Friday 25 May 2012 – Afternoon

AS GCE PHYSICS B (ADVANCING PHYSICS)

G492 Understanding Processes/Experimentation and Data Handling

Candidates answer on the Question Paper.

OCR supplied materials:
- Insert (Advance Notice for this Question Paper) (inserted)
- Data, Formulae and Relationships Booklet (sent with general stationery)

Other materials required:
- Electronic calculator
- Ruler (cm / mm)
- Protractor

Duration: 2 hours

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The Insert will be found in the centre of this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the blank pages at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the bar codes.

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.
- This document consists of **28** pages. Any blank pages are indicated.
- The questions in Section C are based on the material in the Insert.

Answer **all** the questions.

Section A

1 The list below shows different orders of magnitude.

0.01 **0.1** **1** **10** **100** **1000**

(a) Choose the best estimate for the **width** of your arm in metres.

.... **[1]**

(b) Choose the best estimate for the mass of an adult man in kilograms.

.... **[1]**

2 Here is a list of units.

J **N m** **W** **$kg\,m\,s^{-2}$** **$N\,kg^{-1}$**

(a) Which two units are equivalent?

.... and .... **[1]**

(b) Which is a unit for force?

.... **[1]**

(c) Which unit can be used for the acceleration due to gravity, *g*?

.... **[1]**

3 In each of the four equations below, k is a constant.

$y = kx$	$y = \frac{k}{x}$	$y = kx^2$	$y = k\sqrt{x}$
A	**B**	**C**	**D**

Which is the correct equation, **A**, **B**, **C** or **D**, when y and x represent the two quantities given in each case below?

(a) y: the frequency of an electromagnetic wave in a vacuum
x: the wavelength of that wave

.... **[1]**

(b) y: the distance travelled by an object accelerating uniformly from rest
x: the time that the object has been moving

.... **[1]**

(c) y: the speed of an object dropped from rest in a vacuum
x: gravitational potential energy lost to reach that speed

.... **[1]**

4 A 1200 kg car slows down with a constant deceleration of 1.8 m s^{-2}.

(a) Calculate the resultant force acting on the car during the deceleration.

force = ... N **[1]**

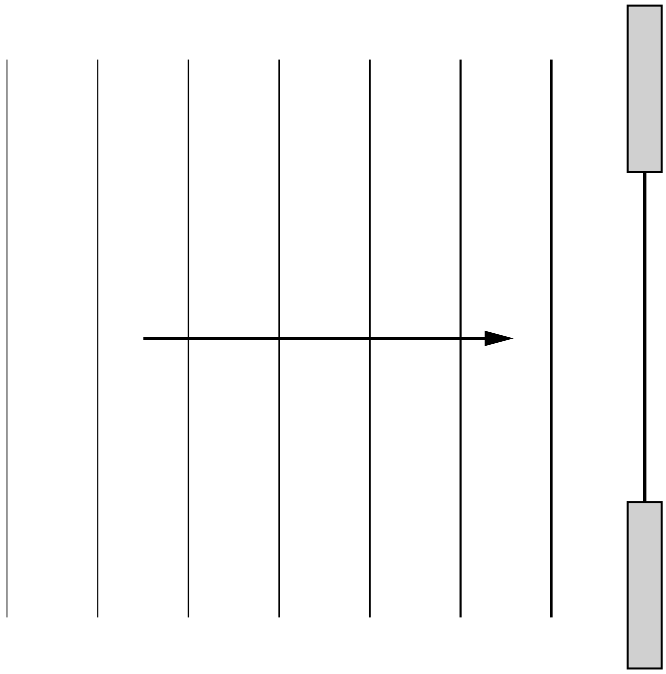
(b) Calculate the distance it travels during deceleration when it slows down from 30 m s^{-1} to 13 m s^{-1}.

distance = ... m **[2]**

5 A diffraction grating has a grating spacing of 1.4×10^{-6} m.
Find the wavelength λ of light which would produce a first-order diffraction maximum at 19°.

λ = ... m **[2]**

6 Surface water waves travel towards an opening in a barrier. The diagram shows the wavefronts to the left of the barrier.

