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.

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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

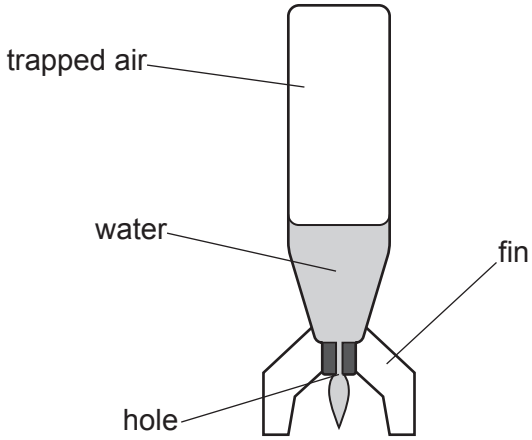


Fig. 1.1

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

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

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(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 = $1.1 \times 10^{-4}\,m^2$
initial pressure of trapped air = $2.4 \times 10^{5}\,Pa$
atmospheric pressure = $1.0 \times 10^{5}\,Pa$
density of water = $1.0 \times 10^{3}\,kg\,m^{-3}$

(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]

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(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.

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..... **[3]**

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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.

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

[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.

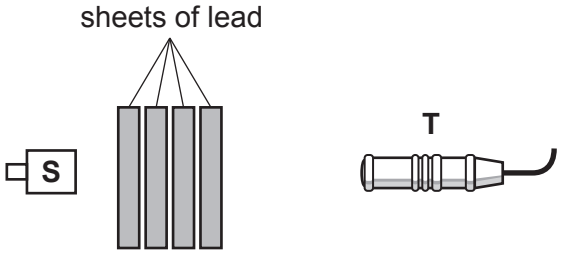


Fig. 2.1

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

Explain why this would not affect the experiment.

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

Question 2 continues on page 6

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(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]

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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]**

