Oxford Cambridge and RSA

Thursday 15 October 2020 – Morning

AS Level Physics B (Advancing Physics)

H157/02 Physics in depth

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 answer 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 **24** pages.

ADVICE

- Read each question carefully before you start your answer.

SECTION A

1 The total mass of an electric train including its coaches and passengers is 369 000 kg. The maximum speed of the train is 200 km hour^{-1}.

(a) The electric motor provides an initial force of 260 kN.

Use this value to calculate the minimum time taken for the train to reach its maximum speed, starting from rest. You can assume that the train is travelling in a horizontal straight line.

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

(b) Explain why the value calculated in **(a)**, using a force of 260 kN, is a minimum time.

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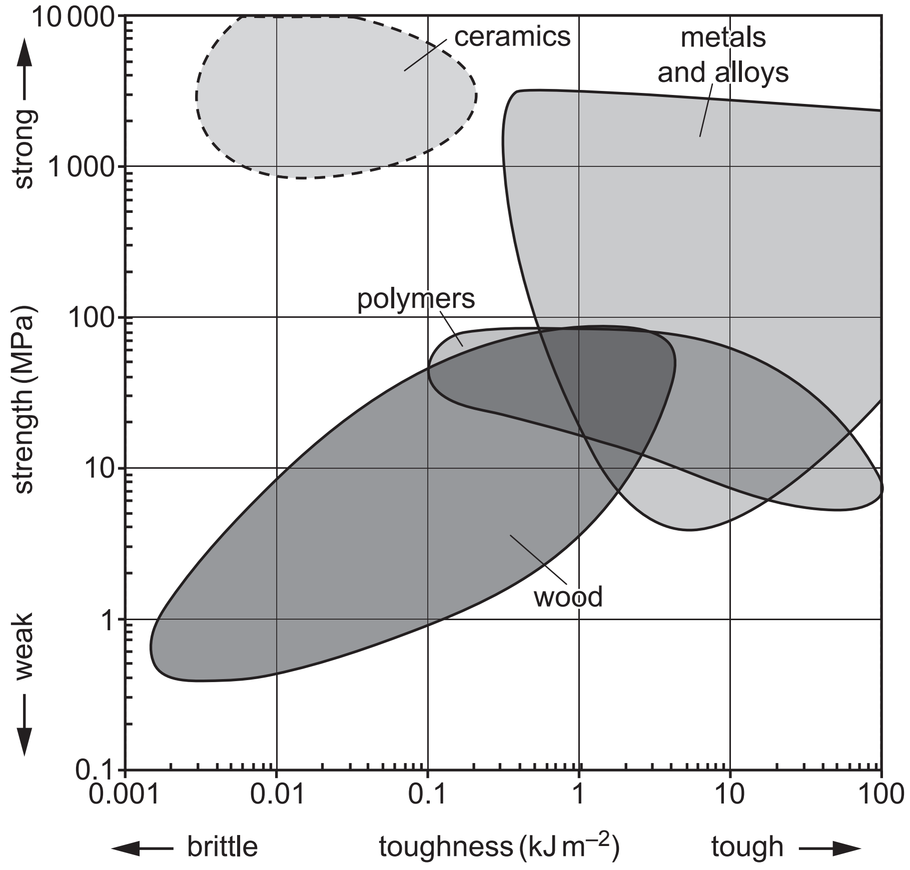
.... **[2]**

2 The chart below displays the ranges of strength and toughness for different materials.



(a) Ceramics and metals are both very strong, but metals are much tougher than ceramics.

Explain the similarity and difference in terms of their structure.

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.... **[2]**

(b) When a sample of a material is stretched until it breaks, the surface area of the sample increases.

Explain why the toughness of the material can be measured in units of kJ m^{-2}.

