OCR
Oxford Cambridge and RSA

A Level Physics A

H556/03 Unified physics

Thursday 29 June 2017 – Morning
Time allowed: 1 hour 30 minutes

You must have:
- The Data, Formulae and Relationship Booklet (sent with general stationery)

You may use:
- a scientific calculator
- a ruler (cm/mm)

First name	
Last name	
Centre number	
Candidate number	

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

INFORMATION
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **20** pages.

Answer **all** the questions

1 A stationary uranium-238 nucleus $\left({}^{238}_{92}\text{U}\right)$ decays into a nucleus of thorium-234 by emitting an alpha-particle.

(a) The chemical symbol for thorium is Th. Write a nuclear equation for this decay.

[2]

(b) The mass of the uranium nucleus is 4.0×10^{-25} kg. After the decay the thorium nucleus has a speed of $2.4 \times 10^{5}\ \text{m s}^{-1}$.

Calculate the kinetic energy, in MeV, of the alpha-particle.

kinetic energy = ... MeV **[4]**

(c) The uranium-238 $\left({}^{238}_{92}\text{U}\right)$ nucleus starts the decay chain which ends with a nucleus of lead-206 $\left({}^{206}_{82}\text{Pb}\right)$.

Show that 14 particles are emitted during this decay chain. Explain your reasoning.

[3]

2 A small thin rectangular slice of semiconducting material has width a and thickness b and carries a current I. The current is due to the movement of electrons. Each electron has charge $-e$ and mean drift velocity v. A uniform magnetic field of flux density B is perpendicular to the direction of the current and the top face of the slice as shown in Fig. 2.1.

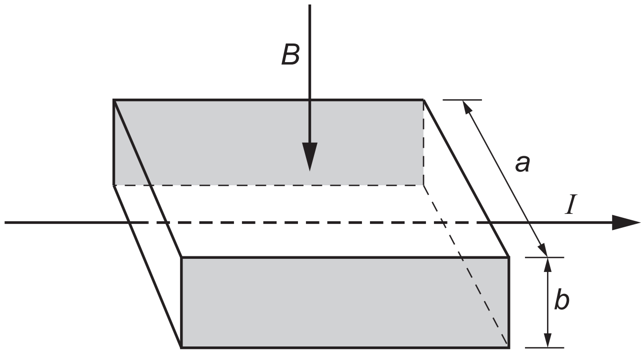


Fig. 2.1

(a) As soon as the current is switched on, the moving electrons in the current are forced towards the shaded rear face of the slice where they are stored. This causes the shaded faces to act like charged parallel plates. Each electron in the current now experiences both electric and magnetic forces. The resultant force on each electron is now zero.

Write the expressions for the electric and magnetic forces acting on each electron and use these to show that the magnitude of the potential difference V between the shaded faces is given by

$$V = Bva.$$

[3]

(b) Here are some data for the slice in a particular experiment.

number of conducting electrons per cubic metre, $n = 1.2 \times 10^{23}\ \mathrm{m^{-3}}$
$a = 5.0\ \mathrm{mm}$
$b = 0.20\ \mathrm{mm}$
$I = 60\ \mathrm{mA}$
$B = 0.080\ \mathrm{T}$

Use this data to calculate

(i) the mean drift velocity v of electrons within the semiconductor

v = ... $\mathrm{m\,s^{-1}}$ **[3]**

(ii) the potential difference V between the shaded faces of the slice.

V = ... V **[1]**

(c) The slice is mounted and used as a measuring instrument called a Hall probe. A cell is connected to provide the current in the slice. The potential difference across the slice is measured by a separate voltmeter.

A student wants to measure the magnetic flux density between the poles of two magnets mounted on a steel yoke as shown in Fig. 2.2. The magnitude of the flux density is between 0.02 T and 0.04 T.

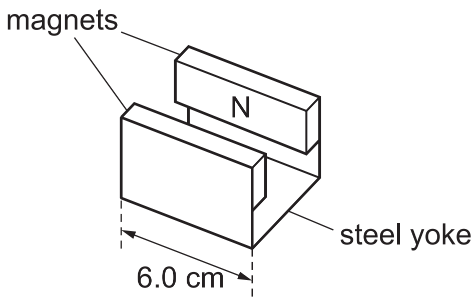


Fig. 2.2

(i) Suggest **one** reason why this Hall probe is **not** a suitable instrument to measure the magnetic flux density for the arrangement shown in Fig. 2.2.

....

....

.... **[1]**

(ii) Another method of measuring the magnetic flux density for the arrangement shown in Fig. 2.2 is to insert a current-carrying wire between the poles of the magnet.
Explain how the magnetic flux density can be determined using this method and discuss which measurement in the experiment leads to the greatest uncertainty in the value for the magnetic flux density.

....

....

....

....

....

....

.... **[4]**

3 A student is investigating how the discharge of a capacitor through a resistor depends on the resistance of the resistor.
The equipment is set up as shown in Fig. 3.1.

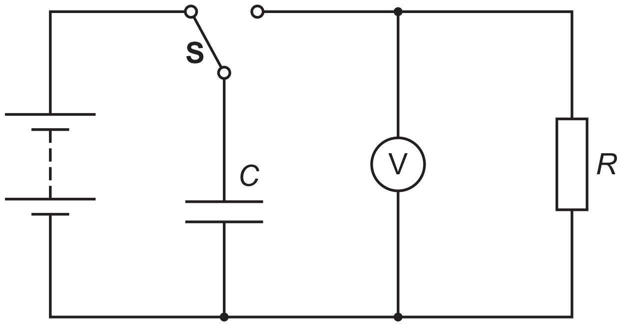


Fig. 3.1

The student charges the capacitor of capacitance C and then discharges it through a resistor of resistance R using switch **S**. After a time t = 15.0 s the student records the potential difference V across the capacitor. The student repeats this procedure for different values of R.

It is suggested that V and R are related by the equation

$$V = V_0 e^{-\frac{t}{CR}}$$

where V_0 is the initial potential difference across the capacitor and t is the time over which the capacitor has discharged.

(a) The student decides to plot a graph of ln (V/V) on the y-axis against $\frac{1}{R}$ on the x-axis to obtain a straight line graph. Show that the magnitude of the gradient is equal to $\frac{15}{C}$.

[2]

(b) Values of R and V at t = 15.0 s are given in the table below.

R/kΩ	V/V	$\left(\frac{1}{R}\right)/10^{-6}\ \Omega^{-1}$	ln (V/V)
56	3.0 ± 0.2	18	
68	3.7 ± 0.2	15	1.31 ± 0.06
100	5.0 ± 0.2	10	1.61 ± 0.04
150	6.4 ± 0.2	6.7	1.86 ± 0.03
220	7.3 ± 0.2	4.5	1.99 ± 0.03
330	8.1 ± 0.2	3.0	2.09 ± 0.03

(i) Complete the missing value of ln (V/V) and its absolute uncertainty in the table above. **[1]**

(ii) Use the data to complete the graph of Fig. 3.2. Four of the six points have been plotted for you. **[2]**

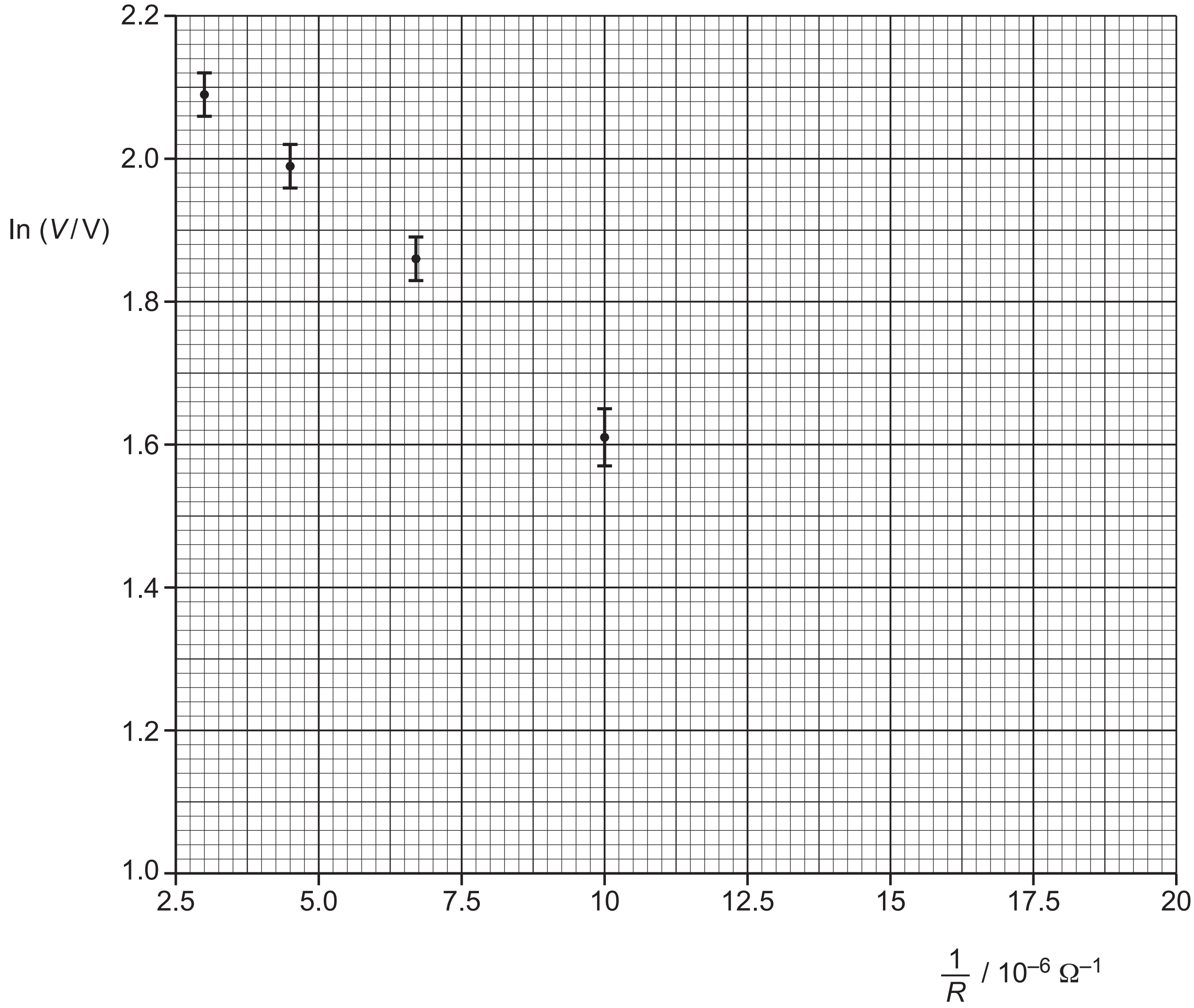


Fig. 3.2

(iii) Use the graph to determine a value for C. Include the absolute uncertainty and an appropriate unit in your answer.

C = ... ± .... unit .... **[4]**

(c) Determine the value of R, in kΩ, for which the capacitor discharges to 10% of its original potential difference in 15.0 s. Show your working.

R = ... kΩ **[2]**

BLANK PAGE

Question 4 begins on page 10.

4 (a)* You are given an unmarked sealed square box which has four identical terminals at each corner.

Fig 4.1 shows the circuit diagram for the contents of the box with the four terminals labelled **A**, **B**, **C** and **D**.

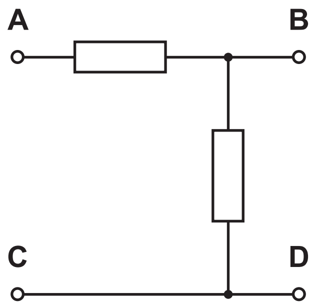


Fig. 4.1

One of the resistors in the box has resistance 220 Ω. The other resistor has resistance 470 Ω. Two of the terminals are connected by a wire.