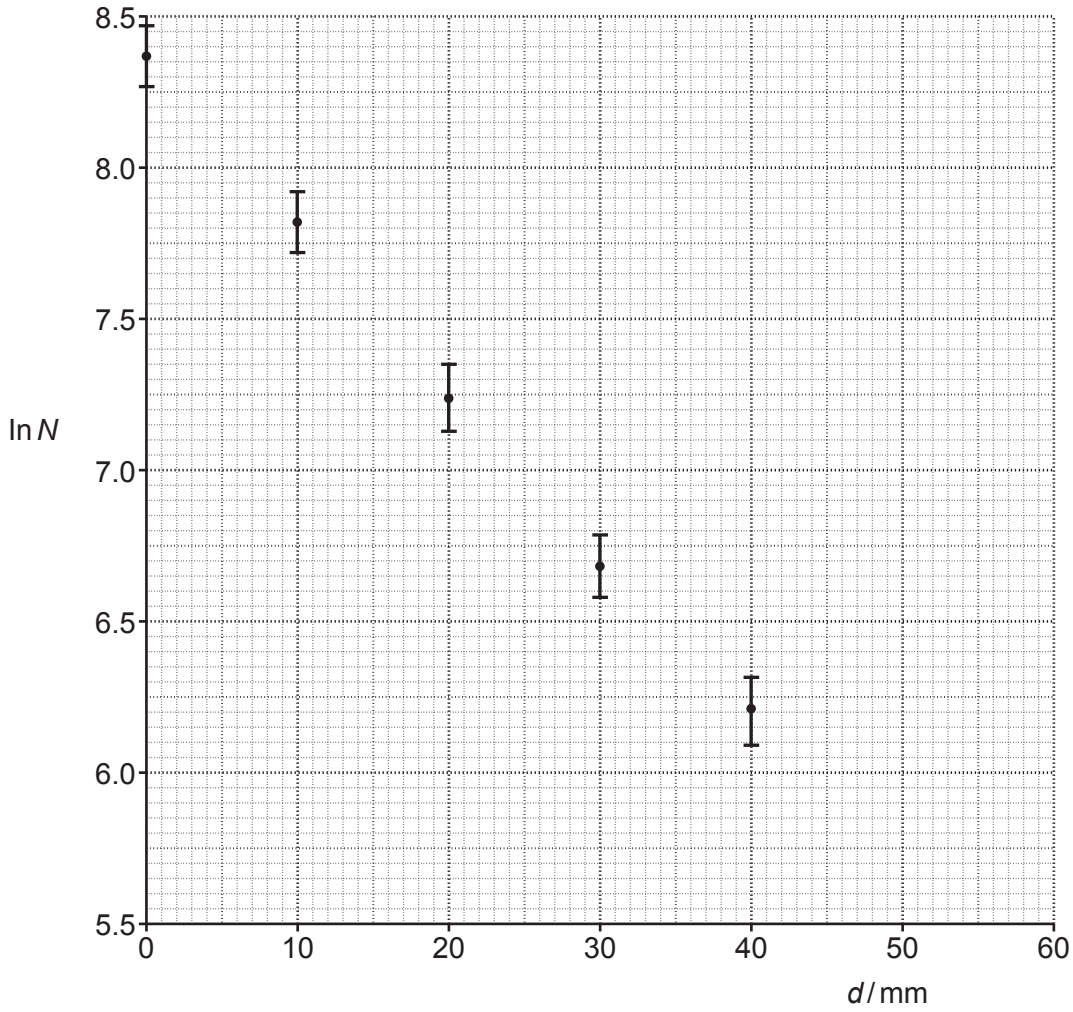


Fig. 2.2

Question 2 continues on page 8

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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]**

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Question 3 begins on page 10.

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

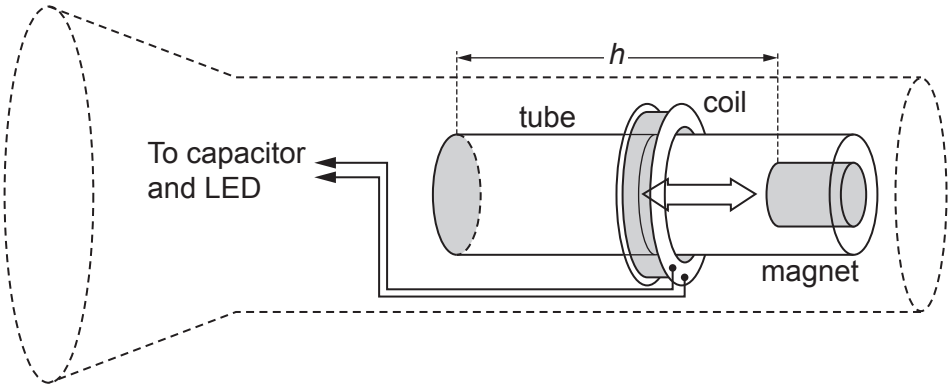


Fig. 3.1

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.

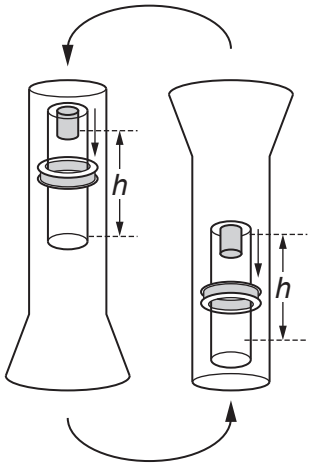


Fig. 3.2

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

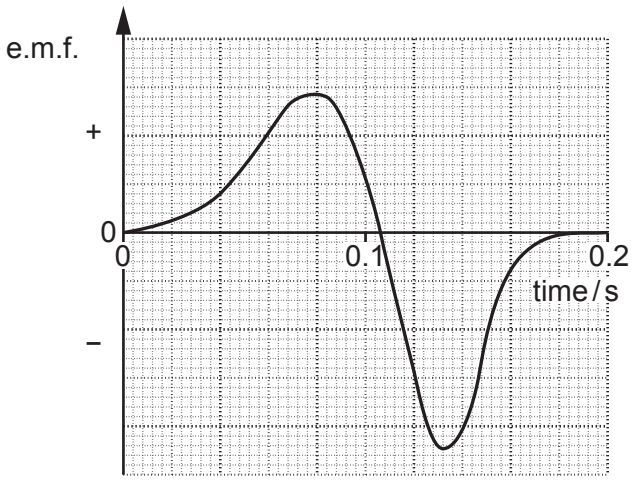


Fig. 3.3

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

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..... **[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

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***(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]**

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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'**.

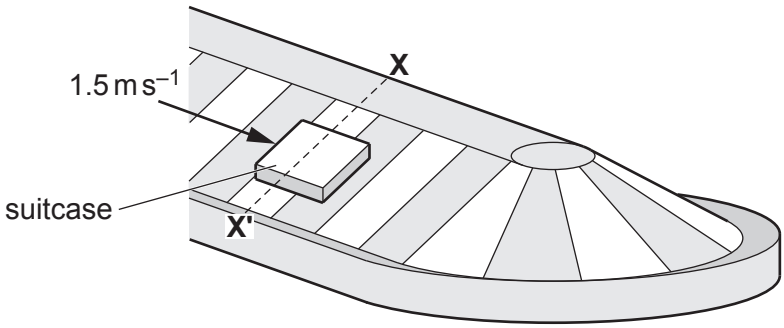


Fig. 4.1

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.

