RAFFLES INSTITUTION
2021 YEAR 5 PROMOTIONAL EXAMINATION

30 September 2021 Time: 2 hr 30 min

H2 PHYSICS

Section A

INSTRUCTIONS TO CANDIDATES

There are 3 sections in this paper.

Section A consists of **15** multiple-choice questions. For each question, four suggested answers are given. You are to choose the most appropriate one and shade your answer on the OMR form, using a soft pencil.

You are advised to attempt Section A first. The **OMR form will be collected at the end of the first 30 minutes**.

Section B consists of **5** structured questions. You are to write your answers in the spaces provided.

Section C consists of **2** longer structured questions. You are to write your answers in the spaces provided.

Attempt ALL questions in Sections A, B and C.

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	$T / °C + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t = \pm\omega\sqrt{x_0^2 - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\ln 2 / t_{1/2}$

Section A (15 marks)

1 The resistive force F acting on a sphere of radius r travelling with speed v through a liquid is given by the equation

$$F = 6\pi\eta r v$$

where η is a constant.

What are the SI units of η?

A kg m^{-1} s^{-1} **B** kg m^{2} s^{-1} **C** kg m^{-1} s^{-2} **D** kg^{-1} s^{-3}

2 Two lengths X and Y are measured to be (51.0 ± 0.1) cm and (49.0 ± 0.1) cm respectively.

Which of the following quantities has the largest percentage uncertainty?

A $X + Y$ **B** $X - Y$ **C** XY **D** $\frac{X}{Y}$

3 Jack and Jill are standing 15 m apart on level ground when Jack throws a ball with speed u at an angle above the horizontal towards Jill.

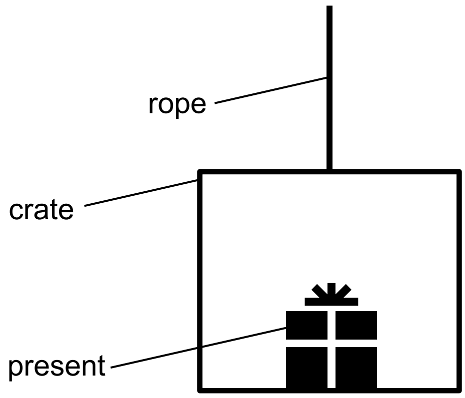
At the same time when Jack throws the ball, Jill runs towards it with a speed of 8.9 m s^{-1} and catches the ball 0.49 s after it is thrown.

The ball is thrown and caught at the same height above the ground.

What is the speed u of the ball?

A 11 m s^{-1} **B** 22 m s^{-1} **C** 31 m s^{-1} **D** 40 m s^{-1}

4 A piece of rope with a maximum allowable tension of 30 N is used to lift a 2.0 kg crate containing a 0.30 kg present.



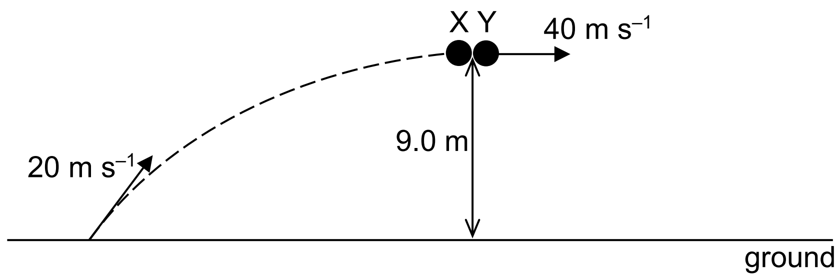
The crate is accelerated upwards at an increasing rate until the rope breaks.

What is the force that the present exerts on the crate just before the rope breaks?

A 3.9 N **B** 4.5 N **C** 9.5 N **D** 26 N

5 A projectile of mass $2m$ is launched at an angle to the ground with a speed of 20 m s^{-1}.

When the projectile is at the peak of its trajectory, 9.0 m above the ground, it explodes into two pieces, X and Y, each of equal mass m.

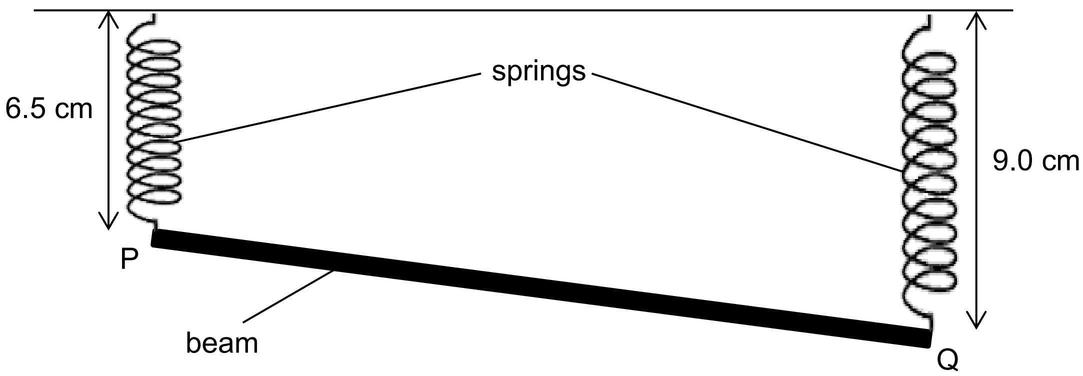


If Y has a speed of 40 m s^{-1} horizontally to the right immediately after the explosion, what is the speed of X immediately after the explosion? Ignore the effects of air resistance.

A 0 m s^{-1} **B** 10 m s^{-1} **C** 25 m s^{-1} **D** 40 m s^{-1}

6 A 2.0 m beam with a non-uniform mass distribution is supported at its ends P and Q by two identical vertical springs of unstretched length 4.0 cm.

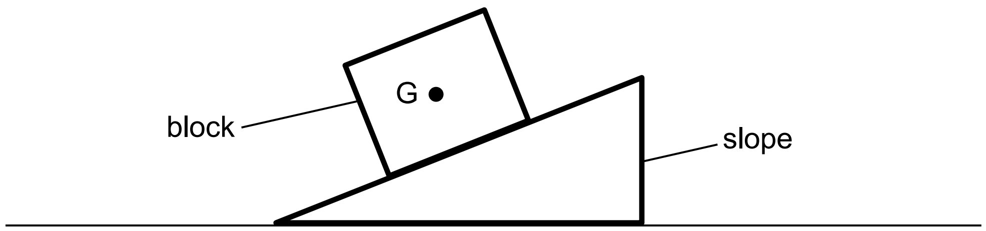
When the beam is in equilibrium, the lengths of each spring are 6.5 cm and 9.0 cm as shown.



