AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname ____________________

Forename(s) ____________________

Candidate signature ____________________
I declare this is my own work.

AS
PHYSICS
Paper 1

Tuesday 12 May 2020 Morning Time allowed: 1 hour 30 minutes

Materials
For this paper you must have:
- a pencil and a ruler
- a scientific calculator
- a Data and Formulae Booklet.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 70.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
TOTAL	

J U N 2 0 7 4 0 7 1 0 1

IB/M/Jun20/E8

7407/1

Answer **all** questions in the spaces provided.

0 1 One strong interaction that occurs when two high-energy protons collide is

$$p + p \rightarrow p + \pi^{+} + \pi^{-} + \mathbf{X}$$

0 1 . 1 Determine the lepton number, strangeness and charge of particle **X**.

[2 marks]

lepton 0 + 0 → 0 + 0 + 0 + 0

Strange 0 + 0 → 0 + 0 + 0 + 0

charge +1e + 1e → +1e + 1e −1e + 1e

lepton number = 0

strangeness = 0

charge = +1e

0 1 . 2 Identify particle **X**.

[1 mark]

proton

0 1 . 3 A possible decay of a negative pion is

$$\pi^- \rightarrow e^- + \mathbf{Y}$$

What is particle **Y**?
Tick (✓) **one** box.

[1 mark]

$\bar{\nu}_e$ ☑

ν_e ☐

π^0 ☐

${}^1_0n$ ☐

Question 1 continues on the next page

0 1 . 4 Some subatomic particles are classified as hadrons. There are two classes of hadrons.

Discuss the nature of hadrons.
Your answer should include:

- the identifying properties of hadrons
- the structure of a hadron in each class
- a discussion of the stability of free hadrons.

[6 marks]

Hadrons are particles that interact via the strong nuclear force. They are composed of quarks. ~~either in~~

The two classes mentioned are mesons and baryons. Mesons are structured in quark - antiquark pairs, such as the π^+ which is $u\bar{d}$. Baryons are are make up of three quarks.

An example of a free hadron is a proton. This is the only stable free baryon. An example of free baryon decay would be a neutron decaying into a proton. An example of free meson decay would be kaon decay into pions. See below the equations for these free hadron decays

Do not write outside the box

$n \rightarrow p + e^- + \bar{\nu}_e$

$K^+ \rightarrow \pi^- + \pi^0$

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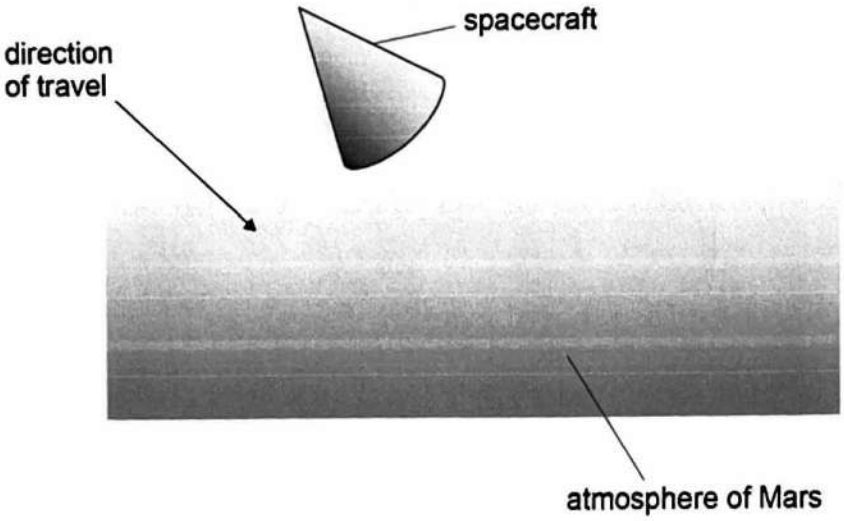
Turn over for the next question

Do not write outside the box

0 2 A spacecraft entering the atmosphere of Mars must decelerate to land undamaged on the surface.

Figure 1



0 2 . 1 **Figure 1** shows the spacecraft of total mass 610 kg entering the atmosphere at a speed of 5.5 km s^{-1}.