The four terminals on your unmarked sealed box are **not** labelled.

You are given a 6.0 V d.c. supply, a 100 Ω resistor (labelled R) and a digital ammeter.

Plan an experiment to determine the arrangement of the components and identify which terminal of your unmarked sealed box is **A**, **B**, **C** and **D**.

A space has been left for you to draw circuit diagrams to illustrate your answer.

[6]

(b) A light-dependent resistor (LDR) is connected between points **X** and **Y** in the circuit of Fig. 4.2. The circuit is used to switch on a lamp during the hours of darkness.

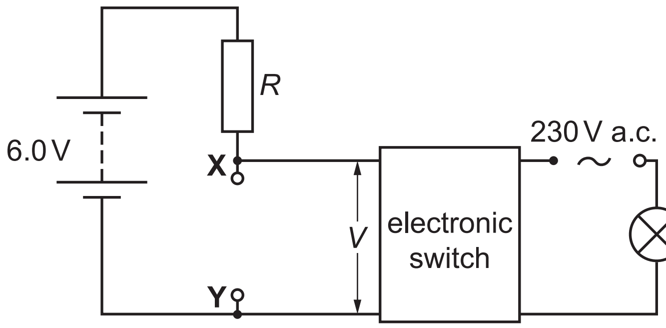


Fig. 4.2

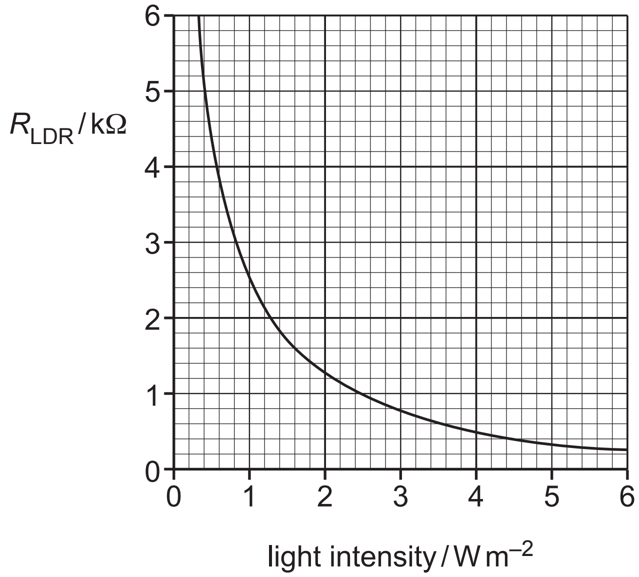


Fig. 4.3

(i) Draw the symbol for an LDR on Fig. 4.2 between **X** and **Y**. **[1]**

(ii) Fig. 4.3 shows how the resistance of the LDR varies with light intensity. The electronic switch closes when V across **XY** is 4.0 V and opens when V across **XY** is 2.4 V. The electronic switch draws a negligible current.

Calculate

1 the resistance R of the resistor for the lamp to switch on at a light intensity of 0.80 W m^{-2}

R = ... Ω **[3]**

2 the light intensity of the surroundings at which the lamp switches off.

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

BLANK PAGE

Question 5 begins on page 14.

5 **(a)** A loudspeaker mounted on a bench is emitting sound of frequency 1.7 kHz to a microphone. Fig. 5.1 shows an illustration of the bulk movement of the air at one instant of time.

Fig. 5.1

The maximum displacement of the air particles from their mean positions is 2.0×10^{-6} m.

The speed of sound in air at 17 °C is 340 m s^{-1}.

(i) On Fig. 5.2, sketch the sinusoidal variation of the displacement of the air with distance between **C** and **R**.

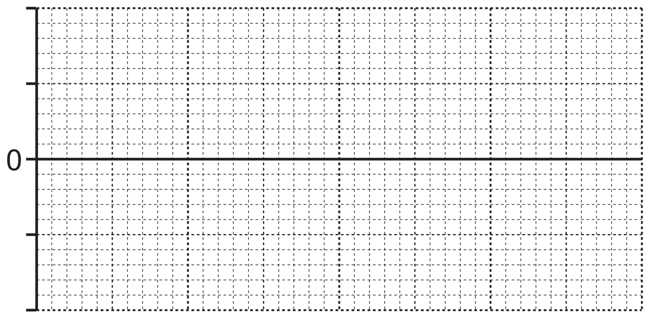


Fig. 5.2

1 Label the axes and include sensible scales.
2 On Fig. 5.2, mark one point where air particles are moving at maximum speed. Label it **X**.
3 On Fig. 5.2, mark one point where air particles are moving at maximum speed but travelling in the opposite direction to the air particles in **2**. Label it **Y**.

[4]

(ii) Calculate
1 the maximum speed v_{max} of the oscillating particles in the sound wave

v_{max} = ... m s^{-1} **[2]**

2 the root mean square speed $c_{r.m.s.}$ of the air molecules in the room.
The molar mass of air is 2.9×10^{-2} kg mol^{-1}.

$c_{r.m.s.}$ = ... m s^{-1} **[2]**

(b)* Students are given the equipment in Fig. 5.1 together with a metre rule. They are also given a second loudspeaker connected to the same signal generator at 1.7 kHz. They are asked to design an experiment where they would need to take just **one** measurement and be able to determine the value of the speed of sound.

They set up the experiment in two different ways as shown in Fig. 5.3(a) and (b).

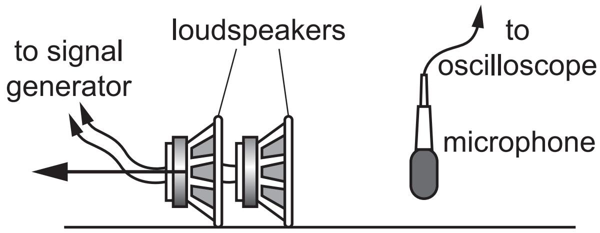


Fig. 5.3(a)

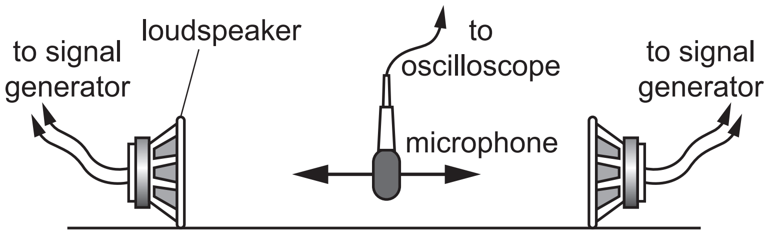


Fig. 5.3(b)

In method **(a)** the microphone is fixed and one loudspeaker is moved to the left as shown in Fig. 5.3(a).
In method **(b)** the microphone is moved to the left or to the right with the loudspeakers fixed a certain distance apart as shown in Fig. 5.3(b).

Describe and explain how both methods can be used to accurately determine the speed of sound. In your description, discuss how the uncertainty in the value for the speed of sound can be minimised in one of the methods, without using any other apparatus. **[6]**

....

....

....

....

....

....

....

....

....

....

....

....

BLANK PAGE

Question 6 begins on page 18.

6 This question is about the motion of a ball suspended by an elastic string above a bench. The mass of the string is negligible compared to that of the ball. Ignore air resistance.

Fig. 6.1

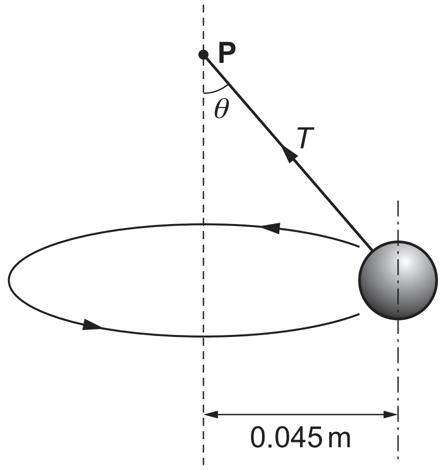


Fig. 6.2 (not to scale)

In Fig. 6.1 the ball of weight 1.2 N hangs vertically at rest from a point **P**. The extension of the string is 0.050 m. The string obeys Hooke's law.

In Fig. 6.2 the ball is moving in a horizontal circle of radius 0.045 m around a vertical axis through **P** with a period of 0.67 s. The string is at an angle θ to the vertical. The tension in the string is T.

(a) On Fig. 6.2 draw and label one other force acting on the ball. **[1]**

(b) **(i)** Resolve the tension T horizontally and vertically and show that the angle θ is 22°.

[2]

(ii) Calculate the extension x of the string shown in Fig. 6.2.

x = ... m **[3]**

(c) Whilst rotating in the horizontal plane the ball suddenly becomes detached from the string. The bottom of the ball is 0.18 m above the bench at this instant. The ball falls as a projectile towards the bench beneath. Fig. 6.3 shows the view from above.

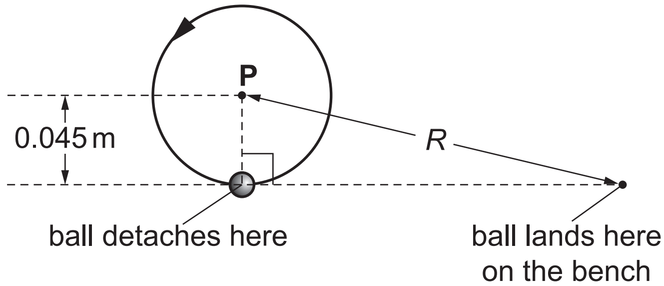


Fig. 6.3

Calculate the horizontal distance R from the point on the bench vertically below the point **P** to the point where the ball lands on the bench.

R = ... m **[4]**

(d) Returning to the situation shown in Fig. 6.2, state and explain what happens when the rate of rotation of the ball is increased.

....

....

....

.... **[2]**

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

OCR
Oxford Cambridge and RSA

A Level Physics A

H556/03 Unified physics

Thursday 14 June 2018 – Morning

Time allowed: 1 hour 30 minutes

You must have:
- The Data, Formulae and Relationship Booklet (sent with general stationery)

You may use:
- a scientific or graphical calculator
- a ruler (cm/mm)

First name	
Last name	

Centre number						Candidate number				

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

INFORMATION
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **20** pages.

Answer **all** the questions

1 This question is about a resistance wire made of nichrome.

(a)* It is suggested that the resistance R of a length of nichrome wire varies with temperature θ in °C according to the equation

$$R = R_0\,(1 + k\theta)$$

where R_0 is the resistance of the wire at 0 °C and k is a constant for the wire.

Fig. 1.1 shows a diagram of the arrangement of apparatus in an experiment to test the relationship between R and θ and to determine the value of k.

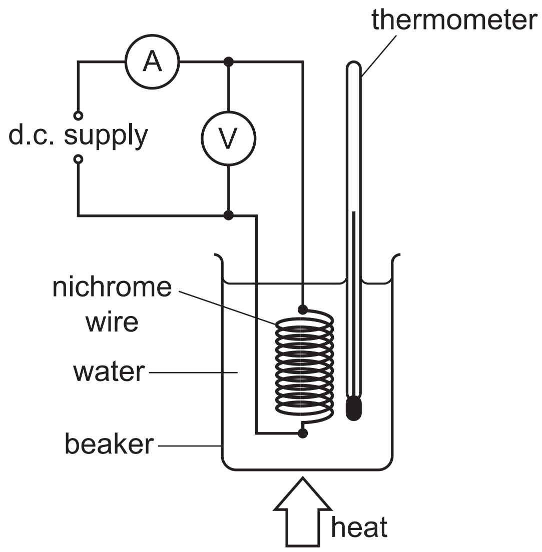


Fig. 1.1

The resistance wire is coiled and placed in a water bath.

