



Oxford Cambridge and RSA

# AS Level Physics B (Advancing Physics)

## H157/02 Physics in depth

### Thursday 9 June 2016 – 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	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="width: 20px; height: 20px;"></td> <td style="width: 20px; height: 20px;"></td> <td style="width: 20px; height: 20px;"></td> <td style="width: 20px; height: 20px;"></td> <td style="width: 20px; height: 20px;"></td> </tr> </table>					
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### 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 This question is about an image in the digital camera built into a mobile phone. When recording an image of a distant object, the lens is 4.0 mm from the light sensitive CCD detector.

(a) Show that the power of the lens is 250 D.

[1]

(b) The camera is now focused on an object, a printed page placed 24 cm from the camera lens.

(i) Show that the lens needs to move less than 0.1 mm from its original position, 4.0 mm from the CCD detector, to give a sharp image of the object page.

[3]

(ii) Explain why a letter 3 mm long on the object page, 24 cm from the lens, will result in an image on the CCD detector which is about 0.05 mm long.

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..... [2]

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(iii) The 5 megapixel CCD detector in the camera is shown in Fig. 1.

Calculate the distance in mm on the object page corresponding to 1 pixel on the detector.

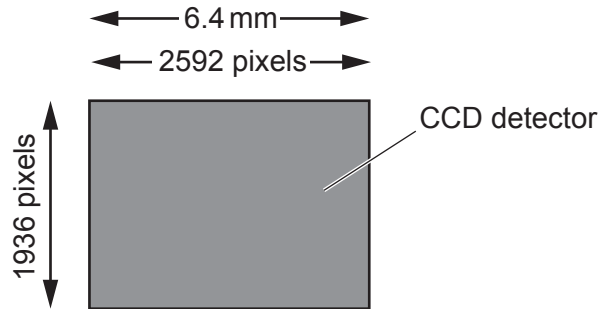


Fig. 1

distance on object page = ..... mm [2]

(iv) Here is an equation printed on the object page:

$$b = \log_2 \left( \frac{V_{\text{total}}}{V_{\text{noise}}} \right).$$

It is the same size on this examination paper as it is on the object page.  
 State and explain whether the equation would be sufficiently resolved on the image of the object page to be certain that the log is to the base 2 ( $\log_2$ ) and not to the base 10 ( $\log_{10}$ ).

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..... [2]

2 This question is about microwaves.

A source of microwaves is placed on a table at a fixed distance from a detector. A vertical reflecting plate is placed a distance  $y$  from the source and detector. Fig. 2 shows the **view from above**.

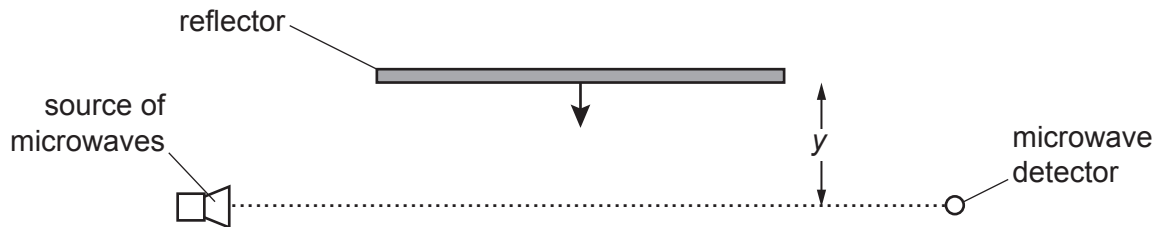


Fig. 2

- (a) When the reflector is first put in position, it is observed that the microwave intensity recorded by the detector **decreases**.

Explain this observation.

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..... [2]

- (b) The reflector is now moved gradually towards the source and detector, in the direction shown by the arrow on the reflector in Fig. 2.

At  $y_1$ , the detector reading falls to a minimum value.

At  $y_2$ , the detector reading is a maximum.

At  $y_3$ , the detector reading is a minimum again.

Explain these observations in terms of phase differences and path differences.