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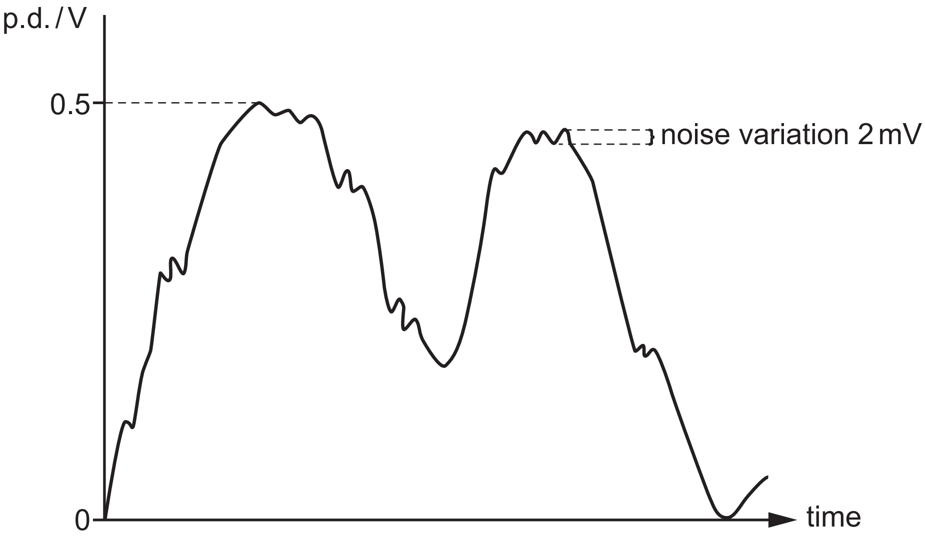
.... **[2]**

3 The diagram shows an analogue signal which contains noise.



(not to scale)

The signal is to be converted into a digital signal, dividing the voltage range into equally spaced levels.

(a) Explain why using 9-bit quantisation to sample the signal is not better than using 8-bit quantisation. Justify your answer with an appropriate calculation.

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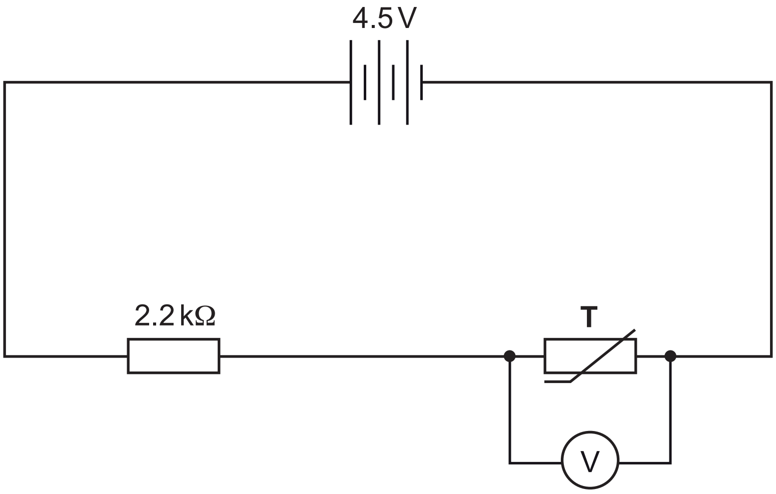
.... **[3]**

(b) The signal consists of two stereo channels, each sampled with 8-bit quantisation as stated in part **(a)**. The sampling rate is 44.1 kHz.

Calculate the rate of transmission in Mbit s^{-1}.

transmission rate = ... Mbit s^{-1} **[2]**

4 The figure shows a sensor circuit used to measure temperature.



The resistance of the thermistor **T** varies with temperature as shown in this table.

Temperature / °C	0	10	20	30	40	50	60
Resistance / Ω	9800	6000	3700	2400	1600	1000	750

(a) The temperature of the thermistor is increased. Without doing any calculations, describe and explain what will be observed on the voltmeter V during the temperature increase.

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.... **[2]**

(b) At one particular temperature, the voltmeter reads 2.1 V.

