Oxford Cambridge and RSA

AS Level Physics B (Advancing Physics)

H157/02 Physics in depth

Thursday 8 June 2017 – Afternoon

Time allowed: 1 hour 30 minutes

You must have:
- the Data, Formulae and Relationships 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. HB pencil may be used 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, you should 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.

SECTION A

Answer all the questions.

1 A diffraction grating is marked '*xxx* lines mm^{-1}' where the number *xxx* cannot be read. Tests show that it has a grating spacing of 1.50×10^{-6} m, measured to 3 significant figures.

(a) Calculate the number of lines per millimetre, *xxx*.

number of lines per millimetre = ... **[2]**

(b) Yellow light of wavelength 583 nm is incident at right angles to the grating. Calculate the angle θ_2 of the second-order diffraction maximum.

θ_2 = ... ° **[2]**

(c) Explain why this yellow light has no third-order maxima.

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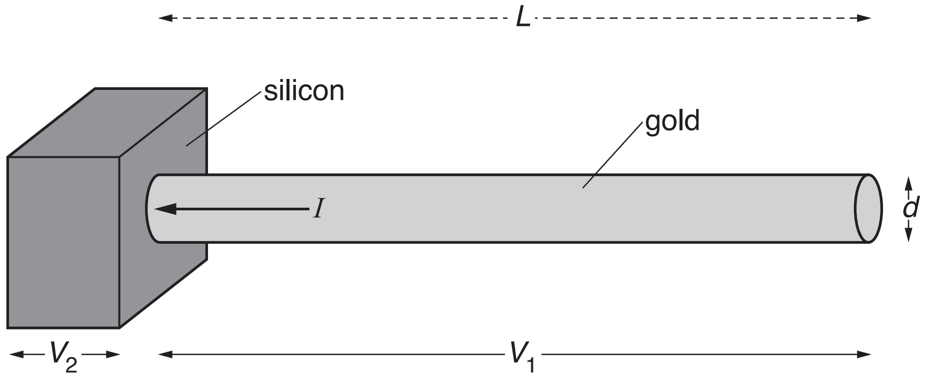
....

.... **[2]**

2 In a computer chip, the connections between the chip terminals and the semiconductor are thin gold wires.

Fig. 2 shows one gold wire and the section of silicon to which it is connected. The p.d.s V_1 and V_2 across the gold wire and the silicon section result in the current I shown.



(not to scale)

Fig. 2

(a) The gold wire has length $L = 3.2 \times 10^{-3}$ m and diameter $d = 2.0 \times 10^{-5}$ m. It carries a current $I = 4.5 \times 10^{-5}$ A.

Calculate the p.d. V_1 across the length L of wire.

resistivity of gold, $\rho = 2.3 \times 10^{-8}\ \Omega$ m

V_1 = ... V **[3]**

(b) The conductance of the silicon section, in the direction of current, is 1.7 mS.

Calculate the p.d. V_2 across the silicon section.

V_2 = ... V **[2]**

3 A source **S** emits monochromatic, coherent light which illuminates three equally-spaced slits **A**, **B** and **C** in an opaque barrier. An interference pattern is observed on a distant screen parallel to the barrier (Fig. 3).

Point **1** is the central maximum in the interference pattern. Moving outwards from **1**, the intensity becomes a minimum, then a maximum again at **2**, then another minimum and then a maximum at **3**.