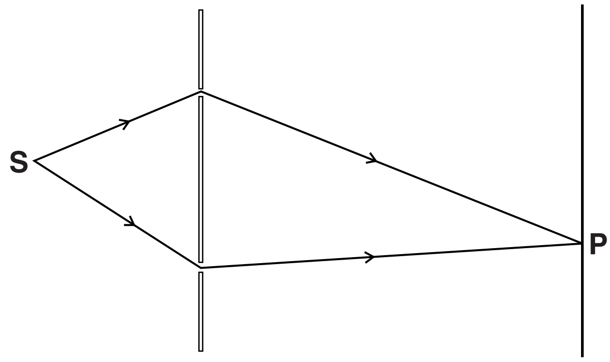


(a) Sketch the first **four** wavefronts on the right-hand side of the diagram to show the effect of the opening on the waves. **[2]**

(b) On the diagram below, sketch the pattern you would see when waves of a **lower** frequency are used.

[2]

7 The diagram shows two different paths for a photon travelling from a source **S** through a screen containing two slits to a point **P** on a distant screen.



At the distant screen, the phasor for each path has the same amplitude **A** represented by the arrow below.

(a) Draw phasor diagrams to show how the resultant amplitude of the two phasors at **P** may be **(i)** 2**A**, **(ii)** $\sqrt{2}$**A**.

(i)	**(ii)**

[2]

(b) When the resultant amplitude is $\sqrt{2}$**A**, the probability of detecting a photon at **P** is half the probability compared with when the resultant amplitude is 2**A**.

Explain what this shows about the relationship between probability and amplitude.

[2]

[Section A Total: 21]

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Section B

8 This question is about the interference of microwaves.
Two students set up the apparatus shown in Fig. 8.1.

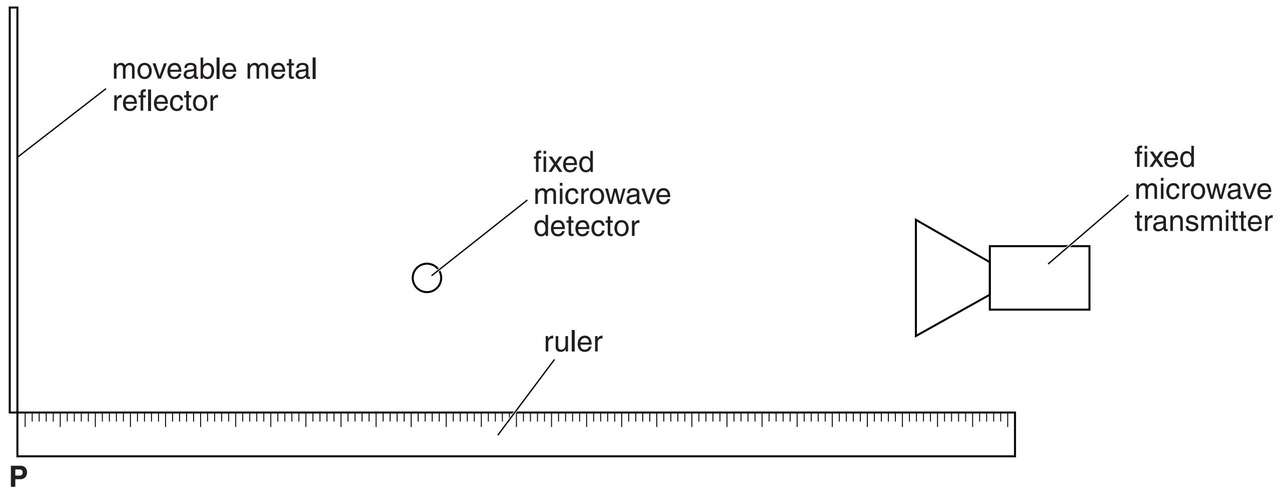

Fig. 8.1

(a) It is observed that when a metal reflector is placed at point **P**, the signal received by the detector falls.
Explain why this happens.

[2]

(b) The reflector is moved slowly towards the microwave detector. The graph of Fig. 8.2 shows how the signal strength at the detector varies for different positions of the reflector.

