

Essential Insight Exam Guide

Physics

Year 12 WACE

Western Australian Curriculum

2025 Edition

William Zheng

Essential Insight Exam Guide

Physics

Year 12 WACE

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Acknowledgements

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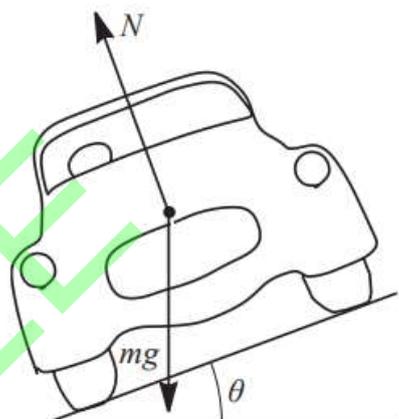
Notes	<ul style="list-style-type: none"> Some question material has not been released by SCSA due to copyright restrictions and are not able to be included in this exam guide. This has been flagged in the relevant questions in the exam guide. Teachers may still be able to locate many of these sources and provide these to students by following the links at the end of the original SCSA exams on the SCSA website.
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Unit 3 – Gravity and electromagnetism

Unit 3 – Gravity and motion

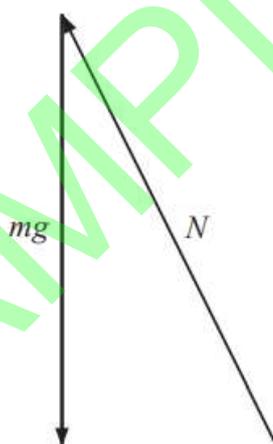
Section 1

2023
Section 1
Question 2
Gravity and
motion



The free body diagram above shows a car going clockwise around a corner on a banked track without relying on friction.

(a) Complete the vector diagram, showing how these two forces result in a centripetal force. Indicate where the angle θ is on your diagram. (2 marks)

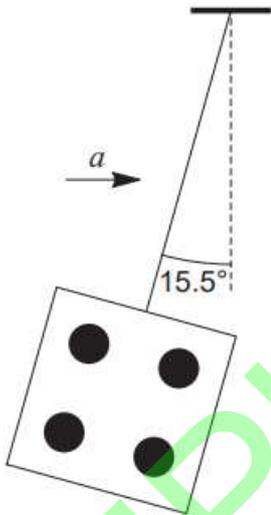


(b) With reference to your diagram in part (a), describe why increasing the angle of the track allows the cars to go around the same radius curve at a greater speed. (2 marks)

2023
Section 1
Question 3

Gravity and motion

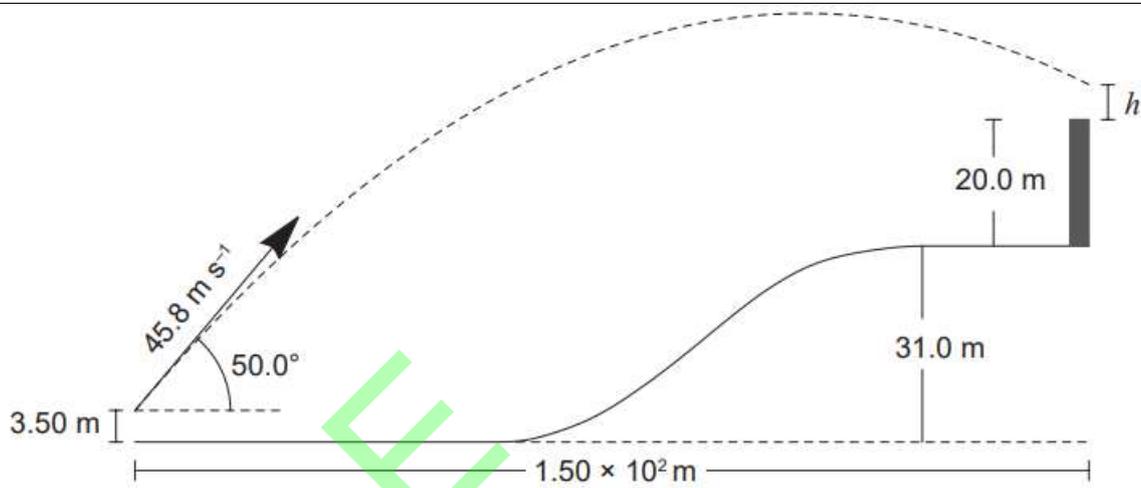
A 370 g single fluffy die on a string is hanging from a baby carriage travelling on a Melbourne tram. The tram accelerates away from the tram stop. At the point of acceleration, the angle between the string and the vertical is 15.5° . Calculate the magnitude of the acceleration of the tram.



Answer: _____ m s^{-2}

2023
Section 1
Question 5

Gravity
and
motion



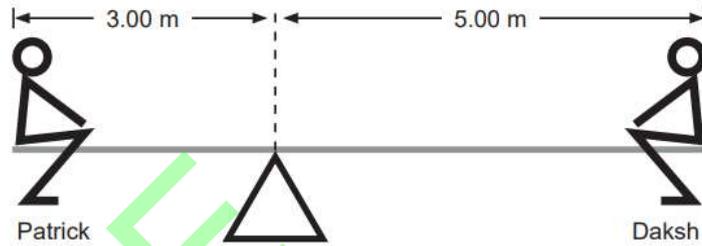
A catapult is 1.50×10^2 m away from a 20.0 m high castle wall on top of a 31.0 m hill. It launches a metal ball at 50.0° to the horizontal 3.50 m above the ground at 45.8 m s^{-1} . Calculate how far above the castle wall the ball passes (*h*). (6 marks)

Answer: _____ m

2022
Section 1
Question 2

Gravity
and
motion

Patrick and Daksh are sitting on a seesaw discussing physics. They decide to place the uniform 15.0 kg beam on the pivot as shown in the diagram below. Daksh estimates that the system is balanced and tells Patrick to lift his feet off the ground. As usual, Daksh is correct and the system is balanced with neither of them touching the ground. Daksh has a mass of 60.0 kg. What is Patrick's mass? (4 marks)

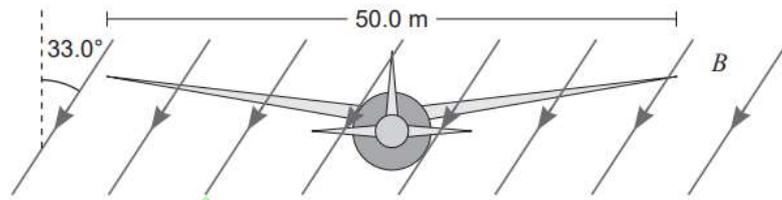


Answer: _____ kg

2022
Section 1
Question 5

Gravity and motion

An aircraft with a wingspan of 50.0 m flies due east parallel to the Earth's surface. The Earth's magnetic field strength at that location is $5.84 \times 10^{-5} \text{ T}$ and it makes an angle of 33.0° to the vertical. The aircraft is travelling at $7.20 \times 10^2 \text{ km hr}^{-1}$.



(a) Using the appropriate component of the magnetic field, calculate the electromotive force (EMF) induced between the ends of the aircraft's wings. (4 marks)

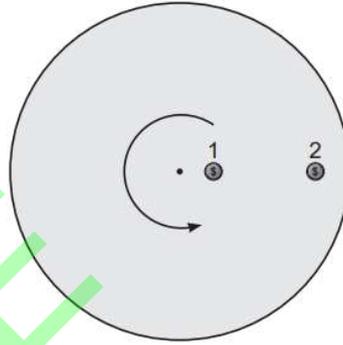
Answer: _____ V

(b) A wire runs between the ends of the wings, parallel to each wing, so as to set up a complete circuit. A sensitive ammeter is placed in the circuit. If the total resistance of the circuit is 1.78Ω , what will be the reading on the ammeter? (1 mark)

Answer: _____ A

2022
Section 1
Question 6
Gravity and motion

Two identical 25.0 g coins are placed on a rotating disc, 0.30 m and 1.20 m respectively from the centre of the disc. The disc begins to rotate. When the frequency of rotation reaches 2.00 Hz, the outer coin flies off the disc. Calculate the frequency of rotation when the inner coin flies off. (6 marks)

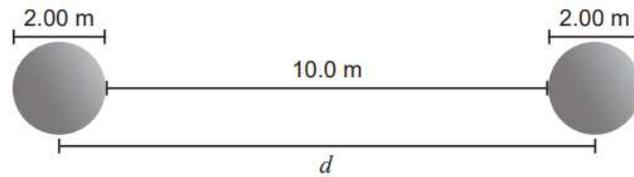


Answer: _____ Hz

2022
Section 1
Question 8

Gravity and motion

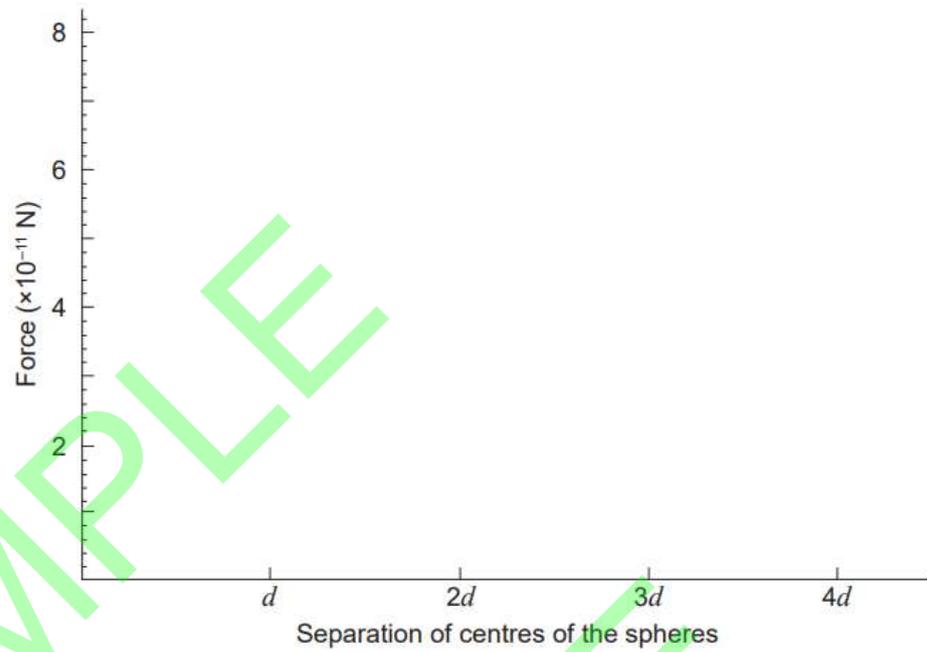
Two identical solid and uniform spheres are separated by a distance of 10.0 m from surface to surface. The distance between their centres is called d .



(a) If each sphere has a mass of 12.50 kg and a diameter of 2.00 m, calculate the gravitational force between them. (3 marks)

Answer: _____ N

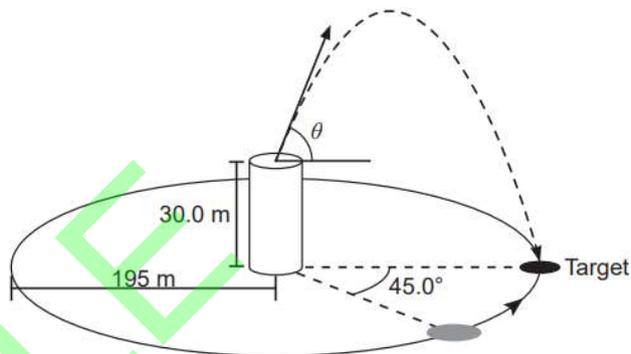
(b) On the axes below, show how the gravitational force between the two spheres varies as they move apart. Indicate the magnitude of the forces on the y-axis at the points $2d$ and $4d$ on the x-axis. If you could not obtain an answer to part (a), use 7.50×10^{-11} N. (4 marks)



2022
Section 1
Question
10

Gravity and
motion

In a video game, the players fire arrows from the top of a 30.0 m high castle tower at a flat, 4.00 m wide target moving in a circular path ($r = 195$ m) around the castle. The player can adjust the vertical angle but the direction of fire is fixed. The launch speed is also fixed at 50.0 m s^{-1} . It takes 32.0 s for the target to complete one revolution of the tower. The shooter fires the arrow when the target has 45.0° of a full revolution to go, as shown in the diagram below.



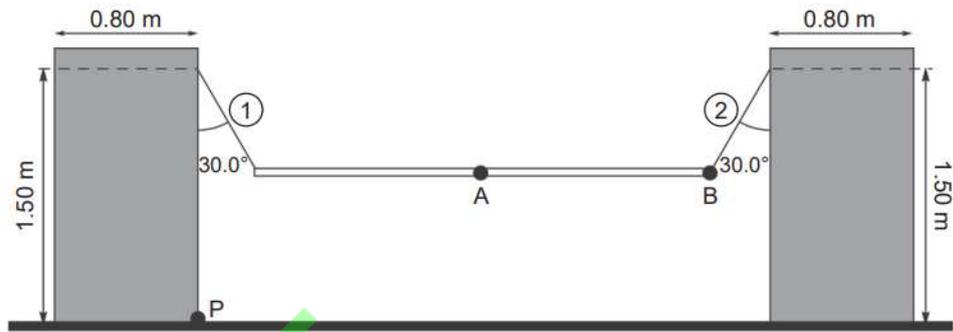
(a) At what angle θ must the shooter fire the arrow above horizontal for it to hit the centre of the target? (4 marks)

Answer: _____ °

(b) With the use of a calculation, confirm that the arrow hits the target. (3 marks)

2022
Section 2
Question
12

Gravity and
motion



An ultra-lightweight 2.00 kg aluminium plank is suspended between two 70.0 kg uniform free-standing supports as part of a children's obstacle course. It is attached to the supports by two chains of equal length. Due to safety restrictions, the apparatus has a maximum load of 60.0 kg. A father with a mass of 80.0 kg mistakenly sits on the plank, halfway between the two supports at point A. His mass exceeds the safety limit, so the free-standing supports should tip inward.

(a) Calculate the tension in each chain when the father sits on the plank, assuming the supports do not tip over. (4 marks)

Answer: _____ N

(b) Calculate the horizontal component of the tension in each chain. (1 mark)

Answer: _____ N

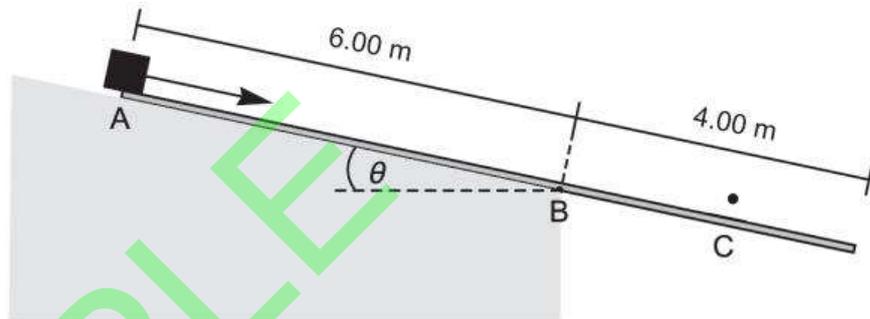
(c) With the use of a calculation, confirm that the supports do tip over when the father sits on the plank. Take moments around P. (5 marks)

(d) Without the use of additional calculations, describe how the tension in each chain would be affected if a 50.0 kg person sitting at A moved to B? Select either increases, decreases or remains constant. (2 marks)

Chain 1	Chain 2

2021
Section 1
Question 6
Gravity and motion

A student is set the task of determining the slope of a concrete structure using only a 15.0 kg beam, a ruler, a 5.00 kg mass with one smooth face and one rough face, and a stopwatch. She places the 10.0 m long uniform beam on top of the sloping structure with 4.00 m of the beam hanging over the end of the structure as shown in the cross-sectional diagram below. The student then places the 5.00 kg mass rough side down at increasing distances from B until the beam starts to tip over. She marks that place as C. The student then lets the 5.00 kg mass slide on its smooth side down the smooth beam from rest at A. She measures the time to reach C as 3.30 s.



(a) Calculate the distance between A and C. (3 marks)

Answer _____ m

(b) Ignoring friction, calculate the angle of the slope measured from the horizontal. (2 marks)

Answer _____ °

<p>2021 Section 1 Question 7</p> <p>Gravity and motion</p>	<p>A bobo doll, as shown below, can never be tipped over. Even if its head is held on the ground, it will stand back up when released. Explain how this works. You must include in your answer the relevant conditions required for static equilibrium. Use the diagram on the right to illustrate your answer. (4 marks)</p> <p style="text-align: center;">Copyright restrictions prohibit the release of this SCSA exam material.</p> <hr/>
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<p>2021 Section 1 Question 9</p> <p>Gravity and motion</p>	<p>A space station is shaped like a huge hollow doughnut that is rotating uniformly. The outer radius is 4.60×10^2 m. What is the period of rotation of the station if a person standing on the outer wall inside the station experiences the same weight force she would experience on Earth? (5 marks)</p> <p style="text-align: center;">Copyright restrictions prohibit the release of this SCSA exam material.</p> <p style="text-align: right;">Answer _____ s</p>
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**2021
Section 2
Question
15**

**Gravity and
motion**

A 42.5 kg gymnast performs her dismount from the 1.25 m high beam. She leaves the beam with a velocity of 3.10 m s^{-1} at an angle of 55.0° to the horizontal.

