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	
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6	
TOTAL	

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

box

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]

Explanation:

p + p → p + π+ + π− + X

Strangeness Number: All particles have a strangeness number of 0.

Lepton Number: All particles have a lepton number of 0

In the reaction p + p → p + π+ + π- + X, the total charge on both sides must be equal to satisfy charge conservation.
On the left-hand side, we have two protons (p), each carrying a charge of +1. So the total charge on the left-hand side is +2.
On the right-hand side, we have a proton (p) and a positively charged pion (π+), each carrying a charge of +1, and a negatively charged pion (π-) carrying a charge of -1. Additionally, we have the X particle with a charge number of +1.

Conclusion:
Based on the charge conservation in the reaction, the X particle with a charge number of **+1**

Strangeness is one of the quantum numbers Strangeness plays a role in understanding the properties and behavior of particles with strange quarks, such as their decay modes and lifetimes. Strangeness is conserved in strong and electromagnetic interactions, meaning the total strangeness remains constant. (zero)

Explanation:

- Strangeness Number: All particles have a strangeness number of 0.
- Lepton Number: All particles have a lepton number of 0.
- Charge Number: Protons and the positively charged pion have a charge number of +1, the negatively charged pion has a charge number of -1, and (X) has a charge number of +1.

lepton number = 0

strangeness = 0

charge = + 1

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

[1 mark]

Explanation:

$$p + p \rightarrow p + \pi^+ + \pi^- + X$$

Conclusion:

- Based on the charge conservation in the reaction, the X particle with a charge number of +1 must be a 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]

�e	□
v_e	□
π^0	□
${}^{1}_{0}n$	□

In the decay of a negative pion (π-) to an electron (e-) and Y, the particle Y is an antineutrino, specifically an electron antineutrino (ve̅).

π− → e− + Y

L: 0 → +1-1

Q: -1 → -1+0

00.

Answer: (ve̅)

Question 1 continues on the next page

Turn over ►

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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 a class of subatomic particles that play a fundamental role in the composition of atomic nuclei and are an important part of the standard model of particle physics. Hadrons are characterized by certain identifying properties, are divided into two main classes, and have distinctive structures. Additionally, their stability when free (not bound within atomic nuclei) is an important aspect of their behavior.

Identifying Properties of Hadrons:

Hadrons are strongly interacting particles, which means they participate in the strong nuclear force, one of the fundamental forces of nature.
Hadrons have fractional electric charges. This is in contrast to leptons (e.g., electrons and neutrinos), which have integral electric charges.
Hadrons experience the strong force and electromagnetic interactions.
Structure of Hadrons in Each Class:
Hadrons are divided into two classes based on their intrinsic properties:

A. Baryons:

Baryons are one class of hadrons, and they include protons and neutrons, which are the building blocks of atomic nuclei.
Baryons are made up of three quarks. These quarks are held together by the exchange of particles called gluons, which mediate the strong force. For example, a proton consists of two up quarks and one down quark, while a neutron consists of two down quarks and one up quark.
B. Mesons:

Mesons are the other class of hadrons, and they include particles like pions and kaons.
Mesons are composed of a quark and an antiquark. They also interact via the strong force and are held together by the exchange of gluons. For instance, a pion can consist of an up quark and an anti-down quark or vice versa.
Stability of Free Hadrons:

Free hadrons, when not bound within atomic nuclei, are generally unstable. This means they have a finite lifetime and eventually decay into other particles.
The relatively short lifetime of free hadrons is due to the strong force, which mediates their interactions. The strong force is very powerful at short distances but weakens rapidly as particles move away from each other.
When free hadrons exist, they eventually undergo a process called hadron decay, where they transform into other particles, typically leptons (e.g., electrons, neutrinos) or other hadrons. This is a fundamental aspect of the behavior of hadrons, and it is a consequence of their strong interactions.

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Turn over for the next question

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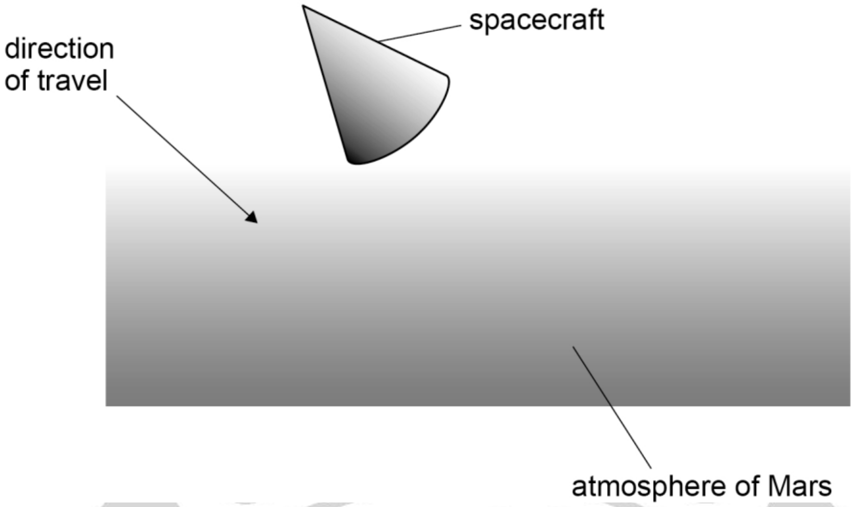
0 2 A spacecraft entering the atmosphere of Mars must decelerate to land undamaged on the surface.

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]

Explanation:

To calculate the kinetic energy of the spacecraft, we can use the formula:
Kinetic Energy = (1/2) * mass * velocity^2
Given: Mass of the spacecraft (m) = 610 kg Velocity of the spacecraft (v) = 5.5 km/s
Converting the velocity from km/s to m/s: 5.5 km/s * 1000 m/km = 5500 m/s
Now we can substitute the values into the formula and calculate the kinetic energy:
Kinetic Energy = (1/2) * 610 kg * (5500 m/s)^2
Kinetic Energy ≈ 0.5 * 610 kg * 30250000 m^2/s^2
Kinetic Energy ≈ 9295250000 kg•m^2/s^2
Rounding to an appropriate number of significant figures: Kinetic Energy ≈ 9.30 × 10^9 J

Therefore, the kinetic energy of the spacecraft as it enters the atmosphere is approximately 9.30 × 10^9 joules.

