

PLUMI PRACTICE PACK

A Level Physics A

OCR-style practice pack (H556)

Question paper | 30 questions: Modelling physics, Exploring physics and Unified physics

Name	Class	Date
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You must have: the Data, Formulae and Relationships Booklet (the data you need are also on page 2)

You can use: a scientific or graphical calculator, a ruler (cm/mm)

Suggested time: about 8 hours, in three sittings (one per section)

Total marks

362

INSTRUCTIONS

- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Answer **all** the questions, in the spaces provided.
- Where appropriate, support your answer with working. Marks may be given for a correct method even if the answer is wrong.
- Give answers to an appropriate number of significant figures and include units where they are not printed.

INFORMATION

- The total mark for this pack is 362. The marks for each question are shown in brackets [].
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- Questions get harder through each section; the last three in each section are stretch-and-challenge questions.

Section	Content	Questions	Marks
A: Modelling Physics	Modules 3 and 5, with practical skills	1 to 10	124
B: Exploring Physics	Modules 4 and 6, with practical skills	11 to 20	120
C: Unified Physics	Synoptic questions across all modules, with practical skills and data analysis	21 to 30	118



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Data

Values as given in the OCR Data, Formulae and Relationships Booklet. Use the formulae and relationships in the booklet. Any other data you need are given in the question.

Quantity	Symbol	Value
acceleration of free fall	g	9.81 m s^{-2}
elementary charge	e	$1.60 \times 10^{-19} \text{ C}$
speed of light in a vacuum	c	$3.00 \times 10^8 \text{ m s}^{-1}$
Planck constant	h	$6.63 \times 10^{-34} \text{ J s}$
Avogadro constant	N_A	$6.02 \times 10^{23} \text{ mol}^{-1}$
molar gas constant	R	$8.31 \text{ J mol}^{-1} \text{ K}^{-1}$
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	ϵ_0	$8.85 \times 10^{-12} \text{ F m}^{-1}$
electron rest mass	m_e	$9.11 \times 10^{-31} \text{ kg}$
proton rest mass	m_p	$1.673 \times 10^{-27} \text{ kg}$
neutron rest mass	m_n	$1.675 \times 10^{-27} \text{ kg}$
alpha particle rest mass	m_α	$6.646 \times 10^{-27} \text{ kg}$
Stefan constant	σ	$5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

Conversions

Quantity	Value
unified atomic mass unit	$1 \text{ u} = 1.661 \times 10^{-27} \text{ kg}$
electronvolt	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$
day	$1 \text{ day} = 8.64 \times 10^4 \text{ s}$
year	$1 \text{ year} \approx 3.16 \times 10^7 \text{ s}$

Turn over



SECTION A: MODELLING PHYSICS

Modules 3 and 5, with practical skills

- 1 Fig. 1.1 shows a stone thrown from the top of a vertical cliff of height 42 m. The stone leaves the cliff top with a velocity of 18 m s^{-1} at an angle of 35° above the horizontal and lands on the level ground below. Air resistance is negligible.

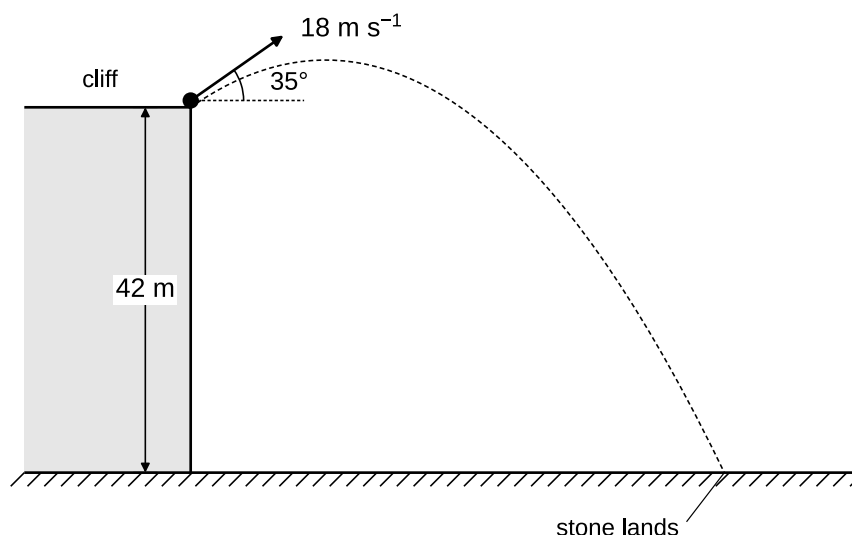


Fig. 1.1
(not to scale)

- (a) Calculate
- (i) the horizontal component of the initial velocity

horizontal component = ... m s^{-1} [1]

- (ii) the vertical component of the initial velocity.

vertical component = ... m s^{-1} [1]

Turn over

- (b) Calculate the time taken for the stone to reach the ground.

time = ... s [3]

- (c) Calculate the horizontal distance from the foot of the cliff to the point where the stone lands.

distance = ... m [2]

- (d) Explain, in terms of the horizontal and vertical components of its velocity, why the path of the stone is curved.

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..... [2]

- (e) Use the principle of conservation of energy to determine the speed of the stone just before it lands.

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

Turn over



- 2 Fig. 2.1 shows a hot-air balloon that is about to leave the ground. The envelope is open at the bottom, at the mouth. A burner below the mouth heats the air inside the envelope.

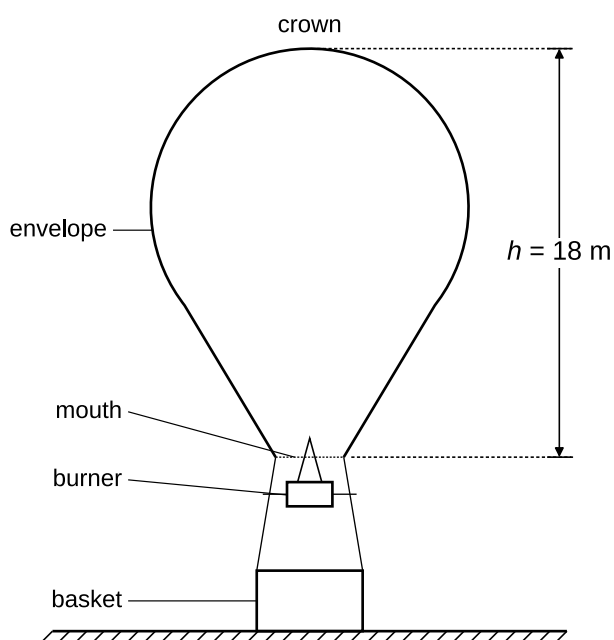


Fig. 2.1
(not to scale)

volume of the envelope = 2800 m^3

total mass of the envelope, burner, basket, fuel and passengers = 620 kg

density of the surrounding air = 1.20 kg m^{-3}

temperature of the surrounding air = 15°C

The mass of 620 kg does not include the air inside the envelope. The volume of the basket, burner and passengers is negligible compared with the volume of the envelope.

- (a) Calculate the upthrust on the balloon.

upthrust = ... N [2]

- (b) The balloon just leaves the ground when the upthrust is equal to the total weight of the balloon, its passengers and the air inside the envelope.

Show that the density of the air inside the envelope is then about 0.98 kg m^{-3} .

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Turn over

[2]

- (c) At the mouth, the pressure of the air inside the envelope is equal to the pressure of the surrounding air. Elsewhere the difference between the two pressures is negligible compared with atmospheric pressure. Both may be treated as ideal gases. Calculate the temperature, in $^{\circ}\text{C}$, of the air inside the envelope when the balloon leaves the ground.

temperature = ... $^{\circ}\text{C}$ [3]

- (d) The crown, at the top of the envelope, is a height h above the mouth, as shown in Fig. 2.1. In each body of air the pressure decreases with height by ρgh , where ρ is the density of that air. Assume that the densities of the air inside and outside the envelope do not change over this height. Calculate how much greater the pressure of the air inside the envelope is than the pressure of the surrounding air, at the crown.

pressure difference = ... Pa [2]

- (e) On a warmer day the density of the surrounding air is lower, at the same pressure. Explain why the air inside the envelope must then be heated to a higher temperature before the balloon can leave the ground.

[2]

Turn over



- 3 Fig. 3.1 shows a uniform horizontal beam AB of length 1.80 m and weight 60 N. The end A is attached to a vertical wall by a hinge. A load of weight 150 N hangs from the end B. The beam is held horizontal by a cable attached to B, which makes an angle of 40° with the beam. The weight of the cable is negligible.

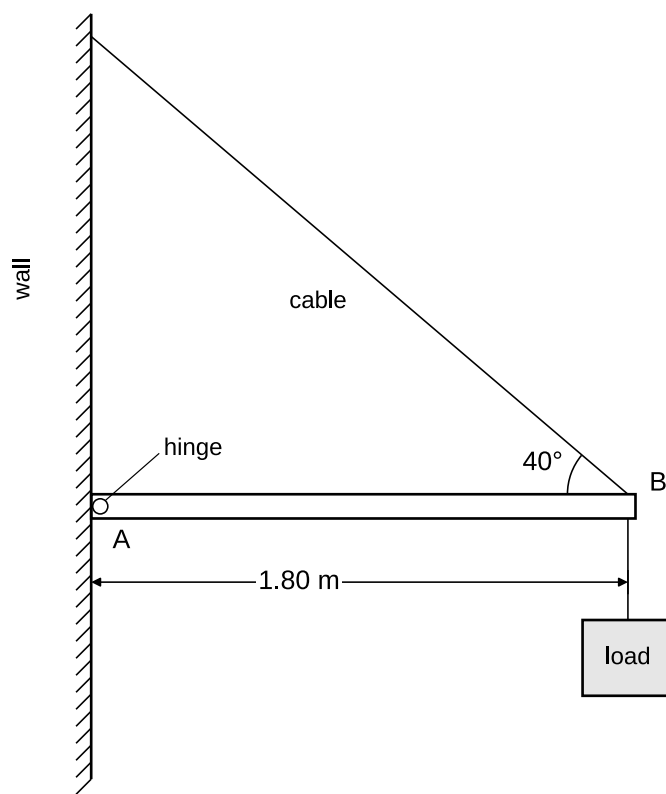


Fig. 3.1
(not to scale)

- (a) State the principle of moments.