Calculate the kinetic energy of the spacecraft as it enters the atmosphere.
Give your answer to an appropriate number of significant figures.

[3 marks]

$E_k = \frac{1}{2} m v^2$

$E_k = \frac{1}{2} \times 610 \times 5.5^2 \times {10^3}^2$

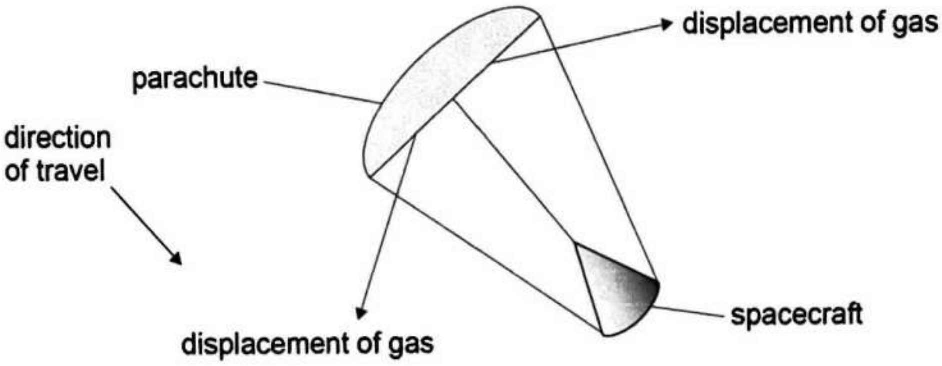
$= 9.23 \times 10^9$

kinetic energy = 9.2×10^9 J

0 2 . 2 A parachute opens during the spacecraft's descent through the atmosphere.

Figure 2 shows the parachute–spacecraft system, with the open parachute displacing the atmospheric gas. This causes the system to decelerate.

Figure 2



Explain, with reference to Newton's laws of motion, why displacing the atmospheric gas causes a force on the system **and** why this force causes the system to decelerate.

[4 marks]

The momentum of the displaced gas is changing. By newton's 2nd law, this requires a force. Therefore the gas exerts a ~~this~~ force on the parachute, and ~~this~~ there is a resistive force on the system. ~~This resistive force is~~ ~~the~~ The parachute is exerting a force on the gas according to newton's 3rd law.

The resistive force of the gas on the parachute is greater than the weight of the spacecraft, so there is a resultant force, and the system decellerates.

Question 2 continues on the next page

0 2 . 3 As the parachute–spacecraft system decelerates, it falls through a vertical distance of 49 m and loses 2.2×10^5 J of kinetic energy.
During this time, 3.3×10^5 J of energy is transferred from the system to the atmosphere.
The total mass of the system is 610 kg.

Calculate the acceleration due to gravity as it falls through this distance.

[3 marks]

KE lost = 2.2×10^5 J

49 m

3.3×10^5 J to atmosphere

$3.3 - 2.2 = 1.1 \times 10^5$ J Energy due to gravity.

$E_p = mgh$

$1.1 \times 10^5 = 610 \times g \times 49$

$g = 1.1 \times 10^5 / 610 \times 49$

acceleration due to gravity = 3.7 m s^{-2}

0 2 . 4 Dust from the surface of Mars can enter the atmosphere. This increases the density of the atmosphere significantly.

Deduce how an increase in dust content will affect the deceleration of the system.

[3 marks]

More dust means there is more particles to collide with, meaning a greater resistive force on the systems acceleration. Therefore there is a greater resultant force acting on the system, and therefore greater deceleration.

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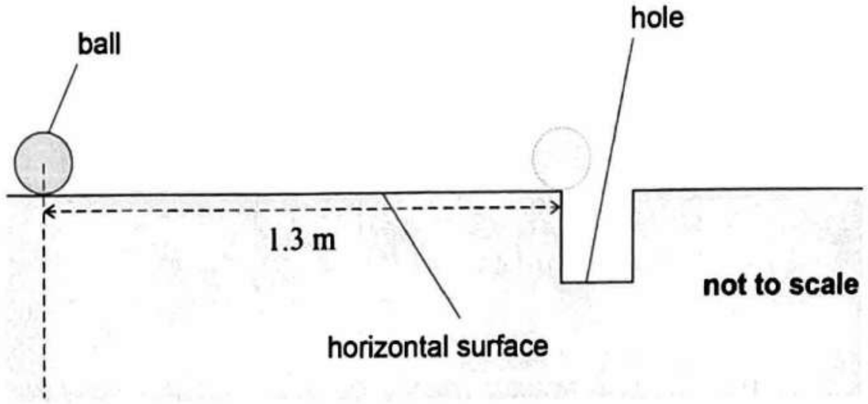
0 3 . 1 **Figure 3** shows a golf ball at rest on a horizontal surface 1.3 m from a hole.

