OCR
RECOGNISING ACHIEVEMENT

Friday 25 May 2012 – Afternoon

AS GCE PHYSICS B (ADVANCING PHYSICS)

G492 Understanding Processes/Experimentation and Data Handling

INSERT

Duration: 2 hours

G412060612

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.

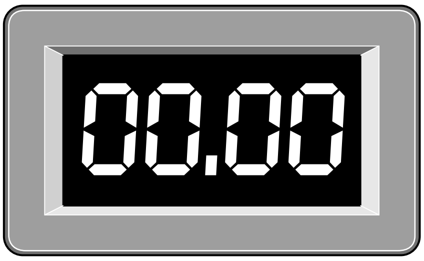
INSTRUCTION TO EXAMS OFFICER / INVIGILATOR

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

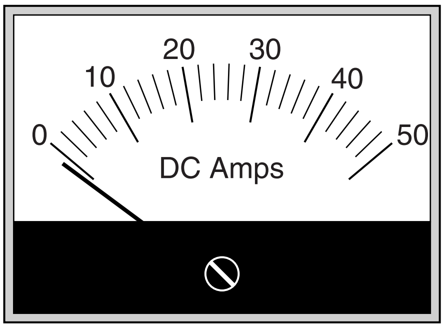
1 Quality of Measurement

When undertaking careful measurements of a physical quantity it is very important to recognise the qualities and limitations of the measuring instruments that are being used. In particular the **resolution**, **sensitivity** and **zero error** of the measuring instrument are all significant things to consider. In making a measurement it is necessary to identify the largest uncertainty and seek out ways of reducing it. This includes zero error which is a good example of a **systematic error**.

The two ammeters shown in Fig. 1 have different qualities and limitations.



digital ammeter
(reading in A)



analogue ammeter

Fig. 1

Other factors affecting the choice of an appropriate meter include response time and the time taken to read the current. The resistance of the ammeter is also an important factor, particularly when large currents are being measured.

2 Measuring the Planck constant using LEDs

You may wish to try out this experiment in the laboratory so that you will know in advance how the experiment works, what the difficulties are and how the data can be processed. The quantisation of light as discrete packets of energy called photons and the relationship $E = hf$ can be explored experimentally using LEDs in a circuit such as that shown in Fig. 2.

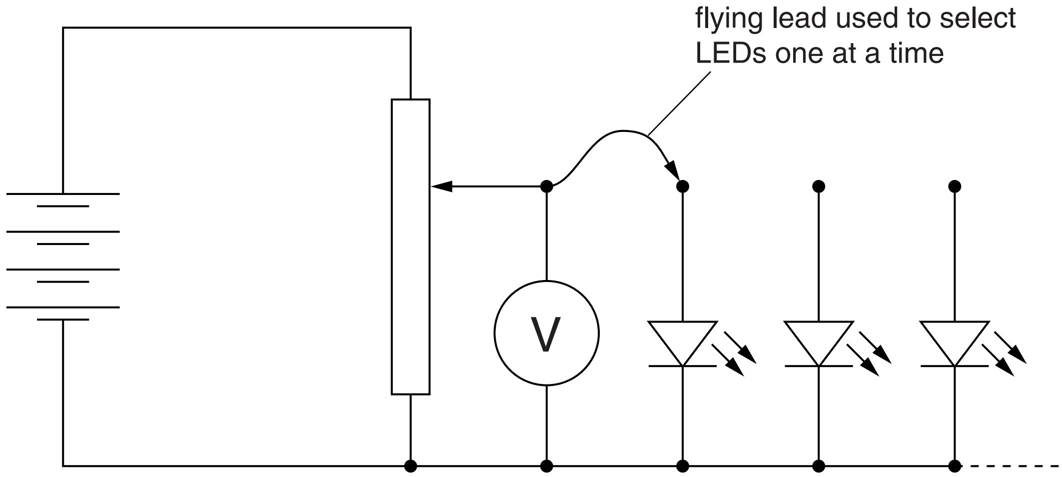


Fig. 2

The potential difference (p.d.) across the LED is gradually increased until it emits photons (strikes). The p.d. at which the LED just emits photons is known as the striking voltage V_s.

Each electron of charge e 'falling through' a p.d. V_s releases energy $E = V_s\, e$ as a single photon of light. The most significant uncertainties in this experiment are associated with consistently and accurately judging the voltage at which the LED strikes. To allow the strike to be detected with greater sensitivity, it is usual to shield the LED with a small opaque paper tube down which the observer can peer at the LED.

Data from one such experiment are shown in the table below.

