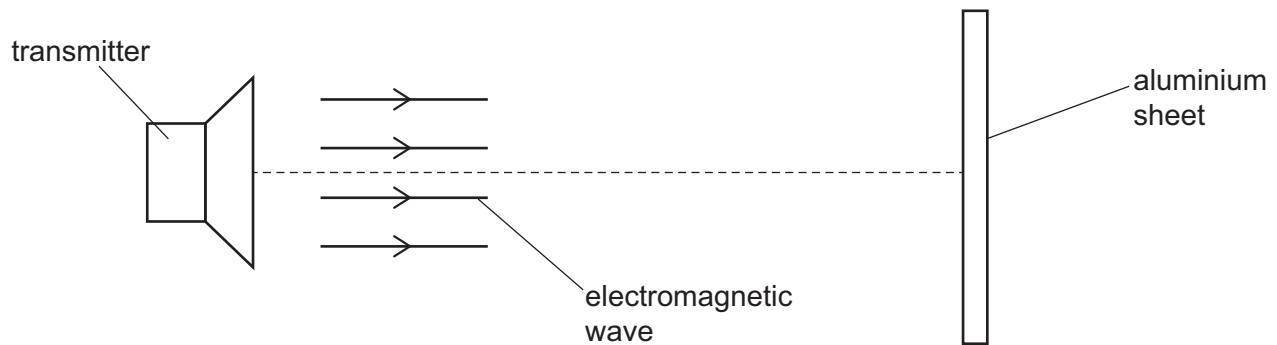


Fig. 4.1

The wave reflects at the aluminium sheet and a stationary wave is formed in the region between the transmitter and the sheet.

- (i) Explain how the stationary wave, including its nodes and antinodes, is formed.

.....

.....

.....

.....

..... [3]

- (ii) Calculate the frequency of the electromagnetic wave.

frequency = ... Hz [2]

- (iii) State the principal region of the electromagnetic spectrum to which the wave belongs.

..... [1]





(iv) Determine the distance between a node and an adjacent antinode.

distance = ... m [1]

[Total: 9]



- 5 A student uses a circuit containing an ammeter, a voltmeter and a cell to take measurements to determine the resistance of a length of nichrome wire.

(a) (i) Define resistance.

.....
 [1]

- (ii) Draw a circuit diagram to show how the components should be connected. Use the symbol for a resistor to represent the nichrome wire.

[2]

- (b) The student also measures the length and the diameter of the wire. Table 5.1 shows the measurements recorded for each quantity.

Table 5.1

quantity	measurement
length	$(0.864 \pm 0.001)\text{m}$
diameter	$(0.496 \pm 0.002)\text{mm}$
voltmeter reading	$(1.38 \pm 0.02)\text{V}$
ammeter reading	$(0.276 \pm 0.001)\text{A}$

- (i) Show that the resistance of the wire is $5.00\,\Omega$.

[1]



(ii) Calculate, to three significant figures, the resistivity ρ of the nichrome.

$$\rho = \dots\dots\dots \Omega \text{ m} \quad [3]$$

(iii) Calculate the percentage uncertainty in ρ .

$$\text{percentage uncertainty} = \dots\dots\dots \% \quad [2]$$

(iv) Determine the absolute uncertainty in ρ .

$$\text{absolute uncertainty} = \dots\dots\dots \Omega \text{ m} \quad [1]$$

[Total: 10]



- 6 Fig. 6.1 shows four alpha particles W, X, Y and Z moving towards a gold nucleus that is in thin gold foil.

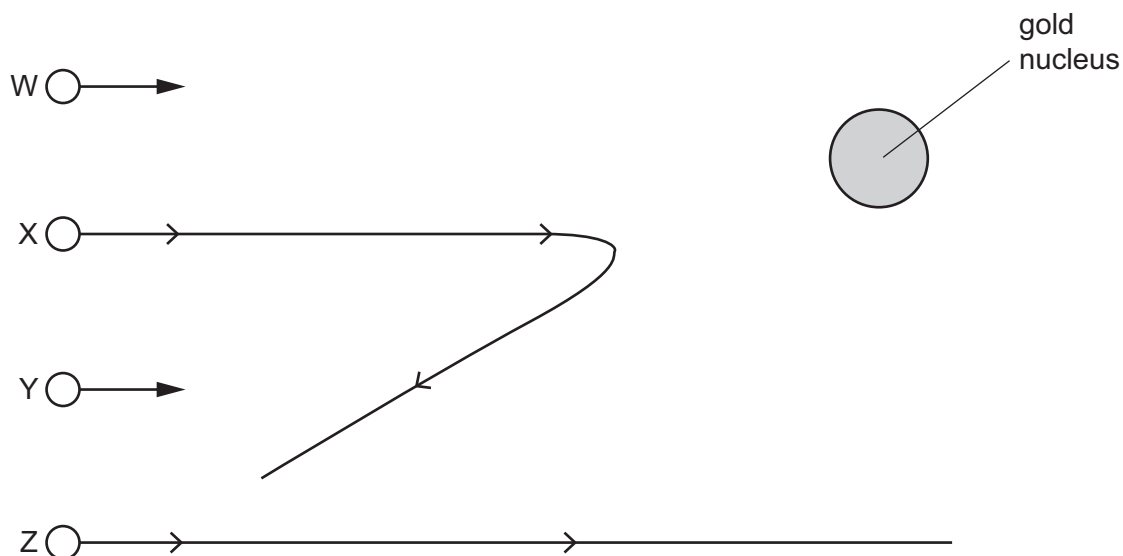


Fig. 6.1 (not to scale)

- (a) (i) The paths of particles X and Z are shown.

Complete Fig. 6.1 to show possible paths for particles W and Y.

[3]

- (ii) Describe what may be inferred about the structure of an atom from the path of particle X.

.....

 [1]

- (iii) When a beam containing many alpha particles is incident on thin gold foil, nearly all of the alpha particles follow paths that are similar to the path of particle Z.

Describe what may be inferred from this about the structure of an atom.

.....

 [1]



- (b) State the mass and the charge, in terms of the atomic mass unit u and the elementary charge e , of an alpha particle.

mass = ... u

charge = ... e
[2]

- (c) There are two types of hadron.
The hadrons that are in alpha particles are each composed of three quarks.

- (i) State the name of this type of hadron.

..... [1]

- (ii) Show, by reference to their constituent quarks, that the hadrons in an alpha particle have charges of either zero or $+1e$.

[2]

[Total: 10]





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