Figure 3



A golfer hits the ball so that it moves horizontally with an initial velocity of $1.8\ \mathrm{m\,s^{-1}}$.
The ball experiences a constant deceleration of $1.2\ \mathrm{m\,s^{-2}}$ as it travels to the hole.

Calculate the velocity of the ball when it reaches the edge of the hole.

[2 marks]

suvat
↑
?

We have s, u, a. Need v: use $v^2 = u^2 + 2as$

$v^2 = 1.8^2 + 2 \times -1.2 \times 1.3$

$v^2 = $ ~~0.36~~ 0.12

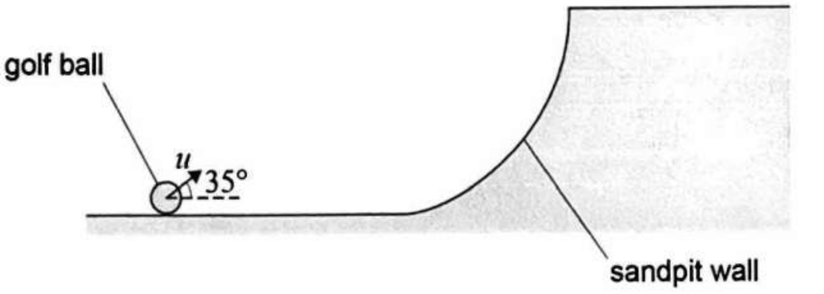
$v = $ ~~2.57 ms⁻¹~~ $0.346\ \mathrm{ms^{-1}}$

velocity = ~~0.6~~ 0.35 $\mathrm{m\,s^{-1}}$

Question 3 continues on the next page

0 3 . 2 Later, the golf ball lands in a sandpit. The golfer hits the ball, giving it an initial velocity u at 35° to the horizontal, as shown in **Figure 4**. The horizontal component of u is $8.8\ \mathrm{m\,s^{-1}}$.

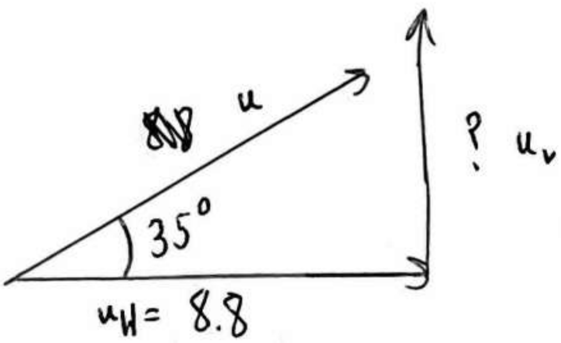
Figure 4



not to scale

Show that the vertical component of u is approximately $6\ \mathrm{m\,s^{-1}}$.

[1 mark]



use tan . . .

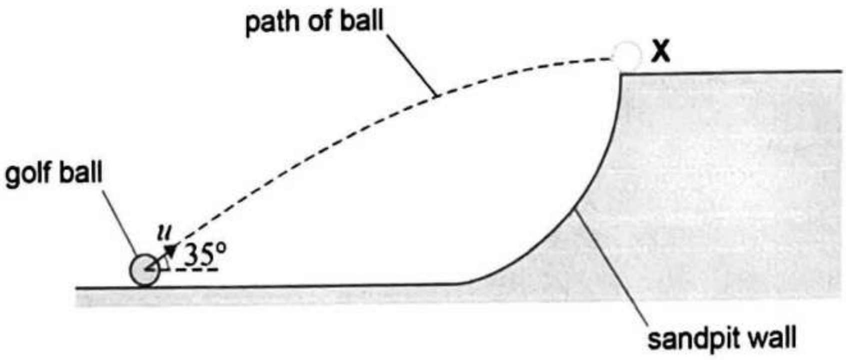
$$\tan 35 = \frac{u_V}{8.8}$$

$$u_V = \tan 35 \times 8.8$$

$$= 6.16\ \mathrm{ms^{-1}}$$

0 3 . 3 The ball is travelling horizontally as it reaches **X**, as shown in **Figure 5**.

