Fort Street High School

Name: ________________

Physics Depth Study Module 5 Advanced Mechanics

Booklet (1 of 3)

Contents

HSC EXAM–TYPE QUESTIONS

Now for the real thing! The following questions are modelled on the types of questions you will face in the HSC Examination. Think about it: if you get extensive practice at answering these sorts of questions, you will be more confident in answering them in the actual HSC Examination. It makes sense, doesn't it?

Another advantage for your exam preparation is the format of the answers: they are deliberately structured to give you strategies on how to answer examination questions. This will help you aim for full marks!

- For each objective-response question you will have the correct answer and an explanation, and reasons why the other answers are incorrect.
- For each short-answer question you will have a detailed answer marked with ticks to indicate what part of the question gains which marks and also, when needed, an examiner's plan (Examiner Maximiser/ EM) to help you get full marks.

When you mark your work, highlight any questions you found difficult and earmark these areas for extra study.

Objective-response questions

(1 mark each)

1 For the projectile shown in Figure 1.16, which of the following statements for the positions marked X and Y is true?

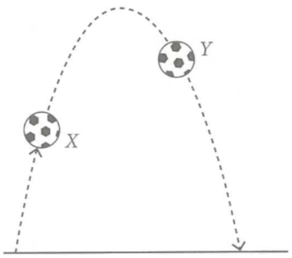


Figure 1.16 Two positions of a soccer ball during its flight

A The acceleration at X is in the opposite direction as the acceleration at Y.
B The magnitude of the vertical velocity is greater at Y than at X.
C The total energy of the ball is greater at Y than at X.
D The momentum of the ball is greater at X than it is at Y.

2 A projectile is launched at 45° above the horizontal, as shown in Figure 1.17. If the projectile was launched with the same initial velocity at 30°, how would the maximum height, time of flight and range change?

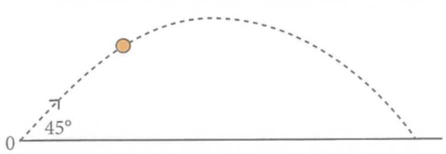


Figure 1.17 Projectile initially launched at 45°

	Maximum height	Time of flight	Range
A	Increased	Decreased	Decreased
B	Decreased	Decreased	Decreased
C	Decreased	Unchanged	Decreased
D	Unchanged	Decreased	Increased

3 Which of the following statements must be true for two projectiles that are launched and land on a horizontal plane and have the same time of flight?

A The vertical component of the final velocity of both projectiles must be equal.
B The projectiles must be launched at the same angle above the horizontal.
C The projectiles must have the same range.
D The projectiles must have the same initial velocity.

4 What variables could be used to calculate the horizontal range of a projectile that was launched and landed at the same height?

A The initial kinetic energy of the projectile.
B The launch angle and initial vertical component of the velocity.
C The initial horizontal component of the velocity of the projectile.
D The initial vertical component of the velocity.

5 When the archer shown in Figure 1.18 fires an arrow at 45° above the horizontal with an initial velocity of u, it has a range of R metres.

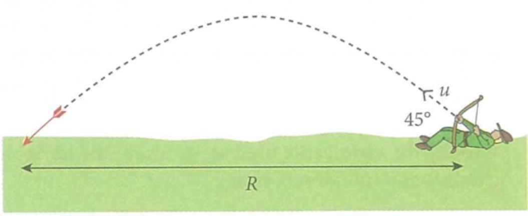


Figure 1.18 Archer firing an arrow from ground level

What would the range R change to if the angle was increased to 50°?

A The range would increase.
B The range would remain constant.
C The range would decrease.
D It is impossible to say from the information given.

Extended-response questions

6 A river flowing at 5 ms^{-1} horizontally produces a waterfall when it reaches a vertical drop of 20 m.

a How long will the water take to reach the bottom of the waterfall? (1 mark)

b How far from the base of the vertical cliff will the water land? (1 mark)

c If the speed of the water was halved and the height of the cliff doubled, how would your answers to parts a and b change? (2 marks)

7 A soccer ball is thrown horizontally by a passenger in a hot air balloon, as shown in Figure 1.19. The passenger notes that the ball is initially moving at 6 ms^{-1} with respect to the balloon, and an observer on the ground sees the balloon moving at 8 ms^{-1} with respect to the ground.

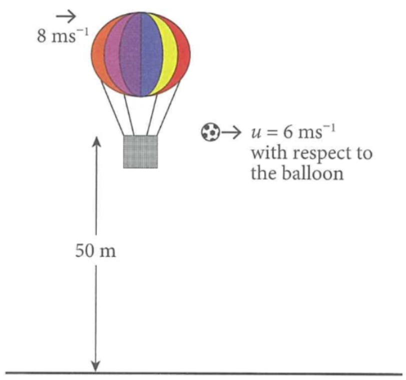


Figure 1.19 Soccer ball launched horizontally from a balloon moving at constant velocity

a Find the initial velocity of the ball with respect to a stationary observer on the ground. (1 mark)

b Calculate the time the ball would take to reach the ground. (1 mark)

c Determine the horizontal distance travelled by the ball with respect to an observer on the ground. (1 mark)

d Determine the horizontal distance travelled by the ball with respect to an observer in the balloon. (1 mark)

8 Figure 1.20 shows how the vertical component of the velocity for a projectile fired at 30° above the horizontal changes as a function of time.

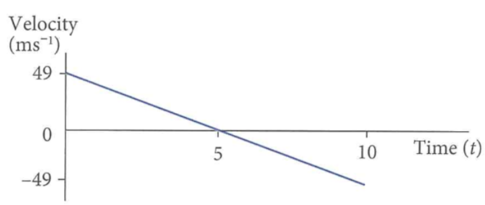


Figure 1.20 Vertical component of velocity as a function of time

Use the graph to find:

a the maximum height reached by the projectile. (1 mark)

b the initial horizontal velocity of the projectile. (2 marks)

c the range of the projectile. (1 mark)

9 A soccer ball is kicked (from ground level on a flat field) and, after being in flight for 2 s, is found to have a velocity of 15 ms^{-1} parallel with the ground. Find:

a the initial horizontal and vertical velocity. (2 marks)

b the maximum height reached by the ball. (1 mark)

c the magnitude and direction of the initial velocity of the ball. (2 marks)

d the horizontal range of the ball. (1 mark)

10 A basketball player throws a ball at 60° above the horizontal, as shown in Figure 1.21. The player is 5 m from the basketball hoop and the hoop is 1 m above the point where the ball left the player's hand.