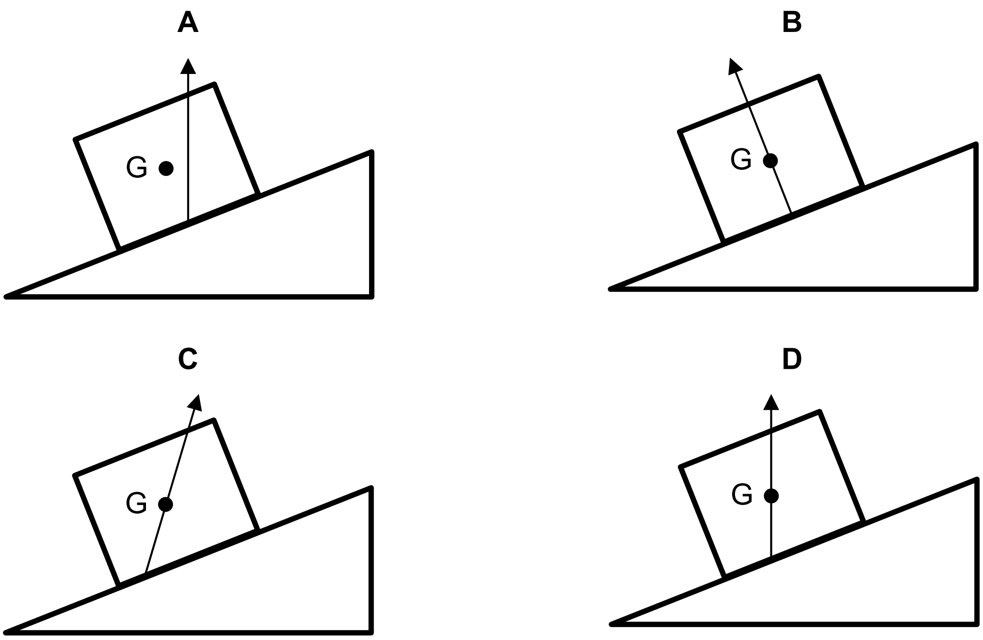
What is the distance between the beam's centre of gravity and end P?

A 1.0 m **B** 1.2 m **C** 1.3 m **D** 1.4 m

7 A block is at rest on a slope. Point G represents the centre of gravity of the wooden block.



Which of the following shows the direction of the force the slope exerts on the block?

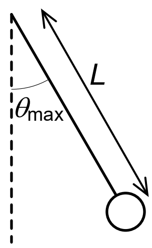


8 Two objects P and Q of masses m and $2m$ respectively are initially at rest on a smooth, horizontal surface.

If the same force acts on each of them for the same duration, the ratio $\dfrac{\text{gain in kinetic energy by P}}{\text{gain in kinetic energy by Q}}$ is

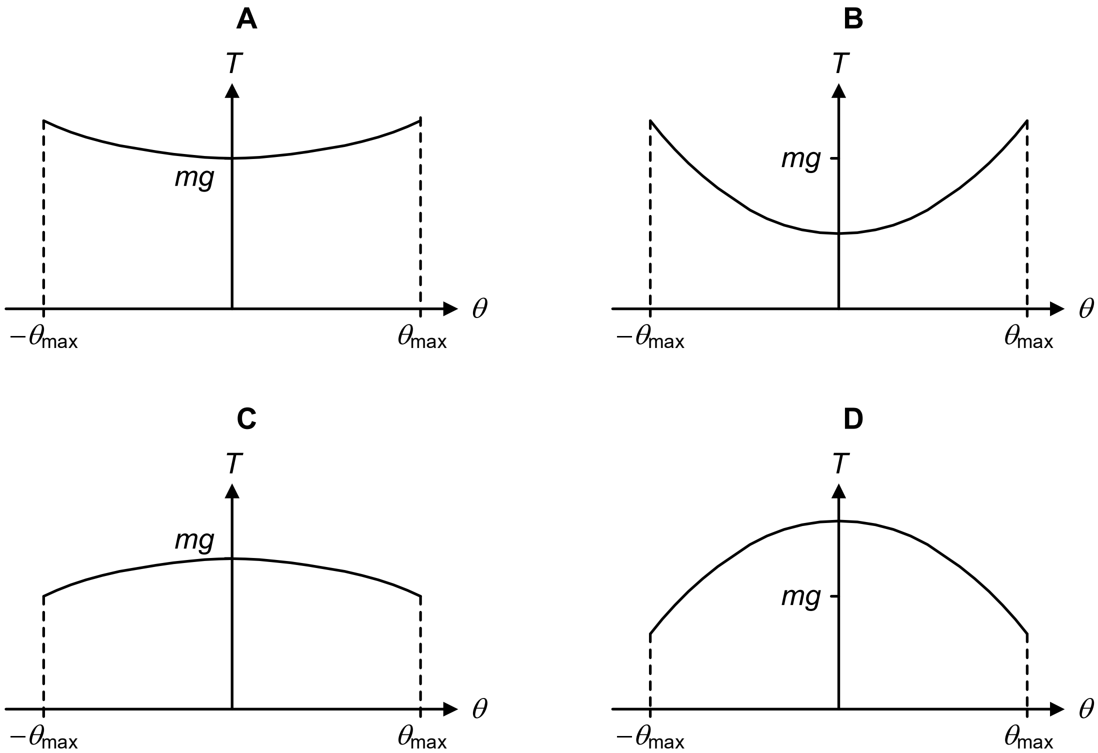
A 0.25 **B** 0.50 **C** 1.0 **D** 2.0

9 A pendulum of length L and mass m is displaced at an angular displacement θ_{max} from the vertical as shown.



The pendulum is released.

Which of the following graph best represents the variation with angular position θ of the tension T in the string?



10 Which row describes the effect of atmospheric drag on a satellite's orbit?

	orbital speed	orbital radius	total energy
A	increases	increases	increases
B	increases	decreases	decreases
C	decreases	increases	increases
D	decreases	decreases	decreases

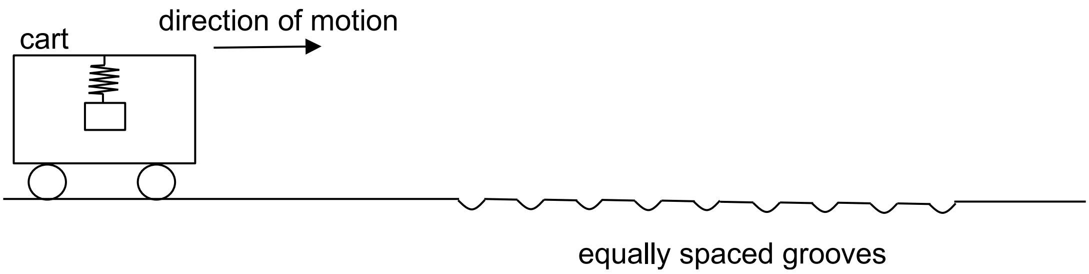
11 A 1.0 kg mass is attached to a horizontal spring on a smooth table. The mass is then displaced horizontally from its equilibrium position by 0.10 m and released from rest. The mass next comes to rest again after 0.50 s.

What is the maximum speed of the mass?

A 0.31 m s^{-1} **B** 0.39 m s^{-1} **C** 0.63 m s^{-1} **D** 0.99 m s^{-1}

12 A 50 g mass is suspended from one end of a light spring of force constant 25 N m^{-1}. The other end of the spring is fixed to the roof of a 200 g cart.