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(a) Calculate the vertical and horizontal components of her launch velocity. (2 marks)

Answer v_v _____ m s^{-1} Answer v_H _____ m s^{-1}

(b) Calculate the time it takes for her to reach the ground, assuming she is vertical at impact. (5 marks)

Answer _____ s

(c) Calculate her range R. (2 marks)

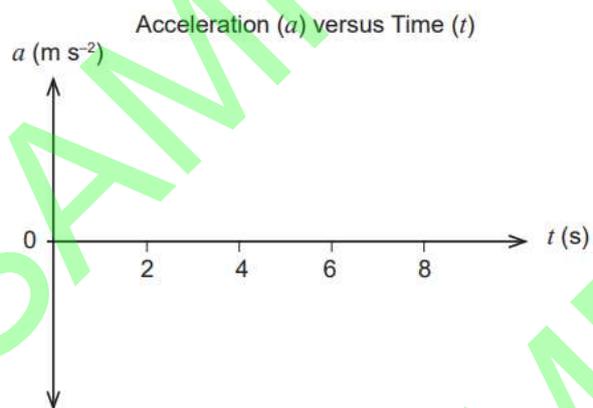
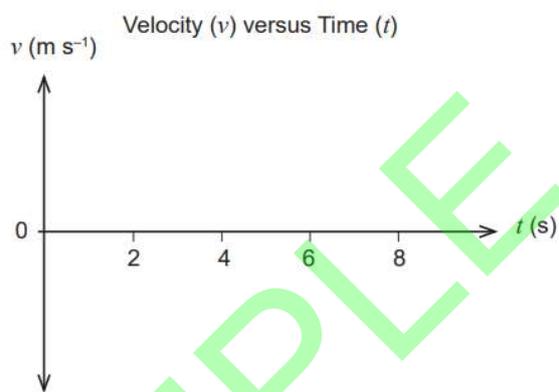
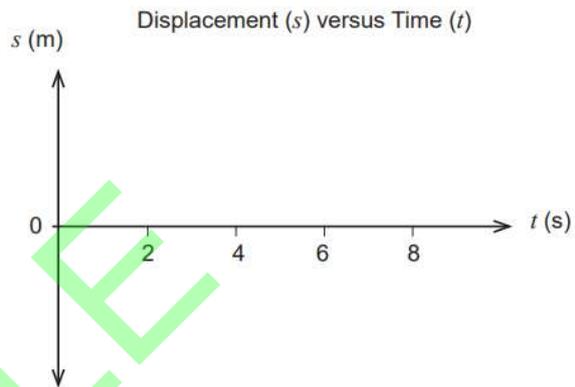
Answer _____ s

(d) Calculate the gymnast's kinetic energy at the top of her flight. (2 marks)

Answer _____ J

2020
Section 1
Question 1
Gravity and motion

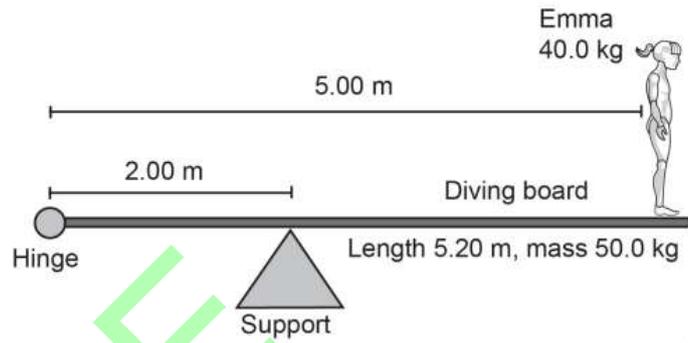
A ball is launched vertically into the air with an initial velocity at $t = 0$ from ground level ($s = 0$) and returns to ground level. It takes four seconds for it to reach its maximum height. Taking upwards as positive, graph the ball's displacement, velocity and acceleration versus time from take-off to landing. Ignore air resistance and do not place any values on the y-axis.



2020
Section 1
Question 5

Gravity and
motion

Emma stands 20.0 cm from the end of a 5.20 m long uniform diving board. Calculate the upwards force the support must exert on the 50.0 kg board for the system to remain in equilibrium. (4 marks)



N

2020
Section 1
Question
10

Gravity and
motion

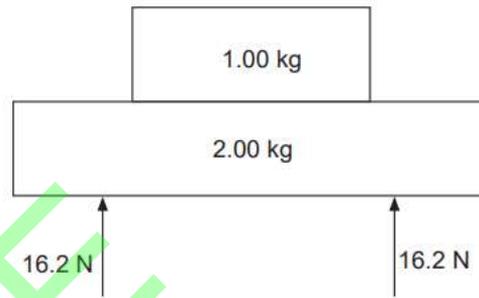
A golfer hits a ball at 37.0 m s^{-1} at 31.0° to the horizontal on a flat fairway. It travels 123 m. She wants to hit a target 135 m away, so she increases the angle at which she hits the ball, without changing the launch speed. Calculate the smallest increase of angle that allows her to reach the target. (Hint: $2\sin\theta\cos\theta = \sin 2\theta$)

o

2020
Section 1
Question
11

Gravity and
motion

Jake is lifting two books of mass 1.00 kg and 2.00 kg respectively. The lighter book sits on top of the heavier book, and each of Jake's hands exerts a vertical force of 16.2 N on the lower book, as shown in the diagram.



(a) What is the magnitude of the acceleration of the books? (3 marks)

_____ m s^{-2}

(b) What is the magnitude of the force that the 2.00 kg book exerts on the 1.00 kg book during this acceleration? (3 marks)

_____ N

2019
Section 1
Question 4

Gravity and motion

Titan is the largest of Saturn's moons. Its orbital radius is 1.22×10^6 km. Use the Formulae and Data booklet and the data in the table below to determine the strength of Saturn's gravitational field where Titan orbits. Give your answer in N kg^{-1} and m s^{-2} .

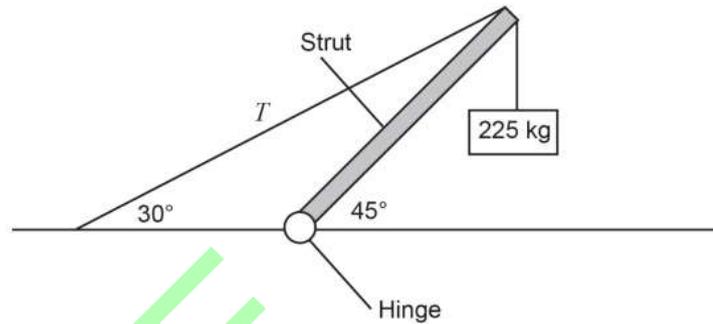
Planet	Mass (Earth masses)
Mercury	0.055
Venus	0.815
Earth	1.000
Mars	0.107
Jupiter	318
Saturn	95
Uranus	14.5
Neptune	17.2
Pluto	0.002

_____ N kg^{-1}

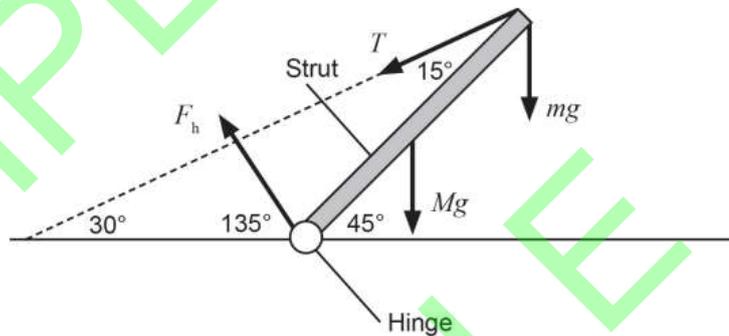
_____ m s^{-2}

2019
Section 1
Question 6
Gravity and
motion

The diagram below shows a system in equilibrium.

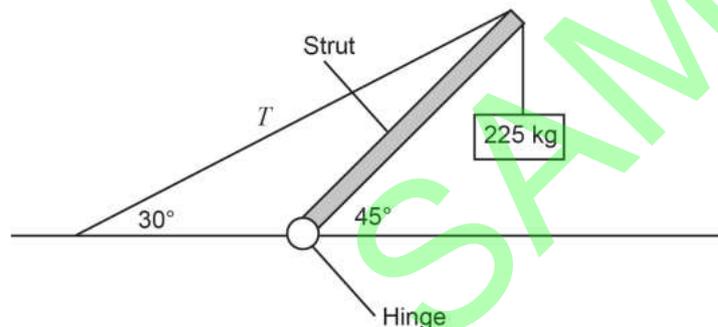


A student drew a diagram of the forces acting on the strut. That diagram is shown below. It is not drawn to scale.



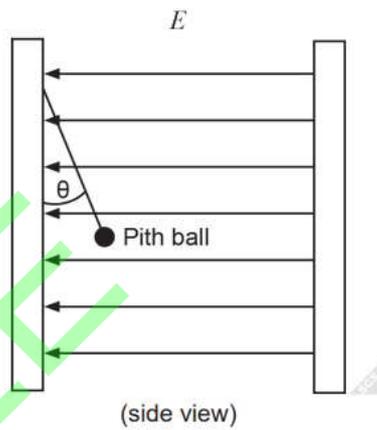
(a) With specific reference to the conditions required for equilibrium, explain why the diagram of the forces is incorrect. (2 marks)

(b) Using the diagram below, show what change(s) should be made to correct it. (Calculations are not required.) (2 marks)



2019
Section 1
Question 7
Gravity and motion

A pith ball is a very small, lightweight object that readily picks up electric charge. A pith ball with a mass of $75.0 \times 10^{-6} \text{ kg}$ is suspended by a string attached to a charged plate. The pith ball has an excess of 2.00×10^{12} electrons on it and the electric field strength between the charged plates is 95.0 N C^{-1} .



(a) In the space below, draw a vector diagram of the forces acting on the pith ball. (3 marks)

(b) Calculate the angle between the string and the charged plate. (5 marks)

2019
Section 1
Question 8

Gravity and
motion

A cyclist is travelling at 6.0 m s^{-1} over a hump in the road that is part of a circle of radius 4.80 m . Calculate the magnitude of the total reaction force of the ground on the cyclist at the top of the hump. The total mass of the cyclist and bicycle is 72 kg . (Note: diagram not to scale, ignore friction.)

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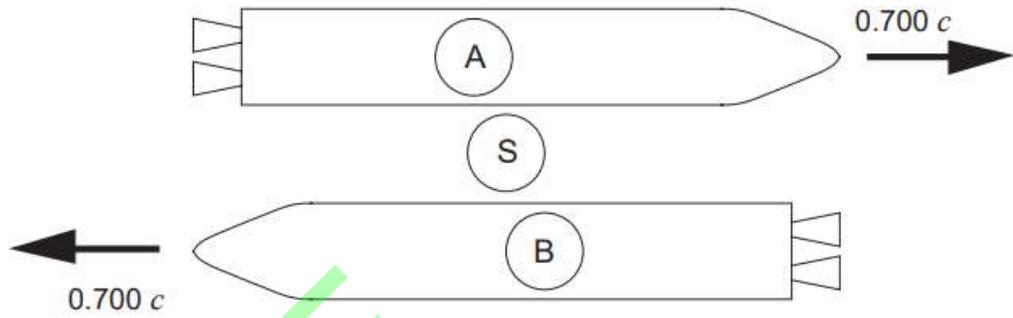
_____ N

SAMPLE
SAMPLE
SAMPLE

Section 2

2023
Section 2
Question
14

Gravity
and
motion



Two 5.00×10^2 m long identical spaceships, 'A' and 'B', pass by an observer S while moving in opposite directions. The observer S measures the velocity of spaceship A as $0.700c$ and spaceship B as $-0.700c$.

- (a) (i) Calculate the velocity of A (in m s^{-1}) as measured by B. (4 marks)

Answer: _____ m s^{-1}

- (ii) Explain why the magnitude of the velocity of B as measured by A would be the same as your answer for part (a)(i), only in the opposite direction. (3 marks)

(b) Calculate the duration of one second on A as measured by the observer S. (3 marks)

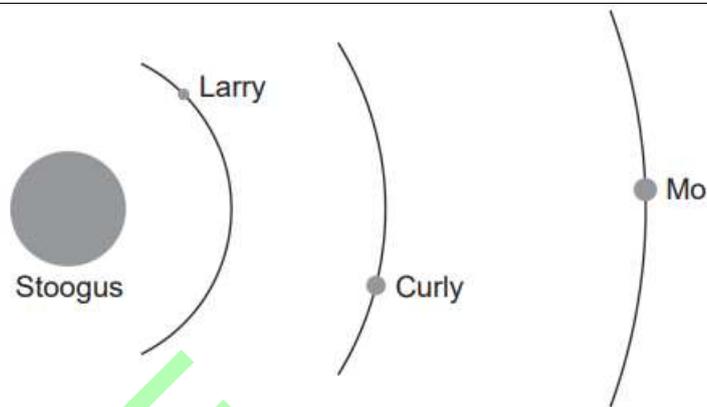
Answer: _____ s

(c) Calculate the length of B as measured by A. If you could not obtain an answer to part (a)(i), use 0.870 c. (3 marks)

Answer: _____ m

2023
Section 2
Question
15

Gravity
and
motion



A recently discovered planet (Stoogus) in a distant solar system has three moons (Larry, Curly and Mo) orbiting at different distances. Stoogus has a mass of 2.37×10^{24} kg and a day on Stoogus lasts 7.50 Earth hours. Assume all three moons have circular orbits as their masses are insignificant compared to that of Stoogus.

- (a) Curly is a geosynchronous satellite that orbits above one specific spot on Stoogus' surface. Calculate the radius of Curly's orbit. (5 marks)

Answer: _____ m

- (b) The gravitational field strength that Mo experiences due to Stoogus is $4.50 \times 10^{-3} \text{ m s}^{-2}$. Calculate the distance between the centre of mass of Mo and the centre of mass of Stoogus. (4 marks)

Answer: _____ m

(c) (i) Derive the mathematical relationship between a moon's orbital speed v and its distance r from the planet's centre of mass. (3 marks)

Answer: _____

(ii) Use this relationship from part (c)(i) to identify which moon of Stoogus has the greatest orbiting speed. Justify your answer. (2 marks)

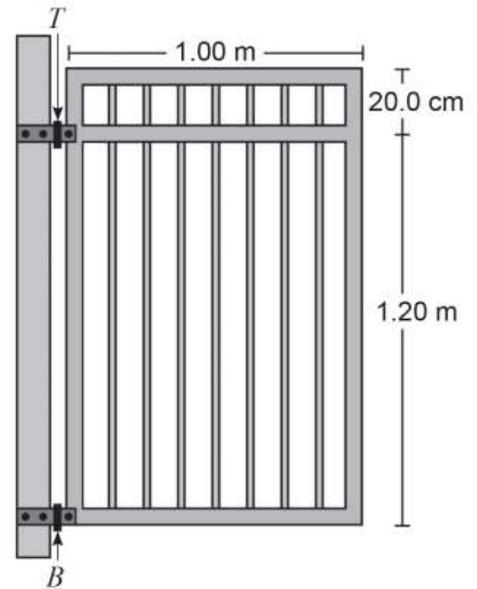
2023
Section 2
Question
17

Gravity
and motion

A uniform garden gate is attached to its support by two hinges (T and B). The top hinge (T) is fixed 20.0 cm below the top of the gate and the bottom hinge is fixed to the bottom of the gate. The gate has a mass of 25.7 kg. It is 1.00 m wide and 1.40 m tall.

Note: The top hinge takes all of the vertical weight force of the gate. The bottom hinge keeps the gate lined up correctly.

- (a) By taking moments around B , calculate the horizontal component of the reaction force of T on the gate. Include a direction in your answer. (5 marks)



Answer: _____ N Direction: _____

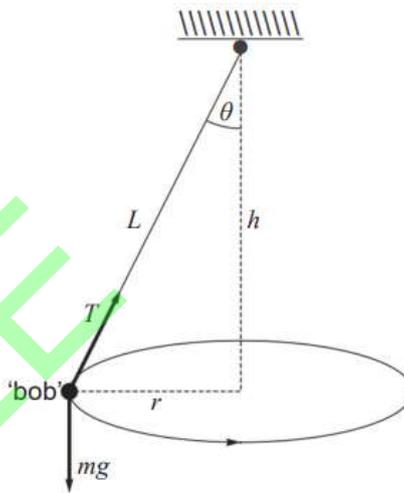
- (b) Calculate the overall reaction force of T on the gate. Include an angle to the horizontal in your answer. If you could not obtain an answer to part (a), use 1.40×10^2 N. (5 marks)

Answer: _____ N at _____ ° to the horizontal

2022
Section 2
Question
17

Gravity and
motion

The diagram to the right shows the two forces acting on a conical pendulum as it spins at a set frequency. The vector addition of these two forces provides the centripetal force on the 'bob'. The mass of the 'bob' is 255 g and the length of the pendulum string L is 1.20 m. When the frequency of rotation is 0.490 Hz, the angle $\theta = 30.0^\circ$.