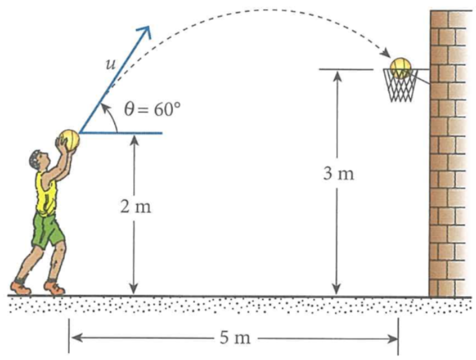


Figure 1.21 Basketball player throwing a ball into a hoop

Given that the ball took 0.8 s to reach the hoop, find:

a the horizontal component of the initial velocity. (1 mark)

b the vertical component of the initial velocity. (1 mark)

c the velocity of the ball at the instant it reached the hoop. (2 marks)

6. a) $s = ut + \frac{1}{2}at^2$

$20 = \frac{1}{2}(9.8)t^2$

$t = \sqrt{400/98}$

$\doteqdot 2.02\ s\ (3\ s.f.)$

$s = \frac{1}{2}at^2$

$t = \sqrt{\frac{2s}{a}}$

b) $s = ut + \frac{1}{2}at^2$

$= 5 \times \sqrt{400/98}$

$= 10.1\ m\ (3\ s.f.)$

c) If the cliff height doubled, the new time would be $\sqrt{2}$ times longer. The new horizontal distance would be half of that based on the new time ($\sqrt{2}/2$ times as far)

$t = \sqrt{2} \times 2.02$

$\doteqdot 2.86\ s\ (3\ s.f.)$

$S = \sqrt{2}/2 \times 10.1$

$= 7.14\ m\ (3\ s.f.)$

7. a) $u = 8 + 6$

$= 14\ ms^{-1}$

b) $s = ut + \frac{1}{2}at^2$

$50 = 0 \times t + \frac{1}{2}(9.8)t^2$

$t = \sqrt{100/9.8}$

$\doteqdot 3.19\ s\ (3\ s.f.)$

c) $S_{horiz.} = 14 \times t$

$= 44.7\ m\ (3\ s.f.)$

d) $S_{horiz.} = 6 \times t$

$= 19.2\ m\ (3\ s.f.)$

8. a) max height at $t=5$

$s = ut + \frac{1}{2}at^2$

$= 49(5) + \frac{1}{2}(-9.8)(5^2)$

$= 122.5$ m

b) $v_{vert} = v\cos(30°) = 49$

$v = 49/\sin(30°)$

$= 98$

$v_{horiz.} = v\cos(30°)$

$= 98\left(\sqrt{3}/2\right)$

$= 84.9\ ms^{-1}$ (3 s.f.)

c) $s = ut$ $\quad [a=0]$

$= 84.9 \times 10$

$= 849$ m

9. a) $u_{horiz.} = 15\ ms^{-1}$

$v_{vert} = u_{vert} + at$

$0 = u_{vert} + (-9.8)(2)$

$u_{vert} = 19.6\ ms^{-1}$

b) $s = ut + \frac{1}{2}at^2$

$= 19.6(2) + \frac{1}{2}(-9.8)(2^2)$

$= 19.6$ m

c) $|u| = \sqrt{u_{horiz}^2 + u_{vert}^2}$

$= 24.7\ ms^{-1}$

$\theta = \tan^{-1}\left(\frac{u_{vert}}{u_{horiz}}\right)$

$\doteqdot 52.6°$

$u = 24.7\ ms^{-1}$ at $52.6°$ to the horiz

d) $s = 15 \times 4$

$= 60 \text{ m}$

10 a) $u_{horiz} = d/t$

$= 5/0.8$

$= 6.25 \text{ ms}^{-1}$

b) $s = ut + \frac{1}{2}at^2$

$1 = u(0.8) + \frac{1}{2}(-9.8)(0.8)^2$

$u = \frac{1 - \frac{1}{2}(-9.8)(0.8)^2}{0.8}$

$= 5.17$

$\therefore u_{vert} = 5.17 \text{ ms}^{-1}$

c) $v^2 = u^2 + 2as$

$v_{vert} = (5.17)^2 + 2(-9.8)(1)$

$= 2.67 \text{ ms}^{-1}$

$v = \sqrt{6.25^2 + 2.67^2}$

$= 6.80 \text{ ms}^{-1}$ (3 s.f.)

$\theta = \tan^{-1}\left(\frac{2.67}{6.25}\right)$

$= 23° 8'$

$\therefore v = 6.80 \text{ ms}^{-1}$ at $23° 8'$ below horiz.

HSC EXAM–TYPE QUESTIONS

Objective-response questions

(1 mark each)

1 **Why is a centripetal acceleration required for an object to undergo uniform circular motion?**

A to ensure the energy of the object continues to increase as it rotates

B to increase the tangential velocity throughout each rotation

C to produce a centripetal force

D to continually change the direction of the tangential velocity

2 **Consider a mass m on the end of a string undergoing uniform circular motion in a horizontal circle of radius *r*. Which of the following answers best describes what would happen if the radius of the string was suddenly halved?**

A The energy of the mass would double but the tension in the string would remain the same.

B The energy would stay the same but the tension in the string would double.

C The energy would stay the same but the tension in the string would halve.

D The energy and the tension in the string would halve.

3 **Which of the following statements best describes what causes a car to change direction when the steering wheel is turned?**

A The car tyres exert a friction force on the road towards the centre of the bend.

B The road exerts a force towards the outside of the bend on the car tyres.

C The wheels turn at a different speed, forcing the car to change direction.

D The road exerts a frictional force on the tyres towards the centre of the bend.

4 **Consider the two masses suspended from the double pulley in Figure 2.16.**

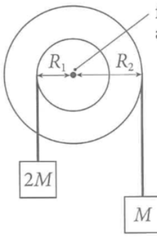


Figure 2.16 Two masses suspended from a double pulley

When released, the lighter mass (M) is observed to accelerate downwards. Assuming the strings are essentially weightless and the pulley is free to turn around the axle, what can we say about the radii of the pulleys?

A $R_2 > 2R_1$

B $R_2 < 2R_1$

C $R_2 = 2R_1$

D $R_2 < R_1$

5 **Why do railway engineers bank circular bends in railway lines?**

A to reduce the sideways force exerted on the tracks by the train

B to reduce the centripetal force on the train

C to increase the sideways force exerted on the tracks by the train

D to increase the centripetal force on the train.

Extended-response questions

6 **When a mechanic has trouble loosening a tight nut on a wheel (as shown in Figure 2.17) they sometimes change to a longer spanner.**

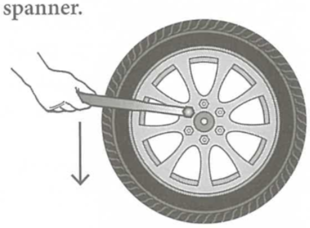


Figure 2.17 Using a spanner to loosen a wheel nut

Explain using physics principles why using a longer spanner is useful in this situation. (3 marks)

7 **Figure 2.18 shows an amusement park ride called The Rotor. The cylinder is spun rapidly and the floor is then lowered while the riders stay fixed to the wall of the rotor.**

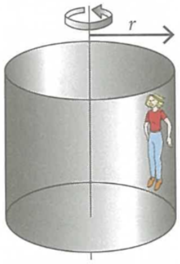


Figure 2.18 The Rotor amusement park ride

The cylinder has a radius of 2.5 m and must be rotated at 0.5 Hz to ensure a 40 kg rider does not slide downwards when the floor is lowered.

a **What provides the centripetal force on the rider?** (2 marks)

b **Determine the tangential velocity of the rider.** (1 mark)

6. $\tau = F_{\perp} r$

More torque is generated with the sane amount of force if the radius of the arn is longer. This allows it to more easily overcone the frictional force holding it in place.

