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OCR A LEVEL PHYSICS A (H556): QUESTIONS BY TOPIC

Circular motion (5.2)

A Level Physics A (H556) · Module 5: Newtonian world and astrophysics

19 questions · 132 marks · Mark schemes included

OCR A Level Physics A (H556), June 2017 – June 2025

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HOW TO USE THIS BOOKLET

Questions run from the lowest mark tariff to the highest, so similar questions sit together.

Click any row below to jump straight to that question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

QUESTION		SOURCE	MARKS	PAGE
1. Q10	<i>also 6.3</i>	H556/02 Exploring physics June 2018	1	4
2. Q7	<i>also 3.5 & 3.3 & 5.4</i>	H556/01 Modelling physics November 2021	1	5
3. Q1	<i>also 2.3 & 3.5 & 3.1 & 4.4</i>	H556/01 Modelling physics June 2022	1	6
4. Q11	<i>also 3.5 & 3.3 & 3.1 & 5.4</i>	H556/01 Modelling physics June 2022	1	7
5. Q12		H556/02 Exploring physics June 2023	1	8
6. Q3	<i>also 3.2</i>	H556/01 Modelling physics June 2024	1	9
7. Q8	<i>also 5.4</i>	H556/01 Modelling physics June 2025	1	10
8. Q20	<i>also 3.2 & 6.4 & 6.3</i>	H556/02 Exploring physics June 2019	7	12
9. Q20	<i>also 2.1 & 3.1</i>	H556/01 Modelling physics November 2020	7	14
10. Q21	<i>also 2.2 & 3.5 & 3.2</i>	H556/01 Modelling physics June 2018	8	17
11. Q4	<i>also 3.2</i>	H556/03 Unified physics June 2019	9	20
12. Q23	<i>also 3.3 & 5.4</i>	H556/01 Modelling physics June 2022	9	22
13. Q22	<i>also 2.2</i>	H556/01 Modelling physics November 2021	10	25
14. Q6	<i>also 3.2</i>	H556/03 Unified physics November 2021	10	27
15. Q6	<i>also 5.5 & 6.5</i>	H556/03 Unified physics June 2019	11	30
16. Q6	<i>also 3.4 & 3.2 & 3.1 & 4.2</i>	H556/03 Unified physics June 2017	12	33
17. Q1	<i>also 2.1 & 3.2 & 3.1 & 5.4</i>	H556/03 Unified physics June 2022	12	35
18. Q22	<i>also 3.3 & 5.4</i>	H556/01 Modelling physics June 2024	14	39
19. Q17	<i>also 3.2</i>	H556/01 Modelling physics June 2023	16	43



QUESTIONS

19 questions · 132 marks · lowest tariff first

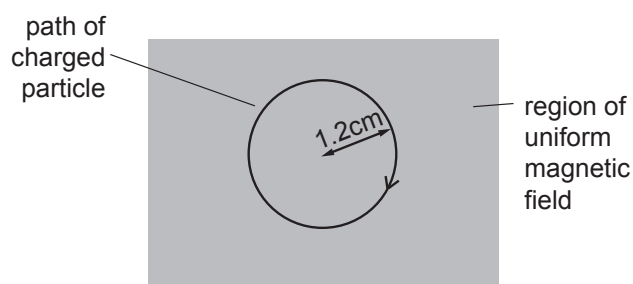


MULTIPLE-CHOICE QUESTIONS

7 questions in this booklet



- 10 A charged particle moves in a circular path of radius 1.2 cm in a uniform magnetic field.



The direction of the magnetic field is perpendicular to the plane of the paper.

The particle has mass m , charge $+Q$ and speed v .

Another particle of mass $3m$, charge $+2Q$ and speed v moves in a circular path of radius R in the same magnetic field.

What is the value of R ?

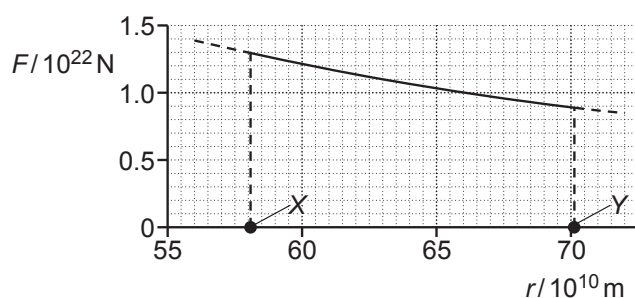
- A 0.8 cm
- B 1.2 cm
- C 1.8 cm
- D 7.2 cm

Your answer

[1]

- 7 The planet Mercury has a highly elliptical orbit around the Sun.

The gravitational force F acting on Mercury due to the Sun varies with its distance r from the centre of the Sun. The graph of F against r for Mercury in its orbit is shown below.



Mercury is closest to the Sun when $r = X$ and furthest when $r = Y$.

What does the **area** under the graph between the distances X and Y represent?

- A The centripetal force acting on Mercury.
- B The change in the gravitational potential energy of Mercury.
- C The impulse of the force acting on Mercury.
- D The kinetic energy of Mercury.

Your answer

[1]

- 1 A student has constructed the table below of possible scalar and vector quantities.

	Scalar	Vector
A	acceleration	momentum
B	displacement	amplitude
C	frequency	wavelength
D	mass	centripetal force

Which row is correct?

Your answer

[1]



11 Which pair of quantities do **not** have the same, or equivalent, units?

- A acceleration, gravitational field strength
- B angular frequency, angular velocity
- C gravitational potential, kinetic energy
- D impulse, momentum

Your answer

[1]

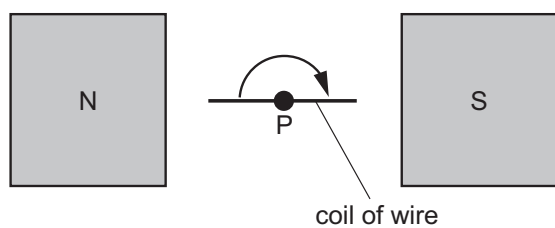
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Turn over

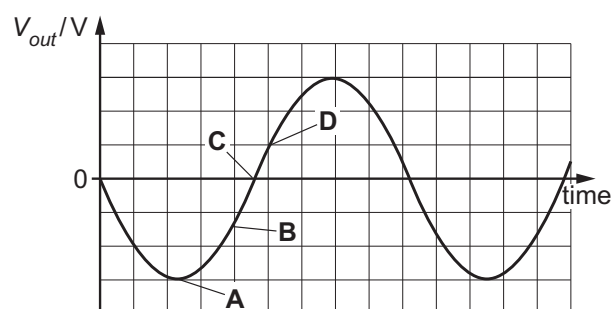


12 The diagram shows a coil of wire rotating between two permanent magnets in a model generator.

The coil is rotating clockwise about point P at constant angular velocity.



Which letter represents the output of the generator at the instant in the diagram?



Your answer

[1]

- 3 A rubber bung is attached to a string. The bung is whirled around in a horizontal circle of radius r . The rotational period of the bung is T . The tension in the string is kept constant as the bung is whirled around at different speeds.

Which relationship is correct for this whirling bung?

A $T \propto r$

B $T^2 \propto r$

C $T \propto r^2$

D $T \propto \sqrt{r}$

Your answer

[1]



- 8 A washing machine with a circular drum of diameter 0.60 m is rotating at an angular velocity of 15 radians per second.

What is the magnitude of the force exerted by the drum on a 0.30 kg item of clothing which is at the bottom of the spinning drum?