(a) Calculate the tension in the string when $\theta = 30.0^\circ$. (4 marks)

Answer: _____ N

(b) Calculate the radius of the circular path the 'bob' is moving in when the angle is 30.0° . (2 marks)

Answer: _____ m

(c) Calculate the new angle between the pendulum string and the vertical if the frequency of rotation is doubled. (6 marks)

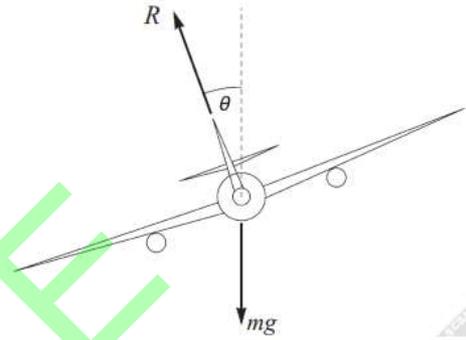
Answer: _____ °

(d) Explain why θ can never equal 90.0° , regardless of how great the frequency of the pendulum becomes. You may use mathematical relationships in your answer. (4 marks)

2021
Section 2
Question
17

Gravity and
motion

Aeroplanes are designed to produce an upthrust that counters their weight force. This allows them to maintain altitude. The magnitude of this upthrust (R) is directly proportional to the forward speed of the aircraft. It always acts perpendicular to the wings. When changing direction, the aeroplane banks in a circular path. A free body diagram of a banking aeroplane is shown below.



(a) Draw a vector diagram showing how the weight force and the upthrust produce a resultant centripetal force. Label the resultant force and include the angle θ shown in the free body diagram. (3 marks)

(b) Calculate the centripetal force on a 5.60×10^3 kg aeroplane banking at an angle of 15.0° to the vertical while maintaining constant altitude. (3 marks)

Answer _____ N

(c) If the aeroplane is travelling at 4.50×10^2 km h⁻¹, calculate the radius of the circular path it takes when banking while maintaining constant altitude. (3 marks)

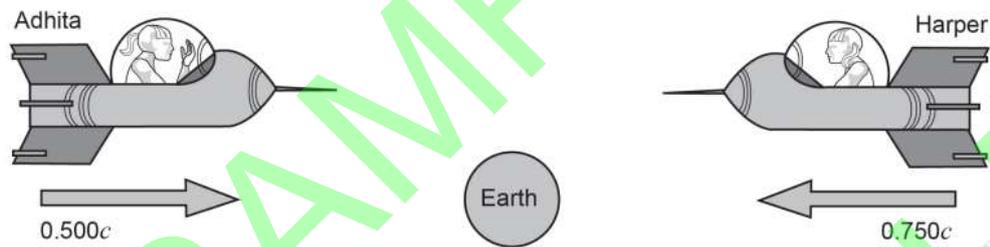
Answer _____ m

(d) With reference to your vector diagram in part (a) and the text, explain why aeroplanes need to increase their speed to maintain altitude when banking. (4 marks)

2020
Section 2
Question
15

Gravity and motion

Two spaceships, captained by Adhita and Harper, are travelling toward each other. They are observed by a person on the Earth to be travelling at the velocities shown in the diagram. Take all velocities to the left as positive.



(a) Calculate the velocity of Harper as measured by Adhita. (4 marks)

_____ c

(b) Harper fires a missile with a velocity of $0.600c$ with respect to her in the direction of Adhita. Calculate the velocity of the missile as measured by an observer on the Earth. (4 marks)

_____ c

(c) Calculate the velocity of the missile as measured by Adhita. (4 marks)

_____ c

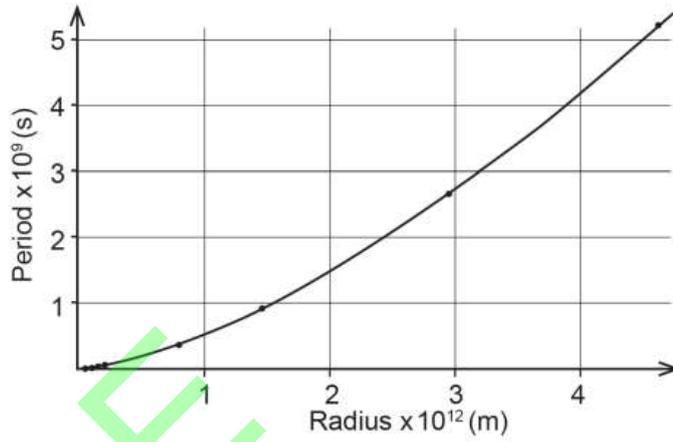
2020
Section 2
Question
17

Gravity and
motion

A satellite is orbiting the Earth 4.00×10^3 km above its surface.

(a) Calculate the period of the satellite. (5 marks)

_____ hours



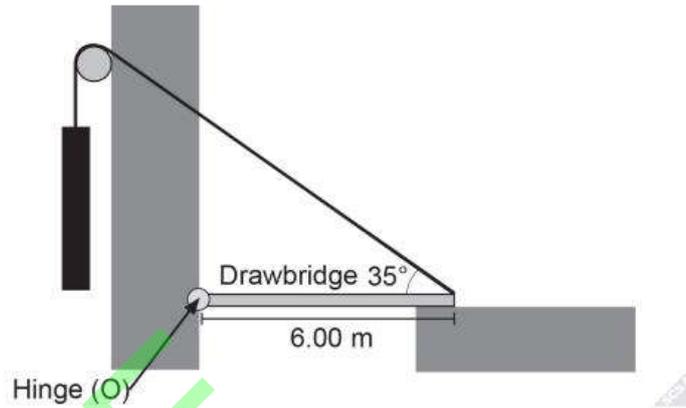
The graph shows the relationship between the period (T) and the orbiting radius (r) of all the planets in our solar system.

(b) (i) With reference to Kepler's Third Law, describe how a straight line graph could be generated using the same two variables. (Do not refer to logarithms.) (2 marks)

(ii) Explain how you could use the gradient of this straight line and Kepler's Third Law to estimate the magnitude of the Newtonian constant of gravitation (G). (Do not try to calculate G from the graph.) (3 marks)

2020
Section 2
Question
18

Gravity and
motion



A castle has a 6.00 m long drawbridge with a mass of 500 kg over its moat. It is attached to a winch by an extremely strong rope at an angle 35.0° to the horizontal.

(a) Calculate the tension in the rope when the drawbridge is just lifted off the rest on the other side of the moat. (4 marks)

(b) Calculate the reaction force of the hinge (O) on the drawbridge at this point. (5 marks)

_____ N

_____ N at _____ $^\circ$ to the horizontal.

The castle comes under attack. The people inside the castle begin to raise the drawbridge. When it is at an angle of 15.0° above horizontal, the angle between the drawbridge and the rope is 40.0° . At this moment, a 95.0 kg soldier being chased by the enemy jumps onto the very end of the drawbridge.

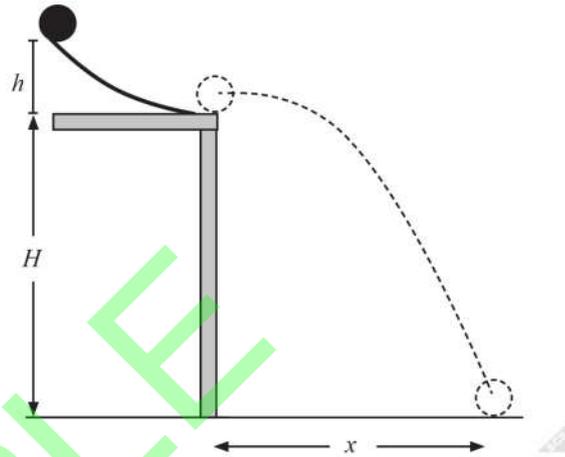
(c) Calculate the new tension in the rope as he hangs from the end. Assume the drawbridge is stationary at this time. (5 marks)

N

2019
Section 2
Question
12

Gravity and
motion

A ball is rolled from rest down a curved slope, across a flat, smooth table leaving the table horizontally and falling to the floor.



If $h = 30.0$ cm and $H = 1.20$ m

(a) Using conservation of energy, calculate the speed with which the ball leaves the table. Assume no energy is lost to friction, air resistance or is transferred to rotational energy. (2 marks)

_____ m s^{-1}

(b) Calculate the distance x . (4 marks)

_____ m

(c) Calculate the velocity of the ball when it hits the floor. (5 marks)

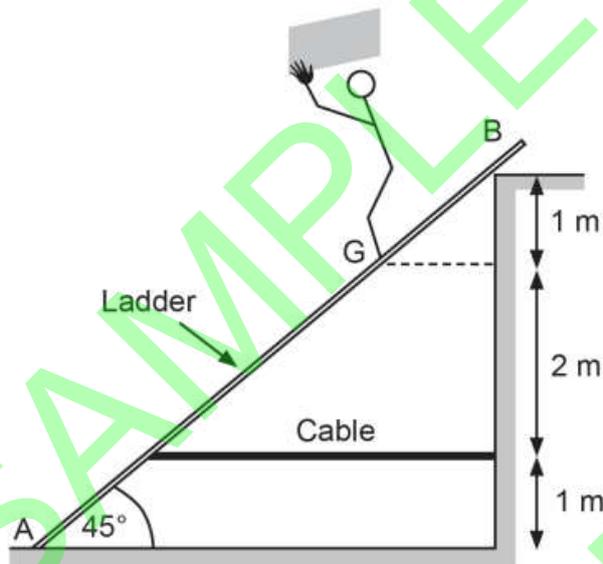
_____ m s^{-1} Angle: _____ $^{\circ}$ above horizontal

(d) Derive an expression for x in terms of h and H only. (Note: may include numbers.) (4 marks)

**2019
Section 2
Question
13**

**Gravity and
motion**

Workers at an ice skating venue use a ladder to fix a sign 5.0 m above the surface of the ice. To prevent the 6.00 m long ladder from slipping on the ice, they tie a cable between the ladder and the 4.00 m high wall. The cable is at right angles to the wall. The uniform 15.0 kg ladder is placed at an angle of 45° between the frictionless surfaces at A and B. A 90.0 kg worker is standing still on the ladder at G.



(a) On the diagram above, draw and label the forces acting on the ladder. Assume the reaction force at B acts at right angles to the ladder. (4 marks)

(b) By taking moments around A, calculate the tension in the cable. (6 marks)

_____ N

2019
Section 2
Question
16

Gravity and
motion

A ball is being swung around in a vertical circle on a string.

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(a) In the table below, match the statements with A, B, C and/or D. (4 marks)

Statement	A, B, C and/or D
point(s) where the centripetal acceleration is the greatest	
point(s) where the tension in the string is the lowest	
point(s) where the net force is not toward the centre of the circle	
point(s) where the ball's weight force is perpendicular to the tension	

(b) Write an expression for the net force acting on the string at point C in terms of the weight force and the tension in the string. (1 mark)

(c) Calculate how fast the 500 g ball can be moving at point A for the 1.20 m long string not to break, if the maximum tension it can withstand at point A is 172 N. (4 marks)

_____ m s⁻¹

(d) Calculate the maximum speed at which the ball can be moving at point C for the string not to break at point A. (3 marks)

_____ m s^{-1}

2022
Section 3
Question
19

Gravity and
motion

Kepler's three laws of planetary motion can be stated as follows:

1. All planets move about the Sun in elliptical orbits, having the Sun as one of the foci.
2. A radius vector joining any planet to the Sun sweeps out equal areas in equal lengths of time.
3. The squares of the periods (of revolution) of the planets are directly proportional to the cubes of their mean distances from the Sun.

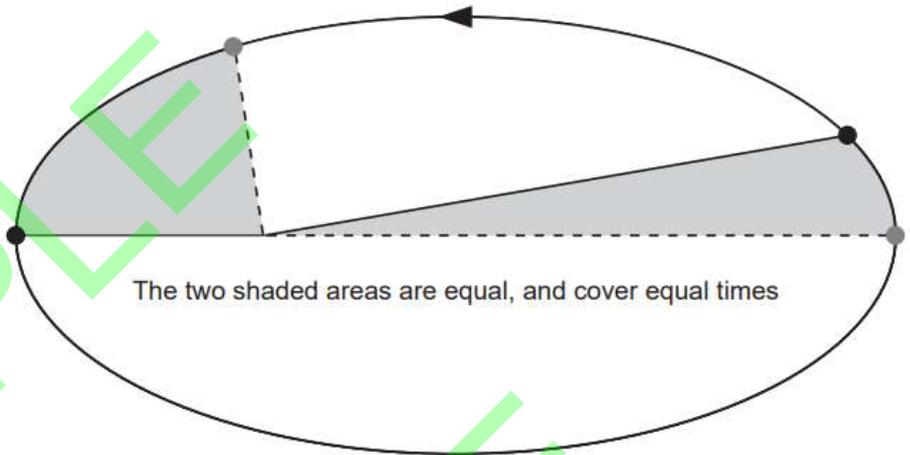


Figure 1: Kepler's 2nd Law

Kepler's 3rd Law, which appears on the Formulae and Data booklet, can be derived for a circular orbit from first principles: the centripetal force between the planet and the Sun is provided by Newton's Law of Gravitation, and $S = vT$, where S is the orbiting circumference and T is the period.

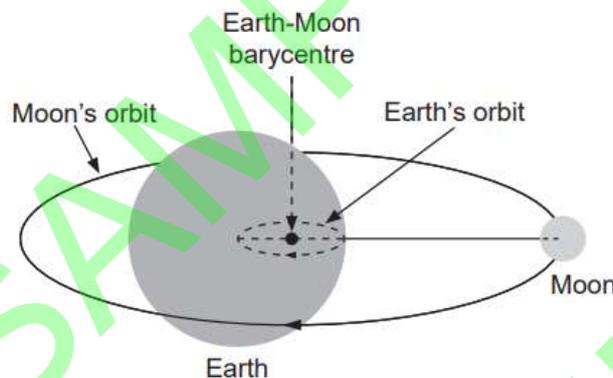


Figure 2: Location of Earth-Moon barycentre

The system of any large celestial body, and its satellite, orbits around a 'barycentre'. This represents the centre of mass of the system. The barycentre of the Earth–Moon system is shown in Figure 2. The system could be seen as a balance beam, with the barycentre located where the fulcrum would be placed to achieve equilibrium. The gravitational field strength due to the Sun is identical for both the Earth and Moon and therefore cancels out when calculating moments around the barycentre.

When the mass of the satellite represents a significant percentage of the system, the barycentre is outside either body. When its mass is significantly less, the barycentre is usually found within the more massive body which appears to 'wobble'. When the mass of the orbiting satellite is insignificant compared to the mass of the body it is orbiting, the barycentre can be assumed to be the centre of mass of the larger body.

(a) (i) Using Kepler's 2nd Law, describe the relationship between the distance a planet is from the Sun it orbits and its orbiting speed by filling in the blank below. (1 mark)

As the distance from the planet increases, the orbiting speed _____.

(ii) Without completing a calculation, justify this relationship with reference to Figure 1. (3 marks)

(b) Using the instructions given in the article, derive Kepler's 3rd Law from first principles, showing each step of the derivation. The final expression must match the equation in the Formulae and Data booklet. Assume the orbit is perfectly circular and the mass of the satellite is insignificant compared to the mass of the body it is orbiting. (5 marks)

(c) Using moments, estimate how far the barycentre of the Earth–Moon system is from the centre of the Earth. (4 marks)

Answer: _____ m

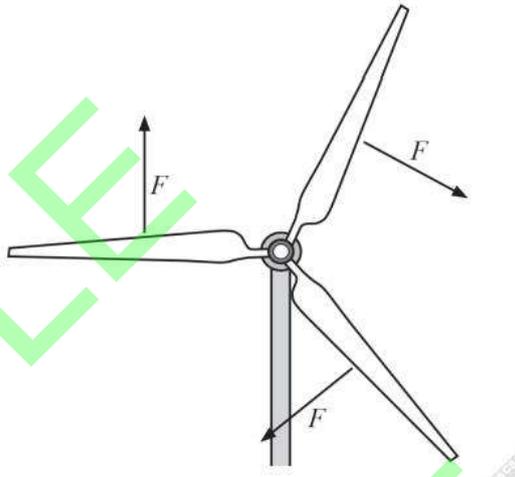
(d) With the use of a calculation and your answer to part (c), show that the Moon is travelling roughly 81 times faster than Earth as they orbit the barycentre. If you could not get an answer to part (c), use 4.81×10^6 m and show that the ratio of the Moon's orbiting velocity to that of the Earth is roughly 80. (4 marks)

Wind turbines

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How do wind turbines work?

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Wind turbine blades vary in length between 40 and 80 m.

A major problem with wind turbines is varying wind speed. The input power must match the output power. The output power depends entirely on rotational speed and torque so how do we keep rotational frequency constant when wind speed keeps changing? The solution is mechanical. The operators use blade pitch control which changes the angle of the blades and reduces the surface area facing the wind. This reduces the amount of energy collected by the turbine and controls the force applied to each blade.

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How the pitch is altered to control the rotational speed.

Each blade experiences a gravitational torque. If the clockwise and anticlockwise gravitational torques add up to zero, the turbine is considered balanced. A symmetrical three-blade turbine is considered balanced at all times.

