OCR

Monday 9 June 2014 – Morning

AS GCE PHYSICS B (ADVANCING PHYSICS)

G492/01   Understanding Processes/Experimentation and Data Handling

Duration: 2 hours

Candidate forename		Candidate surname	

Centre number					Candidate number				

INSTRUCTIONS TO CANDIDATES

* The Insert will be found inside 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 lined 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.

Turn over

Answer **all** the questions.

SECTION A

1 Here is a list of units.

$$\text{kg m s}^{-1} \qquad \text{J s}^{-1} \qquad \text{kg m}^2\text{s}^{-2} \qquad \text{J m} \qquad \text{kg m s}^{-2}$$

(a) Which unit is equivalent to a watt? .... [1]

(b) Which unit is equivalent to a newton? .... [1]

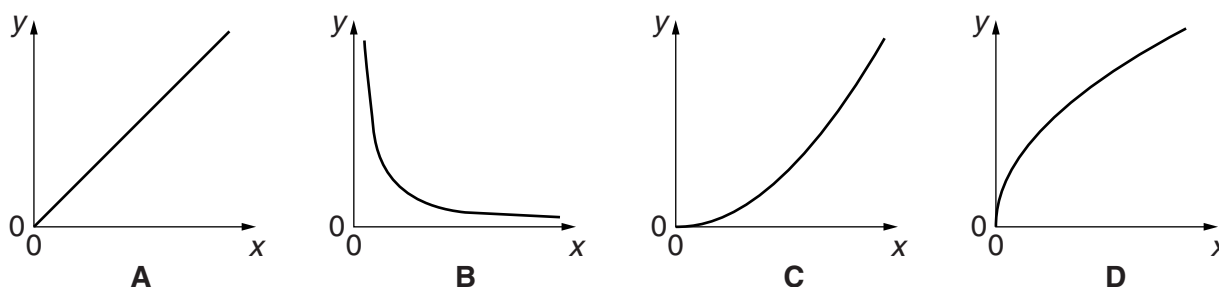**2** Fig. 2.1 shows four graphs, **A**, **B**, **C** and **D**.

Fig. 2.1

Which graph best fits the situation when the *y*- and *x*-axes represent the two quantities given in each case below?

Each graph may be used once, more than once, or not at all.

(a) *y*-axis: the period of a wave
x-axis: its frequency

.... [1]

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

.... [1]

(c) *y*-axis: the separation of interference fringes on a distant screen after light passes through two slits
x-axis: the distance between the two slits and the screen

.... [1]

(d) *y*-axis: the distance travelled by an object moving from rest with constant acceleration
x-axis: the time taken

.... [1]

3 Here is a list of orders of magnitude.

$$10^{-6} \qquad 10^{-4} \qquad 10^{-2} \qquad 1 \qquad 10^2 \qquad 10^4$$

(a) Choose the value closest to the height, in m, of an adult human being.

.... **[1]**

(b) Choose the value closest to the area of cross-section, in m^2, of your finger.

.... **[1]**

4 Which one of the following comparisons between red light of wavelength 650 nm and violet light of wavelength 400 nm is correct?

Put a tick (✓) in the box after the correct statement.

The red light has the higher frequency. ☐

The red light will diffract though a wider angle when passing through a narrow slit. ☐

The red light travels slower in a vacuum. ☐

The interference maxima formed on a distant screen by light passing through two narrow slits will be closer together for red light. ☐

[1]

Turn over

5 Fig. 5.1 shows a wave at an instant in time with eight positions along the wave labelled **A**–**H**.
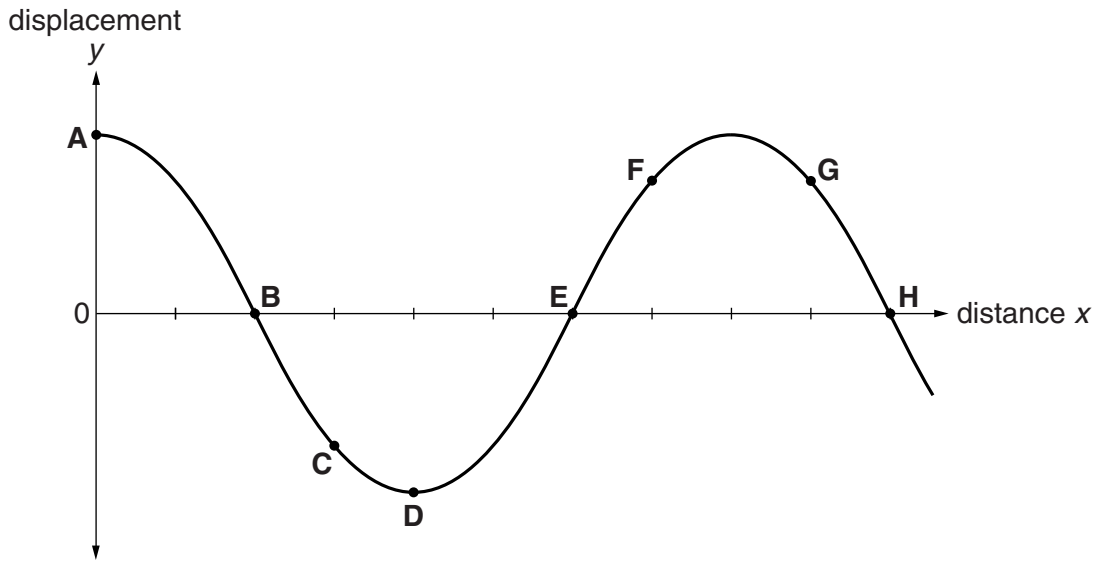
Fig. 5.1

(a) Write down the letters for **two** positions where the wave has the same phase.