7. a) When the drum begins to rotate, the rider will move, exerting a force on to the wall of the drun. A reaction force occurs in the opposite direction, hence creating the required centripetal force.

b) 0.5 Hz : period $(T) = 2$

$v = \frac{2\pi r}{T}$

$= \frac{2\pi(2.5)}{2}$

$= 7.85 \text{ ms}^{-1}$

c) $F_c = \frac{mv^2}{r}$

$= 40(2.5\pi)^2 / 2.5$

$= 100\pi$

$= 314 \text{ N}$ (3 s.f.)

d) To not slide, $F_F = F_G$

$\mu N = mg$

$\mu = mg/N$

$= 40(9.8)/314$

$= 1.25$

c Calculate the centripetal force on the 40 kg rider when The Rotor turns with a frequency of 0.5 Hz. (1 mark)

d Determine the minimum coefficient of friction between the rider and the wall of The Rotor to ensure the 40 kg rider does not slide downwards as the floor is lowered when The Rotor is turning with a frequency of 0.5 Hz. (2 marks)

8 A 5 m long plank with a mass of 20 kg rests between two ladders labelled A and B, as shown in Figure 2.19.

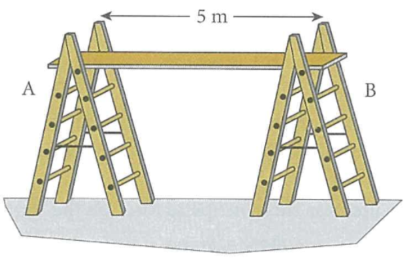


Figure 2.19 Plank of mass 20 kg supported by two ladders 5 m apart

a Determine the force applied by the plank to each ladder. You may assume the mass of the plank is distributed uniformly along the plank. (1 mark)

b If a 100 kg man stood on the plank in the middle, what would be the force exerted by the plank on each ladder? (1 mark)

c If the 100 kg man stood on the plank 2 m from ladder A, what force would the plank exert on each ladder? (2 marks)

9 Part of the fun of riding a rollercoaster is feeling your weight increase and decrease at various points throughout the ride. Consider the rollercoaster shown in Figure 2.20, which starts at rest from position A. Note that the radius of curvature of the rollercoaster track is the same at the points B, C and D.

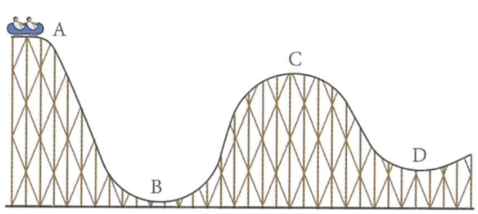


Figure 2.20 Rollercoaster

a Qualitatively compare the apparent weight of the rider at the points A, B, C and D. (1 mark)

b Justify your answer to part a by explaining why the apparent weight of the rider changes throughout the ride. (4 marks)

10 In another amusement park ride the riders sit in swings that rotate around, as shown in Figure 2.21.

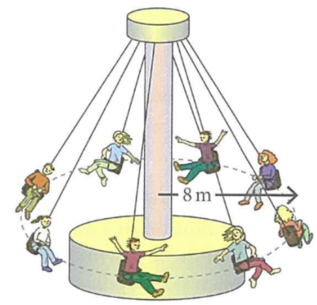


Figure 2.21 Swing carousel

As the carousel turns faster, the riders swing out further and make a greater angle with the vertical. When the carousel takes 8 s to complete each rotation the riders make an angle of 26.7° with the vertical.

a Draw a vector diagram showing the forces acting on the riders when they make an angle of 26.7° with the vertical and indicate the direction of the net force operating on the riders in your diagram. (1 mark)

b Find the angular velocity of the riders when the carousel turns with a period of 8 s. (1 mark)

c If the radius of the horizontal path taken by the riders is 8 m, when the period is 8 s find the centripetal acceleration of the riders. (1 mark)

d If a rider had a mass of 60 kg, find the tension in the cable holding the rider when it made an angle of 26.7° with the vertical. (1 mark)

8. a) mass experienced by each ladder = $^{20}/_{2} = 10$ kg

$F_G = mg$

$= 10 \times 9.8$

$= 98$ N

b) $F_G = \frac{(20+100)(9.8)}{2}$

$= 588$ N

c) $F_A + F_B = (20+100)(9.8)$

$= 1176$ N

$\tau_{man} + \tau_{board} = \tau_B$

$(100 \times 9.8) \times 2 + (20 \times 9.8) \times 2.5 = F_B \times 5$

$F_B = 490$ N

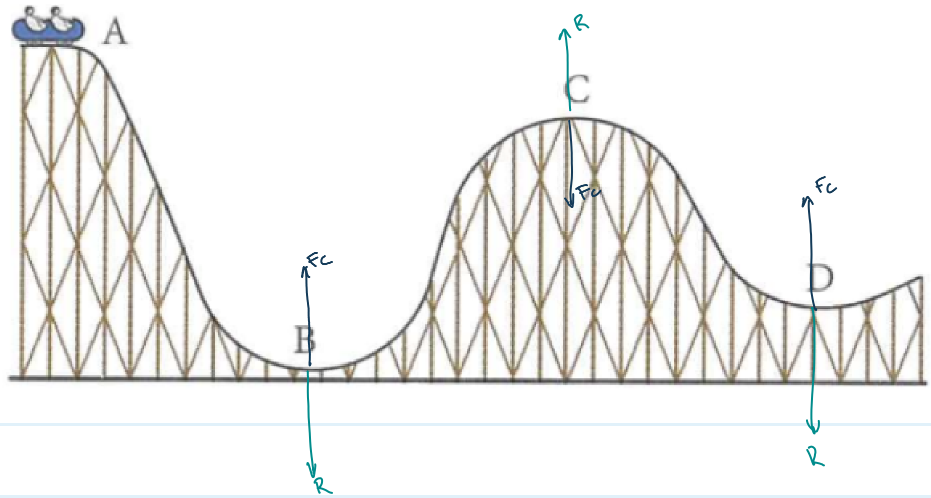
$F_A = 1176 - 490$

$= 686$ N

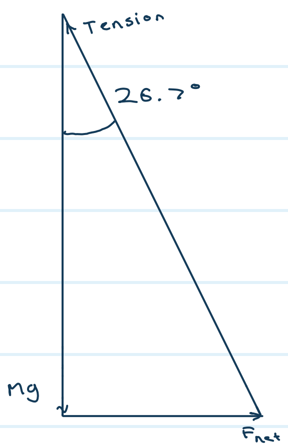
9. a) $W_B > W_D > W_A > W_C$

b) The weight experienced by the rider is determined by the normal reaction force. This depends on the weight and centripetal force at the position.