- A 21 N
B 23 N
C 41 N
D 43 N

Your answer

[1]

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7-MARK QUESTIONS

2 questions in this booklet



20 Fig. 20 illustrates a device used to determine the relative abundance of charged rubidium ions.

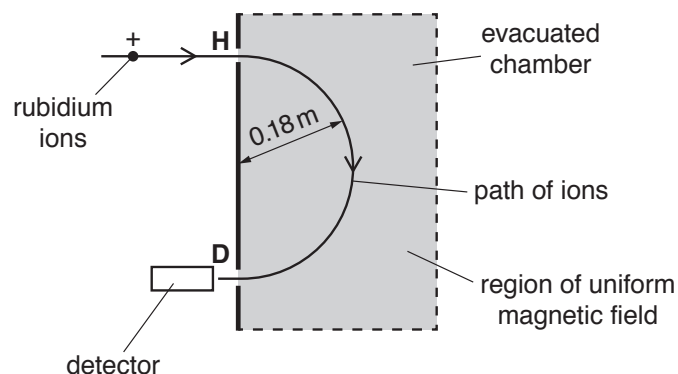


Fig. 20

A uniform magnetic field is applied to an evacuated chamber. The direction of the magnetic field is perpendicular to the plane of the paper.

A beam of positive rubidium ions enters the chamber through a hole at **H**. The ions travel in a semi-circular path in the magnetic field. The ions are detected at point **D**.

- (a) Each rubidium ion has charge $+1.6 \times 10^{-19} \text{ C}$ and speed $4.8 \times 10^4 \text{ ms}^{-1}$.
 The radius of the semi-circular path of the ions is 0.18 m.
 The mass of a rubidium ion is $1.4 \times 10^{-25} \text{ kg}$.

Calculate the magnitude of the magnetic flux density B of the magnetic field.

$B = \dots\dots\dots \text{ T [3]}$

- (b) The chemical composition of ancient rocks found on the Earth can be used to estimate the age of the Earth.

Nuclei of rubidium-87 ($^{87}_{37}\text{Rb}$) decay spontaneously into nuclei of strontium-87 ($^{87}_{38}\text{Sr}$).

The half-life of rubidium-87 is 49 billion years.

- (i) Name the two leptons emitted in the decay of a rubidium-87 nucleus.

1.

2.

[1]

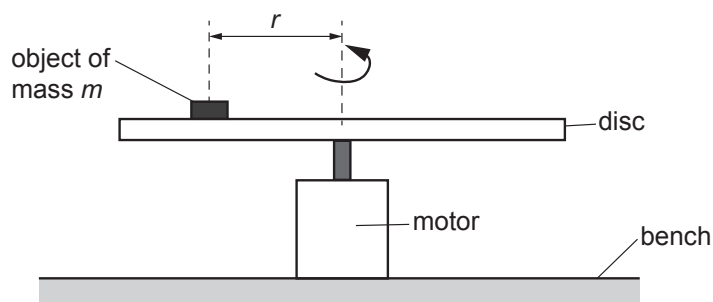
- (ii) The percentage of rubidium **left** in a sample of an ancient rock is 95%.

Estimate the age of the Earth in billion years.

age = ... billion years [3]



- 20 A small object of mass m is placed on a rotating horizontal metal disc at a distance r from the centre of the disc.



The frequency of rotation is adjusted using a motor attached to the disc.

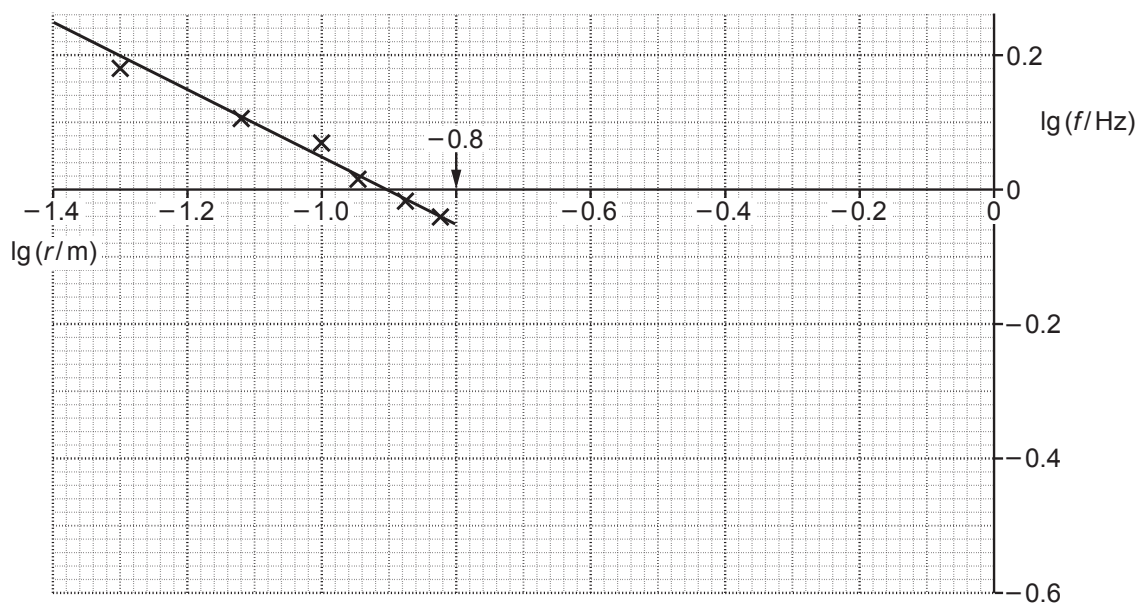
The frequency of rotation of the disc is slowly increased from zero, until the object slips off. At this point, the friction F acting on the object is equal to the centripetal force.

The friction F is given by the expression $F = kmg$, where k is a constant and g is the acceleration of free fall. The constant k has no units.

- (a) Show that the frequency f at which the object slips off is given by the equation $f^2 = \left(\frac{gk}{4\pi^2}\right) \times \frac{1}{r}$.

[3]

(b) A student plots a graph of $\lg(f/\text{Hz})$ against $\lg(r/\text{m})$.



For this graph: $y\text{-intercept} = \frac{1}{2} \times \lg\left(\frac{gk}{4\pi^2}\right)$

Use the graph to determine the constant k . Write your answer to 2 significant figures.

$k = \dots\dots\dots$ [4]

8-MARK QUESTIONS

1 question in this booklet



21 Fig. 21 shows the drum of a washing machine.

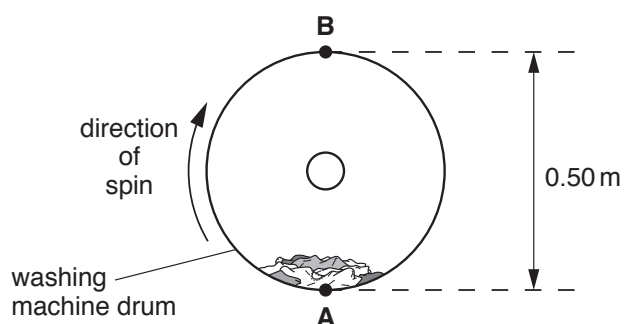


Fig. 21

The clothes inside the drum are spun in a **vertical** circular motion in a clockwise direction.

- (a) When the drum is at rest, the weight of the clothes is equal to the normal contact force on the clothes at point **A**.

Explain why these two forces are not an example of Newton's Third Law of motion.

.....

.....

.....

.....

..... [2]

- (b) The drum has diameter 0.50 m. The manufacturer of the washing machine claims that the drum spins at 1600 ± 100 revolutions per minute.

Calculate the speed of rotation of the drum and the absolute uncertainty in this value.

speed = ... $\pm$ ms^{-1} [3]

- (c) The washing machine is switched off and the speed of the drum slowly decreases. The clothes at the top of the drum at point **B** start to drop off at a certain speed v .

