OXFORD CAMBRIDGE AND RSA EXAMINATIONS

ADVANCED SUBSIDIARY GCE

G492

PHYSICS B (ADVANCING PHYSICS)

Unit G492: Understanding Processes / Experimentation and Data Handling

ADVANCED NOTICE MATERIAL

May be opened and given to candidates upon receipt.

WEDNESDAY 9 JUNE 2010: Morning
DURATION: 2 hours

SUITABLE FOR VISUALLY IMPAIRED CANDIDATES

READ INSTRUCTIONS OVERLEAF

DC (NF/DJ) MEP60081 27508

INSTRUCTIONS TO CANDIDATES

- **Take the article away and read through it carefully. Spend some time looking up any technical terms or phrases you do not understand. You are NOT required to research further the particular topic described in part 3, although you might find it helpful to try out the measurement ideas described in part 2.**

- **For the examination on 9 June 2010 you will be given a fresh copy of this article, together with a question paper. You will not be able to take your original copy into the examination with you.**

- **The values of standard physical constants will be given in the Advancing Physics Data, Formulae and Relationships booklet. Any additional data required are given in the appropriate question.**

INFORMATION FOR CANDIDATES

- **Questions in Section C of paper G492 (Understanding Processes, Experimentation and Data Handling) will refer to this Advance Notice material and may give additional data related to it.**

- **Section C will be worth about 40 marks.**

- **Sections A and B of paper G492 will be worth about 60 marks, and will examine the *Understanding Processes* section of the specification.**

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.

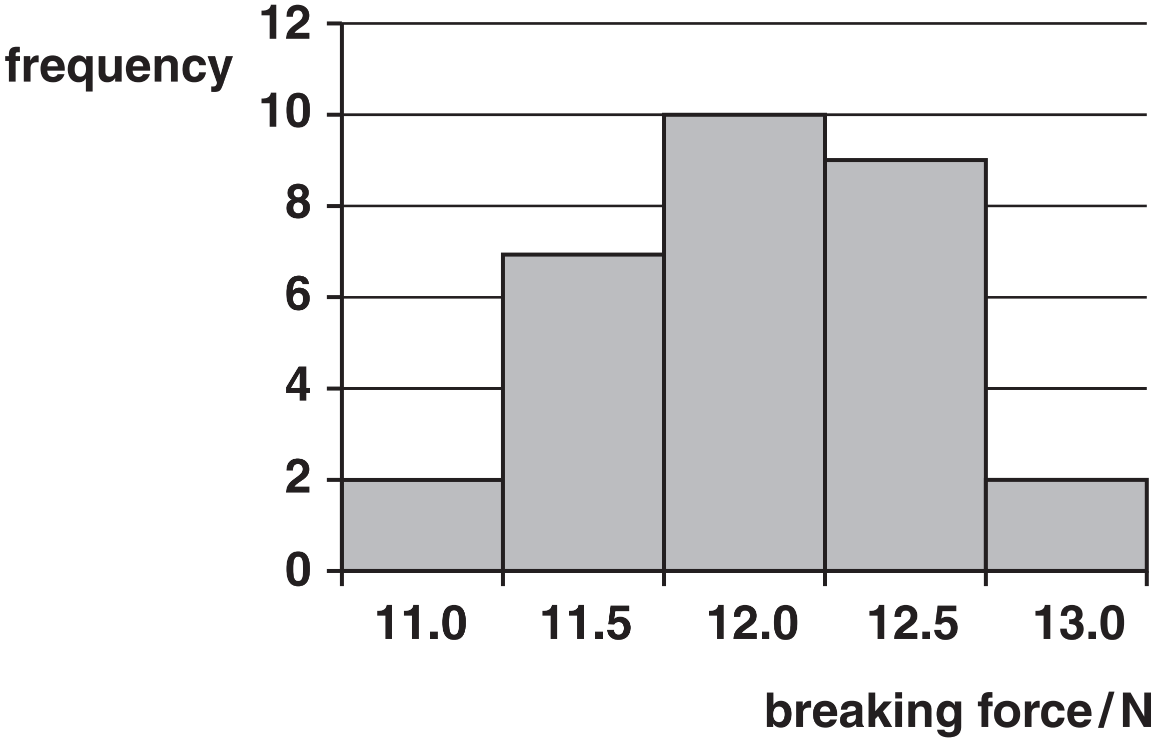

Fig. 1

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} m^2, 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.