At B and D, the experienced weight will be the sum of the weight and centripetal force [$mg + F_c$]. At A, only gravity occurs. [mg]. At C, the weight will fell lower than at A [$mg - F_c$]



10. a)



b) $\omega = \Delta\theta / t$

$= 2\pi / 8$

$= \pi / 4 \text{ rad s}^{-1}$

$\doteqdot 0.785 \text{ rad s}^{-1}$

c) $a_c = v^2 / r$

$v = 2\pi r / T$

$= 2\pi(8) / 8$

$= 6.28 \text{ ms}^{-1}$

$a_c = 6.28^2 / 8$

$= 4.93 \text{ ms}^{-2}$ (3 s.f.)

d) $F_c = {mv^2}/{r}$

$= {60(2\pi)^2}/{8}$

$= 30\pi^2$ N

$F_a = mg$

$= 60 \times 9.8$

$= 588$ N

$F_T = \sqrt{588^2 + (30\pi^2)^2}$

$= 658$ N (3 s.f.)

HSC EXAM–TYPE QUESTIONS

Objective-response questions

(1 mark each)

1 The gravitational field strength on the surface of a planet X is 10 Nkg^{-1}. What would the gravitational strength be on the surface of a planet that was four times more massive but had half the radius of planet X?

A 160 N
B 80 ms^{-2}
C 160 ms^{-2}
D 20 Nkg^{-1}

2 A planet exerts a force of attraction on a satellite. Why does this force not cause the satellite to fall to the surface of the planet?

A The satellite continually falls towards the planet but it has a tangential velocity that prevents it getting closer to the planet.
B A centripetal force opposes the gravitational attraction and hence there is no net force on the satellite.
C Satellites are so far from the planet that the force of gravity on the satellite is negligible.
D The tangential velocity opposes the gravitational attraction, resulting in a net force of zero on the satellite.

3 Figure 3.17 shows a satellite moving from a low altitude circular orbit *A* to a higher altitude circular orbit *B*.

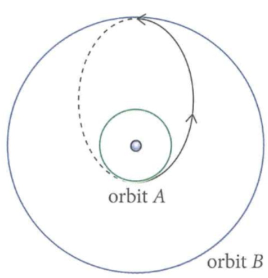


Figure 3.17 Satellite moving from one circular orbit to another circular orbit

Which of the following statements best describes how the energy of the satellite changes when it moves between orbits?

A The kinetic energy decreases and remains positive. The potential energy and total energy increase but both remain negative.
B The kinetic energy decreases and remains positive. The potential energy and total energy increase and both remain positive.
C The kinetic energy and the potential energy increase, producing a net increase in the total energy of the satellite.
D The potential energy increases, but this is offset by a large decrease in the kinetic energy resulting in a small decrease in the total energy.

4 A satellite is in a circular geostationary orbit around the Earth when it initiates a short retrograde rocket burn and slows its velocity a little. How will the orbit be changed by this rocket burn?

A The satellite will move into an elliptical orbit with the Earth at the focus closest to the burn but will still pass through the point where the burn occurred each orbit.
B The satellite will move into an elliptical orbit with the Earth at the focus furthest from the burn but will still pass through the point where the burn occurred each orbit.
C The satellite will spiral slowly towards the Earth.
D The satellite will move into a lower circular orbit.

5 The rocket engine that propelled the *Apollo* astronauts to the Moon operated for only the first 20 minutes of the mission. How did the total energy and velocity of the craft change from the time the rocket engine was switched off until it approached Moon orbit?

A The velocity and total energy remained constant.
B The velocity and energy decreased until the probe was near the Moon and then both began to increase.
C The total energy of the probe remained constant but the velocity decreased until the probe was near the Moon and then began to increase.
D The velocity remained constant throughout the flight but the energy increased until it reached a maximum and began to decrease as the craft neared Moon orbit.

Extended-response questions

6 Newton used a thought experiment to explain satellite motion. He imagined a cannon firing a cannonball horizontally from the top of a mountain that was higher than the atmosphere. Some of the possible trajectories of cannonballs fired with different initial velocities are shown in Figure 3.18.

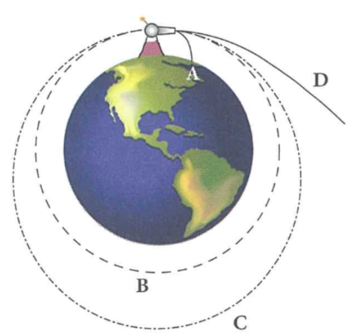


Figure 3.18 Newton's thought experiment on satellite orbits

a Use Newton's law of gravity to derive an equation that would enable you to find the velocity of the cannonball if it followed a circular orbit (i.e. orbit B). (2 marks)

b Compare the initial velocity of the orbits A and C to the initial velocity of the cannonball B that follows a circular orbit. (2 marks)

c Given that trajectory D is not an orbital path, what can we conclude about the initial velocity of the cannonball in this case? (1 mark)

d Which of the cannonballs has the greatest total energy? Justify your answer. (2 marks)

7 The Earth has a mass of 6.0×10^{24} kg and it is 384 400 km from the Moon, which has a mass of 7.35×10^{22} kg. Note also that the Earth has a radius of 6371 km and the Moon has a radius of 1737 km.

a Calculate the orbital velocity and centripetal acceleration of the Moon. (2 marks)

b Determine the period of the Moon's orbit. (1 mark)

c Explain how the Moon's orbit would change if it was hit by a meteorite that decreased the Moon's orbital velocity to zero. Justify your answer. (2 marks)

8 Consider the two small moons orbiting the large planet shown in Figure 3.19. Note that Moon A has three times the mass and twice the orbital radius of Moon B. The moons are so far apart we may ignore the gravitational force between them.

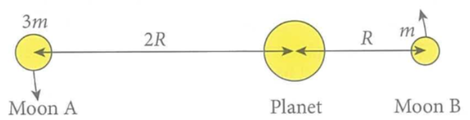


Figure 3.19 Two moons orbiting a planet

a Determine the ratio of the gravitational potential energy of Moon A to the gravitational potential of Moon B. (1 mark)

b Determine the ratio of the centripetal force on Moon A to the centripetal force on Moon B. (1 mark)

c Sketch a diagram to show the most energy-efficient path for a spacecraft to travel from Moon B to Moon A. (2 marks)

d In the time it takes Moon A to complete one orbit, how many orbits would Moon B have completed? (2 marks)

9 Relate the work done and energy changes involved in moving a spacecraft from the surface of the Earth through the atmosphere to a circular geostationary orbit around the Earth. You may use equations in your discussion but no calculations are required. (5 marks)

10 A satellite has a mass of 320 kg and orbits with a radius of 20 000 km around the Earth, which has a mass of 6.0×10^{24} kg.

a Find the kinetic and potential energy of this satellite. (2 marks)

b Determine the tangential velocity of the satellite. (1 mark)

c What minimum change in velocity would be required for this satellite to leave its geostationary orbit and escape the Earth's gravitational pull entirely? (2 marks)

6. a) $F_c = F_G$

$$mv^2/r = \frac{GMm}{r^2}$$

$$v^2 = GM/r$$

$$v = \sqrt{\frac{GM}{r}}$$

b) A has a lower initial velocity than B and C has a higher initial velocity

c) The initial velocity of D was greater than or equal to the escape velocity of the Earth.

d) All cannonballs begin with equal GPE's. However, D has the greatest initial velocity as it is able to escape.

$$KE = 1/2\ mv^2$$

$$\sum E = GPE + KE$$

$\therefore$ cannonball D has the greatest total energy.