.....

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..... [1]

- (b) Show that the tension in the cable is about 2.8×10^2 N.

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..... [3]

Turn over

- (c) Determine the magnitude of the force exerted by the hinge on the beam.

force = ... N [3]

- (d) The end of the cable on the wall is moved higher up the wall, so that the cable makes an angle of 60° with the beam. The cable is still attached to B and the beam stays horizontal. Explain why the tension in the cable decreases.

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..... [2]

Turn over



- 4 Titan is the largest moon of Saturn. Titan's orbit around Saturn may be assumed to be circular, with a radius of 1.22×10^9 m and a period of 15.9 days.

(a) Show that the mass of Saturn is about 5.7×10^{26} kg.

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..... [3]

(b) Calculate the orbital speed of Titan.

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

(c) Another moon of Saturn, Rhea, has a circular orbit of radius 5.27×10^8 m.
Calculate the orbital period of Rhea in days.

period = ... days [2]

(d) Explain why the orbital speed of Rhea is greater than the orbital speed of Titan.

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..... [2]

Turn over



- (e) Show that the SI base units of the gravitational constant G are $\text{kg}^{-1} \text{m}^3 \text{s}^{-2}$.

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..... [2]

Turn over



- 5 Fig. 5.1 shows a satellite S of the Global Positioning System (GPS) in a circular orbit of radius r around the Earth. A receiver at P on the Earth's surface picks up radio signals from S. Fig. 5.1 shows S at the instant it rises above the horizon at P.

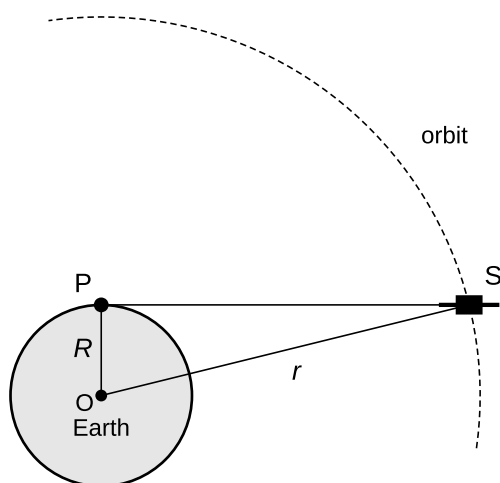


Fig. 5.1
(not to scale)

orbital period of S = 4.31×10^4 s
 mass of S = 1630 kg
 mass of the Earth = 5.97×10^{24} kg
 radius of the Earth = 6.37×10^6 m

Ignore the rotation of the Earth.

- (a) Show that r is about 2.7×10^7 m.

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[3]

Turn over

- (b) Determine the difference between the time taken for a signal to travel from S to P at the instant shown in Fig. 5.1 and the time taken when S is directly above P.

time difference = ... s [4]

- (c) (i) A student says that the minimum energy needed to place S in its orbit, starting from rest on the Earth's surface, is equal to the increase in its gravitational potential energy.

Explain why the student is wrong.

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

- (ii) Calculate the minimum energy needed to place S in its orbit.

energy = ... J [3]

Turn over



- 6 A student investigates how the period T of vertical oscillations of a mass on a spring depends on the mass m hung from the spring. For each mass the student times 20 oscillations three times and calculates the mean time t for 20 oscillations. Table 6.1 shows the results.

Table 6.1

m / kg	t / s	T / s	T^2 / s^2
0.100	8.72	0.436	0.190
0.200	11.80	0.590	0.348
0.300	14.20	0.710	0.504
0.400	16.32	0.816	0.666
0.500	18.10	0.905	0.819
0.600	19.80		

- (a) Explain why the student times 20 oscillations rather than one.

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..... [1]

- (b) Complete Table 6.1 for $m = 0.600$ kg.

[1]

- (c) Fig. 6.1 shows a graph of T^2 against m for the first five rows of Table 6.1. Plot the point for $m = 0.600$ kg on Fig. 6.1 and draw the straight line of best fit.

[2]

Turn over



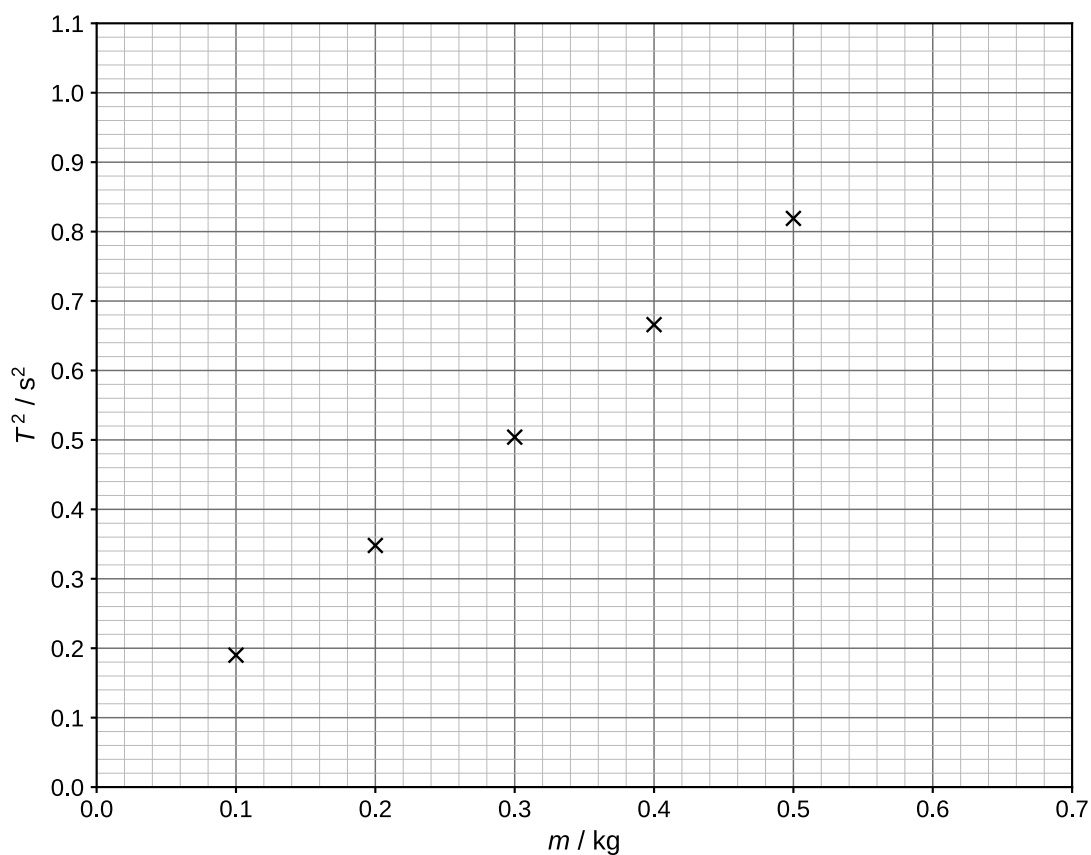


Fig. 6.1

- (d) The period is given by $T = 2\pi\sqrt{M/k}$, where M is the total oscillating mass and k is the force constant of the spring.

Assume that M differs from m by a constant amount. Use your graph to determine k .

$k =$ N m^{-1} [3]

Turn over



- (e) The line of best fit does not pass through the origin.

Use Fig. 6.1 to determine the mass that must be added to m to give M , and suggest what this mass represents.

mass = ... kg [3]

- (f) The uncertainty in each value of t is ± 0.2 s.

Calculate the percentage uncertainty in T^2 for $m = 0.100$ kg.

percentage uncertainty = ... % [2]

- (g) The mass of the spring, measured on a balance, is 0.060 kg.

Use your answer to (e) to determine the fraction of the spring's mass that effectively oscillates with the load.

fraction = ... [2]

Turn over



- 7 Fig. 7.1 shows two identical gliders, A and B, on a horizontal air track. Each glider has mass 0.250 kg and carries a magnet at the end facing the other glider. The magnets repel each other, so the gliders never touch. Friction is negligible. Glider A moves towards B at 0.60 m s^{-1} . Glider B is initially at rest.

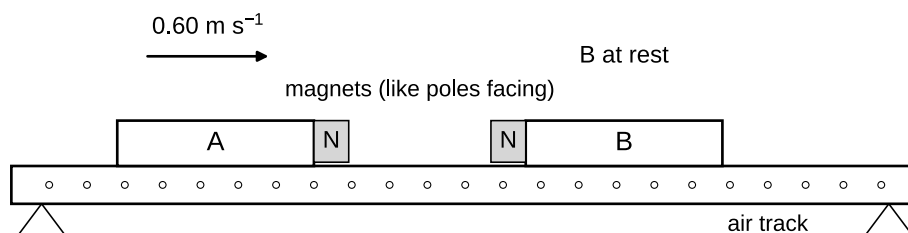


Fig. 7.1

Fig. 7.2 shows how the force F exerted on B by A varies with time t during the interaction.

