

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

StemUp Model Solution

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

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

0 1

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



0 1 . 1

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

[2 marks]

Conserve charge: $+1 + 1 = +1 + 1 - 1 + Q$, so $Q = +1$

Lepton number: $0 = 0 + 0 + 0 + L$, so $L = 0$

Strong interaction, strangeness conserved: $S = 0$

lepton number = 0

strangeness = 0

charge = +1 (e)

0 1 . 2

Identify particle **X**.

[1 mark]

A proton (p)



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

$$\pi^- \rightarrow e^- + Y$$

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

[1 mark]

$\bar{\nu}_e$

☒

ν_e

☐

π^0

☐

${}^1_0\text{n}$

☐

Question 1 continues on the next page

Turn over ►



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 made of quarks (and/or antiquarks). Their identifying property is that they can interact via the strong nuclear force (as well as the weak interaction, and the electromagnetic force if charged). Leptons are not hadrons because they do not feel the strong force.

The two classes of hadrons are baryons and mesons. A baryon is made of three quarks (qqq), for example a proton is uud and a neutron is udd; an antibaryon is made of three antiquarks. A meson is made of a quark and an antiquark (one quark and one antiquark), for example a π^+ is an up quark with an anti-down quark, and a kaon K^+ is an up quark with an anti-strange quark.

Stability: the proton is the only stable free baryon, so all other baryons eventually decay into a proton. For example a free neutron decays (by the weak interaction) into a proton, an electron and an electron antineutrino, with a half-life of about 10 minutes.

Mesons are all unstable as free particles. For example a kaon decays into pions, and pions decay into muons and neutrinos (or into photons for the π^0), so no free meson is stable.



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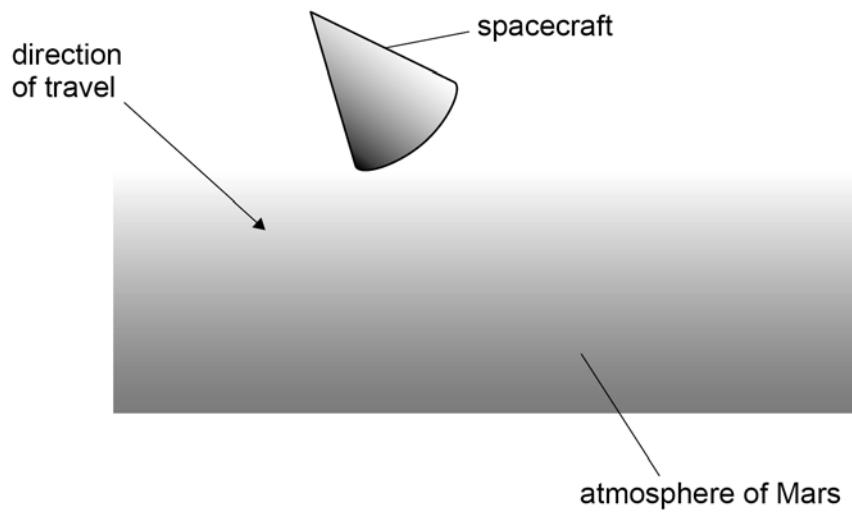
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0 2

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]