(a) (i) Explain why a step-up transformer is used to increase the voltage before transporting the electricity into the National Grid. Use specific equations in your answer. (4 marks)

(ii) Calculate the output voltage of the transformer if the turbine produces 690 V and the ratio of turns is 100 in the primary coil to 2500 in the secondary coil. (2 marks)

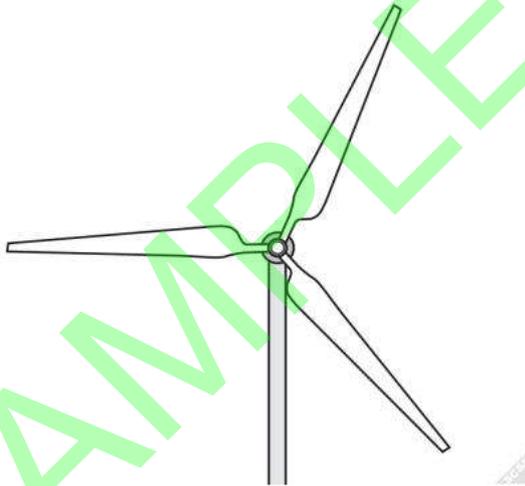
_____ kV

(c) If the 60 m long blades on an average-sized turbine are rotating at 0.20 Hz, estimate the speed of the centre of mass of one of the blades. (4 marks)

_____ m s^{-1}

Consider the three-blade turbine in the diagram to be rotating clockwise. The blade on the left hand side is parallel to the ground. The blades are identical in size and mass.

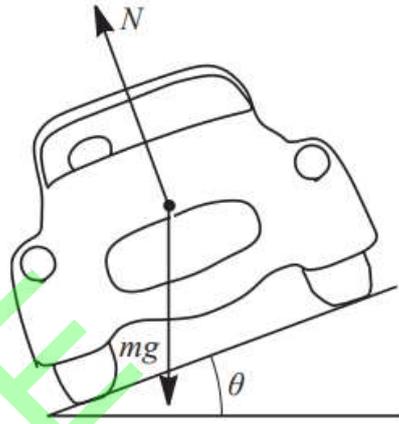
(d) (i) Draw the weight forces acting on the blades. (2 marks)



(ii) Show mathematically that the turbine is balanced in this position. (4 marks)

2023
Section 1
Question 2

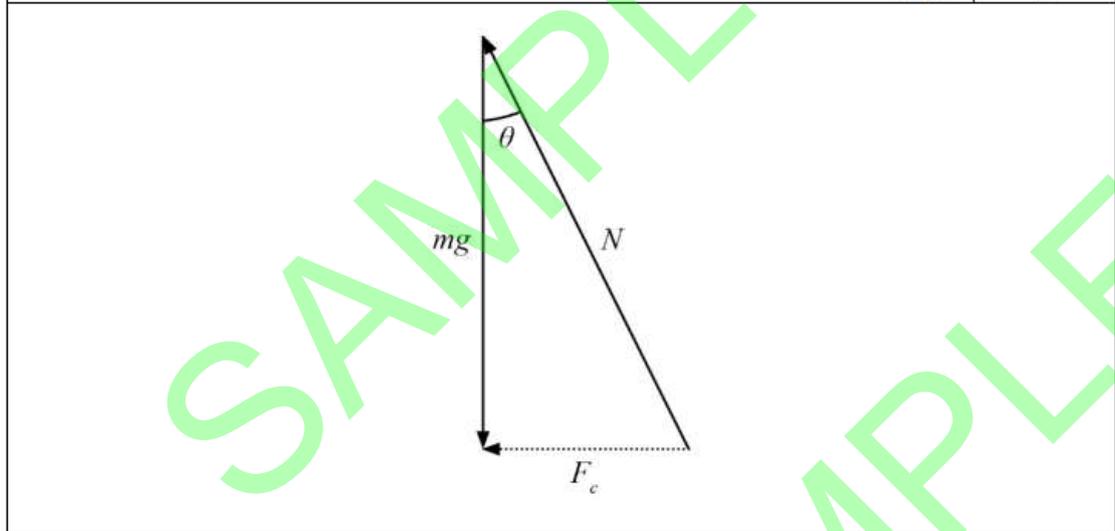
Gravity and motion



The free body diagram above shows a car going clockwise around a corner on a banked track without relying on friction.

(a) Complete the vector diagram, showing how these two forces result in a centripetal force. Indicate where the angle θ is on your diagram. (2 marks)

Description	Marks
θ is in correct position	1
net force is horizontal and labelled F_c	1
Total	2



(b) With reference to your diagram in part (a), describe why increasing the angle of the track allows the cars to go around the same radius curve at a greater speed. (2 marks)

Description	Marks
as θ increases and mg remains constant, F_c increases	1
$F_c = mv^2/r$. If m and r remain constant, then for F_c to increase v must increase	1
Total	2

**2023
Section 1
Question 3**

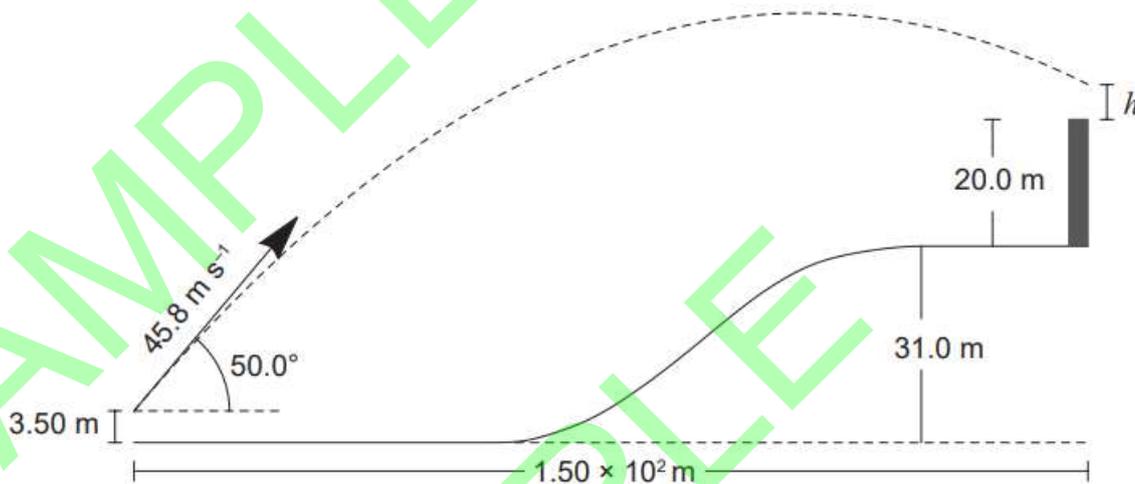
Gravity and motion

A 370 g single fluffy die on a string is hanging from a baby carriage travelling on a Melbourne tram. The tram accelerates away from the tram stop. At the point of acceleration, the angle between the string and the vertical is 15.5° . Calculate the magnitude of the acceleration of the tram.

Element	Description	Marks
Realises net force is vector addition of tension and weight		1
Uses $\tan \theta$	$\tan \theta = \frac{ma}{mg}$	1
Rearranges for a	$a = \tan 15.5^\circ \times 9.80$	1
Calculates answer	$a = 2.72 \text{ m s}^{-2}$	1
Total		4

**2023
Section 1
Question 5**

Gravity and motion

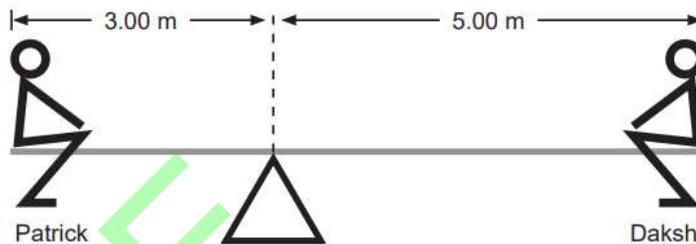


A catapult is $1.50 \times 10^2 \text{ m}$ away from a 20.0 m high castle wall on top of a 31.0 m hill. It launches a metal ball at 50.0° to the horizontal 3.50 m above the ground at 45.8 m s^{-1} . Calculate how far above the castle wall the ball passes (h). (6 marks)

Element	Description	Marks
Calculates horizontal component of velocity	$v_H = 45.8 \times \cos 50.0^\circ = 29.4 \text{ m s}^{-1}$	1
Calculates vertical component of velocity	$v_V = 45.8 \times \sin 50.0^\circ = 35.1 \text{ m s}^{-1}$	1
Calculates t from horizontal	$t = \frac{1.50 \times 10^2}{29.4} = 5.10 \text{ s}$	1
Substitutes correct values for vertical displacement after t	$s_V = (35.1 \times 5.10) - (4.90 \times (5.10)^2) + 3.50$	1
Calculates vertical displacement	$s_V = 179.01 - 127.5 + 3.50 = 55.06 \text{ m}$	1
Calculates clearance	$55.06 - 51.0 = 4.06 \text{ m}$	1
Total		6

2022
Section 1
Question 2
Gravity and motion

Patrick and Daksh are sitting on a seesaw discussing physics. They decide to place the uniform 15.0 kg beam on the pivot as shown in the diagram below. Daksh estimates that the system is balanced and tells Patrick to lift his feet off the ground. As usual, Daksh is correct and the system is balanced with neither of them touching the ground. Daksh has a mass of 60.0 kg. What is Patrick's mass? (4 marks)

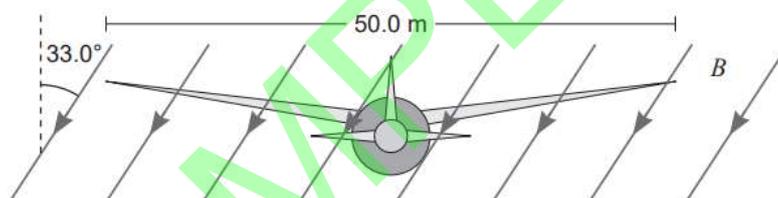


Element	Description	Marks
Takes moments around the pivot	$\Sigma cm = \Sigma acm$	1
Includes mass of beam		1
Uses correct distances from pivot	$m_p g \times 3.00 = (m_b g \times 1.00) + (m_d g \times 5.00)$	1
Calculates the correct answer	$m_p = 105 \text{ kg}$	1
Total		4

Note: If mass of beam is not included, award maximum 2 marks.

2022
Section 1
Question 5
Gravity and motion

An aircraft with a wingspan of 50.0 m flies due east parallel to the Earth's surface. The Earth's magnetic field strength at that location is $5.84 \times 10^{-5} \text{ T}$ and it makes an angle of 33.0° to the vertical. The aircraft is travelling at $7.20 \times 10^2 \text{ km hr}^{-1}$.



(a) Using the appropriate component of the magnetic field, calculate the electromotive force (EMF) induced between the ends of the aircraft's wings. (4 marks)

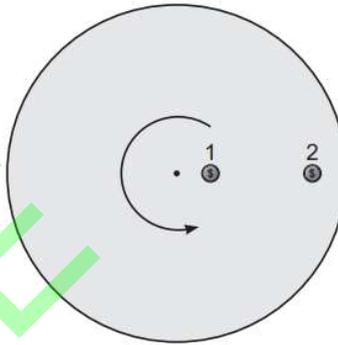
Element	Description	Marks
Converts km hr^{-1} to m s^{-1}	$7.20 \times 10^2 \div 3.6 = 2.00 \times 10^2 \text{ m s}^{-1}$	1
Calculates vertical component of B	$B \cos 33.0^\circ = 4.90 \times 10^{-5} \text{ T}$	1
Substitutes values into correct equation, using calculated component	$\text{EMF} = 4.90 \times 10^{-5} \times 2.00 \times 10^2 \times 50.0$	1
Calculates correct answer	$\text{EMF} = 0.490 \text{ V}$	1
Total		4

(b) A wire runs between the ends of the wings, parallel to each wing, so as to set up a complete circuit. A sensitive ammeter is placed in the circuit. If the total resistance of the circuit is 1.78Ω , what will be the reading on the ammeter? (1 mark)

Description	Marks
0.00 A	1
Total	1

2022
Section 1
Question 6
Gravity and motion

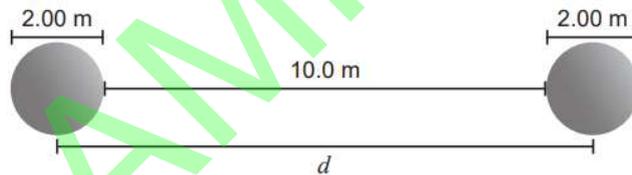
Two identical 25.0 g coins are placed on a rotating disc, 0.30 m and 1.20 m respectively from the centre of the disc. The disc begins to rotate. When the frequency of rotation reaches 2.00 Hz, the outer coin flies off the disc. Calculate the frequency of rotation when the inner coin flies off. (6 marks)



Element	Description	Marks
Realises the centripetal force is supplied by the frictional force	$m_1 v_1^2 / 0.30 = m_2 v_2^2 / 1.20$	1
Cancels m and obtains ratio of velocities.	$v_2^2 / v_1^2 = 4$ $v_2 / v_1 = 2$ or $v_2 = 2v_1$	1
Substitutes $2\pi r / T$ for v		1
Uses 0.500 s for T_2	$1.20 / 0.500 = 2 \times 0.30 / T_1$	1
Calculates T_1	$T_1 = 0.250$ s	1
Calculates frequency of rotation	$f = 1 / T_1 = 4.00$ Hz	1
Total		6

2022
Section 1
Question 8
Gravity and motion

Two identical solid and uniform spheres are separated by a distance of 10.0 m from surface to surface. The distance between their centres is called d .

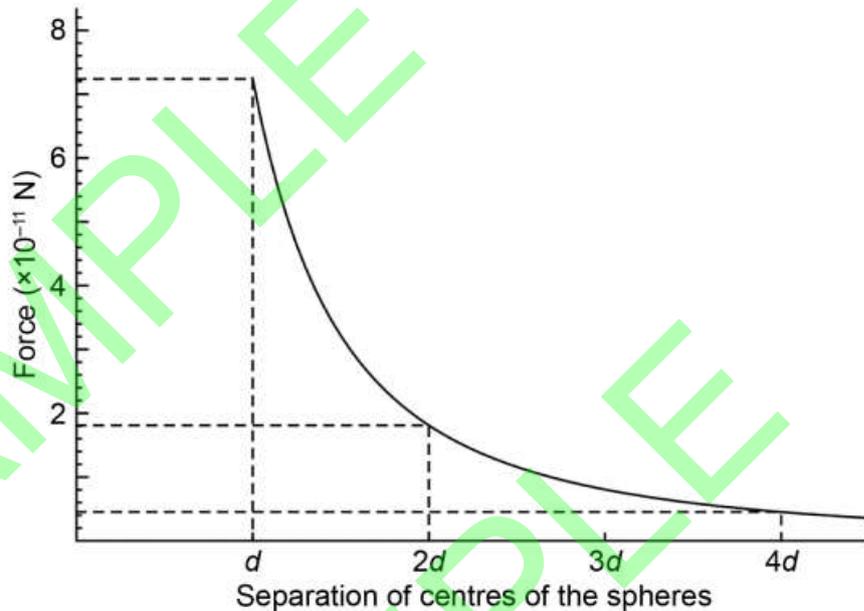


(a) If each sphere has a mass of 12.50 kg and a diameter of 2.00 m, calculate the gravitational force between them. (3 marks)

Element	Description	Marks
Uses 12.0 m as d		1
Uses gravitational force formula correctly	$F = 12.50 \times 12.50 \times 6.67 \times 10^{-11} / 144.0$	1
Calculates correct answer	7.24×10^{-11} N	1
Total		3

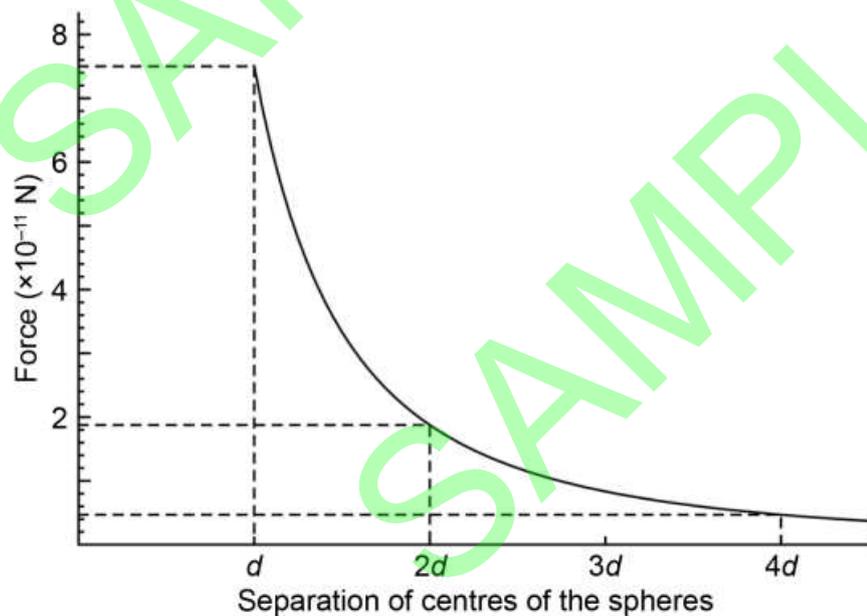
(b) On the axes below, show how the gravitational force between the two spheres varies as they move apart. Indicate the magnitude of the forces on the y-axis at the points $2d$ and $4d$ on the x-axis. If you could not obtain an answer to part (a), use 7.50×10^{-11} N. (4 marks)

Description	Marks
three points plotted	1
indicates on y-axis, or shows by calculation, correct values	1
accurately plotted	1
curve accurately drawn indicating relationship	1
Total	4



$$F(d) = 7.24 \times 10^{-11} \text{ N}, F(2d) = 1.81 \times 10^{-11} \text{ N}, F(4d) = 0.45 \times 10^{-11} \text{ N}$$

If used $F(d) = 7.50 \times 10^{-11}$ N:

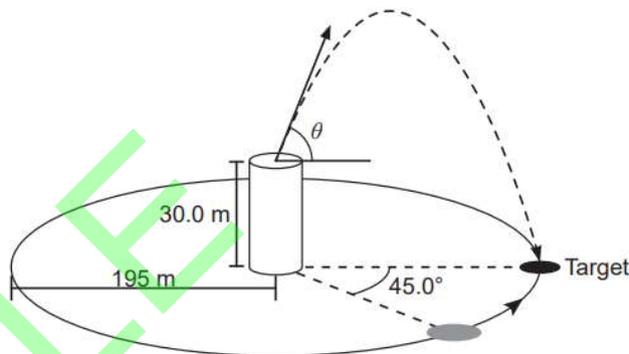


$$F(d) = 7.50 \times 10^{-11} \text{ N}, F(2d) = 1.88 \times 10^{-11} \text{ N}, F(4d) = 0.47 \times 10^{-11} \text{ N}$$

2022
Section 1
Question
10

Gravity and motion

In a video game, the players fire arrows from the top of a 30.0 m high castle tower at a flat, 4.00 m wide target moving in a circular path ($r = 195$ m) around the castle. The player can adjust the vertical angle but the direction of fire is fixed. The launch speed is also fixed at 50.0 m s^{-1} . It takes 32.0 s for the target to complete one revolution of the tower. The shooter fires the arrow when the target has 45.0° of a full revolution to go, as shown in the diagram below.