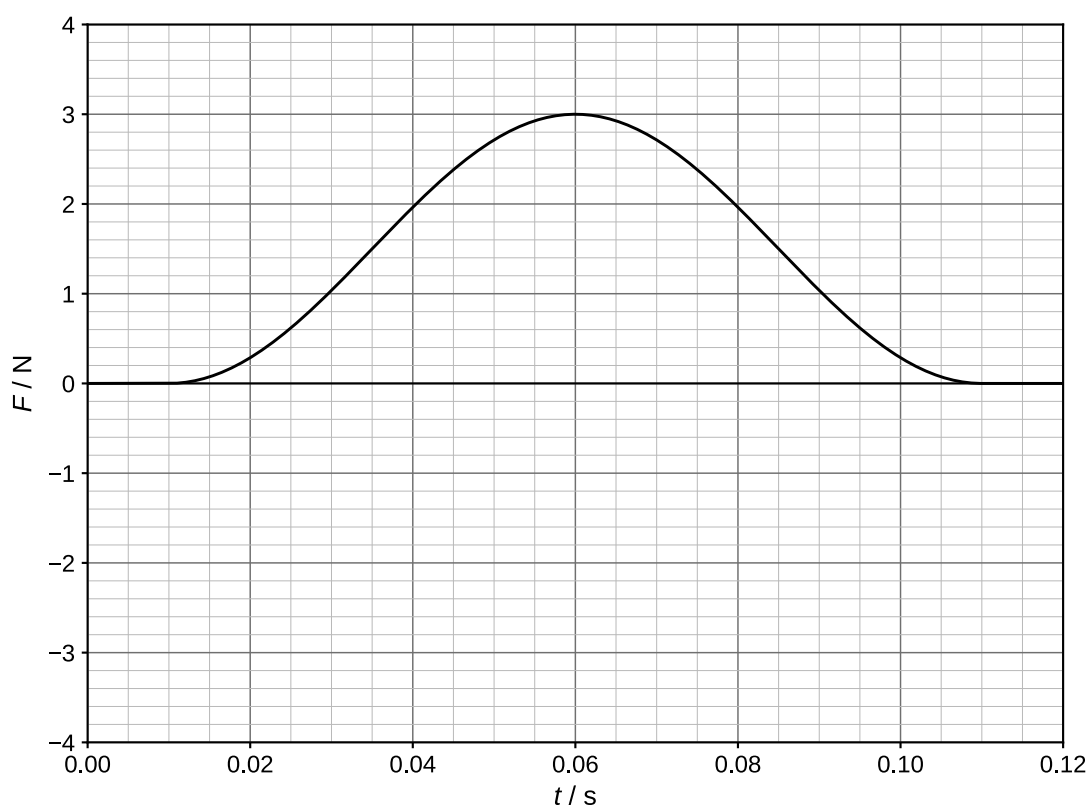


Fig. 7.2

- (a) Use Fig. 7.2 to show that the velocity of B after the interaction is about 0.6 m s^{-1} .

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[3]

Turn over

- (b) Show that the interaction is perfectly elastic.

[3]

- (c) On Fig. 7.2, sketch a graph to show how the force exerted on A by B varies with time during the interaction.

[2]

- (d) The magnets are replaced by pads of putty and a load is fixed to B so that the total mass of B is 0.500 kg. Glider A again moves at 0.60 m s^{-1} towards B, which is at rest. The gliders stick together.
Calculate the percentage of the initial kinetic energy that is transferred to other forms.

percentage = ... % [3]

- (e) A student suggests that, with a softer putty, both gliders could be brought to rest by the collision in (d).
Explain why this is not possible.

[2]

Turn over



- (f) Return to the first interaction, between the magnets. Determine the maximum energy stored in the magnetic interaction between the gliders.

energy = ... J [3]

Turn over



- 8 Fig. 8.1 shows part of a toy track. A small car of mass m is released from rest at a height h above the lowest point of a vertical circular loop of radius r . The car travels down the track and round the inside of the loop. Treat the car as a particle.

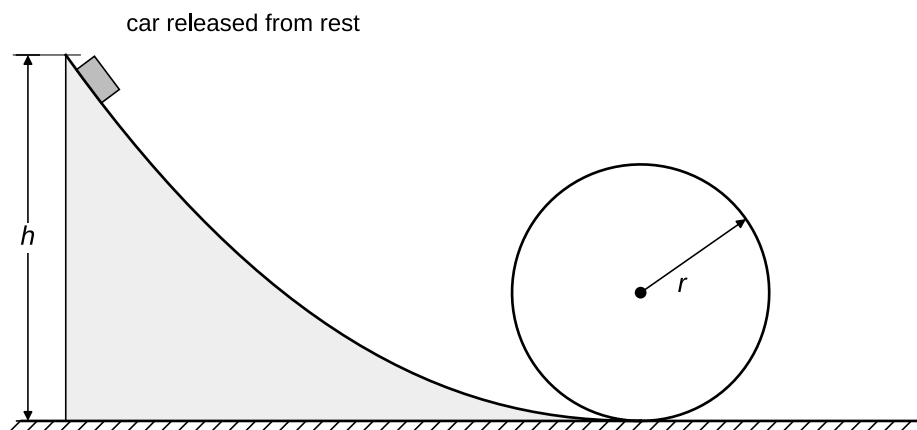


Fig. 8.1
(not to scale)

- (a) Initially assume that there are no resistive forces.
Determine, in terms of r , the minimum value of h for which the car stays in contact with the track all the way round the loop.

minimum $h =$ [4]

Turn over

- (b) The car is released from a height $h = 3r$. There are still no resistive forces.

Determine the ratio

$$\frac{\text{normal contact force on the car at the lowest point of the loop}}{\text{normal contact force on the car at the highest point of the loop}}$$

ratio = ... [4]

- (c) In practice, resistive forces act on the car. The manufacturer claims that a car released from $h = 3r$ will always complete the loop provided that no more than 20% of its initial gravitational potential energy, measured from the lowest point of the loop, is transferred to other forms before it reaches the top of the loop. Evaluate this claim.

..... [3]

- (d) Explain why neither the minimum release height in (a) nor your conclusion in (c) depends on the mass of the car.

..... [2]

Turn over



- 9** A student investigates how the pressure p of a fixed mass of air at constant volume depends on its temperature θ . The air is in a sealed glass flask of internal volume $2.50 \times 10^{-4} \text{ m}^3$, connected by a short narrow tube to a pressure gauge. Fig. 9.1 shows the arrangement. Atmospheric pressure is 101.0 kPa.

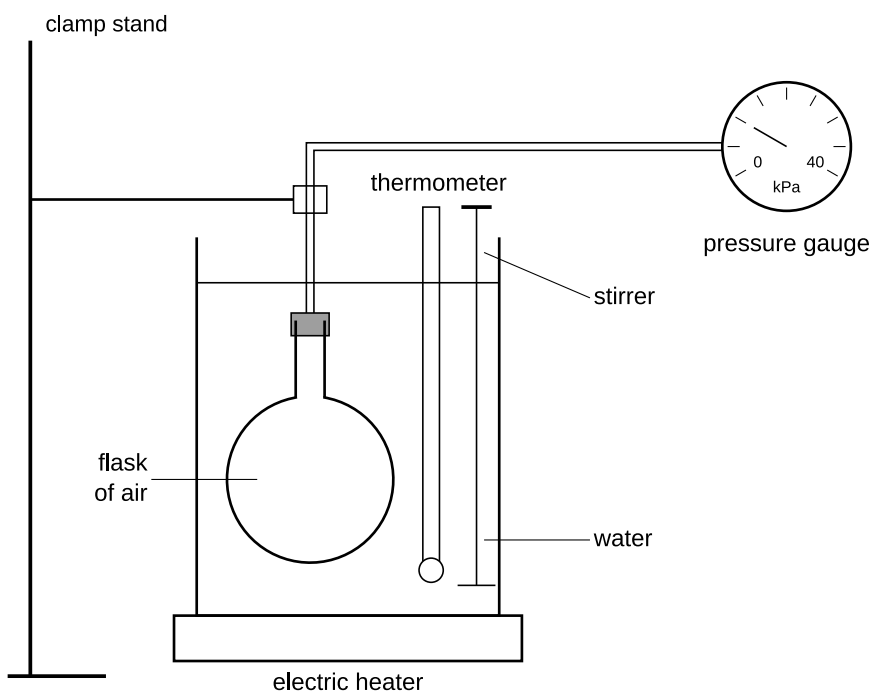


Fig. 9.1

- (a)* Describe how the student should carry out the experiment to obtain accurate results, and explain how the results can be analysed to determine a value for absolute zero in $^{\circ}\text{C}$.

[illegible]

Turn over



[illegible]

Additional answer space if required

Table 9.1 shows the student's results.

Table 9.1

$\theta / ^\circ\text{C}$	10.0	25.0	40.0	55.0	70.0	85.0
gauge reading / kPa	2.6	8.2	13.7	19.1	24.7	30.1

- (b) Use Table 9.1 to determine a value for absolute zero in $^{\circ}\text{C}$.

absolute zero = ... °C [4]

Turn over



- (c) Determine the amount of air, in mol, in the flask.

amount = ... mol [3]

- (d) A second student repeats the experiment using a flask of twice the volume, filled with air at the same initial temperature and pressure.

State and explain the effect, if any, on the gradient of the graph of p against θ .

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..... [2]

Turn over



- 10** Astronomers detect a planet orbiting a distant star by measuring the wavelength of a hydrogen absorption line in the star's spectrum. In the laboratory this line has wavelength 656.28 nm.

The star and the planet both move in circular orbits about their common centre of mass, which is stationary relative to the Earth. The Earth lies in the plane of the orbits. Fig. 10.1 shows how the change $\Delta\lambda$ in the observed wavelength of the line varies with time t .

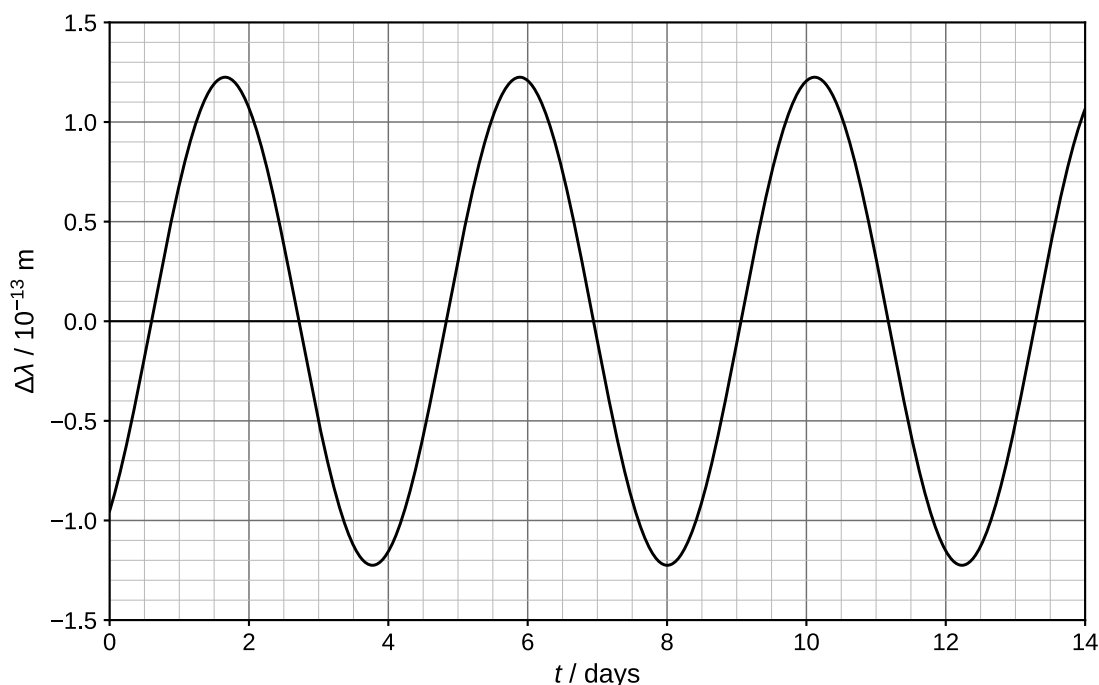


Fig. 10.1

mass of the star = $2.2 \times 10^{30} \text{ kg}$

- (a) Explain why the observed wavelength of the line varies periodically.