When the cart moves over a series of equally spaced grooves, the mass oscillates vertically. The amplitude of oscillation is largest when the speed of the cart is 8.0 m s^{-1}.



What is the separation of the grooves?

(The frequency of oscillation of a loaded spring is given by $\frac{1}{2\pi}\sqrt{\frac{k}{m}}$ where m is the mass suspended from the spring and k is the force constant.)

A 0.20 m **B** 0.44 m **C** 2.2 m **D** 5.0 m

13 A sound wave of frequency 500 Hz is travelling at a speed of 300 m s^{-1}.

What is the phase difference between two points 0.75 m apart along the direction of travel?

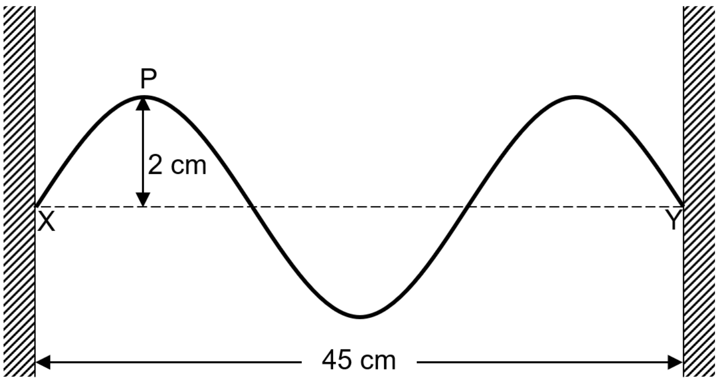
A 0.50π rad **B** 0.90π rad **C** 1.3π rad **D** 1.6π rad

14 Which row correctly compares the characteristics of progressive and stationary waves?

	progressive wave	stationary wave
A	all particles within one wavelength have different phases	particles between adjacent segments have the same phase
B	energy is transported at a speed given by the frequency divided by the wavelength	no net transport of energy
C	distance between two adjacent points that have the same phase is one wavelength	distance between a node and the adjacent antinode is half a wavelength
D	amplitude of vibration is the same at all points	amplitude of vibration varies with position

15 Two sinusoidal waves, travelling in opposite directions along a string XY that is fixed at both ends, form a stationary wave. The separation between X and Y is 45 cm.

The diagram shows the shape of the string at an instant when the antinode P attains its maximum displacement of 2 cm from the equilibrium position.



What is the amplitude and wavelength of each of the sinusoidal wave travelling on the string?

	amplitude	wavelength
A	2 cm	30 cm
B	2 cm	15 cm
C	1 cm	30 cm
D	1 cm	15 cm

END OF SECTION A

Name: ____________________________ (   )   CT Group: 22S0 _______

RAFFLES INSTITUTION

2021 YEAR 5 PROMOTIONAL EXAMINATION

30 September 2021

H2 PHYSICS

Section B

INSTRUCTIONS TO CANDIDATES

Write your name, index number and CT Group.

Write your answers to Section B in the spaces provided on the question paper.

For Examiner's Use		
Section A	MCQ	/ 15
Section B	1	/ 10
	2	/ 10
	3	/ 10
	4	/ 8
	5	/ 12
Section C	6	/ 15
	7	/ 15
Deductions		
Total		/ 95
%		

This document consists of **12** printed pages.

Section B (50 marks)

1 A sphere of mass 0.040 kg and density 8910 kg m^{-3} is suspended by a thin string and submerged in a tall container of liquid of density 1410 kg m^{-3} as shown in Fig. 1.1.

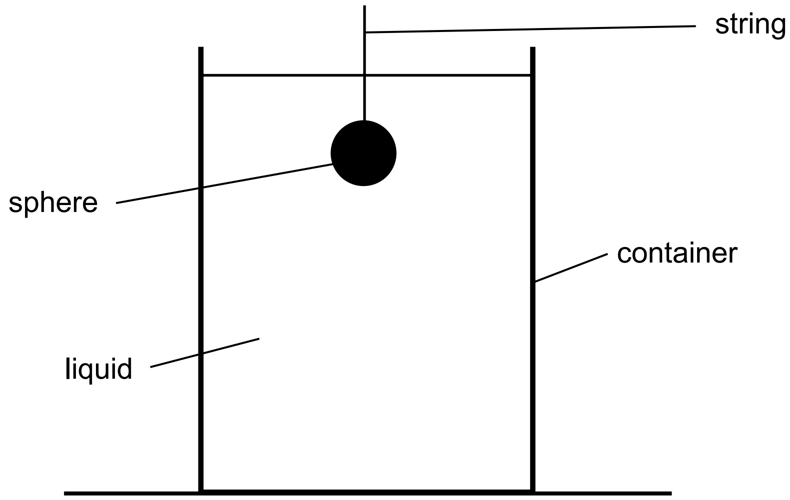


Fig. 1.1

The string is cut and the sphere begins falling from rest through the liquid, where it experiences a drag force F_D such that

$$F_D = \beta v$$

where v is the speed of the sphere and β is a constant with a value of 0.26 kg s^{-1}.

After falling for 2.0 s, the sphere reaches terminal velocity. The sphere then continues to fall at terminal velocity for another 2.5 s.

(a) **(i)** Show that the upthrust on the sphere is 0.062 N.

[1]

(ii) Determine the terminal velocity of the sphere.

terminal velocity = ... m s^{-1} [2]

(iii) Determine the magnitude of the average force acting on the sphere during the first 4.5 s of its motion through the liquid.

average force = ... N [2]

(b) On Fig. 1.2, sketch the variation with time *t* of the displacement *s* of the sphere for the first 4.5 s of the sphere's motion through the liquid.

At t = 0, the string is cut and s = 0. Take the downwards direction to be positive.

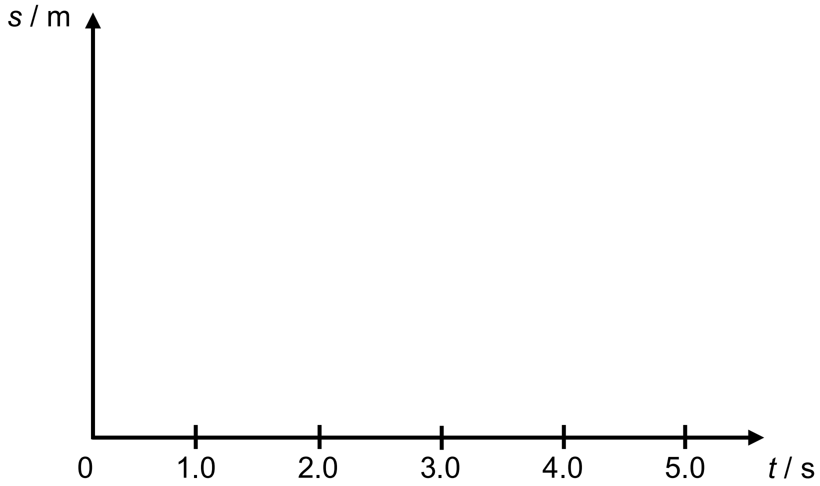


Fig. 1.2 [2]

(c) The setup shown in Fig. 1.1 is placed on top of a mass balance.