At this speed v , the normal contact force on the clothes is zero.

Calculate the speed v .

$v = \dots\dots\dots \text{ms}^{-1}$ [3]

9-MARK QUESTIONS

2 questions in this booklet



- 4 At an airport, the conveyor belt for suitcases moves at a constant speed of 1.5 m s^{-1} . In Fig. 4.1, a suitcase of mass 8.0 kg has reached the line labelled XX' .

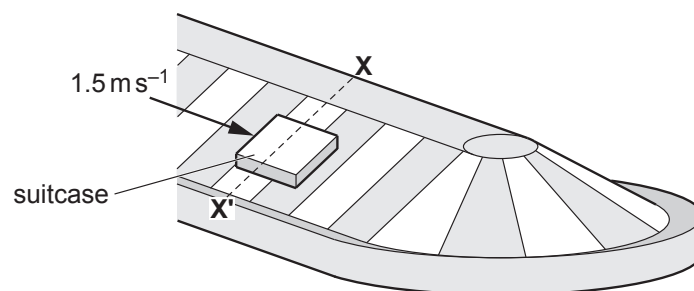


Fig. 4.1

Fig. 4.2 shows the situation in vertical cross-section. The frictional force F prevents the suitcase of weight W from sliding to the bottom of the belt. The normal contact force on the suitcase is R . The belt is inclined at an angle of 30° to the horizontal.

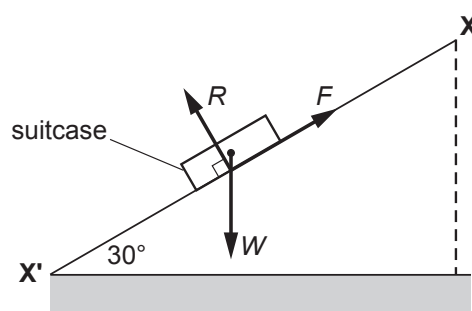


Fig. 4.2 (not to scale)

- (a) By using a vector triangle, or by resolving forces, calculate the magnitude of forces F and R .

$$F = \dots\dots\dots \text{ N}$$

$$R = \dots\dots\dots \text{ N}$$

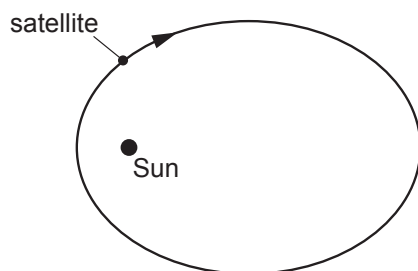
[3]

- 23 (a)** A planet of mass m is in a circular orbit around a star of mass M .

Use the equation for Newton's law of gravitation and your knowledge of circular motion to show that the relationship between the orbital period T of the planet and its orbital radius r is $T^2 \propto r^3$.

[3]

- (b)** The Solar Orbiter satellite was launched in February 2020. This satellite moves around the Sun in an elliptical orbit with a period of 168 days. The diagram below shows the elliptical orbit of this satellite.



The closest distance of the satellite to the Sun is $4.20 \times 10^{10} \text{ m}$ and its furthest distance from the Sun is $1.37 \times 10^{11} \text{ m}$.

The mass of the Sun is $2.0 \times 10^{30} \text{ kg}$ and the mass of the satellite is 209 kg.

- (i) The Earth has a mean orbital distance of 1.50×10^{11} m around the Sun and an orbital period of 365 days.

Use **Kepler's third law** to calculate the mean orbital distance of the satellite from the Sun.

distance = ... m [2]

- (ii) The total kinetic and gravitational potential energy of the satellite in its orbit remains constant.

Calculate the change in the kinetic energy of the satellite as it travels from its furthest point from the Sun to its closest point to the Sun.

change in kinetic energy = ... J [3]

- (iii) Suggest why the total energy of the satellite in its orbit around the Sun is not the same as the total energy of the satellite during its launch from the surface of the Earth.

.....
 [1]

10-MARK QUESTIONS

2 questions in this booklet



- 22 (a)** A particle-accelerator uses a ring of electromagnets to keep protons moving continuously in a circle.

The speed v of the protons depends on the frequency f of rotation of the protons in the circular orbit.

Fig. 22 shows data points plotted on a v against f grid.

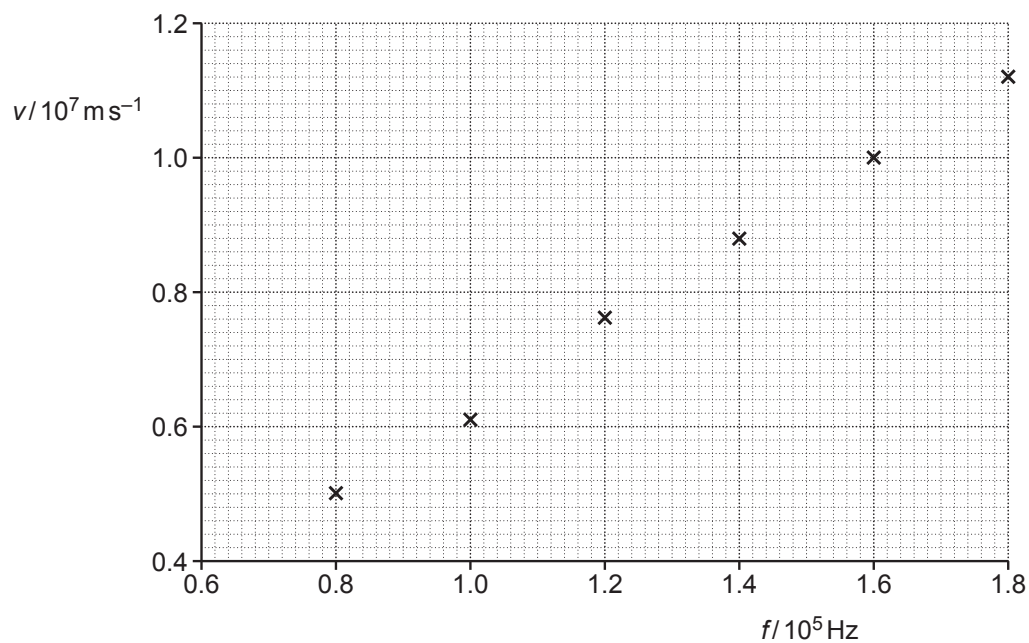


Fig. 22

- (i) Show that the gradient of the graph of v against f is equal to $2\pi r$, where r is the radius of the circular path of the protons.

[2]

- (ii) Show that r is about 10 m by determining the gradient of the line of best fit through the data points in **Fig. 22**.

[3]

- (iii) The maximum speed of the protons from this accelerator is $2.0 \times 10^7 \text{ m s}^{-1}$.

Calculate the maximum centripetal force F acting on a proton at this speed.

- mass of proton = $1.7 \times 10^{-27} \text{ kg}$.

$F = \dots\dots\dots \text{ N}$ [3]

- (b) A new particle-accelerator is now built for moving the protons in a circle of a radius 20 m.

The ring of electromagnets for this new accelerator provides the same **maximum** centripetal force as the accelerator in (a).

Calculate the maximum speed of the protons in this new accelerator.

maximum speed = $\dots\dots\dots \text{ m s}^{-1}$ [2]

- 6 The London Eye, shown rotating anticlockwise in **Fig. 6.1**, is a giant wheel which rotates slowly at a constant speed.

