OCR
RECOGNISING ACHIEVEMENT

Friday 20 January 2012 – Morning

AS GCE PHYSICS B (ADVANCING PHYSICS)

G492 Understanding Processes/Experimentation and Data Handling

Candidates answer on the Question Paper.

OCR supplied materials:
- Insert (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 additional 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 **24** pages. Any blank pages are indicated.
- The questions in Section C are based on the material in the Insert.

Turn over

Answer **all** the questions.

Section A

1 Here is a list of quantities.

energy **force** **power** **speed** **velocity**

(a) Which two quantities can have the same units?

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

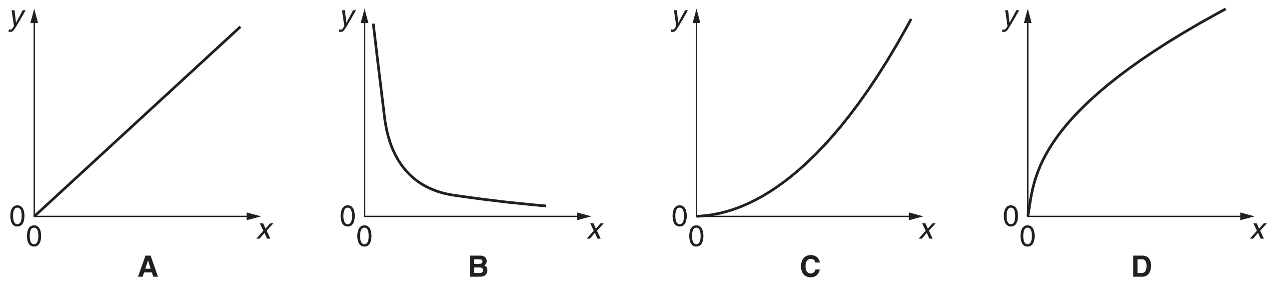
(b) Which two quantities are vectors?

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

(c) Use two of the quantities to complete the following sentence.

.... equals .... divided by time. **[1]**

2



State which graph, **A**, **B**, **C** or **D**, best represents the relationship between the two quantities given in each case below.

(a) *y*-axis: the acceleration of an object
x-axis: the resultant force acting on that object

.... **[1]**

(b) *y*-axis: the wavelength of a wave
x-axis: the frequency of that wave

.... **[1]**

(c) *y*-axis: the kinetic energy of moving objects at a given speed
x-axis: the mass of each object

.... **[1]**

(d) *y*-axis: the distance a free-falling object has fallen from rest
x-axis: the time it has been falling

.... **[1]**

3 Light of a single wavelength passing through two narrow parallel slits forms a pattern of light and dark fringes on a distant screen.

Fig. 3.1

Which of the following changes would **increase** the separation of the fringes?
Put a tick (✓) in the box next to **each** correct change.

decreasing the intensity of the light	☐
increasing the wavelength of the light	☐
moving the screen closer to the slits	☐
replacing the slits with two slits further apart	☐
moving the screen further away from the slits	☐

[2]

4 A ball of mass 0.5 kg is thrown vertically upwards with a speed of $15\,m\,s^{-1}$.

(a) Calculate the gravitational potential energy it has gained when it has risen 8.0 m.
$g = 9.8\,m\,s^{-2}$

gravitational potential energy gained = ... J **[1]**

(b) Find its speed when it has risen 8.0 m. Assume there is no air resistance.

speed = ... $m\,s^{-1}$ **[3]**

5 Fig. 5.1 shows two forces acting on an object. No other forces act on the object.

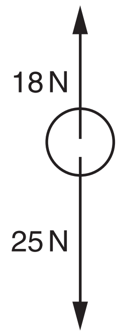


Fig. 5.1

The object has a mass of 2.6 kg.
Calculate the acceleration of the object.

acceleration = ... m s^{-2} **[2]**

6 A sodium lamp emits yellow light at a wavelength of 5.89×10^{-7} m.

(a) Show that the energy of each photon of this light is about 3×10^{-19} J.
speed of light, $c = 3.0 \times 10^{8}\,\text{m s}^{-1}$
Planck constant, $h = 6.6 \times 10^{-34}\,\text{J s}$

