



**ADVANCED SUBSIDIARY GCE
PHYSICS B (ADVANCING PHYSICS)**

G492

Unit G492: Understanding Processes /
Experimentation and Data Handling

Candidates answer on the Question Paper

OCR Supplied Materials:

- Insert (Advance Notice Article for this question paper) (inserted)
- Data, Formulae and Relationships Booklet

Other Materials Required:

- Electronic calculator
- Ruler (cm / mm)

**Wednesday 9 June 2010
Morning**

Duration: 2 hours



Candidate Forename		Candidate Surname	
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Centre Number						Candidate Number				
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INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided. Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [] at the end of each question or part question.
- The total number of marks for this paper is **100**.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- The values of standard physical constants are given in the Data, Formulae and Relationships Booklet. Any additional data required are given in the appropriate question.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.
This means, for example, you should
 - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
 - organise information clearly and coherently, using specialist vocabulary when appropriate.
- The questions in Section C are based on the material in the Insert.
- This document consists of **24** pages. Any blank pages are indicated.

Answer **all** the questions.

Section A

1 Here is a list of units.

J s⁻¹

N kg⁻¹

J m⁻¹

N m

J s

Choose the correct unit for

(a) power

..... [1]

(b) acceleration.

..... [1]

2

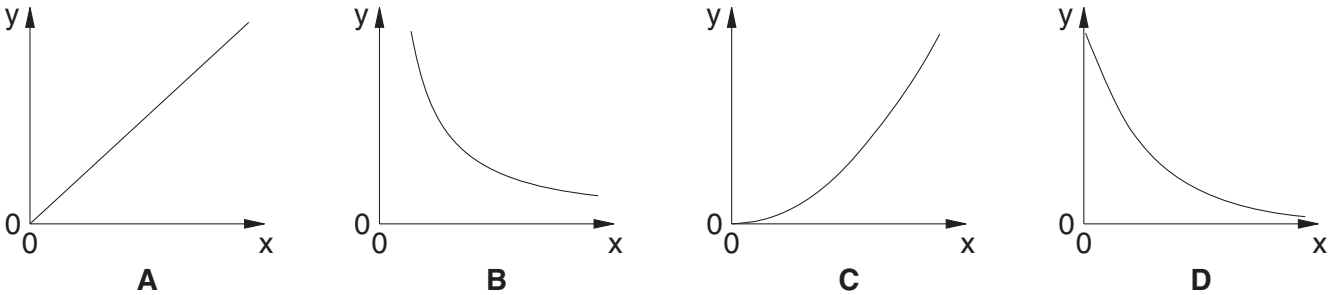


Fig 2.1

Which graph, **A**, **B**, **C** or **D** in Fig. 2.1, is obtained when the y and x axes represent the two quantities given in each case below?

(a) y-axis: the potential energy gained when an object is lifted
x-axis: the vertical height through which it is lifted

..... [1]

(b) y-axis: the kinetic energy of a moving object
x-axis: the speed of the object

..... [1]

(c) y-axis: the energy of a photon of electromagnetic radiation
x-axis: the wavelength of the radiation

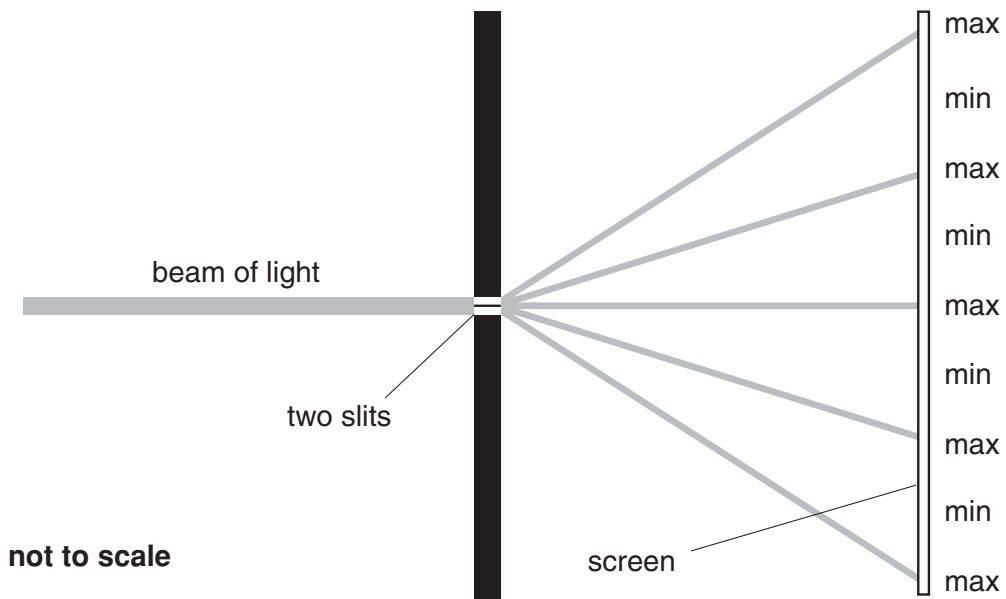
..... [1]

3

- 3 X-rays have a wavelength of 1.8×10^{-10} m.
Calculate the energy of one X-ray photon.
 $c = 3.0 \times 10^8 \text{ m s}^{-1}$
 $h = 6.6 \times 10^{-34} \text{ J s}$

energy = J [3]

- 4 When a beam of light is incident on two slits, an interference pattern is seen on a screen.



Here are some statements about what happens at the screen.

Put a tick (✓) next to **each** correct statement.

A minimum occurs where photons have passed through only one slit.

A maximum occurs where phasors for each path line up.

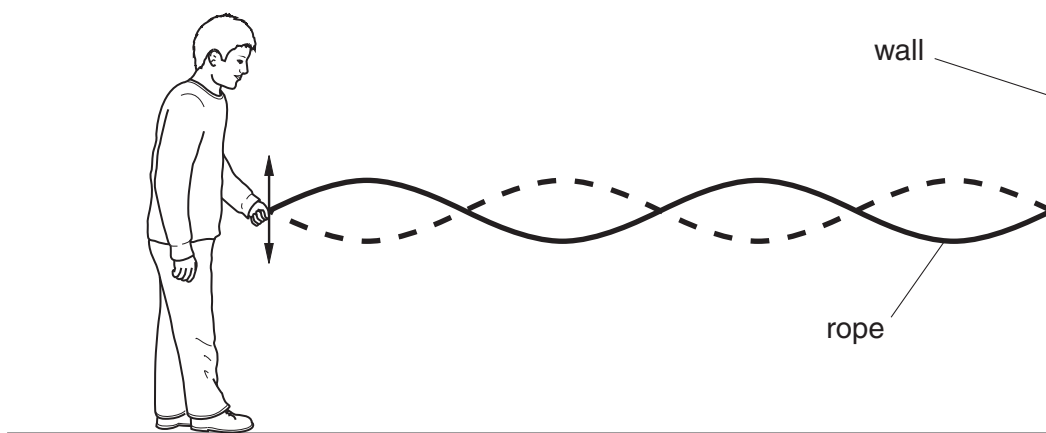
Slits closer together would give a bigger separation of maxima and minima.