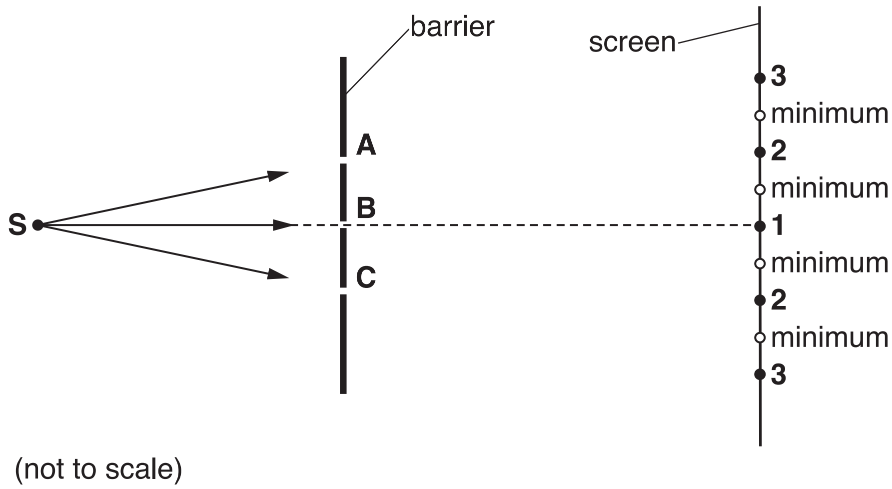
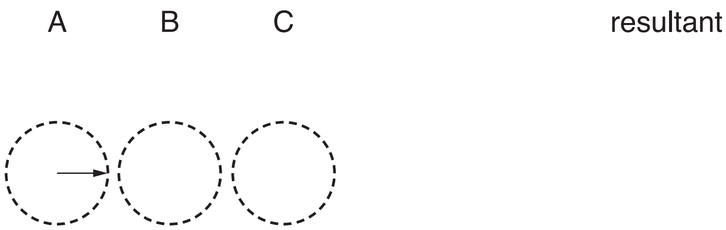


Fig. 3

You can assume that the amplitude of light from **S** reaching any point on the screen is the same whether that light travels through slit **A**, through slit **B** or through slit **C**.

(a) The phasor for the light from slit **A** at point **1** is shown below.
Add to this diagram the phasors for the light at point **1** from slits **B** and **C** and their resultant.



[2]

(b) At the points marked 'minimum', the light has zero intensity. Draw a phasor diagram to show how this is achieved.

[1]

(c) The intensity of light at the maxima marked **3** is exactly the same as at the point marked **1**. At the places marked **2** the intensity of light is much less, even though it is larger than the positions just to the right or left of it. Draw a phasor diagram to show how this is achieved.

[2]

4 Fig. 4 shows a simple model of the structure of a metal.

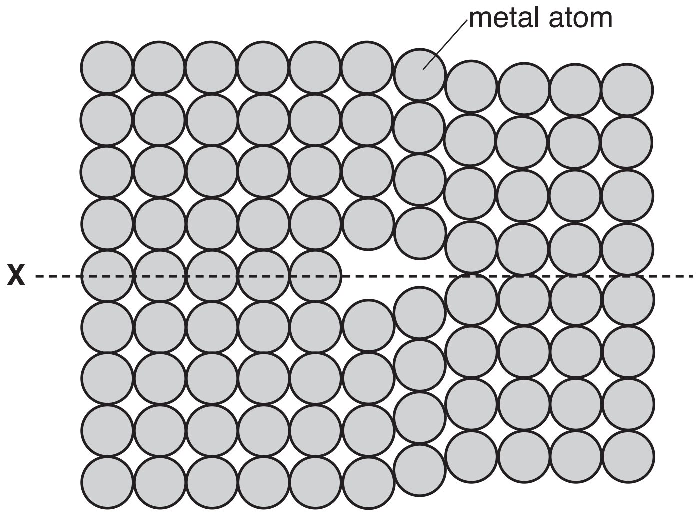


Fig. 4

(a) (i) Identify the structure marked **X.**

X is .... **[1]**

(ii) Explain how structure **X** makes the metal ductile.
You may wish to draw on Fig. 4 to help your explanation.

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.... **[2]**

(b) A pure metal is alloyed by adding a small proportion of atoms of a different metal while the metal is molten. The alloy is often much stiffer and harder than the pure metal of Fig. 4.

Explain why alloying can produce these changes.

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.... **[2]**

5 A laser has an output power of 150 mW and emits light of wavelength 520 nm.

(a) Show that the laser emits about 4×10^{17} photons each second.

$c = 3.0 \times 10^{8}\ \mathrm{m\,s^{-1}}$
$h = 6.6 \times 10^{-34}\ \mathrm{J\,s}$

[3]

(b) Show that the momentum p of each photon emitted by the laser is about $10^{-27}\ \mathrm{kg\,m\,s^{-1}}$.

[1]

(c) The light from the laser strikes a surface which absorbs all light falling on it.
Calculate the force F that the photons exert on this surface.