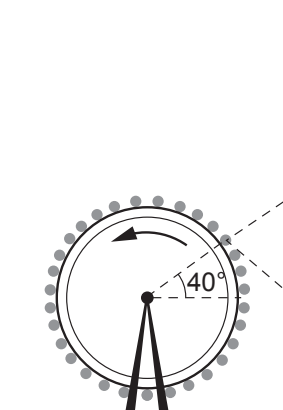


Fig. 6.1

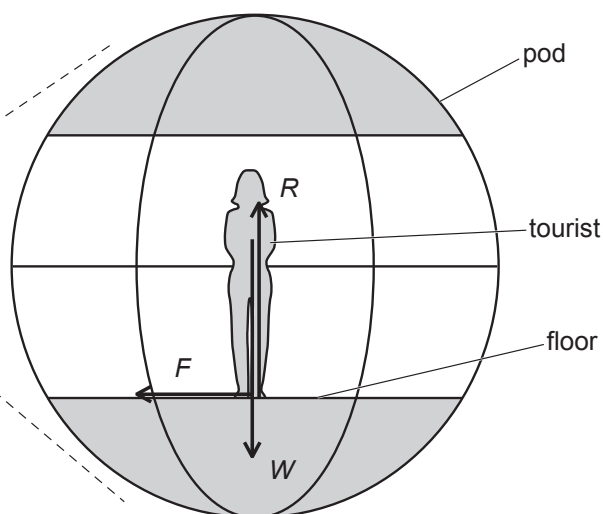


Fig. 6.2

Tourists stand in pods around the circumference of the wheel.

The floor remains horizontal at all times.

At time $t = 0$, a tourist who has a weight W of 650 N enters a pod at the bottom of the wheel.

Fig. 6.2 shows the forces acting on the tourist at a later time, when the angle between the pod's position and the centre of the wheel is 40° above the horizontal. R is the normal contact force and F is friction.

- (a) The resultant upward force ($R - W$) on the tourist changes during the 30 minutes of the rotation of the London Eye as shown in **Fig. 6.3**.

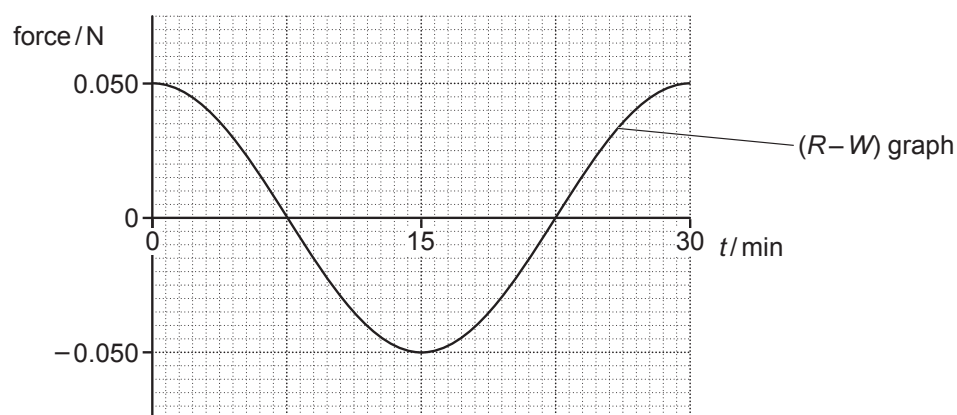


Fig. 6.3

Explain how the graph in **Fig. 6.3** shows that the magnitude of the centripetal force on the tourist during the rotation is 0.050 N.

.....

.....

..... [1]

- (b) (i) Explain why the horizontal force F between the floor and the tourist is necessary.

.....

.....

.....

.....

.....

..... [2]

- (ii) Draw on **Fig. 6.3** the variation of the horizontal force F during the 30 minutes of the anticlockwise rotation of the London Eye. Take forces to the right to be positive. [2]

- (iii) Calculate the magnitude of force F when the pod is at the position shown in **Fig. 6.2**, at 40° above the horizontal.

$$F = \dots\dots\dots \text{ N [2]}$$

- (c) Calculate the distance d of the centre of mass of the tourist from the centre of rotation of the London Eye.

$$d = \dots\dots\dots \text{ m [3]}$$



11-MARK QUESTIONS

1 question in this booklet



- 6 (a) Describe the **Doppler effect**.

.....
 [1]

- (b) Explain how ultrasound is used to measure the speed of blood flow in an artery.

.....

 [2]

- (c) In cosmology, the Doppler effect can be observed with light from distant galaxies. The Doppler effect can also be observed with sound waves.

Two students use sound waves to investigate the Doppler effect.

In an open space, one student swings a loudspeaker at constant speed in a horizontal circle of radius 0.60 m.

The other student stands a large distance away and holds a microphone. The microphone is connected to a data logger and computer.

Fig. 6.1 shows the situation, viewed from above.

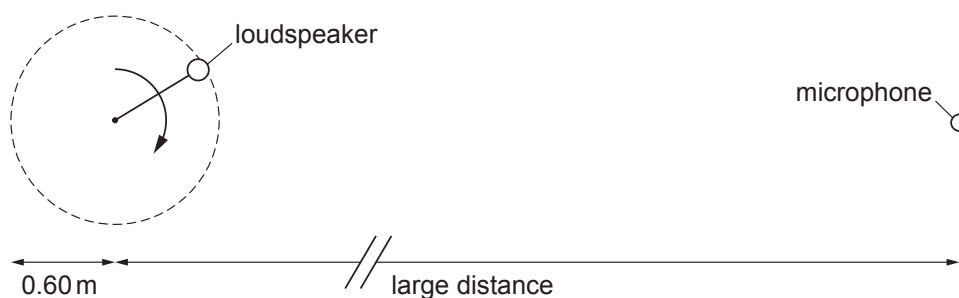


Fig. 6.1

The loudspeaker emits sound in all directions at a single frequency $f_0 = 1700$ Hz.

Fig. 6.2 shows the variation with time t of the frequency f received by the microphone.

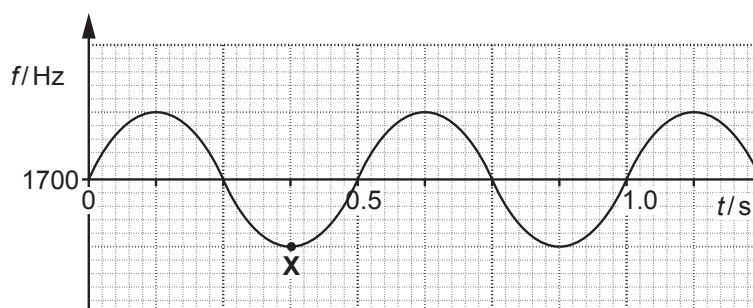


Fig. 6.2

- (i) Use Fig. 6.2 to show that the speed of the loudspeaker is 7.5 m s^{-1} .

[2]

- (ii) The speed of sound in this experiment is 330 m s^{-1} .

Calculate the maximum change in frequency Δf of the sound detected by the microphone.

$\Delta f = \dots\dots\dots \text{ Hz}$ [2]

- (iii) Hence complete the scale on the y-axis of Fig. 6.2. [1]

- (iv) Mark with an **X** on Fig. 6.1 the position of the loudspeaker which corresponds to the point **X** on Fig. 6.2. [1]

- (d) In their laboratory notes, one student writes about the **accuracy** of the measurements whereas the other writes about their **precision**.

Define these terms.

accuracy:

.....

precision:

..... [2]



12-MARK QUESTIONS

2 questions in this booklet



- 6 This question is about the motion of a ball suspended by an elastic string above a bench. The mass of the string is negligible compared to that of the ball. Ignore air resistance.