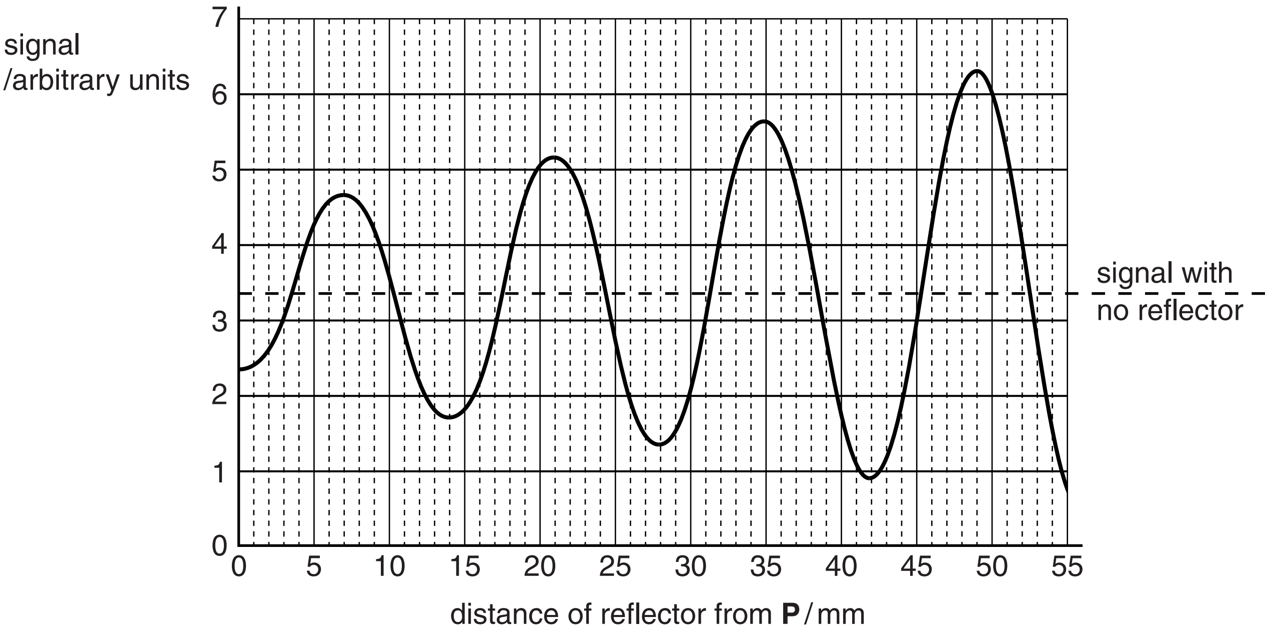

Fig. 8.2

The line of dashes shows the strength of the signal **before** the metal reflector is put at point **P**.

(i) Explain why the signal varies between maxima and minima as the reflector is moved towards the detector.

[2]

(ii) Use information from Fig. 8.2 to calculate the wavelength of the microwaves.
Make your working clear.

wavelength = ... mm **[2]**

(c) The experiment is now repeated with the transmitter closer to the detector. The detector remains fixed in the same place, and the reflector is again moved slowly towards it, starting at **P** as before.
Explain one feature of the results in Fig. 8.2 that would remain the same, and one feature that would change.

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

[4]

[Total: 10]

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9 This question is about solar powered lamps.

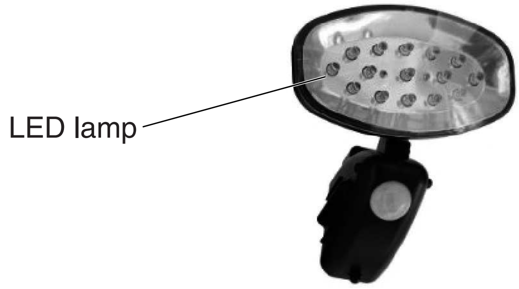

Fig. 9.1

The solar powered lamp shown in Fig. 9.1 contains 15 light-emitting diodes (LEDs).
Each LED has an output power of 80 mW.

(a) Show that the total energy emitted by the lamp in 1 second is about 1 joule.

[1]

(b) The lamp emits light with an average photon energy of 3.7×10^{-19} J.

(i) Show that this light has a wavelength of about 500 nm.

$c = 3.0 \times 10^{8}\,\text{m}\,\text{s}^{-1}$

$h = 6.6 \times 10^{-34}\,\text{J}\,\text{s}$

[2]

(ii) Calculate the number of photons emitted per second by the 15-LED lamp.

number per second = ... **[2]**

(c) Fig. 9.2 shows a photovoltaic solar panel measuring 0.18 m × 0.09 m.