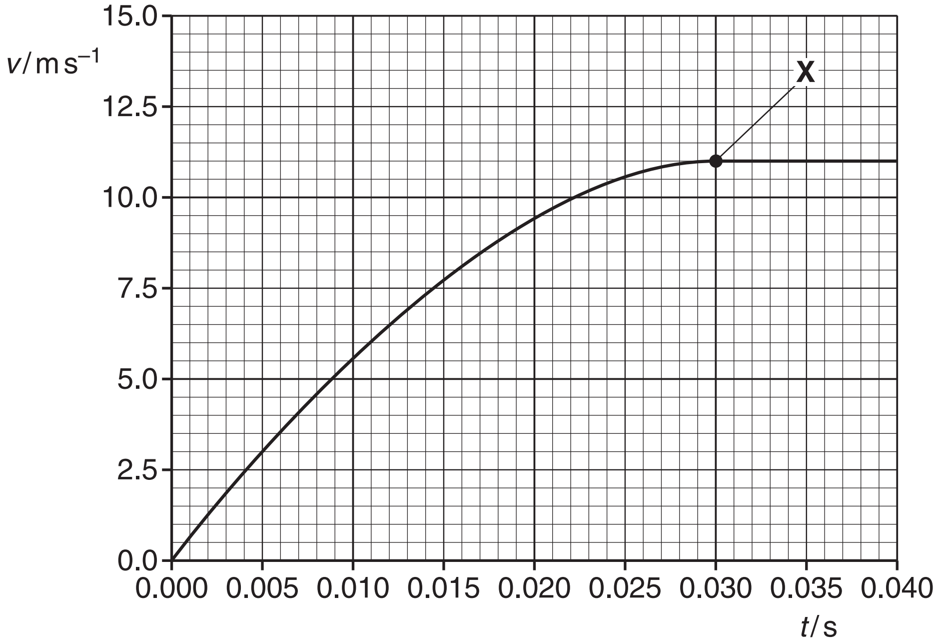
[3]

(b) A sodium lamp draws 100 W from the electricity supply.
Estimate the number of photons of yellow light it emits every second.
State the assumption you need to make.

[2]

7 The graph shows the velocity of a stone being launched from a catapult.

The stone loses contact with the catapult at the point marked **X**.



Use the graph to calculate the distance the stone moved while in contact with the catapult.
Make your working clear on the graph and in this space.

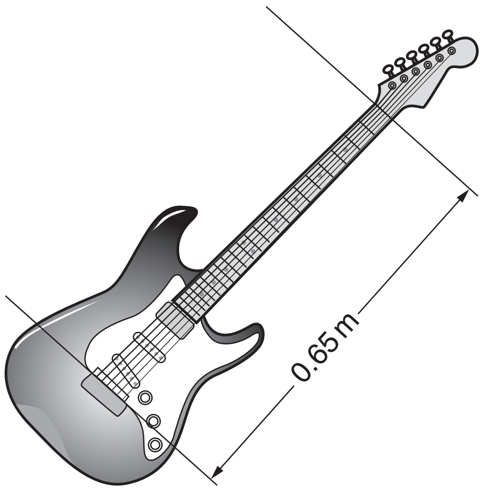
distance = ... m **[3]**

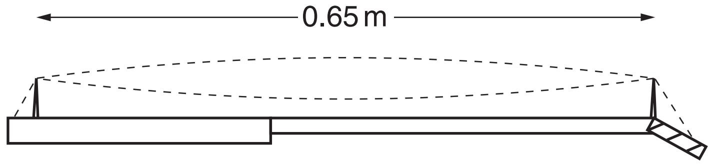
[Section A Total: 23]

Section B

8 This question is about standing waves on guitar strings.

Fig. 8.1 shows a guitar whose strings are 0.65 m long.





the lowest frequency standing wave on a guitar string
(not to scale)

Fig. 8.1

(a) Explain why the wavelength of the standing wave shown in Fig. 8.1 is 1.3 m.

[1]

(b) The lowest frequency standing wave on the thickest guitar string is at 82 Hz.
Show that the speed of the wave travelling along the string is about 100 m s^{-1}.

[2]

(c) **(i)** The speed v of waves along a string is given by the equation

$$v = \sqrt{\frac{T}{\mu}}$$

where T is the tension in the string, and μ is the mass of a metre length of the string.

Use this equation to calculate the tension T in the thickest guitar string where $\mu = 8.4 \times 10^{-3}\,\text{kg}\,\text{m}^{-1}$.

tension = ... N **[2]**

(ii) All strings on the guitar have the same tension and length. Use the equation above to explain why the fundamental frequency of the thinnest string is higher than the fundamental frequency of the thickest string.

[1]

(d) Explain clearly how waves travelling along a string can produce standing waves on the string.

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

[3]

[Total: 9]

9 This question is about the performance of a small, low-powered car.

Fig. 9.1

(a) In a test, the car accelerates from 0 to 27 $m s^{-1}$ (60 mph) in 10.9 s.

(i) Show that the mean resultant force acting on the car during the acceleration is about 2 kN.

mass of car and driver = 860 kg

[3]

(ii) In the acceleration test the driver was alone in the car.
Explain the difference in the 0 to 60 mph test you would expect if the driver were accompanied by a passenger.

[2]

(b) The car now travels at a constant speed of $20\,m\,s^{-1}$ along a straight, horizontal road.