Fig. 6.1

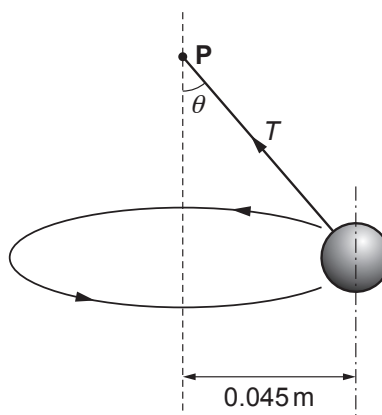


Fig. 6.2 (not to scale)

In Fig. 6.1 the ball of weight 1.2 N hangs vertically at rest from a point P. The extension of the string is 0.050 m. The string obeys Hooke's law.

In Fig. 6.2 the ball is moving in a horizontal circle of radius 0.045 m around a vertical axis through P with a period of 0.67 s. The string is at an angle θ to the vertical. The tension in the string is T .

- (a) On Fig. 6.2 draw and label one other force acting on the ball. [1]
- (b) (i) Resolve the tension T horizontally and vertically and show that the angle θ is 22° . [2]

- (ii) Calculate the extension x of the string shown in Fig. 6.2.

$x = \dots\dots\dots$ m [3]

- (c) Whilst rotating in the horizontal plane the ball suddenly becomes detached from the string. The bottom of the ball is 0.18 m above the bench at this instant. The ball falls as a projectile towards the bench beneath. Fig. 6.3 shows the view from above.

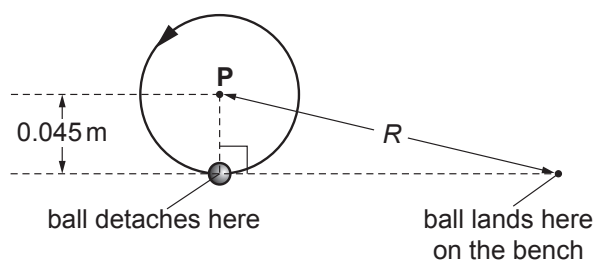


Fig. 6.3

Calculate the horizontal distance R from the point on the bench vertically below the point **P** to the point where the ball lands on the bench.

$R = \dots\dots\dots$ m [4]

- (d) Returning to the situation shown in Fig. 6.2, state and explain what happens when the rate of rotation of the ball is increased.

.....

 [2]

- 1 The table shows some data on the planet Venus.

Mass/kg	4.87×10^{24}
Radius/km	6050
Density of atmosphere at surface/ kg m^{-3}	65
Period of rotation about its axis/hours	5830

- (a) Calculate the magnitude of the gravitational field strength g at the surface of Venus.

Give your answer to **3** significant figures.

$$g = \dots\dots\dots \text{N kg}^{-1} \text{ [3]}$$

- (b) Two identical space probes, **A** and **B**, land on a flat surface on Venus.

Probe **A** lands at the north pole. Probe **B** lands on the equator.

Each probe has mass 760 kg and volume 1.7 m^3 .

- (i) Calculate the centripetal acceleration a of probe **B** at the equator due to the rotation of Venus about its axis.

$$a = \dots\dots\dots \text{ms}^{-2} \text{ [3]}$$

- (ii) The atmosphere exerts the same upthrust on each probe.

Using your answer to (a), calculate the upthrust acting on each probe.

upthrust = ... N [3]

- (iii) Explain which probe will experience the greater normal contact force from the surface of Venus.

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.....
.....
.....
.....
..... [3]

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14-MARK QUESTIONS

1 question in this booklet



22

- (a) A satellite in a geostationary orbit around the Earth appears to remain at the same point in the sky when viewed from the ground.

- (i) State **one** condition required for an orbit to be geostationary.

.....
 [1]

- (ii) Calculate the orbital radius of the geostationary satellite. The mass of the Earth is 6.0×10^{24} kg.

orbital radius = ... m [3]

- (b) A satellite of mass m is in a circular orbit around a planet of mass M . The radius of the orbit from the centre of the planet is r .

The gravitational potential V_g at a point a distance r from the centre of the planet is given by the equation

$$V_g = -\frac{GM}{r}.$$

- (i) By considering the cause of the centripetal force on the satellite, show that the kinetic energy of the satellite is equal to half the magnitude of its gravitational potential energy.

[2]

- (ii) A tiny satellite of mass 1.0 kg is to be launched from rest from the surface of the Earth into a low Earth orbit. The gravitational potential at any point in this orbit is -56 MJ kg^{-1} .

The value of the gravitational potential at the Earth's surface is -63 MJ kg^{-1} .

Show that the satellite must gain more than 30 MJ of **total** energy to achieve and remain in orbit.

[2]

- (c)* Large satellites are often launched by rockets from sites near the equator. The rotation of the Earth increases the initial kinetic energy of the rocket and satellite.

A new strategy is to launch using a smaller rocket from a high flying aircraft.

Using the information in (b)(ii) and the data below, evaluate the advantages and limitations of this strategy. Use calculations to support your evaluation.

Rotational speed at the equator	460 ms^{-1}	Typical aircraft operating altitude	$10,000\text{ m}$
		Aircraft cruise velocity (relative to the ground)	230 ms^{-1}

[6]

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Additional space if required

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16-MARK QUESTIONS

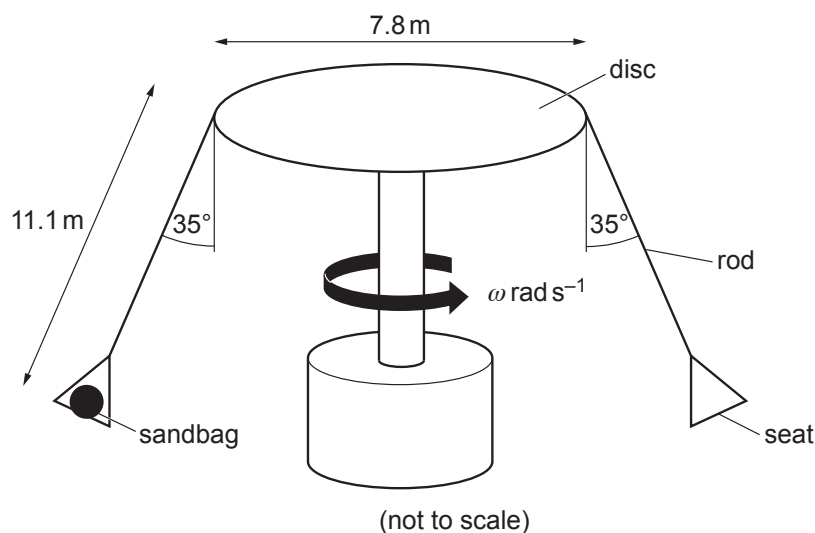
1 question in this booklet



17 The diagram below shows a fairground ride. Each rider is secured in a seat suspended by a rod.

The distance from the top of the rod to the base of the seat is 11.1 m.

The rod is attached to the edge of a disc of diameter 7.8 m.



To test the equipment a sandbag is attached to the seat and the ride is started.

The combined mass of the seat and the sandbag is 12 kg.

The rod makes an angle of 35° with the vertical.

- (a) (i) Draw an arrow labelled T on the diagram to represent the tension in the rod. [1]
- (ii) Show that the radius of the circular path followed by the sandbag is about 10 m.

[2]

- (iii) Calculate the tension T in the rod.

$$T = \dots\dots\dots \text{ N [3]}$$

- (iv) Show that the angular velocity of the ride is about 0.8 radians per second.

[2]

- (b) When the seat is at its highest point the sandbag is 17 m above the ground. The sandbag is released from the seat to model an object being dropped by a rider.

- (i) Calculate t , the time taken for the sandbag to reach the ground.

$$t = \dots\dots\dots \text{ s [2]}$$

- (ii) Using your answer to (a)(iv), determine the horizontal displacement s travelled by the sandbag before hitting the ground.

$$s = \dots\dots\dots \text{ m [3]}$$

Turn over

- (iii) Determine, with reasons, the effect on the horizontal displacement travelled if the object released from the ride was a shoe from a rider.