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.....

..... [2]

- (b) Use Fig. 10.1 to show that the maximum speed of the star along the line of sight is about 56 m s^{-1} .

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..... [2]

Turn over

- (c) Determine the orbital radius of the planet.

radius = ... m [4]

- (d) Determine the mass of the planet.

mass = ... kg [3]

- (e) For most stars with planets the Earth does not lie in the plane of the orbits.
Explain why the method in (d) then gives only a minimum value for the mass of the planet.

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..... [2]

Turn over



SECTION B: EXPLORING PHYSICS

Modules 4 and 6, with practical skills

- 11** Fig. 11.1 shows a light sensor circuit. A light-dependent resistor (LDR) is connected in series with a fixed resistor R of resistance $10\text{ k}\Omega$ across a supply of e.m.f. 9.0 V and negligible internal resistance. The output p.d. V_{out} across R is measured by a voltmeter of very high resistance.

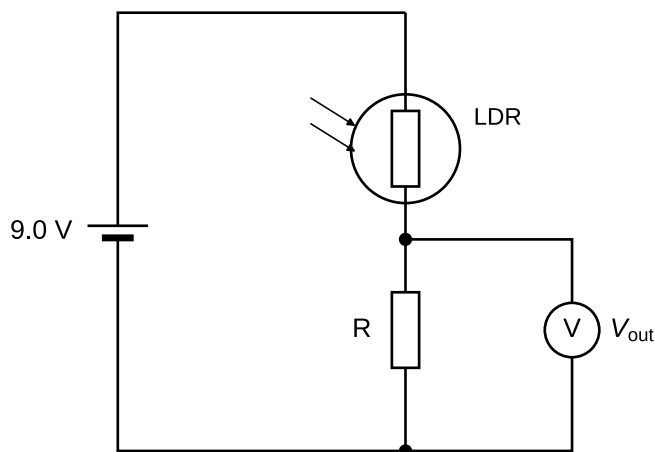


Fig. 11.1

- (a) State how the resistance of the LDR changes as the intensity of the light on it increases.

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..... [1]

- (b) In bright light the resistance of the LDR is $1.5\text{ k}\Omega$. Calculate V_{out} .

$V_{\text{out}} = \dots\dots\dots \text{ V}$ [2]

- (c) In a dark room V_{out} is 1.0 V . Show that the resistance of the LDR is then $8.0 \times 10^4\text{ }\Omega$.

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..... [2]

Turn over

- (d) Explain why V_{out} increases when the intensity of the light on the LDR increases.

[2]

- (e) Describe a change to the circuit, using the same components, so that the output p.d. increases when the light intensity decreases.

[1]

Turn over



- 12** A digital clock is kept running during a power cut by a capacitor of capacitance 0.33 F . While the supply is on, the capacitor is kept charged to a p.d. of 5.0 V . When the supply fails, switch S opens and the capacitor discharges through the clock circuit, which behaves as a resistor of constant resistance $30 \text{ k}\Omega$. Fig. 12.1 shows the circuit. The clock stops working when the p.d. across it falls below 2.0 V .

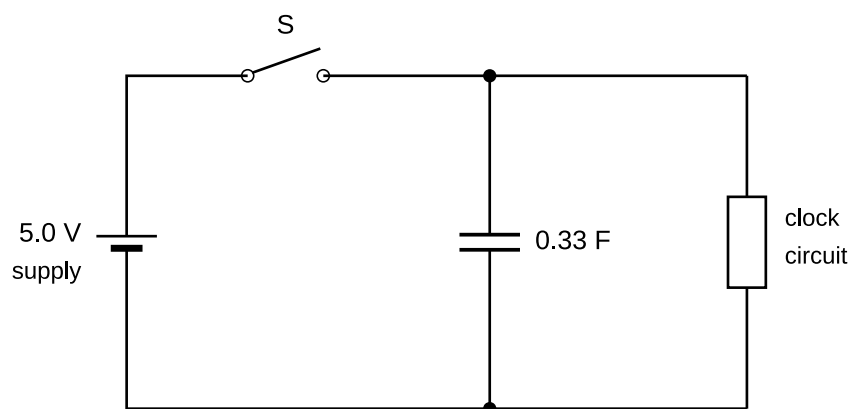


Fig. 12.1

- (a) Show that the time constant of the circuit is about $1 \times 10^4 \text{ s}$.

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..... [2]

- (b) Calculate the time for which the clock keeps running after the power cut begins.

time = ... s [2]

- (c) Calculate the energy transferred from the capacitor to the clock circuit during this time.

energy = ... J [2]

Turn over

- (d) The designer wants the clock to keep running for at least 6.0 hours. The clock circuit and the initial p.d. are unchanged.
Determine the minimum capacitance needed.

capacitance = ... F [3]

- (e) A second clock, identical to the first, is connected in parallel with it across the original fully charged 0.33 F capacitor.
State and explain the effect on the time for which the clocks keep running.

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..... [2]

Turn over



- 13** Fig. 13.1 shows an electron diffraction tube. Electrons are accelerated from rest through a p.d. of 4000 V and then pass through a thin layer of graphite. A pattern of bright rings is seen on the fluorescent screen. The first bright ring is formed by electrons diffracted through an angle $\theta = 9.1^\circ$ from the direction of the beam.

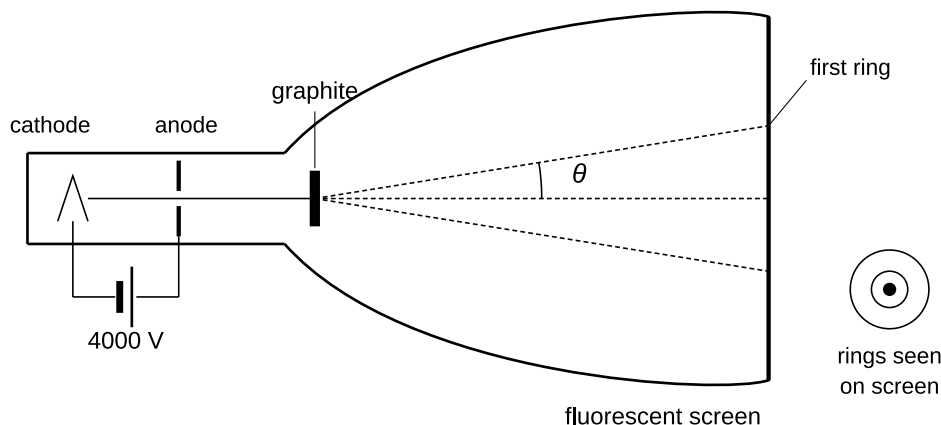


Fig. 13.1
(not to scale)

- (a) Calculate the speed of the electrons.

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

- (b) Calculate the de Broglie wavelength of the electrons.

wavelength = ... m [2]

Turn over

- (c) Treat the graphite as a diffraction grating, with the first bright ring as the first-order maximum.

Calculate the spacing d between the rows of carbon atoms.

$d =$ m [2]

- (d) Explain how the rings provide evidence that electrons behave as waves.

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..... [2]

- (e) The accelerating p.d. is increased. State and explain the effect on the diameter of the rings.

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..... [2]

Turn over



- 14 An X-ray tube is operated with an accelerating p.d. of 80 kV. The intensity of the X-ray beam where it enters a patient is 120 W m^{-2} . Fig. 14.1 shows how the intensity I of the beam varies with the thickness x of soft tissue it has passed through.

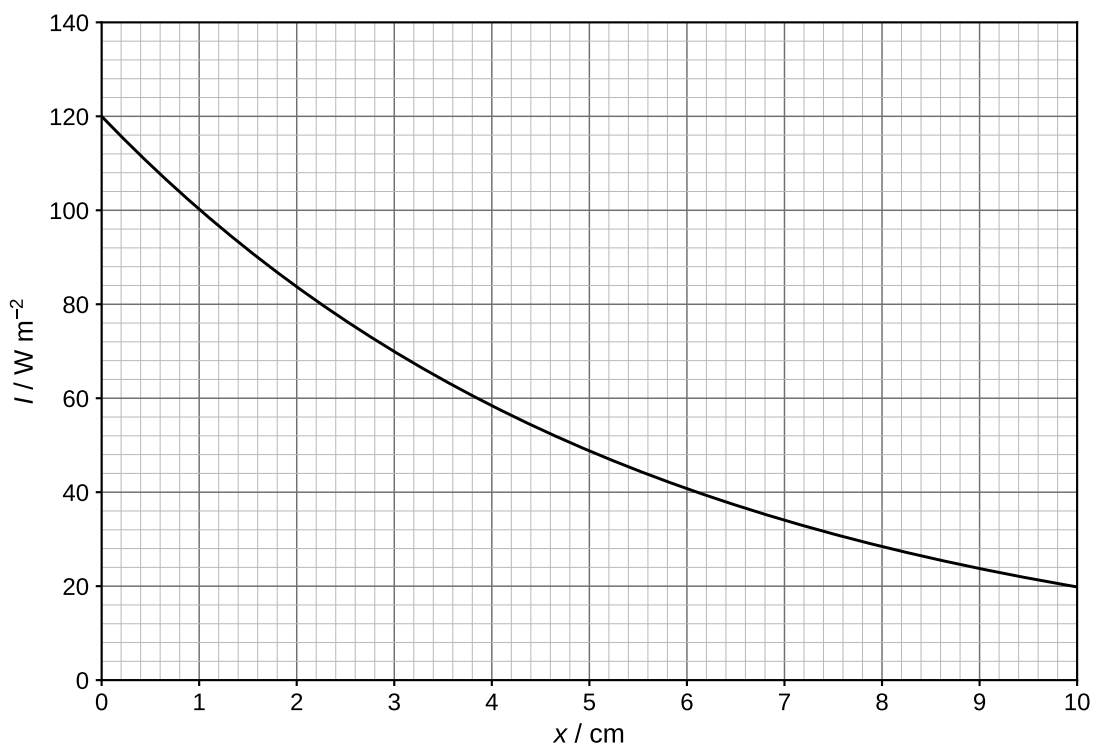


Fig. 14.1

- (a) Calculate the minimum wavelength of the X-ray photons produced by the tube.

wavelength = ... m [2]

- (b) Use Fig. 14.1 to determine the intensity of the beam after it has passed through 6.0 cm of soft tissue.

intensity = ... W m^{-2} [1]

Turn over



- (c) Hence calculate the attenuation coefficient μ of soft tissue for this beam.

$$\mu = \text{.....} \text{ cm}^{-1} \quad [2]$$

- (d) The attenuation coefficient of bone for this beam is 0.48 cm^{-1} .
Calculate the thickness of bone that halves the intensity of the beam.

$$\text{thickness} = \text{.....} \text{ cm} \quad [2]$$

- (e) Explain why a contrast medium containing barium is given to a patient before an X-ray image of the intestines is taken.