The photons arrive at the screen at a rate proportional to the resultant phasor amplitude.

[2]

- 5 Phil creates standing waves on a rope by shaking one end of it vertically.

The other end of the rope is fixed to a wall.



- (a) Write the letter **A** on the diagram at the position of one **antinode**. [1]
- (b) The distance from Phil's hand to the wall is 2.4 m.
Phil is shaking the rope end with a time period of 0.4 s.
Calculate the wavelength and frequency of the waves travelling along the rope.

wavelength $\lambda =$ m

frequency $f =$ Hz
[2]

6 A high-performance car has an acceleration of $0.86g$.

(a) Calculate the time it takes to reach a velocity of 27 m s^{-1} ($60 \text{ miles hour}^{-1}$).

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

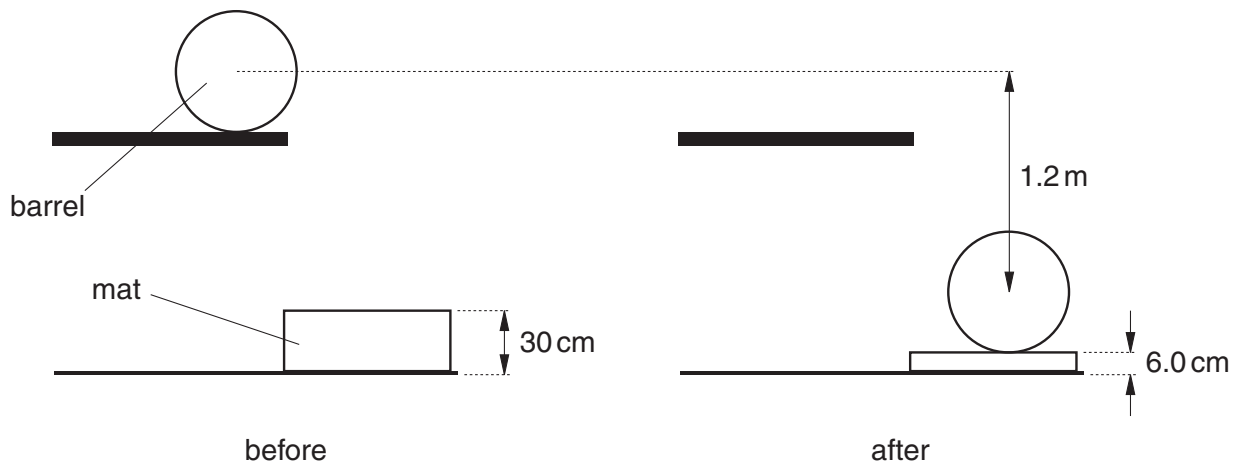
time = s [2]

(b) The car can brake from 27 m s^{-1} to rest in a distance of 35 m .
Calculate the mean force exerted by the brakes.

$$\text{mass of car} = 1600 \text{ kg}$$

mean force = N [2]

- 7 When heavy barrels are unloaded off a lorry, they are dropped onto a thick mat to stop them breaking open when hitting the ground.
The mat compresses from a thickness of 30 cm to a thickness of 6.0 cm.
This decelerates the barrel.



- (a) Show that the work that must be done to decelerate a barrel to rest after it has fallen 1.2 m is about 1.3 kJ.

$$\text{mass of barrel} = 110 \text{ kg}$$

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

[2]

- (b) Calculate the mean force exerted by the mat to decelerate the barrel to rest.

Assume that no energy is lost before the barrel hits the mat.

mean force = N [2]

[Section A Total: 21]

Section B

- 8 This question is about forces on a helium party balloon.
A helium balloon rising in the air has more than one force acting on it.

Besides weight, there is upthrust.

The upthrust is equal in magnitude to the weight of the air which would have occupied the volume taken up by the balloon.

When the balloon is moving there is also air resistance.

- (a) Fig. 8.1 shows a helium party balloon.

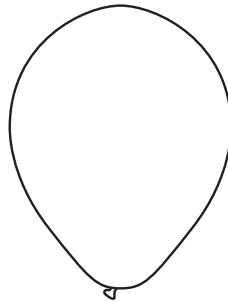


Fig. 8.1

On Fig. 8.1, draw three arrows, labelled **W**, **U** and **AR**, to show the directions of the weight, the upthrust and the air resistance acting on this balloon **as it rises through the air**. [1]

- (b) The balloon is released at time $t = 0$.

- (i) Explain why the air resistance force **AR** is zero at time $t = 0$.

[1]

- (ii) Use the data below to show that the resultant force acting on the balloon at time $t = 0$ is about 0.02 N. Show your working clearly.

mass of rubber and helium = 0.0035 kg
mass of air taking up the same volume = 0.0060 kg
 $g = 9.8 \text{ m s}^{-2}$

[2]

- (c) Air resistance forces increase as the balloon accelerates.

In a mathematical model to analyse the motion of the balloon, the air resistance force F_{AR} is given by

$$F_{\text{AR}} = kv$$

where v is the velocity of the balloon and k is a constant.

- (i) Suggest and explain one change to the balloon which would make the value of k **smaller**.



In your answer you should use technical terms, spelled correctly.

[2]

Using the mathematical model $F_{\text{AR}} = kv$ with one particular value of k gives the graph in Fig. 8.2.