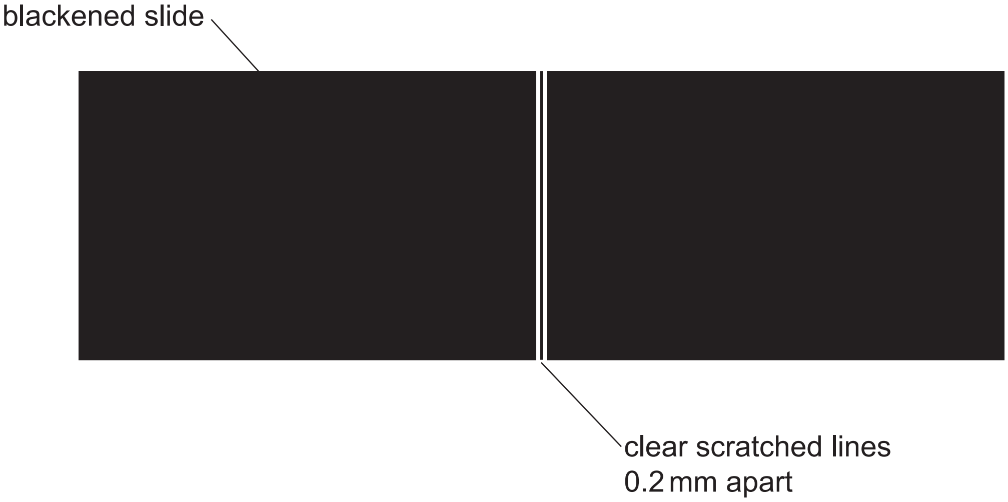
(i) Calculate the resistance of the thermistor at this temperature.

resistance = ... Ω **[3]**

(ii) Use the data in the table to make an estimate of the temperature.

temperature = ... °C **[1]**

5 A microscope slide coated with black paint has two thin lines scratched into the paint as shown in the figure.



The slide is mounted with the two scratched lines vertical, and light from a laser is directed at the scratched lines, striking them perpendicularly.

A pattern of equally-spaced bright and dim interference fringes is observed on the laboratory wall, which is a distance of 4.20 m away from the microscope slide. The mean separation of these fringes is 13 mm.

Calculate the wavelength of the laser light. Justify the number of significant figures in your answer.

wavelength = ... m **[4]**

SECTION B

6 This question is about the wave-like behaviour of electrons.

(a) **Fig. 6.1** shows apparatus which is used to demonstrate electron diffraction.

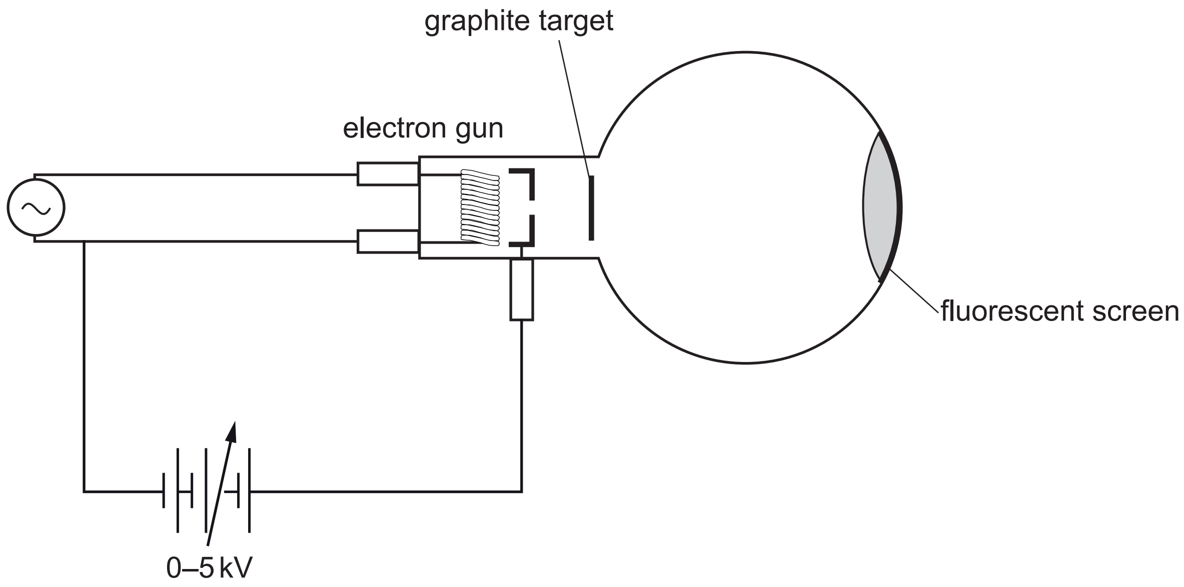


Fig. 6.1

(i) Apply the principle of conservation of energy to show that the speed v of an electron accelerated through a p.d. V is given by

$$v = \sqrt{\frac{2eV}{m}}$$

where e and m are the charge and mass of the electron respectively.