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

(b) The phasor for the wave at position **A** at this instant is shown in Fig. 5.2.
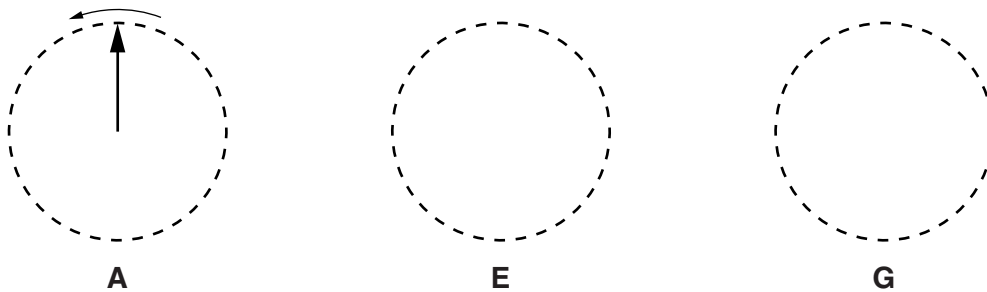

Fig. 5.2

Sketch phasors for points **E** and **G** in the appropriate places in Fig. 5.2. **[2]**

(c) Three waves, each with the same amplitude and wavelength, can superpose to give a resultant amplitude of zero.
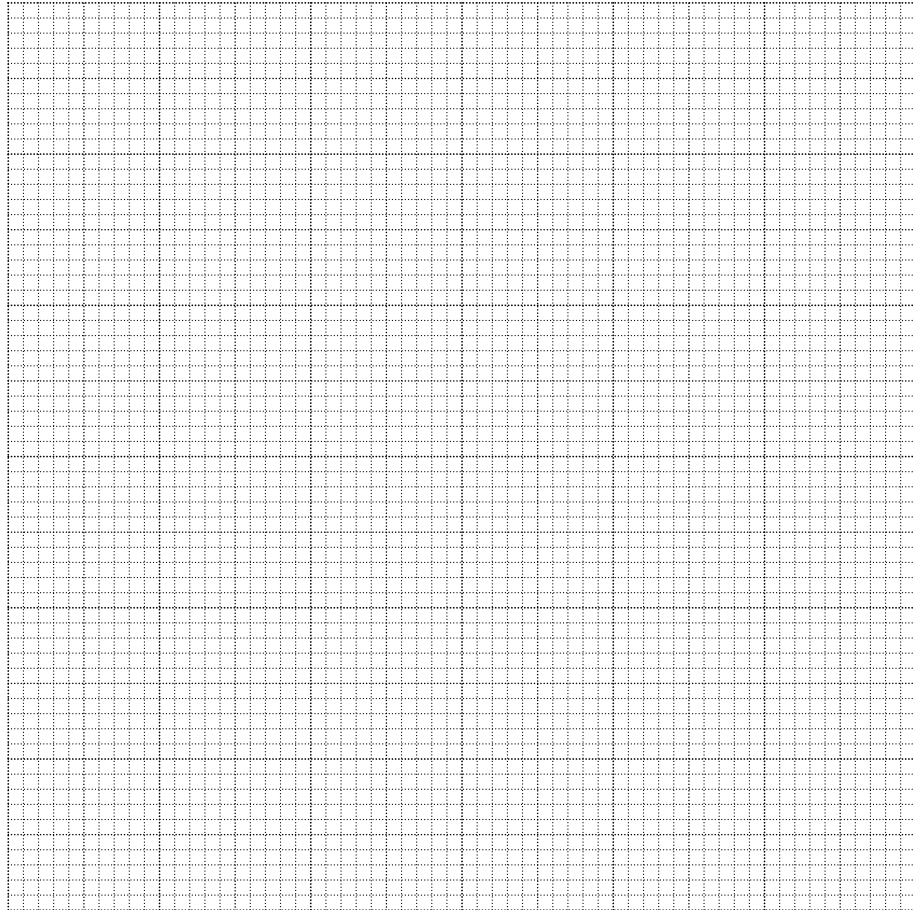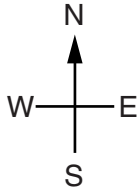Complete the phasor diagram below to show this.

[1]

6 An aircraft is in level flight through still air.

It has the following components of velocity:
  north-south: $50\,\text{m s}^{-1}$ towards the south
  east-west: $35\,\text{m s}^{-1}$ towards the east

(a) Using a suitable scale, draw these components on the grid below.
Hence or otherwise find the speed and direction of flight of the aircraft.

N
W———E
S

speed = ... m s^{-1}

direction = ...
                                                          [4]

(b) A wind later acts upon the aircraft, changing the aircraft's direction so that it travels due south.
Deduce the speed and direction of this wind.

speed = ... m s^{-1}

direction = ...
                                                          [2]