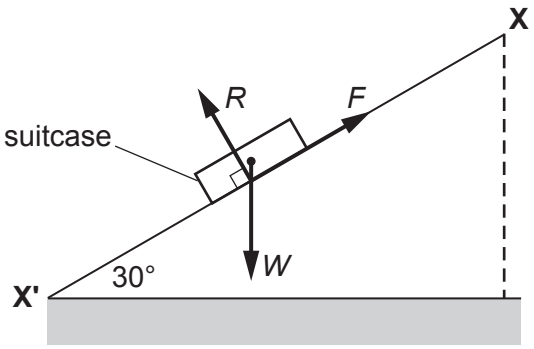


Fig. 4.2 (not to scale)

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

F = ... N

R = ... N
[3]

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

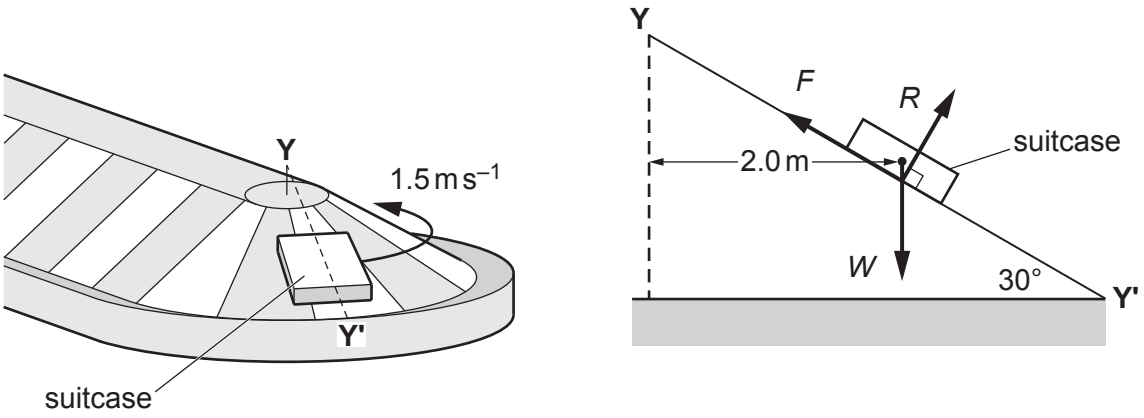


Fig. 4.3

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.

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..... **[4]**

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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.

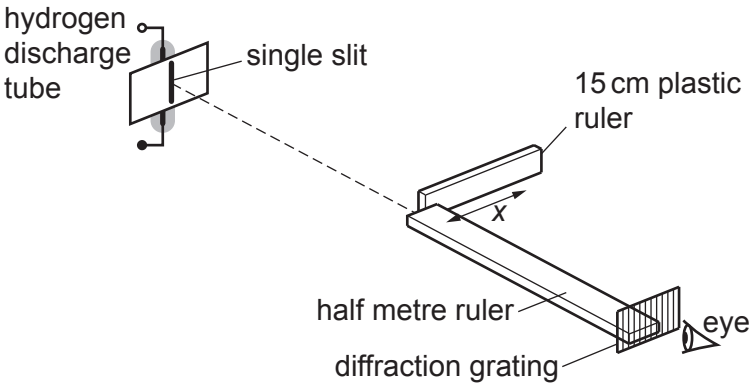


Fig. 5.1 (not to scale)

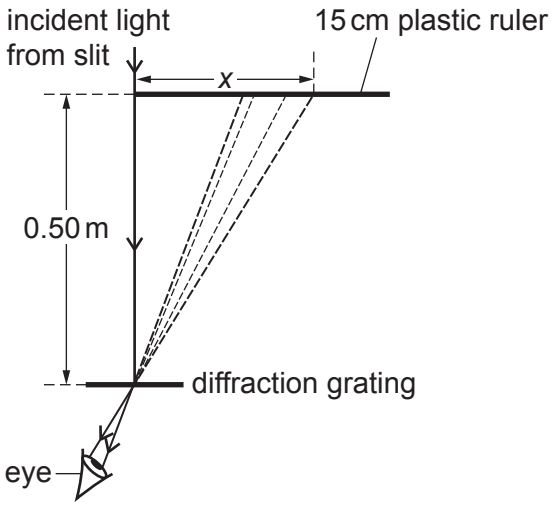


Fig. 5.2 (not to scale)

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.