Fig. 9.2

(i) The energy per second reaching the top of the Earth's atmosphere from the Sun is 1.4 kW for every square metre of surface that it illuminates.
Show that the maximum possible solar energy per second illuminating the solar panel is about 20 W.

[1]

(ii) Suggest one reason why you might expect the actual maximum solar energy per second illuminating the solar panel to be less than 20 W.

[1]

(iii) The solar panel is used to recharge batteries. These batteries are used to power the lamp. Suggest and explain why the lamp is not powered directly by the solar panel.

[2]

[Total: 9]

10 This question is about the vector nature of displacement, velocity and acceleration.

(a) An object moves in the *x*–*y* plane along a semi-circular path from **A** to **C** as shown in Fig. 10.1. **B** is mid-way between **A** and **C**. The radius of the path is 3.0 m and the object moves at a constant speed of 5.0 m s^{-1}.

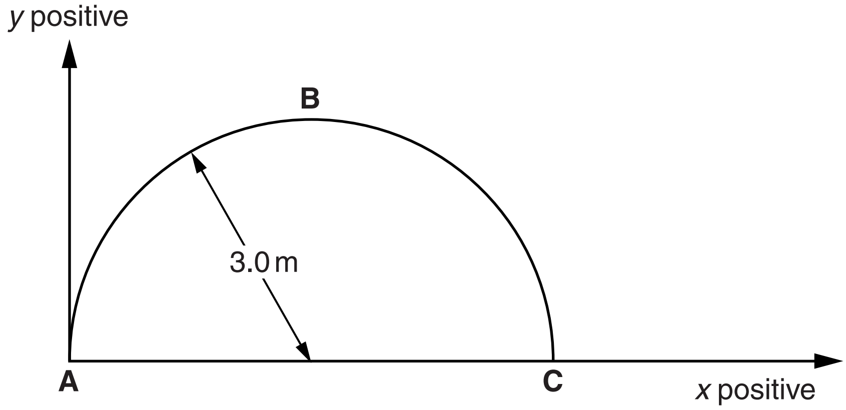

Fig. 10.1

(i) Show that it takes about 2 seconds for the object to travel from **A** to **C**.

[1]

(ii) Write down the values of the *x*- and *y*-components of the **velocity** of the object when at **A**, **B** and **C** in the table below.

	velocity at **A** / m s^{-1}	velocity at **B** / m s^{-1}	velocity at **C** / m s^{-1}
x-component			
y-component			

[2]

(iii) Write down the values of the *x*- and *y*-components of the **displacement** of the object from **A** when at **B** and **C** in the table below.

	displacement from **A** to **B** / m	displacement from **A** to **C** / m
x-component		
y-component		

[2]

(b) A car travels around a roundabout at a constant speed of $12\,m\,s^{-1}$.
Its direction changes by 40° when moving from **D** to **E**, as shown in Fig. 10.2.