7. a) $v = \sqrt{GM/r}$

$$= \sqrt{(6.67\times10^{-11})(6.0\times10^{24})/384400000}$$

$$\doteqdot 1020\ ms^{-1}\ (3\ s.f.)$$

b) $v = 2\pi r/T$

$$\sqrt{\frac{GM}{r}} = \frac{2\pi r}{T}$$

$$\frac{GM}{r} = \frac{4\pi^2 r^2}{T^2}$$

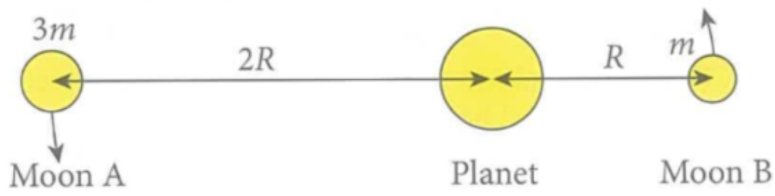
$$GM = \frac{4\pi^2 r^3}{T^2}$$

$$T = \sqrt{\frac{4\pi^2 r^3}{GM}}$$

$$= 2.37\times10^6\ s$$

c) If the moon had zero orbital velocity, it would fall towards the Earth at $9.8\ ms^{-2}$

8.



a) $U_A = -\frac{GMm}{r}$

$= -\frac{GM(3m)}{2R} = \frac{3}{2}\left(-\frac{GMm}{R}\right)$

$U_B = -\frac{GMm}{r}$

$= -\frac{GMm}{R}$

$\therefore$ Moon A has 3/2 times as much gravitational potential energy

b) $F_{CA} = \frac{GMm}{r^2}$

$= \frac{GM(3m)}{4R^2}$

$= \frac{3}{4} \times \frac{GMm}{R^2}$

$F_{CB} = \frac{GMm}{r^2}$

$= \frac{GM(m)}{R}$

$F_{CA} / F_{CB} = 3/4$

c)

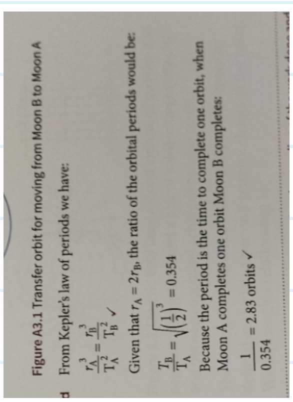


Figure A3.1 Transfer orbit for moving from Moon B to Moon A

From Kepler's law of periods we have:

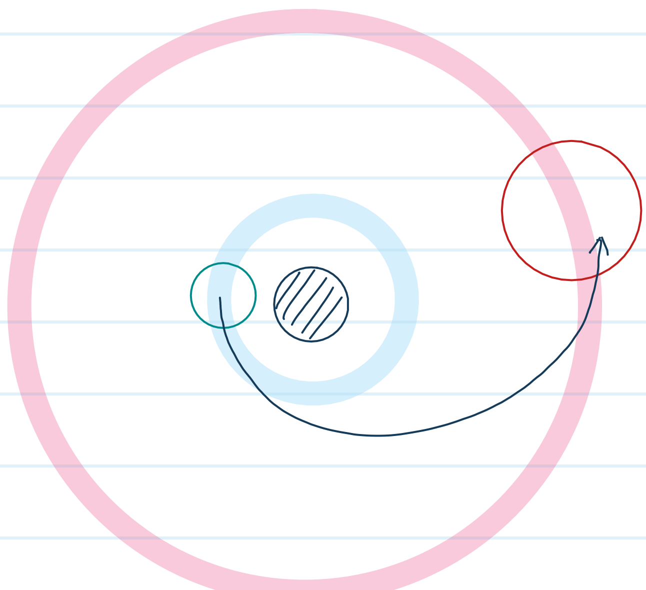
$\frac{r_A^3}{T_A^2} = \frac{r_B^3}{T_B^2}$ ✓

Given that $r_A = 2r_B$, the ratio of the orbital periods would be:

$\frac{T_B}{T_A} = \sqrt{\left(\frac{1}{2}\right)^3} = 0.354$

Because the period is the time to complete one orbit, when Moon A completes one orbit Moon B completes:

$\frac{1}{0.354} = 2.83$ orbits ✓



d) $\frac{r_A^3}{T_A^2} = \frac{r_B^3}{T_B^2}$

$r_A = 2r_B$

$T_B / T_A = \sqrt{\left(\frac{1}{2}\right)^3} \doteq 0.354$

$\therefore$ Moon B completes $1/0.354 = 2.83$ orbits.

9. To launch a satellite into a geostationary orbit, it must reach a required altitude and enough kinetic energy to maintain its altitude. By increasing altitude, gravitational potential energy is needed. As well as this, kinetic energy is needed to maintain orbit. Therefore, work must be done to produce the energy requirements.

10. a) $KE = -\frac{1}{2} U$

$$= \frac{GMm}{2r}$$

$$= \frac{(6.67\times10^{-11})(6\times10^{24})(320)}{2\times20000\times10^{3}}$$

$$\doteqdot 3.2\times10^{9}\ J$$

b) $v = \sqrt{GM/r}$

$$= \sqrt{\frac{(6.67\times10^{-11})(6\times10^{24})}{20000\times10^{3}}}$$

$$\doteqdot 4473\ ms^{-1}$$

c) $K_{esc} = |U|$

$K = \frac{1}{2}mv^2$, $v_{esc} = \sqrt{\frac{2k}{m}} = \sqrt{\frac{2\times6.4\times10^{9}}{320}}$

$$= 6325\ ms^{-1}$$

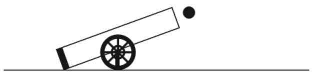
$\Delta v = 6325 - 4473$

$$= 1852\ ms^{-1}$$

3. Past HSC questions

M5 Projectile Motion

2019 1 A projectile is launched by a cannon as shown.



Which arrow represents the velocity of the projectile at its maximum height?

A. ↑

B. ↓

C. ↘

D. →

2020

5 A student throws a ball that follows a parabolic trajectory.

What change to the initial velocity would make the ball's time of flight shorter?