Describe how you would carry out the experiment, analyse the data to verify the relationship between R and θ and determine a value for k.
In your description, state any precautions that you would take to improve the accuracy and precision of the measurements.

[6]

Question 1 is continued on page 4.

(b) A student is investigating a 230 V, 1.0 kW heating element. The heating element is shown in Fig. 1.2.

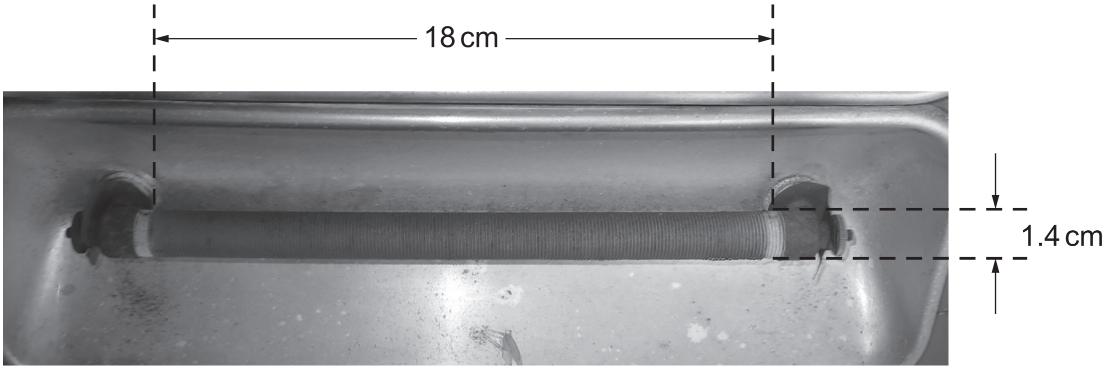


Fig. 1.2

A length of nichrome wire is wound in a spiral groove along 18 cm of a ceramic cylinder of diameter 1.4 cm. The distance between the centres of adjacent turns of the wire is 1.5 mm.

The numbers labelling the reels of loose wire on the laboratory shelf are the *imperial standard wire gauge* (swg). The student wishes to find out which reel holds the same wire as that wound on the heating element of Fig. 1.2.

The book of data gives the following information:

resistivity of nichrome at operating temperature = $1.1 \times 10^{-6}\,\Omega\,m$

swg	24	26	28	30	32
diameter of wire / 10^{-3} m	0.56	0.46	0.38	0.32	0.27
cross-sectional area / 10^{-6} m^2	0.25	0.16	0.11	0.08	0.06

(i) Show that the resistance of the nichrome wire wound on the ceramic cylinder is 53 Ω.

[2]

(ii) Show that the length of wire wound on the heating element is 5.3 m.

[2]

(iii) Use the information given in **(i)** and **(ii)** to determine the swg number of the wire used as the heating element.

swg number = ... **[3]**

2 The 500 m tall Taipei 101 tower is shown in Fig. 2.1. The tower has a massive sphere suspended across five floors near the top of the building to dampen down movement of the tower in high winds and earthquakes. The sphere is connected to pistons (not shown) which drive oil through small holes providing damping. The vibration energy of the sphere is converted to thermal energy.

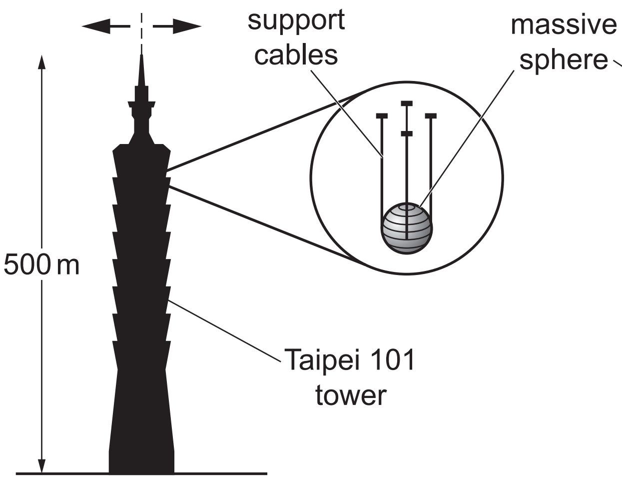


Fig. 2.1

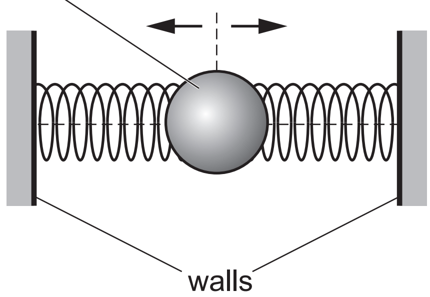


Fig. 2.2

Fig. 2.2 models the damper system as the sphere held between two springs. The movement of the walls of the tower forces the sphere to oscillate in **simple harmonic motion**.

In the strongest wind, the natural frequency of the oscillations of the tower is 0.15 Hz and the maximum acceleration of the sphere is $0.050\,\text{m}\,\text{s}^{-2}$.

(a) Calculate the maximum displacement of the sphere in the strongest wind.

maximum displacement = ... m **[3]**

(b) Explain why the natural frequency of the damper system must be about 0.15 Hz.

....

....

....

.... **[2]**

(c) The acceleration a of the sphere is given by the equation

$$a = -\left(\frac{k}{m}\right)x$$

where k is the force constant of the spring combination, x is the displacement of the sphere and m is the mass of the sphere.

The mass of the sphere is 6.6×10^5 kg. The natural frequency of the oscillations of the sphere is 0.15 Hz.

(i) Show that the force constant k of the spring combination is about $6 \times 10^5\,\mathrm{N\,m^{-1}}$.

[3]

(ii) The S-wave of an earthquake causes a sudden movement of the building displacing the sphere 0.71 m from its equilibrium position relative to the building.

Use your answer in **(i)** to calculate the energy transferred to the springs of the damper system.

energy transferred = ... J **[2]**

3 A binary star is a pair of stars which move in circular orbits around their common centre of mass.

In this question consider the stars to be point masses situated at their centres.

(a) Fig. 3.1 shows a binary star where the mass of each star is m. The stars move in the same circular orbit.

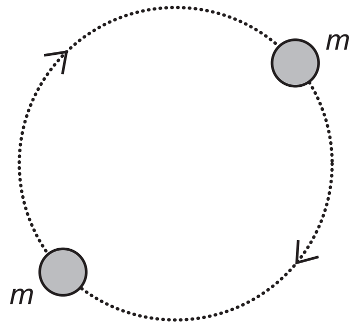


Fig. 3.1

(i) Explain why the stars of equal mass must always be diametrically opposite as they travel in the circular orbit.

....

....

....

....

.... **[2]**

(ii) The centres of the two stars are separated by a distance of $2R$ equal to 3.6×10^{10} m, where R is the radius of the orbit. The stars have an orbital period T of 20.5 days. The mass of each star is given by the equation

$$m = \frac{16\pi^2 R^3}{GT^2}$$

where G is the gravitational constant.

Calculate the mass m of each star in terms of the mass $M_\odot$ of the Sun.

1 day = 86400 s
$M_\odot = 2.0 \times 10^{30}$ kg

m = ... $M_\odot$ **[3]**

(iii) The stars are viewed from Earth in the plane of rotation.
The stars are observed using light that has wavelength of 656 nm in the laboratory. The observed light from the stars is Doppler shifted.

Calculate the maximum change in the observed wavelength $\Delta\lambda$ of this light from the orbiting stars. Give your answer in nm.

$\Delta\lambda$ = ... nm **[2]**

(b) Fig. 3.2 shows a binary star where the masses of the stars are 4*m* and *m*.

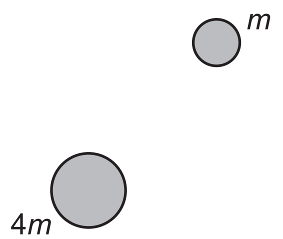


Fig. 3.2

(i) The centre of mass of the binary star lies at the surface of the star of mass 4*m*. Draw on **Fig. 3.2** two circles to represent the orbits of **both** stars. **[1]**

(ii) Explain why the smaller mass star travels faster in its orbit than the larger mass star.

....

....

....

....

.... **[2]**

4 Fig. 4.1 shows an arrangement used by a student to determine the acceleration of free fall.

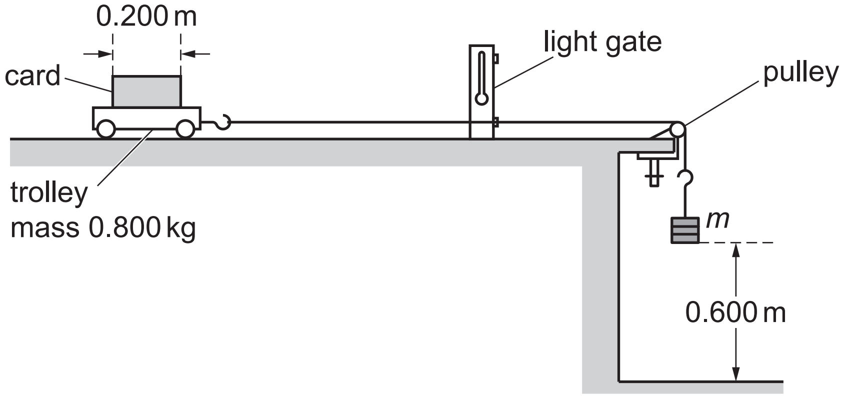


Fig. 4.1

A trolley is attached to a variable mass m by a string which passes over a pulley.

The mass m is released from rest and falls through a fixed height of 0.600 m accelerating the trolley of mass 0.800 kg. When the mass m hits the floor, the trolley then continues to move at a **constant** velocity v.

This constant velocity v is determined by measuring the time t for the card of length 0.200 m to pass fully through a light gate connected to a timer.

Frictional forces on the trolley and the falling mass m are negligible.

(a) Show that the relationship between v and m is

$$v^2 = \frac{1.20mg}{(m + 0.800)}$$

where g is the acceleration of free fall.

[2]

(b) The student records the information from the experiment in a table. The column headings and just the last row for m = 0.600 kg from this table are shown below.

m / kg	t / 10^{-3} s	$\frac{m}{(m+0.800)}$	v / m s^{-1}	v^2 / m^2 s^{-2}
⋮	⋮	⋮	⋮	⋮
0.600	90 ± 2	0.429	2.22 ± 0.05	

(i) Complete the missing value of v^2 in the table including the absolute uncertainty. **[2]**

(ii) Fig. 4.2 shows some of the data points plotted by the student. Plot the missing data for m = 0.600 kg on Fig. 4.2 and draw the straight line of best fit. **[2]**