(i) Explain why the force pushing the car forward must be equal in magnitude to the resistive force acting on the car.

[1]

(ii) In these conditions the useful mechanical output power from the car engine is 15 kW. Calculate the resistive force acting against the car.

force = ... N **[2]**

(iii) At a constant speed of $20\,m\,s^{-1}$ on a straight, horizontal road, the car can travel for 18 km on 1 litre of fuel.
The fuel releases 33 MJ $litre^{-1}$ when burnt in the engine.
Show that at this speed the energy released per second by the fuel is nearly 40 kW.

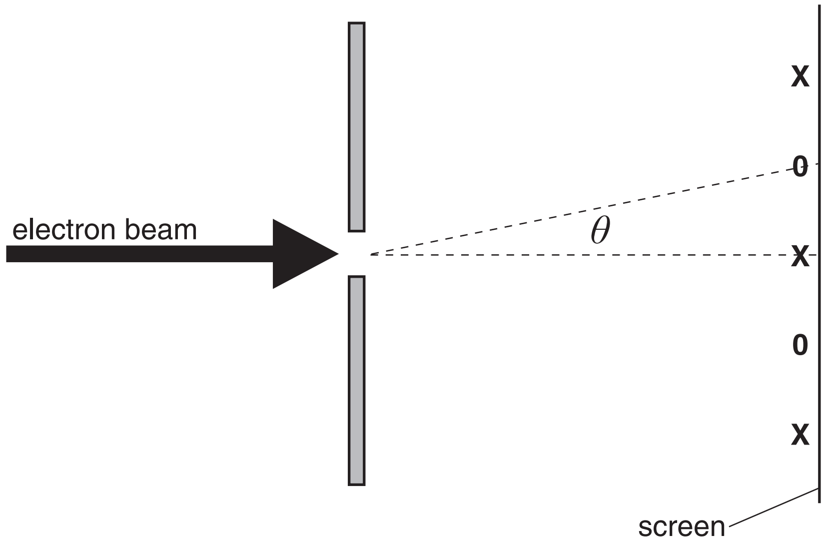
[2]

(iv) Account for the difference between the values of power in **(ii)** and **(iii)**.

[1]

[Total: 11]

10 This question is about electron diffraction.
When a parallel beam of electrons is incident on a narrow slit, a diffraction pattern can be observed on a screen.



0 = place with a low probability of detecting an electron
X = place with a high probability of detecting an electron

Fig. 10.1

(a) To observe a diffraction pattern on the screen, the slit needs to be very small indeed.
The equation for single-slit diffraction is

$$\lambda = b \sin\theta$$

where λ is the wavelength, b the width of the narrow slit and θ the angle of the first minimum, shown above.

Calculate the width b of the slit needed to give an angle θ of 1° for a wavelength of 7.0×10^{-11} m.

b = ... m **[1]**

(b) The wavelength associated with the electrons depends on their energy.
For low energy electrons of mass *m* and speed *v*, the wavelength is given by:

$$\lambda = \frac{h}{mv}$$

(i) Calculate the speed of electrons with wavelength $\lambda = 7.0 \times 10^{-11}$ m.
$h = 6.6 \times 10^{-34}$ J s
$m = 9.1 \times 10^{-31}$ kg

speed = ... $\mathrm{m\,s^{-1}}$ **[2]**

(ii) Suggest and explain what will happen to the pattern seen in Fig. 10.1 when the energy of the electron beam is increased.

In your answer, you should make the steps in your reasoning clear.

[3]

(c) The pattern is seen on the screen even when the beam of electrons is so weak that only one electron at a time passes through the apparatus.
Explain, in terms of the phasors for each possible path, why an electron reaching the slit has a very low probability of reaching the points marked **0** in Fig. 10.1.

[2]

(d) Electron diffraction is used to study the arrangement of atoms in the surface layers of solids.
Explain why the diffraction of electrons is better than the diffraction of light of wavelength 600 nm for studying the arrangement of atoms of spacing about 0.1 nm.

[2]

[Total: 10]

11 This question is about the vector nature of velocity and acceleration.
At time $t = 0$, an object is moving in the x-direction at $5.0\,\mathrm{m\,s^{-1}}$ as shown in Fig. 11.1.
Two seconds later, it is moving at 40° to that direction, but at the same speed.