A. Increasing only the vertical component

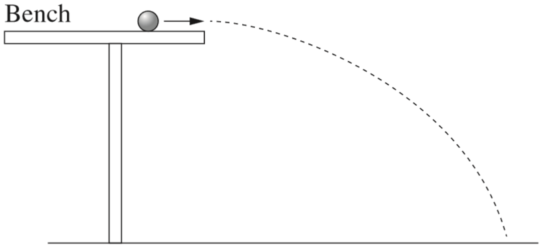
B. Decreasing only the vertical component

C. Increasing only the horizontal component

D. Decreasing only the horizontal component

2021

1 A marble is rolled off a horizontal bench and falls to the floor.

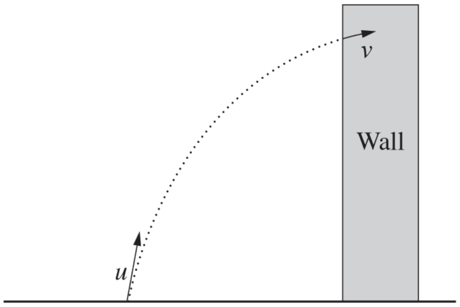


Rolling the marble at a slower speed would

A. increase the range.
B. decrease the range.
C. increase the time of flight.
D. decrease the time of flight.

2022

8 An object is launched with an initial velocity, u, and hits a wall with a final velocity, v.

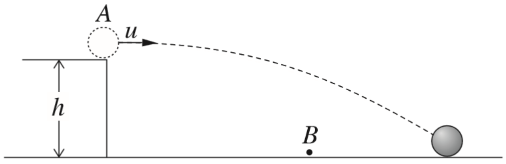


Which statement correctly compares components of u and v?

A. The vertical component of v is less than the vertical component of u.
B. The vertical component of v is greater than the vertical component of u.
C. The horizontal component of v is less than the horizontal component of u.
D. The horizontal component of v is greater than the horizontal component of u.

2023

8 A ball is launched from a platform at position *A* with velocity *u*. It lands in the position shown.



The ball could be made to land at position *B* by increasing the

A. velocity *u*.

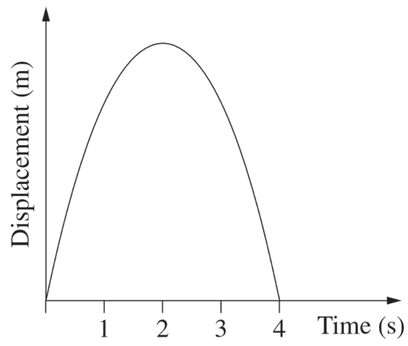
B. launch angle.

C. mass of the ball.

D. height of the platform.

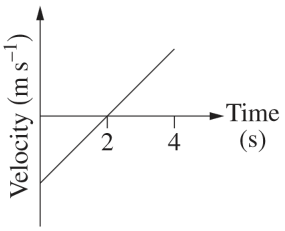
2022

11 A projectile is launched vertically upwards. The displacement of the projectile as a function of time is shown.

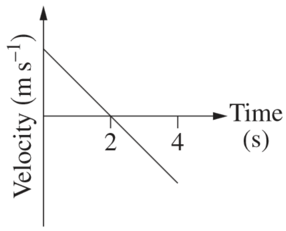


Which velocity–time graph corresponds to this motion?

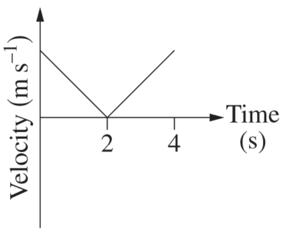
A.



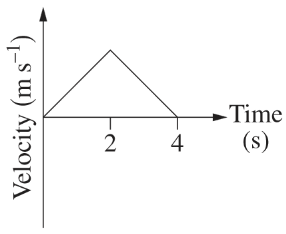
B.



C.



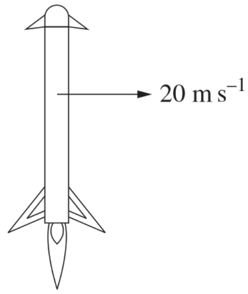
D.



2020

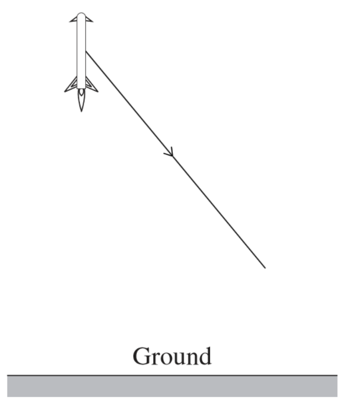
15 A rocket returns to Earth for reuse after launching satellites, using its engines to make a controlled landing.

The rocket having a mass of 7800 kg is on approach to the ground, travelling horizontally at 20 m s^{-1} as shown in the diagram, when the engine thrust is changed to 90 000 newtons.

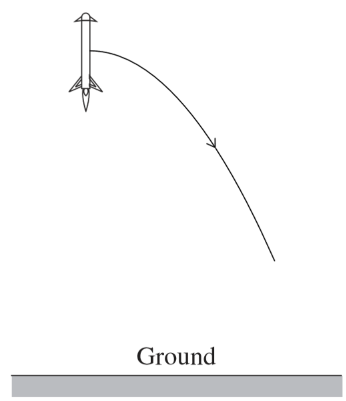


Which diagram shows the trajectory of the rocket following this change of thrust?

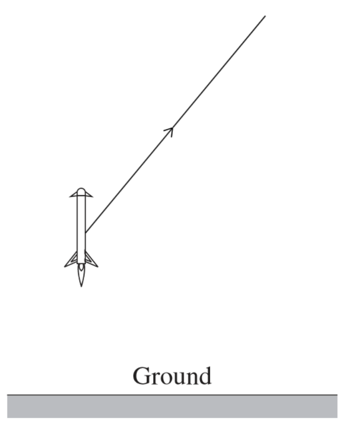
A.



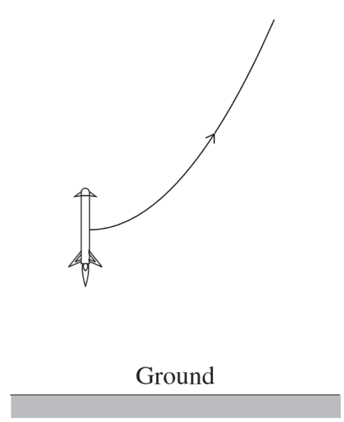
B.



C.



D.



2023

18 The diagrams show the trajectories of two particles with the same mass and charge and which initially have the same velocity u, as shown. The subsequent motion of each particle is determined by its properties and by its interaction with the field in which it is moving.