Turn over

7 Light of wavelength 590 nm is incident on a diffraction grating as shown in Fig. 7.1. Three orders of diffraction are produced.
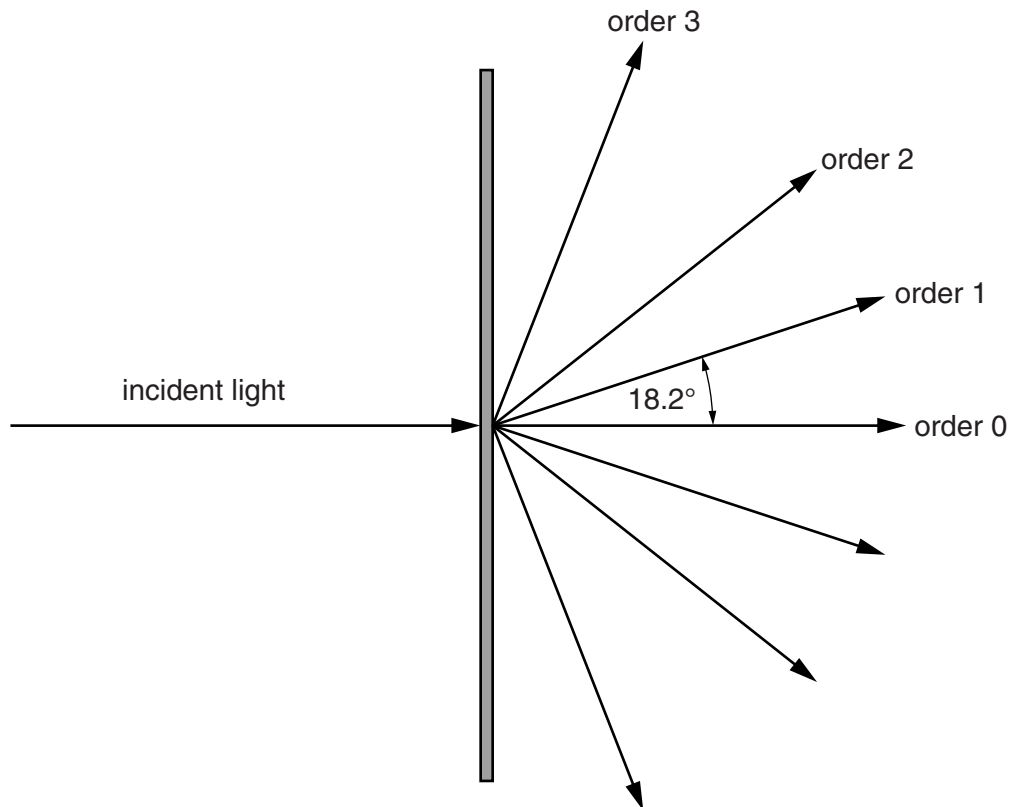

Fig. 7.1

The first-order angle of diffraction is 18.2°.

(a) Show that the separation of lines in this grating is about 2 μm.

[2]

(b) Calculate the longest wavelength of light which will produce three orders of diffraction with this grating.

[1]

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Question 8 begins on page 8

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SECTION B

8 One alternative energy project involves extracting energy from tidal flows of water.

The test unit, shown in Fig. 8.1, has three turbines on a triangular frame of side 35 m. The unit is fixed to the sea bed and is completely submerged at all times. The turbines turn to face the direction of water flow.
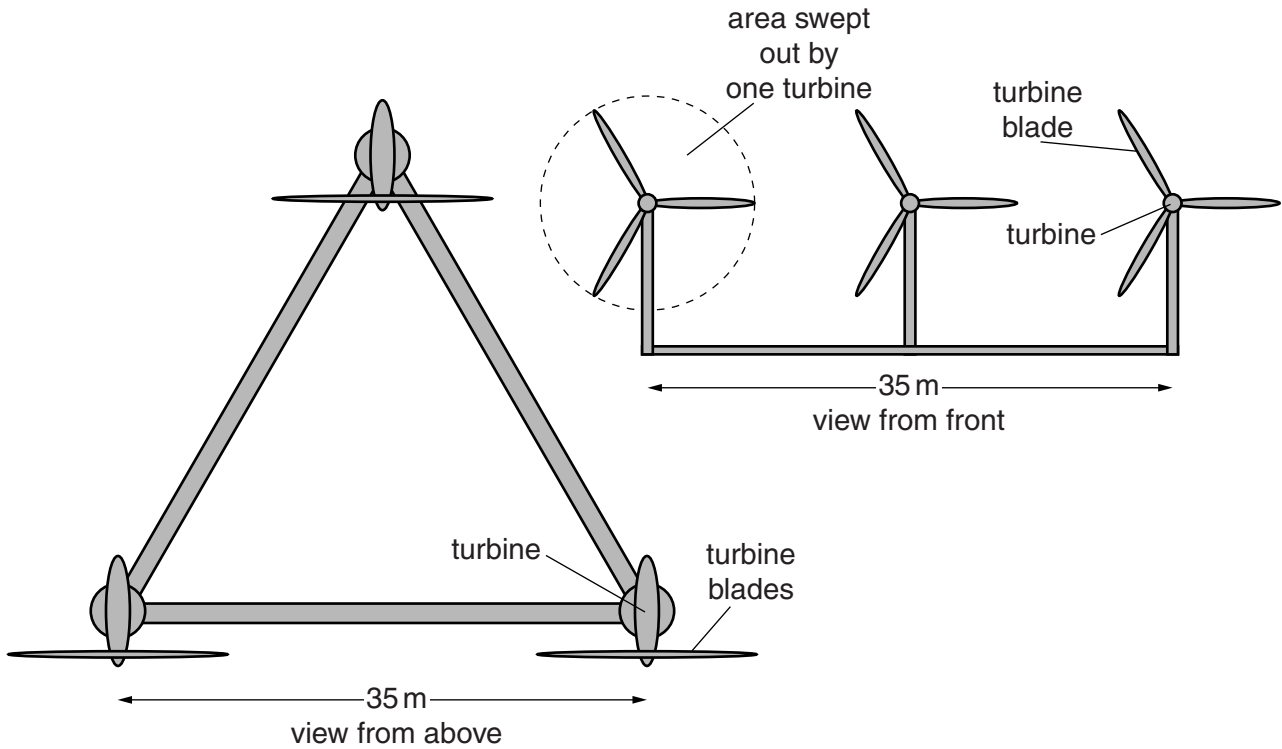

Fig. 8.1

(a) (i) The diagrams are drawn to scale.
Use measurements from the diagram to show that the area swept out by all three turbines is about 500 m².

[2]

(ii) The speed of the water moving into the turbines is $2.5\,\text{m s}^{-1}$.

Show that the mass of water passing through an area of $500\,\text{m}^2$ in one second is about $1 \times 10^6\,\text{kg}$.

density of sea water $= 1030\,\text{kg m}^{-3}$

[2]

(b) (i) Use the answer to **(a)(ii)** to show that the total kinetic energy of the water passing into the three turbines in one second is about $4\,\text{MJ}$.