$$v = 5.5 \text{ km s}^{-1} = 5.5 \times 10^3 \text{ m s}^{-1}$$

$$E_k = \frac{1}{2}mv^2$$

$$E_k = 0.5 \times 610 \times (5.5 \times 10^3)^2$$

$$E_k = 9.23 \times 10^9 \text{ J}$$

$$= 9.2 \times 10^9 \text{ J (2 s.f., same as the data)}$$

kinetic energy = 9.2×10^9 J

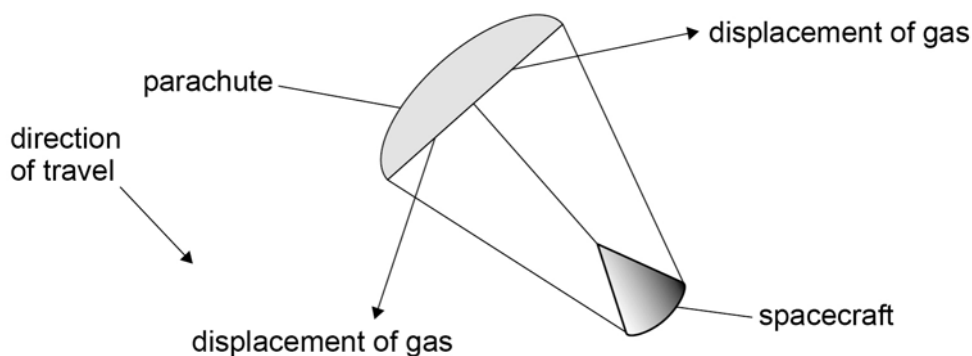


0 2 . 2

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 parachute pushes the gas out of the way, so the gas is accelerated and its momentum is changing. By Newton's 2nd law a (resultant) force must act on the gas to change its momentum, so the parachute exerts a force on the gas.

By Newton's 3rd law the gas exerts an equal magnitude and opposite direction force on the parachute, so there is a resistive (drag) force on the system acting upwards.

This resistive force is greater than the weight of the system, so the resultant force acts in the opposite direction to the motion (upwards).

By Newton's 2nd law the acceleration is in the same direction as the resultant force, so the system decelerates.

Question 2 continues on the next page

Turn over ►



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]

Conservation of energy:

energy to atmosphere = loss of E_k + loss of E_p

loss of $E_p = 3.3 \times 10^5 - 2.2 \times 10^5 = 1.1 \times 10^5$ J

$E_p = mgh$, so $g = E_p \div mh$

$g = 1.1 \times 10^5 \div (610 \times 49)$

$g = 3.68 \text{ m s}^{-2}$

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]

With more dust the atmosphere is denser, so at any given speed the

parachute has more mass (more gas and dust particles) to displace and

collide with each second.

So there is a greater rate of change of momentum of the gas and dust,

which means a greater resistive (drag) force on the system.

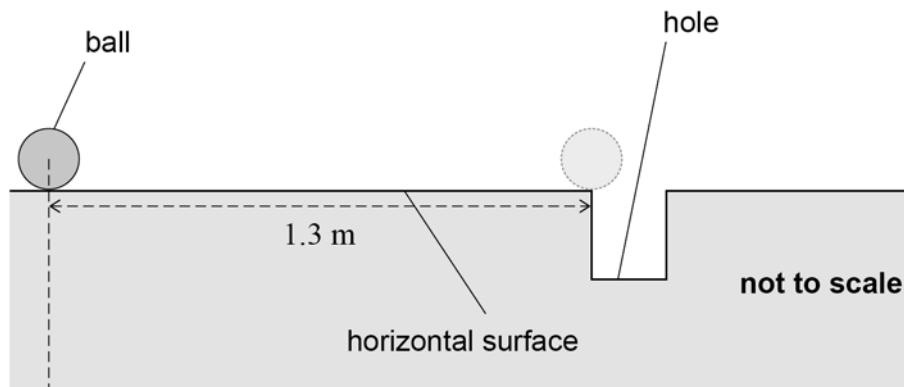
The weight is unchanged, so there is a greater resultant force upwards

on the system and therefore a greater deceleration.



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 m s^{-1} . The ball experiences a constant deceleration of 1.2 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]