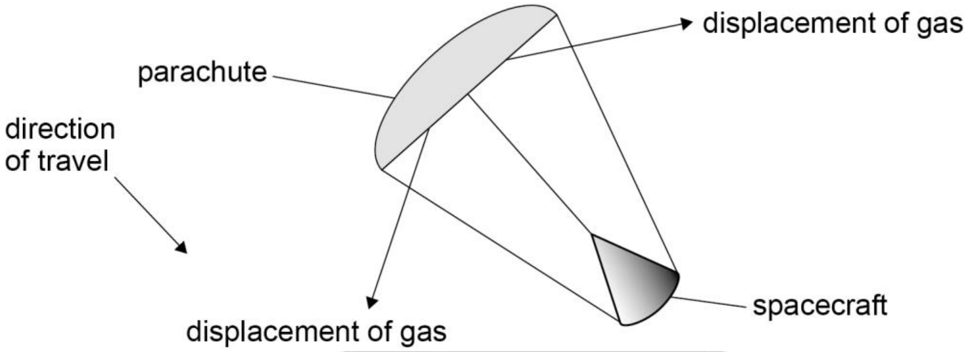
kinetic energy = 9.30×10^{9} J

Do not write outside the box

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.

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Explanation:
1. Newton's third law: When the parachute displaces atmospheric gas, the gas particles exert an equal and opposite force on the parachute according to Newton's third law of motion.
2. Momentum transfer: The collision of the parachute with the gas particles results in a transfer of momentum between them. The gas particles gain momentum due to the force imparted by the parachute.
3. Change in momentum: The change in momentum (Δp) of the gas particles is given by $\Delta p = F * \Delta t$, where F is the force exerted by the parachute and Δt is the time interval of the collision.
4. Force on the parachute: Applying Newton's second law of motion ($F = \Delta p/\Delta t$), we find that the change in momentum ($\Delta(mv)$) of the gas particles during the collision results in a force (F) being exerted on the parachute.
5. Equal and opposite forces: Newton's third law implies that the force exerted by the gas particles on the parachute is equal in magnitude but opposite in direction to the force exerted by the parachute on the gas particles.
6. Deceleration: As a consequence of the equal and opposite forces, the parachute (part of the system) experiences a force in the opposite direction to its motion, leading to deceleration or a reduction in velocity.
7. Net force and acceleration: The net force acting on the system is the difference between the forward force of the spacecraft and the opposing drag force. This net force causes the system to decelerate as described by Newton's second law ($F = ma$).

In summary,
the collision between the parachute and gas particles results in a force that causes deceleration, as explained by Newton's third law and the equation for momentum transfer.

Question 2 continues on the next page

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

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

[3 marks]

Explanation:
Given:
Vertical distance fallen (h) = 49 m
Change in kinetic energy (ΔKE) = 2.2 × 105 J
Energy transferred to the atmosphere (ΔE) = 3.3 × 105 J
Mass of the system (m) = 610 kg
Using the principle of conservation of energy, we can write the equation:
ΔE(total)= ΔKE + ΔPE = 0
Substituting the given values and rearranging the equation:
0 = 2.2 × 105 J + mgh - 3.3 × 105 J
Rearranging and solving for g:
mgh = 3.3 × 105 J - 2.2 × 105 J
gh = (3.3 × 105J - 2.2 × 105 J) / m
g = (3.3 × 10^5 J - 2.2 × 10^5 J) / (m * h)

Substituting the given values:
g = (3.3 × 10^5 J - 2.2 × 10^5 J) / (610 kg * 49 m)
Calculating the acceleration due to gravity:
g ≈ 1.1 × 10^5 J / (29990 kg•m)
g ≈ 3.67 m/s^2

The positive value indicates that the acceleration due to gravity acts in the downward direction, aligning with the motion of the system.
Therefore, the acceleration due to gravity as the parachute-spacecraft system falls through a vertical distance of 49 m is approximately 3.67 m/s^2 in the

acceleration due to gravity = 3.67 $\mathrm{m\ s^{-2}}$

Do not write outside the

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]

Expalanation:

- Increased mass of dust particles: Dust particles in the atmosphere are heavier compared to gas molecules, resulting in a higher mass per unit volume.
- Greater momentum transfer: Collisions between the parachute and heavier dust particles lead to a more significant transfer of momentum and energy from the system to the dust particles.
- Opposing force: The increased dust content increases the density of the atmosphere, resulting in a higher opposing force acting on the parachute. This stronger opposing force contributes to faster deceleration.
- Need for greater force: Heavier dust particles require a greater force to accelerate due to their higher mass. As the parachute collides with these particles, it experiences a stronger force in the opposite direction, leading to faster deceleration.

In summary

An increase in dust content in the Martian atmosphere, where dust particles are heavier, causes a stronger deceleration of the parachute-spacecraft system due to the increased mass and momentum transfer, enhanced drag force resulting from higher density, and the need for greater force to accelerate the heavier dust particles.

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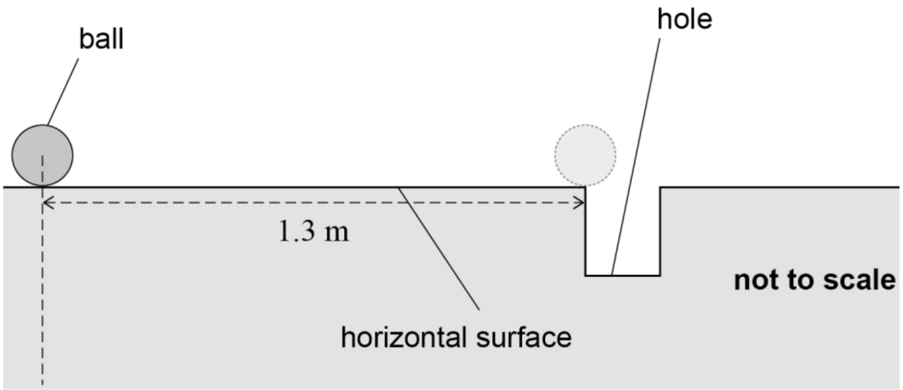
0 3 . 1 **Figure 3** shows a golf ball at rest on a horizontal surface 1.3 m from a hole.