[1]

(ii) The electrical energy output of the test unit is $1.2\,\text{MJ}$ per second under the conditions above.

Suggest and explain **two** reasons for the difference between this value and the answer to **(b)(i)**.

✏️ *In your answer, distinguish clearly between the two reasons you suggest and link each reason to its explanation.*

[4]

[Total: 9]

Turn over

9 This question is about the quantum behaviour of photons and electrons.

(a) An X-ray photon has an energy of 3.0×10^{-15} J.

    (i) Calculate the wavelength of these X-rays. Express your answer in pm.

$$c = 3.0 \times 10^8 \, \text{m s}^{-1}$$
$$h = 6.6 \times 10^{-34} \, \text{J s}$$

wavelength = ... pm **[2]**

    (ii) An X-ray generator of input power 12 kW transfers 0.50 % of the input energy into photons of energy 3.0×10^{-15} J.

Calculate the number of photons emitted each second.

number per second = ... s^{-1} **[2]**

    (iii) Suggest why the X-ray generator in **(ii)** has to be fitted with a powerful cooling device.

[1]

(b) The wavelength associated with electrons of mass m and speed v is

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

 (i) The electrons used in an electron diffraction experiment each have a kinetic energy of 7.0×10^{-17} J.

Show that the electron speed v is about $1 \times 10^7 \, \text{m s}^{-1}$.

$m = 9.1 \times 10^{-31}$ kg

[2]

 (ii) Show that these electrons show wave behaviour corresponding to a wavelength of about 60 pm.

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

[1]

 (iii) Explain what would happen to this wavelength if the kinetic energy of the electrons was reduced by a factor of 4.

.

[2]

[Total: 10]

Turn over

10 A flautist (Fig. 10.1) produces notes on the flute by blowing near one end. This produces stationary waves in the flute. In this question, the flautist uses her fingers to close the holes so that the flute is treated as a tube open at both ends.

Fig. 10.1

(a) Any standing wave produced in the flute has a displacement antinode at each end.

   (i) Calculate the **lowest** (fundamental) frequency that can be produced.

   speed of sound in air = 340 m s^{-1}
   length of flute = 66 cm

   frequency = ... Hz **[2]**

   (ii) By blowing differently, a note of three times the fundamental frequency can be produced.

   On the sectional diagram of a flute in Fig. 10.2, indicate the positions of displacement nodes and antinodes for this higher note. Mark each node **N** and each antinode **A**.

not to scale

Fig. 10.2

[3]

(b) During a long concert, the flute and the air inside it become warmer, making the speed of sound higher. To compensate for this, the flautist must adjust the length of the flute.

(i) Explain whether the flute needs to be made shorter or longer to keep it in tune.

[2]

(ii) The speed of sound v in air depends on the air temperature according to the relationship

$$v = k \sqrt{T}$$

where k is a constant and T is the absolute temperature of the air in kelvin, obtained from

T in kelvin = temperature in °C + 273.

In a concert, the air temperature inside the flute can rise from 10 °C to 25 °C.

Calculate the percentage change in the frequency of the note that this temperature rise would produce if the player did not adjust the length of the flute.

change in frequency = ... % **[3]**

[Total: 10]

Turn over

11 This question is about a person diving into a swimming pool from a springboard.
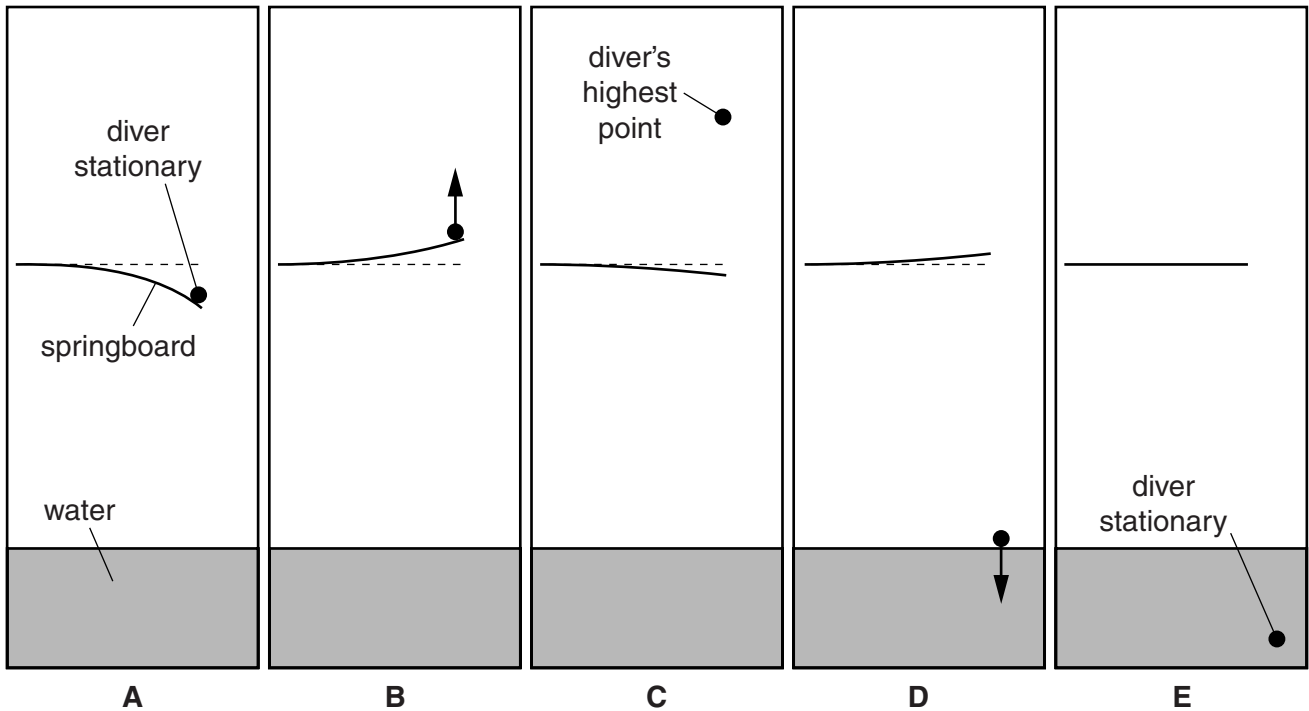Fig. 11.1 shows the sequence of events.