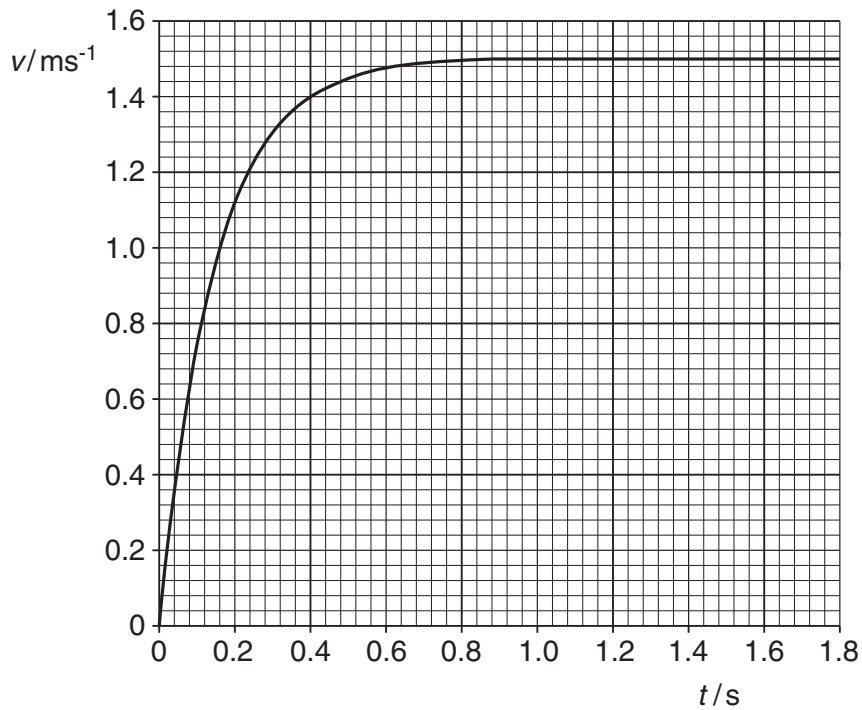


Fig. 8.2

- (ii) Explain why the graph becomes less steep, and eventually horizontal, as time increases.

[2]

- (iii) Fig. 8.2 shows that the velocity reaches a maximum of 1.5 ms^{-1} . Show that this is consistent with a value of $k = 0.016 \text{ N s m}^{-1}$.

[2]

[Total: 10]

- 9 This question is about the colours seen in light reflected from DVDs. The surface of a DVD contains a regular array of closely spaced tracks which acts like a reflection diffraction grating. The first order of diffraction is at the same angle θ for a reflection grating and a transmission grating with the same grating spacing, as shown in Fig. 9.1.

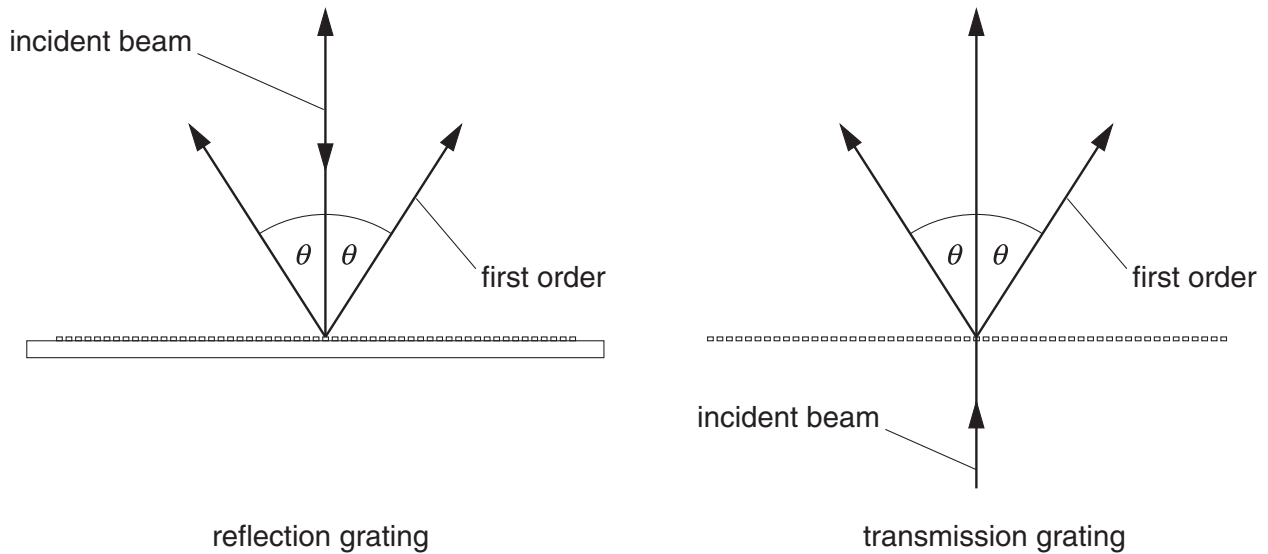


Fig. 9.1

The similarity shown in Fig. 9.1 means that the equation $n\lambda = d \sin \theta$ can be used for a reflection grating as well as for a transmission grating.

- (a) The distance between tracks (the grating spacing) on a DVD is 1.3×10^{-6} m.
- (i) Show that the angle θ is about 30° for the first order of incident red light of wavelength 700 nm.
- [2]
- (ii) Without calculation, state and explain the difference you would observe when the red light is incident on a CD where the distance between tracks is slightly larger than on a DVD.

- (b) (i) Calculate the wavelength of light which gives a second-order ($n = 2$) angle of 90° when reflected from the DVD.

wavelength $\lambda = \dots\dots\dots$ m [2]

- (ii) Explain why there is no second-order for light of wavelength 700 nm.

[2]

- (c) The DVD reflection grating is now illuminated with white light containing **all** wavelengths between 400 nm and 700 nm.

For red light of wavelength 700 nm there is only one order r_1 . However, for violet light of wavelength 400 nm, there are three orders v_1 , v_2 and v_3 .

These are shown in Fig. 9.2.

For clarity, orders are shown only on one side of the incident beam.

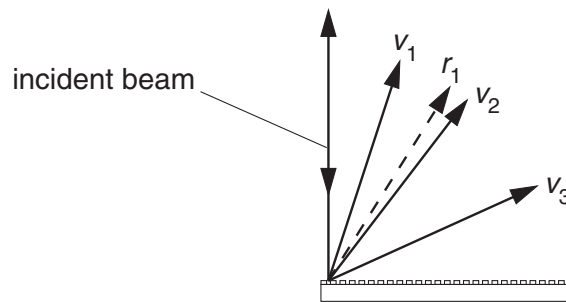


Fig. 9.2

Explain why no light is seen in the region between the angles of the first-order red r_1 and the second-order violet v_2 .

[2]

[Total: 10]

10 This question is about earthquake waves.

- (a) When earthquakes occur longitudinal P-waves and transverse S-waves spread out in all directions.
Explain clearly the difference between transverse and longitudinal waves.

[2]

- (b) Seismometers measure the displacement of the ground as a function of time, and record the results on graphs as shown in Fig. 10.1.

$t = 0$ is set at the time of arrival of the P-waves.