F = ... N **[1]**

SECTION B

Answer all the questions.

6 This question is about projectile motion.

Fig. 6.1 shows the path taken by an object thrown with an initial velocity v at a direction θ to the horizontal.

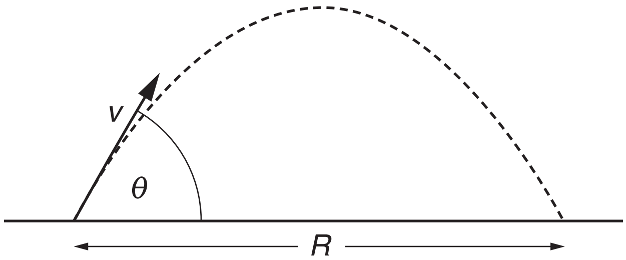

Fig. 6.1

(a) The range, R, of the projectile is given by $R = v\cos\theta\, t$ where t is the total time of travel of the projectile. Ignore air resistance.

(i) Show that the time t is given by the equation

$$t = \frac{2v\sin\theta}{g}.$$

[2]

(ii) Use the equation from part **(a)(i)** above to complete this table for a projectile of initial speed $v = 24\,\mathrm{m\,s^{-1}}$ by adding the value of R for an angle of 76°.

θ/°	15	25	35	49	58	67	76
R/m	29.4	45	55.2	58.2	52.8	42.3	

Plot the new value of R on the graph in Fig. 6.2 opposite, draw a best-fit curve and determine the maximum range R_{max} for the projectile with initial speed $24\,\mathrm{m\,s^{-1}}$.

$g = 9.8\,\mathrm{m\,s^{-2}}$

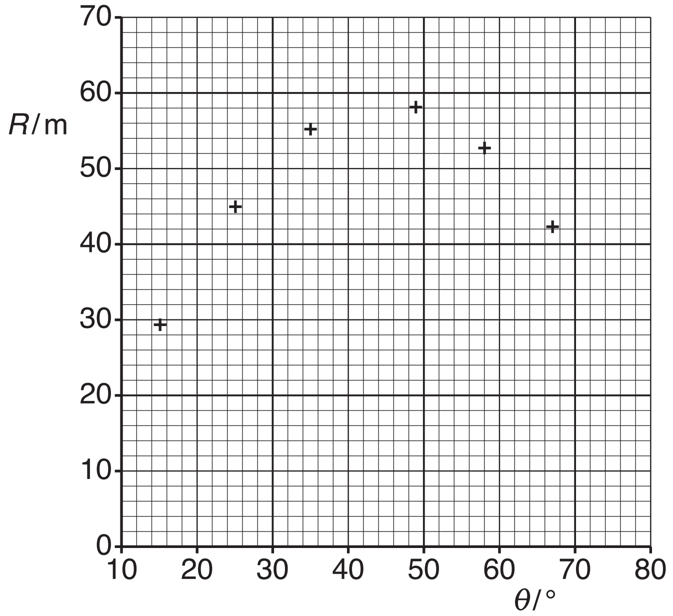

Fig. 6.2

R_{max} = ... m **[3]**

(b) A real projectile such as a tennis ball is greatly affected by air resistance.

State and explain how you would expect the R–θ graph for such a projectile, also thrown at 24 m s^{-1}, to differ from the theoretical graph of Fig. 6.2.

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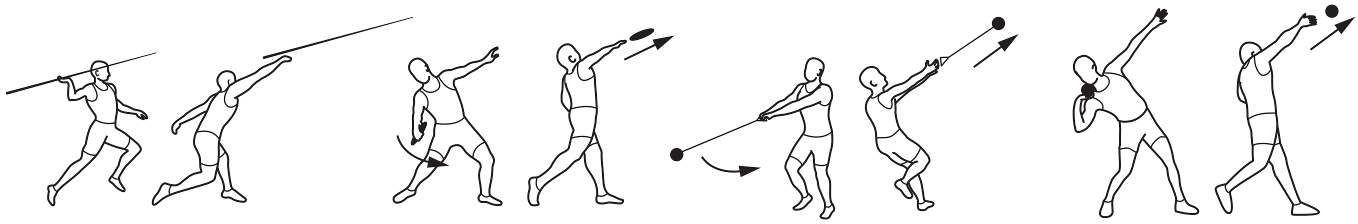
.... **[3]**