[3]

(ii) Show that the maximum speed that an electron can gain in the apparatus of **Fig. 6.1** is about $4 \times 10^{7}\,\mathrm{m\,s^{-1}}$.

[2]

(iii) Calculate the de Broglie wavelength λ of an electron travelling at the maximum speed and use the properties of the moving electron to state why this is the smallest wavelength that can be produced in this apparatus.

λ = ... m

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.... **[3]**

(b) Graphite consists of flat sheets of carbon atoms arranged as shown in **Fig. 6.2**.

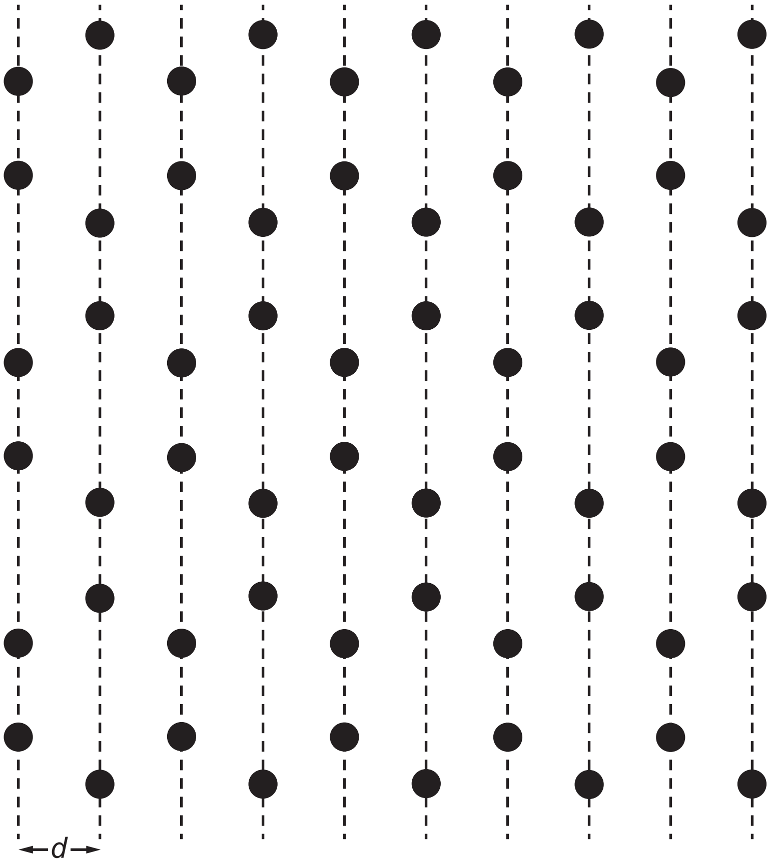

Fig. 6.2

The direction of the electron beam is into the diagram, so that it meets the sheet of carbon ‘head on’.

The regular repeating arrangement of carbon atoms results in the sheet of carbon behaving like a diffraction grating. The equally-spaced dashed lines in **Fig. 6.2** can be thought of as the ‘ridges’ in a diffraction grating with grating spacing d = 0.14 nm.

(i) The p.d. applied to the electron gun in **Fig. 6.1** is gradually increased from 0, and diffraction orders produced by the above grating are seen on the fluorescent screen (**Fig. 6.3**).

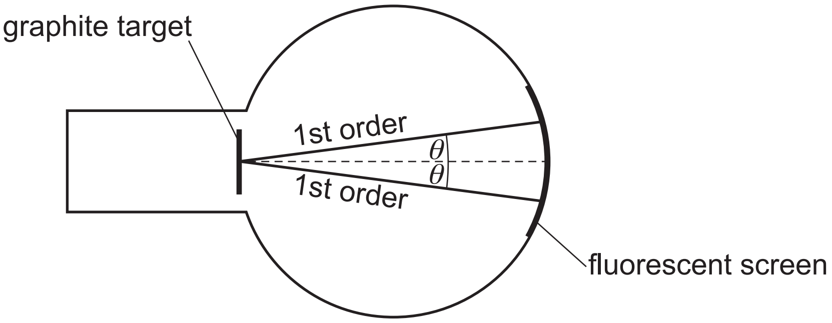

Fig. 6.3

For one particular p.d. *V*, the first order diffraction occurs at an angle $\theta = 7.5°$ to the main beam.