Fig. 11.1

In this simplified model, the diver is shown as a point and the horizontal outwards component of the diver's velocity is ignored, so only vertical motion is shown.

The diver jumps vertically at the end of the springboard and then lands on it, bending it downwards to the position shown in **A**. This is the time *t* = 0. The board then accelerates the diver upwards as it springs back, launching the diver upwards (time **B**). On leaving the board, the diver is in free-fall, rising to his highest point (time **C**), until he hits the water (time **D**). He then decelerates to a stop (time **E**).

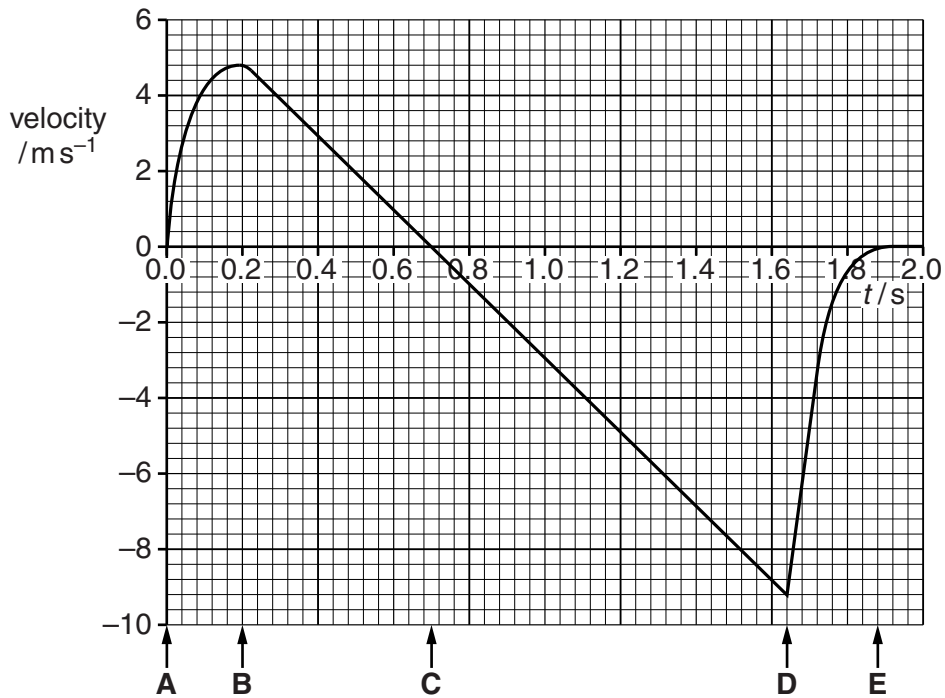Fig. 11.2 shows the velocity-time graph for the diver's vertical motion with the times **A** to **E** shown.

Fig. 11.2

(a) Explain how the graph of Fig. 11.2 shows that the force exerted on the diver by the springboard between times **A** and **B** is greatest at the start.

[2]

(b) Explain how the graph shows that:

(i) The diver leaves the board at time **B**,

[1]

(ii) The diver is at his highest point at time **C**.

[1]

Turn over

(c) (i) State what the area between the graph and the time axis between **B** and **C** represents.

[1]

(ii) Use data from Fig. 11.2 to calculate the distance fallen by the diver between **C** and **D**.

Show your working clearly.

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

(d) Use information from Fig. 11.2 to describe how the resultant force upon the diver changes between **D** and **E**.

Suggest why the force changes in this way.

[2]

[Total: 9]

Question 12 begins on page 18

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SECTION C

The questions in this section are based on the material in the insert.
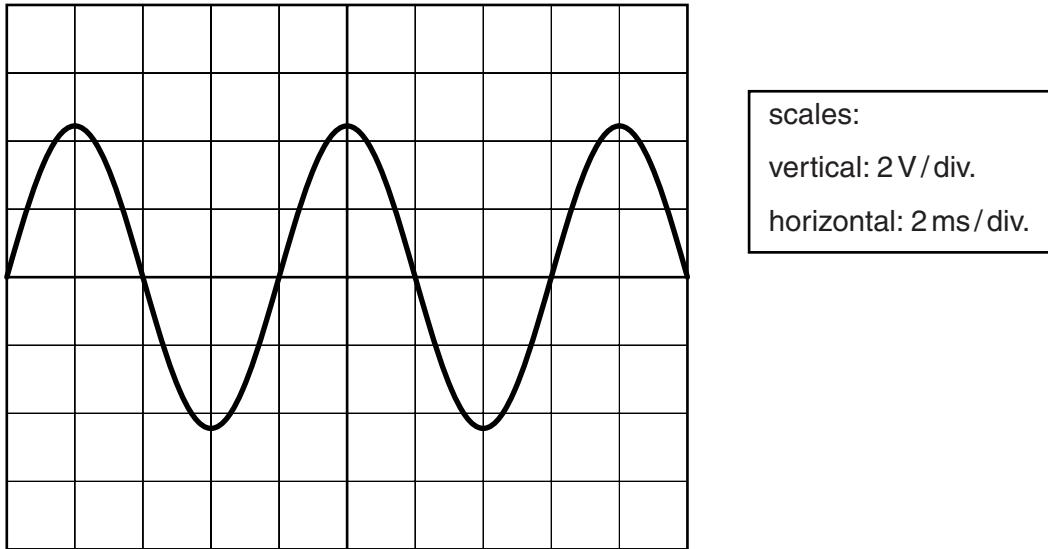
12 This question is about the article *Oscilloscopes*.

scales:

vertical: 2 V / div.

horizontal: 2 ms / div.