(c)* Four athletics events involve throwing an object with the aim of achieving the largest range possible. These four are shown in Fig. 6.3.



javelin throw | discus throw | hammer throw | shot put

Fig. 6.3

The javelin is a sharp rod about 2.6 m in length, the discus is a flat disc and both hammer and shot have metal spheres. For the javelin throw, the athlete runs a fixed distance before throwing. For the other three events, the athlete must remain within a marked circle during the throw. In each of these events, good performance depends on the power developed by the athlete and the impulse exerted on the thrown object.

The table shows data for these four events. All data refer to the men's competition.

event	hammer	discus	javelin	shot
mass of object thrown / kg	7.3	2.0	0.80	7.3
world championship record range / m	86.74	74.08	98.48	23.12

Discuss how the very different ranges achieved may depend on factors particular to each event.

[6]

7 In 1974, the Mariner 10 space probe took the first digital photographs of the surface of the planet Mercury.

(a) In each photograph, every pixel had a value from 0 (white) to 255 (black).

(i) State how this fact shows that each pixel was encoded by one byte (8 bits) of data.

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.... **[2]**

(ii) Radiation from the Sun affected the cameras in the probe, changing the values of some pixels, so the photograph of Fig. 7.1 was severely affected by noise.

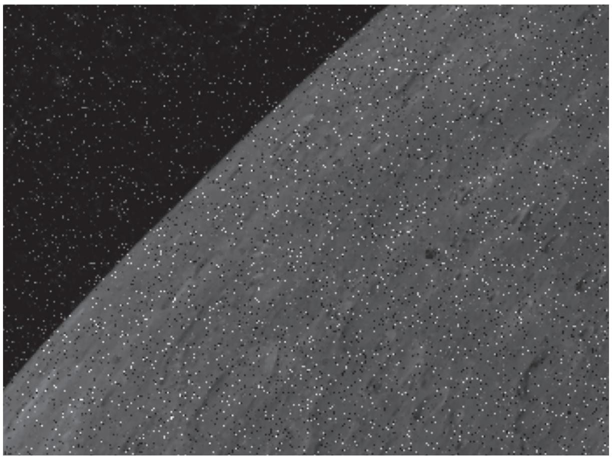

Fig. 7.1

State and explain how Fig. 7.1 shows that noise resulted in changes to the values encoded in some pixels.

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.... **[2]**

(b) Fig. 7.2 is a magnified view of part of Fig. 7.1.

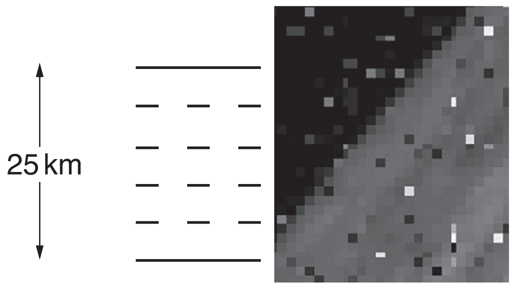

Fig. 7.2

Use Fig. 7.2 to estimate the resolution of the surface of Mercury in this image. Show your working.

resolution = ... m **[2]**

(c) The data generating Fig. 7.1 was processed by computer to give the image shown in Fig. 7.3.

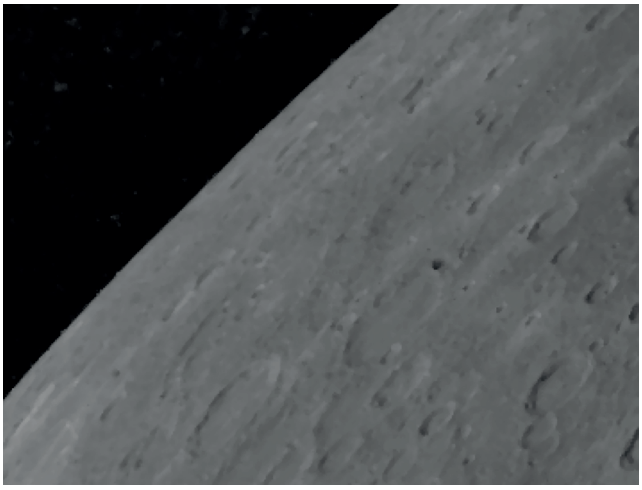

Fig. 7.3

Removal of noise has both advantages and disadvantages.
Suggest and explain one advantage and one disadvantage of this noise removal.