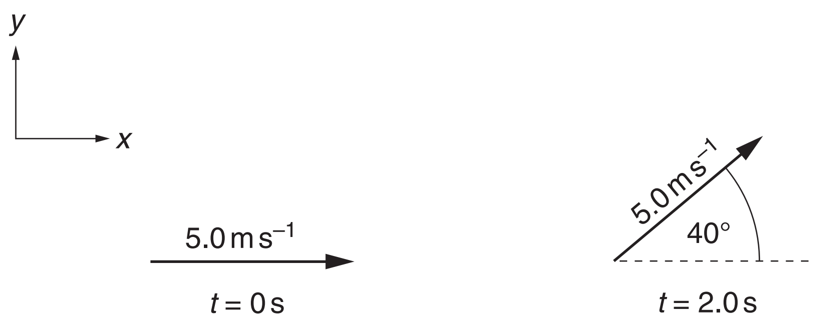


Fig. 11.1

(a) **(i)** Show that the x-component of velocity at time $t = 2.0\,\mathrm{s}$ is about $4\,\mathrm{m\,s^{-1}}$ and that the y-component of velocity at this time is about $3\,\mathrm{m\,s^{-1}}$.

[2]

(ii) Show that the mean x-component of acceleration during the 2.0 s is about $-0.6\,\mathrm{m\,s^{-2}}$.

[2]

(b) The mean y-component of acceleration during the 2.0 s is $+\,1.6\,\mathrm{m\,s^{-2}}$.

Choosing an appropriate scale, draw the two vector components of acceleration on the grid of Fig. 11.2 opposite and determine the magnitude and direction of the resultant acceleration.

magnitude of acceleration = ... $\mathrm{m\,s^{-2}}$

direction of acceleration = ... °

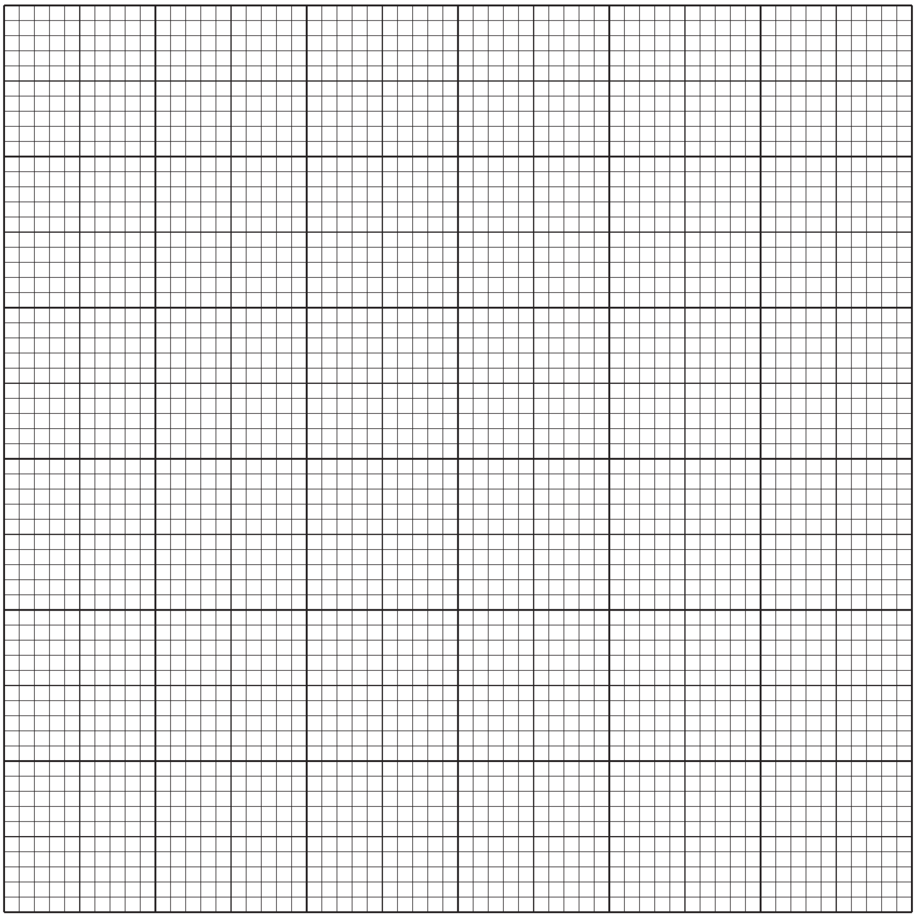


Fig. 11.2

[4]

(c) The force which accelerated the object was at right angles to the direction of motion.
Use the definition of **work** to explain why this force does no work on the object in this time.

[2]

[Total: 10]

[Section B Total: 40]

Section C

12 This question is about the article *Dot plots*.

A group of 16 students carried out an experiment to calculate the speed of sound in air. The group found an isolated wall at one end of their school. They measured their distance from the wall. The teacher made a loud noise by banging together two hardwood blocks. Each student started a stopwatch when the blocks were banged together and stopped when the echo was heard.

The dot plot in Fig. 12.1 shows a set of results for this experiment where **each** of the 16 students has made one measurement.