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]

Explanation:

Given values:
Initial velocity (u) = 1.8 m/s
Deceleration (a) = -1.2 m/s2
Displacement (s) = 1.3 m

Substitute the values into the kinematic equation: v2 = u2+ 2as
Calculate the values:

U2 = (1.8 m/s)2 = 3.24 m2/s2
2as = 2(-1.2 m/s^2)(1.3 m) = -3.12 m2/s2
Combine the values: v^2 = 3.24 m^2/s^2 + (-3.12 m^2/s^2) = 0.12 m^2/s^2
Solve for v: v = √(0.12 ≈ 0.35 m/s

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

Question 3 continues on the next page

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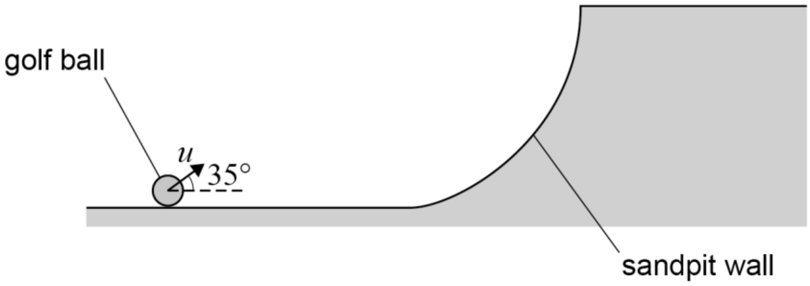
Turn over ►

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



not to scale

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

[1 mark]

Explanation:

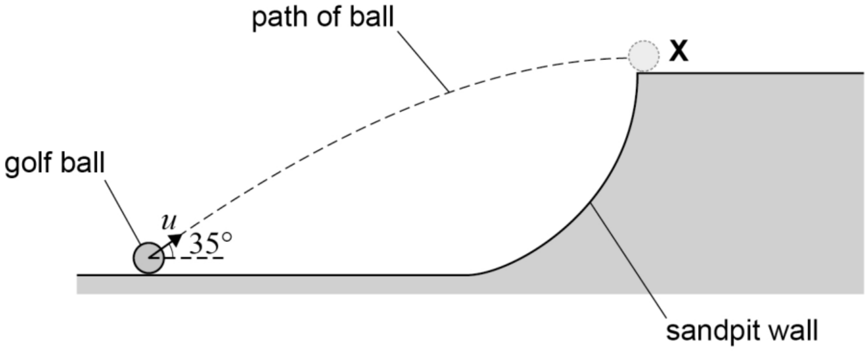
1. Given values:
- Horizontal component of u (Ux) = 8.8 m/s
- Angle of u with the horizontal (θ) = 35°
2. Use the trigonometric relationship for the tangent:
- $\tan(\theta) = U^y / U^x$
3. Substitute the values into the equation:
- $\tan(35°) = U^y / 8.8$ m/s
4. Solve for U^y:
- $U^y = \tan(35°) * 8.8$ m/s
5. Calculate the value of tan(35°):
- $\tan(35°) \approx 0.7002$
6. Substitute the value back into the equation:
- $U^y \approx 0.7002 * 8.8$ m/s
7. Calculate the vertical component of the initial velocity:
- $U^y \approx 6.1602$ m/s

Final result:

The vertical component of the initial velocity (u) is approximately 6.2 m/s.

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]

Explanation:

1. **Given values:**

- **Horizontal displacement (s) = 1.3 m**
- **Horizontal component of initial velocity (Ux) = 6.2 m/s**
- **Acceleration due to gravity (a) = -9.8 ms-2**
- **Vertical component of initial velocity (Uy) = 0 m/s**

2. Use the equation Uy = Ux + at to solve for time (t): 0 = 6.2 m/s + (-9.8 ms-2) * t
3. Rearrange the equation to solve for t: -9.8 ms-2 * t = -6.2 m/s

4. Calculate t: t = (-6.2 m/s) / (-9.8 ms-2)

5. Simplify the expression: t ≈ 0.6327 s

time = 0.63 s

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

Do not write outside the

[2 marks]

Explanation:

Given:
Uy = 0 m/s (vertical component of initial velocity)
t = 0.6327 s (time of flight)
a = -9.8 ms-2 (acceleration due to gravity)

Using the formula for average displacement:

s = (Uy + Vy) / 2 * t

Now we can calculate the vertical distance (s):

s = (0 + (-6.1926 m/s)) / 2 * 0.6327 s

s ≈ -1.9579 m
s = | -1.9579 m |
s ≈ 1.9579 m

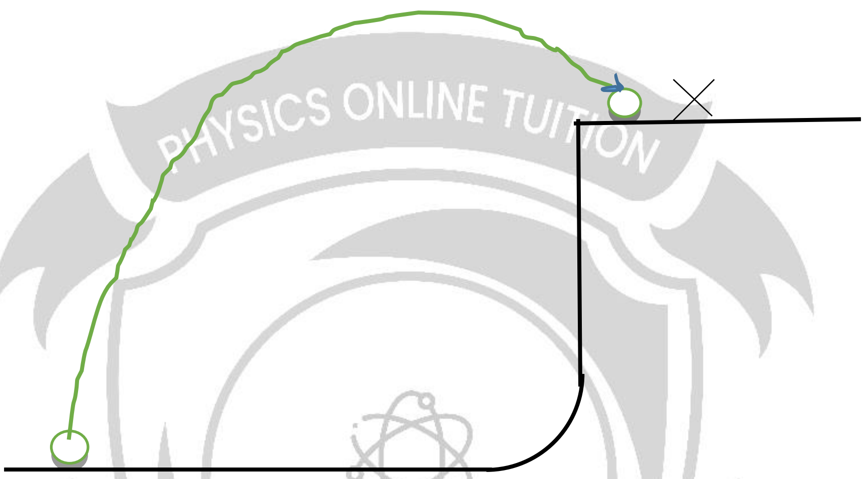
vertical distance = 1.9 m

Question 3 continues on the next page

Turn over ►

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]

Higher initial angle to the horizontal:

When you launch an object at a higher angle to the horizontal, you are essentially giving it a steeper initial trajectory. This means the angle of launch is closer to vertical (90 degrees), which can lead to specific advantages in certain situations.