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..... [3]

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MARK SCHEMES

official OCR mark schemes



10	C		1	
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7	B	1	
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1	D	1	
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11	C		1	
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12	A	1	
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3	B or D	1	
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8	B	1	
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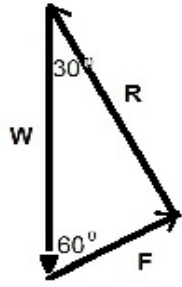


20	(a)		$F = BQv$ and $F = mv^2/r$ or $B = mv/Qr$ (Any subject) $(B =) \frac{1.4 \times 10^{-25} \times 4.8 \times 10^4}{1.6 \times 10^{-19} \times 0.18}$ $B = 0.23$ (T)	C1 C1 A1	Allow e
	(b)	(i)	Electron and (electron) antineutrino	B1	Allow beta-minus (particle) / β^- ; $\bar{\nu}_{(e)}$ Allow anti electron neutrino
		(ii)	$\lambda = \ln 2/49$ or $\lambda = 0.0141$ (billion y^{-1}) $0.95 = e^{-0.0141t}$ or $0.95 = e^{-4.48 \times 10^{-19}t}$ (age = $-\ln(0.95)/0.0141$) age = 3.6 (billion years)	C1 C1 A1	Allow $\frac{\ln 2}{49 \times 10^9 \times 3.16 \times 10^7}$ or $4.48 \times 10^{-19} \text{ (s}^{-1}\text{)}$ Allow both C1 marks for $\ln(0.95) = \ln(0.5) \times t/49$ Allow $0.05/0.0141 \approx t$ (this gives 3.5.. for the final mark) Note age in seconds is 1.15×10^{17} (s); this will score 2 marks
			Total	7	

20	(a)	$F = m\omega^2 r$ and $\omega = 2\pi f$ $kmg = m\omega^2 r$ Clear algebra leading to $f^2 = \left(\frac{gk}{4\pi^2}\right) \times \frac{1}{r}$	M1 M1 A1	Allow $F = mv^2/r$ and $v = 2\pi fr$ Allow this mark for $kmg = mv^2/r$
	(b)	y-intercept = - 0.45 $\frac{1}{2} \lg\left(\frac{gk}{4\pi^2}\right) = -0.45$ $\left(\frac{gk}{4\pi^2}\right) = 10^{-0.9}$ $k = \frac{0.126 \times 4 \times \pi^2}{9.81}$ $k = 0.51$	C1 C1 C1 A1	Allow ± 0.05 Allow attempt at calculating y-intercept using gradient and a point on the line . Not $e^{-0.9}$ wrong physics Allow k in range 0.48 to 0.63 Note Answer must be to 2 SF
		Total	7	

21	(a)	Both forces act on the same object (AW) The types of forces are different / one force is gravitational and the other force is electrostatic	B1 B1	 Allow: one force is gravitational (and the other is not)
	(b)	$T = 60/1600$ or $T = 3.75 \times 10^{-2}$ (s) $(v = \pi \times 0.50/3.75 \times 10^{-2})$ speed = 42 (m s ⁻¹) uncertainty = 3 (m s ⁻¹)	C1 A1 A1	Allow: $f = 26.7$ or $\frac{1600}{60}$ (Hz) or $\omega = 168$ (s ⁻¹) Note: v must be to 2 or more SF Note: uncertainty must be to 1 SF Allow: ecf on candidate's value for speed i.e. uncertainty = candidate's value / 16 (to 1 SF) Allow for 2 marks max: 84 ± 5 (m s⁻¹)
	(c)	$mv^2/r = mg$ or $v^2/r = g$ $v^2 = 9.81 \times 0.25$ $v = 1.6$ (m s ⁻¹)	C1 C1 A1	Allow: $v^2/r = a$ <u>and</u> $a = g$ or $mv^2/r = ma$ <u>and</u> $a = g$ Allow: any subject Allow: any subject Note: qualified 2.21 (ms ⁻¹) scores 2 marks.
		Total	8	



4	(a)		$W (= mg) = 8.0 \times 9.81$ $F = (W \sin 30 = 78.5 \times 0.5 =) 39 \text{ (N)}$ $R = (W \cos 30 = 78.5 \times 0.87) = 68 \text{ (N)}$	C1 $= 78(.5) \text{ (N) not } 80 \text{ (N)}$ Allow 8g A1 x 2 Allow 1/2 for F and R the wrong way round	 Credit full marks for use of a scale drawing which gives answers correct to $\pm 2\text{N}$ Special case: Allow 2/3 for use of $W = 80 \text{ (N)}$ giving $F = 40 \text{ (N)}$ and $R = 69 \text{ (N)}$
	(b)	(i)	$F = (mv^2/r =) 8.0 \times 1.5^2/2.0$ $F = 9.0 \text{ (N)}$	C1 A1	Allow answer to 1s.f.

H556/03			Mark Scheme		June 2019
Question			Answer	Marks	Guidance
	(b)	(ii)	- Suitcase accelerates / changes its velocity / (constantly) changes direction / has a resultant force acting on it / is no longer in equilibrium - The resultant force must act (horizontally) towards centre of circle / to the left - The centripetal force can only be provided by (an increase in) F - Increased vertical component of F means the vertical component of R must decrease (in order to balance W) So R must decrease	B1 x 4 A0	Any answer that mentions centrifugal force scores 0/4 Ignore any statement that treats the centripetal force as an extra force Allow net or unbalanced or total for resultant throughout or $F\cos 30^\circ - R\sin 30^\circ$ increases (from 0 to 9.0 (N)) / the (magnitude of the) horizontal component of F must exceed the (magnitude of the) horizontal component of R not a resultant force acts towards Y e.g. Friction is the only force able to provide the centripetal force / only F has a component to the left Allow F provides the centripetal force Not the horizontal force must increase / increases or $F\sin 30^\circ + R\cos 30^\circ = W$ / W is the vector sum of F and R / $W = (F^2 + R^2)^{1/2}$ (and F increases while W remains constant)
			Total	9	

H556/03

Mark Scheme

June 2019

Question	Answer	Marks	Guidance
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Question	Answer	Mark	Comments
23 a	$G \frac{Mm}{r^2} = \frac{mv^2}{r}$ or $G \frac{Mm}{r^2} = mr\omega^2$ $v = \frac{2\pi r}{T}$ or $\omega = \frac{2\pi}{T}$ Substitution and manipulation to give $T^2 = \frac{4\pi^2}{GM} r^3$ (with $\frac{4\pi^2}{GM}$ is constant)	M1 M1 A1	Allow any subject
b i	$\left(\frac{168}{365}\right)^2 = \left(\frac{r}{1.50 \times 10^{11}}\right)^3$ distance = 8.9×10^{10} (m)	C1 A1	Ignore calculation of arithmetic mean of data in question Allow substitution into $T^2 = \frac{4\pi^2}{GM} r^3$ Ignore units for subs into Kepler's law NOT 8.95 or $9(.0) \times 10^{10}$ (m) (mean calculated)
ii	$(\Delta GPE = \Delta KE)$ $GMm \left(\frac{1}{4.20 \times 10^{10}}\right)$ or $GMm \left(\frac{1}{1.37 \times 10^{11}}\right)$ (change in KE =) $6.67 \times 10^{-11} \times 2.0 \times 10^{30} \times m \left(\frac{1}{4.20 \times 10^{10}} - \frac{1}{1.37 \times 10^{11}}\right)$ change in kinetic energy = 4.6×10^{11} (J)	C1 C1 A1	Allow this mark without the m Allow this mark without the m Allow 2 marks for 2.2×10^9 ; ΔV calculated Ignore sign
iii	Description of reasonable effect of Earth has been ignored / work done by fuel (during lift off) / idea that atmosphere has been ignored previously	B1	
	Total	9	