Figure 5



not to scale

Assume that weight is the only force acting on the ball when it is in the air.

Calculate the time for the ball to travel to **X**.

[2 marks]

$u_v = 6.16\ ms^{-1}$

$a = -9.81\ ms^{-2}$

$t = ?$

$V_v = 0\ ms^{-1}$

$\frac{V-u}{t} = a$

$\frac{V-u}{a} = t \qquad t = \frac{-6.16}{-9.81}$

time = 0.63 s

0 3 . 4 Calculate the vertical distance of **X** above the initial position of the ball.

[2 marks]

now we need s;

$s = ut + \frac{1}{2}at^2$

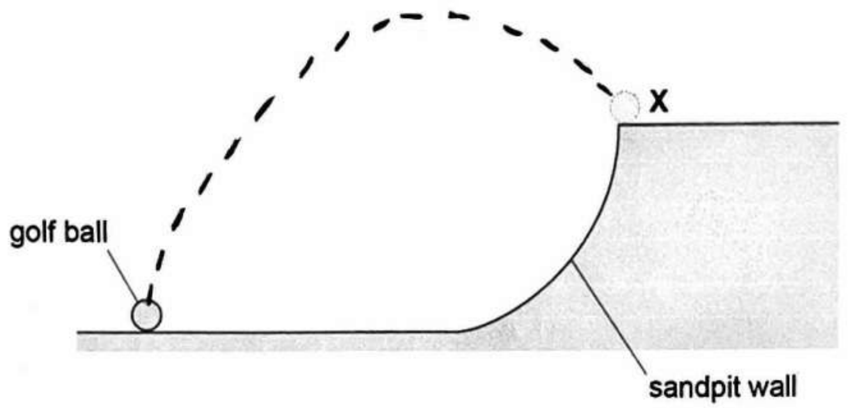
$s = 6.16 \times 0.63 + \frac{1}{2} \times -9.81 \times 0.63^2 = 1.93\ m$

vertical distance = 1.9 m

Question 3 continues on the next page

The golfer returns the ball to its original position in the sandpit. He wants the ball to land at **X** but this time with a **smaller** horizontal velocity than in **Figure 5**.

Figure 6



0 3 . 5 Sketch on **Figure 6** a possible trajectory for the ball.

[1 mark]

0 3 . 6 Explain your reason for selecting this trajectory.

[2 marks]

~~The angle is increased vert~~
The angle relative to the horizontal is increased, meaning the ball goes higher and is in the air for more time. It covers the same horizontal distance in more time hence has a smaller horizontal velocity

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Maths Made Easy

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0 4 A sample of pure boron contains only isotope **X** and isotope **Y**.
A nucleus of **X** has more mass than a nucleus of **Y**.

0 4 . 1 The sample is ionised, producing ions each with a charge of $+1.6 \times 10^{-19}$ C.
The specific charge of an ion of **X** is 8.7×10^{6} C kg^{-1}.

Calculate the mass of an ion of **X**.

[1 mark]

$\frac{Q}{m} = 8.7 \times 10^{6}$

$m = Q / 8.7\ 10^{6}$

$m = 1.6 \times 10^{-19} \div 8.7 \times 10^{6}$

mass of ion = 1.8×10^{-26} kg

0 4 . 2 Determine the number of nucleons in a nucleus of **X**.

mass of a nucleon = 1.7×10^{-27} kg

[2 marks]

$1.8 \times 10^{-26} \div 1.7 \times 10^{-27} = 10.6$

round up to 11

number of nucleons = 11

0 4 . 3 Compare the nuclear compositions of **X** and **Y**.