Fig. 12.1

(a) (i) Use data from Fig. 12.1 to calculate a value for the amplitude of the signal.

amplitude = ... V **[1]**

(ii) Use data from Fig. 12.1 to calculate the frequency of the signal shown.

frequency = ... Hz **[2]**

(b) A CRO has time-base settings ranging from 20 ns / div to 5 s / div. It is possible to take a reading from the screen of this CRO to the nearest 0.1 division.

State the best possible time-resolution of this CRO.

resolution = ... s **[1]**

(c) Describe and explain one advantage and one disadvantage of a CRO as a method of displaying changing voltages.

[2]

(d) Over the past 20 years, CROs have been largely replaced by digital storage oscilloscopes.

Describe and explain developments that were necessary for this change to happen.

[4]

[Total: 10]

13 This question is about the article *Powering electric cars.*

(a) Table 1 in the article (reproduced below) compares three different types of battery.

Battery type	Max energy density/$Wh\,kg^{-1}$	Percentage energy efficiency in discharging	Battery cost per kWh capacity
lead-acid	35	85	£65
NiMH	80	80	£320
lithium-ion	200	90	£500

Table 1

   (i) Modern electric vehicles have batteries of 24 kWh capacity.

   Show that a lead-acid battery of this capacity has a mass of over half a tonne (1 tonne = 1000 kg).

[2]

   (ii) Explain why this would be a disadvantage for a car, but an advantage for a forklift truck.

   ✎ *In your answer, you should describe in detail the physics of the disadvantage and advantage.*

[3]

(iii) NiMH batteries have the lowest efficiency in charging and discharging.

Use data from Table 1 to calculate the energy dissipated per second in the battery when it delivers an output power of 50 kW.

energy dissipated in one second = ... J **[2]**

(iv) Explain why this energy dissipation is a significant disadvantage for NiMH batteries.

[2]

Turn over

(b) Table 2 in the article has performance data for different electric cars. The performance data for the Peugeot Ion car are reproduced below.

Mass /kg	Maximum power/kW	Charging time/h	Time/s to accelerate from 0–27 m s^{-1}	Battery capacity /kWh
1170	49	7	15.4	16

(i) Show that the mean resultant force on the Peugeot Ion while accelerating from 0–27 m s^{-1} is about 2 kN.

[2]

(ii) Calculate the mean power required to accelerate this car from 0–27 m s^{-1}.

Make your method clear.

mean power = ... W **[2]**

(iii) Peugeot state the range of the Ion is 120 km at a cruising speed of 80 km/h for a battery charged to 16 kWh.

Show that these data imply an output power much less than the 49 kW given in the table.

[2]

[Total: 15]

14 This question is about the article *Simple pendulum experiment*.

(a) A student obtains the following data for a pendulum of length 30 cm.

Time for 10 oscillations/s									
10.9	10.9	11.0	11.0	10.9	11.0	11.0	11.1	10.9	11.0

(i) The student uses a stopwatch which records time to the nearest 0.01 s.

She decides to quote the data to one decimal place.

Give a reason for this choice.

[1]

(ii) State why measuring the time for 10 oscillations instead of one improves the quality of the results.

[1]

(iii) For the data above, the student correctly writes:

mean time for 10 oscillations = 11.0 ± 0.1 s.

Explain why the uncertainty in the period *T* is ± 0.01 s.

[1]

(iv) Show that a period $T = 1.10 \pm 0.01\,\text{s}$ leads to a value of

$$T^2 = 1.21 \pm 0.02\,\text{s}^2.$$

[2]

(b) A second student times 10 oscillations for the range of lengths given in the table. He does not repeat the timing at each length.

.

L/m	Time for 10 oscillations/s	T/s	T^2/s^2
0.10	6.0		
0.15	7.9		
0.20	9.2	0.92	0.85
0.25	10.0	1.00	1.00
0.30	11.2	1.12	1.25
0.35	11.7	1.17	1.37
0.40	12.5	1.25	1.56

(i) Complete the first two rows of the table, and use those data to complete the graph opposite. **[2]**