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..... [3]

5

- (c) Describe and explain how the observations in this experiment, as the reflector is moved from  $y_1$  to  $y_3$ , would be different if the experiment had used a source of microwaves with **half** the original wavelength.

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..... [2]

3 This question is about sensor circuits.

Fig. 3.1 shows a circuit which can be used as a simple light meter. The light-dependent resistor **X** has a resistance  $R_x$  which decreases when it is more brightly lit.  $R_x$  varies with light intensity as shown in Fig. 3.2.

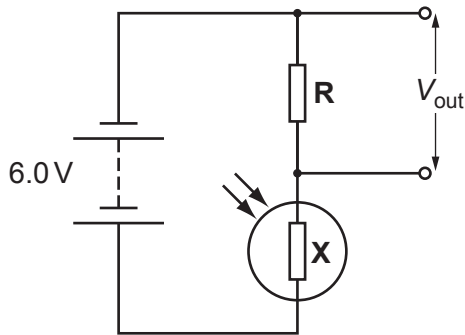


Fig. 3.1

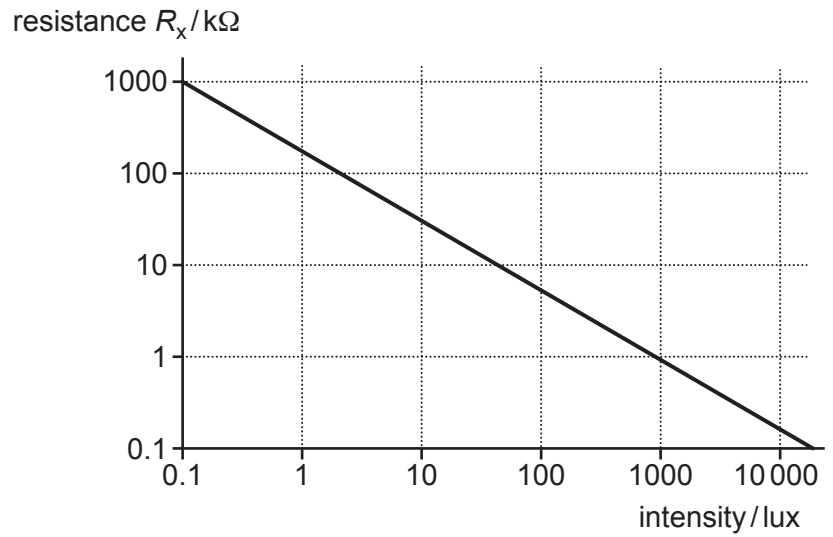


Fig. 3.2

(a) Fig. 3.2 is classified as a log-log graph because each scale division along both axes is a fixed factor larger than the preceding one (in this case, ten times).

Suggest **one** advantage and **one** disadvantage of displaying data on this type of graph.

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..... [2]

7

- (b) The table below shows typical values of light intensity in different situations. The SI unit of intensity is the lux.

Situation	night sky with full moon	home lighting	office lighting	full daylight
Intensity / lux	1	100	500	10 000

Use the data given to choose an appropriate value of resistance  $R$  of the fixed resistor **R** to use in a circuit to measure the light intensity in homes and offices.

Explain your reasoning clearly.

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resistance = .....  $\Omega$  [3]

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## SECTION B

Answer **both** questions.

- 4 This question is about white light-emitting diode (LED) lamps (Fig. 4.1).

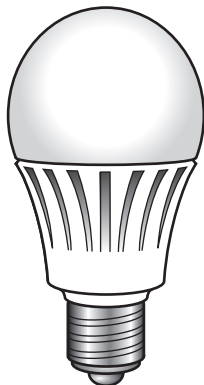


Fig. 4.1

Most white LED lamps consist of two components: a blue LED and a phosphor (a chemical which absorbs blue light and emits light of a range of colours). The phosphor absorbs most of the blue light but does transmit some.