Calculate *V* in kV.

V = ... kV **[4]**

(ii) Other diffraction patterns, not shown in **Fig. 6.3**, are produced by the graphite lattice. These are given by atom alignments in directions different from the one shown in **Fig. 6.2**.

Use a ruler to draw, on **Fig. 6.2**, at least three equally-spaced straight lines through adjacent layers of atoms. These layers should have a separation different from *d* in **Fig. 6.2**.

State, with an explanation, how the angle θ for the first order maxima from this 'diffraction grating' would differ from that in **(b)(i)**.

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.... **[3]**

7 This question is about the forces and motion of a tennis ball struck by a racket.

The following data will be needed in this question:

Mass of tennis ball	58.0 g
Diameter of tennis ball	6.70 cm
Length of tennis court from server to opponent	18.2 m

(a) A tennis player ‘serves’ by tossing the ball into the air and hitting it with the tennis racket moving at high speed (**Fig. 7.1**).

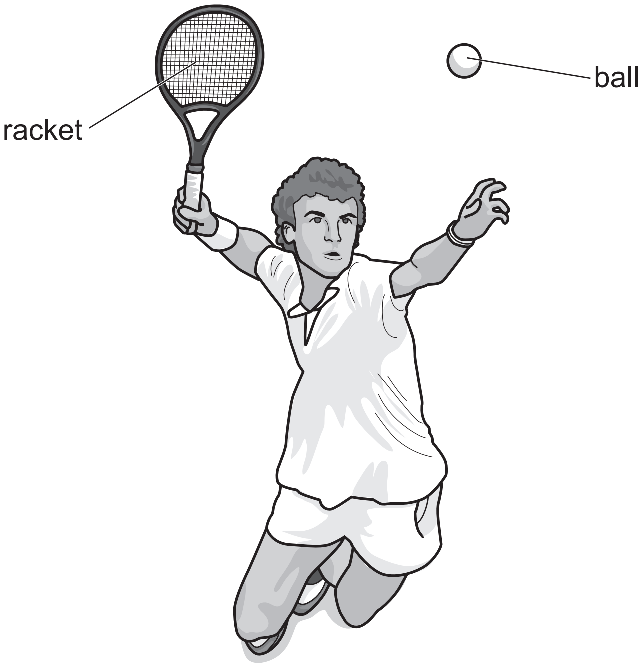

Fig. 7.1 A tennis serve (seen from above)

The ball leaves the racket at 28 m s^{-1}.

(i) Calculate the time that the opponent has to react before the ball reaches him, assuming that the frictional forces from the air are negligible.

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

(ii) The ball is stationary when the racket first hits it and the ball is in contact with the strings of the racket for 2.0 ms.

Show that the mean force that the ball experiences during the serve is about 800 N.

[2]

(b) The ball becomes compressed and the racket strings stretch slightly during the impact, as shown in the sectional view of **Fig. 7.2**.