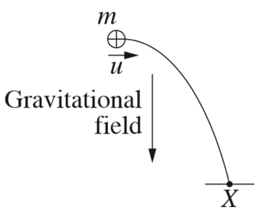


Figure I

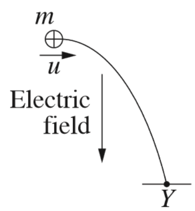
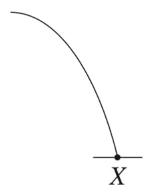
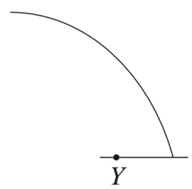
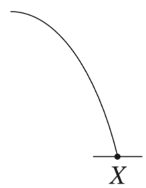
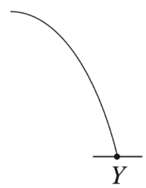
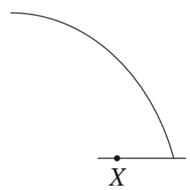
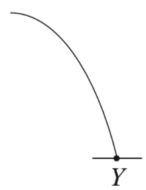


Figure II

X and Y represent the landing points in Figures I and II.

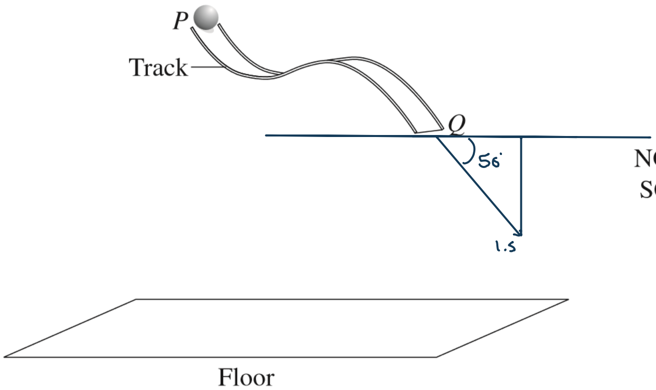
Which row of the table shows the correct paths of the particles if the mass of each is increased by the same amount and they are given the same initial velocity u?

	Gravitational field	Electric field
A.		
B.		
C.		
D.		

Do NOT write in this area.

2019 Question 30 (6 marks)

A ball, initially at rest in position *P*, travels along a frictionless track to point *Q* and then falls to strike the floor below.



At the instant the ball leaves the track at *Q* it has a velocity of 1.5 m s^{-1} at an angle of 50° to the horizontal.

(a) Calculate the difference in height between *P* and *Q*. **3**

$V_{vert.} = 1.5 \sin 50°$

$v^2 = u^2 + 2as$

$(1.5\sin(50°))^2 = 0^2 + 2(9.8)s$

$s = (1.5\sin(50°))^2 / 2(9.8)$

$\doteqdot 0.059$ m

(b) The ball takes 0.5 s to reach the floor after leaving the track at*Q*. **3**

Calculate the height of *Q* above the floor.

$s = ut + \frac{1}{2}at^2$

$= (1.5\sin(50°)) \times 0.5 + \frac{1}{2}(9.8)(0.5)^2$

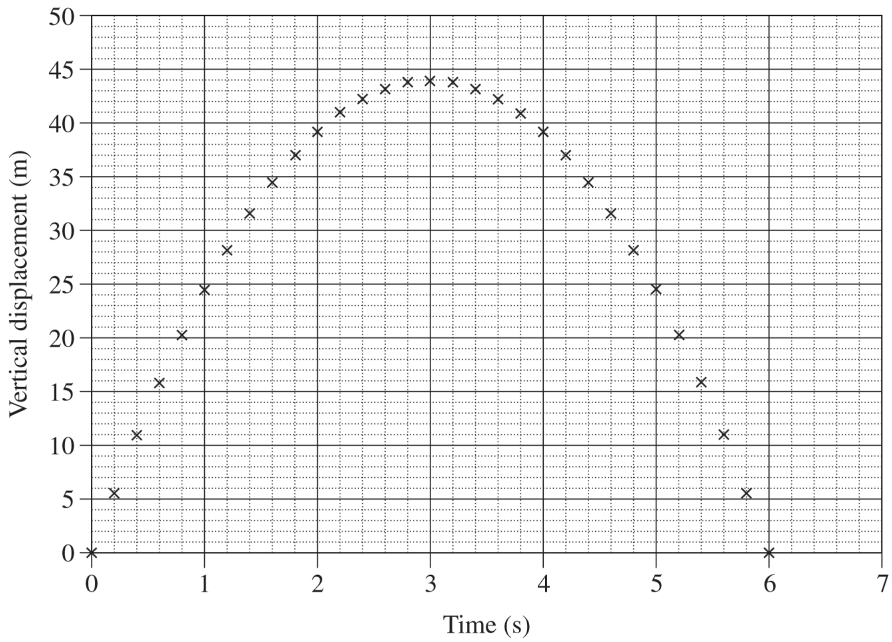
$= 1.8$ m (2 s.f.)

Do NOT write in this area.

2020

Question 24 (4 marks)

The graph shows the vertical displacement of a projectile throughout its trajectory. The range of the projectile is 130 m. **4**



Calculate the initial velocity of the projectile.

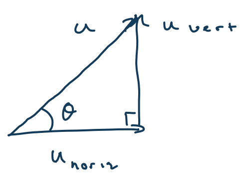
$u_{horiz.} = 130m / 6s$

$= 65/3 \ ms^{-1}$

$s = u_{vert} t + 1/2 \, a t^2$

$44 = u_{vert.} (3) + 1/2 (-9.8)(3)^2$

$u_{vert.} = \dfrac{44 - 1/2(-9.8) \times 3^2}{3}$



$u = \sqrt{u_{vert}^2 + u_{horiz}^2}$ $\qquad \theta = \tan^{-1}\left(\dfrac{u_{vert.}}{u_{horiz}}\right)$

$\doteqdot 36.5 \ ms^{-1}$ $\qquad \doteqdot 53° 35'$

$\therefore$ Initial velocity = 36.5 ms⁻¹ at 53° 35' to +ve horiz.

Do NOT write in this area.

2022

Question 29 (4 marks)

An apple was thrown horizontally to the east from the window of a car which was moving with a uniform velocity to the north. **4**

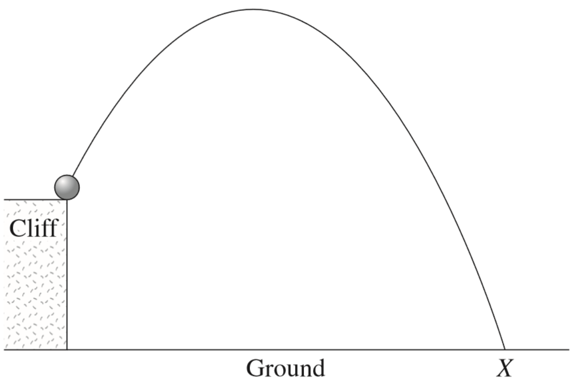
Explain the horizontal and vertical components of the apple's motion during its flight.

The horizontal motion would be determined by the resultant velocity of the motion of the car north, and the person throwing the apple east. Therefore, the resultant velocity would be in some direction in the north-east quadrant. No forces affect the horizontal velocity during flight, therefore it is constant. The vertical velocity would increase at $9.8 ms^{-2}$ due to the Earth's gravity. This acceleration would affect the apple's flight for its entire duration.