Immediately after the string is cut, the reading on the mass balance is X. When the sphere is moving at terminal velocity, the reading on the mass balance is Y.

State and explain if Y is smaller, equal to, or larger than X.

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.... [3]

2 A small smooth ring of mass m is threaded on a light inextensible string of length $8L$. The two ends of the string are fixed at a distance of $4L$ apart on a vertical rod as shown in Fig. 2.1.

The ring is then made to move in a horizontal circle around the rod at constant speed with the string taut and the lower portion of the string horizontal.

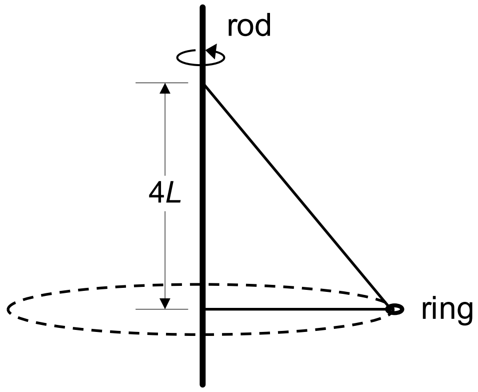

Fig. 2.1

(a) Determine, in terms of m, L and the acceleration of free-fall g, where appropriate,

(i) the radius of the circular motion of the ring,

radius = ... [2]

(ii) the tension in the string,

tension = ... [3]

(iii) the angular speed of the ring,

angular speed = ... [2]

(iv) the linear speed of the ring.

linear speed = ... [1]

(b) State and explain in terms of the forces acting on the ring, whether the ring will rise or fall while undergoing circular motion if its angular speed is increased slightly.

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.... [2]

3 (a) A ball thrown vertically upwards from the edge of a tabletop reaches its highest point, reverses direction and bounces off the ground below the table, before returning to its initial position. Fig. 3.1 shows this path of the ball.

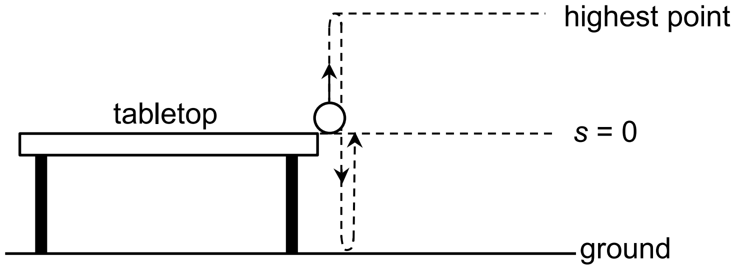

Fig. 3.1

Fig. 3.2 shows the variation with vertical displacement s from the tabletop of the acceleration a of the ball, with the position of the tabletop taken as s = 0. Ignore all energy losses.

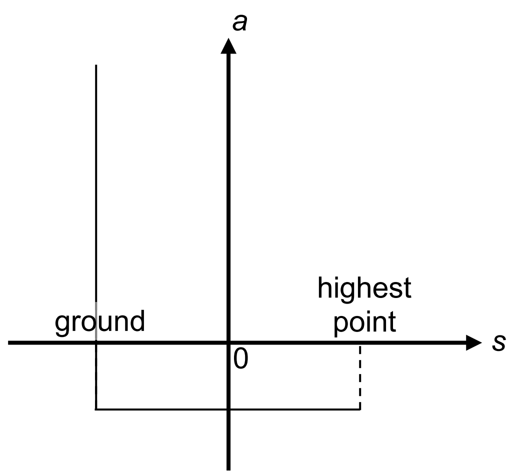

Fig. 3.2

With reference to Fig. 3.2 and the definition for simple harmonic motion, discuss whether the motion of this bouncing ball is considered simple harmonic.

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.... [3]

(b) A pendulum of length *L* is suspended from a fixed point as shown in Fig. 3.3.

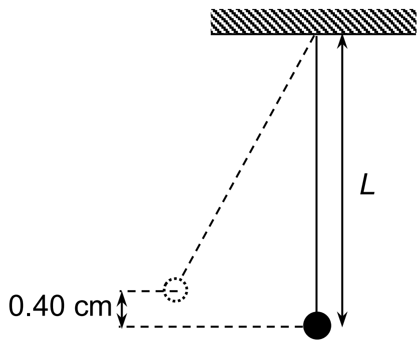

Fig. 3.3
(not drawn to scale)

Keeping the string taut, the pendulum of mass *m* is displaced by a small angle such that its centre of mass rises vertically by 0.40 cm.

When the pendulum is released from this position, it performs simple harmonic motion.

The total potential energy of the pendulum is zero at the equilibrium position.

The variation with horizontal displacement *x* from the equilibrium position of the kinetic energy E_K of this pendulum is as shown in Fig. 3.4.

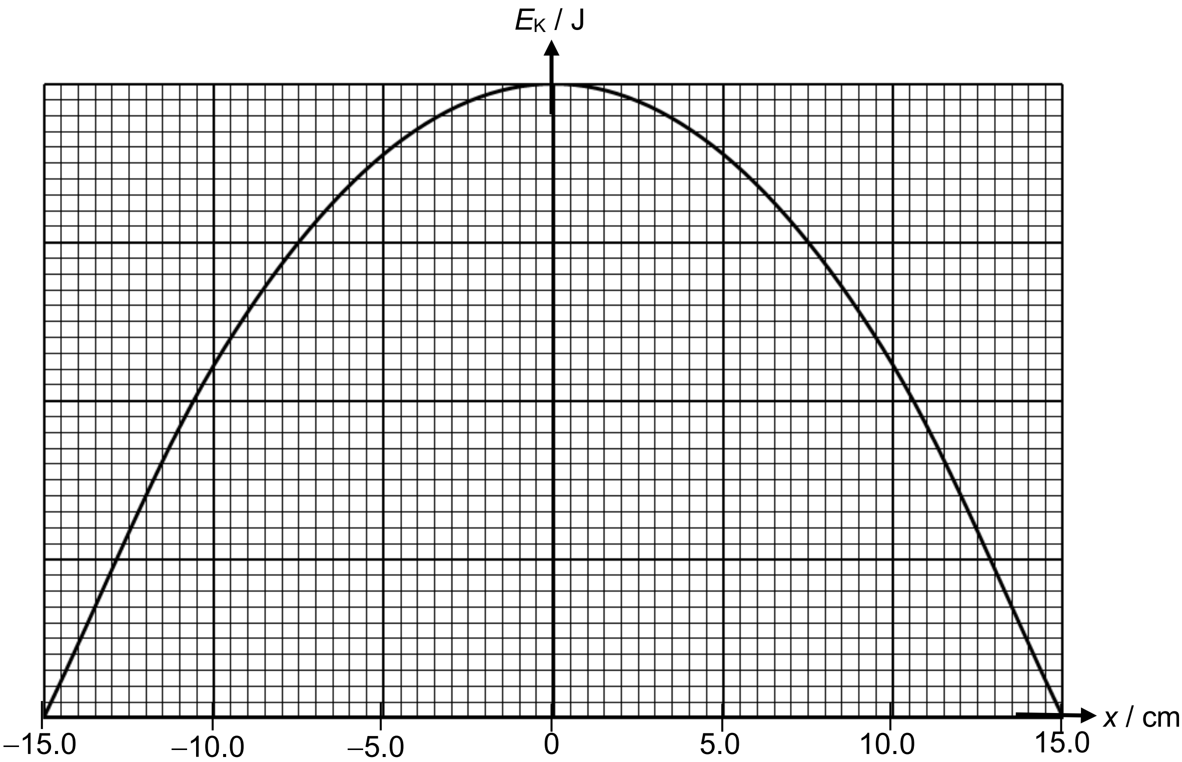

Fig. 3.4

(i) Determine an expression, in terms of m and the acceleration of free-fall g, for the total energy of the pendulum.