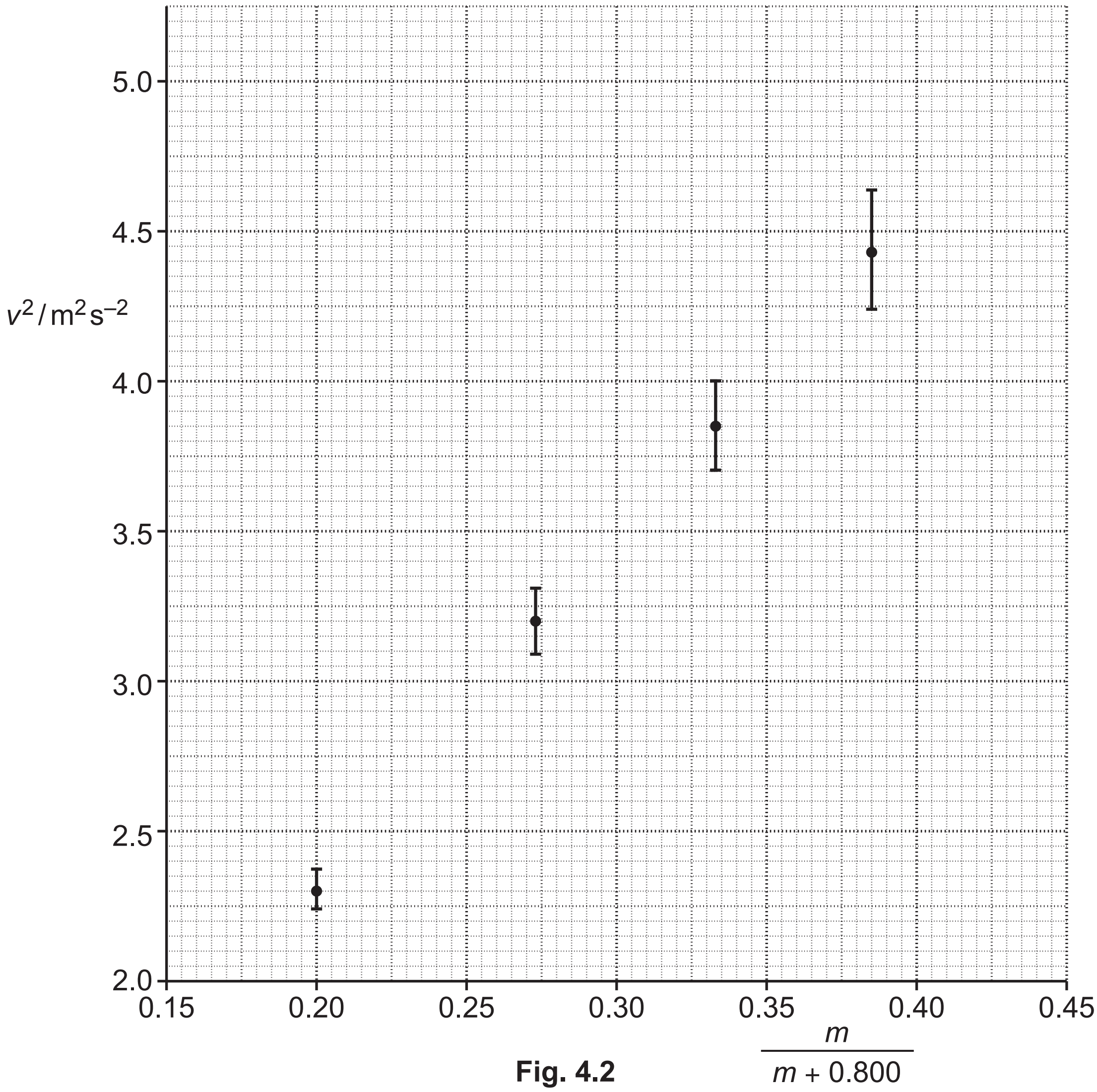


Fig. 4.2

(c) **(i)** Use the equation given in **(a)** to show that the gradient of the graph of v^2 against $\frac{m}{(m+0.800)}$ is equal to 1.20 g.

[1]

(ii) Assume that the best-fit straight line through the data points gives 9.5 m s^{-2} for the experimental value of g. Draw a worst-fit line through the data points on Fig. 4.2 and determine the absolute uncertainty in the value for g.

absolute uncertainty = ± .... m s^{-2} **[4]**

Question 4 is continued on page 12.

(d) It is suspected that the card on the trolley did not pass at right angles through the light beam.

Discuss, without doing any calculations, the effect this may have on the experimental value for the acceleration of free fall *g*.

....

....

....

....

....

....

....

....

.... **[4]**

5 **(a)** A magnet rotates inside a shaped soft iron core. A coil is wrapped around the iron core as shown in Fig. 5.1. The coil is connected to an oscilloscope.

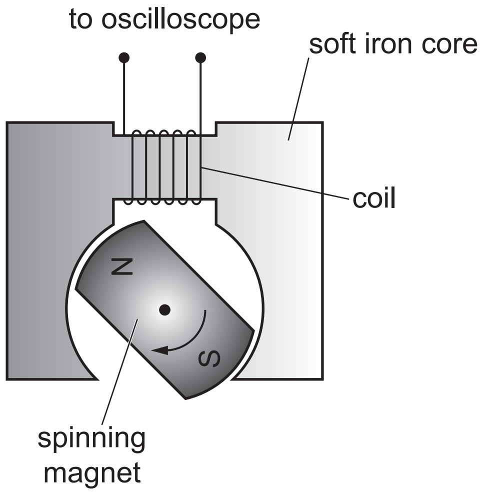


Fig. 5.1

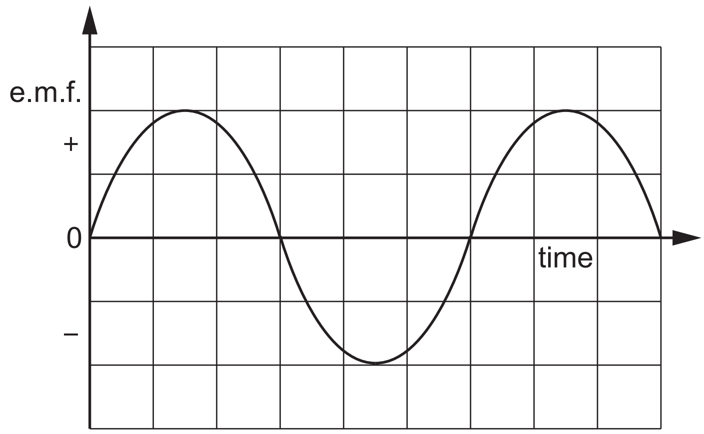


Fig. 5.2

The spinning magnet induces an e.m.f. in the coil. A graph of the e.m.f. displayed on the oscilloscope screen is shown in Fig. 5.2.

(i) Explain the shape of the graph in terms of the magnetic flux linking the coil.

....

....

....

.... **[2]**

(ii) On Fig. 5.3 sketch a graph of the magnetic flux linkage of the coil against time. The variation of the induced e.m.f. across the coil is shown as a dotted line. **[1]**

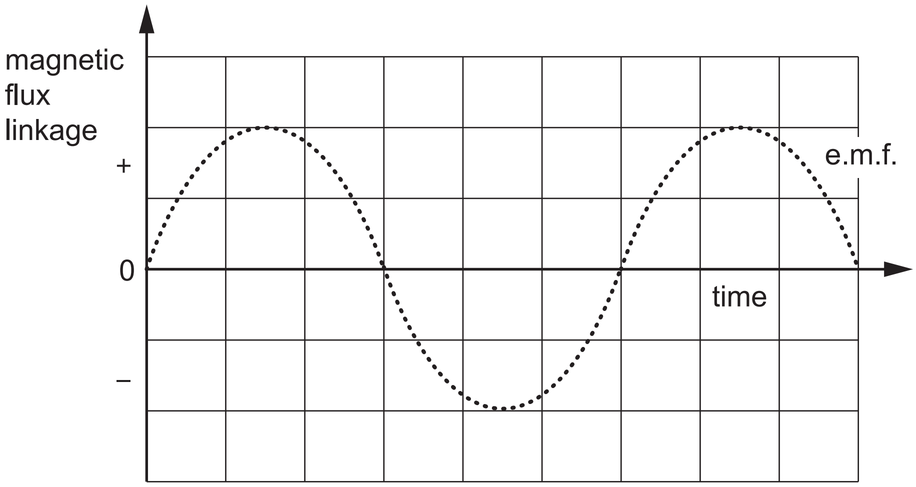


Fig. 5.3

Question 5 is continued on page 14.

(iii) The coil shown in Fig. 5.1 has 150 turns. The maximum induced e.m.f. V_0 across the coil is 1.2 V when the magnet is rotating at 24 revolutions per second.

Calculate the maximum **magnetic flux** through the coil using the equation

$$V_0 = 2\pi \times \text{(frequency)} \times \text{(maximum magnetic flux linkage)}$$

Give a unit with your answer.

maximum flux = ... unit .... **[2]**

(b)* A student is given a transformer with coils **X** and **Y**, as shown in Fig. 5.4.

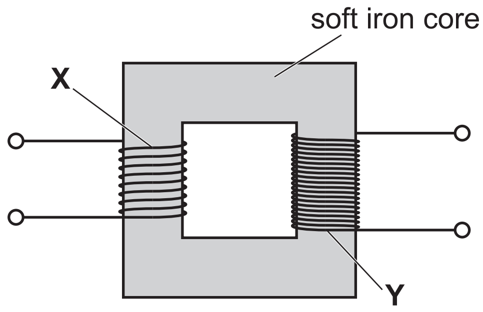


Fig. 5.4

The student is intending to investigate how the maximum induced e.m.f. V_0 in coil **Y** depends on the frequency f of the alternating current in coil **X**.

The changing magnetic flux density in coil **X** induces an e.m.f. in coil **Y**. Faraday's law indicates that the maximum induced e.m.f. V_0 should be directly proportional to f.

Describe how you would investigate the suggested relationship between V_0 and f in the laboratory using these coils. In your description include all of the equipment used and how you would analyse the data collected.

Use the space below to draw a suitable diagram.

[6]

6 Fig. 6.1 shows a single photomultiplier tube and its internal components. The tube can detect gamma photons in high-energy physics experiments.
A single gamma photon incident on the scintillator crystal generates many photons of blue light. These visible light photons travel to the photocathode where they are converted into photoelectrons. The number of electrons is then multiplied in the photomultiplier tube with the help of electrodes called dynodes. A short pulse of electric current is produced at the output end of the photomultiplier tube.

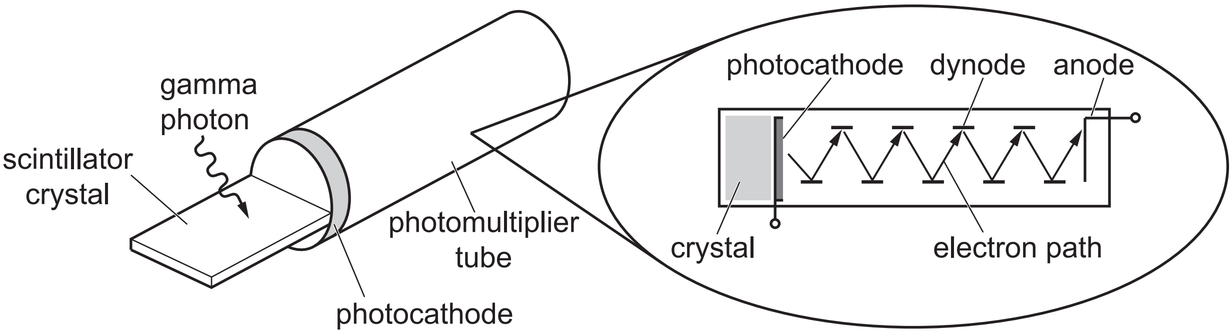


Fig. 6.1

(a) Fig. 6.2 shows a section through the scintillator crystal in air.

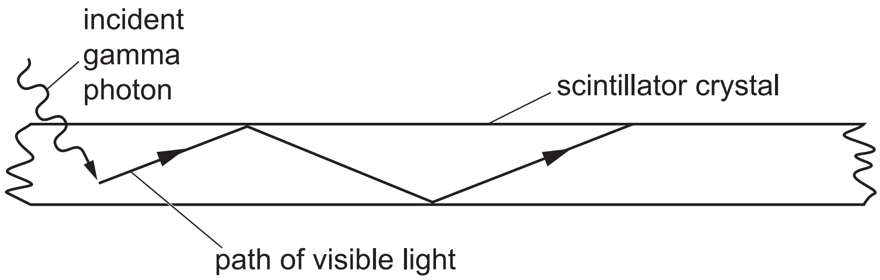


Fig. 6.2

(i) The refractive index of the scintillator crystal for visible light is 1.69. The refractive index of air is 1.00. Calculate the critical angle C for this crystal.