(a) At what angle θ must the shooter fire the arrow above horizontal for it to hit the centre of the target? (4 marks)

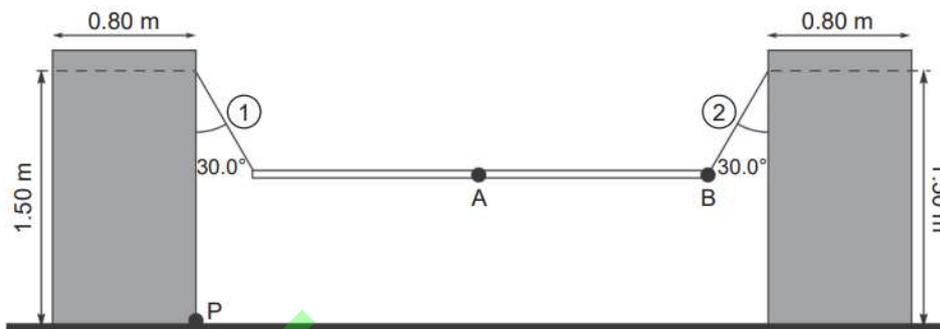
Element	Description	Marks
Calculates time for target to reach destination	$32.0/8 = 4.00 \text{ s}$	1
Uses correct vertical component		1
Uses vertical displacement of velocity	$-30.0 = 50.0 \sin \theta \times 4.00 - 4.90 \times 16.00$	1
Calculates correct angle	$\theta = 14.0^\circ$	1
Total		4
Accept other relevant methods of calculation e.g. using horizontal component.		

(b) With the use of a calculation, confirm that the arrow hits the target. (3 marks)

Element	Description	Marks
Uses correct horizontal component		1
Uses horizontal component of velocity	$s = vt = 50.0 \times \cos 14.0^\circ \times 4.00 = 194 \text{ m}$	1
Confirms arrow hits target	194 is between 193 and 197 m	1
Total		3
Note: Candidate must use the alternate component of velocity in part (b) to the component they used in part (a).		

2022
Section 2
Question
12

Gravity and
motion



An ultra-lightweight 2.00 kg aluminium plank is suspended between two 70.0 kg uniform free-standing supports as part of a children's obstacle course. It is attached to the supports by two chains of equal length. Due to safety restrictions, the apparatus has a maximum load of 60.0 kg. A father with a mass of 80.0 kg mistakenly sits on the plank, halfway between the two supports at point A. His mass exceeds the safety limit, so the free-standing supports should tip inward.

(a) Calculate the tension in each chain when the father sits on the plank, assuming the supports do not tip over. (4 marks)

Element	Description	Marks
Uses sum of vertical forces = 0		1
Correct equation	$2T \times \cos 30.0^\circ = \Sigma mg$	1
Includes mass of plank		1
Correctly calculates answer	$T = 82.0 \times 9.80 / (2 \cos 30.0^\circ) = 464 \text{ N}$	1
Total		4

(b) Calculate the horizontal component of the tension in each chain. (1 mark)

Description	Marks
$T_h = T \times \sin 30.0^\circ = 464 \times 0.500 = 232 \text{ N}$	1
Total	1

(c) With the use of a calculation, confirm that the supports do tip over when the father sits on the plank. Take moments around P. (5 marks)

Element	Description	Marks
Takes moments around inside base of support	$\Sigma cm > \Sigma acm$ if tips over	1
Uses 1.50 m as distance to pivot of T_h		1
Uses 0.40 m as distance to pivot of m_s		1
Correctly calculates moments	$232 \times 1.50 > 70.0 \times 9.80 \times 0.400$	1
Confirms support tips over	$348 \text{ N m} > 274 \text{ N m}$	1
Total		5

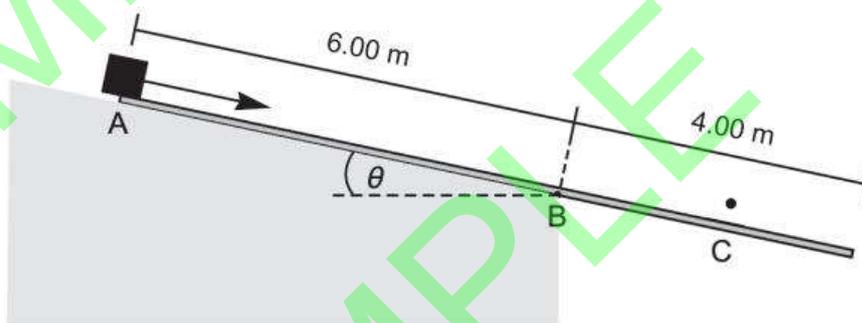
(d) Without the use of additional calculations, describe how the tension in each chain would be affected if a 50.0 kg person sitting at A moved to B? Select either increases, decreases or remains constant. (2 marks)

Chain 1	Chain 2
decreases	increases

Description	Marks
chain 1 decreases	1
chain 2 increases	1
Total	2

2021
Section 1
Question 6
Gravity and motion

A student is set the task of determining the slope of a concrete structure using only a 15.0 kg beam, a ruler, a 5.00 kg mass with one smooth face and one rough face, and a stopwatch. She places the 10.0 m long uniform beam on top of the sloping structure with 4.00 m of the beam hanging over the end of the structure as shown in the cross-sectional diagram below. The student then places the 5.00 kg mass rough side down at increasing distances from B until the beam starts to tip over. She marks that place as C. The student then lets the 5.00 kg mass slide on its smooth side down the smooth beam from rest at A. She measures the time to reach C as 3.30 s.



(a) Calculate the distance between A and C. (3 marks)

Element	Description	Marks
Uses moments to solve problem	$\Sigma cm = \Sigma acm$	1
Uses 1.00 m as distance from B to COM of beam	$(5.00)(9.80) \times BC \cos\theta = (15.0)(9.80) \times 1.00 \cos\theta$ $BC = 3.00 \text{ m}$	1
Correctly calculates answer	$AC = 6.00 + 3.00 = 9.00 \text{ m}$	1
Total		3

(b) Ignoring friction, calculate the angle of the slope measured from the horizontal. (2 marks)

Element	Description	Marks
Uses $s = ut + 0.5 at^2$ where $u = 0$ and $a = g \sin\theta$	$9.00 = 0.5 \times 9.80 \sin\theta \times 3.30^2$	1
Correctly calculates answer	$\sin\theta = 0.1687 \quad \theta = 9.71^\circ$	1
Total		2

2021 Section 1 Question 7 Gravity and motion	A bobo doll, as shown below, can never be tipped over. Even if its head is held on the ground, it will stand back up when released. Explain how this works. You must include in your answer the relevant conditions required for static equilibrium. Use the diagram on the right to illustrate your answer. (4 marks)
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Description	Marks
Diagram shows labelled line of action of the weight force to the left of the pivot (where the base of the bobo doll touches the ground).	2
Person holding doll down provides a balancing torque to keep the doll in static equilibrium	1
When opposing moment holding head on the ground is removed, the restoring moment of the weight force rights the doll	1
Total	4

2021 Section 1 Question 9 Gravity and motion	A space station is shaped like a huge hollow doughnut that is rotating uniformly. The outer radius is 4.60×10^2 m. What is the period of rotation of the station if a person standing on the outer wall inside the station experiences the same weight force she would experience on Earth? (5 marks)
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Element	Description	Marks
Centripetal force is supplied by the reaction force.	$mv^2/r = R$	1
Reaction force equals mg	$mv^2/r = mg$	1
Correctly rearranges formula to calculate velocity	$v = \sqrt{rg} = \sqrt{4.60 \times 10^2 \times 9.80} = 67.1 \text{ m s}^{-1}$	1
Period is circumference over time	$T = 2\pi r/v$	1
Correctly calculates period	$T = 43.0 \text{ s}$	1
Total		5

2021 Section 2 Question 15 Gravity and motion	A 42.5 kg gymnast performs her dismount from the 1.25 m high beam. She leaves the beam with a velocity of 3.10 m s^{-1} at an angle of 55.0° to the horizontal.
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(a) Calculate the vertical and horizontal components of her launch velocity. (2 marks)

Element	Description	Marks
Vertical component	$v_V = 3.10 \times \sin 55.0^\circ = 2.54 \text{ m s}^{-1}$	1
Horizontal component	$v_H = 3.10 \times \cos 55.0^\circ = 1.78 \text{ m s}^{-1}$	1
Total		2

(b) Calculate the time it takes for her to reach the ground, assuming she is vertical at impact. (5 marks)

There are 3 different alternatives to solve this problem.

1. Quadratic equation

Element	Description	Marks
$s = ut + 0.5 at^2$		
s and a are negative, u is positive.	$-1.25 = 2.54t - 4.90t^2$	1
Uses v_V for u		1
Rearranges equation correctly to equal 0	$4.90t^2 - 2.54t - 1.25 = 0$	1
Substitutes correct values into quadratic formula	$t = \frac{2.54 \pm \sqrt{-2.54^2 - 4 \times 4.90 \times -1.25}}{2 \times 4.90}$	1
Correctly calculates answer	$t = 0.827 \text{ s}$	1
Total		5

2. Calculates final vertical velocity

Element	Description	Marks
$v^2 = u^2 + 2as$		
a and s are negative	$v_V^2 = 2.54^2 + (2 \times -9.80 \times -1.25)$	1
uses v_V		1
Solves for v correctly	$v_V = \pm 5.56 \text{ m s}^{-1}$	1
$v = u + at$, v and a are negative	$-5.56 = 2.54 - 9.80t$	1
Correctly calculates answer	$t = 0.827 \text{ s}$	1
Total		5

3. Splits flight into up and down sections

Element	Description	Marks
Calculate time to apex using v_V	$v = u + at$ $t = 0.259 \text{ s}$	1
Calculates how high she goes	$s = ut + 0.5 at^2$ $s = 0.329 \text{ m}$	1
Adds 1.25 to answer	$s = 1.58 \text{ m}$	1
Calculates how long to fall to ground	$s = ut + 0.5 at^2$ $t = 0.568 \text{ s}$	1
Adds two times correctly	0.827 s	1
Total		5

(c) Calculate her range R. (2 marks)

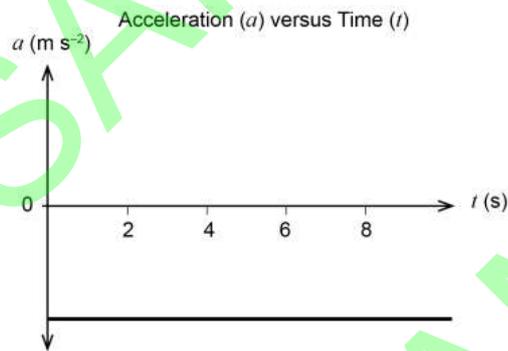
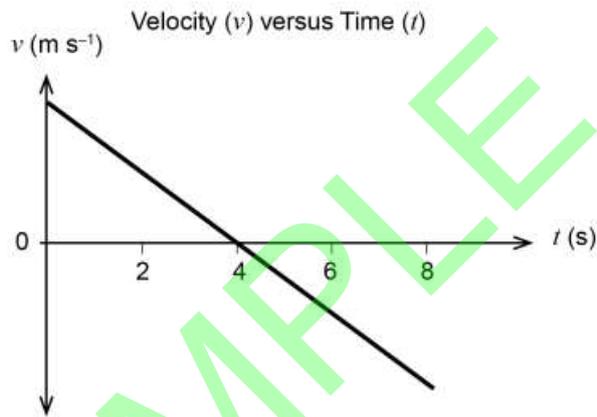
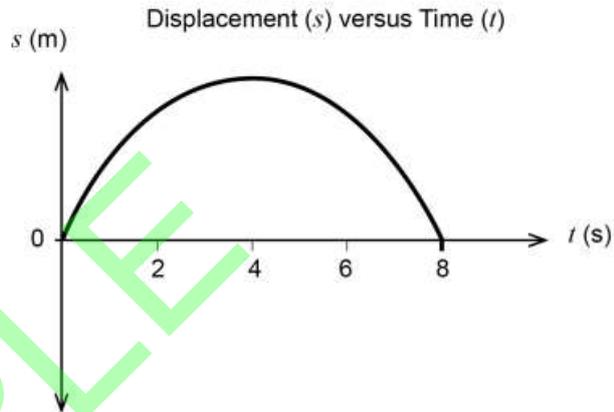
Element	Description	Marks
$s = vt$ Uses v_H	$s = 1.78 \times 0.827$	1
Correctly calculates answer	$s = 1.47 \text{ m}$	1
Total		2

(d) Calculate the gymnast's kinetic energy at the top of her flight. (2 marks)

Element	Description	Marks
Uses v_H	$E_k = 0.5 \times 42.5 \times 1.78^2$	1
Correctly calculates answer	67.3 J	1
Total		2

2020
Section 1
Question 1
Gravity and motion

A ball is launched vertically into the air with an initial velocity at $t = 0$ from ground level ($s = 0$) and returns to ground level. It takes four seconds for it to reach its maximum height. Taking upwards as positive, graph the ball's displacement, velocity and acceleration versus time from take-off to landing. Ignore air resistance and do not place any values on the y-axis.

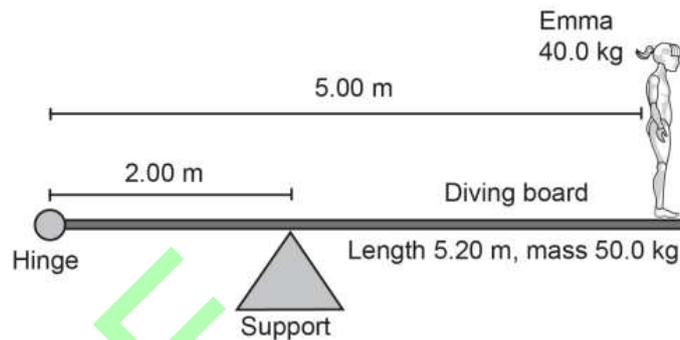


Description	Marks
1 mark for each graph completely correct.	1–3
apex of parabola must be at 4.0 s. Velocity graph must go through (4,0).	
Total	3

**2020
Section 1
Question 5**

**Gravity and
motion**

Emma stands 20.0 cm from the end of a 5.20 m long uniform diving board. Calculate the upwards force the support must exert on the 50.0 kg board for the system to remain in equilibrium. (4 marks)



Element	Description	Marks
takes moments around hinge	$\Sigma acm = \Sigma cm$	1
correctly identifies direction of moments	$(m_E \times g \times 5.0) + (m_b \times 9.8 \times 2.6) = 2F$	1
uses 5.0 m not 5.2 m, 2.6 m not 2.5 m	$(40 \times 9.8 \times 5.0) + (50 \times 9.8 \times 2.6) = 2F$	1
correct/consistent answer	1620 N or 1.62×10^3 N	1
Total		4

**2020
Section 1
Question
10**

**Gravity and
motion**

A golfer hits a ball at 37.0 m s^{-1} at 31.0° to the horizontal on a flat fairway. It travels 123 m. She wants to hit a target 135 m away, so she increases the angle at which she hits the ball, without changing the launch speed. Calculate the smallest increase of angle that allows her to reach the target. (Hint: $2\sin\theta\cos\theta = \sin 2\theta$)

Element	Description	Marks
expresses t as range over horizontal velocity	$t = 135/37 \cos\theta$	1
substitutes time into equation for vertical displacement ($s = 0$)	$0 = 37 \sin\theta - 4.9 (135/37 \cos\theta)$ $37^2 \sin\theta \cos\theta = 4.9 \times 135$	1-2
solves for angle using expression given	$\sin 2\theta = 2 \times 4.9 \times 135/37^2$ $2\theta = 75.1^\circ$ $\theta = 37.5^\circ$	1-2
subtracts initial angle to find change of angle	$37.5 - 31 = 6.5^\circ$	1
Total		6
Note: other equivalent methods can be used, such as $v = u + at$ or $s = ut + \frac{1}{2}at^2$ to get an expression that eliminates t		

**2020
Section 1
Question
11**

**Gravity and
motion**

Jake is lifting two books of mass 1.00 kg and 2.00 kg respectively. The lighter book sits on top of the heavier book, and each of Jake's hands exerts a vertical force of 16.2 N on the lower book, as shown in the diagram.