[2 marks]

They both have the same number of protons. However X has more neutrons than Y because the charges are the same but X has more mass than Y.

Question 4 continues on the next page

Turn over ▶

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0 4 . 4 Ions of **Y** have the same charge as ions of **X**.

State and explain how the specific charge of an ion of **X** compares with that of an ion of **Y**.

[2 marks]

Specific charge on ion X is less than that of Y, because X has more mass and specific charge is inversely proportional to mass.

0 4 . 5 **Table 1** contains data about two completely ionised samples of pure boron. Each sample contains only isotopes **X** and **Y**.

Table 1

Sample number	Number of ions in sample	Mass of sample / kg	Charge on each ion / C
1	3.50×10^{16}	6.31×10^{-10}	$+1.60 \times 10^{-19}$
2	3.50×10^{7}	6.20×10^{-19}	$+1.60 \times 10^{-19}$

Deduce which sample, **1** or **2**, contains a greater percentage of isotope **Y**.

[3 marks]

Specific charge:

Sample 1: $(3.50 \times 10^{16} \times 1.6 \times 10^{-19}) \div 6.31 \times 10^{-10}$

$= 8.9 \times 10^{6}\ C\,kg^{-1}$

Sample 2: $(3.50 \times 10^{7} \times 1.6 \times 10^{-19}) \div 6.20 \times 10^{-19}$

$= 9.0 \times 10^{6}\ C\,kg^{-1}$

Sample 2 has a higher specific charge and therefore it contains a greater percentage of isotope Y.

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0 5 A cell has an emf of 1.5 V and an internal resistance of 0.65 Ω.
The cell is connected to a resistor **R**.

0 5 . 1 State what is meant by an emf of 1.5 V.

[2 marks]

It means that 1.5 J of work is done moving 1 C charge through the cell.

0 5 . 2 The current in the circuit is 0.31 A.

Show that the total power output of the cell is approximately 0.47 W.

[1 mark]

$P = VI$

$P = 0.31 \times 1.5 =$ ~~0.47W~~ $0.465 W$

0 5 . 3 Calculate the energy dissipated per second in resistor **R**.

[2 marks]

~~$\varepsilon = I(R+r)$~~

~~Wasted energy is $Ir = 0.31 \times 0.65 = 0.2015$~~

$I = \frac{\varepsilon}{R+r}$ $R = \frac{\varepsilon}{I} - r$ $R = \frac{1.5}{0.31} - 0.65 = 4.2\Omega$

energy dissipated per second = 0.40 J s^{-1}

$P = I^2 R$

$P = 0.31^2 \times 4.2 = 0.403 W$

Question 5 continues on the next page

Turn over ▶

0 5 . 4 The cell stores 14 kJ of energy when it is fully charged. The cell's emf and internal resistance are constant as the cell is discharged.

Calculate the maximum time during which the fully-charged cell can deliver energy to resistor **R**.

[2 marks]

$E = pt$

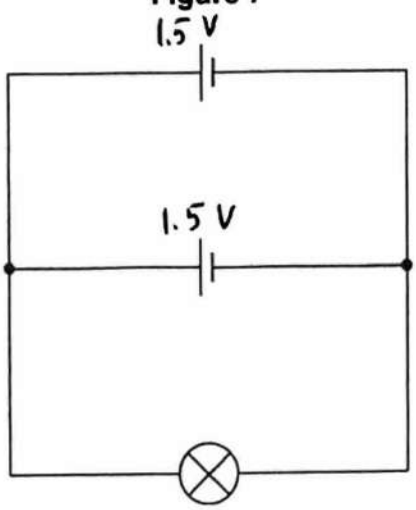
$\frac{E}{p} = t \qquad p = I^2 R = 0.31^2 \times 4.84 = 0.465$

$\frac{14k}{0.465} = 3.01 \times 10^4 \text{ s}$

maximum time = 3.01×10^4 s

0 5 . 5 A student uses two cells, each of emf 1.5 V and internal resistance 0.65 Ω, to operate a lamp. The circuit is shown in **Figure 7**.

Figure 7



The lamp is rated at 1.3 V, 0.80 W.