- (a) The phosphor absorbs one blue photon for each photon that it emits.  
Explain why the light emitted by the phosphor **cannot** have a wavelength smaller than that of the blue light.

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 ..... [2]

- (b) The spectrum of light from the lamp is analysed using a diffraction grating. The observed first-order spectrum has a sharp and intense maximum at  $32^\circ$  and a broad, less intense maximum between  $35^\circ$  and  $50^\circ$ .

- (i) The diffraction grating used had  $1100 \text{ lines mm}^{-1}$ .  
Show that this corresponds to a grating spacing of about  $9 \times 10^{-7} \text{ m}$ .

[1]

- (ii) Calculate the wavelength in nm of the light giving a first-order maximum at  $32^\circ$ .

wavelength = ..... nm [2]



(iii) Sketch the observed spectrum on the axes in Fig. 4.2.

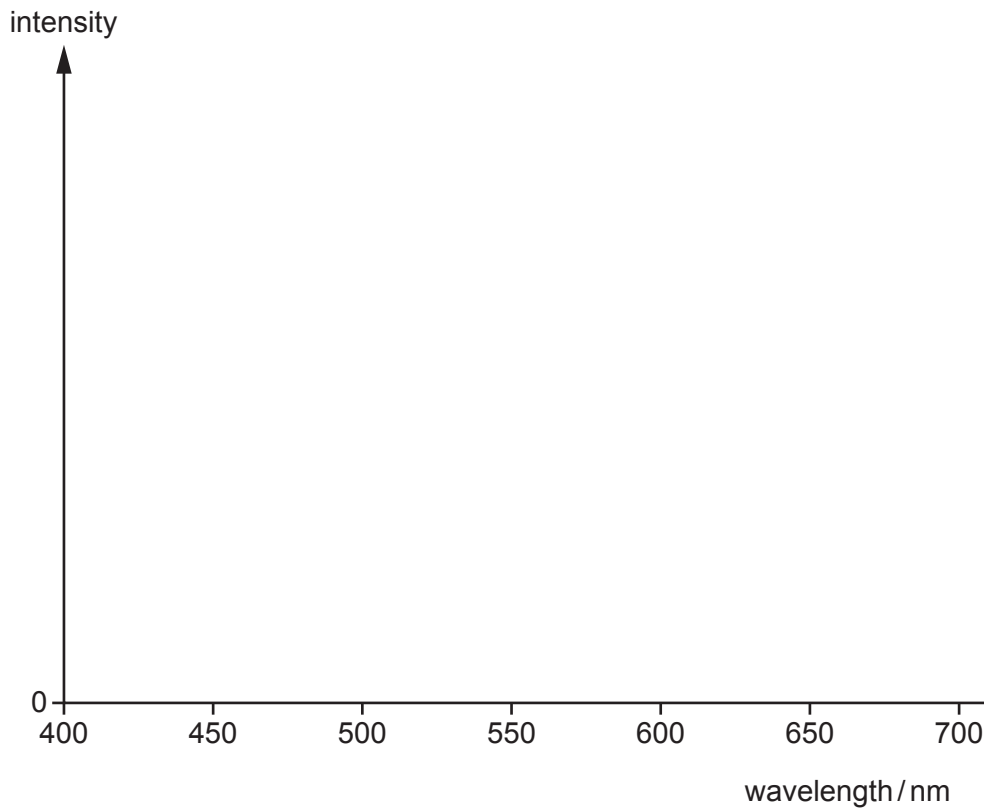


Fig. 4.2

[2]

(c) (i) Each photon of blue light emitted by the LED is produced by an electron making a transition between two energy levels.  
Calculate the energy difference between the two levels.

energy difference = .....J [2]

(ii) Each photon of light emitted by the phosphor is also produced by an electron making a transition between two energy levels.

State and explain **one** way in which the energy levels in the phosphor must be different from those in the blue LED.

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..... [2]

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- (d) Compact fluorescent lamps (CFLs) are energy efficient but they contain toxic mercury. White light LEDs are now rapidly replacing CFLs in many applications.