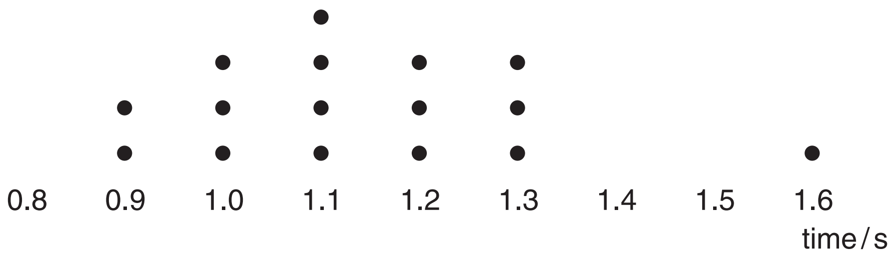


Fig. 12.1

(a) (i) Calculate the mean and spread of the data values **leaving out** the result of 1.6 s.

time = ... ± .... s **[2]**

(ii) Use the answer to **(i)** to decide whether the value of 1.6 s could be an outlier.

[1]

(iii) Use the answer to **(i)**, together with the fact that the reflecting wall was 165 m away, to show that the value obtained for the speed of sound in air is less than the 340 $m\,s^{-1}$ expected.

[1]

(b) Describe and explain **one** possible source of systematic error or uncertainty in these measurements obtained using a stopwatch.

[2]

(c) Suggest and explain one improvement the group of students might have made to the experiment to give a better set of measurements.

[2]

[Total: 8]

13 This question is about the article *Measuring g by freefall*.

A student carries out an experiment to measure g in the classroom using the equipment described in the article and shown in Fig. 13.1.

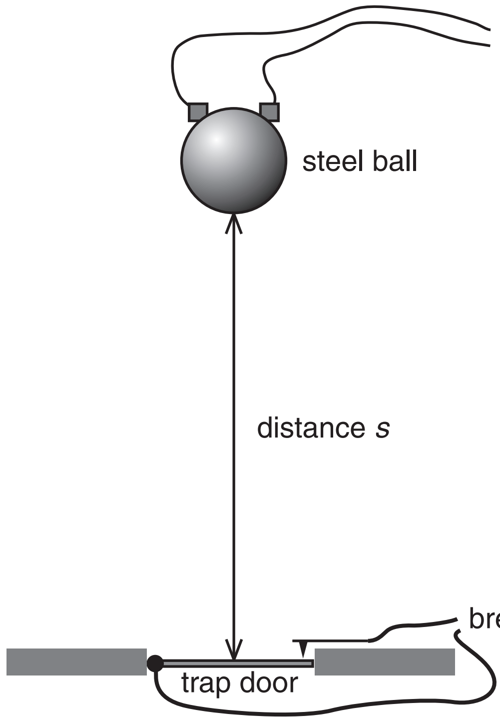


Fig. 13.1

She sets up the equipment and judges the uncertainty in the two measurements. The timing device measures to within 0.01 s and the distance s is measured to within 0.01 m.