Smaller horizontal velocity:

With a higher launch angle, more of the initial velocity is directed vertically (Vy) and less is directed horizontally (Vx). This results in a smaller horizontal velocity, meaning the object moves more vertically compared to a lower launch angle where more of the initial velocity is in the horizontal direction.

Parabolic trajectory:

This is a key characteristic of projectile motion. When you launch an object at any angle, its trajectory will form a parabolic path. However, the steepness of the parabola varies with the launch angle.

Curve starts below the 'golf ball' and ends at point label X: This implies that the trajectory starts from a position lower than the golf ball's initial height and reaches point X. A higher launch angle could achieve this as it allows for a steeper initial ascent.

Maximum turning point above the midpoint between the ball and label X:

A higher launch angle results in a higher peak in the trajectory. This point is where the object momentarily stops moving upwards before it starts descending. A steeper trajectory ensures that this point is above the midpoint between the starting point (golf ball) and the target point (X).

Descent and landing at or near position X:

If the goal is to hit or reach point X, a higher launch angle helps in ensuring the object reaches or lands near the desired target.

Smaller horizontal velocity at landing:

Again, due to the distribution of velocity components, a higher launch angle will result in a smaller horizontal velocity at landing, which can be advantageous in controlling the horizontal position.

At a higher initial angle to the horizontal, the vertical component of the velocity (Vy) will increase while the horizontal component (Vx) will decrease: This is a fundamental principle of projectile motion. By increasing the launch angle, you increase the vertical component of velocity, which can be beneficial in achieving a desired vertical position or reaching a higher peak.

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**.

Explanation:
Given:
Specific charge (q/m) = 8.7 × 106 C kg-1
Charge of the ion = +1.6 × 10-19 C

We'll use the same equation as before:

(q/m) = (charge / mass)

Plugging in the values:

8.7 × 106 C kg-1 = (1.6 × 10-19 C) / mass

Solving for mass:

mass = (1.6 × 10-19 C) / (8.7 × 106 C kg-1)

mass = 0.183× 10-19-6 kg

mass = 0.183× 10-25 kg

mass = 1.8 × 10-26 kg

[1 mark]

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]

Explanation:

Given:

Mass of a nucleon = 1.7 × 10-27 kg
Mass of an ion of X = 1.839 × 10-26 kg (as calculated earlier)
To determine the number of nucleons in a nucleus of X:

Calculate the number of nucleons by dividing the mass of the ion of X by the mass of a nucleon:

Number of nucleons = Mass of ion of X / Mass of a nucleon
Substitute the values into the formula:
Number of nucleons = (1.839 × 10-26 kg) / (1.7 × 10-27 kg n-1)
Simplify the expression to approximate the number of nucleons:
Number of nucleons ≈ 10.823
Round the value to the nearest whole number to obtain the final result:
Number of nucleons ≈ 11

number of nucleons = ____________________

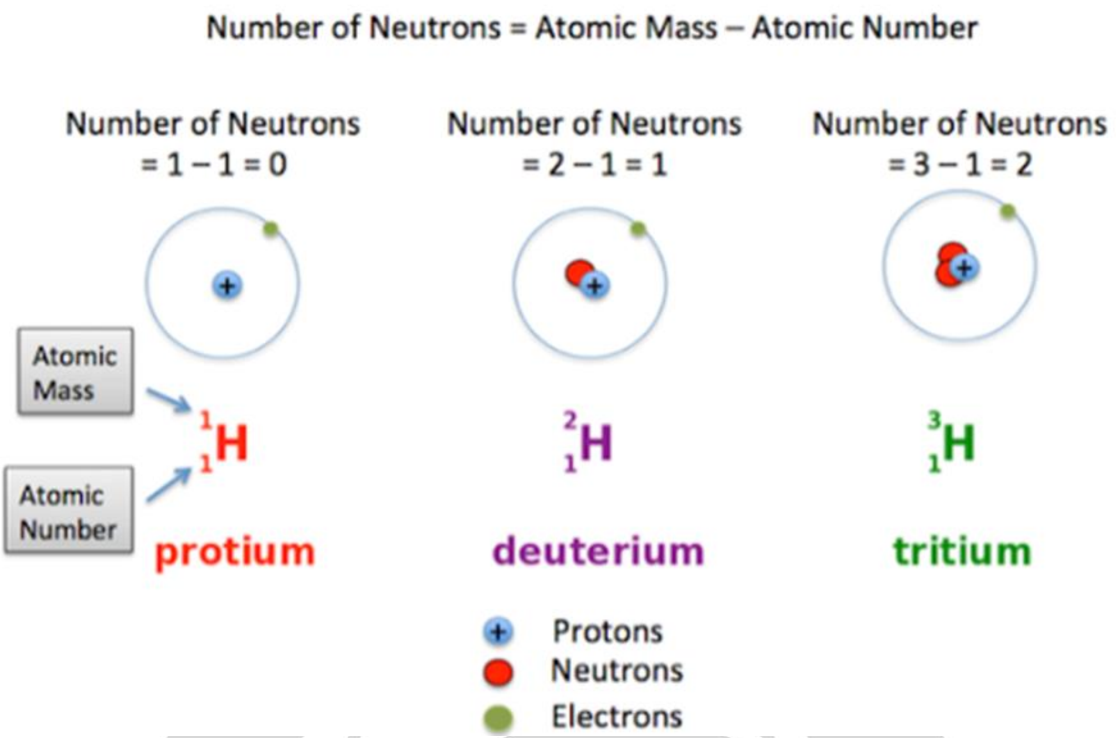
0 4 . 3 Compare the nuclear compositions of **X** and **Y**.