The lumen is the SI unit used in measurements of the total light energy per second, averaged over all directions, emitted by a lamp. The brightness of the lamp is usually quoted as the output in lumens per watt of electrical power input. Two lamps are compared in the table below.

Lamp type	Brightness /lumen $W^{-1}$	Power rating /W	Price of lamp	Lifetime /hours
CFL	50	15	£3.50	10 000
LED	80	10	£6.50	30 000

(Data from April 2015)

Use these data to discuss which type of lamp would be most suitable for use in the home.

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..... [4]

5 This question is about archery.

The bow, originally a weapon, is now used for sport. An early bow consisted of a single, straight piece of wood about 2.0 m long. When the bowstring is attached to the ends of the bow it bends the wood into an arc (Fig. 5.1).



Fig. 5.1

- (a) An archer pulls back the bowstring a distance of 71 cm with a force that increases as he pulls. The maximum force is 84 N.
- (i) Assume that the force is directly proportional to the distance the string is pulled back. Calculate the work done.

work done = ..... J [2]

- (ii) The arrow, of mass 26 g, leaves the bow at  $45 \text{ m s}^{-1}$ . Calculate its kinetic energy, and explain any difference between this value and the answer to part (a)(i).

kinetic energy = ..... J

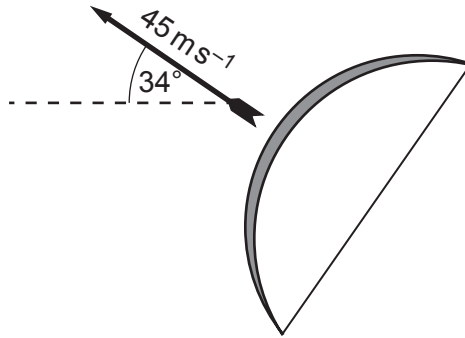
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- (b) The arrow leaves the bow at an angle of  $34^\circ$  to the horizontal, as shown in **Fig. 5.2**. The arrow strikes a target that is exactly level with the height at which it left the bow.



**Fig. 5.2**

- (i) Show that the arrow takes about 5 s to reach the target. Ignore any effect of the air.

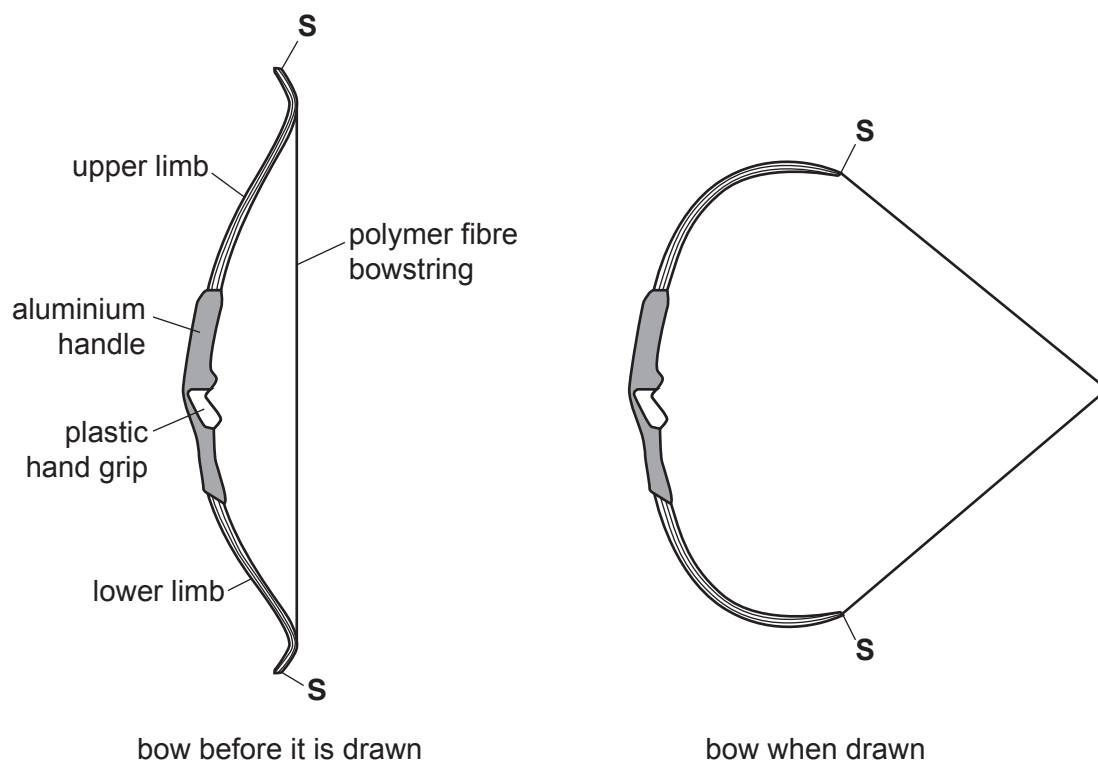
[3]