(a) What is the magnitude of the acceleration of the books? (3 marks)

Element	Description	Marks
subtracts the weight force from the total upwards force	$F_{\text{net}} = 32.4 - (3 \times 9.8) = 3.0 \text{ N}$	1–2
uses net force to calculate the acceleration	$a = F/m = 3.0/3.0 = 1.00 \text{ m s}^{-2}$	1
Total		3

(b) What is the magnitude of the force that the 2.00 kg book exerts on the 1.00 kg book during this acceleration? (3 marks)

Element	Description	Marks
adds weight force to net force to get total force	$F_{\text{Tot}} = mg + ma$ $= 9.8 + 1.0$	1–2
correct/consistent answer	10.8 N	1
Total		3

**2019
Section 1
Question 4**

**Gravity and
motion**

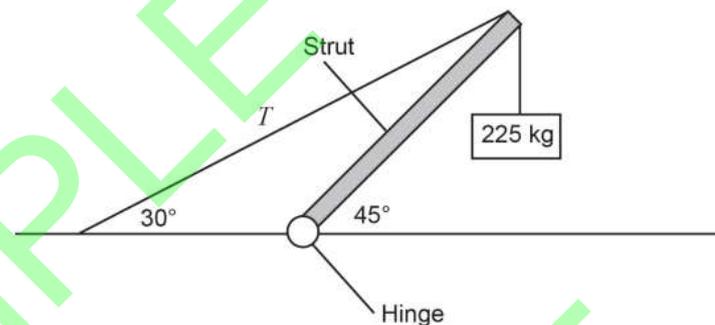
Titan is the largest of Saturn's moons. Its orbital radius is $1.22 \times 10^6 \text{ km}$. Use the Formulae and Data booklet and the data in the table below to determine the strength of Saturn's gravitational field where Titan orbits. Give your answer in N kg^{-1} and m s^{-2} .

Planet	Mass (Earth masses)
Mercury	0.055
Venus	0.815
Earth	1.000
Mars	0.107
Jupiter	318
Saturn	95
Uranus	14.5
Neptune	17.2
Pluto	0.002

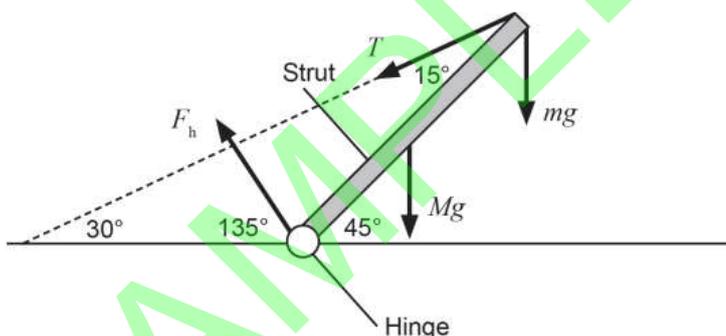
Description	Marks
$r = 1.22 \times 10^9 \text{ m}$	1
$M = 95 M_E = 5.67 \times 10^{26} \text{ kg}$	1
$g = MG/r^2$ $g = 5.67 \times 10^{26} \times 6.67 \times 10^{-11} / (1.22 \times 10^9)^2$ $g = 2.54 \times 10^{-2} \text{ N kg}^{-1}$	1-2
$g = 2.54 \times 10^{-2} \text{ m s}^{-2}$	1
Total	5

2019
Section 1
Question 6
Gravity and
motion

The diagram below shows a system in equilibrium.



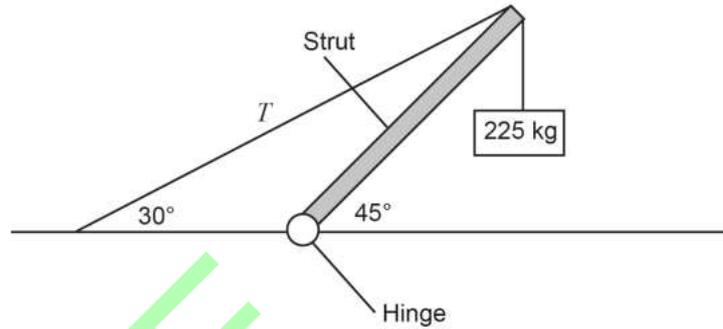
A student drew a diagram of the forces acting on the strut. That diagram is shown below. It is not drawn to scale.



(a) With specific reference to the conditions required for equilibrium, explain why the diagram of the forces is incorrect. (2 marks)

Description	Marks
Σ horizontal forces should = 0	1
No F_H to the right to counter component of T to the left: unbalanced	1
Total	2

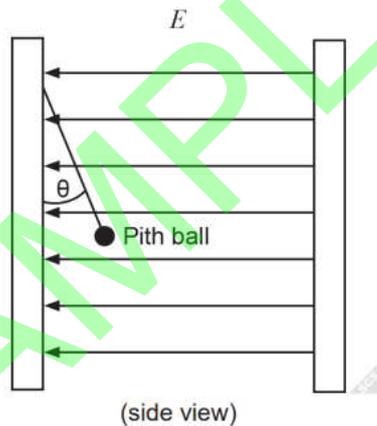
(b) Using the diagram below, show what change(s) should be made to correct it. (Calculations are not required.) (2 marks)



Description	Marks
F_{hinge} must be to the right and a vertical component	1
	1
Total	2

2019
Section 1
Question 7
Gravity and motion

A pith ball is a very small, lightweight object that readily picks up electric charge. A pith ball with a mass of $75.0 \times 10^{-6} \text{ kg}$ is suspended by a string attached to a charged plate. The pith ball has an excess of 2.00×10^{12} electrons on it and the electric field strength between the charged plates is 95.0 N C^{-1} .



(a) In the space below, draw a vector diagram of the forces acting on the pith ball. (3 marks)

Description	Marks
correct forces	1
closed right triangle	1
correct labels	1
Total	3

(b) Calculate the angle between the string and the charged plate. (5 marks)

Description	Marks
$\tan \theta = F_E / mg$	1
$F_E = Eq = 95 \times 2 \times 10^{12} \times 1.6 \times 10^{-19} = 3.04 \times 10^{-5}$	1–2
$mg = 75 \times 10^{-6} \times 9.8 = 7.35 \times 10^{-4}$	1
$\tan \theta = 3.04 \times 10^{-5} / 7.35 \times 10^{-4} \quad \theta = 2.37^\circ$	1
Total	5

2019
Section 1
Question 8

Gravity and motion

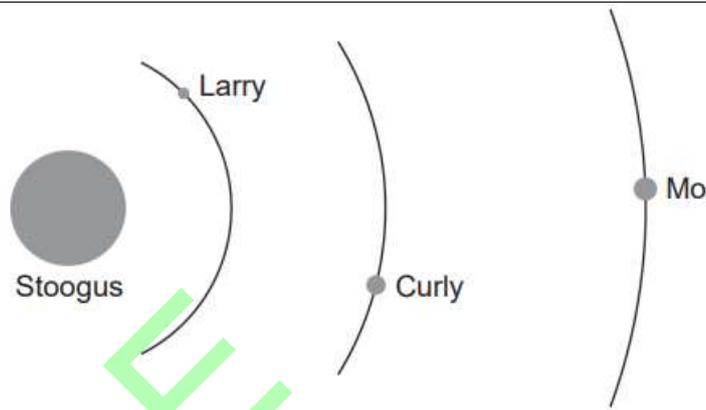
A cyclist is travelling at 6.0 m s^{-1} over a hump in the road that is part of a circle of radius 4.80 m . Calculate the magnitude of the total reaction force of the ground on the cyclist at the top of the hump. The total mass of the cyclist and bicycle is 72 kg . (Note: diagram not to scale, ignore friction.)

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Description	Marks
$F_c = mg - R$	1-2
$R = mg - mv^2/r$	
$= 72(9.8 - 36/4.8)$	1
$= 166 \text{ N}$	1
Total	4

2023
Section 2
Question
15

Gravity
and
motion



A recently discovered planet (Stoogus) in a distant solar system has three moons (Larry, Curly and Mo) orbiting at different distances. Stoogus has a mass of 2.37×10^{24} kg and a day on Stoogus lasts 7.50 Earth hours. Assume all three moons have circular orbits as their masses are insignificant compared to that of Stoogus.

- (a) Curly is a geosynchronous satellite that orbits above one specific spot on Stoogus' surface. Calculate the radius of Curly's orbit. (5 marks)

Element	Description	Marks
Uses Kepler's 3rd law	$\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$	1
Rearranges for r^3	$r^3 = \frac{GMT^2}{4\pi^2}$	1
Converts hours to seconds	$T = 7.50 \times 60 \times 60 = 2.70 \times 10^4$ s	1
Substitutes correct values into equation	$r = \left(\frac{6.67 \times 10^{-11} \times 2.37 \times 10^{24} \times (2.70 \times 10^4)^2}{4\pi^2} \right)^{\frac{1}{3}}$	1
Calculates value for r	$r = 1.43 \times 10^7$ m	1
Total		5

- (b) The gravitational field strength that Mo experiences due to Stoogus is 4.50×10^{-3} m s⁻². Calculate the distance between the centre of mass of Mo and the centre of mass of Stoogus. (4 marks)

Element	Description	Marks
Uses correct equation	$g = \frac{GM}{r^2}$	1
Rearranges for r^2	$r^2 = \frac{GM}{g}$	1
Substitutes correct values	$r = \sqrt{\left(\frac{6.67 \times 10^{-11} \times 2.37 \times 10^{24}}{4.50 \times 10^{-3}} \right)}$	1
Calculates answer	$= 1.87 \times 10^8$ m	1
Total		4

(c) (i) Derive the mathematical relationship between a moon's orbital speed v and its distance r from the planet's centre of mass. (3 marks)

Element	Description	Marks
Uses Kepler's 3rd Law and rearranges for T	$T^2 = \frac{4\pi^2 r^3}{GM}$	1
Substitutes $\frac{2\pi r}{v}$ for T	$\frac{4\pi^2 r^2}{v^2} = \frac{4\pi^2 r^3}{GM}$	1
Simplifies and isolates v^2	$v^2 = \frac{GM}{r}$	1
Total		3

Alternative solution

Element	Description	Marks
States F_c is provided by the F_g	$F_c = F_g$	1
Expands formulae correctly	$\frac{mv^2}{r} = \frac{GMm}{r^2}$	1
Simplifies and isolates v	$v^2 = \frac{GM}{r}$	1
Total		3

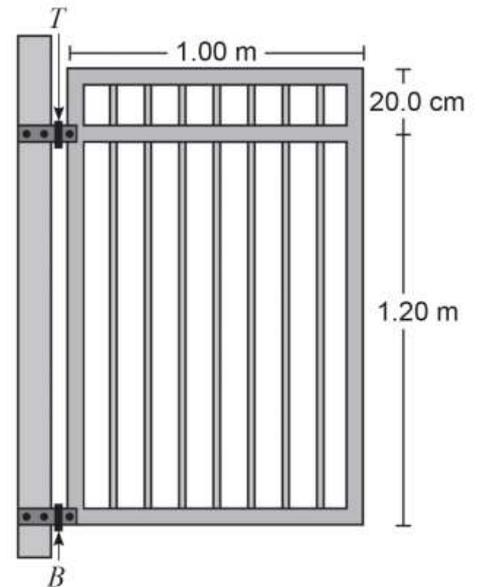
(ii) Use this relationship from part (c)(i) to identify which moon of Stoogus has the greatest orbiting speed. Justify your answer. (2 marks)

Description	Marks
Larry is travelling the fastest	1
As G and M are constant, as r decreases, velocity increases	1
Total	2

2023
Section 2
Question
17

Gravity and
motion

A uniform garden gate is attached to its support by two hinges (T and B). The top hinge (T) is fixed 20.0 cm below the top of the gate and the bottom hinge is fixed to the bottom of the gate. The gate has a mass of 25.7 kg. It is 1.00 m wide and 1.40 m tall.



Note: The top hinge takes all of the vertical weight force of the gate. The bottom hinge keeps the gate lined up correctly.

- (a) By taking moments around B , calculate the horizontal component of the reaction force of T on the gate. Include a direction in your answer. (5 marks)

Element	Description	Marks
Correctly identifies moments around B	mg and horizontal component of R_T	1
Substitutes correct values into moments equation, specifically distances to pivot	$\Sigma acm = \Sigma cm$ $R_{HT} \times 1.20 = 25.7 \times 9.80 \times 0.50$	1–2
Calculates correct answer for R_{HT}	$R_{HT} = 105 \text{ N}$	1
Includes direction	left	1
Total		5

- (b) Calculate the overall reaction force of T on the gate. Include an angle to the horizontal in your answer. If you could not obtain an answer to part (a), use $1.40 \times 10^2 \text{ N}$. (5 marks)

Element	Description	Marks
Uses Pythagoras to solve for net overall reaction force		1
Substitutes correct values	$R_{net}^2 = (25.7 \times 9.8)^2 + 105^2$	1
Calculates answer	$R_{net} = 273 \text{ N}$	1
Uses correct trig function to calculate θ	e.g. $\tan \theta = 251.9/105$	1
Calculates θ	$\theta = 67.4^\circ$	1
Total		5
If used $1.40 \times 10^2 \text{ N}$, $R_{net} = 288 \text{ N}$, $\theta = 60.9^\circ$		

(c) Discuss how the angle in part (b) would be affected if the top hinge was fixed at the top of the gate. Include a mathematical expression in your answer. (4 marks)

Element	Description	Marks
Uses moments equation from part (a)	$\Sigma acm = \Sigma cm$ $R_{HT} \times 1.20 = 25.7 \times 9.80 \times 0.50$	1
Σcm is constant		1
If we increase d from 1.20 to 1.40 m, R_{HT} will decrease		1
If R_{HT} decreases, θ increases		1
Total		4

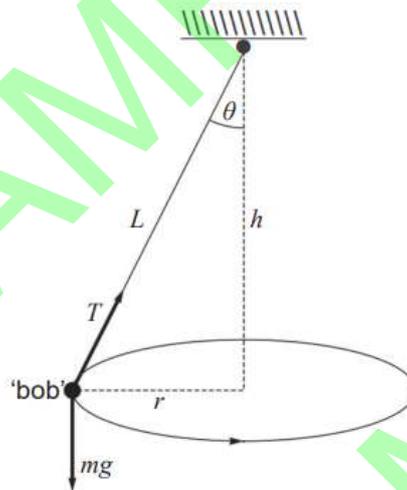
Alternative solution

Element	Description	Marks
Uses moments equation from part (a) and uses distance = d	$\Sigma acm = \Sigma cm$ $R_{HT} \times d = 25.7 \times 9.80 \times 0.50$	1
Σcm is constant	$R_{HT} = 126/d$	1
If we increase d from 1.20 to 1.40 m, R_{HT} will decrease	$\tan \theta = Rv/Rh$ $= 252/(126/d) = 2d$	1
If d increases, $\tan \theta$ and hence θ increases		1
Total		4

2022
Section 2
Question
17

Gravity and
motion

The diagram to the right shows the two forces acting on a conical pendulum as it spins at a set frequency. The vector addition of these two forces provides the centripetal force on the 'bob'. The mass of the 'bob' is 255 g and the length of the pendulum string L is 1.20 m. When the frequency of rotation is 0.490 Hz, the angle $\theta = 30.0^\circ$.



(a) Calculate the tension in the string when $\theta = 30.0^\circ$. (4 marks)

Element	Description	Marks
Uses correct relationship	$\cos 30.0^\circ = mg/T$	1
Isolates T correctly	$T = mg/\cos 30.0^\circ$	1
Converts to kg	$T = 0.255 \times 9.80/\cos 30.0^\circ$	1
Calculates correct answer	$T = 2.89 \text{ N}$	1
Total		4

(b) Calculate the radius of the circular path the 'bob' is moving in when the angle is 30.0° . (2 marks)

Element	Description	Marks
Uses correct identity	$\sin 30.0^\circ = r/L$	1
Calculates correct answer	$r = L \sin 30.0^\circ = 0.600 \text{ m}$	1
Total		2

(c) Calculate the new angle between the pendulum string and the vertical if the frequency of rotation is doubled. (6 marks)

Element	Description	Marks
Calculates new period	$T = 1/0.980 = 1.02 \text{ s}$	1
Uses correct relationship	$\tan \theta = mv^2/r/mg = v^2/rg$	1
Substitutes $2\pi r/T$ for v	$9.80 \tan \theta = 4 \pi^2 r/T^2$	1
Substitutes $L \sin \theta$ for r	$9.80 \sin \theta/\cos \theta = 4 \pi^2 \times 1.20 \sin \theta/T^2$	1
Simplifies and isolates $\cos \theta$	$\cos \theta = 9.80 \times 1.02^2/(4 \pi^2 \times 1.20)$	1
Calculates correct angle	$\theta = 77.6^\circ$	1
Total		6
Note: If assumes r or v remains constant, award maximum 3 marks.		