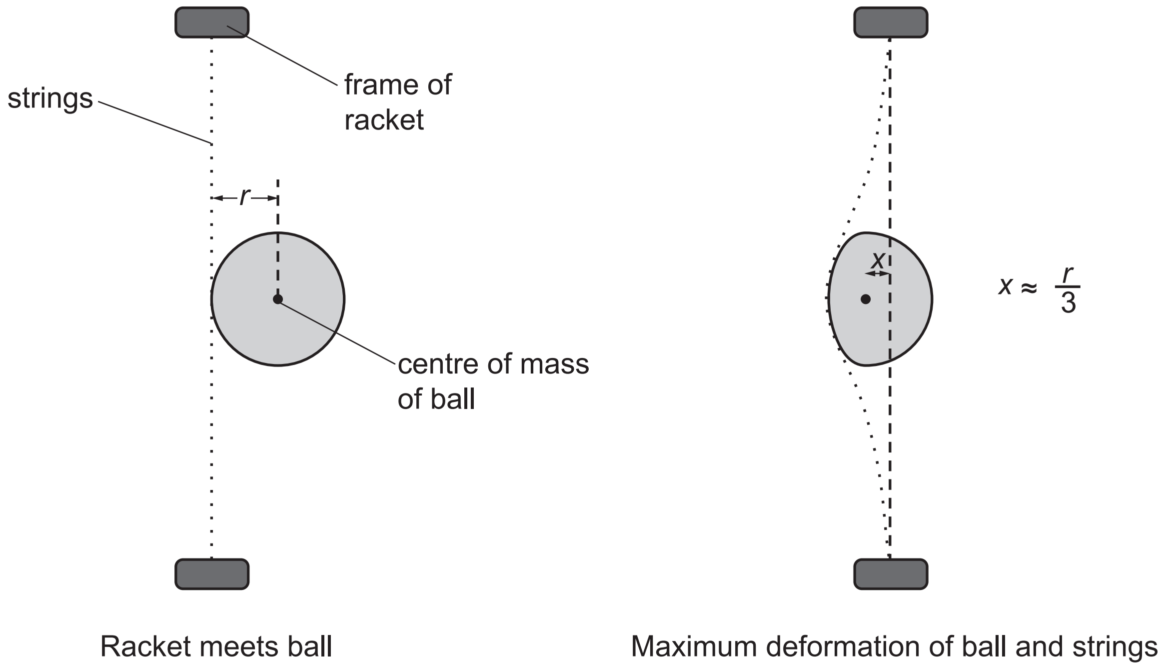

Fig. 7.2

Use information from **Fig. 7.2** and the data given on page 12 together with the mean force from **(a)(ii)** to calculate E_p, the energy stored in the deformed strings and ball. Compare this energy with E_k, the kinetic energy given to the ball, and suggest a reason for any difference.

E_p = ... J

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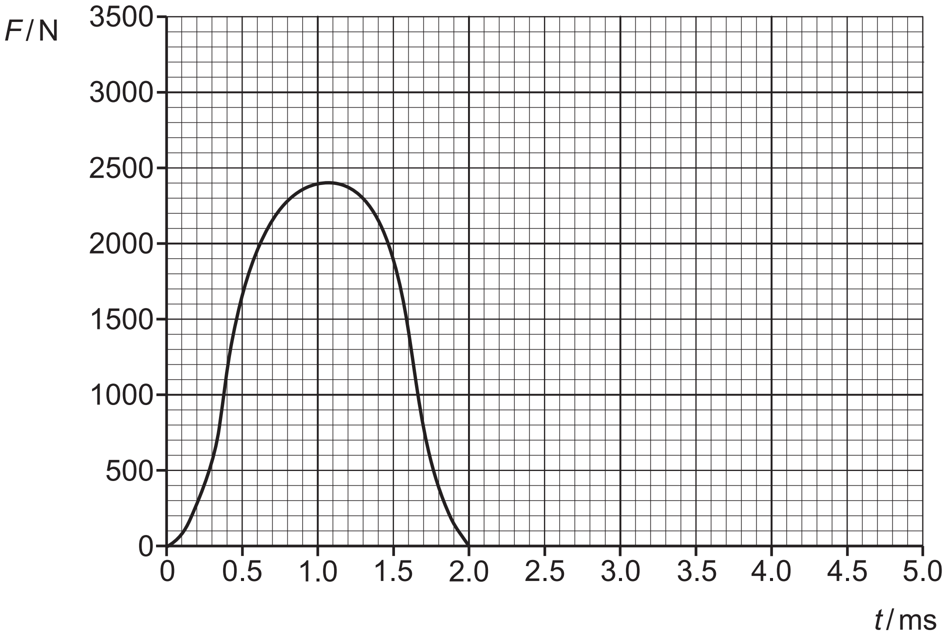
.... **[5]**

(c)* The graph shows how the force on the ball varies during a different impact.



Describe how the mean force of this impact differs from that described in part **(a)** of this question.

Sketch on the graph the force-time graph you would expect if the ball had been hit by an identical racket with strings at a lower tension. You can assume the racket and ball meet with the same relative velocity.

Explain in detail any differences between the two graphs and the resulting motion of the ball.
[6]

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SECTION C

8 Sam is attempting to find the Young modulus of copper.

She uses a very long piece of wire cut from a new roll, so that the metal has not been twisted or bent before she stretches it.