22	(a)	(i)	$\{v = \omega r \text{ and } \omega = 2\pi f\} \text{ or } v = 2\pi fr$ Comparison with $y = mx$ leading to gradient = $2\pi r$ or $\Delta v / \Delta f = 2\pi r$	B1 B1	Allow $v/f = 2\pi r$
		(ii)	Line of best fit drawn Gradient = 62.5 (m) $2\pi r = 62.5$ $r = 9.9$ (m)	B1 M1 M1 A0	Allow ± 3 Allow ECF on gradient
		(iii)	$F = \frac{mv^2}{r} \text{ or } F = ma \text{ and } a = \frac{v^2}{r}$ $F = \frac{1.7 \times 10^{-27} \times [2.0 \times 10^7]^2}{9.9}$ $F = 6.8 \times 10^{-14} \text{ (N)}$	C1 C1 A1	Allow use of candidate's answer for (ii) or use of '10' Expect answers of 6.8 or 6.9×10^{-14} (N)
	(b)		$r \propto v^2$ / speed increases by a factor of $\sqrt{2}$ maximum speed = $2.8 \times 10^7 \text{ (m s}^{-1}\text{)}$	C1 A1	Allow substitution into correct equation with r doubled Allow recalculation from previous value of force in (a)(iii)
			Total	10	

Question	Answer	Marks	Guidance
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6	(a)		At $t = 0$ (and $t = 15, 30$) the (magnitude of the) centripetal force equals $R - W$ (as only vertical forces act on the tourist)	B1	Allow at $t = 0$ (or the bottom of the circle) the centripetal force is provided by the resultant/ upwards/vertical force
	(b)	(i)	(For circular motion) there must (always) be a resultant force towards the centre The resultant force is not always vertical/sometimes has a horizontal component This can only be provided by friction/cannot be provided by R and W / R and W are always vertical/only F is horizontal	B1 x 2	any 2 from 3 marking points Allow F provides the horizontal (component of the) centripetal force
		(ii)	Sine wave with period 30 min and amplitude 0.050 (N) Correct phase, i.e. <u>negative</u> sine wave	B1 B1	Must start at the origin
		(iii)	$F = 0.050 \cos 40^\circ$ $F = 0.038$ (N)	C1 A1	Allow alternative methods e.g. triangle of forces Allow ECF from graph if used
	(c)		$m = 650/g$ or $m = 650/9.81$ (= 66.3 kg) ($F = mr\omega^2$ gives) $d = 0.050 / m\omega^2 = 0.050 / 66.3 \times (3.5 \times 10^{-3})^2$ $d = 62$ (m)	C1 C1 A1	Not $m = 650$ kg or $m = 65$ kg or ($F = mv^2/r$ and $v = 2\pi r/T$ gives) $d = 0.050 \times (30 \times 60)^2 / (4\pi^2 \times 66.3)$
			Total	10	

6	(a)	Observed frequency is different to source frequency when source moves relative to observer.	B1	Allow synonyms for ‘observed’ e.g. perceived / detected / measured Allow any correct description of relative motion e.g. when source moves towards an observer (but not when source / observer moves) Allow the change in <u>observed</u> frequency / the <u>apparent</u> change or shift in frequency when source moves relative to observer Allow wavelength in place of frequency Answers must convey the difference between observed frequency and source frequency rather than a change in source frequency
	(b)	<u>Pulses</u> (of ultrasound waves) are aimed at / reflected from the (moving) blood (cells in the artery). - The probe / transducer is placed at an angle (usually 60°) (to the artery) - The (detected) frequency of <u>returning/reflected</u> waves is different to that of the emitted waves. (Knowing the speed of ultrasound in blood and) the <u>ratio</u> of the frequencies enables the speed (of blood flow) to be calculated/AW	B1 x 2	Max 2 marks from 4 marking points Allow ultrasound is emitted at an angle Allow there is a change in frequency when the wave is reflected Allow v found using formula $\Delta f = 2fv\cos\theta/c$ with c defined as velocity of (ultra)sound (in the medium) not light

H556/03			Mark Scheme		June 2019
Question			Answer	Marks	Guidance
	(c)	(i)	$T = 0.50$ (s) or $f = 2.0$ (Hz)	C1	
			$v = (2\pi r/T) = 2\pi \times 0.60/0.5$	M1	Allow $1.2\pi/0.5$ or 2.4π
			$v = 7.5$ (m s ⁻¹)	A0	$= 7.54$ (m s ⁻¹)
					Alternative method: $\omega = 4\pi$ or 12.6 (rad s ⁻¹) (C1) $v (= r \omega) = 0.60 \times 12.6$ or 2.4π (M1) $= 7.54$ (m s ⁻¹) (A0)
		(ii)	$\Delta f (\approx vf/c) = (7.5 \times 1700) / 330$	C1	Note that c represents the velocity of sound
			$\Delta f = 40$ (Hz) (or 39Hz)	A1	
		(iii)	y-axis labelled with correct scale	B1	Allow as a minimum one labelled point i.e. 1740 or 1660
					ECF(c)(ii) for incorrect Δf
		(iv)	X labelled at lowest point of circle on Fig. 6.1	B1	
	(d)		Accuracy is (a quality denoting) the closeness of the measured value to the true value	B1	Allow readings/results/data/values/measurements for <i>measured value</i> ; actual/real/allowed/correct for <i>true</i>
			Precision is (a quality denoting) the closeness of agreement between measured values (obtained by repeated measurements)	B1	Allow measurements are close together/are similar/have small range/have low spread/have low scatter/have good agreement/are all close to the average
			Total	11	



Question	Answer	Mark	Guidance
6	arrow down through centre of ball labelled weight or W or mg or 1.2 N	B1	zero if any other arrows or forces present
(b) (i)	(horizontally) mv^2/r (or $mr\omega^2$) = $T \sin \theta$ and (vertically) W or mg = $T \cos \theta$ ($\tan \theta = v^2/rg$ or $r\omega^2/g$) $\tan \theta = 0.045 \times 4 \times 9.87 \times 2.2/9.81$ or $0.48/1.2$ (= 0.40) $\theta = 22^\circ$	M1 A1 A0	accept figures in place of algebra, $r = 0.045$ m $v = 0.42$ m s ⁻¹ $\omega = 3\pi$ rad s ⁻¹ ; $r\omega^2 = 4.0$ m s ⁻² ; $W = 1.2$ N and $m = 0.12$ kg and $mr\omega^2 = 0.48$ N accept labelled triangle of forces diagram N.B. this is a <i>show that Q</i> ; sufficient calculation must be present to indicate that the candidate has not worked back from the answer
(ii)	$k = (mg/x_0 = 1.2 / 0.050) = 24$ (N m ⁻¹) ($T = mg / \cos \theta = kx$ giving) $x = 1.2 / 24 \cos 22$ $x = 0.054$ (m)	C1 C1 A1	or solution by ratios
(c)	($y = \frac{1}{2}gt^2 \Rightarrow 0.18 = 0.5 \times 9.81 \times t^2$ giving $t = 0.19$ (s) ($x = vt \Rightarrow 0.42 \times 0.19 = 0.08$ (m) distance = $\sqrt{r^2 + x^2} = \sqrt{0.0020 + 0.0064} = 0.092$ (m)	C1 C1 C1 A1	alt: projectile motion: $x = vt$, $y = \frac{1}{2}gt^2$ $y = \frac{1}{2}g(x/v)^2$ ecf (b)i for v ; $x^2 = 2yv^2/g = 2 \times 0.18 \times 0.42^2/9.81$
(d)	T increases or string stretches or angle θ increases to provide/create a larger centripetal force	M1 A1	allow mv^2/r or $mr\omega^2$ in place of <i>centripetal force</i> causality must be implied to gain the A mark
	Total	12	