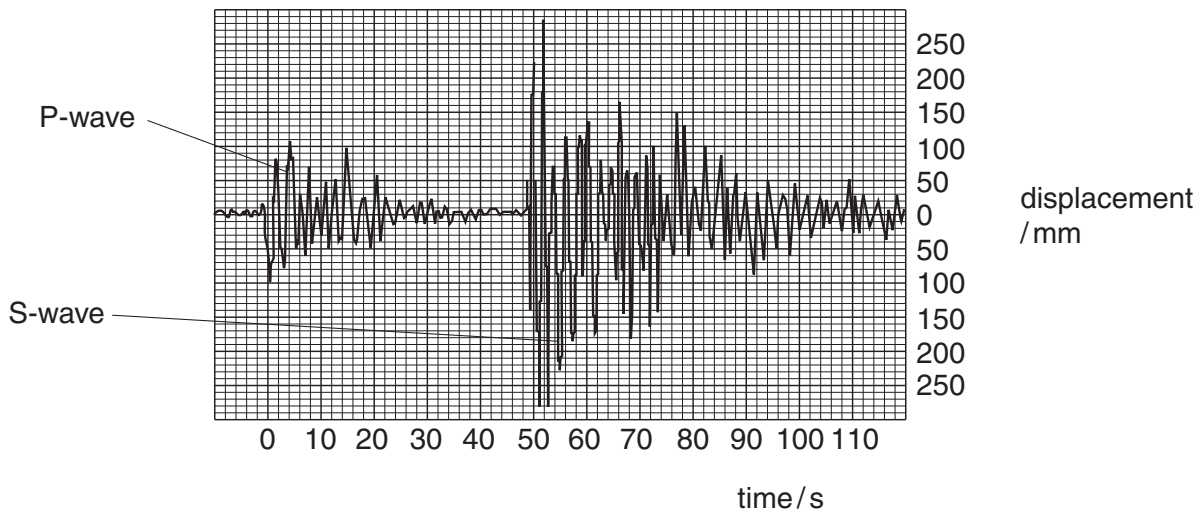


Fig. 10.1

- (i) Show that the time delay Δt between the arrival of P-waves and S-waves from an earthquake a distance D from the seismograph is given by

$$\Delta t = D \left(\frac{1}{v_S} - \frac{1}{v_P} \right) \text{ where } v_S \text{ and } v_P \text{ are the velocities of S-waves and P-waves respectively.}$$

[2]

(ii) Use data from Fig. 10.1 to calculate the distance D .

$$v_S = 3500 \text{ m s}^{-1}$$

$$v_P = 8000 \text{ m s}^{-1}$$

$$D = \dots\dots\dots \text{ m [3]}$$

(c) Given that the power delivered by a wave is proportional to (amplitude)², use data from Fig. 10.1 to calculate the ratio

$$\frac{\text{maximum power delivered by S-waves}}{\text{maximum power delivered by P-waves}}$$

[2]

(d) The Richter scale for measuring the magnitude M of earthquakes where they happen is given by the equation

$$M = \log(A) + (\text{factor depending on distance from earthquake})$$

where A is the maximum amplitude of the strongest waves received by the seismometer.

Suggest one advantage of having a logarithmic scale for earthquake magnitudes.

[1]

[Total: 10]

11 This question is about a sport called kitesurfing (Fig. 11.1).

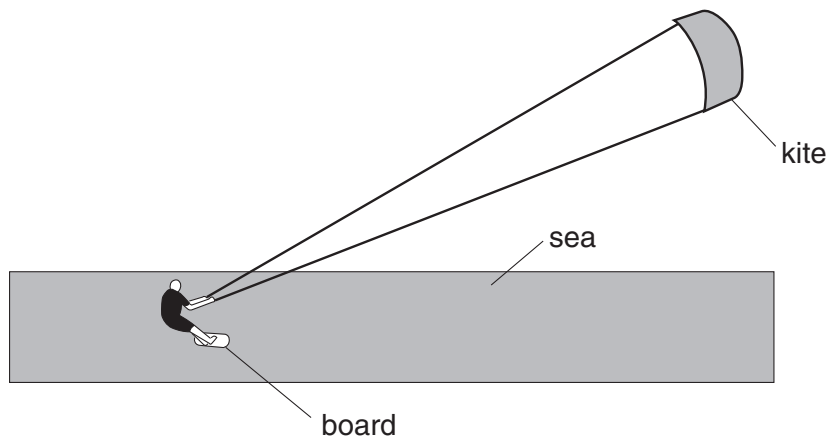


Fig. 11.1

The kitesurfer stands on the board, and is pulled along the surface of the sea by the lines attached to the kite.

The kitesurfer, lines and board are modelled in the diagram in Fig. 11.2.

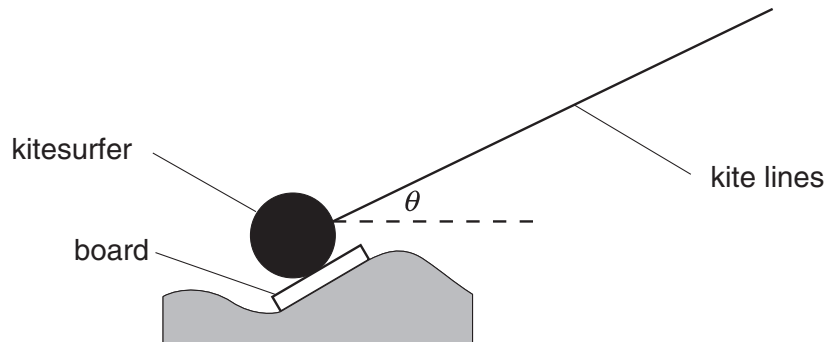


Fig. 11.2

- (a) The total tension in the kite lines is 1000 N.
By scale drawing or calculation, show that, when the angle $\theta = 30^\circ$, the horizontal force pulling the kitesurfer is about 900 N.

[3]

- (b) (i) Explain why the kitesurfer in this situation needs to have a mass of more than 51 kg. Your answer should refer to the components of forces.

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

[2]

- (ii) A kitesurfer usually takes a selection of kites of different sizes to the water. Suggest and explain the reason for this.

[2]

- (c) The kitesurfer is pulled along horizontally at a **steady speed** by the force described in part (a). State what this tells you about the forces between the board and the water. You should refer to components of forces in your answer.

[2]

[Total: 9]

[Section B Total: 39]

16
Section C

12 This question is based on the article *Uncertainty in a calculated result*.

Students in a class measured the force needed to break 29 samples of copper wire from the same reel.

Their results are shown in the chart in Fig. 12.1.