Explain your working clearly.

total energy = ... J [2]

(ii) If the angular frequency ω of the pendulum is $\sqrt{\frac{g}{L}}$, use your expression in **(b)(i)** to deduce the length L of the pendulum.

L = ... m [3]

(iii) The pendulum is now displaced such that its centre of mass rises vertically by 0.30 cm instead and released.

Without any further calculations, use Fig. 3.4 to determine the new amplitude of the oscillations.

Show your construction clearly on Fig. 3.4.

amplitude = ... cm [2]

4 **(a)** State what is meant by *polarisation* with respect to an electromagnetic wave.

....

....

....

.... [2]

(b) Two sheets of polarisers P and Q are placed close to each other with their polarising axes vertical.

A parallel beam of unpolarised light passes through polariser P. After passing through polariser P, the light beam has amplitude A_0 and intensity I_0.

The light beam then passes through polariser Q.

Polariser Q is now rotated clockwise about the axis of the light beam through an angle θ as shown in Fig. 4.1. At this angle θ, the amplitude of the light beam after passing through polariser Q first reaches $\frac{A_0}{3}$.

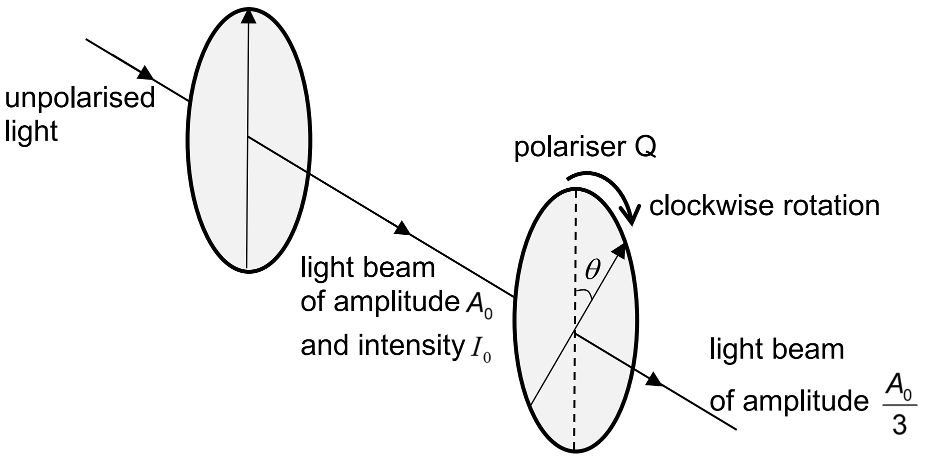

Fig. 4.1

(i) Determine, in terms of I_0, the intensity of the light beam after passing through polariser Q.

intensity = ... [2]

(ii) Calculate the angle θ.

θ = ... ° [2]

(iii) State the angles through which polariser Q must be further rotated from the angle calculated in **(b)(ii)** in the clockwise direction, to observe two consecutive intensity maxima of the light beam after passing through polariser Q.

Explain your answers.

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.... [2]

5 **(a)** A loudspeaker is connected to a signal generator to produce a progressive longitudinal sound wave.

Fig. 5.1 shows the variation with distance from the loudspeaker of the displacement of air particles at a particular instant in time. Displacement towards the right is taken to be positive.

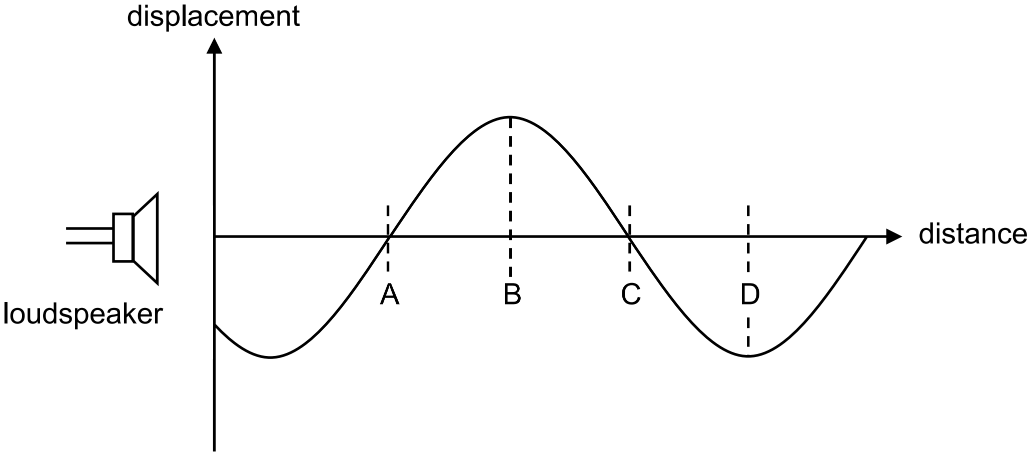

Fig. 5.1

(i) Distinguish between *longitudinal* and *transverse* waves in terms of the motion of the particles.

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.... [2]

(ii) State and explain which point (A, B, C or D) has the highest pressure.

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.... [2]

(b) To produce a stationary wave, a tube QR with a piston P is placed in front of the loudspeaker as shown in Fig. 5.2. As piston P is moved from Q towards R, a loud sound is first heard when QP is 0.15 m. The next loud sound is heard when QP is 0.47 m.

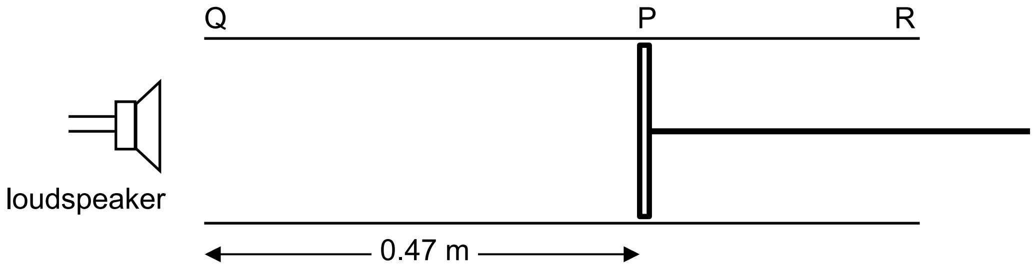

Fig. 5.2

(i) Explain the formation of a *stationary wave* in the tube.