C = ... ° **[2]**

(ii) Explain why the visible light inside the scintillator crystal follows the path shown in Fig. 6.2.

....

....

....

.... **[2]**

(b) A high energy gamma photon passing through the scintillator crystal converts some of its energy into visible light photons of mean wavelength 450 nm.

Show that the energy of a single photon of wavelength 450 nm is less than 3 eV.

[3]

(c) The photocathode is coated with potassium which has a work function of 2.3 eV. Each emitted photoelectron is accelerated by a potential difference of 100 V between the photocathode and a metal plate, called the first dynode.

(i) Show that the maximum kinetic energy of an emitted electron at the photocathode is very small compared to its kinetic energy of 100 eV at the first dynode.

[1]

(ii) 2000 photoelectrons are released from the photocathode. Each photoelectron has enough energy to release four electrons from the first dynode at the collision. These four electrons are then accelerated to the next dynode where the process is repeated. There are 9 dynodes in the photomultiplier tube. The total number of electrons collected at the anode for each photoelectron is 4^9.

The pulse of electrons at the anode lasts for a time of 2.5×10^{-9} s.

Calculate the average current due to this pulse.

average current = ... A **[3]**

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

OCR

Oxford Cambridge and RSA

Monday 3 June 2019 – Afternoon

A Level Physics A

H556/03 Unified physics

Time allowed: 1 hour 30 minutes

You must have:
- The Data, Formulae and Relationships Booklet (sent with general stationery)

You may use:
- a scientific or graphical calculator
- a ruler (cm/mm)

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) ______________________

Last name ______________________

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.

INFORMATION
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **24** pages.

Answer **all** the questions

1 A toy rocket is made from a 1.5 litre plastic bottle with fins attached for stability.

The bottle initially contains 0.30 litres of water, leaving 1.2 litres of trapped air at a temperature of 17 °C.
A pump is used to increase the pressure of the air within the plastic bottle to 2.4×10^5 Pa at the start of lift-off.

Fig. 1.1 shows the rocket at the start of lift-off.

1 litre = 10^{-3} m^3

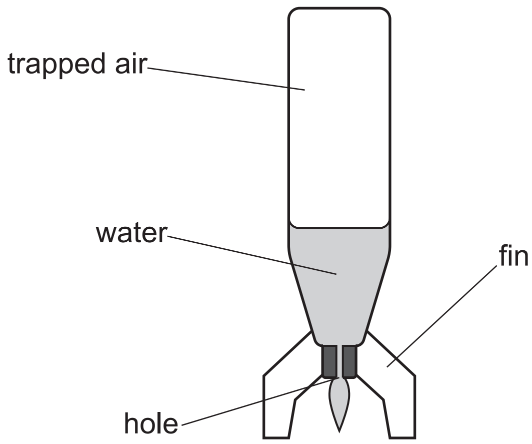


Fig. 1.1

(a) Calculate, in moles, the amount of trapped air in the bottle at the start of lift-off.

amount of air = ... mol **[2]**

(b) The trapped air pushes the water downwards out of the hole, causing the rocket to rise. The temperature of this air remains constant.

Calculate the final pressure of the trapped air just before all the water has been released.

final pressure = ... Pa **[3]**

(c) Here is some data on the toy rocket.

mass of empty bottle and fins = 0.050 kg
area of cross-section of hole = 1.1×10^{-4} m^2
initial pressure of trapped air = 2.4×10^5 Pa
atmospheric pressure = 1.0×10^5 Pa
density of water = 1.0×10^3 kg m^{-3}

(i) Use the data above to show that the **upwards** force on the rocket at the start of lift-off is about 15 N.

[2]

(ii) Hence calculate the initial vertical acceleration of the rocket.

initial acceleration = ... $m\,s^{-2}$ **[3]**

(d) Discuss whether adding more water initially would enable the rocket to reach a greater height.

....

....

....

....

....

....

....

....

....

.... **[3]**

2 $^{60}_{27}Co$ is produced by irradiating the stable isotope $^{59}_{27}Co$ with neutrons.

Each nucleus of $^{60}_{27}Co$ then decays into a nucleus of nickel (Ni) by the emission of a low energy beta-minus particle, one other particle and two gamma photons.

(a) Complete the nuclear equations for these two processes.

$$^{59}_{27}Co + ^{\cdots\cdots}_{\cdots\cdots}n \longrightarrow ^{60}_{27}Co \longrightarrow ^{\cdots\cdots}_{\cdots\cdots}Ni + ^{\cdots\cdots}_{\cdots\cdots}e + \cdots\cdots\cdots + 2\gamma$$

[3]

(b) Students want to carry out an investigation into gamma photon absorption using a source of $^{60}_{27}Co$.
They add sheets of lead between the source **S** and a radiation detector **T**, to give a total thickness *d* of lead. **S** and **T** remain in fixed positions, as shown in Fig. 2.1.

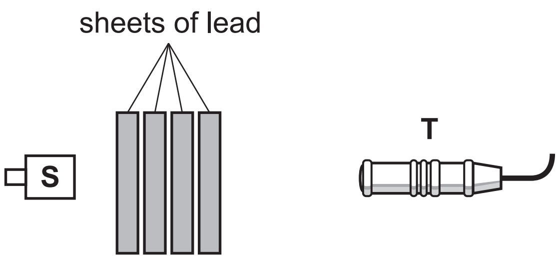


Fig. 2.1

(i) The $^{60}_{27}Co$ source emits beta radiation as well as gamma radiation.

Explain why this would not affect the experiment.

....

.... **[1]**

Question 2 continues on page 6

(ii) The students record the number N of gamma photons detected by **T** in 10 minutes for each different thickness d of lead. The background count is negligible.

The results are shown in a table. The table includes values of ln N, including the absolute uncertainties.

N	d/mm	ln N
4300 ± 440	0	8.37 ± 0.10
2500 ± 250	10	7.82 ± 0.10
1400 ± 150	20	7.24 ± 0.11
800 ± 90	30	6.68 ± 0.11
500 ± 60	40	6.21 ± 0.12
300 ± 40	50	

N and d are related by the equation $N = N_0 e^{-\mu d}$ where N_0 and μ are constants.

1. The students decide to plot a graph of ln N against d.

Show that this should give a straight line with gradient = $-\mu$ and y-intercept = ln N_0.

[1]

2. Complete the missing value of ln N in the table, including the absolute uncertainty.

Show your calculation of the absolute uncertainty in the space below.

[2]

3. In Fig. 2.2, five of the data points have been plotted, including error bars for ln *N*.

- Plot the missing data point and error bar.
- Draw a straight line of best fit and one of worst fit. **[2]**

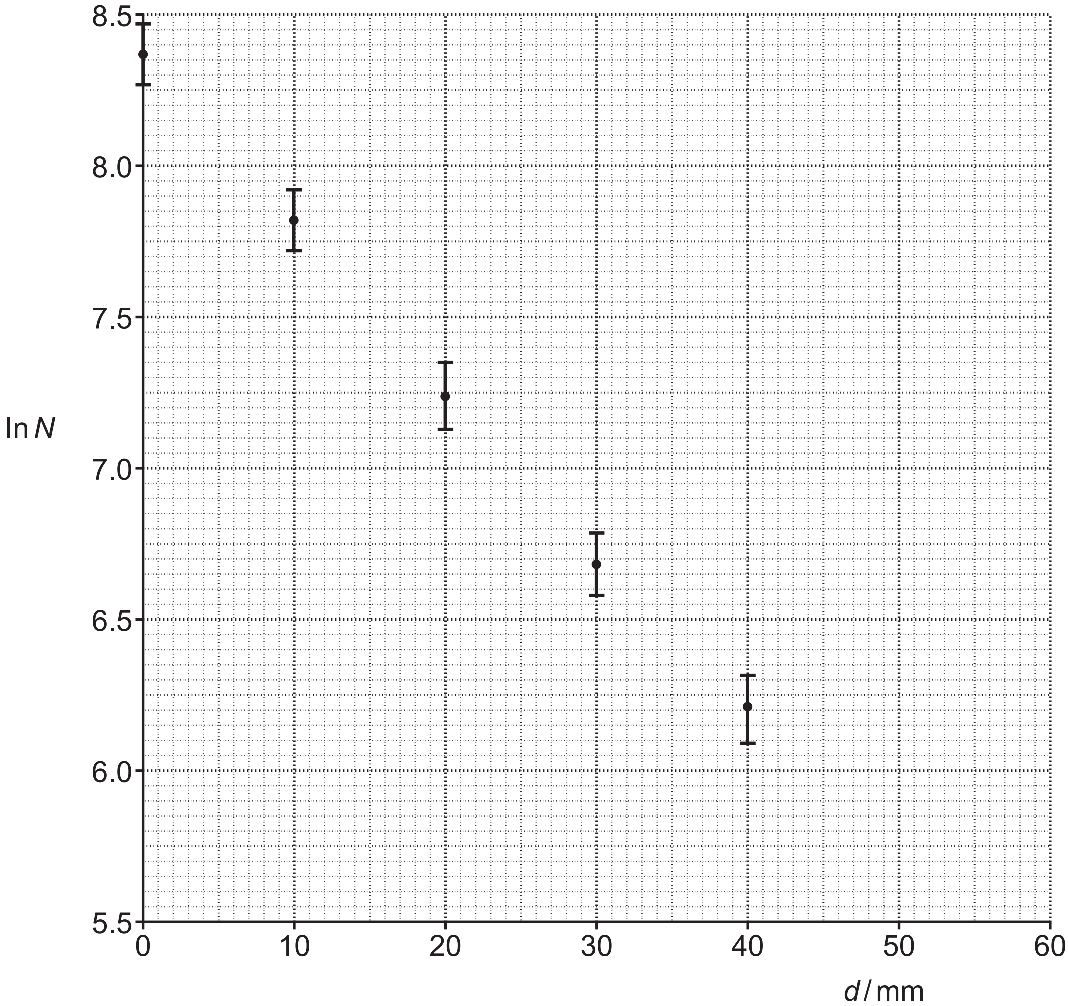


Fig. 2.2

Question 2 continues on page 8

4. Use Fig. 2.2 to determine the value of μ in m^{-1}, including the absolute uncertainty.

μ = ... ± .... m^{-1} **[4]**

5. Determine the thickness, $d_{½}$, of lead which halves the number of gamma photons reaching **T**.

$d_{½}$ = ... m **[2]**

BLANK PAGE

Question 3 begins on page 10.

3 Fig. 3.1 shows the design of a 'mechanical' torch.

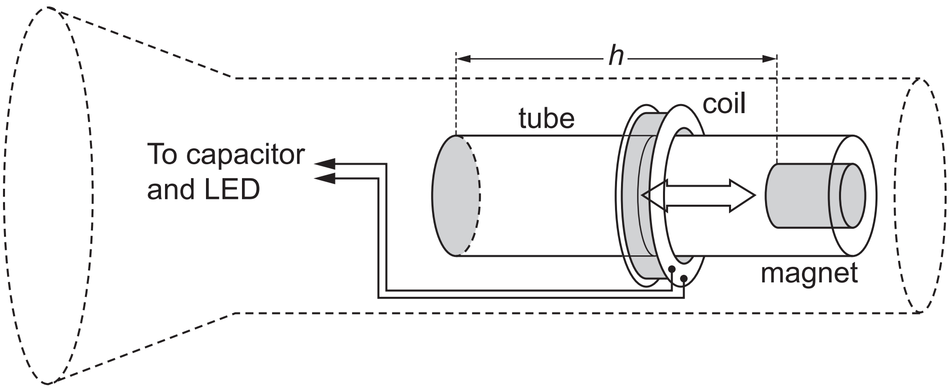


Fig. 3.1

There is no battery in the torch. Instead, when the torch is inverted, the magnet falls a short vertical distance *h* through the coil of wire, as shown in Fig. 3.2. This induces an electromotive force (e.m.f.) across the ends of the coil. The e.m.f. is used to store charge in a capacitor, which lights a light-emitting diode (LED) when it discharges.