Deduce whether this circuit provides the lamp with 0.80 W of power at a potential difference (pd) of 1.3 V.
Assume that the resistance of the lamp is constant.

[4 marks]

internal resistance = 0.65

current in lamp required: $I = \frac{P}{V} = \frac{0.8}{1.3} = 0.615$ A

~~current resistance in each cell: $R = \frac{V}{I}$ $I = \frac{V}{R} =$~~

resistance in lamp: $R = \frac{V^2}{P} = 2.11\ \Omega$

current in each cell: 0.31 A

lost volts: $V = IR = 0.31 \times 0.65 = 0.2$ V

This lamp does provide 1.3 V and 0.80W, because terminal pd = emf - lost volts
$= 1.5 - 0.2 = 1.3$V

Question 5 continues on the next page

Turn over ►

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0 5 . 6 The lamp operates at normal brightness across a pd range of 1.3 V to 1.5 V.

State and explain how more of these cells can be added to the circuit to make the lamp light at normal brightness for a longer time.
No further calculations are required.

[3 marks]

More cells can be added in parallel, because there is more energy stored in the cells but the voltage across the bulb is still 1.5V as it doesn't increase.

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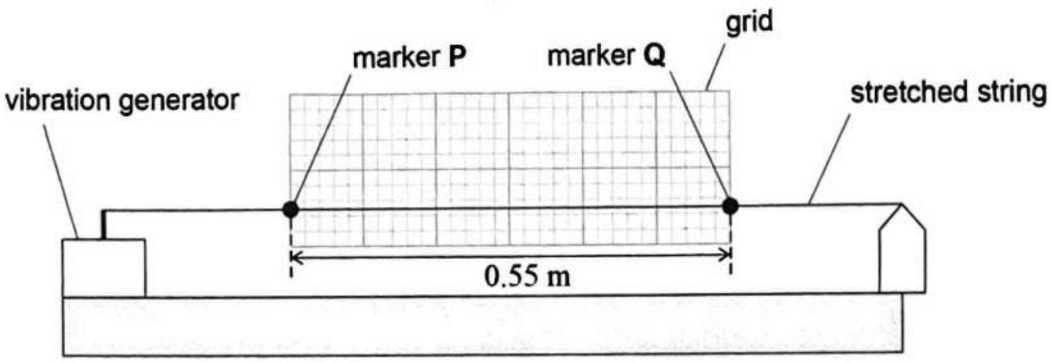
0 6 **Figure 8** shows the apparatus a student uses to investigate stationary waves in a stretched string.

Two small pieces of adhesive tape are fixed to the string as markers **P** and **Q**. Markers **P** and **Q** are 0.55 m apart and an equal distance from the ends of the string. A graph paper grid is placed behind the string between **P** and **Q**.

Figure 8



not to scale

0 6 . 1 The string is made to vibrate at the second harmonic.

Compare the motion of **P** with that of **Q**.

[2 marks]

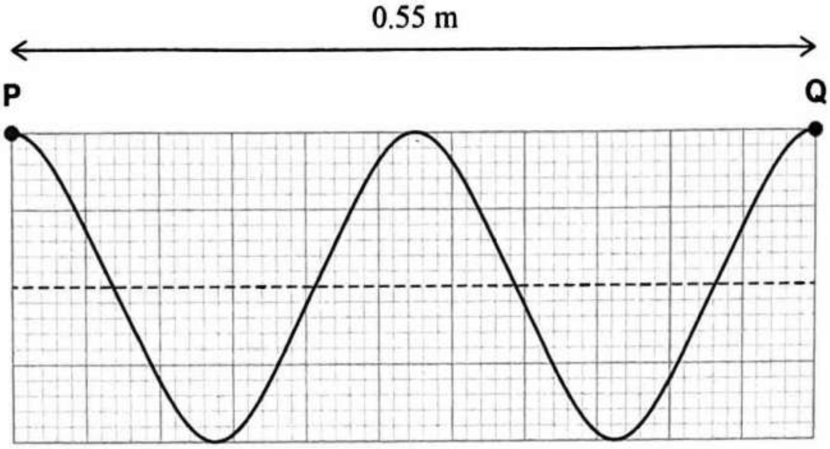
In terms of position, p and Q are completely out of phase. They do though have similar amplitudes.