- (ii) Calculate the distance from the archer to the target.

distance = ..... m [2]

(c)\* For many centuries, traditional British bows were straight pieces of yew wood which were bent and strung with bowstrings made from linen. Environmental conditions, such as moistness, affect both of these natural materials, particularly the linen bowstring.

One design of a modern competition bow consists of three parts: a central handle, an upper limb and a lower limb. The upper and lower limbs are composite materials constructed of layers of wood and carbon-fibre reinforced plastic. The bow is constructed so that the two tips bend forward when the string is attached, as shown in Fig. 5.3A, and bend backwards when the bow is drawn as in Fig. 5.3B. The bowstring is a polymer fibre attached to the bow limbs at the points marked **S**.



**Fig. 5.3A**

**Fig. 5.3B**

In competition archery accuracy, range and consistency are vital. Discuss the advantages of this design of bow over the traditional yew bow (Fig. 5.1) for competition archery.

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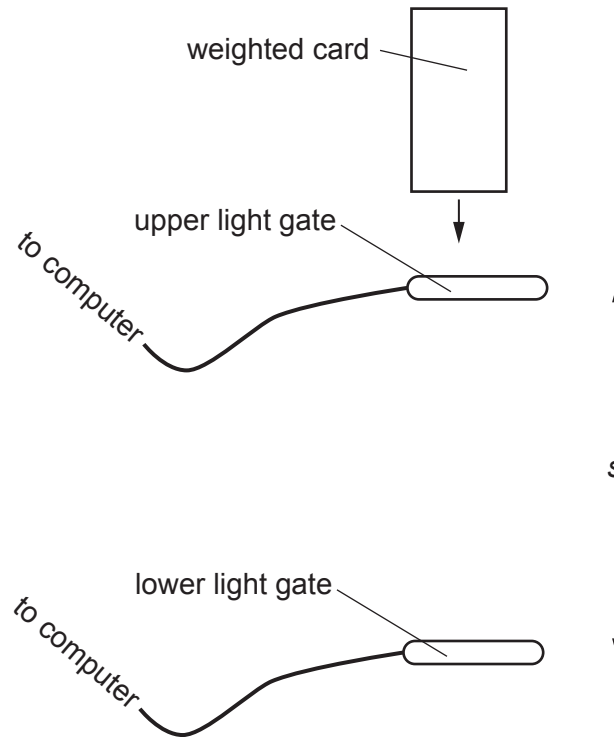
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**[6]**

## SECTION C

Answer **all parts** of this question.

- 6 This question is about an experiment performed in AS physics to determine the acceleration due to gravity,  $g$ . Two students have chosen to do this experiment in different ways. Anna is using a pair of light gates, each of which can time an object passing through it. Her set-up is shown in Fig. 6.1.



**Fig. 6.1**

As the weighted card falls, it interrupts the beam in each light gate. The computer records the time for which each beam has been interrupted and uses these times to calculate the mean speed of the card passing through each beam.

Anna drops the card from the same position each time.