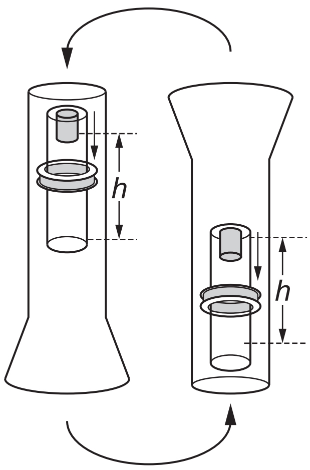


Fig. 3.2

Fig. 3.3 shows the variation with time of the e.m.f. generated as the magnet falls the distance *h*.

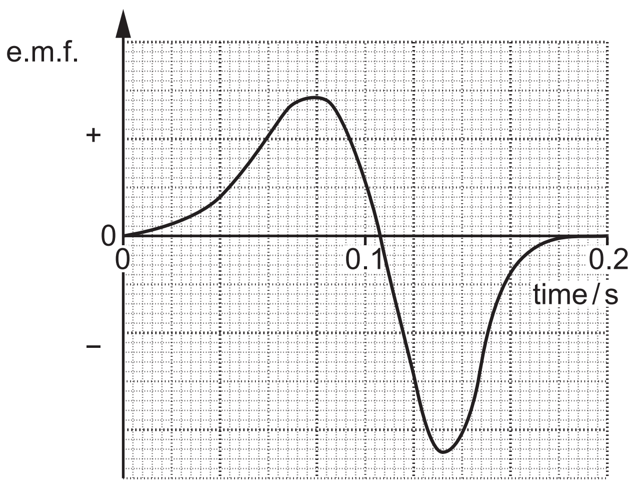


Fig. 3.3

(a) Explain the shape of the curve in Fig. 3.3.

....

....

....

....

....

....

....

.... **[3]**

(b) When the torch is inverted, the pulses of e.m.f. shown in Fig. 3.3 cause a capacitor of capacitance 0.12 F to become charged.
Each positive **and** each negative pulse adds 9.0×10^{-3} C to the charge stored in the capacitor.

(i) The torch is inverted 80 times.

Calculate the total energy stored in the capacitor.

total energy = ... J **[3]**

(ii) When the torch is switched on, the energy stored in the capacitor lights a 50 mW LED.

Estimate the time for which the LED lights.

time = ... s **[1]**

Question 3 continues on page 12

***(c)** In the torch, the gravitational potential energy of the magnet is converted into electrical energy supplied to the 50 mW LED.

You are asked to investigate whether the efficiency of this energy conversion depends on the number of inversions of the torch.

- Describe how you will make accurate measurements to collect your data. Assume that both the torch and the tube can be opened.
- Explain how you will use the data to reach a conclusion. **[6]**

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

Additional answer space if required.

....

....

....

....

....

....

....

....

....

....

....

....

4 At an airport, the conveyor belt for suitcases moves at a constant speed of $1.5\,m\,s^{-1}$.
In Fig. 4.1, a suitcase of mass 8.0 kg has reached the line labelled **XX'**.

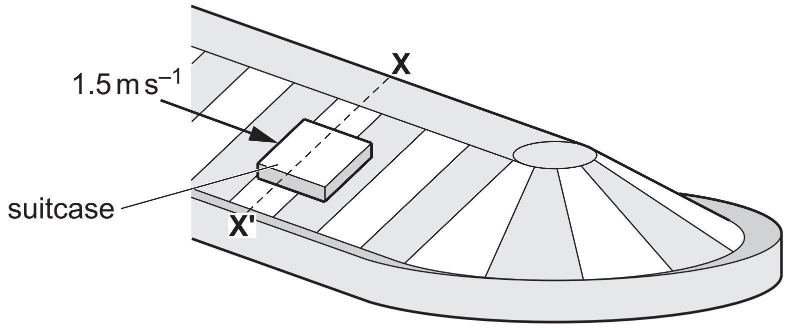


Fig. 4.1

Fig. 4.2 shows the situation in vertical cross-section.
The frictional force *F* prevents the suitcase of weight *W* from sliding to the bottom of the belt.
The normal contact force on the suitcase is *R*.
The belt is inclined at an angle of 30° to the horizontal.

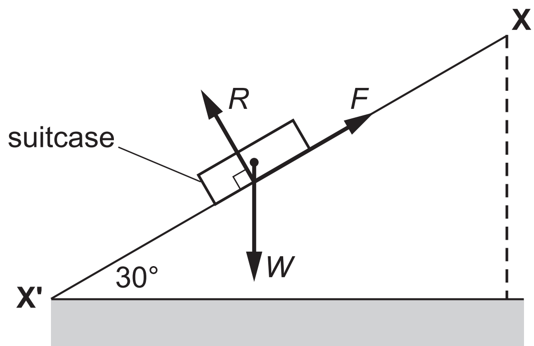


Fig. 4.2 (not to scale)

(a) By using a vector triangle, or by resolving forces, calculate the magnitude of forces *F* and *R*.

F = ... N

R = ... N
[3]

(b) Fig. 4.3 shows the suitcase and the forces acting on it at the line labelled **YY'**.

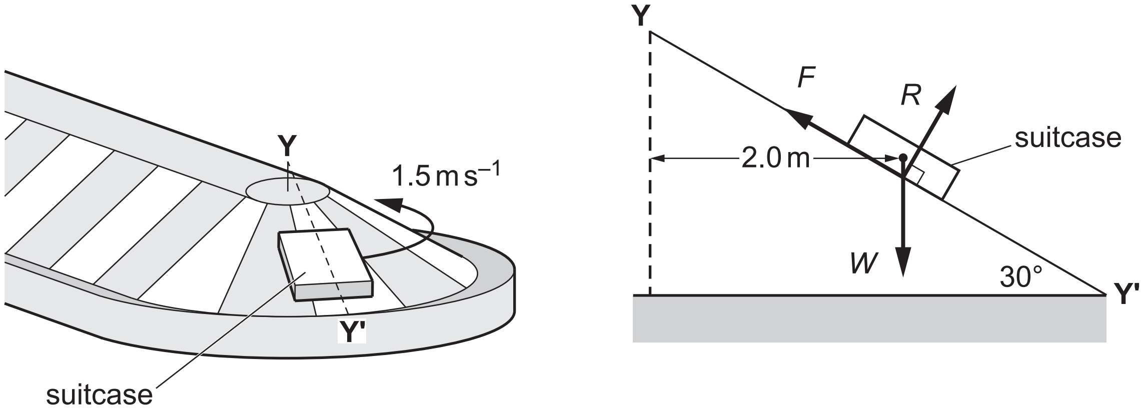


Fig. 4.3

The centre of mass of the suitcase is now moving at 1.5 m s^{-1} along a semi-circular arc of radius 2.0 m.

(i) Calculate the magnitude of the centripetal force acting on the suitcase.

centripetal force = ... N **[2]**

(ii) When the suitcase is at line **YY'**, the magnitude of force *F* is larger and the magnitude of force *R* is smaller than at **XX'**.

Explain why this is so.

....

....

....

....

....

....

....

....

....

.... **[4]**

5 Hydrogen atoms excited in a discharge tube only emit four different discrete wavelengths of visible photons.

***(a)** In a semi-darkened room, a single slit is placed in front of the discharge tube. A student holds a diffraction grating which has 300 lines per millimetre.
The student looks through the grating at a 15 cm plastic ruler placed 0.50 m away, as shown in Fig. 5.1.
The paths of the different colours of light from the slit to the student's eye are shown in Fig. 5.2.

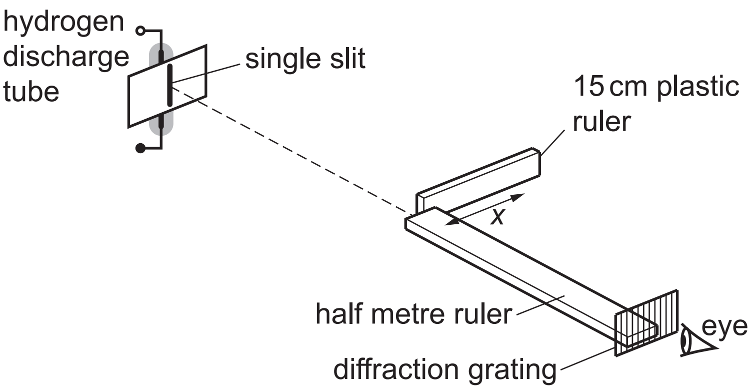


Fig. 5.1 (not to scale)

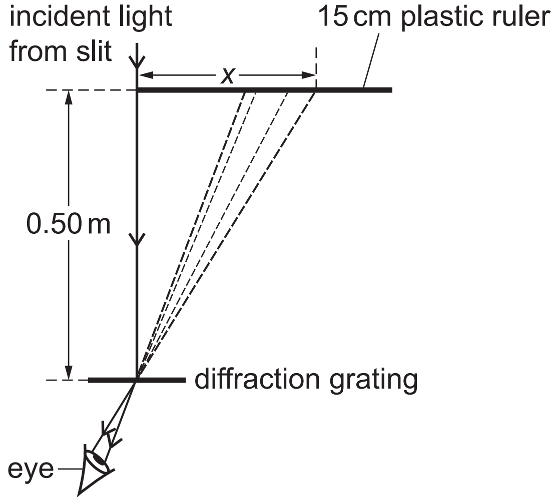


Fig. 5.2 (not to scale)

Four **first** order images of the slit, one at each photon wavelength, are observed as vertical lines against the background of the plastic ruler, as shown in Fig. 5.3.

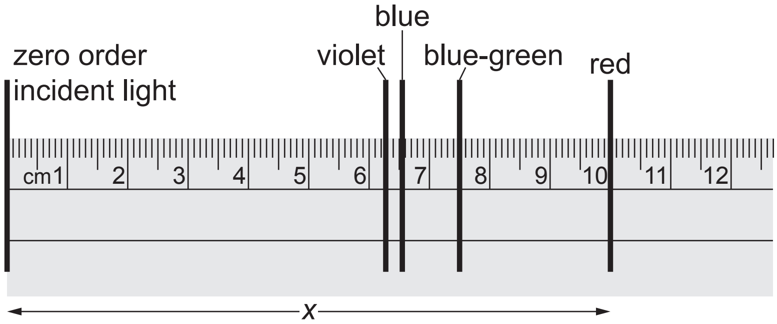


Fig. 5.3

The student decides to determine the wavelength of the photons which form the **red** line observed at x = 10 cm on the ruler.

- Describe how the information that has been given can be used to determine the wavelength of the red photons.
- Estimate the percentage uncertainty in the measured value of the wavelength. **[6]**

Additional answer space if required.

Question 5 continues on page 18

(b) **(i)** Show that the energy of a photon of wavelength 486 nm is 4.09×10^{-19} J.

[1]

(ii) Fig. 5.4 shows some of the energy levels of an electron in a hydrogen atom.

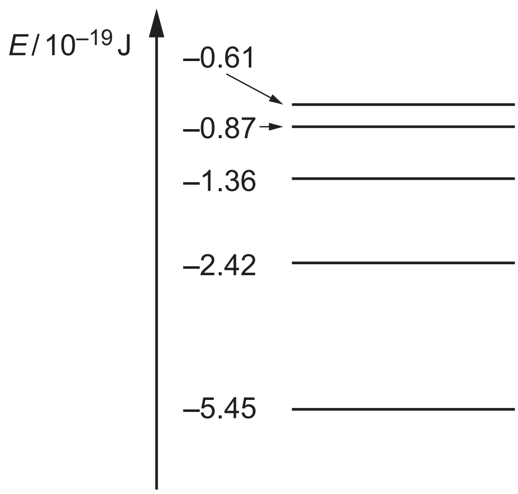


Fig. 5.4 (not to scale)

Draw an arrow on Fig. 5.4 to show an electron transition which would cause the **emission** of a photon of wavelength 486 nm. **[2]**

BLANK PAGE

Question 6 begins on page 20

6 **(a)** Describe the **Doppler effect**.