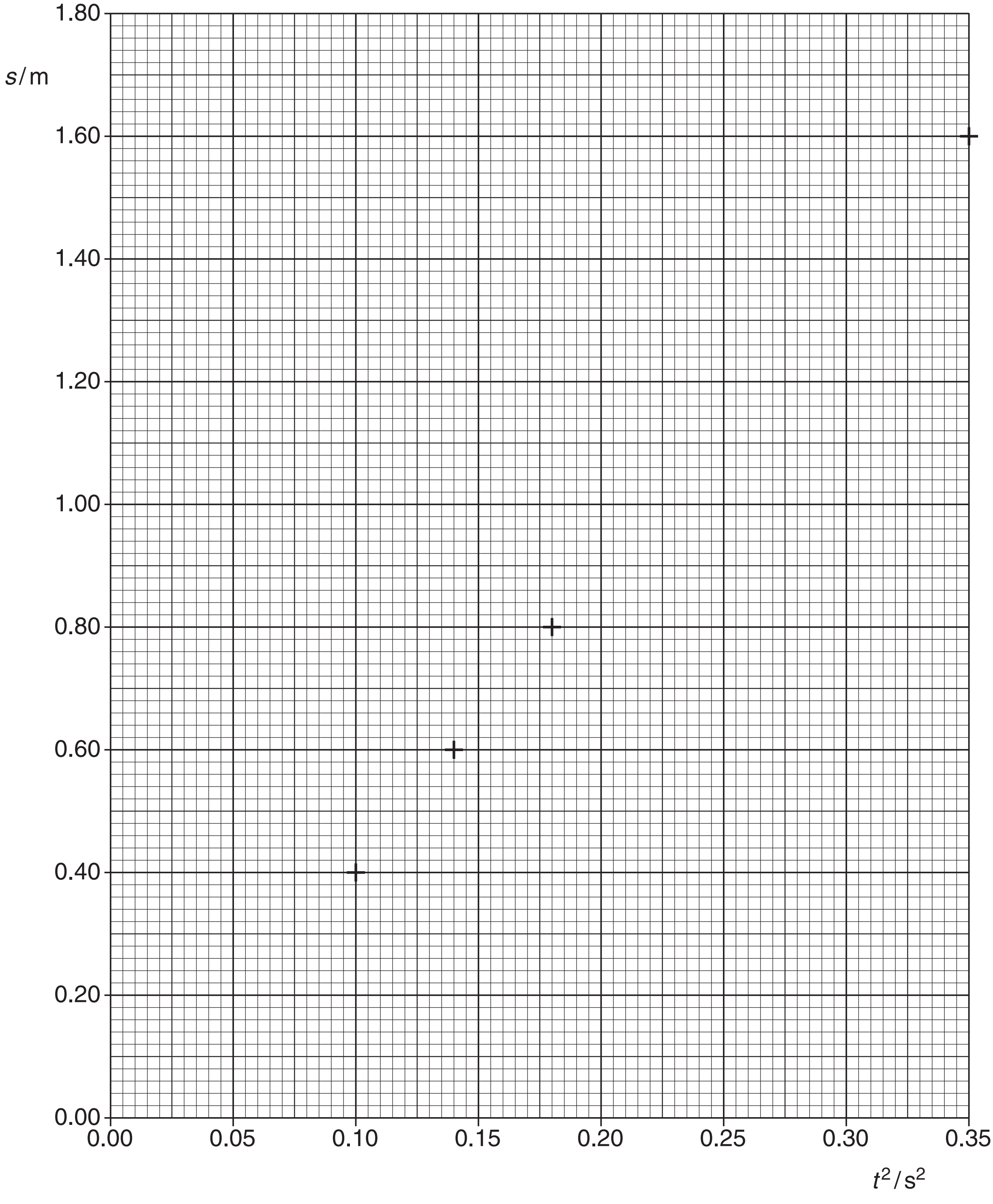
(a) The student records the following data for a range of distances, averaging the time t at each distance s over several drops. She intends to plot a graph of s against t^2.

(i) Complete the table.

s/m	mean t/s	t^2/s^2
0.40	0.31	0.10
0.60	0.38	0.14
0.80	0.42	0.18
1.00	0.47	
1.20	0.51	
1.40	0.55	
1.60	0.59	0.35

[2]

(ii) Using your values from the table, complete the graph of s against t^2 opposite and draw a straight line of best fit.



[3]

(b) (i) Explain why the equation $s = ut + \frac{1}{2}at^2$ would lead you to expect the graph to go through the origin.

[2]

(ii) Calculate the gradient of the graph.
Show your working clearly on the graph or in this space.

gradient = ... **[2]**

(iii) Use your answer to **(ii)** to obtain a value for the acceleration due to gravity, *g*.

g = ... unit ....**[2]**

(c) **(i)** The graph does not pass through the origin. Suggest one way in which this may have come about, and what effect it would have on the recorded values.

[2]

(ii) Explain whether this source of systematic error would affect the value of *g* obtained as in **(b)(iii)**.

[2]

[Total: 15]

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Turn over for question 14

14 This question is about the article *Can we measure the size of atoms?*

(a) **(i)** The measurement for the diameter of the oil droplet on the loop of wire is 0.5 ± 0.1 mm. Calculate the percentage uncertainty in this measurement.

percentage uncertainty = ... % **[2]**

(ii) A ruler is used to measure the 'patch' on the water. The average value for its diameter is 100 ± 5 mm.
State and explain whether this measurement, or the one in **(a)(i)**, gives the greater uncertainty to the final result.

[2]

(b) Show how the two equations

Volume of oil drop $V = \frac{4}{3}\pi r^3$ where r is the radius of the oil droplet.	Area of patch on water $A = \pi R^2$ where R is the radius of the patch.

can be combined to form the equation

$$t = \frac{4r^3}{3R^2}$$

where t is the thickness of the patch of olive oil.

[3]

(c) **(i)** The diameter of the oil drop is given as 0.5 ± 0.1 mm.
Explain why the value for the radius r can be quoted as 0.25 ± 0.05 mm.

[1]

(ii) Using $r = 0.25$ mm for the radius of the oil drop and $R = 50$ mm for the radius of the patch of oil on the surface of the water, show that the thickness t of the oil patch is about 8×10^{-9} m. Hence calculate the diameter x of an **atom**.

x = ... m **[3]**

(iii) Calculate the percentage uncertainty in the value for the diameter x of the atom caused by the uncertainty in the measurement of the radius r of the oil drop.
Give your answer to an appropriate number of significant figures.

percentage uncertainty = ... % **[3]**

[Total: 14]

[Section C Total: 37]

END OF QUESTION PAPER

ADDITIONAL PAGE

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

ADDITIONAL PAGE

ADDITIONAL PAGE

OCR
RECOGNISING ACHIEVEMENT

Friday 20 January 2012 – Morning

AS GCE PHYSICS B (ADVANCING PHYSICS)

G492 Understanding Processes/Experimentation and Data Handling

INSERT

G411650112

Duration: 2 hours

INSTRUCTIONS TO CANDIDATES

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

INFORMATION FOR CANDIDATES

- This document consists of **4** 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. Dot plots

When collecting data which is liable to some variation, for example using a stopwatch to time an event, it is good practice to make a simple, quick plot of the values. One method is a *dot plot*, which can produce results like those in Fig. 1.