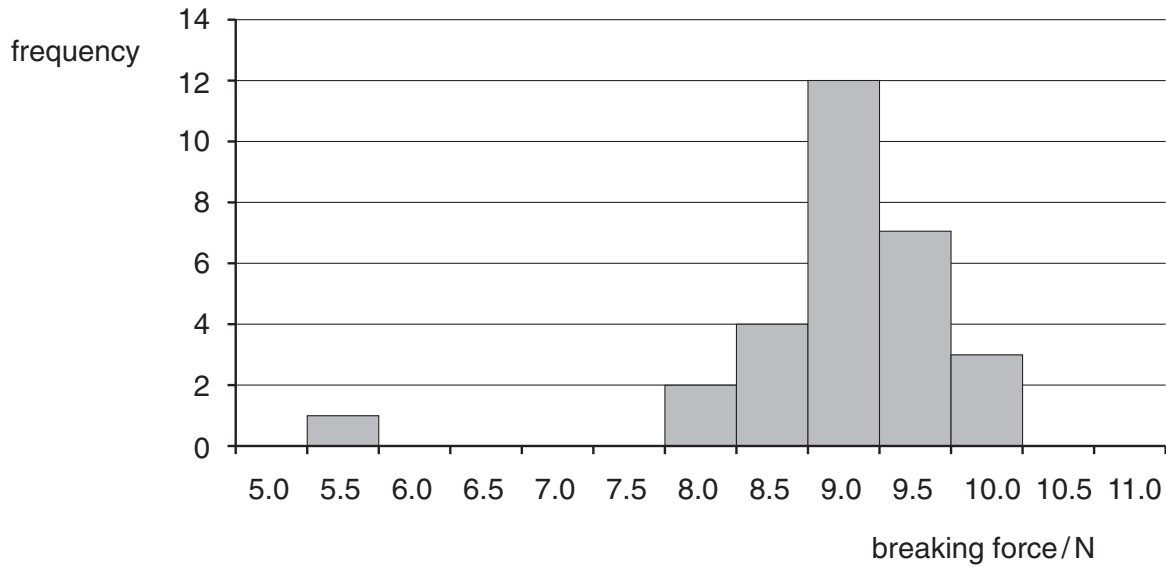


Fig. 12.1

(a) (i) Explain why the single value at 5.5 N needs to be considered to be a possible outlier.

[2]

(ii) Suggest what may have happened **to the wire** to give the much smaller breaking force of 5.5 N.

[1]

(b) A student calculates the mean value of the remaining 28 values as 9.089 286 N. Use the bar chart to write down the best estimate and uncertainty of the breaking force of the copper, using an appropriate number of significant figures.

breaking force = \pm N [2]

- (c) The diameter of the wire used is measured at several points along its length with a micrometer. The reading is 0.38 ± 0.005 mm each time.
- (i) Calculate the percentage uncertainty in the diameter measurement. Give your answer to an appropriate number of significant figures.

uncertainty = \pm % [2]

- (ii) Explain why the uncertainty in the diameter measurement can be ignored when calculating the breaking stress of copper.

[1]

- (d) Use the answer to (b) to calculate the mean breaking stress of copper and to estimate the uncertainty in this value.

cross-sectional area of copper wire = $1.1 \times 10^{-7} \text{ m}^2$

breaking stress = \pm Pa [3]

[Total: 11]

13 This question is based on the article *Water rockets*.

(a) The graph in Fig. 13.1 shows the way in which the mean height of the water rocket varies with time.

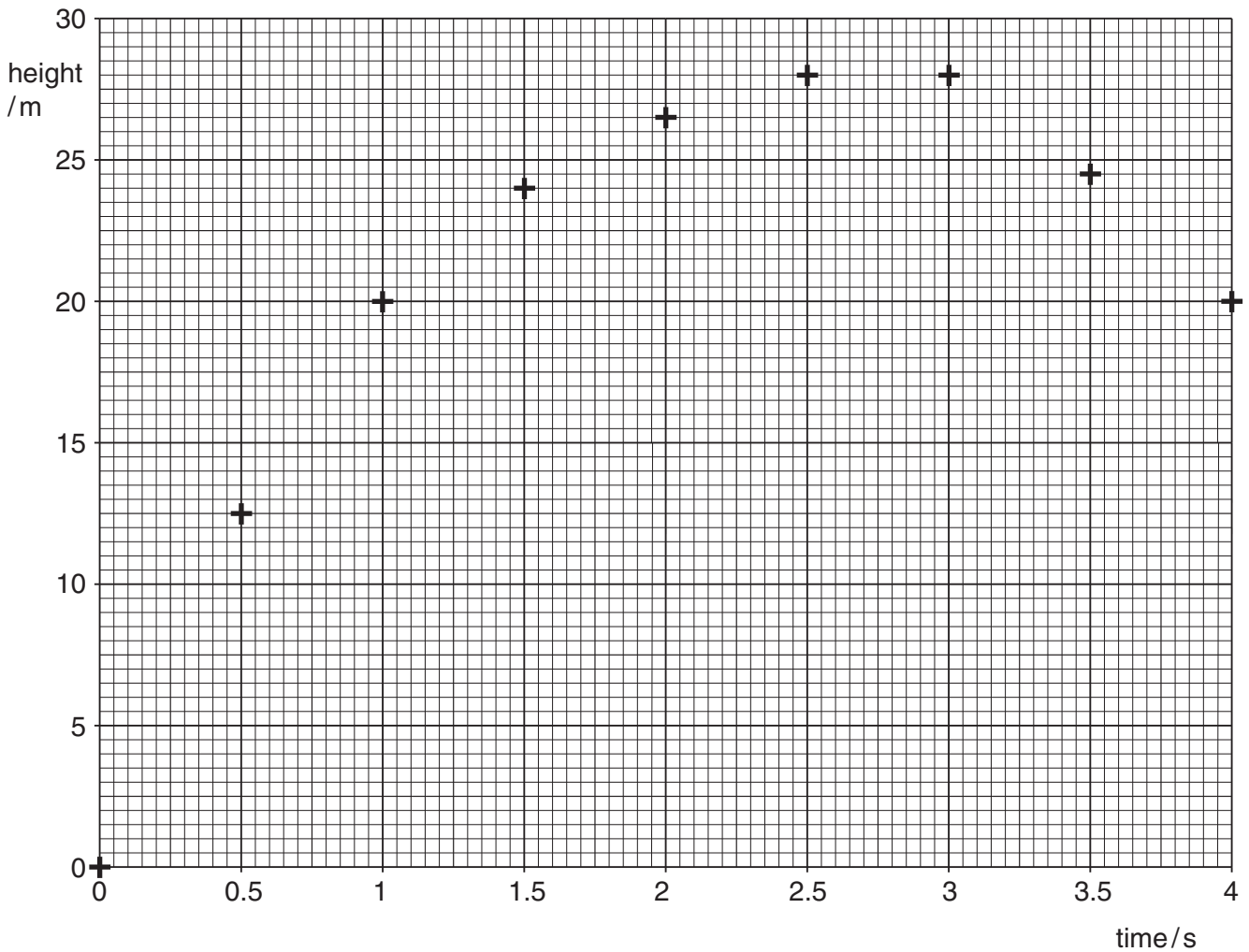


Fig. 13.1

(i) Draw a best-fit curve through the points and use the graph to obtain a value for the maximum height reached by the water rocket.

maximum height = m [1]

(ii) Use the graph to show that the initial velocity of the rocket is about 25 m s^{-1} .