[2 marks]

Explanation:

In general, isotopes of the same element have the same number of protons (atomic number) since they belong to the same element. However, they can have different numbers of neutrons (different mass numbers) which accounts for their different masses.

Therefore, in the case of X and Y, X will have a greater number of neutrons in its nucleus compared to Y, resulting in a heavier mass for isotope X.



Isotopes of Hydrogen

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**.

Explanation:

The formula for specific charge (q/m) is given by:

Specific charge = Charge (q) / Mass (m)

The specific charge represents the ratio of the charge of a particle to its mass. It is typically expressed in units of coulombs per kilogram (C/kg).

Therefore

We can conclude that there is an inverse relationship between the mass and specific charge of a particle. When the mass is large, the specific charge tends to be small, and when the mass is small, the specific charge tends to be large.

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]

Do not write outside the

Sample 1:
- Number of ions: 3.50 × 1016
- Mass of sample: 6.31 × 10^{10} kg
- Charge on each ion: +1.60 × 10^{19} C

Sample 2:
- Number of ions: 3.50 × 107
- Mass of sample: 6.20 × 10^{19} kg
- Charge on each ion: +1.60 × 10^{19} C

For Sample 1:
Mean mass of one ion in Sample 1 = Mass of sample 1 / Number of ions in Sample 1
= (6.31 × 10-10 kg) / (3.50 × 1016 ions)
= 1.80 × 10^{26} kgn-1

For Sample 2:
Mean mass of one ion in Sample 2 = Mass of sample 2 / Number of ions in Sample 2
= (6.20 × 10^{19} kg) / (3.50 × 10^{7} ions)
= 1.77 10^{26} kgn-1

10

Mean mass of nucleons represents the average mass of the individual particles (protons and neutrons) within the sample.

Based on the mean mass, we can conclude that Sample 2 (Y) has a lower mean mass compared to Sample 1 (X), indicating a greater percentage of isotope Y in Sample 2.

Do not write outside the box

0 5 A cell has an emf of $1.5\ \text{V}$ and an internal resistance of $0.65\ \Omega$.
The cell is connected to a resistor **R**.

0 5 . 1 State what is meant by an emf of $1.5\ \text{V}$.

[2 marks]

Explanation:

1. Given: Work done (W) = 1.5 J
2. Formula: W = Q * V, where W is the work done, Q is the charge, and V is the potential difference across the cell.
3. Rearranging the formula: V = W / Q
4. Substituting the given values: V = 1.5 J / 1 C
5. Calculation: V = 1.5 V

Summary:

The potential difference across the cell is 1.5 V when 1 C of charge is moved through the cell, and the work done is 1.5 J.

0 5 . 2 The current in the circuit is $0.31\ \text{A}$.

Show that the total power output of the cell is approximately $0.47\ \text{W}$.

Explanation:

1. Given:
- Current (I) = 0.31 A
- Emf of the cell = 1.5 V
- Internal resistance = 0.65 Ω

Given:

Using the formula P = E * I:
P = 1.5 V * 0.31 A
P ≈ 0.465 W

Therefore, the power output of the cell is approximately 0.465 W.

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

[2 marks]

Explanation:
1. Given:
- Current passing through the circuit (I) = 0.31 A
- Resistance of resistor R (R) = 0.65 Ω
2. Calculate the power dissipated in the resistor using the formula:
- P = I2 * R
- P = (0.31 A)2 * 0.65 Ω
- P ≈ 0.060545 W

Calculate the power dissipated through resistor R:
Pr = P(total) – P(lost)
Pr = 0.465 W - 0.062 W
Pr = 0.403 W

The power lost in the circuit is 0.062 W, and the power dissipated through resistor R is 0.403 W.

To find the energy dissipated through resistor R, we need to multiply the power dissipated by the time (t) for which it is dissipated. Let's assume a time of 1 second for simplicity:

Energy dissipated through resistor R (Er) = Pr * t
Er = 0.403 W * 1 s
Er = 0.403 J

Energy dissipated per second = 0.403 $J\ s^{-1}$

Question 5 continues on the next page

Turn over ►

0 5 . 4 The cell stores $14\ \mathrm{kJ}$ 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]

Explanation:

Given:
Energy stored in the fully charged cell (E) = 1.4 * 104 J
Power dissipated in the circuit (P) = 0.47 W

Using the formula:
Time (t) = Energy (E) / Power (P)

Substituting the given values:
t = (1.4 * 104 J) / (0.47 W)

Converting the power to joules per second (W to J/s):
t = (1.4 * 104 J) / (0.47 J/s)
t ≈ 29787.23 seconds

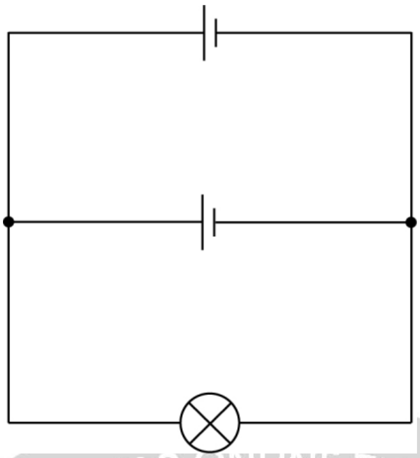
Rounding to the appropriate number of significant figures:
t ≈ 3.0 * 104 seconds

Therefore, the maximum time during which the fully-charged cell can deliver energy to resistor R is approximately 3.0 * 104 seconds or 30,000 seconds.

maximum time = 3×10^4 s

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

Figure 7



The lamp is rated at $1.3\ \text{V}$, $0.80\ \text{W}$.

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

[4 marks]

Explanation:

Given: Emf of each cell (E) = 1.5 V
Difference across the lamp (V) = 1.3 V
Rated power of the lamp (P) = 0.80 W

1. Calculate the internal resistance of each cell (r):
   - r = 0.65 Ω / 2
   - r = 0.325 Ω
2. Calculate the current flowing through the circuit using Ohm's Law:
   - I = (E - V) / r
   - I = (1.5 V - 1.3 V) / 0.325 Ω
   - I = 0.2 V / 0.325 Ω
   - I ≈ 0.615 A
3. Calculate the power delivered to the lamp using the current and potential difference:
   - P = I * V
   - P = 0.615 A * 1.3 V
   - P ≈ 0.80095 W
4. Rounded power delivered to the lamp: ≈ 0.80 W

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17

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0 5 . 6 The lamp operates at normal brightness across a pd range of $1.3\ \mathrm{V}$ to $1.5\ \mathrm{V}$.