....

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....

.... [2]

(ii) Given that the speed of sound in air is 330 m s^{-1}, determine

1. the end-correction for the tube,

end-correction = ... m [2]

2. the frequency of the sound waves.

frequency = ... Hz [2]

(iii) Complete Fig. 5.2 to represent the stationary wave in the tube when QP is 0.47 m. Indicate the positions of antinodes with A and nodes with N.

[2]

END OF SECTION B

Name: ____________________________ (   ) CT Group: 22S0 _______

RAFFLES INSTITUTION

2021 YEAR 5 PROMOTIONAL EXAMINATION

30 September 2021

H2 PHYSICS

Section C

INSTRUCTIONS TO CANDIDATES

Write your name, index number and CT Group.

Write your answers to Section C in the spaces provided on the question paper.

For Examiner's Use		
Section C	6	/ 15
	7	/ 15

This document consists of **10** printed pages.

Section C (30 marks)

6 **(a)** **(i)** Define *gravitational potential* at a point.

....

....

.... [1]

(ii) Explain why gravitational potential in a gravitational field is negative.

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.... [2]

(b) The variation with distance r of the gravitational potential ϕ from the centre of a planet is shown in Fig. 6.1.

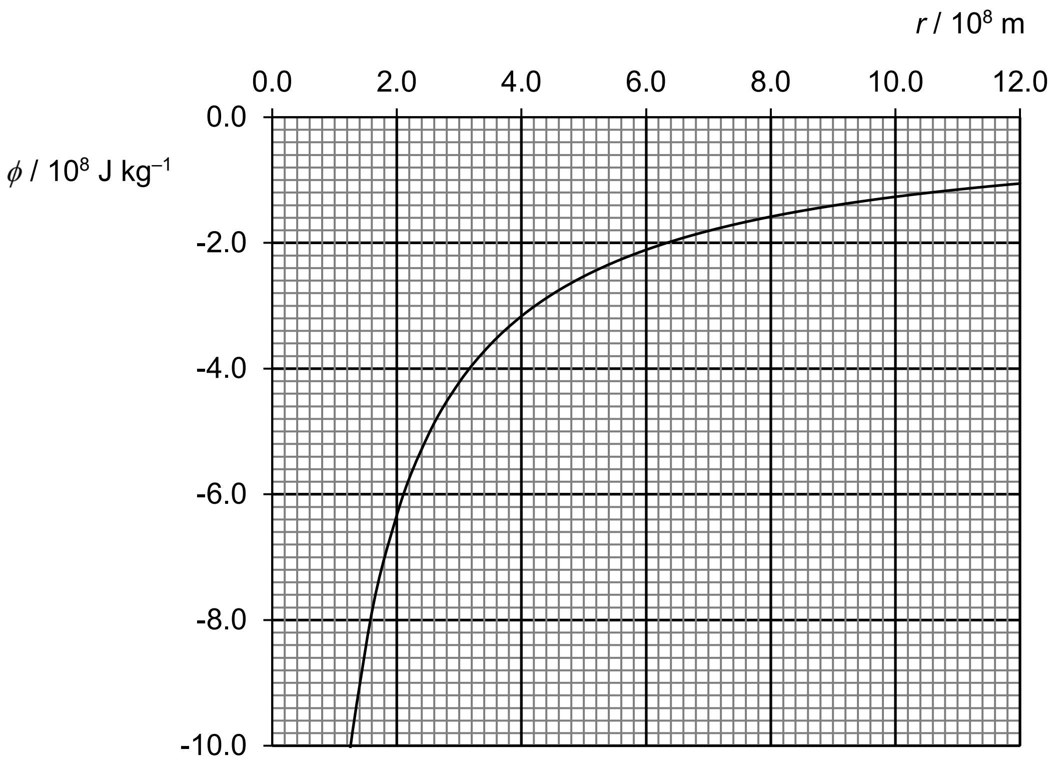

Fig. 6.1

(i) Using Fig. 6.1, show that the mass of the planet is 1.9×10^{27} kg.

[1]

(ii) Fig. 6.2 shows the planet and two points, X and Y, in its gravitational field. Points X and Y are 8.0×10^{8} m and 2.0×10^{8} m from the centre of the planet respectively.

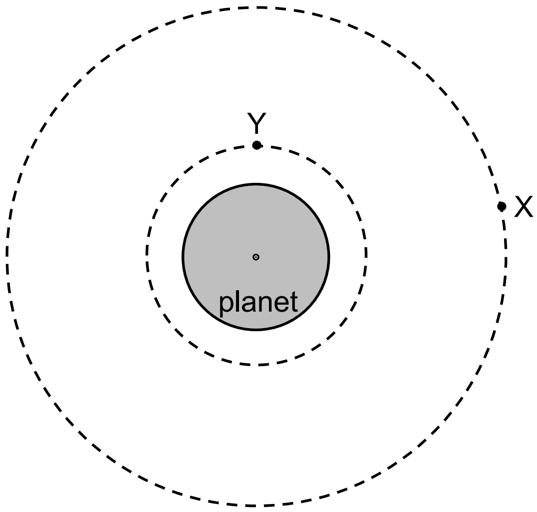

Fig. 6.2

1. Determine the orbital speed of an object that is orbiting the planet with a radius of 2.0×10^{8} m.

Explain your working.

orbital speed = ... m s^{-1} [3]

2. As a space stone approaches the planet, it passes through point X with a speed of 3.5×10^4 m s^{-1} and continues to pass through point Y.

The direction in which the space stone passes through point Y is parallel to a tangent to the planet's surface as shown in Fig. 6.3.

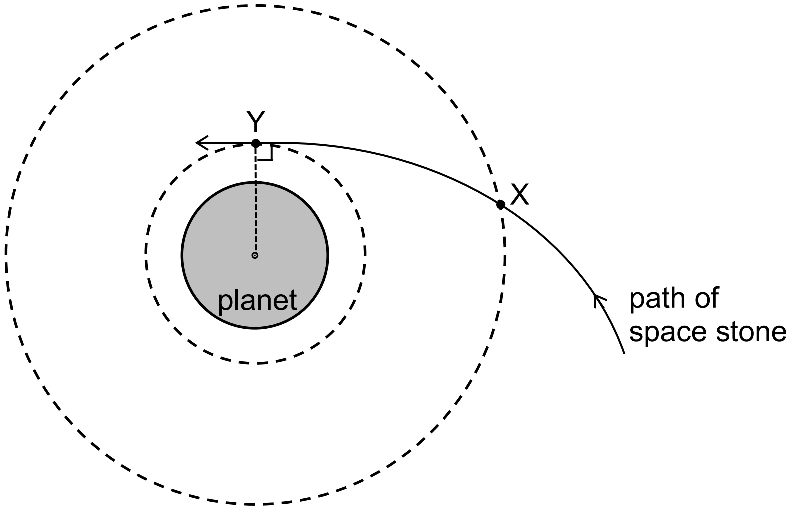

Fig. 6.3

Explain why the space stone will not move in a circular orbit around the planet when it reaches point Y.