$$v^2 = u^2 + 2as \quad (a = -1.2 \text{ m s}^{-2})$$

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

$$v^2 = 3.24 - 3.12 = 0.12$$

$$v = \sqrt{0.12} = 0.346 \text{ m s}^{-1}$$

velocity = 0.35 m s⁻¹

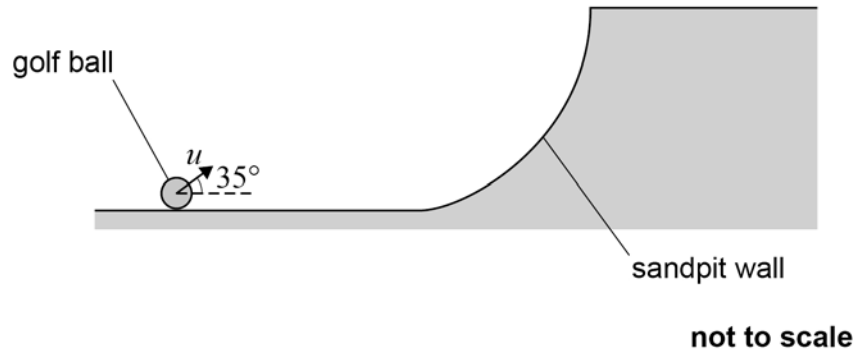
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0 3 . 2

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 m s^{-1} .

Figure 4

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

[1 mark]

$$\tan 35^\circ = u_v \div u_h$$

$$u_v = 8.8 \times \tan 35^\circ$$

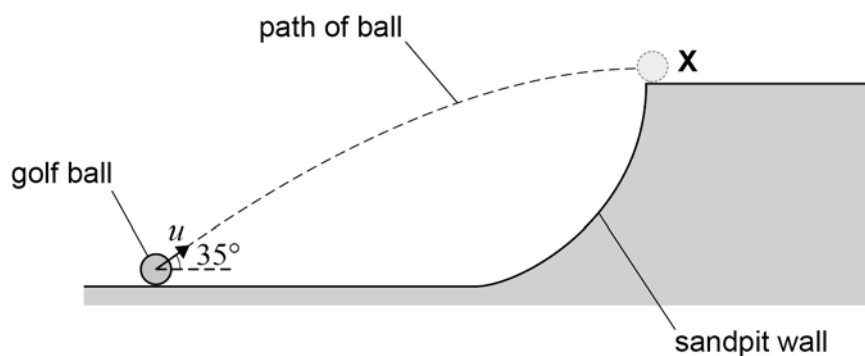
$$u_v = 6.16 \text{ m s}^{-1} \approx 6 \text{ m s}^{-1}$$



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]

At X vertical velocity = 0, so $v = u + at$ with $a = -9.81 \text{ m s}^{-2}$

$0 = 6.16 - 9.81t$, so $t = 6.16 \div 9.81$

$t = 0.628 \text{ s}$

time = 0.63 s

0 3 . 4

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

[2 marks]

$v^2 = u^2 + 2as$ with $v = 0$: $s = u^2 \div 2g$

$s = 6.16^2 \div (2 \times 9.81) = 1.93 \text{ m}$

vertical distance = 1.9 m

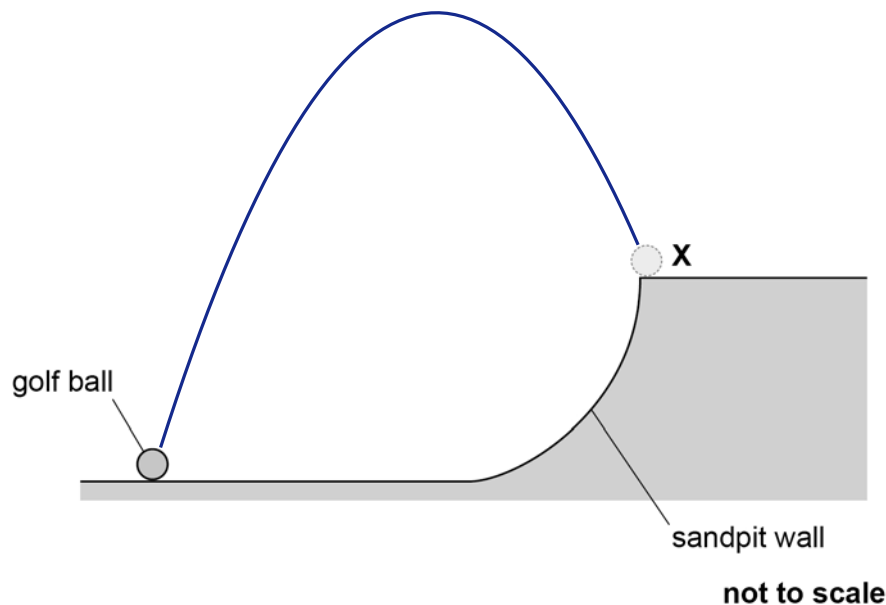
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The golfer returns the ball to its original position in the sandpit. He wants the ball to land at **X** but this time with a **smaller** horizontal velocity than in **Figure 5**.