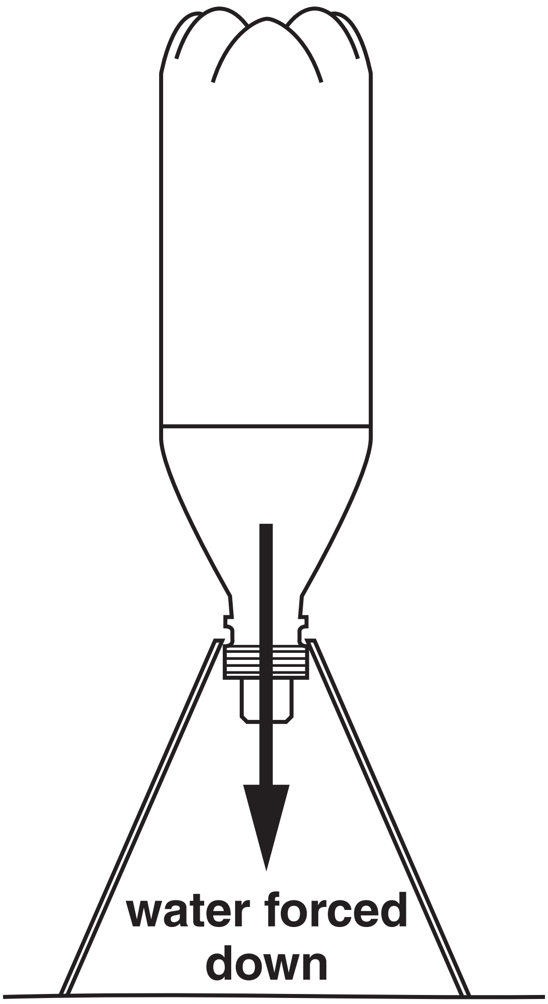

Fig. 2

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

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

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 on page 8.

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.

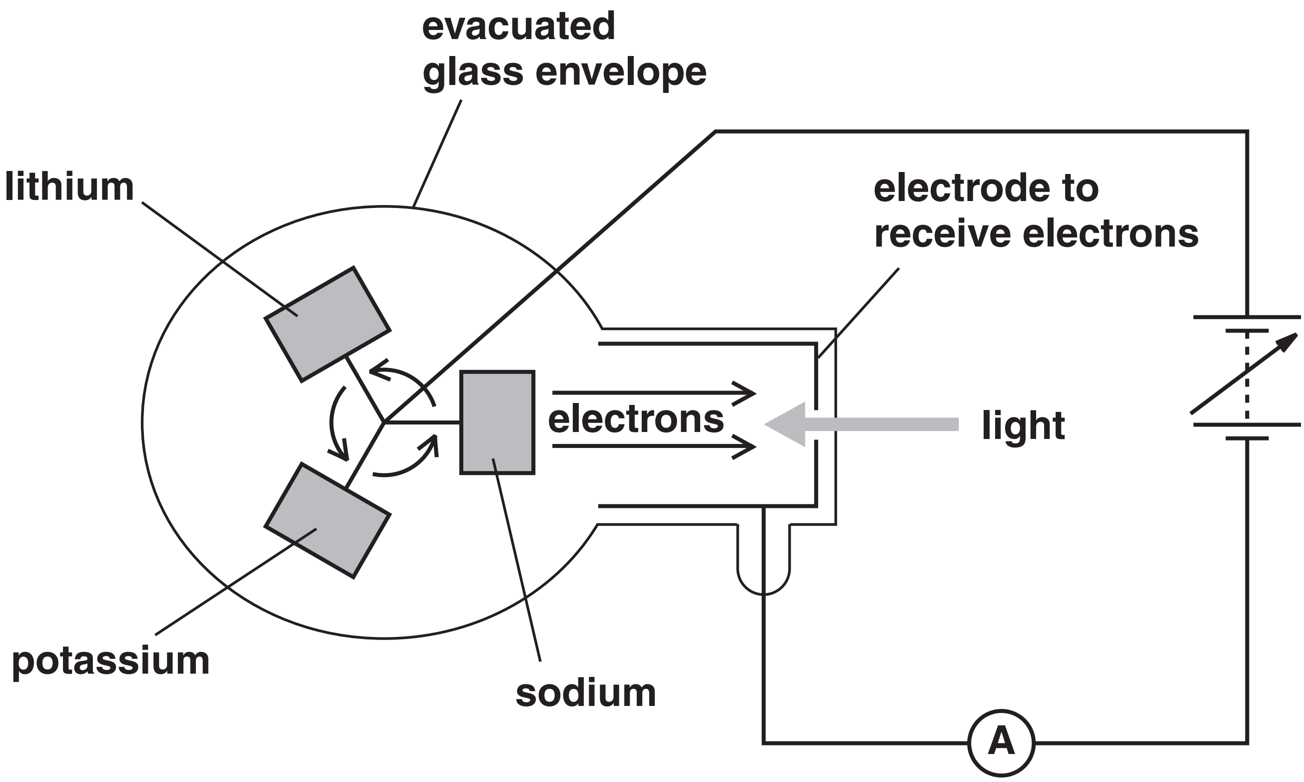

Fig. 3

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 0.55 V.