(ii) Explain why the gradient of this graph should be

$$\frac{4\pi^2}{g}$$

given that

$$T = 2\pi\sqrt{\frac{L}{g}}$$

[2]
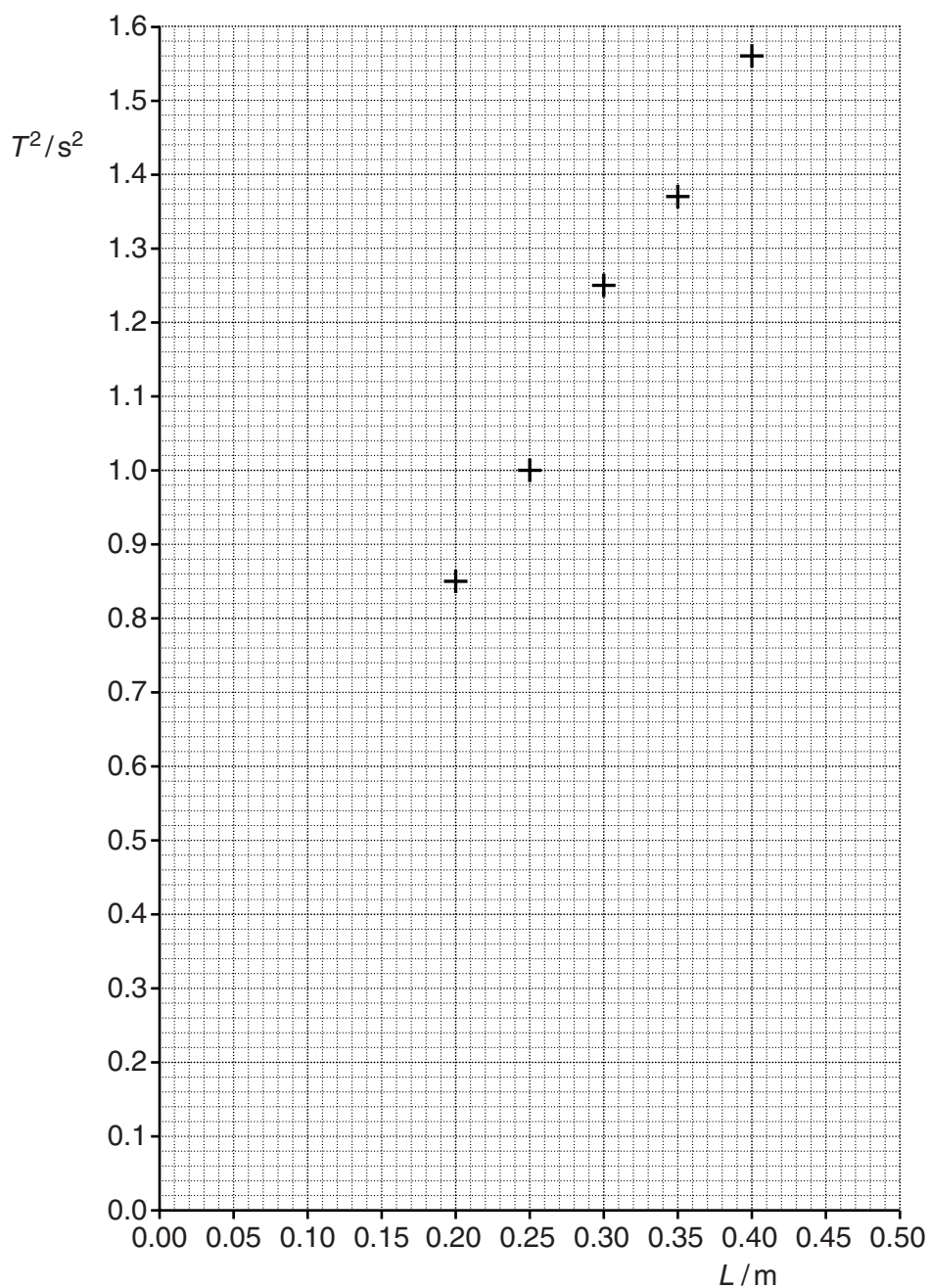
(iii) Use the graph to determine a value for *g*. Show your working clearly.

g = ... m s^{-2} **[3]**

Turn over

(c) A third student suggests that the experiment could be improved by using pendulums of lengths between 2 m and 3 m.

Discuss the advantages and disadvantages of this suggestion.

[3]

[Total: 15]

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional answer space is required, you should use the following lined pages. The question number(s) must be clearly shown in the margins.

OCR

Monday 9 June 2014 – Morning

AS GCE PHYSICS B (ADVANCING PHYSICS)

G492/01   Understanding Processes/Experimentation and Data Handling

INSERT

Duration: 2 hours
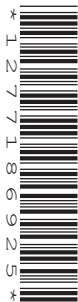
INSTRUCTIONS TO CANDIDATES

*   This Insert contains the article 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 recycled. Please contact OCR Copyright should you wish to re-use this document.

1 Oscilloscopes

For many years cathode-ray oscilloscopes (CROs) were the only way to display rapidly changing voltages. The voltage input to a CRO moves a beam of electrons ('cathode rays') vertically on the screen, while an electronic circuit simultaneously moves the beam sideways at a steady rate. Once the trace reaches the end of the screen, the circuit moves the beam quickly back to the start and waits for the signal to reach the same phase before starting again. This ensures that the next trace exactly follows the pattern of the previous one. The glowing phosphor on the screen and the persistence of vision of the user give a steady graph of the voltage-time signal as shown in Fig. 1.

trace

gridlines marked on the screen
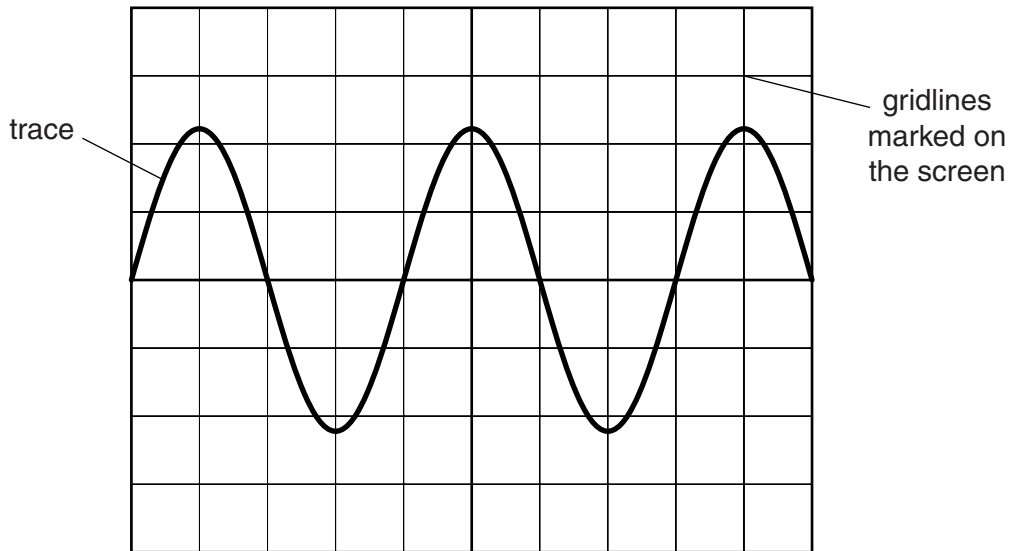
Fig. 1

The *x*-axis is called the time base and each square (division) represents a unit of time. The unit of measurement on the *y*-axis is volts per division (volts/div). Values for the amplitude, time period and frequency of the signal can easily be obtained, though the screen display has limited precision.