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]

To have a smaller horizontal velocity the ball must be hit at a larger angle to the horizontal, so it has a greater initial vertical velocity and goes higher than X before falling.

So it is in the air for a longer time and covers the same horizontal distance with a smaller horizontal velocity. It must be falling towards the ground (past its maximum height) when it lands at X.



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 $+1.6 \times 10^{-19} \text{ C}$.
The specific charge of an ion of **X** is $8.7 \times 10^6 \text{ C kg}^{-1}$.

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

[1 mark]

$$\text{specific charge} = Q \div m, \text{ so } m = Q \div \text{specific charge}$$

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

$$\text{mass of ion} = 1.84 \times 10^{-26} \text{ kg}$$

0 4 . 2

Determine the number of nucleons in a nucleus of **X**.

$$\text{mass of a nucleon} = 1.7 \times 10^{-27} \text{ kg}$$

[2 marks]

$$\text{number of nucleons} = \text{mass of ion} \div \text{mass of a nucleon}$$

$$= 1.84 \times 10^{-26} \div 1.7 \times 10^{-27} = 10.8$$

must be a whole number, so 11

$$\text{number of nucleons} = 11$$

0 4 . 3

Compare the nuclear compositions of **X** and **Y**.

[2 marks]

Both X and Y have the same number of protons (5, as they are both boron isotopes).

X has more neutrons than Y (Y has fewer neutrons than X).

Question 4 continues on the next page

Turn over ►



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]

The specific charge of an ion of X is less than that of an ion of Y.

*For the same charge, specific charge is inversely proportional to mass,
and X has more mass than Y.*

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]

$$\text{Mean mass of an ion in sample 1} = 6.31 \times 10^{-10} \div 3.50 \times 10^{16} = 1.80 \times 10^{-26} \text{ kg}$$

$$\text{Mean mass of an ion in sample 2} = 6.20 \times 10^{-19} \div 3.50 \times 10^7 = 1.77 \times 10^{-26} \text{ kg}$$

$$\text{Specific charge of sample 1} = 1.60 \times 10^{-19} \div 1.80 \times 10^{-26} = 8.87 \times 10^6 \text{ C kg}^{-1}$$

$$\text{Specific charge of sample 2} = 1.60 \times 10^{-19} \div 1.77 \times 10^{-26} = 9.03 \times 10^6 \text{ C kg}^{-1}$$

*Sample 2 contains a greater percentage of Y, because it has a higher
specific charge (lower mean mass per ion) and Y has less mass than
X.*

10



0 5

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

0 5 . 1

State what is meant by an emf of 1.5 V.

[2 marks]

*1.5 J of energy is converted from other forms (chemical) to electrical
energy per 1 C of charge passing through the cell, i.e. 1.5 J of work is
done in moving 1 C of 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]

Total power output $P = \epsilon I$

$$P = 1.5 \times 0.31 = 0.465 \text{ W} \approx 0.47 \text{ W}$$

0 5 . 3

Calculate the energy dissipated per second in resistor **R**.