(d) Explain why θ can never equal 90.0° , regardless of how great the frequency of the pendulum becomes. You may use mathematical relationships in your answer. (4 marks)

Description	Marks
Tension consists of two components, vertical and horizontal.	1
The vertical component counters mg .	1
When angle = 90° , the vertical component = 0.	1
This means there is nothing holding the weight of the 'bob', which is impossible.	1
Total	4

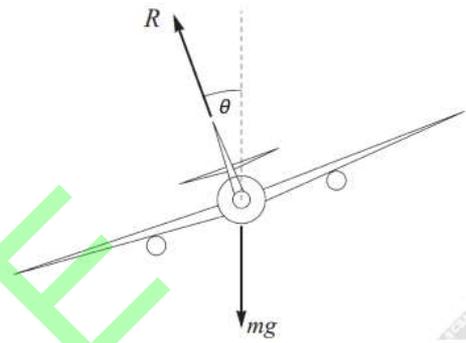
Alternate solution:

Description	Marks
$\cos \theta = mg/T$	1
$T = mg/\cos \theta$	1
As θ approaches 90° , T approaches infinity.	1
Infinite T is impossible.	1
Total	4

**2021
Section 2
Question
17**

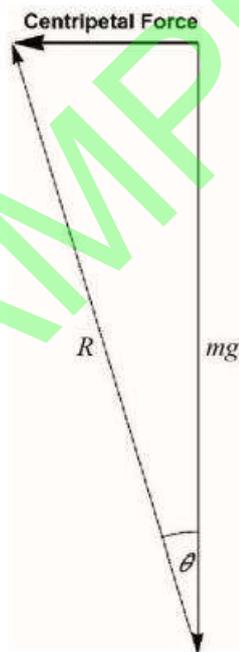
**Gravity and
motion**

Aeroplanes are designed to produce an upthrust that counters their weight force. This allows them to maintain altitude. The magnitude of this upthrust (R) is directly proportional to the forward speed of the aircraft. It always acts perpendicular to the wings. When changing direction, the aeroplane banks in a circular path. A free body diagram of a banking aeroplane is shown below.



(a) Draw a vector diagram showing how the weight force and the upthrust produce a resultant centripetal force. Label the resultant force and include the angle θ shown in the free body diagram. (3 marks)

Description	Marks
All forces labelled correctly	1
Right angle triangle with resultant horizontal	1
θ correctly placed	1
Total	3



(b) Calculate the centripetal force on a 5.60×10^3 kg aeroplane banking at an angle of 15.0° to the vertical while maintaining constant altitude. (3 marks)

Element	Description	Marks
Uses correct trigonometric function	$\tan 15.0^\circ = F_c / mg$	1
Substitutes correct values into equation and isolates F_c correctly	$F_c = mg \tan 15.0^\circ = 5.60 \times 10^3 \times 9.80 \times 0.268$	1
Calculates correct answer	1.47×10^4 N	1
Total		3

(c) If the aeroplane is travelling at 4.50×10^2 km h⁻¹, calculate the radius of the circular path it takes when banking while maintaining constant altitude. (3 marks)

Element	Description	Marks
Converts km h ⁻¹ to m s ⁻¹	$450 / 3.6 = 125$ m s ⁻¹	1
Substitutes values and rearranges equation correctly	$r = 5.60 \times 10^3 \times 125^2 / 1.47 \times 10^4$	1
Correctly calculates answer	5.95×10^3 m	1
Total		3

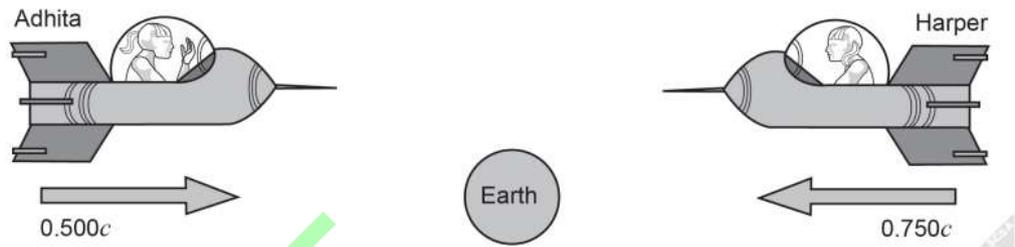
(d) With reference to your vector diagram in part (a) and the text, explain why aeroplanes need to increase their speed to maintain altitude when banking. (4 marks)

Description	Marks
Upthrust counters weight force	1
Upthrust is directly proportional to forward speed	1
Upthrust acts perpendicular to wings	1
As seen in diagram, only vertical component of upthrust counters weight therefore needs to increase speed to maintain altitude	1
Total	4

2020
Section 2
Question
15

Gravity and
motion

Two spaceships, captained by Adhita and Harper, are travelling toward each other. They are observed by a person on the Earth to be travelling at the velocities shown in the diagram. Take all velocities to the left as positive.



(a) Calculate the velocity of Harper as measured by Adhita. (4 marks)

Element	Description	Marks
uses consistent sign convention.	$v = -0.5c$ $u = 0.75c$	1
correctly identifies frames of reference	looking for u'	1
enters correct values and directions into correct equation.	$u' = (0.75c - (-0.5c))/(1 - (0.75 \times -0.5))$	1
correct answer	$0.909c$	1
can be solved from Earth's perspective finding u' , where $u = 0.93c$ and $v = -0.50c$		
Total		4

(b) Harper fires a missile with a velocity of $0.600c$ with respect to her in the direction of Adhita. Calculate the velocity of the missile as measured by an observer on the Earth. (4 marks)

Element	Description	Marks
uses correct sign convention	all velocities are positive	1
correctly identifies FOR	looking for u	1
enters correct values into correct equation	$(0.75 + 0.6)c/(1 + (0.75 \times 0.6))$	1
correct/consistent answer	$0.931c$	1
Total		4

(c) Calculate the velocity of the missile as measured by Adhita. (4 marks)

Element	Description	Marks
uses consistent sign convention	all velocities are positive	1
correctly identifies FOR	looking for u	1
enters correct values into correct equation	$u = (0.91 + 0.6)c/(1 + (0.91 \times 0.6))$	1
correct/consistent answer	$u = 0.976c$	1
Total		4
Note: The problem can be resolved from Earth's perspective using u' , where $u = 0.931c$ and $v = -0.500c$		

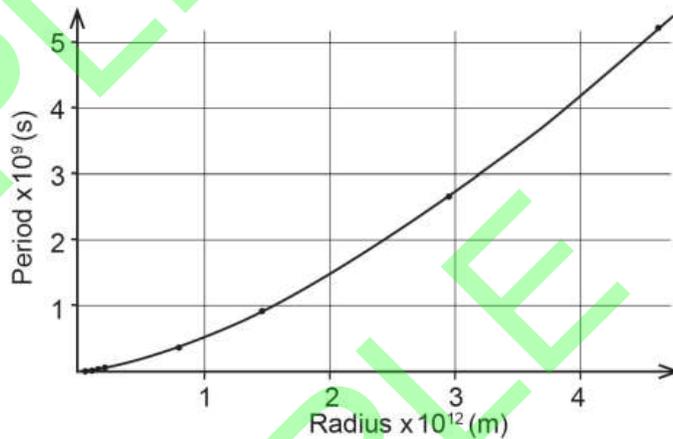
2020
Section 2
Question
17

Gravity and motion

A satellite is orbiting the Earth 4.00×10^3 km above its surface.

(a) Calculate the period of the satellite. (5 marks)

Element	Description	Marks
converts km to m	$T^2 = 4\pi^2 (4.0 \times 10^6 + 6.37 \times 10^6)^3 / (6.67 \times 10^{-11} \times 5.97 \times 10^{24})$	1
adds altitude to radius of Earth		1
cubes distance and square roots answer		1
correct answer	1.05×10^4 s	1
converts to hours	2.92 hours	1
Total		5



The graph shows the relationship between the period (T) and the orbiting radius (r) of all the planets in our solar system.

(b) (i) With reference to Kepler's Third Law, describe how a straight line graph could be generated using the same two variables. (Do not refer to logarithms.) (2 marks)

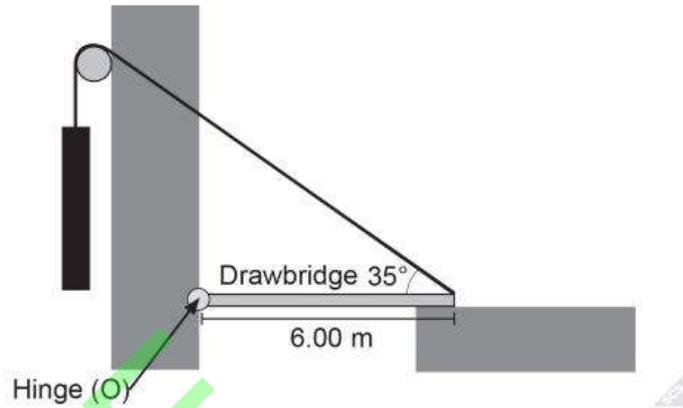
Description	Marks
in Kepler's 3 rd Law, T^2 is proportional to r^3	1
graph T^2 vs r^3	1
Total	2

(ii) Explain how you could use the gradient of this straight line and Kepler's Third Law to estimate the magnitude of the Newtonian constant of gravitation (G). (Do not try to calculate G from the graph.) (3 marks)

Element	Description	Marks
isolates expression for gradient from Kepler's Third Law.	gradient = $T^2/r^3 = 4\pi^2/GM$	1
isolates G from equation including gradient	$G = 1/\text{gradient} \times 4\pi^2/M$	1
recognises M (of the Sun) is constant therefore G can be calculated		1
Total		3

2020
Section 2
Question
18

Gravity and
motion



A castle has a 6.00 m long drawbridge with a mass of 500 kg over its moat. It is attached to a winch by an extremely strong rope at an angle 35.0° to the horizontal.

(a) Calculate the tension in the rope when the drawbridge is just lifted off the rest on the other side of the moat. (4 marks)

Element	Description	Marks
takes moments around hinge	$acm = cm$	1
identifies acm and cm	$T \times d = 500 \times 9.80 \times 3.00$	1
calculates perpendicular distance from hinge to rope	$d = 6 \sin 35$	1
correct answer	$T = 4270 \text{ N}$ or $4.27 \times 10^3 \text{ N}$	1
Total		4

(b) Calculate the reaction force of the hinge (O) on the drawbridge at this point. (5 marks)

Element	Description	Marks
Calculates the horizontal component of the reaction force from horizontal component of tension.	$R_H = 4271 \cos 35 = 3500 \text{ N}$	1
Calculates vertical component of reaction force by subtracting vertical component of T from mg .	$R_V = mg - T_V = 4900 - 4271 \sin 35 = 2450 \text{ N}$	1
Adds the two components using Pythagoras.	$R_N^2 = 3500^2 + 2450^2$	1
correct answer	4271 N	1
calculates angle correctly	$\tan \theta = 2450/3500 \quad \theta = 35.0^\circ$	1
Total		5

Note: Candidates could identify that $R = T$ through vector diagram but they would have to give a good explanation of what they did.

The castle comes under attack. The people inside the castle begin to raise the drawbridge. When it is at an angle of 15.0° above horizontal, the angle between the drawbridge and the rope is 40.0° . At this moment, a 95.0 kg soldier being chased by the enemy jumps onto the very end of the drawbridge.

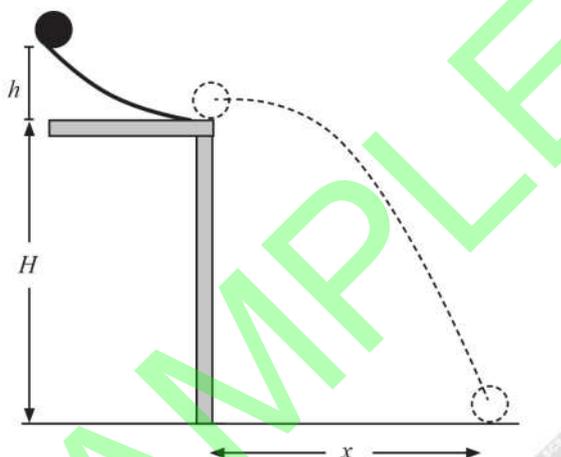
(c) Calculate the new tension in the rope as he hangs from the end. Assume the drawbridge is stationary at this time. (5 marks)

Element	Description	Marks
takes moments around hinge	$acm = cm$	1
correctly identifies acm and cm	$T \times d_1 = (m_d \times g \times d_2) + (m_s \times g \times d_3)$	1
calculates three new distances from pivot	$d_1 = 6.00 \sin 40 = 3.86\text{ m}$ $d_2 = 3.00 \cos 15 = 2.90\text{ m}$ $d_3 = 6.00 \cos 15 = 5.80\text{ m}$	1–2
correct/consistent answer	5080 N or $5.08 \times 10^3\text{ N}$	1
Total		5

2019
Section 2
Question
12

Gravity and
motion

A ball is rolled from rest down a curved slope, across a flat, smooth table leaving the table horizontally and falling to the floor.



If $h = 30.0\text{ cm}$ and $H = 1.20\text{ m}$

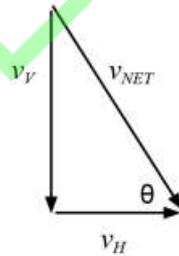
(a) Using conservation of energy, calculate the speed with which the ball leaves the table. Assume no energy is lost to friction, air resistance or is transferred to rotational energy. (2 marks)

Description	Marks	
$mgh = mv^2/2$	1	
$v = \sqrt{2gh} = \sqrt{2 \times 9.80 \times 0.3}$		
$= 2.42\text{ m s}^{-1}$	1	
Total		2

(b) Calculate the distance x . (4 marks)

Description	Marks
$s = 0.5 a t^2$	1
$t = \sqrt{1.20/4.9}$	
$= 0.495 \text{ s}$	1
$x = v_H \times t$	1
$= 2.42 \times 0.495 = 1.20 \text{ m}$	1
Total	4

(c) Calculate the velocity of the ball when it hits the floor. (5 marks)



Description	Marks
$v_V = 0 + 9.8 \times 0.495$	1
$= 4.85 \text{ m s}^{-1}$	1
$v_{N2} = v_V^2 + v_H^2$	1
$v_N = \sqrt{4.85^2 + 2.42^2}$	
$= 5.42 \text{ m s}^{-1}$	1
$\tan \theta = 4.85/2.42$	1
$\theta = 63.5^\circ$	
Total	5

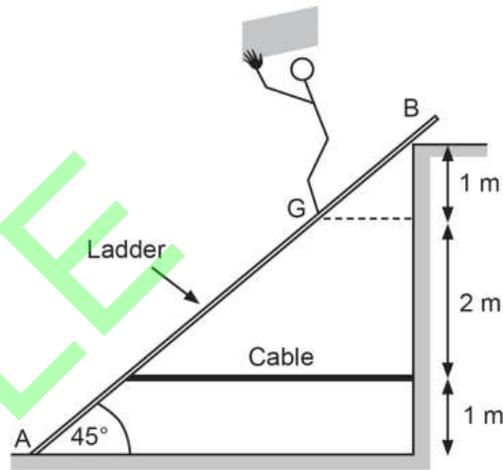
(d) Derive an expression for x in terms of h and H only. (Note: may include numbers.) (4 marks)

Description	Marks
$v_H = \sqrt{2 g h}$	1
$t = \sqrt{2 H / g}$	1
$x = v_H \times t$	1
$= \sqrt{2 \times g \times h} \times \sqrt{2H / g}$	
$= 2 \sqrt{h \times H}$	1
Total	4

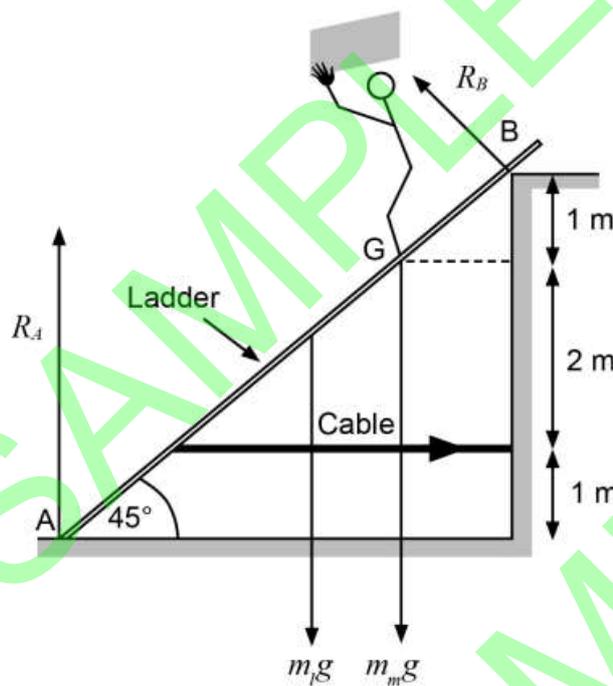
2019
Section 2
Question
13

Gravity and motion

Workers at an ice skating venue use a ladder to fix a sign 5.0 m above the surface of the ice. To prevent the 6.00 m long ladder from slipping on the ice, they tie a cable between the ladder and the 4.00 m high wall. The cable is at right angles to the wall. The uniform 15.0 kg ladder is placed at an angle of 45° between the frictionless surfaces at A and B. A 90.0 kg worker is standing still on the ladder at G.