Support your explanation with appropriate calculations and with reference to your answer in **(b)(ii)1.**

....

....

.... [4]

3. If the mass of the space stone is 1.5×10^5 kg, calculate the total energy of the space stone.

total energy = ... J [2]

4. Deduce if the space stone will escape the gravitational field of the planet after it passes through point Y.

State your reason.

....

....

.... [2]

7 A hyperloop is a potential super speed transportation system that consists of a system of tubes with vacuum interiors that makes it very energy efficient. People can travel in a hovering pod inside these vacuum tubes at speeds close to the speed of sound in air. Fig. 7.1 shows what a hovering pod in a hyperloop may look like.

A proposed route runs from Los Angeles to San Francisco Bay. It takes about half an hour to cover this 500 km route. This is considerably shorter than current rail or air times.

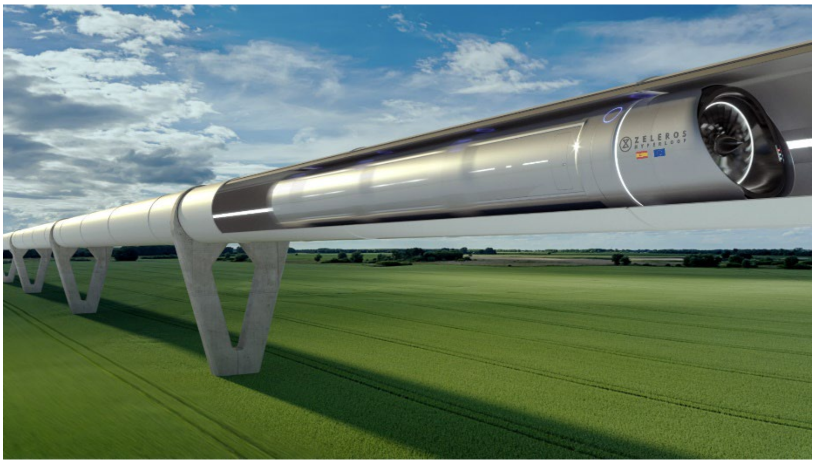

Fig. 7.1

Groups of engineers from different companies have conceptualised the idea and worked on prototypes of the hyperloops. The first stage of testing is to use computer simulations and compare it with experiments to see whether there are differences in the theoretical and actual results.

(a) In one computer simulation, the pod in the hyperloop starts from rest, accelerates uniformly before travelling at a constant speed, then finally decelerates uniformly to rest. Theoretical values of the distance *s* travelled by the pod at various times *t* are obtained. Fig. 7.2 shows the values of *s* for part of the journey from $t = 0.0$ min to $t = 3.0$ min .

t / min	*s* / m	*t* / min	*s* / m
0.0	0.000	1.6	13 310
0.2	209	1.8	16 440
0.4	835	2.0	19 570
0.6	1 879	2.2	22 700
0.8	3 341	2.4	25 830
1.0	5 220	2.6	28 960
1.2	7 517	2.8	32 090
1.4	10 230	3.0	35 220

Fig. 7.2

(i) Using kinematics equation(s) and relevant data from Fig. 7.2, show that the acceleration of the pod during the initial part of the journey is 2.9 m s^{-2} .

[1]

(ii) Estimate the time taken for the pod to accelerate to its constant speed. Explain your working.

time taken = ... min [3]

(iii) The technology of the hyperloop can actually accelerate the pod at accelerations much greater than 2.9 m s^{-2}.

Suggest a reason for not doing so despite potentially saving transport time.

....

....

.... [1]

(b) The engineers also studied the motion of objects that are dropped in the pod while it travels in the hyperloop. This study serves to inform them whether the high speed at which the pod travels may cause potential danger to passengers when objects are dropped in front of or behind them.

Fig. 7.3 shows a pod within a hyperloop tube travelling to the right at constant speed when a passenger in the pod releases a box from rest.

Fig. 7.4 shows the pod and passenger a while later when the box hits the floor of the pod.

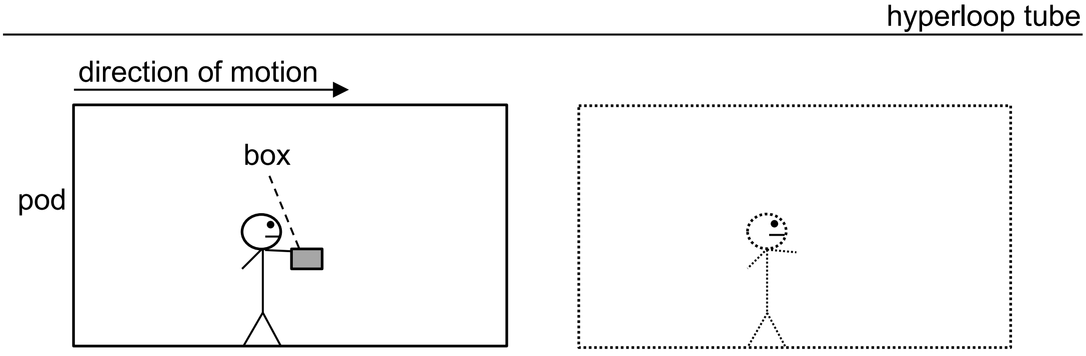

Fig. 7.3 **Fig. 7.4**

(i) **1.** On Fig. 7.4, draw the position of the box when it hits the floor of the pod. [1]

2. Draw the path of the box from the moment the box is released in Fig. 7.3 to the moment the box hits the floor in Fig. 7.4, as seen by an observer outside the pod. [1]

(ii) The pod now decelerates uniformly. The passenger repeats the experiment again by releasing the box just before the pod starts to decelerate and observes the motion of the box until it hits the floor.

Describe the motion of the box as observed by the passenger in the pod and compare the position of the box where it hits the floor with the position you have drawn in **(b)(i)1.**

....

....

....

.... [2]

(c) **(i)** In an experiment, a scaled-down prototype of the hyperloop is made with a straight tube that contains air. The engineers used this to study the effects of resistive forces on the motion of the pod travelling in such a hyperloop.

The known specifications of the prototype are such that the variation with the pod's speed v of the total resistive force F_R experienced by the pod is as shown in Fig. 7.5.