....

.... [1]

(b) Explain how ultrasound is used to measure the speed of blood flow in an artery.

....

....

....

.... [2]

(c) In cosmology, the Doppler effect can be observed with light from distant galaxies. The Doppler effect can also be observed with sound waves.

Two students use sound waves to investigate the Doppler effect.
In an open space, one student swings a loudspeaker at constant speed in a horizontal circle of radius 0.60 m.
The other student stands a large distance away and holds a microphone. The microphone is connected to a data logger and computer.

Fig. 6.1 shows the situation, viewed from above.

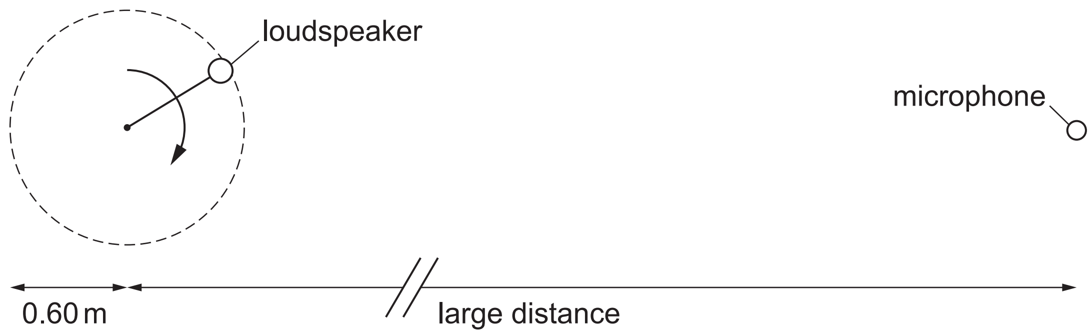


Fig. 6.1

The loudspeaker emits sound in all directions at a single frequency f_0 = 1700 Hz.

Fig. 6.2 shows the variation with time t of the frequency f received by the microphone.

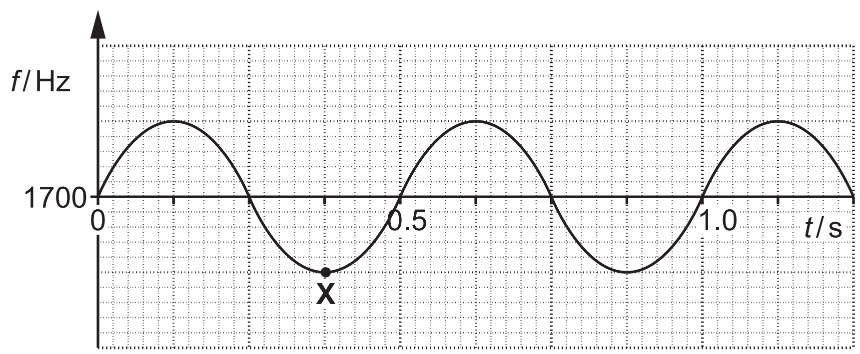


Fig. 6.2

(i) Use Fig. 6.2 to show that the speed of the loudspeaker is $7.5\,m\,s^{-1}$.

[2]

(ii) The speed of sound in this experiment is $330\,m\,s^{-1}$.

Calculate the maximum change in frequency Δf of the sound detected by the microphone.

Δf = ... Hz **[2]**

(iii) Hence complete the scale on the *y*-axis of Fig. 6.2. **[1]**

(iv) Mark with an **X** on Fig. 6.1 the position of the loudspeaker which corresponds to the point **X** on Fig. 6.2. **[1]**

(d) In their laboratory notes, one student writes about the **accuracy** of the measurements whereas the other writes about their **precision**.

Define these terms.

accuracy: ....

....

precision: ....

.... **[2]**

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

Oxford Cambridge and RSA

Wednesday 21 October 2020 – Morning

A Level Physics A

H556/03 Unified physics

Time allowed: 1 hour 30 minutes

You must have:
- the Data, Formulae and Relationships Booklet

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

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) ______________________

Last name ______________________

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks might be given for a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **20** pages.

ADVICE
- Read each question carefully before you start your answer.

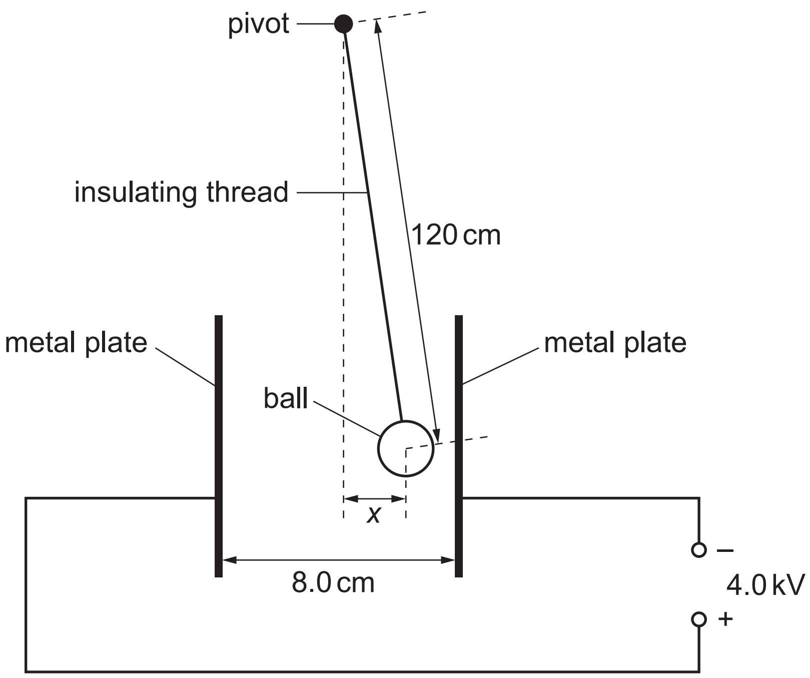
DC (CE/SW) 193302/6

Answer **all** the questions.

1 A ball coated with conducting paint has weight 0.030 N and radius 1.0 cm. The ball is suspended from an insulating thread. The distance between the pivot and the centre of the ball is 120 cm.

The ball is placed between two vertical metal plates. The separation between the plates is 8.0 cm. The plates are connected to a 4.0 kV power supply.

(a) The ball receives a positive charge of 9.0 nC when it is made to touch the positive plate. It then repels from the positive plate and hangs in equilibrium at a displacement x from the vertical, as shown below. The diagram is **not** drawn to scale.



(i) Show that the electric force acting on the charged ball is 4.5×10^{-4} N.

[2]

(ii) Draw, on the diagram above, arrows which represent the **three** forces acting on the ball. Label each arrow with the name of the force it represents. **[2]**

(iii) By taking moments about the pivot, or otherwise, show that $x = 1.8\,\text{cm}$.

[2]

(b) The ball is still positively charged.

The plates are now moved slowly towards each other whilst still connected to the 4.0 kV power supply. The plates are stopped when the separation is 5.0 cm.

Explain the effect that this has on the deflection of the ball and explain why the ball eventually starts to oscillate between the plates.

....

....

....

....

....

....

....

....

....

.... **[4]**

Question 1 continues on page 4

(c) When the ball oscillates between the plates, the current in the external circuit is 3.2×10^{-8} A.

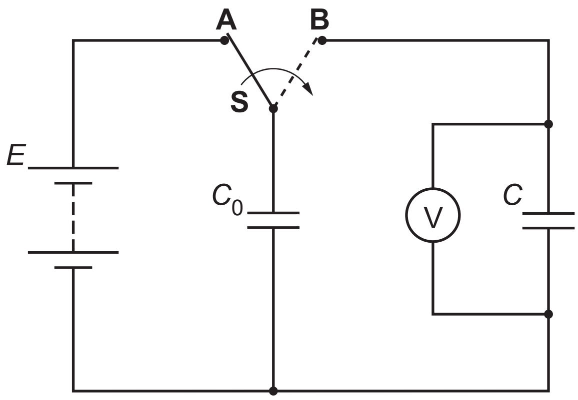
A charge of 9.0 nC moves across the gap between the plates each time the ball makes one complete oscillation.

Calculate the frequency f of the oscillations of the ball.

f = ... Hz **[2]**

2 The diagram below shows a circuit containing two capacitors which are both initially uncharged. The battery has e.m.f. E and negligible internal resistance.

The switch **S** is first moved to position **A** until the capacitor of capacitance C_0 is fully charged.



The switch **S** is then moved to position **B**. The initial charge stored by the capacitor of capacitance C_0 is shared between the two capacitors.
The final reading on the voltmeter is V.

(a) Show that $V = \dfrac{C_0}{C + C_0} E$.

[2]

(b) A student wants to determine the values of E and C_0 by repeating the experiment above and measuring the potential difference (p.d.) V for a selection of capacitors of capacitance C.

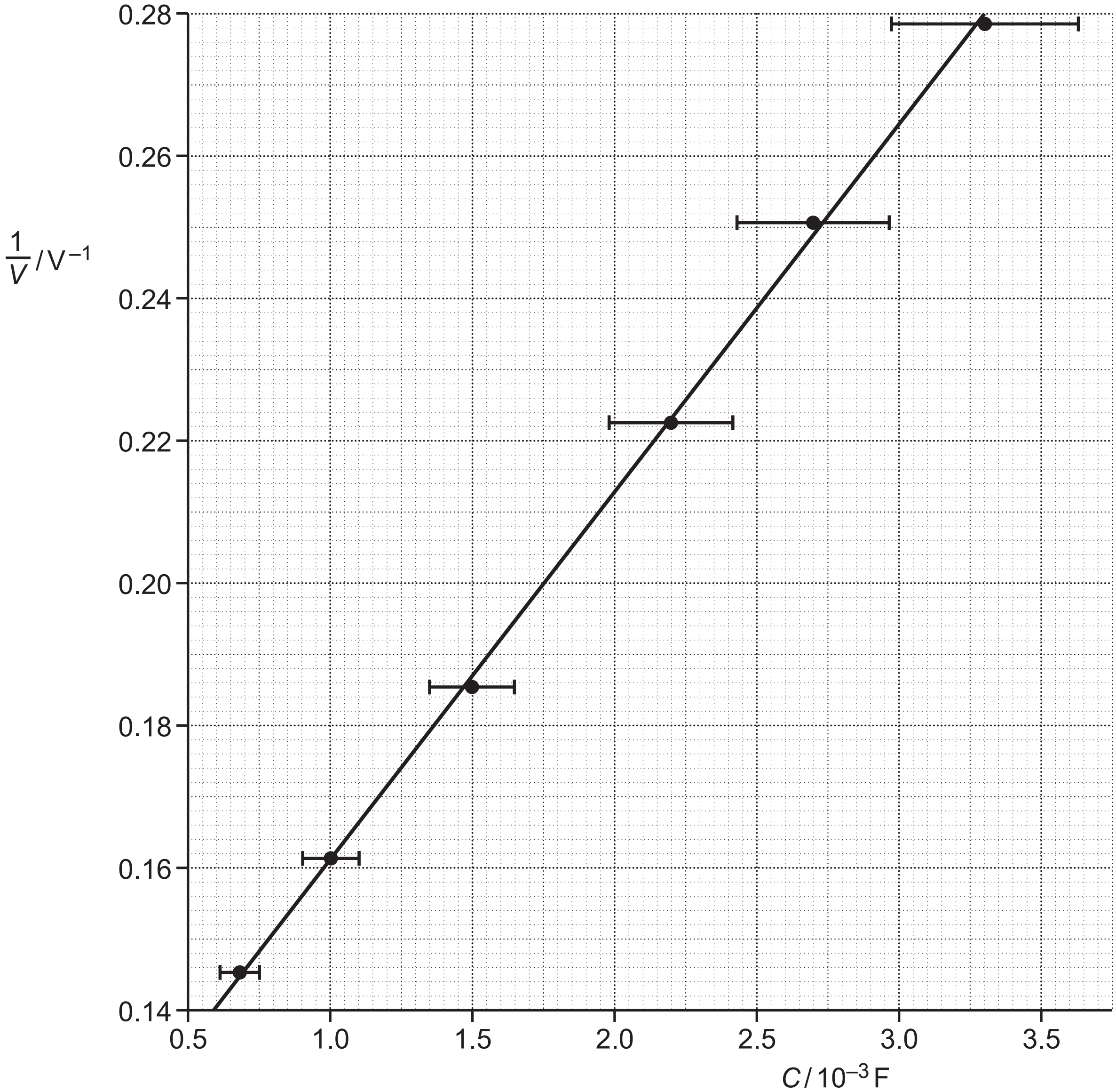
The student decides to plot a graph of $\dfrac{1}{V}$ against C.