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..... [2]

Turn over



- 15** A recycling plant separates flakes of two plastics, PET and PVC. The flakes are tumbled together so that the PET flakes become positively charged and the PVC flakes become negatively charged. They are then released from rest midway between two large, vertical, parallel metal plates, level with the top of the plates, as shown in Fig. 15.1.

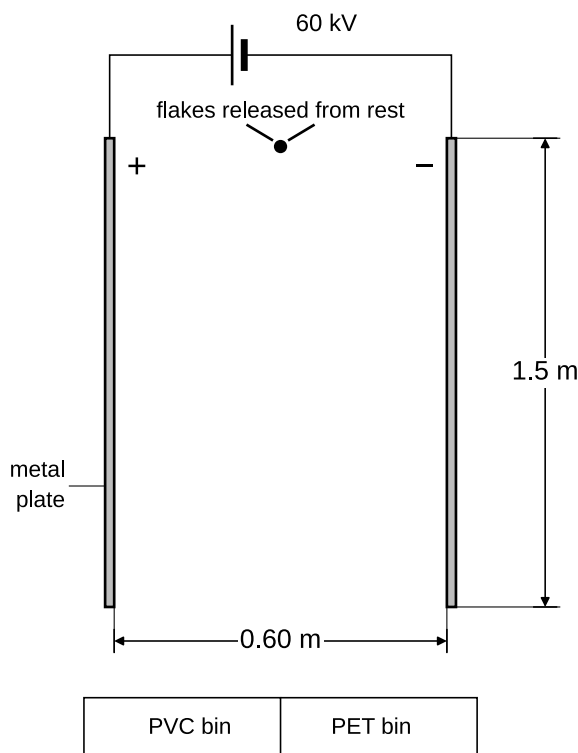


Fig. 15.1

(not to scale)

The plates are 0.60 m apart and 1.5 m high. A p.d. of 60 kV is maintained between them. A typical PET flake has mass 3.0×10^{-6} kg and charge $+4.0 \times 10^{-11}$ C. Air resistance on the flakes is negligible.

- (a) Calculate the electric force on a PET flake between the plates.

force = ... N [2]

- (b) Show that a flake takes about 0.55 s to fall the full height of the plates.

.....

 [2]

Turn over

- (c) Determine whether a PET flake reaches the bottom of the plates without striking a plate.

[illegible]

[4]

- (d) Explain why the path of a flake between the plates is a straight line and not a parabola.

[2]

- (e) A PVC flake of the same mass carries a charge of -2.5×10^{-11} C. Calculate the distance between the points at which a PET flake and a PVC flake reach the bottom of the plates.

distance = _____ m [2]

Turn over



- 16** Fig. 16.1 shows apparatus used to investigate stationary waves. A microwave transmitter T faces a flat metal plate M. A small detector D, connected to a meter, is moved slowly along the line between T and M. The meter reading rises and falls repeatedly.

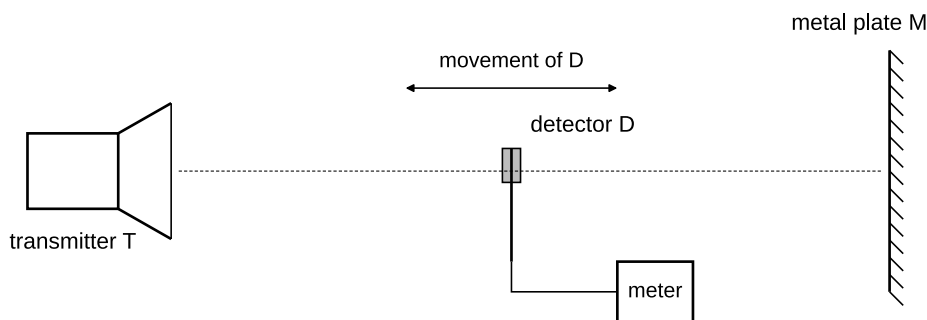


Fig. 16.1
(not to scale)

The student measures the distance between the first and the eleventh positions of minimum reading as 141 mm, with an uncertainty of ± 2 mm.

- (a) Explain how a stationary wave is formed between T and M.

.....

.....

.....

.....

..... [2]

- (b) Calculate the frequency of the microwaves.

frequency = ... Hz [3]

- (c) Calculate the absolute uncertainty in your value for the frequency.

uncertainty = $\pm$ Hz [2]

Turn over

Fig. 16.2 represents the stationary wave between T and M. P, Q and R are three points on the line between T and M. P and Q are a quarter of a wavelength apart.

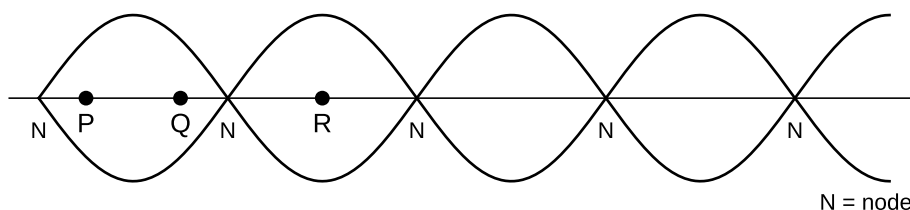


Fig. 16.2
(not to scale)

- (d) (i) State the phase difference between the oscillations at P and at Q.

[1]

- (ii) State the phase difference between the oscillations at P and at R.

[1]

- (iii) A student says that the phase difference between P and Q must be 90° , because they are a quarter of a wavelength apart.
Explain why the student is wrong.

[2]

- (e) M is replaced by a board that reflects only part of the microwaves. The meter reading is proportional to the amplitude of the microwaves at D. The ratio of the reading at a maximum to the reading at a neighbouring minimum is now 9.0.
Determine the ratio of the amplitude of the reflected wave to the amplitude of the incident wave.

ratio = ... [3]

Turn over

- 17 A student shines monochromatic light onto a metal surface in a vacuum tube. For each frequency f , the student measures the stopping potential V_s , the smallest p.d. that reduces the photoelectric current to zero, so that eV_s is the maximum kinetic energy of the emitted electrons. Fig. 17.1 shows the results with a line of best fit.

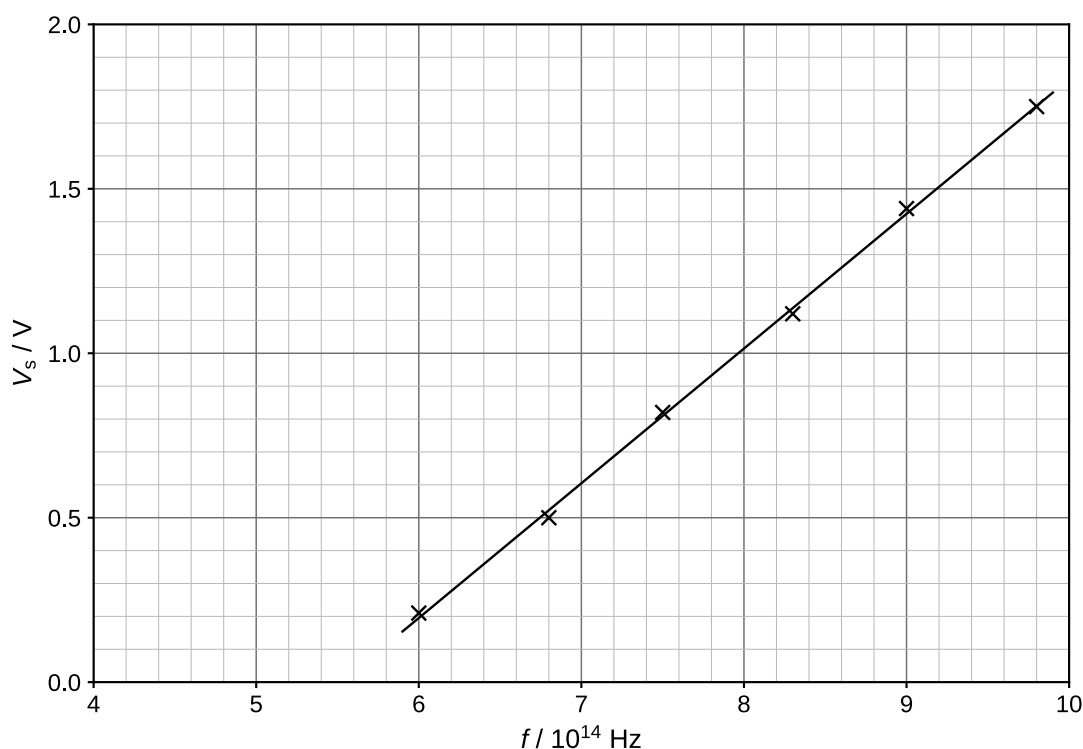


Fig. 17.1

- (a) Explain why no electrons are emitted when f is below a certain value, however intense the light.

.....

.....

.....

.....

..... [2]

Turn over



- (b) Use Fig. 17.1 to determine a value for the Planck constant.