The initial length *L*, measured from the place where the wire is clamped to the marker used to measure extensions, was 2.80 m.

The wire is stretched by a series of different weights, as shown in **Fig. 8.1**.

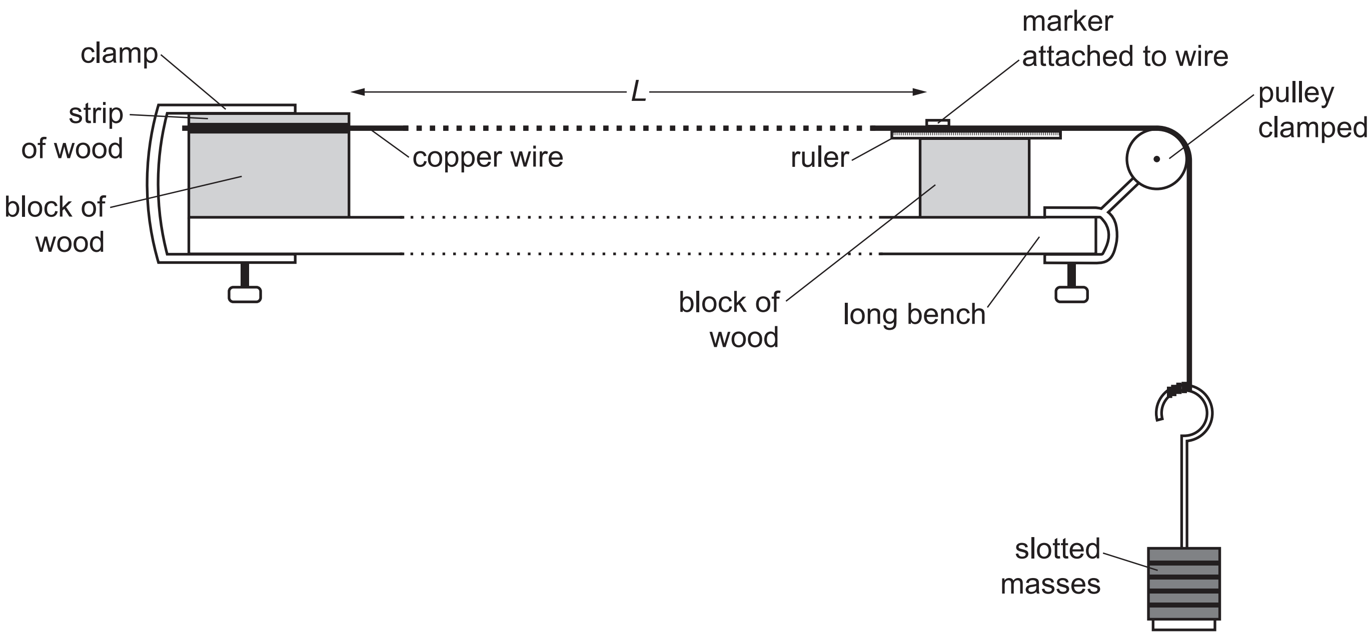

Fig. 8.1

(a) Sam uses a micrometer to make a number of measurements of the diameter of the wire at different points along its length. She records her readings in this dot-plot.

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		●	●	●	
	●	●	●	●	●
diameter / mm	0.313	0.314	0.315	0.316	0.317

Use these data to find the mean diameter d of the wire and its uncertainty, Δd.

Express both values to an appropriate number of significant figures.

d = ... mm Δd = ... mm **[3]**

(b)* Sam decides to measure the extension e of the wire for a range of masses m using the arrangement shown in **Fig. 8.1**.

Describe how Sam should perform the experiment to give reliable data which would lead to an accurate value of the Young modulus of elasticity for copper over the range of stresses for which the extension follows Hooke's Law.

You can assume that Hooke's Law will apply for strains less than 0.1%.

You do not need to show how the data will be used. **[6]**

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(c) The data from the experiment are to be analysed using a suitable graph.

(i) Show that the Young modulus of the metal, E is given by

$$E = \left(\frac{gL}{A}\right)\left(\frac{m}{x}\right)$$

where A is the cross-sectional area of the wire, L its length and x the extension produced by adding the mass m.