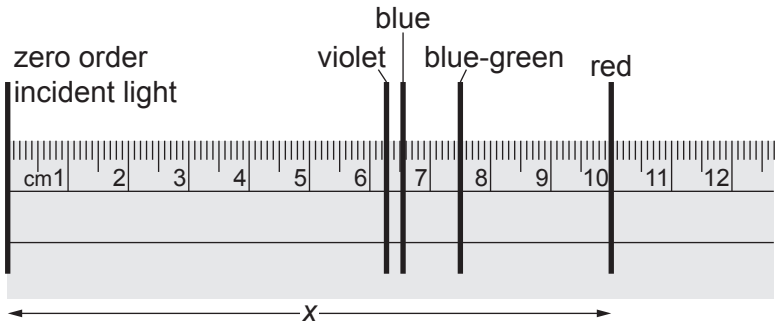


Fig. 5.3

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]**

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Additional answer space if required.

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Question 5 continues on page 18

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(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.

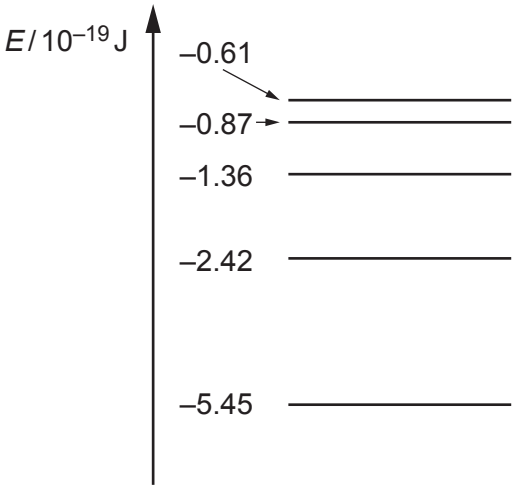


Fig. 5.4 (not to scale)

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]**

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Question 6 begins on page 20

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

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

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

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..... **[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.

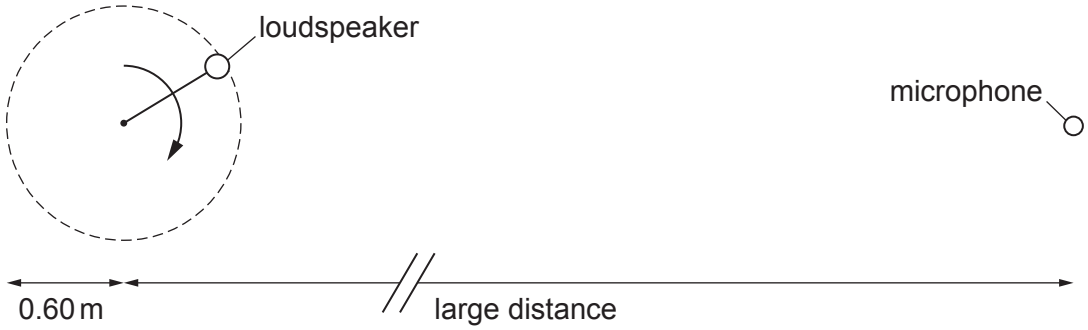


Fig. 6.1

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.

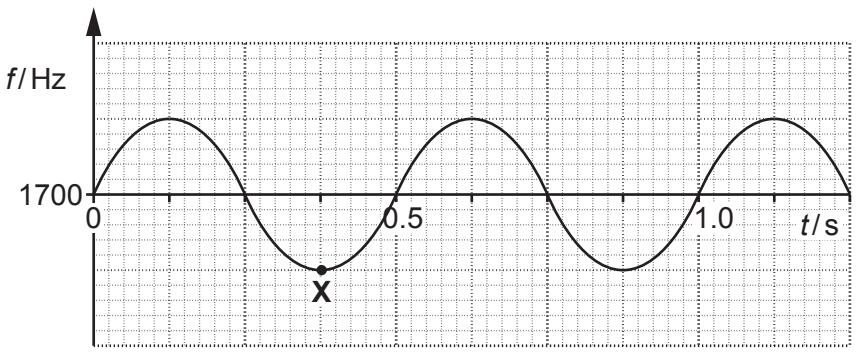


Fig. 6.2

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(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: .....

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precision: .....

..... **[2]**

END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

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