$h =$ J s [3]

- (c) Use Fig. 17.1 to determine the work function of the metal, in eV.

work function = ... eV [2]

- (d) Light of frequency 8.0×10^{14} Hz and power 2.0 mW is incident on the metal. On average, one photon in 200 releases an electron.
Calculate the maximum photoelectric current.

current = ... A [3]

- (e) The intensity of the light at each frequency is doubled. State and explain the effect, if any, on

- (i) the graph in Fig. 17.1

.....

 [1]

- (ii) the current in (d).

.....
 [1]

Turn over



- (f) Electrons emitted with the maximum kinetic energy by light of frequency 9.0×10^{14} Hz enter a uniform magnetic field of flux density 2.0 mT, at right angles to their velocity. Use Fig. 17.1 to determine the radius of their circular path.

radius = ... m [3]

Turn over



- 18** Fig. 18.1 shows a design for an instrument to separate the isotopes neon-20 and neon-22. Singly charged positive neon ions, initially at rest, are accelerated through a p.d. V . They pass through a slit into a region of uniform magnetic field of flux density 0.20 T , directed out of the plane of the paper. Each ion travels in a semicircle and hits a detector plate in the same plane as the slit.

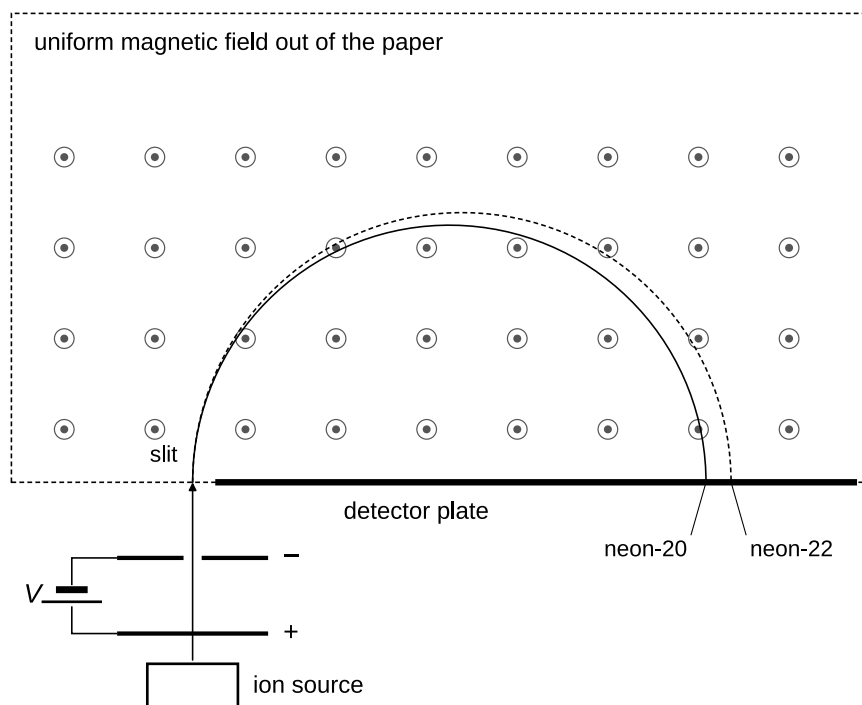


Fig. 18.1
(not to scale)

mass of a neon-20 ion = 19.99 u

mass of a neon-22 ion = 21.99 u

The detector can separate the two isotopes only if the points where they hit the plate are at least 10.0 mm apart.

- (a) Explain why the speed of an ion is constant while it is in the magnetic field.

.....

.....

.....

.....

.....

[2]

Turn over

- (b) Determine the minimum value of V for the instrument to separate the two isotopes.

$V =$ V [5]

- (c) An engineer suggests that the instrument would separate the isotopes with a smaller accelerating p.d. if the magnetic flux density were doubled. Evaluate this suggestion.

..... [2]

- (d) A few neon-20 atoms lose two electrons and become doubly charged ions. Determine the distance between the points where singly and doubly charged neon-20 ions hit the detector, when V has the value found in (b).

distance = ... m [3]

Turn over



- 19** A student wants to determine the capacitance C of a large capacitor labelled ' $470\ \mu\text{F} \pm 20\%$ '. The student charges the capacitor to $6.00\ \text{V}$ using a battery and then opens switch S , so that only a digital voltmeter of resistance $10.0\ \text{M}\Omega \pm 5\%$ remains connected across the capacitor, as shown in Fig. 19.1. The reading on the voltmeter falls slowly. Assume that no charge leaks through the capacitor itself.

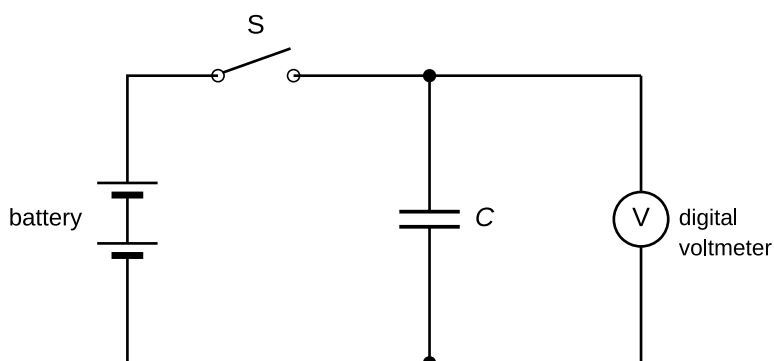


Fig. 19.1

- (a)* Describe how the student can use this arrangement to collect data to determine C , and explain how the data should be analysed graphically to obtain C .

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Turn over

[6]

Table 19.1 shows the student's results.

Table 19.1

t/s	0	1200	2400	3600	4800	6000
V/V	6.00	4.77	3.78	3.00	2.38	1.89

- (b) Use Table 19.1 to determine C .

C = ... **F [3]**

- (c) Evaluate whether the student's value is consistent with the label on the capacitor. Take account of the uncertainty in the resistance of the voltmeter.

Turn over



[3]

- (d) Calculate the time taken for the energy stored in the capacitor to fall to half its initial value.

time = ... s **[3]**

Turn over

- 20 In positron emission tomography (PET), a patient is injected with a tracer containing fluorine-18, which decays by β^+ emission with a half-life of 110 minutes. Each positron travels about a millimetre through the tissue before it annihilates with an electron. The two gamma photons produced are detected by a ring of detectors around the patient, as shown in Fig. 20.1.

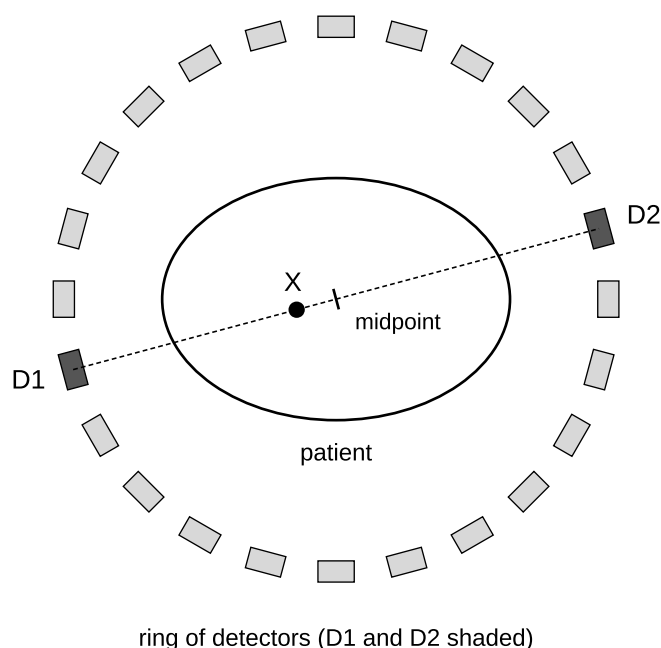


Fig. 20.1
(not to scale)

- (a) (i) Explain why the two photons are detected on opposite sides of the ring.

.....

.....

.....

.....

[2]

- (ii) Show that the energy of each photon is about 8.2×10^{-14} J.

.....

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.....

.....

[2]

Turn over

- (b) In Fig. 20.1 the detectors D1 and D2 are 0.80 m apart. An annihilation occurs at a point X on the line D1D2. The scanner's clock starts at a trigger signal. The photon reaching D1 is detected 1.63 ns after the trigger and the photon reaching D2 is detected 2.03 ns after the trigger.
- Determine the distance of X from D1 and the time, after the trigger, at which the annihilation happened.

distance from D1 = ... m

time after trigger = ... ns [4]

- (c) The scanner measures each arrival-time difference with an uncertainty of ± 0.20 ns. The manufacturer claims that the scanner locates each annihilation along a line such as D1D2 to within ± 2 cm.
- Evaluate this claim.

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.....

..... [3]

Turn over



- (d) The dose must have an activity of 350 MBq at the moment of injection. The dose is prepared 2.0 hours before the injection.
Calculate the activity of the dose when it is prepared.

activity = ... MBq [3]

Turn over



SECTION C: UNIFIED PHYSICS

Synoptic questions across all modules, with practical skills and data analysis

- 21** A student determines the resistivity of the metal of a wire. The student measures the diameter of the wire at five different places along it using a micrometer screw gauge. Table 21.1 shows the readings.

Table 21.1

diameter / mm	0.37	0.38	0.38	0.36	0.36
---------------	------	------	------	------	------

- (a) Explain why the student measures the diameter at several places along the wire.

.....

.....

..... [1]

- (b) Calculate the mean diameter d of the wire and its absolute uncertainty.

$$d = \text{.....} \pm \text{.....} \text{ mm} \quad [2]$$

The student measures the resistance R of different lengths L of the wire. Fig. 21.1 shows the results and the line of best fit.