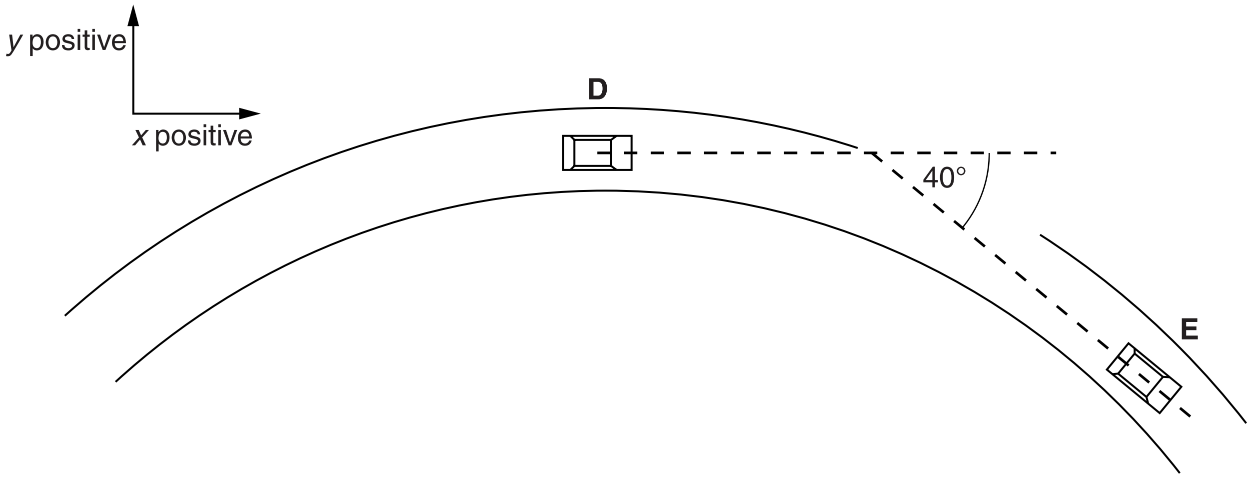

Fig. 10.2

Because the velocity vector changes, the car has an acceleration.
The car takes 1.6 s to travel from **D** to **E**.
Calculate the mean values of the *x*- and *y*-components of acceleration between **D** and **E**.
Show your working clearly.

x-component

mean *x*-acceleration = ... $m\,s^{-2}$

y-component

mean *y*-acceleration = ... $m\,s^{-2}$

[4]

[Total: 9]

11 This question is about a pile-driver – a machine for hammering piles into the ground. A pile is a foundation post for a building.
The pile-driver is attached to the top of the pile.

Fig. 11.1 shows the sequence of operations by which it hammers the pile into the ground.

A ⟶ **B** A heavy weight resting on top of the pile is lifted by a motor.
B ⟶ **C** The weight drops back onto the top of the pile.
C ⟶ **D** The moving weight pushes the pile into the ground until the weight and pile come to rest.

The process is then repeated until the pile is at the required depth.

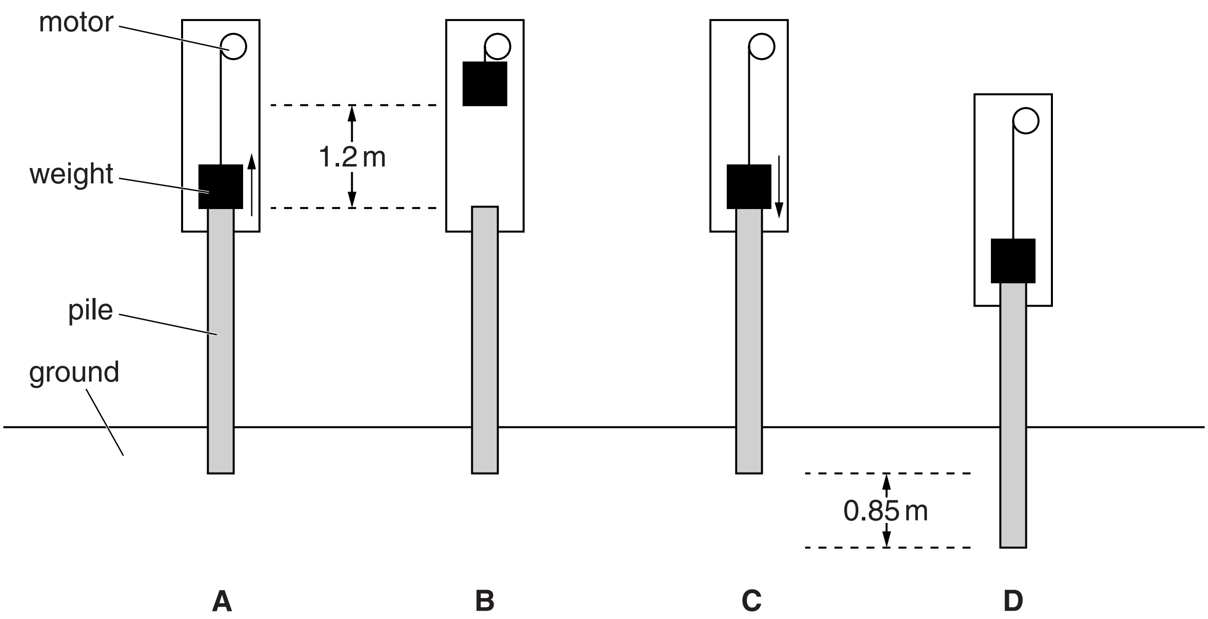

Fig. 11.1

(a) The weight has a mass of 2100 kg.
Show that the increase in gravitational potential energy of the weight when lifted 1.2 m is about 25 kJ.
$g = 9.8\ \mathrm{m\,s^{-2}}$

[1]

(b) **(i)** By considering the change of gravitational potential energy of the weight between steps **B** and **D**, show that the total work done by the moving weight in falling and pushing the pile 0.85 m into the ground is about 40 kJ.