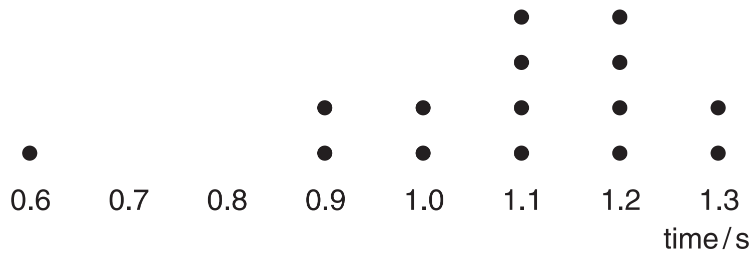

Fig. 1

With a dot plot, you can look at the distribution of values and identify possible outliers. Excluding the outlier, you can find the **mean** of the distribution and the **spread**, or **uncertainty** about the mean, which is half of the range.

As the outlying reading of 0.6 s in Fig. 1 is more than twice the spread from the mean of the remaining measurements, it is significantly different, and should be investigated further. Measuring time with a stopwatch is subject to both systematic error and uncertainty, and it would be important to consider how this variation could have arisen.

2. Measuring *g* by freefall

A direct measurement of *g*, the acceleration due to gravity, can be made by timing an object in freefall. An example of the method using standard school equipment is shown in Fig. 2. The break-to-start and break-to-stop contacts are connected to an electronic timer.

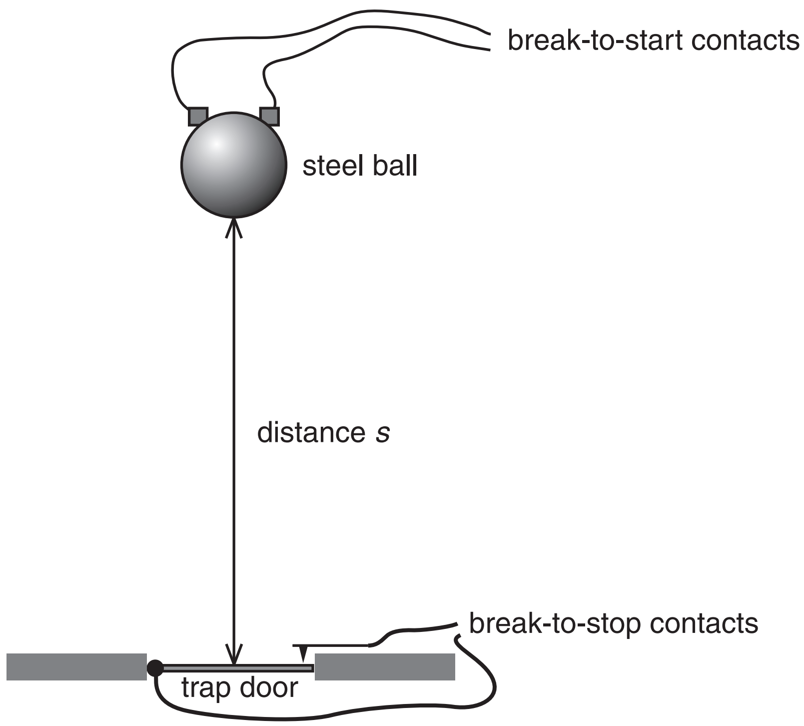

Fig. 2

As the steel ball bearing is released, the electronic timer starts. The ball falls a distance *s* before it hits a hinged metal 'trap door'. The trap door opens, breaks the circuit and stops the timer. The time *t* can be measured to the nearest 0.01 of a second and the distance *s* is measured with a tape measure to the nearest centimetre. This procedure can be repeated to give a mean time *t* for this value of *s*.

The values of *t* and *s* can be substituted into the equation $s = ut + \frac{1}{2}at^2$ to find the acceleration. However, it is best not to rely upon the mean time *t* for one particular distance *s*. A more accurate and reliable value for *g* can be obtained by taking measurements at different values of *s* and then plotting a suitable straight line graph. Such a graph may also reveal any systematic errors in the experiment.