(i) Use the expression in **(a)** to show that the graph should be a straight line of gradient $\dfrac{1}{C_0 E}$ and y-intercept $\dfrac{1}{E}$.

[1]

Question 2 continues on page 6

(ii) The data points, error bars and the line of best fit drawn by the student are shown in the graph below.



The gradient of the line of best fit is 51 $V^{-1} F^{-1}$. The value of E is 9.1 V.

Determine the value of C_0 in millifarads (mF). Write your answer to 2 significant figures.

C_0 = ... mF **[2]**

(iii) Draw on the graph a straight line of worst fit.

Use this line to determine the absolute uncertainty in your value of C_0. Write your answer to an appropriate number of significant figures.

absolute uncertainty = ... mF **[4]**

(c) The experiment is repeated with a resistor of resistance 10 kΩ placed in series between **S** and the capacitor of capacitance C_0.

State with a reason what effect, if any, this would have on the experiment.

....

....

....

.... **[1]**

3 This question is about the Sun and its radiation.

(a) **(i)** Use the data below to show that the luminosity of the Sun is about 4×10^{26} W.

- radius of Sun = 7.0×10^{8} m
- surface temperature of Sun = 5800 K

[1]

(ii) Sirius, the brightest star in the night sky, has a luminosity 25 times greater than that of the Sun. It has diameter 1.7 times greater than that of the Sun.

Calculate the surface temperature *T* of Sirius.

T = ... K **[3]**

***(b)** A student attends a lecture about the Sun and makes the following notes.

1. The Sun loses more than 4×10^9 kg of its mass every second to maintain its luminosity.
2. Treating hydrogen nuclei (protons) as an ideal gas, a temperature of 10^{10} K provides a kinetic energy of about 1 MeV, which is necessary for fusion.
3. However, the Sun's core temperature is only 10^7 K, so the chance of protons fusing on collision is very small. This explains why the Sun has such a long lifetime.

Explain the principles of physics which are involved in each of the three points.
You should include relevant formulae, but no numbers or calculations are required.

[6]

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

Additional answer space if required.

4 The International Space Station (ISS) orbits the Earth at a height of 4.1×10^5 m **above** the Earth's surface.

The radius of the Earth is 6.37×10^6 m. The gravitational field strength g_0 at the Earth's surface is $9.81\,N\,kg^{-1}$.

(a) Both the ISS and the astronauts inside it are in free fall.

Explain why this makes the astronauts feel **weightless**.

....

....

.... **[1]**

(b) **(i)** Calculate the value of the gravitational field strength g at the height of the ISS above the Earth.

g = ... $N\,kg^{-1}$ **[3]**

(ii) The speed of the ISS in its orbit is $7.7\,km\,s^{-1}$. Show that the period of the ISS in its orbit is about 90 minutes.

[2]

Question 4 continues on page 12

(c) Use the information in **(b)(ii)** and the data below to show that the root mean square (r.m.s.) speed of the air molecules inside the ISS is approximately 15 times smaller than the orbital speed of the ISS.

- molar mass of air = $2.9 \times 10^{-2}\,\text{kg}\,\text{mol}^{-1}$
- temperature of air inside the ISS = 20 °C

[3]

(d) The ISS has arrays of solar cells on its wings. These solar cells charge batteries which power the ISS. The wings always face the Sun.

Use the data below and your answer to **(b)(ii)** to calculate the **average** power delivered to the batteries.

- The total area of the cells facing the solar radiation is $2500\,m^2$.
- 7% of the energy of the sunlight incident on the cells is stored in the batteries.
- The intensity of solar radiation at the orbit of the ISS is $1.4\,kW\,m^{-2}$ outside of the Earth's shadow and zero inside it.
- The ISS passes through the Earth's shadow for 35 minutes during each orbit.

average power = ... W **[4]**

5 This question is about investigations involving an electromagnetic wave.

A vertical transmitter aerial emits a **vertically polarised** electromagnetic wave which travels towards a vertical receiver aerial. The wavelength of the wave is 0.60 m.

Fig. 5.1 shows a short section of the oscillating electric field of the electromagnetic wave.

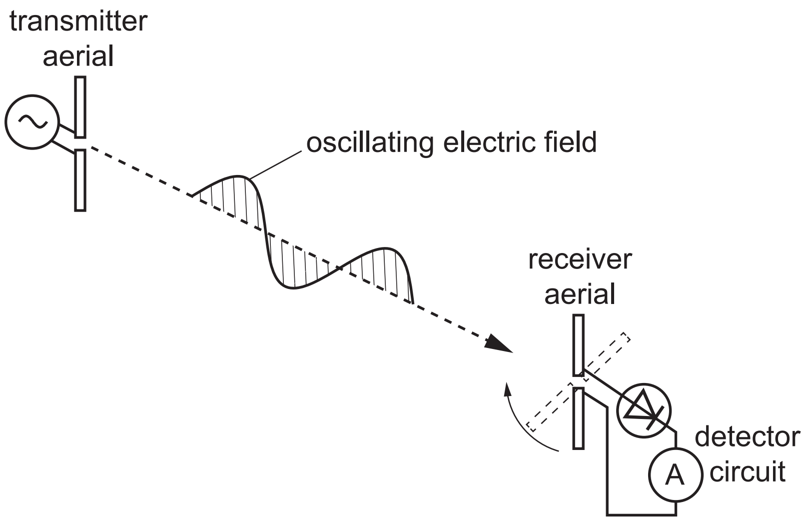


Fig. 5.1

(a) Calculate the frequency f of the transmitted wave.

f = ... Hz **[2]**

(b) The electromagnetic wave is caused by electrons oscillating in the transmitter aerial. Each electron oscillates with simple harmonic motion.

Calculate the maximum acceleration a_{max} of an electron which oscillates with an amplitude of 4.0×10^{-6} m.

a_{max} = ... $m\,s^{-2}$ **[3]**

(c) Suggest why the diode in **Fig. 5.1** is necessary for an ammeter to detect a signal at the receiver aerial.

....

....

.... **[1]**

***(d)** A student carries out two investigations with these electromagnetic waves.

In **investigation 1**, the student rotates the receiver aerial about the horizontal axis joining the two aerials, as shown in **Fig. 5.1**.

In **investigation 2**, the student places a metal sheet behind the receiver aerial. The student moves the sheet backwards and forwards along the horizontal axis joining the two aerials, as shown in **Fig. 5.2**.

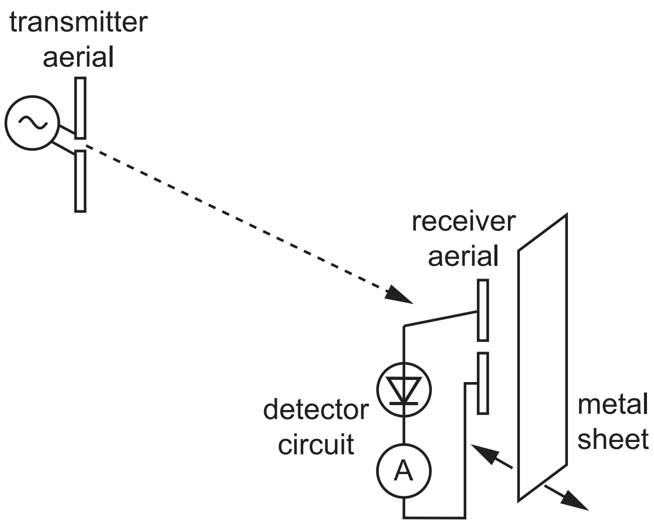


Fig. 5.2

For each of these two investigations:

- Explain why the ammeter sometimes gives a maximum reading and sometimes a zero (or near zero) reading.
- State the orientations of the receiver aerial in **investigation 1**, and the positions of the metal sheet in **investigation 2**, where these maximum and zero readings would occur.

[6]

....

....

....

....

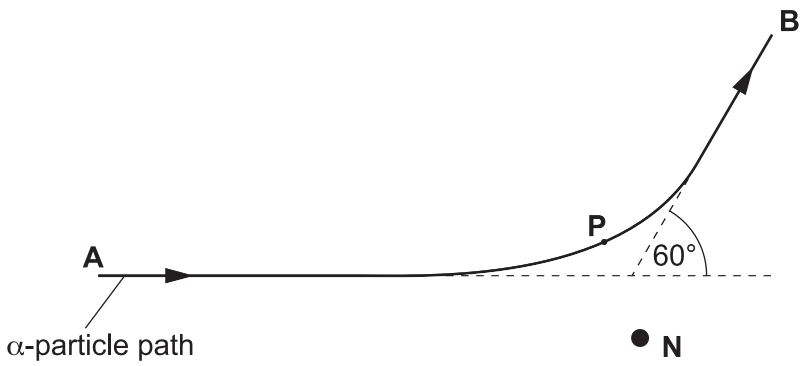
....

Additional answer space if required.

6 A beam of α-particles is incident on a thin gold foil. Most α-particles pass straight through the foil. A few are deflected by gold nuclei.

The diagram shows the path of one α-particle which passes close to a gold nucleus **N** in the foil. The α-particle is deflected through an angle of 60° as it travels from **A** to **B**.

P marks its position of closest approach to the gold nucleus.



(a) Another α-particle in the beam is deflected by the same gold nucleus **N** through an angle of 30°.

Sketch its path onto the diagram above. **[2]**

(b) The distance between **P** and **N** is 6.8×10^{-14} m.

Calculate the magnitude of the electrostatic force *F* between the α-particle ($^{4}_{2}He$) and the gold nucleus ($^{197}_{79}Au$) when the α-particle is at **P**.

F = ... N **[4]**

Question 6 continues on page 18

(c) The initial kinetic energy of each α-particle is 5.0 MeV.

Show that the magnitude of the initial momentum of each α-particle is about 10^{-19} kg m s^{-1}.
Take the mass of the α-particle to be 6.6×10^{-27} kg.

[3]

(d) The **magnitude** of the final momentum of the α-particle at **B** is equal to its initial value at **A**.

The gold nucleus **N** is initially at rest. During the passage of the α-particle from **A** to **B**, no other forces act on the two particles.

In the following questions label any relevant angles.

(i) Draw two vectors in the spaces below to represent the initial momentum and the final momentum of the α-particle.

initial momentum at **A**

final momentum at **B**

[2]

(ii) Draw a vector in the space below to represent the momentum of the nucleus **N** when the α-particle reaches **B**.

Explain how you determined this momentum.

....

....

.... **[2]**

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).