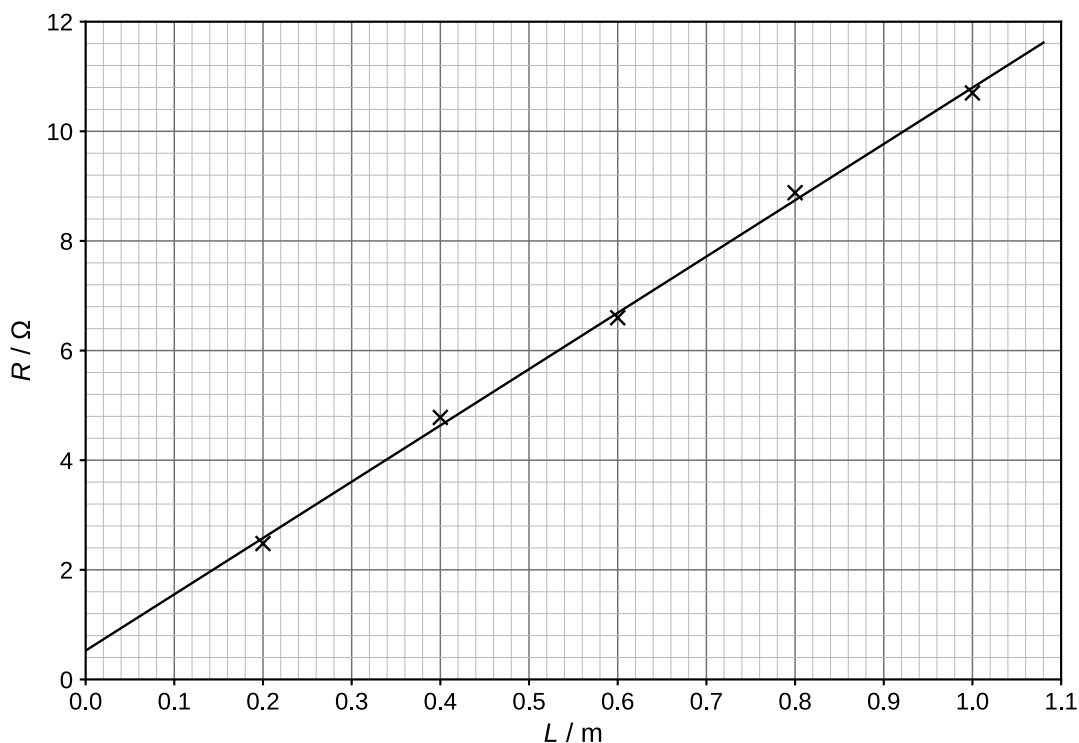


Fig. 21.1

Turn over



- (c) Use Fig. 21.1 and your answer to (b) to determine the resistivity of the metal.

resistivity = ... $\Omega \text{ m}$ [3]

- (d) The line of best fit does not pass through the origin.
Suggest a reason for this and explain why it does not affect the value of the resistivity.

.....

.....

.....

.....

..... [2]

Turn over



- 22** A farm uses a small hydroelectric generator on a mountain stream. Each second, 20 kg of water falls through a vertical height of 6.0 m before driving a turbine. The turbine turns a generator coil in a uniform magnetic field.

- (a) Show that the rate at which the falling water loses gravitational potential energy is about 1.2×10^3 W.

[2]

- (b) The turbine and generator together have an efficiency of 60%. Calculate the electrical power output.

power = ... W [2]

- (c) The generator coil has 200 turns, each of area 0.012 m^2 . It rotates at 25 revolutions per second in a uniform magnetic field of flux density 0.25 T. The flux linkage of the coil is greatest when the plane of the coil is perpendicular to the field. Calculate the average e.m.f. induced in the coil during the quarter of a turn that starts from this position.

average e.m.f. = ... V [3]

- (d) Explain why the e.m.f. induced in the coil alternates, and why it is greatest when the plane of the coil is parallel to the magnetic field.

Turn over



[3]

- (e) In a dry summer the mass of water falling each second halves, but the coil is kept rotating at 25 revolutions per second.

State and explain the effect on the peak e.m.f. and on the electrical power available.

[2]

Turn over



- 23** A proposed lunar mass driver is a long, straight electromagnetic track laid on the surface of the Moon. It would accelerate payloads horizontally from rest to a speed high enough for them to escape from the Moon completely, without any rocket fuel.

mass of the Moon = 7.35×10^{22} kg

radius of the Moon = 1.74×10^6 m

mass of one payload = 25 kg

greatest acceleration the payload can withstand = 200 m s^{-2}

- (a) Calculate the gravitational field strength at the surface of the Moon.

field strength = ... N kg^{-1} [2]

- (b) Show that a payload launched from the surface needs a speed of about $2.4 \times 10^3 \text{ m s}^{-1}$ to escape from the Moon.

.....

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..... [3]

- (c) Calculate the minimum length of the track.

length = ... m [2]

Turn over



- (d) Calculate the mean power delivered to one payload while it is being accelerated.

power = ... W [3]

- (e) Suggest two reasons why a mass driver of this kind is practical on the Moon but not on the Earth.

.....

.....

.....

..... [2]

Turn over



- 24** An electric shower heats water as it flows through it. The heating element has a power of 9.0 kW when connected to the 230 V mains supply. Cold water enters the shower at 12 °C.

specific heat capacity of water = $4200 \text{ J kg}^{-1} \text{ K}^{-1}$

- (a) Calculate the current in the heating element.

current = ... A [1]

- (b) Calculate the maximum mass of water that can flow through the shower each minute if the water leaves the shower at 40 °C. Assume that all of the energy from the element is transferred to the water.

mass = ... kg [3]

- (c) The element is a coiled metal ribbon of resistivity $1.1 \times 10^{-6} \Omega \text{ m}$ and cross-sectional area $1.5 \times 10^{-6} \text{ m}^2$, cooled by the water flowing past it. Calculate the length of the ribbon.

length = ... m [3]

- (d) Explain why the cable that connects the shower to the mains must have a large cross-sectional area.

.....

.....

.....

.....

..... [2]

Turn over



- (e) In winter the cold water enters at 5 °C. Calculate the flow rate needed for the water to leave the shower at 40 °C.

flow rate = ... kg per minute [2]

Turn over



- 25 A student investigates how the period T of a simple pendulum depends on its length L . The student suggests that $T = kL^n$, where k and n are constants. Table 25.1 shows the results.

Table 25.1

L / m	T / s	$\lg(L / \text{m})$	$\lg(T / \text{s})$
0.200	0.90	-0.699	-0.046
0.400	1.27	-0.398	0.104
0.600	1.55	-0.222	0.190
0.800	1.80	-0.097	0.255
1.000	2.00	0.000	0.301
1.200	2.20		

- (a) Show that a graph of $\lg T$ against $\lg L$ should be a straight line, and state how n and k can be found from it.

.....

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.....

[2]

- (b) Complete Table 25.1. Then plot the remaining point on Fig. 25.1 and draw its error bar, using the information in (e).

[3]

Turn over



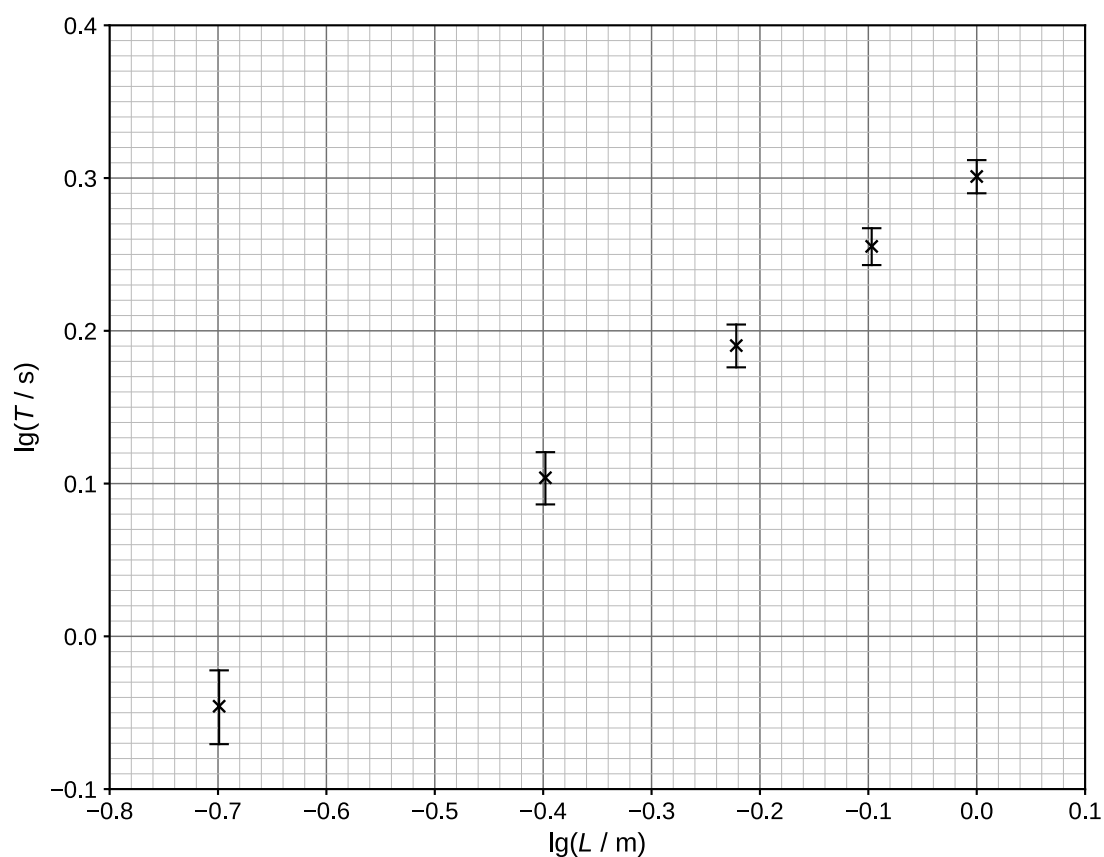


Fig. 25.1

- (c) Draw the straight line of best fit and use it to determine n .

$n =$ [2]

- (d) Theory suggests that $T = 2\pi\sqrt{L/g}$.
Use your graph to determine a value for g .

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

Turn over



- (e) The uncertainty in each value of T is ± 0.05 s. The error bars on Fig. 25.1 show the resulting uncertainty in $\lg T$.

Use Fig. 25.1 to determine whether the data support the claim that $n = 0.5$ exactly.

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.....

..... [3]

Turn over



- 26 Fig. 26.1 shows the ionisation chamber of a smoke alarm. It has two parallel metal plates connected to a d.c. supply of p.d. 9.0 V and to a sensitive ammeter. A thin source of americium-241 is fixed to the surface of one of the plates.