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.... **[4]**

(d) The data for the image in Fig. 7.1 was sent from the Mariner space probe back to Earth at a rate of 117.6 kilobits s^{-1}. The complete image was transmitted in 22 blocks, each containing 31 944 bytes.

Calculate, to the nearest second, the time taken to send the complete image.

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

SECTION C

Answer all the questions.

8 Carol and Jason are investigating momentum and energy changes in collisions.

They are using two trolleys on a table and measuring velocities with light gates connected to data-loggers. Each trolley has a pad of 'impact material' (rubber) attached to the front.

As each timing card passes through a light gate, it cuts a light beam and the attached data-logger records the time for which the beam has been cut. Fig. 8.1 shows the two trolleys approaching each other, having just passed through the light gates.

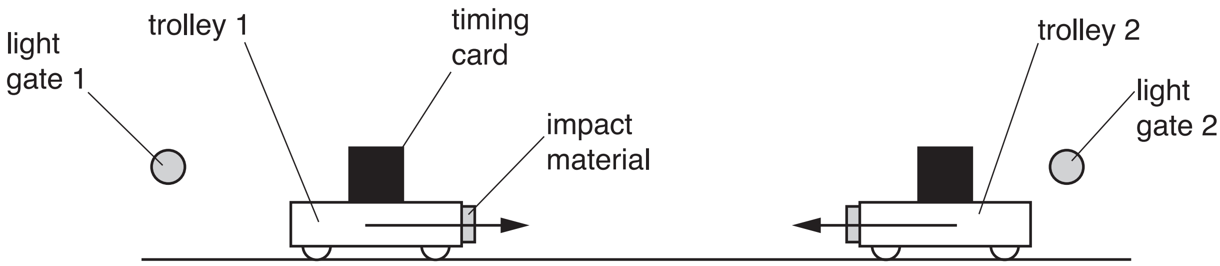

Fig. 8.1

(a) The data-logger and light gate together have a timing uncertainty of 4 μs. Typical times recorded in the experiment are in the range 0.1 s to 1.0 s.

The timing cards are each cut to be 10.0 cm wide in the direction of motion, and the uncertainty in the card width is ± 0.1 cm.

(i) Explain in terms of percentage uncertainty why the timing uncertainty can be ignored in this experiment.

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.... **[2]**

(ii) The time recorded by the data-logger when a trolley passes the light gate is 0.1453 s.
Calculate the mean speed of the trolley and its uncertainty.
Give both values to an appropriate number of significant figures.

mean speed = ... ± .... $m\,s^{-1}$ **[3]**

(b) The data for one collision is given below. After the impact, the two trolleys reversed direction and moved back outwards. Each trolley has a mass of 0.800 kg.

trolley 1			trolley 2		
before or after collision?	before	after	before or after collision?	before	after
time / s	0.1233	0.1645	time / s	0.1052	0.2123
v / m s^{-1}	0.811	−0.608	v / m s^{-1}	−0.951	0.471
p / kg m s^{-1}	0.649	−0.486	p / kg m s^{-1}	−0.761	0.377

(i) All the values of time are positive but some values of velocity and momentum are positive and some are negative. Explain this difference.

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.... **[1]**

(ii) Carol says, "These results seem to contradict the law of conservation of momentum." Evaluate this comment.

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.... **[3]**

(iii) Show that kinetic energy is **definitely** not conserved in this collision and suggest why this is the case.

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.... **[2]**

(c)* After a few trials of this method, Jason says, “I think the results we are getting here are too variable. We need to set this up in a way that lets us have the same initial velocities each time, so that we can get repeat readings to give better estimates of energy and momentum and their uncertainties. I think our timing method could be improved, too.”

Evaluate Jason’s comments and suggest ways in which Jason’s concerns could be addressed in order to obtain more accurate results in this investigation of conservation of momentum and energy.

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.... **[6]**

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).