[2 marks]

$$\text{wasted power in cell} = I^2 r = 0.31^2 \times 0.65 = 0.0625 \text{ W}$$

$$\text{power in R} = 0.465 - 0.0625 = 0.403 \text{ W}$$

$$\text{energy dissipated per second} = \underline{0.40} \text{ J s}^{-1}$$

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]

$$E = Pt, \text{ so } t = E \div P$$

$$t = 14 \times 10^3 \div 0.465$$

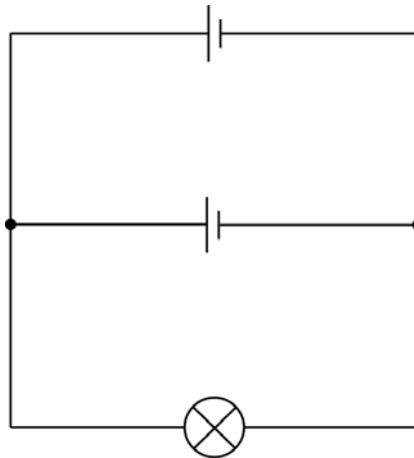
$$t = 3.01 \times 10^4 \text{ s}$$

maximum time = 3.0 × 10⁴ 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]

$$\text{Lamp: } R = V^2 \div P = 1.3^2 \div 0.80 = 2.11 \, \Omega; I = P \div V = 0.80 \div 1.3 = 0.62 \, \text{A}$$

$$\text{Two identical cells in parallel: current in each cell} = 0.62 \div 2 = 0.31 \, \text{A}$$

$$\text{lost volts} = Ir = 0.31 \times 0.65 = 0.20 \, \text{V}$$

$$\text{terminal pd} = 1.5 - 0.20 = 1.3 \, \text{V}$$

$$(\text{check: total } r = 0.325 \, \Omega, \text{ total } R = 2.44 \, \Omega, V = 2.11 \times 1.5 \div 2.44 = 1.3 \, \text{V})$$

Yes: the pd across the lamp is 1.3 V, so the circuit provides the lamp with 0.80 W at 1.3 V.

Question 5 continues on the next page

Turn over ►



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]

The extra cells must be added in parallel with the existing cells.

This means more energy is stored in the bank of cells, and the current is shared between more cells, so less power is taken from each cell and the energy lasts longer.

The terminal pd (and the pd across the lamp) is not increased above 1.5 V, so the lamp still works at normal brightness.

14

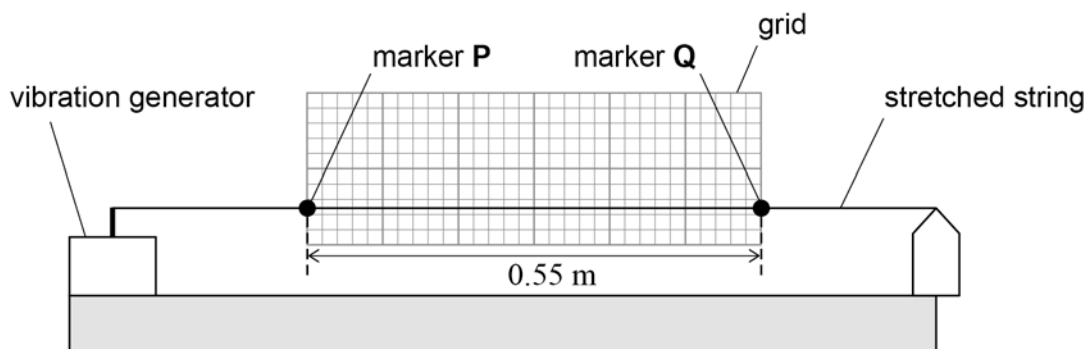


0 6

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]

P and Q are in antiphase (180° , π rad out of phase): when P is at its maximum upward displacement Q is at its maximum downward displacement.

They have the same amplitude (same magnitude of displacement at any instant) and the same frequency.