Question 6 continues on the next page

0 6 . 2 The frequency of the vibration generator is increased, and a higher harmonic of the stationary wave is formed.

Figure 9 shows the string between **P** and **Q** at an instant in time. The dashed horizontal line indicates the position of the string at rest when the vibration generator is switched off.

Figure 9



The frequency of the vibration generator is 250 Hz.

Calculate the wave speed.

[2 marks]

$v = f\lambda$

$f = 250$ Hz

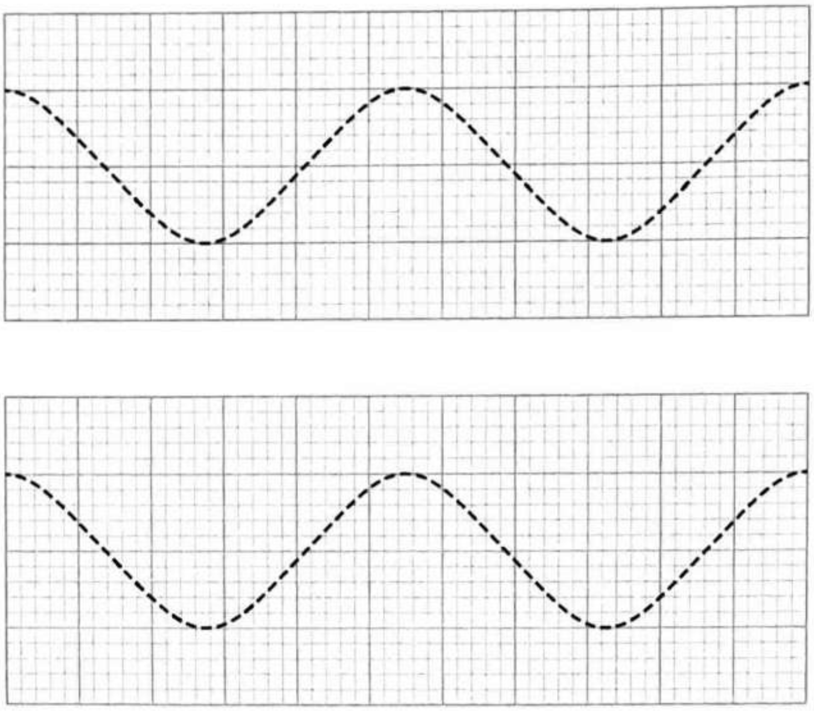
$\lambda = \frac{0.55}{2} = 0.275$ m

$v = 250 \times 0.275 = 68.75$ ms^{-1}

wave speed = 69 m s^{-1}

0 6 . 3 The instantaneous position of the string in **Figure 9** can be explained by the superposition of two waves. The instantaneous positions of these waves between **P** and **Q** are shown in **Figure 10**.

Figure 10



Describe the properties that the waves must have to form the shape shown in **Figure 9**.

[3 marks]

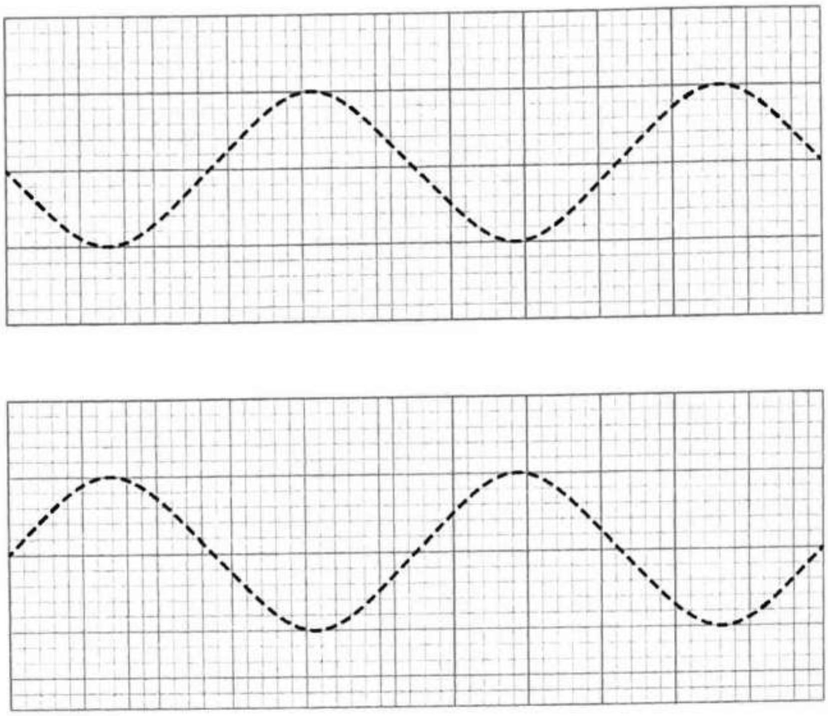
The waves must be of the same speed. They must be moving in opposite directions, and have the same frequency.