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]

Explanation:

Adding Cells to Extend Lamp Operation Time

1. **Connect Cells in Parallel:**
- By connecting cells in parallel, the total emf of the circuit remains unchanged.
- Cells in parallel maintain a consistent potential difference across the lamp.

2. **Increased Energy Capacity:**
- Adding cells in parallel increases the total energy capacity of the circuit.
- The lamp can operate for a longer duration before the cells are depleted.

3. **Maintaining Normal Brightness:**
- With more cells in parallel, the lamp can continue to operate at normal brightness.
- The potential difference across the lamp remains within the desired range.

4. **Reduced Power Losses:**
- Connecting cells in parallel reduces the total internal resistance of the circuit.
- This minimizes power losses within each cell and improves the overall efficiency.

5. **Smaller Current through Each Cell:**
- When cells are connected in parallel, the total current is distributed among the cells.
- Each cell carries a smaller current compared to when cells are connected in series.

6. **Unchanged Emf:**
- When cells are connected in parallel, the emf of each individual cell remains the same.
- The total emf of the circuit is the sum of the emfs of the cells.

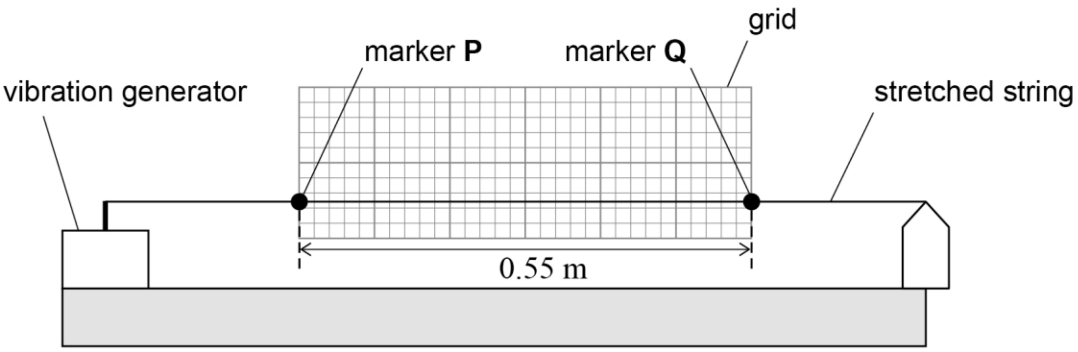
By considering these factors and adding more cells in parallel, the lamp can maintain normal brightness for an extended period. This is achieved by increasing the energy capacity, reducing power losses, distributing smaller currents to each cell, and keeping the emf consistent across the circuit.

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 $0.55\ \mathrm{m}$ 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



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

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

[2 marks]

Explanation:

Marker P:
- Undergoes simple harmonic motion
- Reaches maximum displacement in one direction
- Moves up and down with a large amplitude
- Motion is exactly out of phase by 180 degrees (π radians) with marker Q

Marker Q:
- Undergoes simple harmonic motion
- Reaches maximum displacement in the opposite direction of marker P
- Moves up and down with a large amplitude
- Motion is exactly out of phase by 180 degrees (π radians) with marker P

In summary:

When markers P and Q are both at adjacent antinodes with a phase difference of 180 degrees (π radians), they undergo simple harmonic motion with a large amplitude. Their motion is exactly out of phase, where one marker reaches maximum displacement while the other reaches maximum displacement in the opposite direction.

Question 6 continues on the next page

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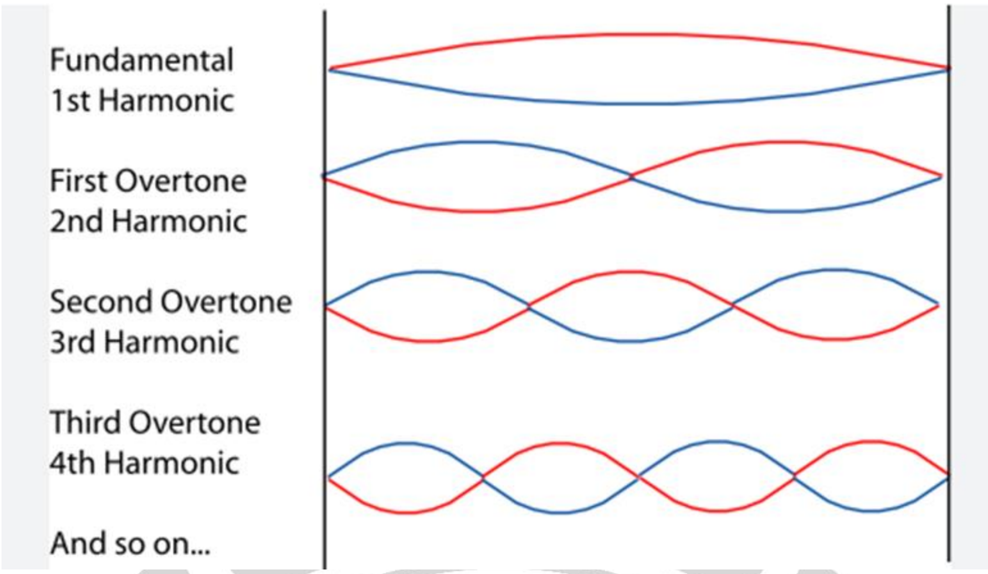