Question 6 continues on the next page

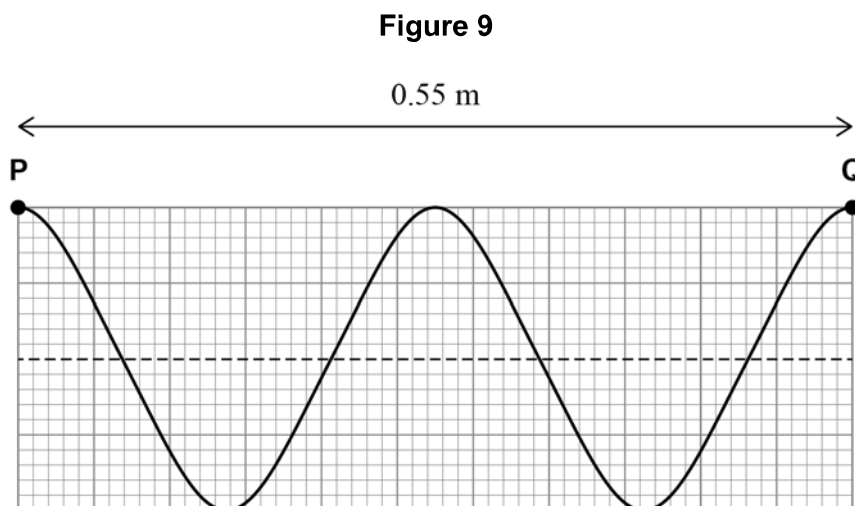
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0 6 . 2

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.



The frequency of the vibration generator is 250 Hz.

Calculate the wave speed.

[2 marks]

Figure 9 shows 2 complete wavelengths between P and Q

$$\lambda = 0.55 \div 2 = 0.275 \text{ m}$$

$$v = f\lambda = 250 \times 0.275 = 68.8 \text{ m s}^{-1}$$

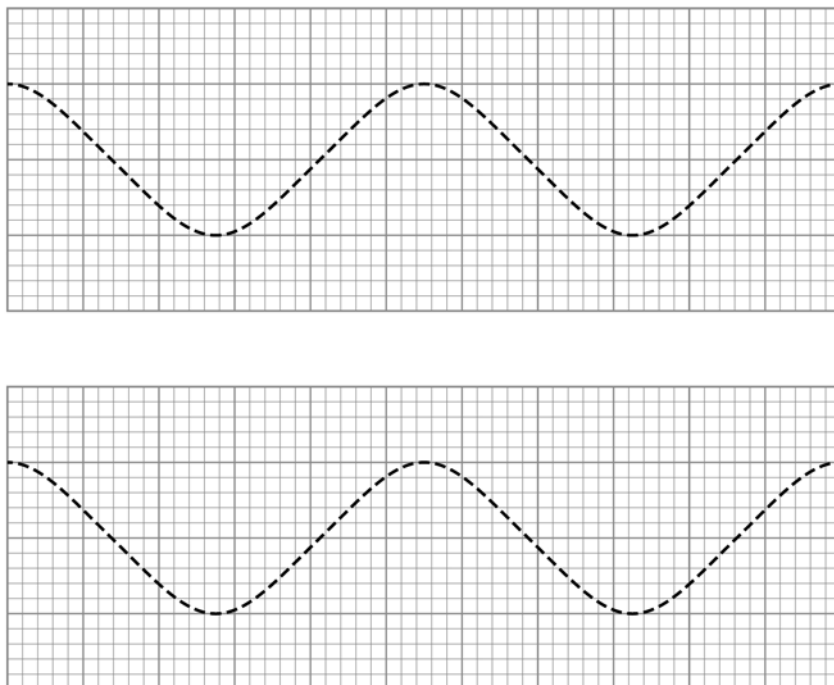
wave speed = 69 m s⁻¹



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 two waves must travel at the same speed in opposite directions along the string.

They must have the same wavelength and the same frequency, and the same (or similar) amplitude.