[2]

(ii) Calculate the average force exerted on the pile as it is pushed into the ground. Assume there are no energy losses.

average force = ... N **[1]**

(iii) The mass of the pile is not included in the calculation of part **(ii)**. Explain, without calculation, how the value for the average force would change if the mass of the pile were included.

[1]

Question 11 continues on the next page

(c) The data for successive 'drops' of the pile-driver weight are shown in the table. d is the distance moved after a particular drop, and N is the drop number.

drop number, N	1	2	3	4
distance moved by pile, d/m	0.85	0.63	0.48	0.36

(i) Suggest and explain one reason d decreases as N increases.

[2]

(ii) It is suggested that the distance moved by the pile is given by the equation

$$d = \frac{k}{\sqrt{N}} \text{ where } k \text{ is a constant.}$$

Plan and carry out a simple arithmetic test to check if this relationship is true.

Test:	Calculation:
Conclusion:	

[4]

[Total: 11]

[Section B Total: 39]

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Section C

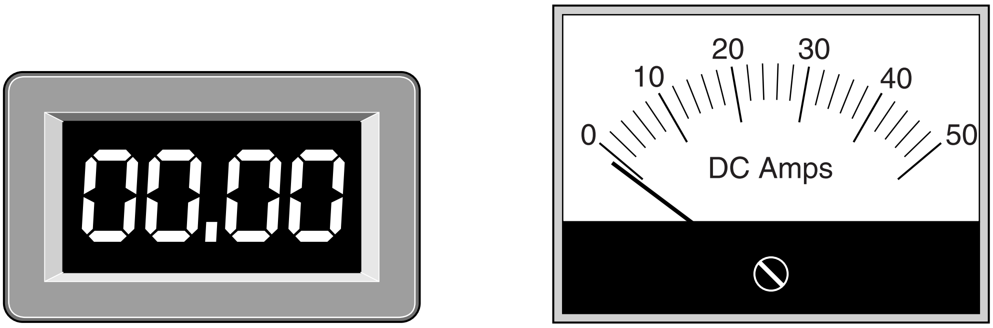
The questions in this section are based on the material in the Insert.

12 This question is about the article *Quality of measurement*.

(a) State what is meant by the **resolution** of a measuring instrument.

[1]

(b) The two ammeters referred to in the article are shown in Fig. 12.1.



digital ammeter (reading in A) analogue ammeter

Fig. 12.1

(i) Suggest and explain a value for the resolution of each ammeter in Fig. 12.1.

resolution of digital ammeter = ± .... A

explanation: ....

....

resolution of analogue ammeter = ± .... A

explanation: ....

.... **[4]**

(ii) Calculate the percentage uncertainty in the measurement of the **digital** ammeter when it is used to measure a current of 3 A.

uncertainty = ± .... % **[2]**

(c) The zero error shown on the analogue ammeter is a systematic error.

(i) State the consequence of ignoring **this** systematic error when taking readings.

[1]

(ii) Describe one way in which this systematic error could be removed.

[1]

(d) The pointer of the **analogue** ammeter moves through an angle of 90° when the current increases from 0 to 50 A.
Calculate a value for the current when the angle between the pointer and 0 is 23°.

current = ... A **[1]**

(e) One application of an ammeter is to monitor a current to check that it does not suddenly increase to a much larger value.
Explain why the analogue ammeter may be a better choice than the digital ammeter for this application.

[1]

(f) Suggest why an ammeter for use in circuits carrying large currents should have a very low resistance.

[1]

[Total: 12]

13 This question is about the article *Measuring the Planck constant using LEDs*.

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

LED	λ /nm	f /10^{14} Hz	*average* V_s /volts
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

(a) **(i)** Use the table to complete the graph of Fig. 13.1. The first five points have been plotted for you.
Draw the best-fit straight line and show that its gradient is about 4×10^{-15} V Hz^{-1}.
Show your working clearly.