She repeats this five times for a value of  $s = 0.24$  m, and gets the results shown in Table 6.2.

Trial number	1	2	3	4	5
speed at upper light gate, $u/\text{m s}^{-1}$	1.40	1.44	1.36	1.41	1.38
speed at lower light gate, $v/\text{m s}^{-1}$	2.61	2.64	2.58	2.62	2.60

**Table 6.2**

- (a) Anna correctly records the values of  $u$  and  $v$  and their uncertainties for  $s = 0.24$  m as follows.

$s/\text{m}$	$u/\text{m s}^{-1}$	$v/\text{m s}^{-1}$
0.24	$1.40 \pm 0.04$	$2.61 \pm 0.03$

**Table 6.3**

Explain how Anna obtained the values for  $u$  and its uncertainty, and how she decided on the number of significant figures to use.

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..... [3]

- (b) Anna repeats the experiment for different values of  $s$ . She intends to plot a graph of  $v^2 - u^2$  ( $y$ -axis) against  $s$  ( $x$ -axis).

Explain why this should result in a straight line through the origin with gradient  $2g$ .

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..... [2]

- (c) When  $s = 0.24$  m, the mean value of  $v^2 - u^2 = 4.9 \text{ m}^2 \text{ s}^{-2}$ .

- (i) Use the data from **Table 6.3** to show that the uncertainty in  $v^2 - u^2$  is  $0.3 \text{ m}^2 \text{ s}^{-2}$  when  $s = 0.24$  m.

[2]

- (ii) Anna decides to use this value of uncertainty for each uncertainty bar in her graph of  $v^2 - u^2$  against  $s$ .

Suggest why this may not be accurate when  $s$  is much greater than 0.24 m.

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..... [2]

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- (d) Anna repeats her measurements for five further values of  $s$  and plots the graph of Fig. 6.4. Draw suitable lines on the graph and use them to determine the value for  $g$ , the acceleration due to gravity, including its uncertainty.