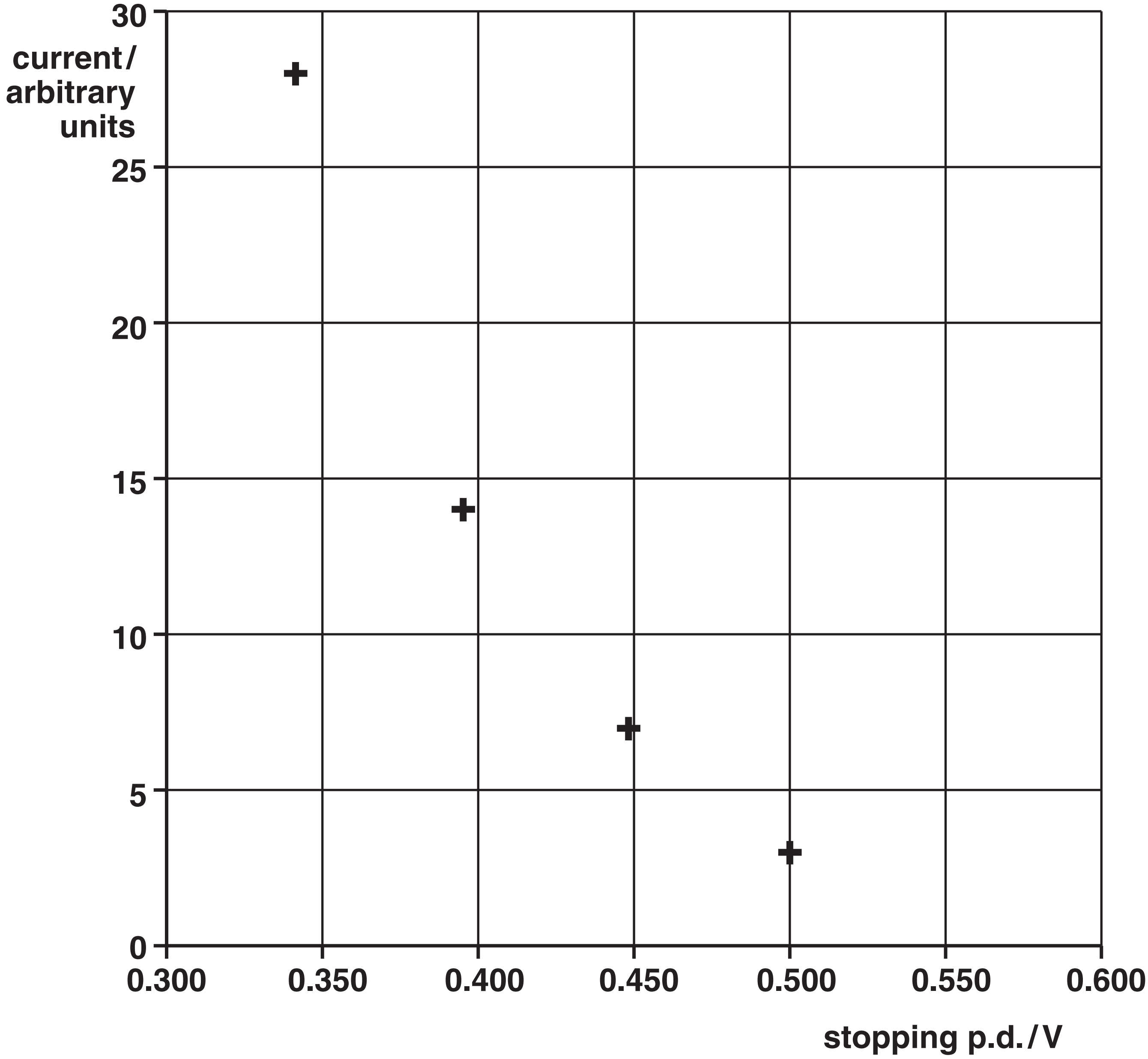

Fig. 4

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} J s, for which Millikan estimated the uncertainty as ± 0.5% However, Millikan was still not convinced about Einstein's theory of light particles (photons).

END OF ARTICLE

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