A set of readings obtained in this way is given in the table below.

s / m	mean *t* / s
0.40	0.27
0.50	0.31
0.60	0.34
0.70	0.38
0.80	0.41
0.90	0.43
1.00	0.45
1.20	0.50

3. Can we measure the size of atoms?

The English physicist Lord Rayleigh (Fig. 3) won the Nobel Prize in 1904. He made an estimate of the size of an atom by measuring the maximum spread of a tiny drop of olive oil placed on a clean water surface. Lord Rayleigh knew that the oil molecule consisted of chains of atoms. He expected the oil to spread until it was one molecule thick and could not spread any more. Chemical knowledge about the nature of olive oil suggested that the oil molecules stand on end, with one end at the water surface. His estimate has since been verified with alternative measurements.

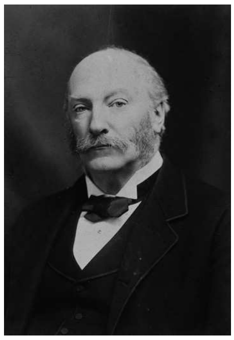

FIg. 3

This intriguing experiment is easily recreated in the classroom. In this experiment a very small drop of oil is placed into a tray of water. The oil spreads out on top of the water. It is straightforward to measure this 'patch' of oil and using various assumptions it is possible to calculate a value for the approximate length of an oil molecule.

This classic experiment can be set up as shown in Fig. 4.

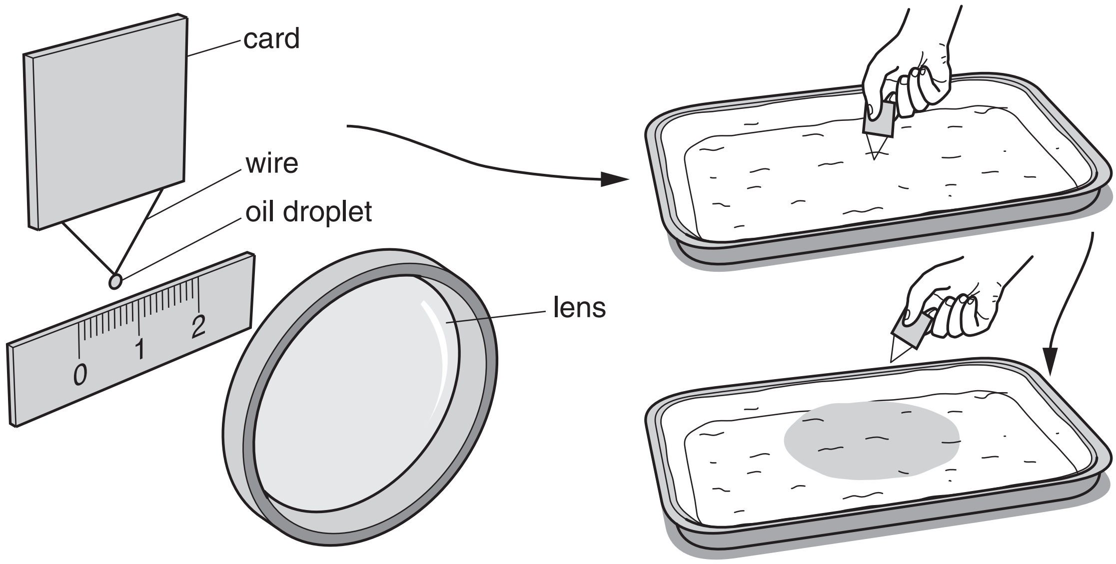

Fig. 4

A large tray filled with clean water is lightly dusted with a very fine white powder. A loop of very thin wire, mounted onto card, is dipped into olive oil and removed to form a very small droplet of the oil. The diameter of the droplet can be measured by placing it against a finely graded rule and viewing it through a magnifying glass. Ideally the diameter will be about 0.5 mm, with a likely uncertainty of ± 0.1 mm. When this droplet of oil is placed onto the water it spreads out across the surface in a roughly circular fashion. This can be seen as the powder is pushed back leaving a central clear patch. The diameter of this circular patch, typically of the order of about 100 mm, can be measured with a ruler to within 5 mm. The following calculations can be made to give a value of the approximate size (diameter) of an atom to a reasonable order of magnitude.

Volume of oil droplet $V = \frac{4}{3}\pi r^3$ where r = radius of oil droplet.

The volume of the drop of oil stays the same when it spreads out on the surface of the water and the area of the circular patch, $A = \pi R^2$, where R = radius of patch. This allows the thickness of the circular patch to be calculated.

The oil spreads out as far as it can until the patch is 1 molecule thick. Dividing the volume of the oil drop by the area of the patch will give a value for the length of a molecule. The olive oil molecule is known to have a length equal to 12 atom diameters. The value for the length of the molecule divided by 12 will give a reasonable estimate for the size of an atom.

END OF ARTICLE