The CRO can display a great range of voltages from microvolt pulses from a heart monitor to hundreds of volts from the mains. The low inertia of the electron beam – the 'pointer' of this meter – means that very rapid changes can be plotted. Although the oscilloscope has excellent time resolution, only repeating signals can be displayed.

In recent years, developments in electronics have transformed oscilloscopes. Large, high-speed computer memories allow great quantities of voltage data to be stored and accessed rapidly, and sensors with rapid response times give digital storage oscilloscopes time resolutions to compete with CROs. Just as the old electron-beam televisions and computer monitors have been replaced by LCD and plasma screens, so CROs have been replaced by digital storage oscilloscopes in laboratories.

2 Powering electric cars

Electric vehicles, driven by electric motors powered by batteries, were first developed before internal combustion engines. However, their low speeds and short ranges meant that the introduction of petrol-driven vehicles drove them from the streets in the 1920s.

In recent years, the environmental damage caused by burning fossil fuels led to new research into electric vehicles. They had never gone away completely: milk floats have silently carried milk deliveries around towns and cities in the very early morning at 10 mph, and many factories and stores use electric forklift trucks to lift and move goods, where the very heavy lead-acid battery in the base of the truck is a distinct advantage.

Since the 1990s nickel-metal hydride (NiMH) batteries have been used in some vehicles. These have several advantages over lead-acid batteries, but have a tendency to self-discharge, where charge flows within the battery itself. This self-discharge becomes worse with an increase in temperature.

A more recent development is the lithium-ion battery, used in most modern electric cars. These do not have the self-discharge problems of the NiMH batteries, but are more expensive.

Table 1 compares these three types of battery.

Battery type	Max energy density/Wh kg^{-1}	Percentage energy efficiency in discharging	Battery cost per kWh capacity
lead-acid	35	85	£65
NiMH	80	80	£320
lithium-ion	200	90	£500

Table 1

Performance data for electric cars using lithium-ion batteries are shown in Table 2.

Car	Mass/kg	Maximum power/kW	Charging time /h	Time/s to accelerate from 0–27 m s^{-1}	Battery capacity / kWh
Ford Focus Electric	1640	107	4	9.5	23
Nissan Leaf	1540	80	7	11.9	24
Peugeot Ion	1170	49	7	15.4	16
Volvo Electric C30	1650	83	7	11.0	24

Table 2

Electric cars are rather expensive. Continued developments in electric motor and battery technology, as well as pressure from governments, are likely to make electric cars more and more common in the future.

3   Simple pendulum experiment

You may wish to try out this experiment in the laboratory so that you know in advance how the experiment works, how to analyse the data collected and what the uncertainties are. The simple arrangement of Fig. 3 can be used to carry out the practical task.
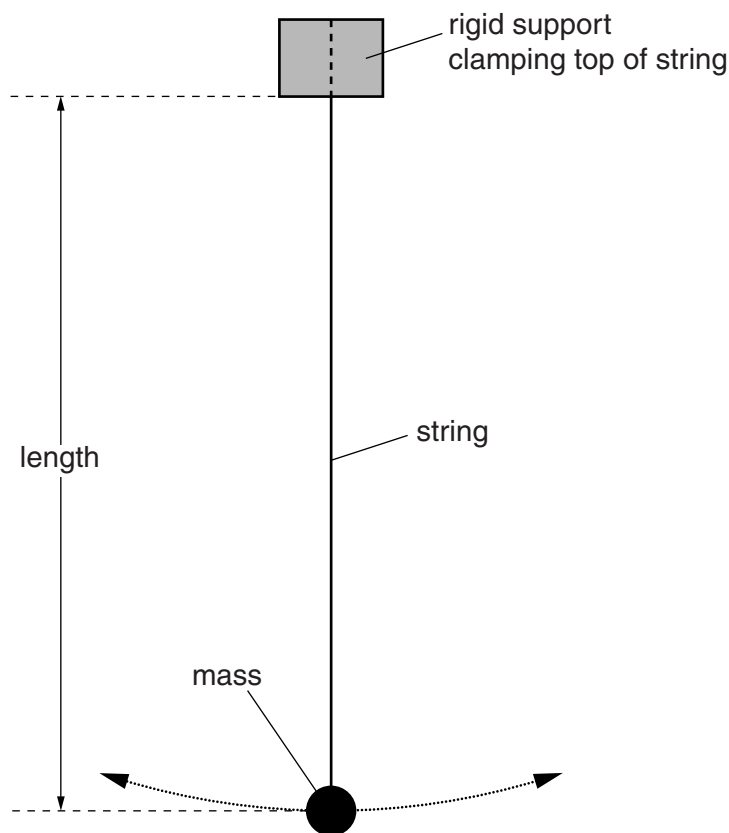

Fig. 3

A simple pendulum consists of a mass suspended from a fixed point by a string. If set into motion with care, the mass oscillates about the rest position. The time taken for one complete oscillation is called the period, *T*. For small amplitude oscillations the relationship between the period *T* and length *L* of the pendulum is given by

$$T = 2\pi\sqrt{\frac{L}{g}}.$$

You are not required to know the theory for this equation in AS Physics.

By timing an appropriate number of oscillations of pendulums of different lengths you can determine a value for *g*, the acceleration due to gravity.