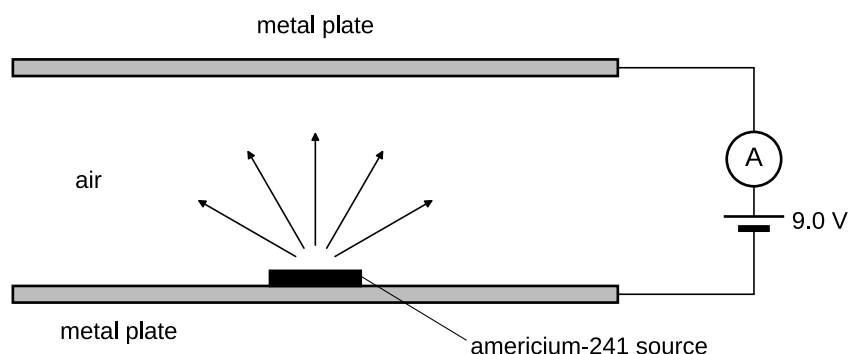


Fig. 26.1
(not to scale)

Americium-241 emits alpha particles equally in all directions, with a half-life of 432 years. When the alarm is new, the activity of the source is 3.7×10^4 Bq. Each alpha particle that enters the air between the plates has an initial kinetic energy of 5.5 MeV and loses all of this energy in the air. On average, 35 eV is needed to produce one ion pair (a positive ion and an electron) in air. Every ion and electron produced reaches a plate.

- (a) Suggest why a source that emits alpha particles, rather than beta or gamma radiation, is used.

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.....

[2]

Turn over

- (b) Determine the current in the ammeter when the alarm is new and there is no smoke in the chamber.

current = ... A [5]

- (c) Smoke reduces the current. The alarm sounds when the current falls below 75% of the value in (b). The alarm is designed to work for 10 years. A householder is concerned that the decay of the source will make the alarm sound, with no smoke present, before the 10 years are over.

Evaluate this concern.

.....

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.....

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.....

..... [3]

Turn over



- 27** A bright star has a peak emission wavelength of 302 nm. The intensity of the star's radiation at the Earth, above the atmosphere, is $2.3 \times 10^{-8} \text{ W m}^{-2}$. The parallax angle of the star is 0.130 arcseconds.

Wien's constant: $\lambda_{\text{max}} T = 2.90 \times 10^{-3} \text{ m K}$

1 pc = $3.09 \times 10^{16} \text{ m}$

radius of the Sun = $6.96 \times 10^8 \text{ m}$

- (a) Calculate the surface temperature of the star.

temperature = ... K [2]

- (b) Determine the radius of the star as a multiple of the radius of the Sun.

radius = ... $\times$ radius of the Sun [5]

- (c) Estimate the number of photons from the star that enter the pupil of an observer's eye each second. The pupil has a diameter of 6.0 mm. Assume that all the photons have the peak wavelength and ignore absorption by the atmosphere.

number per second = ... [3]

Turn over



- (d) The percentage uncertainty in the peak wavelength is $\pm 2\%$. Determine the resulting percentage uncertainty in the radius found in (b).

percentage uncertainty = ... % [2]

Turn over



- (a)* Describe how the student can determine V_0 for each LED, including a labelled circuit diagram, and explain how the results can be analysed graphically to determine h .

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Turn over



[6]

Additional answer space if required

Fig. 28.1 shows the student's results plotted as a graph of V_0 against $1/\lambda$, with error bars.

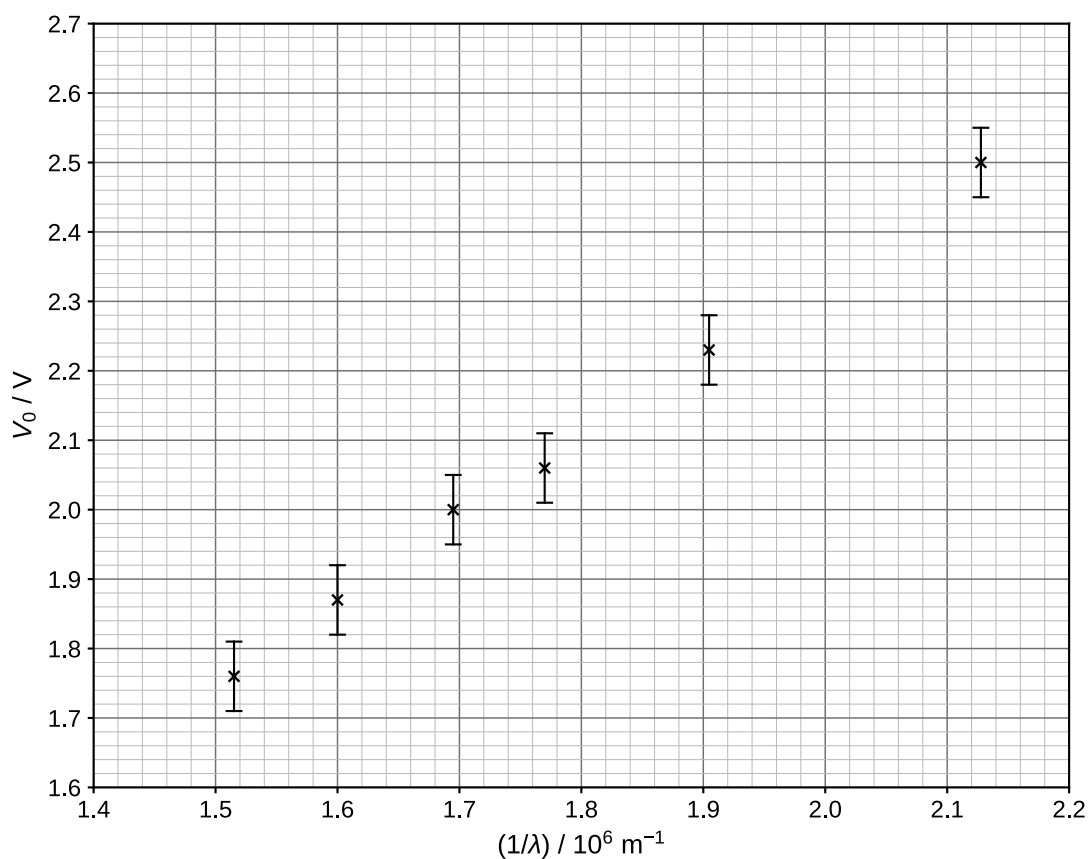


Fig. 28.1

- (b) (i) On Fig. 28.1 draw the straight line of best fit and a worst acceptable straight line.

Turn over



[2]

(ii) Use your lines to determine h and its absolute uncertainty.

$$h = \text{.....} \pm \text{.....} \text{ s [4]}$$

- (c) The accepted value of the Planck constant is $6.63 \times 10^{-34} \text{ J s}$.
Evaluate whether the student's experiment gives an accurate value for h .

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.....

.....

.....

..... [2]

Turn over



- 29** A steel guitar string is stretched between two fixed points, the nut and the bridge, 0.648 m apart, as shown in Fig. 29.1. When plucked, the string vibrates at its fundamental frequency of 330 Hz.

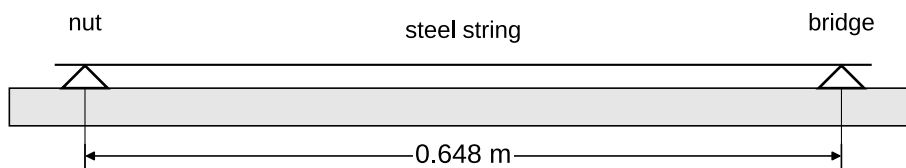


Fig. 29.1
(not to scale)

The speed v of transverse waves on a stretched string is given by $v = \sqrt{T/\mu}$, where T is the tension and μ is the mass per unit length of the string.

diameter of the string = 0.254 mm

density of steel = 7800 kg m^{-3}

Young modulus of steel = 2.0×10^{11} Pa

ultimate tensile strength of steel = 2.2×10^9 Pa

- (a) Explain how a stationary wave is formed on the plucked string, and why the wavelength of the fundamental mode is $2 \times 0.648 \text{ m}$.

[2]

- (b) Show that the tension in the string is about 72 N.

[4]

Turn over

- (c) Calculate the strain in the string.

strain = ... [2]

- (d) A guitarist wants to tune this string up to 660 Hz, an octave higher, without changing the length between the nut and the bridge.
Evaluate whether this is possible.

..... [3]

- (e) A second guitarist suggests using a thicker string of the same steel, of the same length, tuned to 660 Hz.
Explain why this does not solve the problem.

..... [2]

Turn over



- 30** A camera drone has four horizontal rotors, each of radius 0.12 m, and a total mass of 1.20 kg. When it hovers, the rotors push air vertically downwards, as shown in Fig. 30.1.

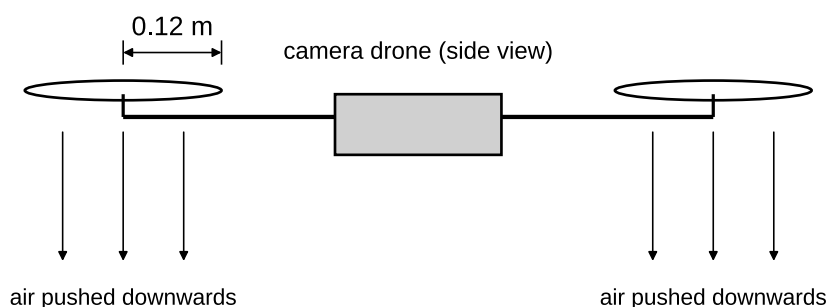


Fig. 30.1

(side view, two of the four rotors shown; not to scale)

Model the air as being accelerated from rest to a speed v as it passes through the total area swept out by the four rotors. The density of the air is 1.20 kg m^{-3} .

The drone's battery has an e.m.f. of 11.1 V and a capacity of 5000 mA h. The motors and rotors together transfer 40% of the electrical energy supplied to kinetic energy of the air.

- (a) Explain, using Newton's laws of motion, how the rotors produce an upward force on the drone.

[2]

- (b) Show that, when the drone hovers, v is about 7.4 m s^{-1} .

[4]

Turn over



- (c) Determine the maximum time for which the drone can hover.

time = ... s [4]

- (d) The manufacturer claims that fitting an extra 0.60 kg camera reduces the hovering time in proportion to the increase in total mass, to two thirds of the value in (c).
Evaluate this claim.

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..... [3]

END OF QUESTION PAPER





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