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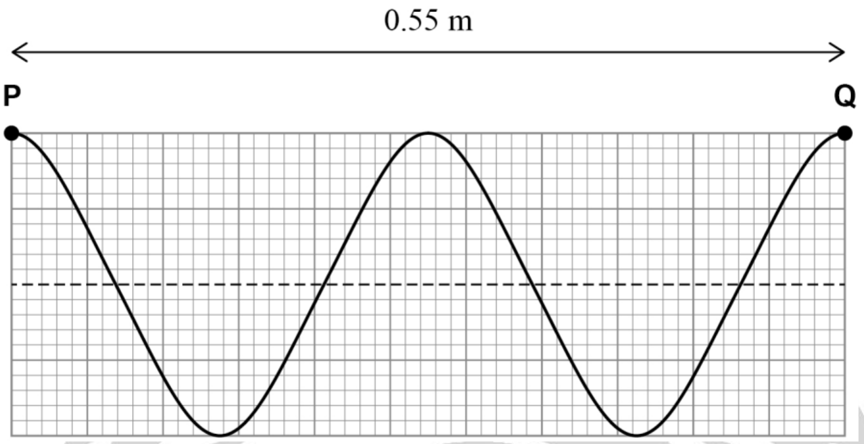
0 6 . 2 The frequency of the vibration generator is increased, and a higher harmonic of the stationary wave is formed.

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.

Figure 9



The frequency of the vibration generator is 250 Hz.

Calculate the wave speed.

[2 marks]

Explanation:

If we are given that the distance between markers P and Q, which is 0.55 m, is equal to 2 times the wavelength (2λ), we can calculate the wavelength as follows:

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

Dividing both sides by 2:

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

Now that we have the wavelength, we can use the frequency ($f = 250$ Hz) and the calculated wavelength ($\lambda = 0.275$ m) to find the wave speed (v) using the formula:

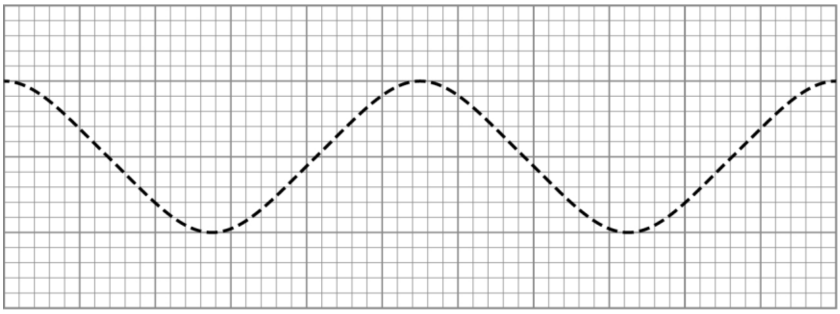
$v = \lambda * f$

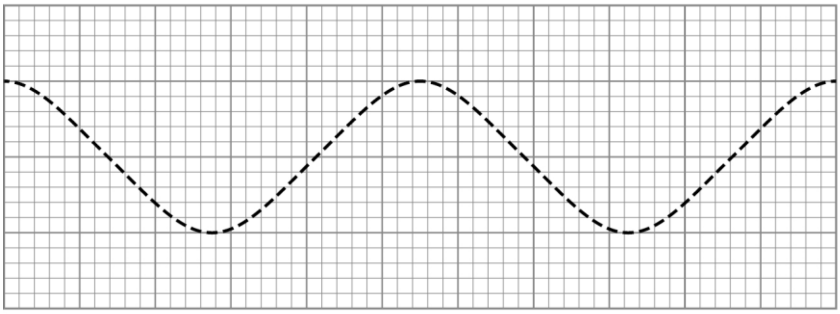
$v = 0.275\text{ m} * 250\text{ Hz}$
$v = 68.75\text{ m/s}$

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]

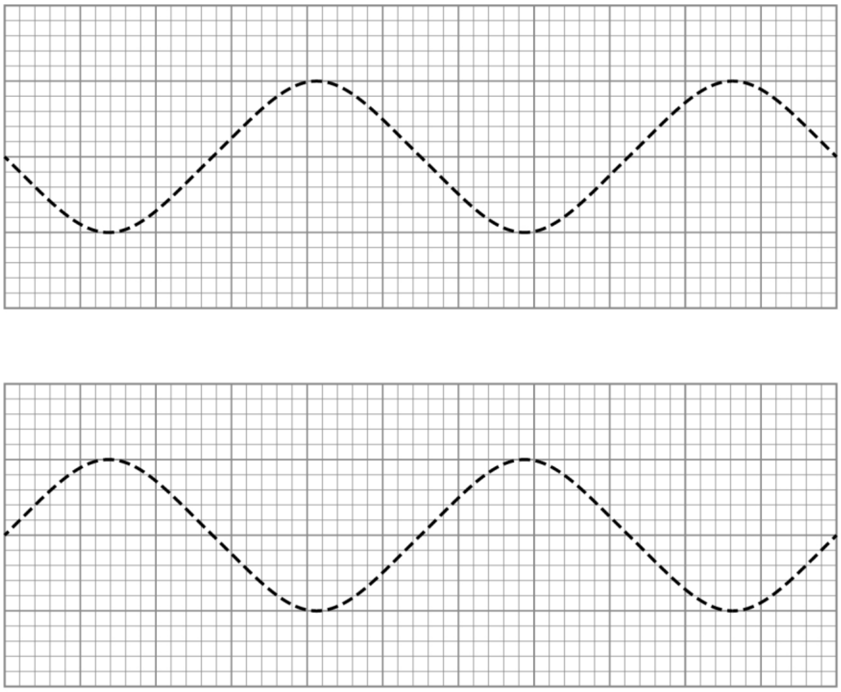
Explanation:

1. Same speed: Both waves must travel at the same speed along the string.
2. Moving in opposite directions: The waves should propagate in opposite directions along the string.
3. Same wavelength: Both waves must have the same wavelength.
4. Same frequency: The waves should have the same frequency.
5. Similar amplitudes: The waves should have similar amplitudes.