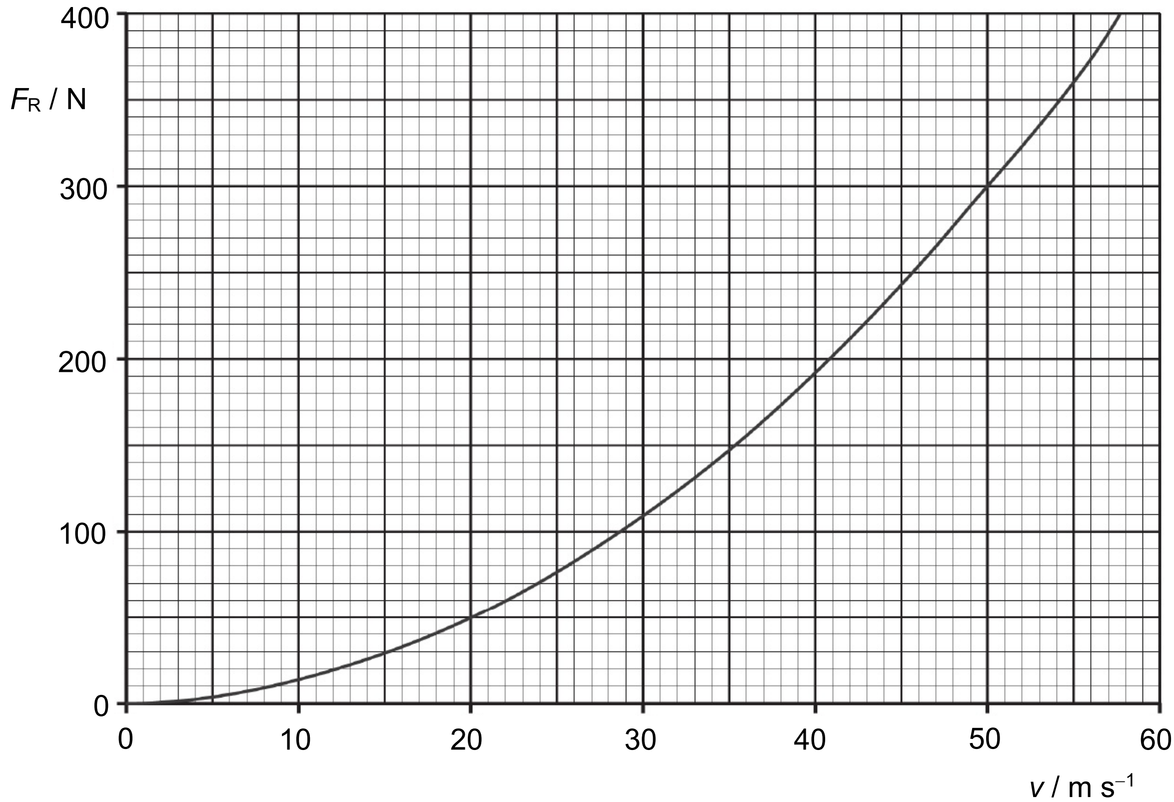

Fig. 7.5

During a test run, a constant driving force of 390 N is exerted on pod P in the forward direction. The variation with time t of pod P's speed v for the first 70 s is as shown in Fig. 7.6.

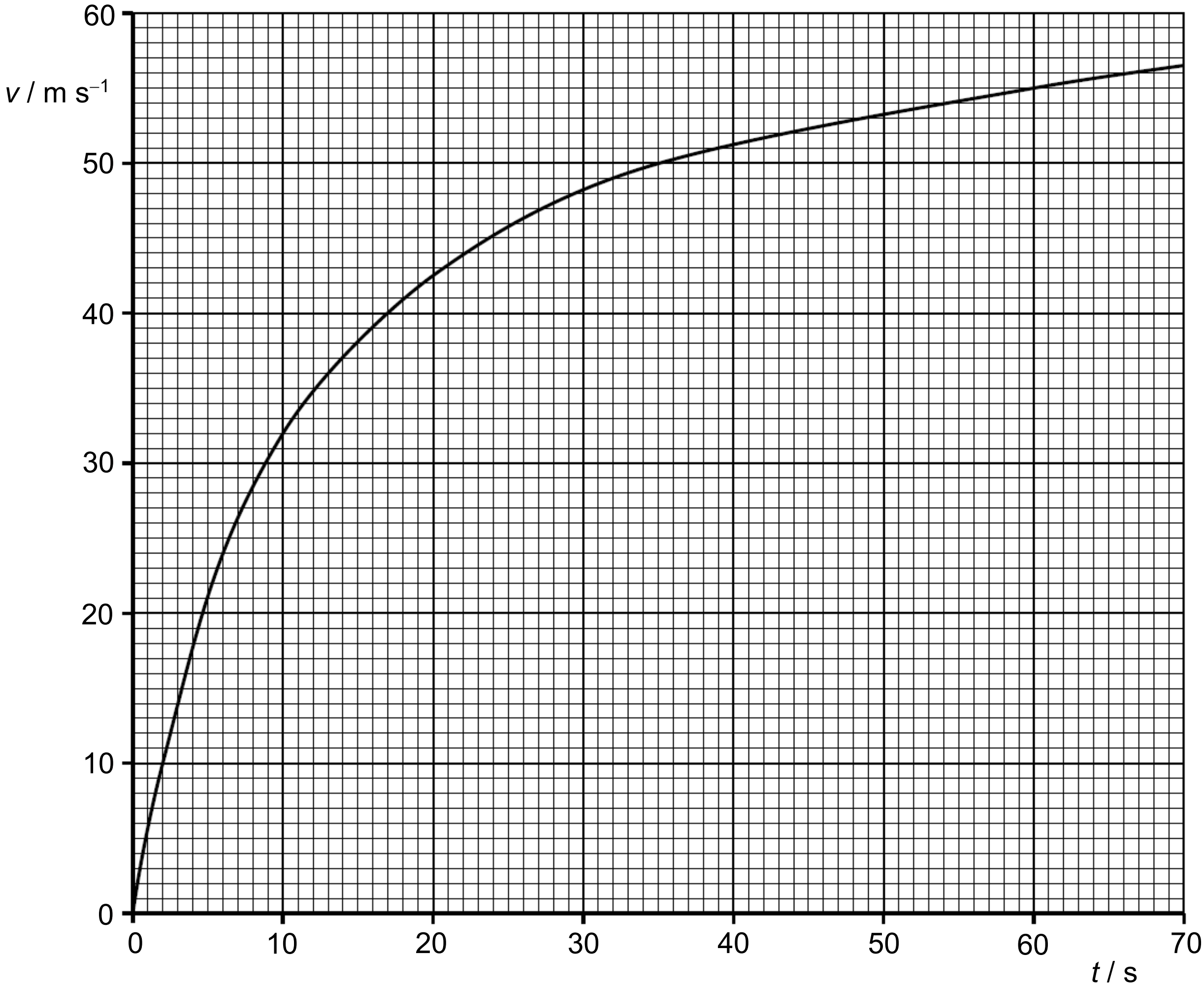

Fig. 7.6

1. Using Fig. 7.6, determine the acceleration of pod P at $t = 20$ s.

acceleration = ... m s^{-2} [1]

2. Hence, determine the mass of pod P.

mass = ... kg [2]

(ii) In another experiment, a second scaled-down prototype of the hyperloop is made with a straight vacuum tube, such that the pod experiences negligible resistive forces.

A constant driving force is exerted on pod Q, which is initially at rest in the vacuum tube. After 70 s, it reaches the same speed as pod P in **(c)(i)**.

1. On Fig. 7.6, shade an area that is equal to the difference in the distances travelled by pod P and pod Q during the first 70 s of their motion. [1]

2. A student states that although pod P and pod Q have travelled different distances in the same amount of time, the two pods have the same average acceleration during the first 70 s of their motion.

State and explain if the student's statement is correct.

....

....

....

.... [2]

END OF SECTION C