[2]

- (iii) Explain how the graph shows that the rocket has an acceleration downwards for its entire flight.

[2]

- (b) (i) Use the equations for uniformly accelerated motion to show that a maximum height of about 30 m can be reached by an object projected vertically with an initial vertical velocity of 25 m s^{-1} .

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

[3]

- (ii) Suggest and explain one reason why the rocket did not reach the maximum height calculated in (b)(i).

[2]

(c) This question refers to the second set of results where the students' experiment was affected by a horizontal wind.

(i) Explain why the height reached by the water rocket was not affected by the wind.

[2]

(ii) Use data from the graph of Fig. 13.1 to estimate the speed of the wind which resulted in the rocket landing 37 m from its launch position.

[2]

[Total: 14]

21
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14 This question is based on the article *Robert Millikan and the Planck constant*.

(a) In his measurements, Millikan found the 'stopping p.d.' by extrapolating the current curves to zero current.

(i) Draw a best-fit curve to find the stopping p.d. for the data in the graph in Fig. 14.1, for sodium metal illuminated with light of wavelength 404.7 nm.

Use your value to complete the table underneath.

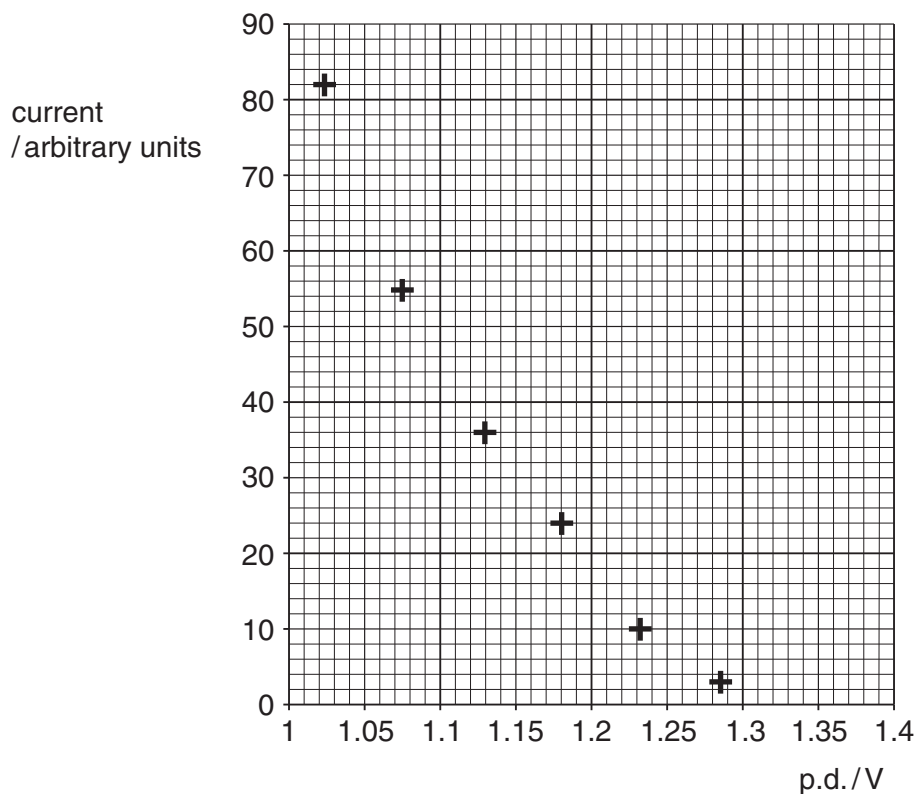


Fig. 14.1

wavelength, λ / nm	frequency, f / 10^{14} Hz	stopping p.d. / V
546.1	5.494	0.55
433.9	6.914	1.12
404.7	7.413	
365.0	8.219	1.68
312.6	9.597	2.22
253.5	11.834	3.12

[2]

- (ii) Use the table to complete the graph of Fig. 14.2 and determine the gradient of the best-fit straight line through the data. Show your working clearly.

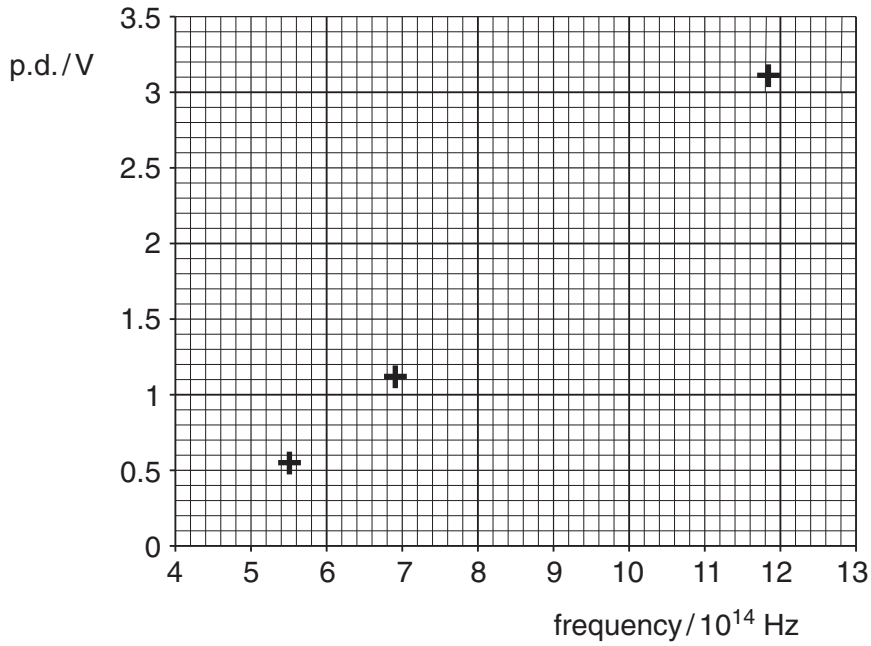


Fig. 14.2

gradient of best-fit line = V Hz⁻¹ [5]

- (iii) The gradient of the graph of Fig. 14.2 is $\frac{h}{e}$.
 Calculate the Planck constant, h .
 $e = 1.6 \times 10^{-19}$ C

$h =$ J s [1]

- (b) (i) Millikan's published value of the Planck constant was 6.57×10^{-34} J s with an uncertainty of $\pm 0.5\%$.

Calculate the maximum likely value of h using this information.

maximum $h =$ J s [2]

- (ii) The accepted value of the Planck constant, according to the National Physical Laboratory (1998), is $(6.626\ 068\ 8 \pm 0.000\ 000\ 5) \times 10^{-34}$ Js.