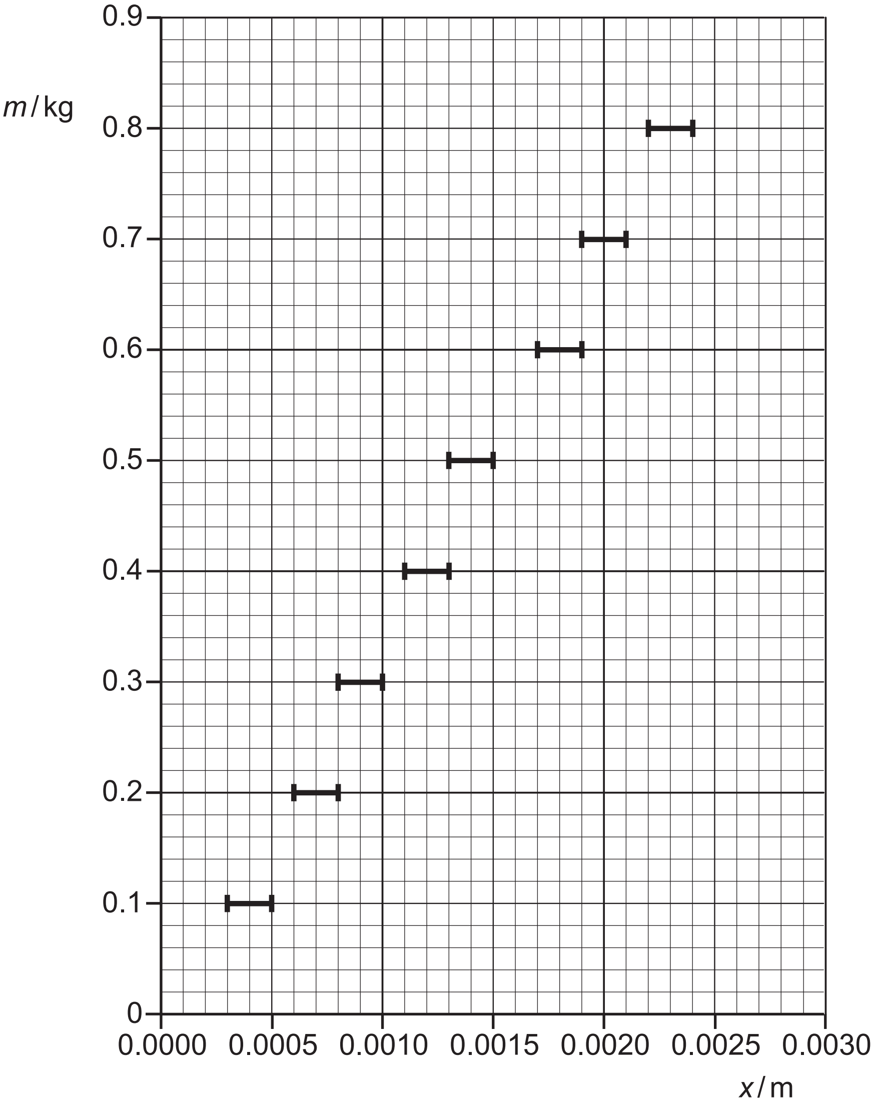
[2]

(ii) Sam decides that the uncertainties in m are far less than those in x, and plots the data as shown opposite.

Use the graph to find $\left(\frac{m}{x}\right)$ and its uncertainty.

Show your working clearly.

$\left(\frac{m}{x}\right)$ = ... kg m^{-1} $\Delta\left(\frac{m}{x}\right)$ = ... kg m^{-1} **[3]**



Part (c) continues over the page.

(iii) Data books state that the Young modulus of copper is 120 GPa.

Use this value, together with data from earlier in this question and the equation

$$E = \left(\frac{gL}{A}\right)\left(\frac{m}{x}\right)$$

to calculate $\left(\frac{m}{x}\right)$ for this wire.

Compare this value with your value of $\left(\frac{m}{x}\right) \pm \Delta\left(\frac{m}{x}\right)$ in **(c)(ii)**.

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.... **[3]**

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If you need extra space use the following lined pages. The question numbers must be clearly shown.