1	(a)		$g = GM/r^2$ $g = \frac{6.67 \times 10^{-11} \times 4.87 \times 10^{24}}{(6\,050 \times 10^3)^2}$ $g = 8.87 \text{ (N kg}^{-1}\text{)}$	C1 Allow m for M Allow d or D or x or X or R for r C1 Full substitution needed Allow $r = 6\,050$ for this C1 mark A1 Allow a negative answer Answer must be to exactly 3sf for the A1 mark. Do not use the SF penalty for the paper here
	(b)	(i)	$a = \omega^2 r$ and $\omega = 2\pi / T$ or $a = v^2 / r$ and $v = 2\pi r / T$ Either $\omega = \frac{2\pi}{5830 \times 3600}$ or $v = \frac{2\pi \times 6050 \times 10^3}{5830 \times 3600}$ or $a = \frac{4\pi^2}{(5830 \times 3600)^2} \times 6050 \times 10^3$ $a = 5.42 \times 10^{-7} \text{ (m s}^{-2}\text{)}$	C1 Allow use of $T^2 = 4\pi^2 r^3 / (GM)$ and $v = 2\pi r / T$ C1 $\omega = 2.99 \times 10^{-7} \text{ (rad s}^{-1}\text{)}$ $v = 1.81 \text{ (m s}^{-1}\text{)}$ $a = \omega^2 r = (2.99 \times 10^{-7})^2 \times 6050 \times 10^3$ $a = v^2 / r = 1.81^2 / (6050 \times 10^3)$ Do not allow incorrect or omitted conversion of T A1 Allow answer given to 2sf Allow any answer which rounds to 5.4×10^{-7} Do not penalise incorrect km conversion (giving $a = 5.42 \times 10^{-10}$) if already penalised in (a)



[illegible]

22	a	i	Period equal to one day/24 hours/rotational period of Earth Or Rotation in same direction as the rotation of the Earth (on its axis) Or Equatorial orbit Or radius of orbit is approx 42 000 km Or height of orbit above Earth's surface is approx 36 000 km Or zero velocity relative to Earth's surface	B1	
		ii	Use of $T=3600 \times 24$ (or 86,400 from data book) Substitution into $T^2 = \frac{4\pi^2}{GM} r^3$ i.e. $(86400)^2 = (4\pi^2 / (G \times 6.0 \times 10^{24})) r^3$ $r = 4.2 \times 10^7$ (m)	C1 C1 A1	NOT 'is in the same place in the sky'
	b	i	$\frac{GMm}{r^2} = \frac{mv^2}{r}$ $\frac{1}{2}mv^2 = \frac{1}{2} \frac{GMm}{r}$	M1 A1	Allow omission of 'm' on both sides of equation (gravitational field strength = centripetal acceleration) Cancelling/rearrangement/identification of GMm/r as GPE
	b	ii	(Increase in) GPE = $(-56 - -63 \text{ MJ}) = 7 \text{ (MJ)}$ or (Increase in) KE = $0.5 \times 56 = 28 \text{ (MJ)}$ Sensible reasoning, e.g. $7+28 > 30$	M1 A1	Allow evaluation of total energy of 35 (MJ)

Question		Answer	Mark	Guidance
22	c	Level 3 (5–6 marks) Correct calculations, and advantages and limitations discussed. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Correct calculations and an advantages discussed or Correct calculations and a limitation discussed. <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Attempted calculations or a single correct calculation or incomplete explanations of advantages and/or limitations. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	B1 x 6	Use level of response annotations in RM Assessor Ignore general knowledge answers e.g. accidents, cost, politics Allow references to energy, energy per unit mass or potential as interchangeable Allow ecf from candidate's value for total energy per unit mass in orbit from (i.e. 35 MJ) 22bii or use of 30 (MJ) Indicative scientific points may include: Calculations • (Minimum) additional KE from aircraft=26 kJ • Additional GPE from aircraft = 100 kJ • Additional KE from equatorial launch=110 kJ • GPE calculated by mgh as an acceptable approximation • (Without taking Earth's rotation into account,) KE at equator is about 4x aircraft KE • GPE calculated from $v_g = (-)GM/r$ • Total energy = $0.5GM/r$

Question			Answer	Mark	Guidance
					Advantages • Aircraft launch provides KE and GPE • Aircraft velocity will be higher than 230 depending on where the aircraft takes off. • Less (rocket) fuel required • Aircraft launch has similar/slightly larger energy to equatorial • Equatorial launches can only happen in limited locations/aircraft launches can take place almost anywhere Limitations • Aircraft launches only suitable for small satellites. • Effects (for either) only significant for near earth orbits/low altitudes • Either launch provides very small fraction (less than 1%) of the energy required
			TOTAL	14	

17	(a)	(i)	Arrow along the line of the support rod labelled tension or T.	B1	Allow unlabelled single arrow along either rod Allow unlabelled arrows along both rods Allow arrow(s) up, down or both NOT any contradictory arrows
		(ii)	11.1 sin 35 or 11.1 cos 55 seen addition of 3.9 (half the diameter of the support disc) to candidate's horizontal component of rod length Total= 10.3m	M1 M1 A0	NOT use of tan 35 or tan 55 allow 7.8/2 for 3.9 10.27 to 2 dp NB use of 11.1 cos 35 or 11.1 sin 55 arriving at 12.99 scores 1 (wrong trig) NB reject use of radians (scores 0)
		(iii)	$mg = T \cos 35$ $T = mg \div \cos 35$ $= 140 \text{ N}$	C1 C1 A1	Allow use of sin 55 NOT use of tan 35 or tan 55 Answer is 143.7 N to 4 sf

Question			Answer	Mark	Guidance
		(iv)	$T \sin 35 = mr\omega^2$ $\omega = \sqrt{\frac{T \sin 35}{mr}}$ $= 0.8(17) \text{ radian s}^{-1}$	M1 A1 A0	Allow use of $W \tan 35$ or $W \tan 55$ Allow use of $\cos 55$ and/or mv^2/r Allow use of Pythagoras to find centripetal force (82.4...) NOT use of $T \tan 35$ or $T \tan 55$ Allow ω^2 subject. Allow any combination of rearrangement and substitution ECF allowed for T and r. Use of 2 s.f. values for T and r gives 0.84 m



Question			Answer	Mark	Guidance
		(iii)	Relevant variable identified	M1	e.g mass/weight, drag/air resistance, radius, height, starting condition (e.g. kicking shoe off) Assume "it" in response refers to the shoe.
			Effect on speed of shoe or time of flight of shoe correctly identified	M1	ignore velocity for first M1 allow correct explanation of "no effect" on speed or time by change of mass
			Conclusion consistent with relevant physics	A1	
			e.g. - Shoe is lower mass yet no change in angular velocity or radius since independent of mass so no change in horizontal displacement. - Shoe is below seat so would be travelling with larger radius/speed so larger distance travelled horizontally - Shoe might have be kicked off backwards so have lower speed so lower distance - Shoe would come from below the seat/lower than the sandbag i.e. vertical distance to fall less, thus time of flight and horizontal distance less. - Effect of air resistance hadn't been included so shoe suffers drag, decelerating horizontally so distance would be smaller		
			TOTAL	16	