Question 6 continues on the next page

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

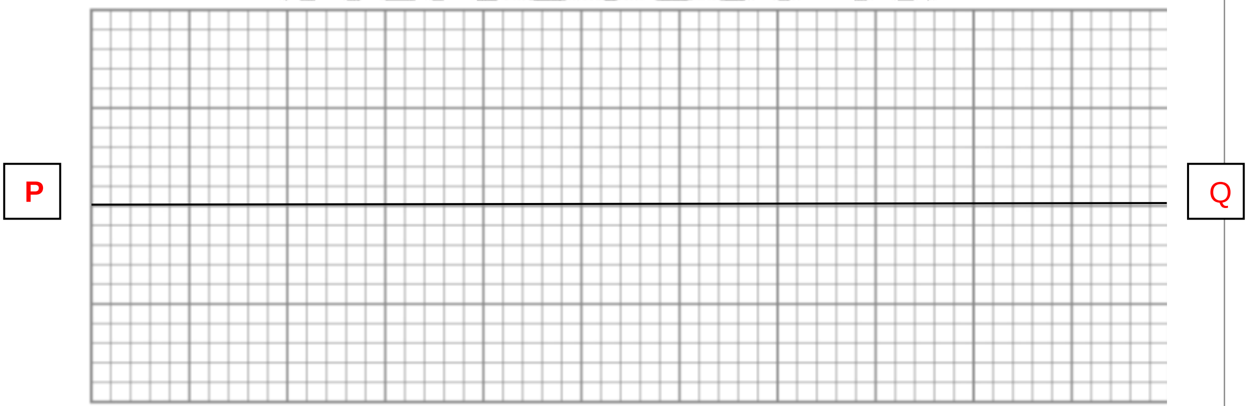
Figure 11



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

[1 mark]

Figure 12



Explanation:

1. Represents string at rest: The line indicates the equilibrium position of the string.

2. Indicates destructive interference: It visually shows where the waves cancel each other out.

3. Signifies zero net displacement: The line represents points where the combined Q displacements of the waves add up to zero.

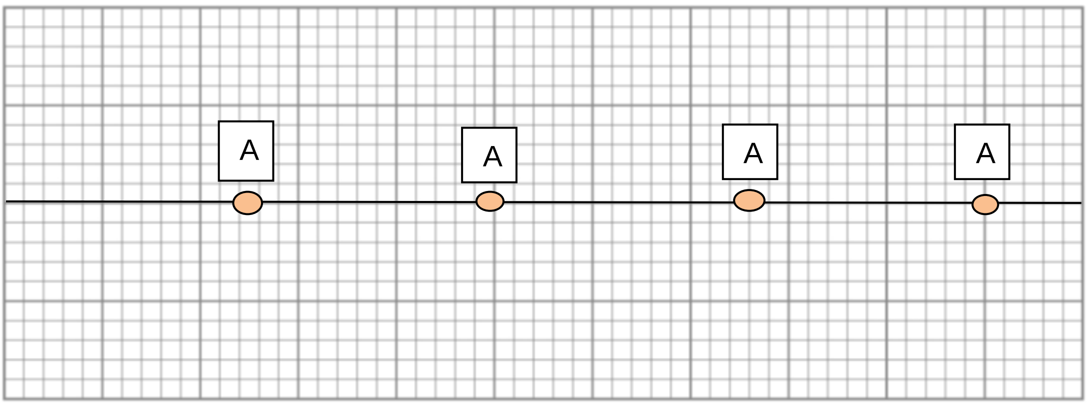
4. Represents a specific moment in time: The configuration captured by the line reflects a particular instant when the waves interfere destructively.

In summary

The horizontal line drawn from marker P to marker Q in Figure 11 represents the string at rest, illustrates destructive interference, signifies zero net displacement, and indicates a specific moment in time.

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

[2 marks]



Explanation:

Nodes:

1. Occur at points where the two waves interfere destructively.
2. Represent regions of zero net displacement.
3. Specific positions depend on the relative speeds and wavelengths of the waves

Antinodes:

1. Occur at points where the two waves interfere constructively.
2. Represent regions of maximum displacement.
3. Specific positions depend on the relative speeds and wavelengths of the waves

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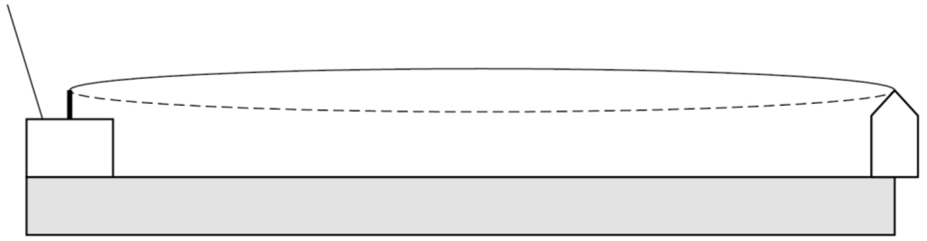
0 6 . 6 The frequency of the vibration generator is reduced until the first harmonic is observed in the string, as shown in **Figure 13**.

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]

Explanation:
The formula for the frequency (f) of the first harmonic in a stretched string is given by:
f = (1/2L) * √(T/μ)

Wave Speed:

1. The wave speed (v) on a string is given by the formula: v = √(T/μ), where T is the tension in the string and μ is the linear density (mass per unit length) of the string.

2. Increasing the mass of the string by 9 times means the new linear density is 9 times the original linear density: μ' = 9μ.

3. The new wave speed (v') with the increased linear density is calculated as follows: v' = √(T/μ') = √(T/(9μ)) = (1/3)√(T/μ) = (1/3)v.

4. Therefore, the new wave speed (v') is one-third (1/3) of the original wave speed (v).

Harmonics:
1. Harmonic frequencies decrease proportionally with the decrease in wave speed.
2. The pattern and spacing between harmonics remain unchanged.
3. The frequency of each harmonic in the new string is one-third (1/3) of the original frequency.
4. The formula for the frequency of the nth harmonic is f_n = n(v/2L).
5. The new frequency for each harmonic can be calculated as f'_n = (1/3)f_n .

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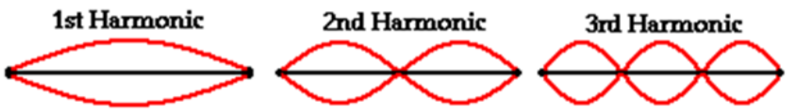

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