Question 6 continues on the next page

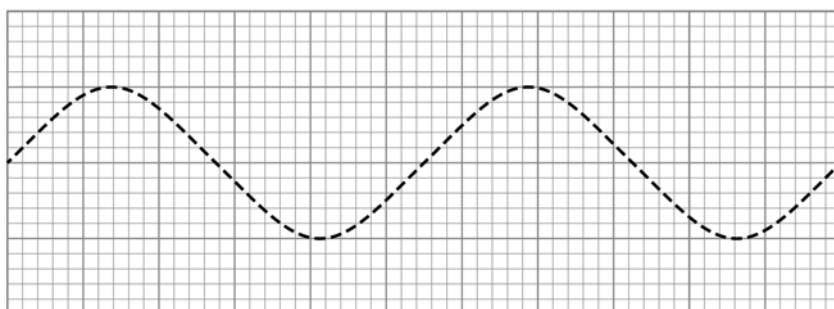
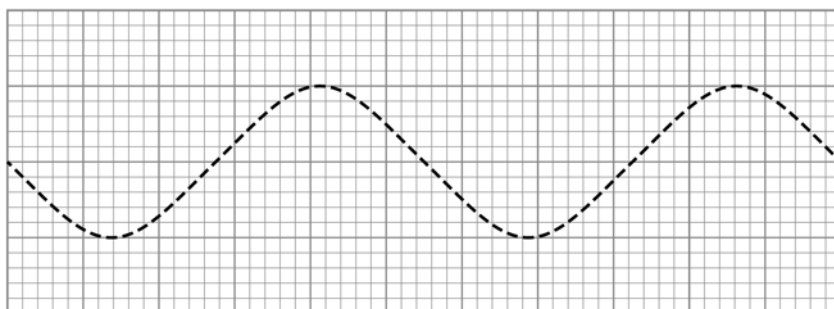
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0 6 . 4

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

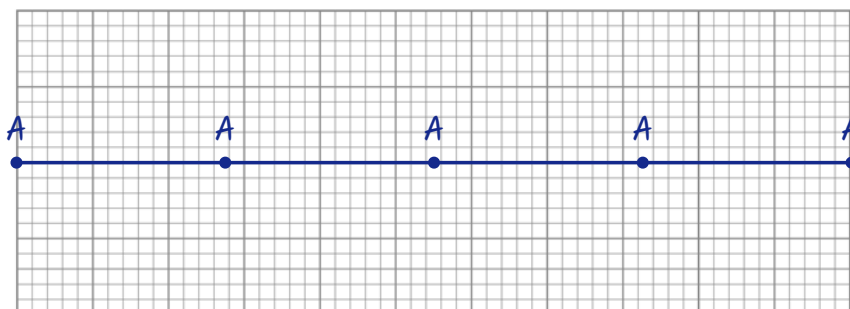
Figure 11



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

[1 mark]

Figure 12



0 6 . 5

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

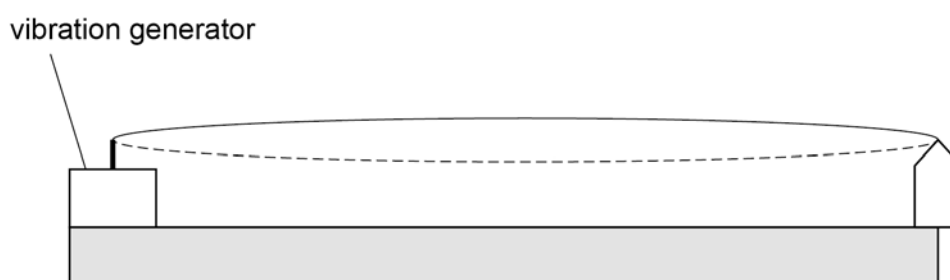
[2 marks]



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]

$$v = \sqrt{T \div \mu}: \mu \text{ increases } \times 9, \text{ so } v \text{ decreases to } 1/3 \text{ of previous}$$

$$f_1 = v \div 2L, \text{ so the first harmonic frequency is } 1/3 \text{ of previous}$$

$$f = (1/3) \times (1 \div 2L) \times \sqrt{T \div \mu}$$

The generator frequency is unchanged, so the string is now being driven at three times its new first harmonic frequency.

So the third harmonic is observed (three loops between the ends).

END OF QUESTIONS



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