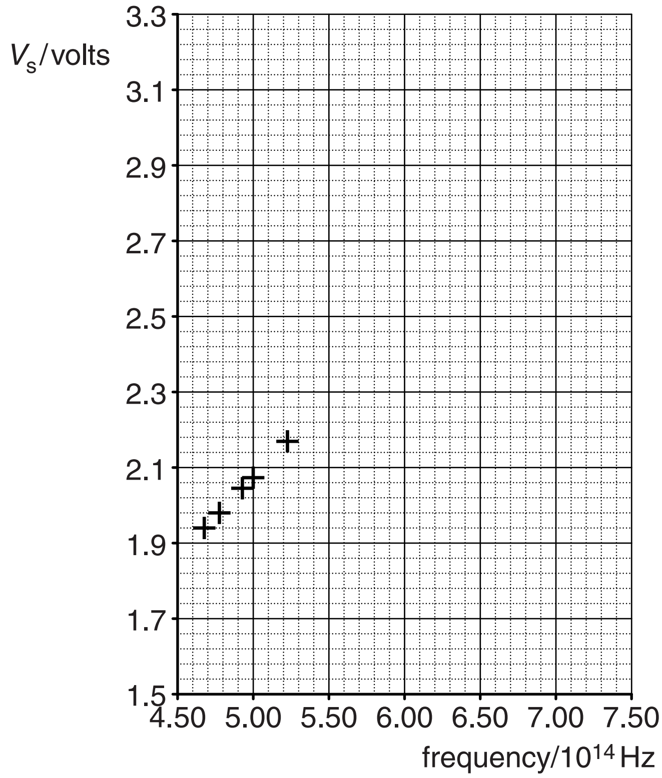


Fig. 13.1

gradient of best-fit line .... V Hz^{-1} **[5]**

(ii) The gradient of the line in Fig. 13.1 is equal to h/e where h is the Planck constant and e is the charge on an electron.
Show that the units of the Planck constant (J s) are consistent with the units of the gradient of the graph.

[2]

(iii) Calculate a value for the Planck constant h using the value for the gradient of the graph.
$e = 1.6 \times 10^{-19}\,\text{C}$

h = ... J s **[2]**

(b) (i) An extra measurement is made in this experiment by adding an additional green LED of wavelength 539 nm. The measured striking voltage V_s is 2.60 V. By comparing this result with the existing data, show that the measurement is probably an outlier and suggest a practical reason for this.

[3]

(ii) The overall uncertainty for the striking voltage measurement is estimated to be ± 0.2 V. The manufacturer of the LEDs states that there is a tolerance of 0.5% in the marked value of each wavelength.
With the aid of suitable calculations, show that the uncertainty in the manufacturer's marked value of the wavelength can be ignored in any calculation of h.

[2]

[Total: 14]

14 This question is about the article *Cavendish: Measuring the Earth's Density*.

(a) (i) The first suspension wire used by Cavendish was not stiff enough, so he replaced it with a stiffer one.
Suggest **one** way in which the second wire may have differed from the first one.

[1]

(ii) Even though Cavendish realised that his first wire was not good enough, he still used it to obtain some trial data.
Explain why this was good experimental practice.

[2]

(iii) Show that the mean density calculated for the experiments with the first wire was less than the value of 5480 kg m^{-3} obtained for the second wire, but that the difference is probably not significant.

data for first wire:

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

[3]

(b) In his experiment, Cavendish made a number of improvements to John Michell's original design.
Describe and explain **two** procedures mentioned in the article which show Cavendish's meticulous care in experimentation.

In your answer you should ensure that each improvement is clearly linked to its effect.

[4]

(c) (i) Use Cavendish's data for his second wire to confirm his statement '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 value.'

data for 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	

[2]

Question 14 continues on the next page.

(ii) Show that Cavendish's value of mean density and uncertainty compare favorably with the modern accepted value of the mean density of the Earth (5520 kg m^{-3}).

[2]

[Total: 14]

[Section C Total: 40]

END OF QUESTION PAPER

ADDITIONAL PAGE

If additional space is required, you should use the blank pages below. The question number(s) must be clearly shown.

ADDITIONAL PAGE

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.