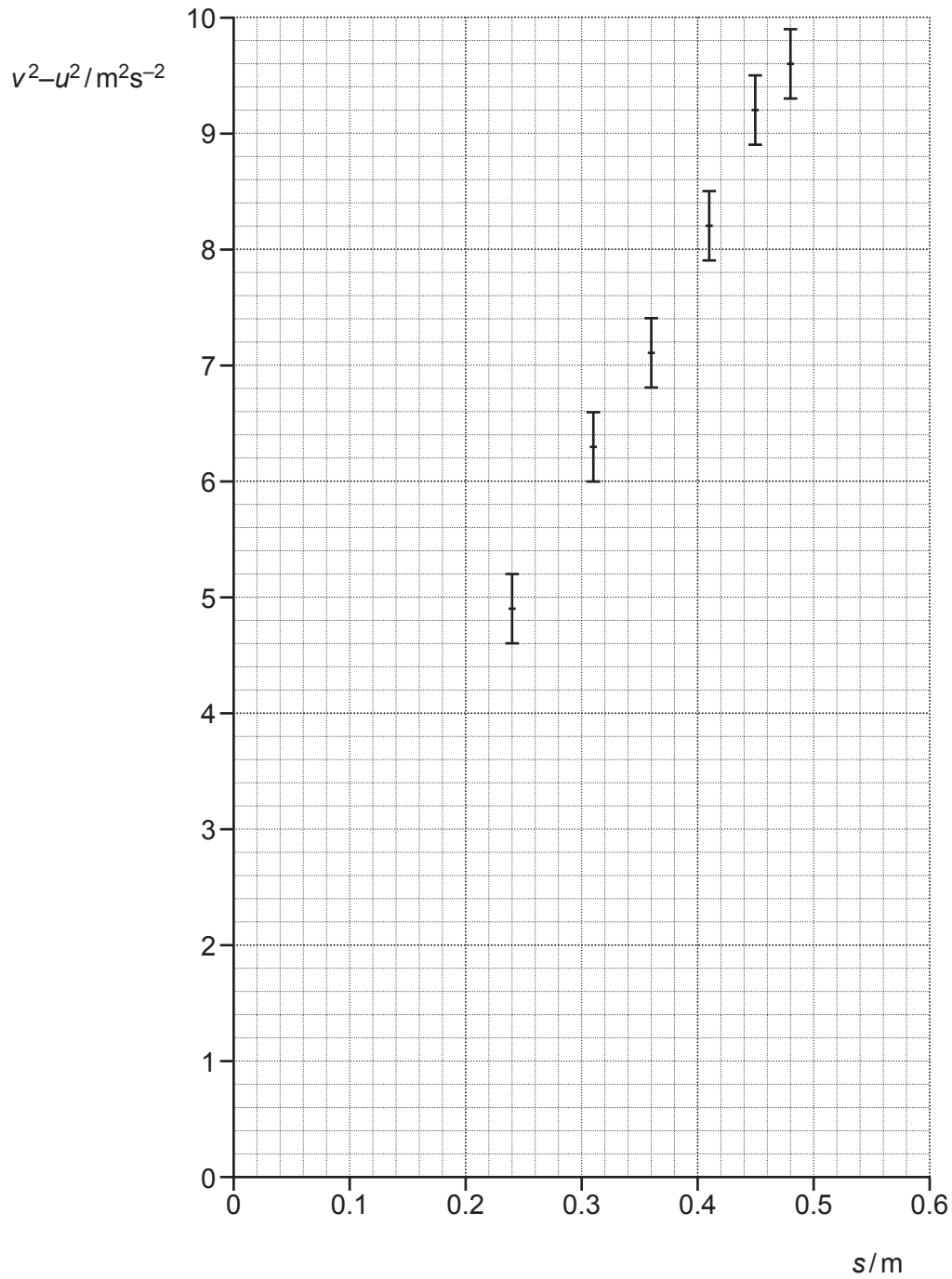


Fig. 6.4

$g = \dots \pm \dots \text{ms}^{-2}$  [3]



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(e)\* Simon chose to find the acceleration due to gravity by using a tablet computer to record a video of a golf ball falling against a dark background. The dark background had parallel horizontal white lines 0.10m apart marked on it. The computer produced the time-lapse image shown in Fig. 6.5. Images of the falling ball were recorded 30 times per second, and are superimposed on the same image.

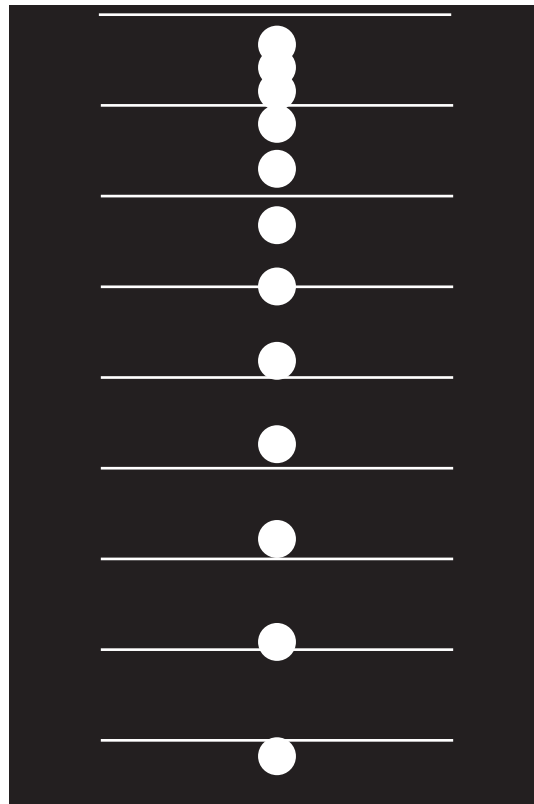


Fig. 6.5

Explain how Simon could use the image to obtain a value for  $g$  and discuss how you would expect it to compare with Anna's method. You are not expected to do any calculations based on measurements from Fig. 6.5. [6]

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**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.

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