Question 6 continues on the next page

Turn over ▶

0 6 . 4 **Figure 11** shows the positions of the two waves between **P** and **Q** a short time later.

Figure 11

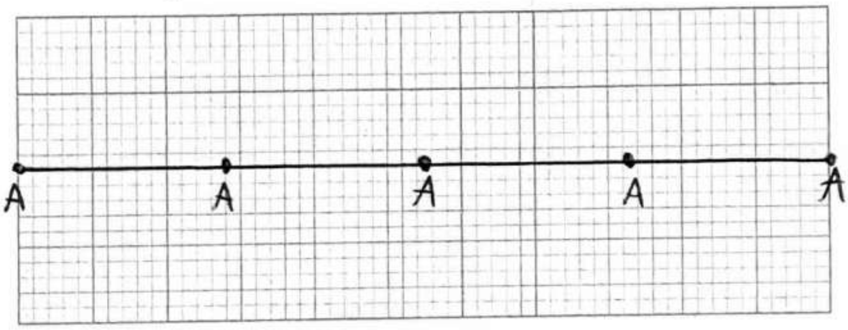


Draw, on **Figure 12**, the appearance of the string between **P** and **Q** at this instant.

[1 mark]

(destructive interference)

Figure 12

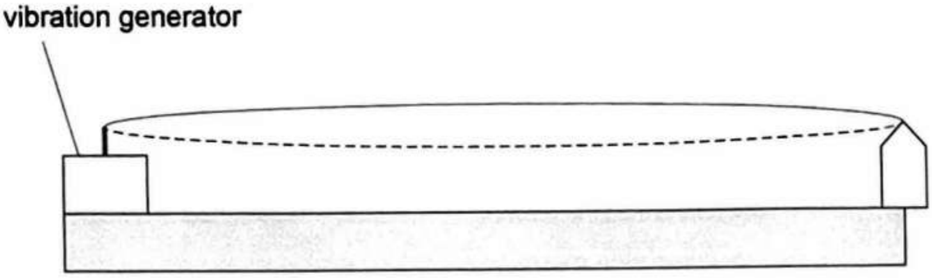


0 6 . 5 Annotate (with an **A**) the positions of any antinodes on your drawing in **Figure 12**.

[2 marks]

0 6 . 6 The frequency of the vibration generator is reduced until the first harmonic is observed in the string, as shown in **Figure 13**.

Figure 13



The string in **Figure 13** is replaced with one that has 9 times the mass per unit length of the original string. All other conditions are kept constant, including the frequency of the vibration generator and the tension in the string.

Deduce the harmonic observed.

[3 marks]

using $f = \frac{1}{2L}\sqrt{\frac{T}{\mu_1}}$ $\quad 9\mu_1 = \mu_{new}$

$f = \frac{1}{2L}\sqrt{\frac{T}{9\mu_{1}}}$ $\quad f = \frac{1}{2L}\sqrt{\frac{T}{\mu_{1}}} \propto \frac{1}{3}$

so new first harmonic is $f = \frac{1}{6L}\sqrt{\frac{T}{\mu_{1}}}$

Therefore the frequency for 1st harmonic reduces to 1/3 of the original frequency. ∴ The new harmonic is a third harmonic and the string is being driven at 3 times this frequency.

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END OF QUESTIONS