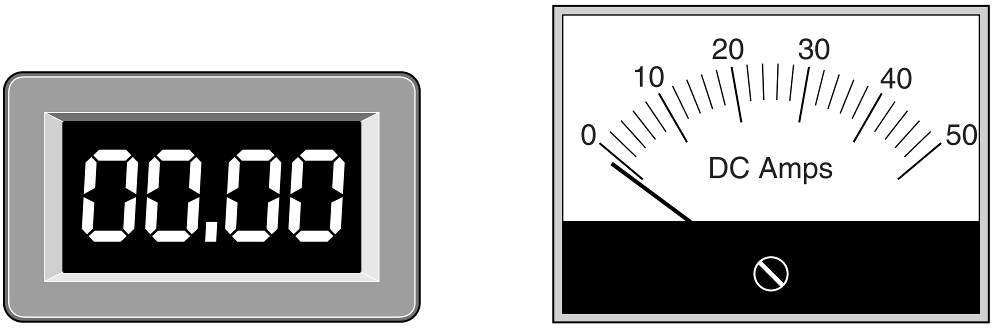
INSTRUCTION TO EXAMS OFFICER / INVIGILATOR

- 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.

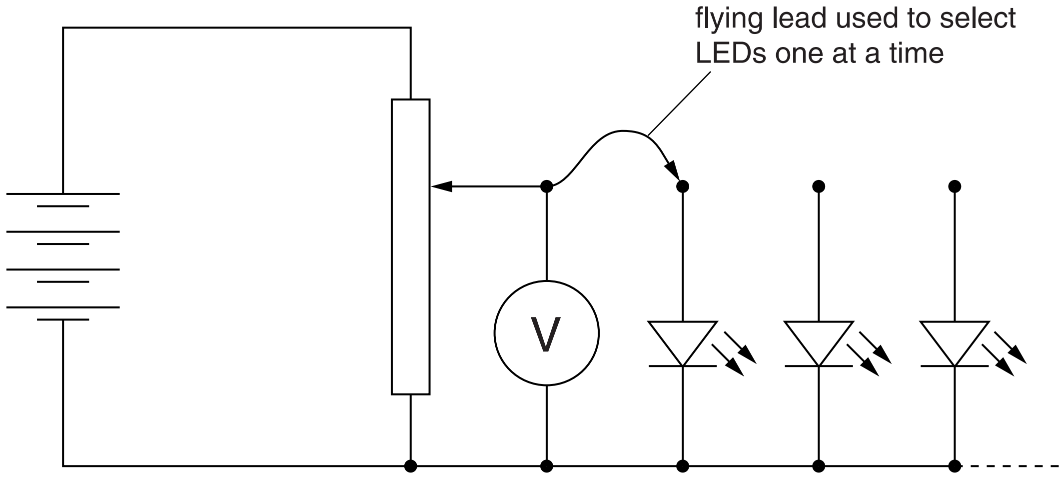


Fig. 2

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

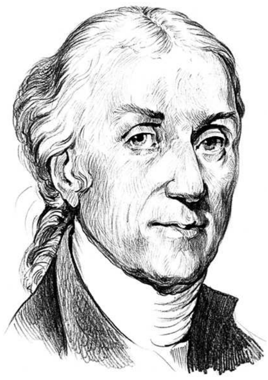


Fig. 3 Henry Cavendish

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.

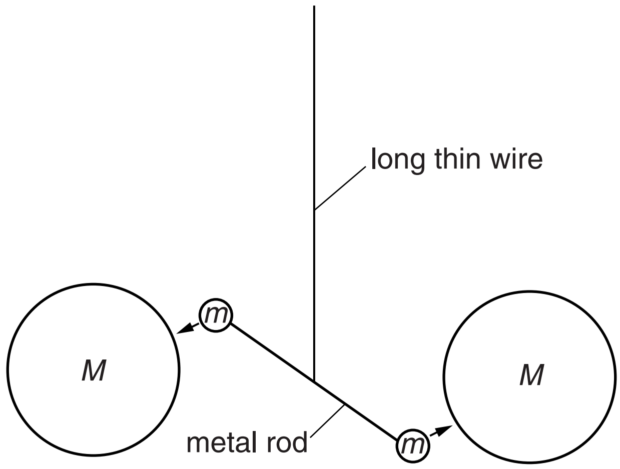


Fig. 4

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 $kg\,m^{-3}$.

END OF ARTICLE