Compare this value with Millikan's, and suggest and explain one possible reason for any difference.



In your answer, you should make it clear which of the measurements that Millikan relied on might be at fault, and a possible reason for this.

[3]

- (c) Millikan's experimental work showed that Einstein's equation worked well, but he did not accept the quantum theory which inspired it.

Suggest two reasons why Millikan and other scientists of his time might have been reluctant to accept the new theory.

[2]

[Total: 15]

[Section C Total: 40]

END OF QUESTION PAPER

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**ADVANCED SUBSIDIARY GCE
PHYSICS B (ADVANCING PHYSICS)**

G492

Unit G492: Understanding Processes/
Experimentation and Data Handling

INSERT

**Wednesday 9 June 2010
Morning**

Duration: 2 hours



INSTRUCTION TO EXAMS OFFICER/INVIGILATOR

- Do not send this Insert for marking; it should be retained in the centre or destroyed.

INSTRUCTIONS TO CANDIDATES

- This insert contains the article required to answer the questions in Section C.

INFORMATION FOR CANDIDATES

- This document consists of **8** pages. Any blank pages are indicated.

1. Uncertainty in a calculated result

When thinking about the uncertainty in an experiment, you need to consider the uncertainty in every measurement. It is important to identify the most uncertain measurement, because this is the measurement which will be most worthwhile improving. Also, this uncertainty is the one which contributes most to the uncertainty of the final result. Fig. 1 shows a chart of repeated measurements of the breaking force of samples of the same cotton thread.

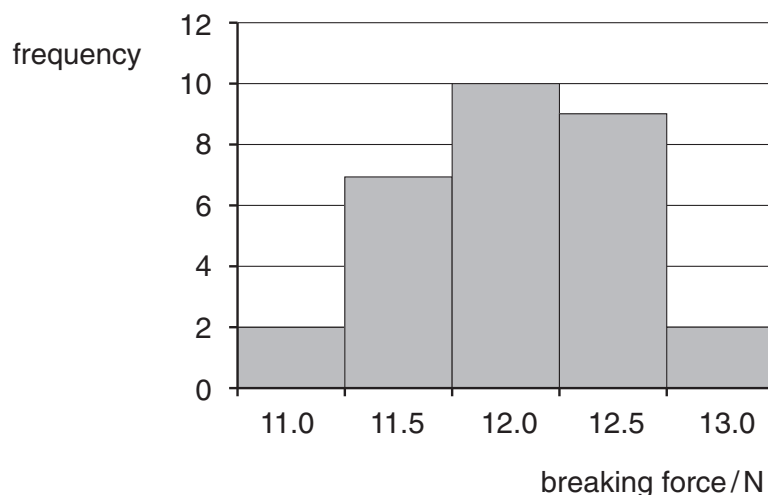


Fig. 1

There are no outliers in this data, and you can easily find the mean of the 30 measurements, which is 12.0 N. The spread (half the range) is 1 N, so the value is (12 ± 1) N, giving a percentage uncertainty of 8%.

Measuring the diameter of the same cotton thread with a micrometer shows that the diameter measurement is less variable than that of the breaking force, so you can get a minimum estimate of the variation in breaking stress from the variation in breaking force.

In this case, the diameter of the thread is 0.24 mm (2.4×10^{-4} m), giving a cross-sectional area of 4.5×10^{-8} m², so the breaking stress can be easily calculated for the maximum and minimum values of breaking force. This allows calculation of the mean breaking stress and also an estimate of its uncertainty.

2. Water rockets

The use of water rockets is a popular way to study force and motion in A-Level physics. This article describes an experiment carried out by students with a particular water rocket on the school playing fields. A plastic drinks bottle is used with a toy rocket kit that involves filling the bottle one-third to a half full with water (Fig. 2). This is then attached to a foot pump via a valve and tube. As air is pumped into the bottle the internal pressure increases. When the pressure inside the bottle exceeds the maximum capacity of the valve, the valve and tube are forced free and the rocket takes off.

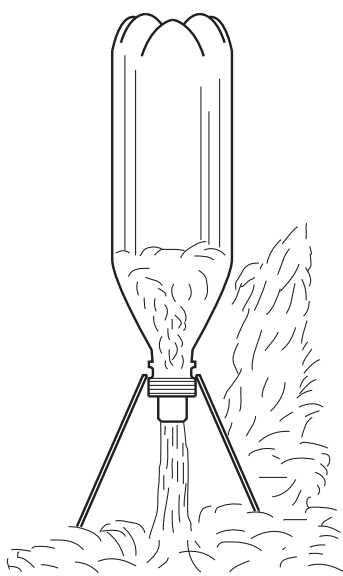


Fig. 2

Due to the internal pressure, the water is forced out in a downward direction. An equal and opposite force is exerted on the rocket which accelerates it upwards. The water is all released very quickly and the rocket continues upwards until it reaches its maximum height. From here it falls back to the ground.

The students found it very difficult to make measurements and eventually settled on using a digital video camera with a freeze-frame facility to measure the height of the rocket every 0.5 seconds.

The following table contains an average of several trials. In each case, the rocket was fired vertically into the air.

time /s	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00
height /m	0.0	12.4	19.9	24.2	26.4	28.1	27.9	24.4	20.0

The students carried out a second set of experiments later the same day, using exactly the same experimental arrangements. This time, however, there was a horizontal wind which affected the overall path of the water rocket. The rocket now travelled a mean distance of 37 m away from the original launch position, although the maximum height and time of flight were similar to the earlier experiments.

3. Robert Millikan and the Planck constant

Albert Einstein, in one of his great 1905 papers, showed that the kinetic energy of electrons emitted by the photoelectric effect is given by

$$\frac{1}{2}mv^2 = hf - \phi$$

where the work function ϕ is the minimum energy needed to remove the electron from the surface of the metal. The American physicist Robert Millikan was not convinced by this theory, and devised an elegant experiment to test it.

A simplified diagram of the apparatus Millikan constructed is shown in Fig. 3.

Pieces of the alkali metals sodium, lithium and potassium were mounted in an evacuated glass envelope on a support which could be rotated to permit experiments on the three metals separately. Light was incident on the metal being tested, causing the metal to emit electrons which then struck an electrode, forming part of a circuit.