LED colour	λ/nm	f/Hz ($\times 10^{14}$)	*Average* V_s/V
deep red	641	4.68	1.94
red	627	4.78	1.98
orange	609	4.93	2.04
yellow	600	5.00	2.07
green	574	5.23	2.17
turquoise	494	6.07	2.52
blue	468	6.41	2.66
deep blue	451	6.65	2.76
violet	411	7.30	3.02

The relationship $E = hf$ can be explored using the data obtained from the experiment. Plotting an appropriate graph of the data allows a value for the Planck constant to be determined.

3 Cavendish: Measuring the Earth's Density

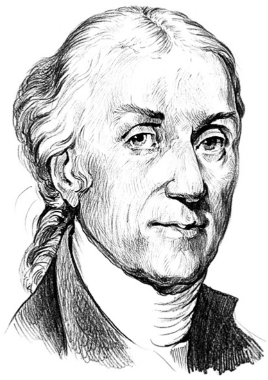


Fig. 3 Henry Cavendish

In 1798 the English scientist Henry Cavendish performed an experiment to calculate the density of the Earth. He wanted to use a laboratory procedure to refine an earlier estimate made by Maskelyne.

The idea for the experiment originated with geologist John Michell who died in 1793 before he could complete his work. Cavendish obtained and rebuilt Michell's apparatus and performed the experiment.

It is commonly stated that this experiment was the first time that the mass of the Earth was calculated and is popularly known as the *weighing the Earth* experiment. However Cavendish did not determine the mass of the Earth; he determined its average density.

The method Cavendish used to calculate the Earth's density consisted in measuring the force on a small ball of mass m caused by a large ball of known mass M, and comparing it with the force on the small ball caused by the Earth.

He hung a metal rod carrying two identical small lead balls m on a long thin wire, and fixed a large lead ball of mass M close to the side of each ball, as shown in Fig. 4. The large balls and small ones attracted each other gravitationally, making the rod rotate until the gravitational force was balanced by the restoring twist provided by the stiffness of the wire.

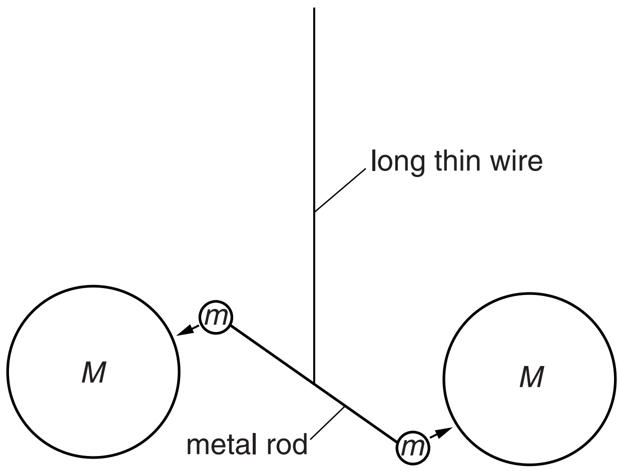


Fig. 4

By measuring the displacement of one of the masses m, Cavendish was able to compare the force rotating the rod with the attraction of the Earth on the small balls. With this comparison, and knowing the distances between m and the centre of the nearer large lead ball M, and between m and the centre of the Earth, he was able to show that the Earth had a density of a little less than half that of the lead ball, i.e. $5480\,\text{kg}\,\text{m}^{-3}$.

Cavendish showed his experimental skills in the care he took with his experimentation. The rod with its masses m was suspended in a draught-proof box with glass sides, and the whole experiment done in a sealed room – Cavendish made his observations from outside, using a telescope. He heated and cooled the large masses M, to check the effect of convection currents and expansion of the apparatus, and carefully eliminated the possibility of magnetic effects producing extra forces. He also allowed for other gravitational forces affecting each small mass m apart from its nearby large mass M.

The first wire he used was not stiff enough, so the tiny gravitational forces made the small masses *m* move too far, touching the sides of the glass box. However, he did not abandon the six results he obtained with this wire, but used them as a preliminary trial before more detailed measurements with a stiffer suspension wire.

His sets of results are given below:

First wire:

density/ $kg\,m^{-3}$					
5500	5610	4880	5070	5260	5550

Second wire:

density/ $kg\,m^{-3}$					
5360	5290	5580	5650	5570	5530
5620	5290	5440	5340	5790	5100
5270	5390	5420	5470	5630	5340
5460	5300	5750	5680	5850	

With the second set of results, Cavendish concluded that the mean density of the Earth was $5480\,kg\,m^{-3}$.

In Cavendish's own words, 'the extreme difference of the results of the 23 observations made with the second wire ... do not differ from the mean by more than $\frac{1}{14}$ of the whole, and therefore the density should seem to be determined hereby, to great exactness.'

This experiment was not reproduced with smaller uncertainty for over a century. The modern accepted value of the mean density of the Earth is $5520\,kg\,m^{-3}$.

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