(a) On the diagram above, draw and label the forces acting on the ladder. Assume the reaction force at B acts at right angles to the ladder. (4 marks)



Description	Marks
forces: R_A , R_B , T , $m_l g$ and $m_m g$	
all five correctly labelled with directions	4
all five, one incorrectly labelled or directed	3
four correctly labelled	3
four, one incorrectly labelled or directed or all five, two incorrectly labelled or directed	2
three correct	1
Total	4

(b) By taking moments around A, calculate the tension in the cable. (6 marks)

Description	Marks
$\Sigma F_H = 0$ $T = R_B \cos 45$ $R_B = T/\cos 45$	1–2
Taking moments at A: $(T \times 1) + (90 \times 9.8 \times 3) + (15 \times 9.8 \times 3 \cos 45) = R_B \times 4/\cos 45$	1–2
Sub for R_B : $T + 2650 + 312 = 4T/(\cos 45)^2$	1
$2960 = 8T - T$ $T = 423 \text{ N}$	1
Total	6

2019
Section 2
Question
16

Gravity and
motion

A ball is being swung around in a vertical circle on a string.

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(a) In the table below, match the statements with A, B, C and/or D. (4 marks)

Description		Marks
point(s) where the centripetal acceleration is the greatest	A	1
point(s) where the tension in the string is the lowest	C	1
point(s) where the net force is not toward the centre of the circle	B and D (no mark for just one)	1
point(s) where the ball's weight force is perpendicular to the tension	B	1
Total		4

(b) Write an expression for the net force acting on the string at point C in terms of the weight force and the tension in the string. (1 mark)

Description	Marks
$F_C = T + mg$ (could use F_{net})	1
Total	1

(c) Calculate how fast the 500 g ball can be moving at point A for the 1.20 m long string not to break, if the maximum tension it can withstand at point A is 172 N. (4 marks)

Description	Marks
At A: $T = F_C + mg$	1
$T = 0.5(v^2/1.2 + 9.8)$	1
$172/0.5 - 9.8 = v^2/1.2$ $v = 20.0 \text{ m s}^{-1}$	1–2
Total	4

(d) Calculate the maximum speed at which the ball can be moving at point C for the string not to break at point A. (3 marks)

Description	Marks
At C: $E_{total} = 0.5mv_C^2 + mg \times 2.4 = m20^2/2$	1
$v_C = \sqrt{2(200 - 23.5)}$	1
$= 18.8 \text{ m s}^{-1}$	1
Total	3

2022
Section 3
Question 19
Gravity and motion

Kepler's three laws of planetary motion can be stated as follows:

1. All planets move about the Sun in elliptical orbits, having the Sun as one of the foci.
2. A radius vector joining any planet to the Sun sweeps out equal areas in equal lengths of time.
3. The squares of the periods (of revolution) of the planets are directly proportional to the cubes of their mean distances from the Sun.

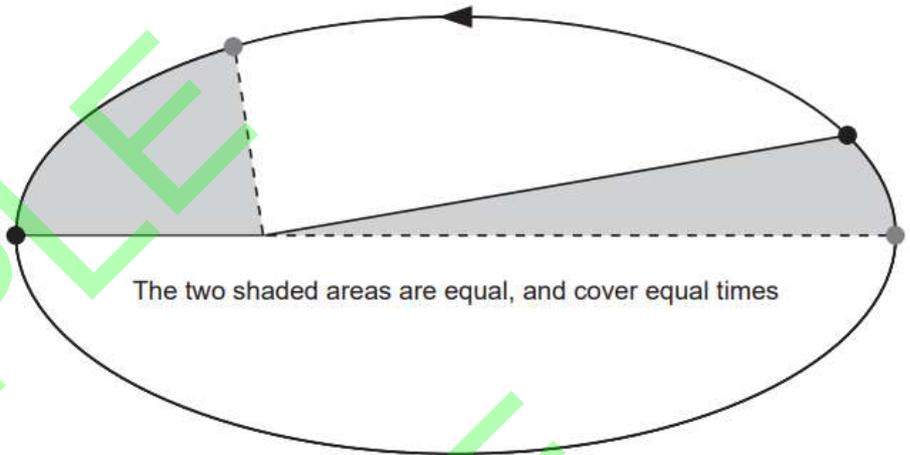


Figure 1: Kepler's 2nd Law

Kepler's 3rd Law, which appears on the Formulae and Data booklet, can be derived for a circular orbit from first principles: the centripetal force between the planet and the Sun is provided by Newton's Law of Gravitation, and $S = vT$, where S is the orbiting circumference and T is the period.

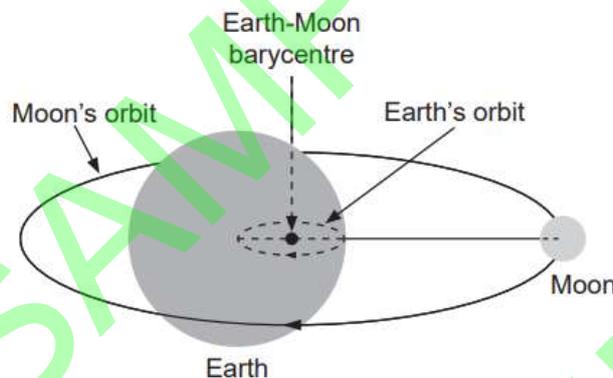


Figure 2: Location of Earth-Moon barycentre

The system of any large celestial body, and its satellite, orbits around a 'barycentre'. This represents the centre of mass of the system. The barycentre of the Earth–Moon system is shown in Figure 2. The system could be seen as a balance beam, with the barycentre located where the fulcrum would be placed to achieve equilibrium. The gravitational field strength due to the Sun is identical for both the Earth and Moon and therefore cancels out when calculating moments around the barycentre.

When the mass of the satellite represents a significant percentage of the system, the barycentre is outside either body. When its mass is significantly less, the barycentre is usually found within the more massive body which appears to 'wobble'. When the mass of the orbiting satellite is insignificant compared to the mass of the body it is orbiting, the barycentre can be assumed to be the centre of mass of the larger body.

(a) (i) Using Kepler's 2nd Law, describe the relationship between the distance a planet is from the Sun it orbits and its orbiting speed by filling in the blank below. (1 mark)

As the distance from the planet increases, the orbiting speed _____.

Description	Marks
decreases	1
Total	1

(ii) Without completing a calculation, justify this relationship with reference to Figure 1. (3 marks)

Description	Marks
The shaded areas in the diagram show the same time interval.	1
The satellite further from the Sun travels less distance in the same time.	1
Therefore the further from the Sun, the lower the speed.	1
Total	3

(b) Using the instructions given in the article, derive Kepler's 3rd Law from first principles, showing each step of the derivation. The final expression must match the equation in the Formulae and Data booklet. Assume the orbit is perfectly circular and the mass of the satellite is insignificant compared to the mass of the body it is orbiting. (5 marks)

Element	Description	Marks
Equates gravitational force to centripetal force.	$mMG/r^2 = mv^2/r$	1
Cancels mass and r	$MG/r = v^2$	1
Substitutes $2\pi r/T$ for v	$MG/r = 4\pi^2 r^2/T^2$	1
Simplifies by cross multiplying	$T^2 MG = 4\pi^2 r^3$	1
Rearranges to match formula on data sheet	$T^2/r^3 = 4\pi^2/GM$	1
Total	5	

(c) Using moments, estimate how far the barycentre of the Earth–Moon system is from the centre of the Earth. (4 marks)

Element	Description	Marks
Uses moments around barycentre to solve problem	$\Sigma cm = \Sigma acm$	1
Uses d and $(3.84 \times 10^8 - d)$ as distances	$5.97 \times 10^{24} \times g \times d$ $= 7.35 \times 10^{22} \times g \times (3.84 \times 10^8 - d)$	1
Solves for d	$d = 4.7 \times 10^6 \text{ m}$	1
2 significant figures		1
Total	4	

Alternate solution:

Element	Description	Marks
Uses moments around centre of Earth to solve problem	$\Sigma cm = \Sigma acm$	1
Uses $\Sigma m \times g \times d$ as acm	$(5.97 \times 10^{24} + 7.35 \times 10^{22}) \times g \times d$ $= 7.35 \times 10^{22} \times g \times 3.84 \times 10^8$	1
Solves for d	$d = 4.7 \times 10^6 \text{ m}$	1
2 significant figures		1
Total	4	

(d) With the use of a calculation and your answer to part (c), show that the Moon is travelling roughly 81 times faster than Earth as they orbit the barycentre. If you could not get an answer to part (c), use 4.81×10^6 m and show that the ratio of the Moon's orbiting velocity to that of the Earth is roughly 80. (4 marks)

Element	Description	Marks
Realises the period for both Earth and Moon are identical	$T = 28$ days (± 1 day only)	1
Uses $T = 2\pi r/v$	$2\pi r_m/v_m = 2\pi r_E/v_E$	1
Simplifies and uses correct radii	$v_m/v_E = (3.84 \times 10^8 - 4.670 \times 10^6)/4.670 \times 10^6$	1
Calculates correct answer	$v_m/v_E = 81.2$	1
Total		4

Note: If used 4.81×10^6 , $v_m/v_E = 78.8$, therefore roughly 80 times.

2020
Section 3
Question
21

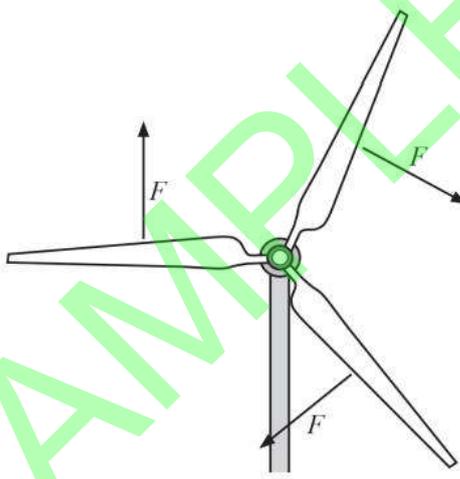
Gravity and
motion

Wind turbines

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How do wind turbines work?

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Wind turbine blades vary in length between 40 and 80 m.

A major problem with wind turbines is varying wind speed. The input power must match the output power. The output power depends entirely on rotational speed and torque so how do we keep rotational frequency constant when wind speed keeps changing? The solution is mechanical. The operators use blade pitch control which changes the angle of the blades and reduces the surface area facing the wind. This reduces the amount of energy collected by the turbine and controls the force applied to each blade.

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How the pitch is altered to control the rotational speed.

Each blade experiences a gravitational torque. If the clockwise and anticlockwise gravitational torques add up to zero, the turbine is considered balanced. A symmetrical three-blade turbine is considered balanced at all times.

(a) (i) Explain why a step-up transformer is used to increase the voltage before transporting the electricity into the National Grid. Use specific equations in your answer. (4 marks)

Description	Marks
It is more efficient to step-up the voltage.	1
$P = VI$ so if we increase V we have less current for the same power.	1
$P_{lost} = I^2R$ power is lost as heat	1
The lower the current, the lower the power lost due to heat.	1
Total	4

(ii) Calculate the output voltage of the transformer if the turbine produces 690 V and the ratio of turns is 100 in the primary coil to 2500 in the secondary coil. (2 marks)

Element	Description	Marks
uses ratio of coils = ratio of voltages correctly	$V_S = N_S V_P / N_P$	1
correct answer	$= 2500 \times 690 / 100 = 17.2 \text{ kV}$	1
Total		2

(b) With specific reference to the text, explain why the pitch of the rotor blades is changed by the operators of the turbine. (4 marks)

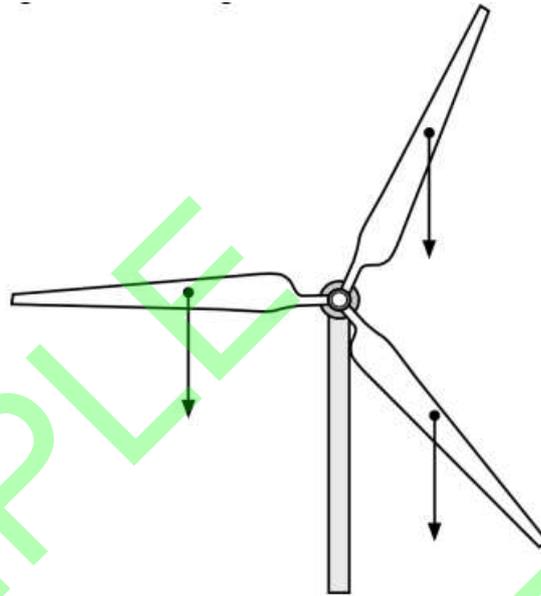
Description	Marks
The power input (wind energy) must match the power output (voltage produced).	1
The power output depends on rotational speed which must be kept constant.	1
The operators use pitch control which changes the angle of the blades.	1
This reduces or increases the amount of energy collected by the turbine and controls the force applied.	1
Total	4

(c) If the 60 m long blades on an average-sized turbine are rotating at 0.20 Hz, estimate the speed of the centre of mass of one of the blades. (4 marks)

Element	Description	Marks
Takes average length of 60 m and estimates the distance of COM from pivot as less than half of the length.	Take COM as 20 m from pivot	1
converts f to T	$0.2 \text{ Hz} = 5 \text{ s period}$	1
uses $v = \text{circ}/T$	$v = 2\pi \times 20/5 = 25 \text{ m s}^{-1}$	1
two significant figures		1
Total		4

Consider the three-blade turbine in the diagram to be rotating clockwise. The blade on the left hand side is parallel to the ground. The blades are identical in size and mass.

(d) (i) Draw the weight forces acting on the blades. (2 marks)



Description	Marks
all three mg drawn equal distance from axle along blade	1
all same size	1
Total	2

(ii) Show mathematically that the turbine is balanced in this position. (4 marks)

Element	Description	Marks
calculates angles correctly	Angle between blades is 120° therefore angle to calculate r is 60°	1
identifies acm and cm correctly in equation and	$(mg \times r \cos 60) + (mg \times r \cos 60) = mg \times r \cos 0$	1
derives the correct moment equation		1
solves equation to show LHS = RHS	$\cos 60 + \cos 60 = \cos 0$ $0.5 + 0.5 = 1.0$	1
Total		4

Unit 3 – Electromagnetism

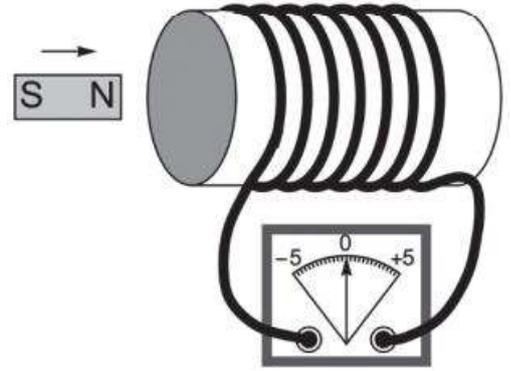
Section 1

<p>2023 Section 1 Question 1</p> <p>Electro- magnetism</p>	<p>A DC motor is attached to a 6.00 V supply, as shown in the diagram on the right. The square coil has a side length of 8.60 cm and contains 50 turns. The total resistance of the circuit is 3.00Ω and it sits in a $3.70 \times 10^{-3} \text{ T}$ magnetic field.</p> <p style="text-align: center;">Copyright restrictions prohibit the release of this SCSA exam material.</p> <p>(a) Which way will the coil rotate when observed from X? Circle your answer. (1 mark)</p> <p>A. Clockwise B. Anticlockwise.</p> <p>(b) Calculate the magnitude of the initial torque on the coil in the position shown in the diagram. (4 marks)</p> <p style="text-align: right;">Answer _____ N m</p>
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2023
Section 1
Question 7

Electro-
magnetism

The north pole of a bar magnet is moved at a constant speed of 0.370 m s^{-1} towards a coil of wire. The coil has seven turns and a cross sectional area of 0.0240 m^2 . The ends of the wire are connected to a galvanometer (which measures very small currents).



(a) State Lenz's law. (2 marks)

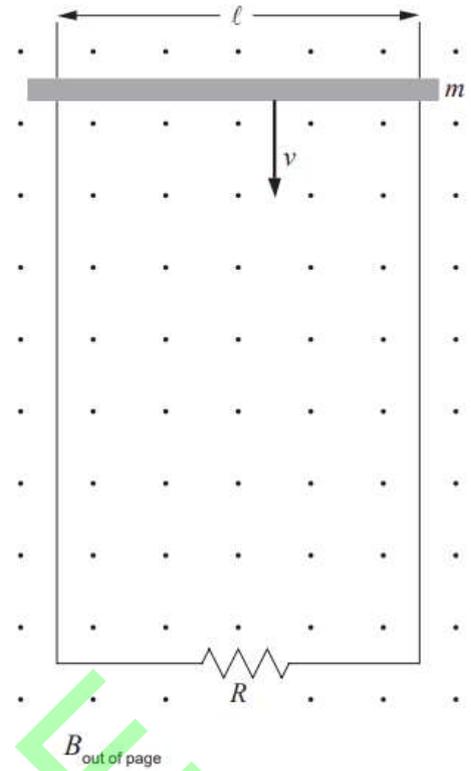
(b) With reference to Lenz's law, explain why the needle in the galvanometer moves to the left, i.e. the current in the galvanometer flows right to left. (3 marks)

(c) Explain why the emf induced in the coil is not constant, even though the speed of the magnet remains constant. (2 marks)

2023
Section 1
Question
12

Electro-
magnetism

A metal bar of mass m is falling through a uniform horizontal magnetic field of strength B . The effective length of the bar in the field is ℓ . The bar, which maintains contact with the frictionless wire, completes an external circuit with a resistance of R . Derive an expression for the velocity of the bar in terms of m , g , R , B and ℓ given the velocity is constant.



Answer: $v =$ _____