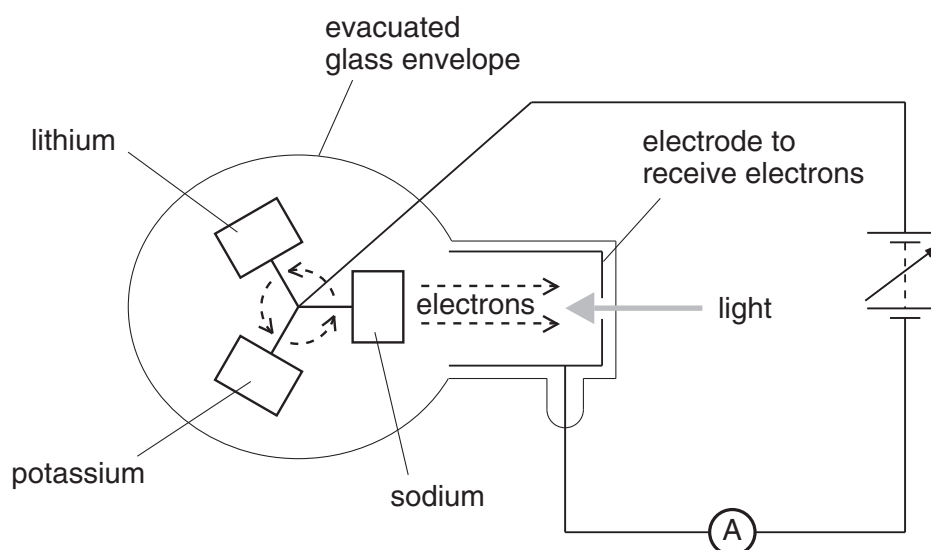


Fig. 3

The current in this circuit was measured as a varying voltage was applied to repel the electrons from the electrode. When the measured current was zero, the potential energy provided by the 'stopping p.d.' V was equal to the kinetic energy of the emerging photoelectrons, so that

$$eV = hf - \phi.$$

Millikan plotted working graphs for a number of different wavelengths of light. By extrapolating back to zero current, he found the stopping p.d. V in each case.

The graph of Fig. 4 shows his data for light of wavelength 546.1 nm, which he used to find the stopping p.d. of 0.55V.

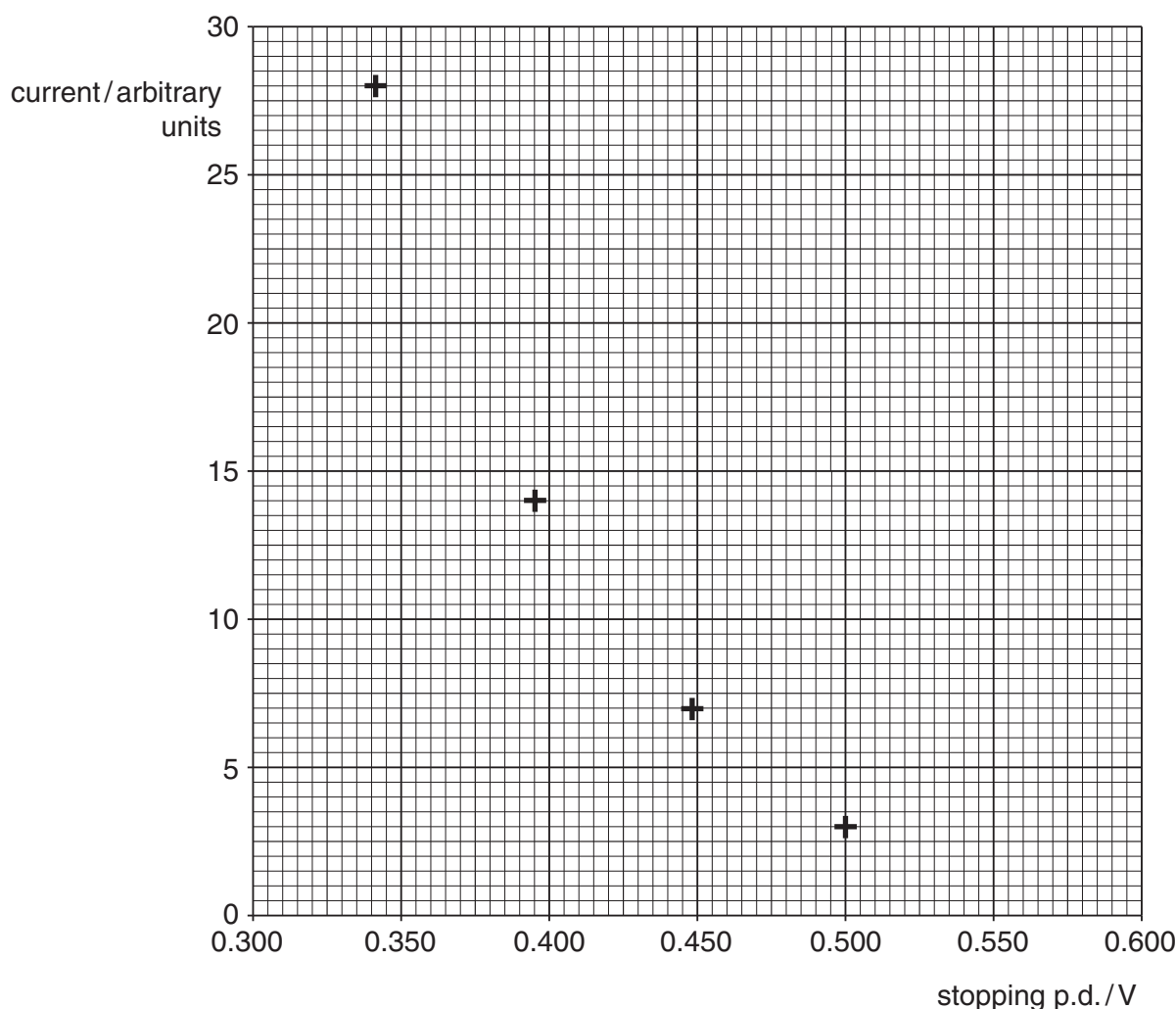


Fig. 4

He was then able to plot graphs of the stopping p.d. against the frequency of the light to check Einstein's equation.

One difficulty that Millikan had to overcome was that the stopping voltage as measured was not equal to the photoelectric p.d. produced by the effect of light striking the alkali metal. There was an extra p.d. involved, which is the contact p.d. between the alkali metal used and the copper conductor to which it was attached. These contact p.d.s were initially found to vary, but by careful preparation of the surfaces of the alkali metals, and the use of a good vacuum, Millikan managed to obtain constant contact p.d.s throughout his experiments. He knew that a constant extra p.d. in his readings would not affect his test of the equation

$$eV = hf - \phi$$

nor the calculation of the Planck constant h from the gradient of a graph of V against f .

Millikan's results were conclusive. They confirmed the Einstein equation, and obtained the most accurate measurements at the time of the Planck constant: 6.57×10^{-34} Js, for which Millikan estimated the uncertainty as $\pm 0.5\%$. However, Millikan was still not convinced about Einstein's theory of light particles (photons).

END OF ARTICLE

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