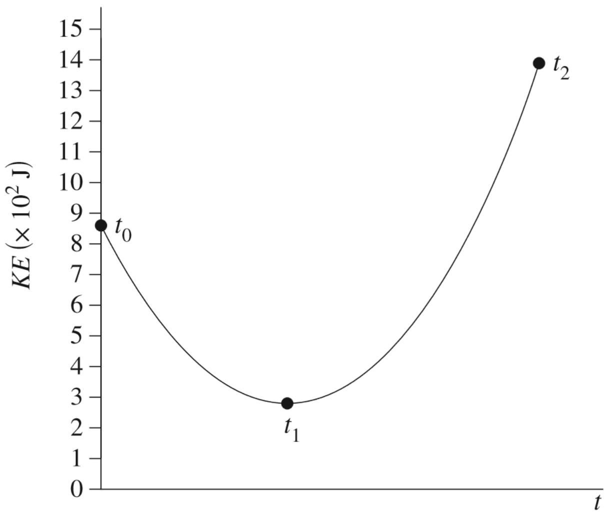
2021

Question 34 (7 marks)

A 3.0 kg mass is launched from the edge of a cliff.



The kinetic energy of the mass is graphed from the moment it is launched until it hits the ground at X. The kinetic energy of the mass is provided for times t_0, t_1 and t_2.



Time (t)	*KE* (J)
t_0	864
t_1	284
t_2	1393

Question 34 continues on next page

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Question 34 (continued)

(a) Account for the relative values of kinetic energy at t_0, t_1 and t_2. **4**

t_1 has the lowest kinetic energy as it is at the highest point of its flight and therefore only accounts for horizontal movement. t_2 has a higher KE in comparison to t_0 because it is lower and therefore has a lower GPE. Hence, its KE is higher.

(b) The horizontal component of the velocity of the mass during its flight is $13.76\ \text{m s}^{-1}$. **3**

Calculate the time of flight of the mass.

At $t=0$: $KE = \frac{1}{2}mv^2$

$864 = \frac{1}{2}(3)v^2$

$v = \sqrt{\frac{864 \times 2}{3}}$

$v_{vert.} = \sqrt{\frac{864 \times 2}{3} - 13.76^2}$

At $t=2$: $KE = \frac{1}{2}mv^2$

$1393 = \frac{1}{2}(3)v^2$

$v = \sqrt{\frac{1393 \times 2}{3}}$

$v_{vert.} = \sqrt{\frac{1393 \times 2}{3} - 13.76^2}$

$v = u + at$

$t = \frac{v-u}{a} = \frac{\sqrt{\frac{1393 \times 2}{3} - 13.76^2} - \left(-\sqrt{\frac{864 \times 2}{3} - 13.76^2}\right)}{9.8}$

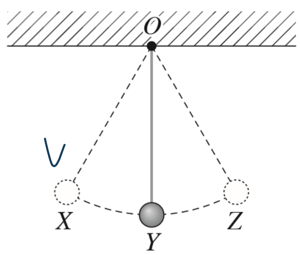
$= 4.8$ seconds (2 s.f.)

End of Question 34

M5 Circular Motion

2023

17 A mass attached to a lightweight, rigid arm hanging from point O, oscillates freely between X and Z.



Which statement best describes the torque acting on the arm as it oscillates?

A. It is constant in magnitude and direction.

B. It is zero at Y and a maximum at X and Z.

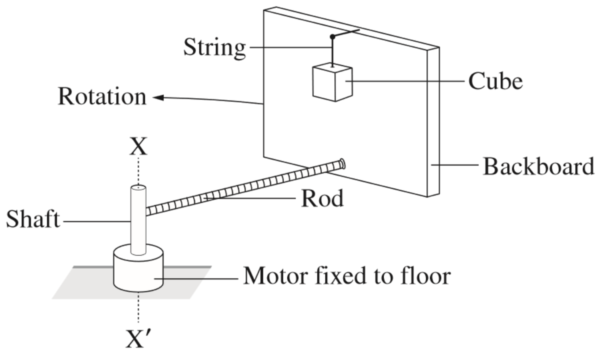
C. It is zero at X and Z and a maximum at Y.

D. It is constant in magnitude but its direction changes.

2019

Q20 In the apparatus shown, a backboard is connected by a rod to a shaft. The shaft is spun by an electric motor causing the backboard to rotate in the horizontal plane around the axis X–X′.

A cube is suspended by a string so that it touches the surface of the backboard.



When the angular velocity of the motor is great enough, the string is cut and the position of the cube does not change relative to the backboard.

Which statement correctly describes the forces after the string is cut?

A. The sum of the forces on the cube is zero.

B. The horizontal force of the backboard on the cube is equal in magnitude to the horizontal force of the cube on the backboard.

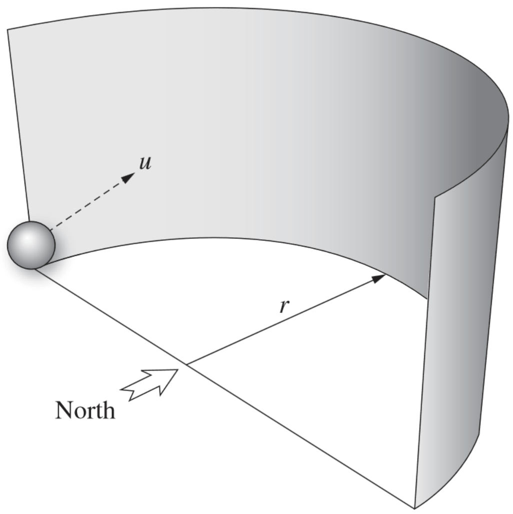
C. The horizontal force of the backboard on the cube is greater than the horizontal force of the cube on the backboard, resulting in a net centripetal force.

D. The force of friction between the cube and the backboard is independent of the force of the backboard on the cube because these forces are perpendicular to each other.

2020

20 The diagram shows a smooth, semi-circular, vertical wall with radius, *r*.

A ball is launched from the position shown with a velocity *u* towards north at an angle to the horizontal.



The ball follows a trajectory around the wall before landing on the ground, opposite its starting point. It does not reach the top of the wall.

Assume that there is no friction between the ball and the wall.

Which statement correctly describes the net force acting on the ball during its motion?

A. The magnitude of the net force remains constant.

B. The direction of the net force is vertically downwards.

C. The direction of the net force is perpendicular to the wall.

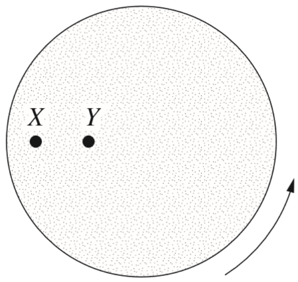
D. The magnitude of the net force reaches a minimum when the ball is at its highest point.

Do NOT write in this area.

2021

Question 22 (3 marks)

A horizontal disc rotates at a constant rate as shown. Two points on the disc, *X* and *Y*, are labelled. *X* is twice as far away from the centre of the disc as *Y*. **3**



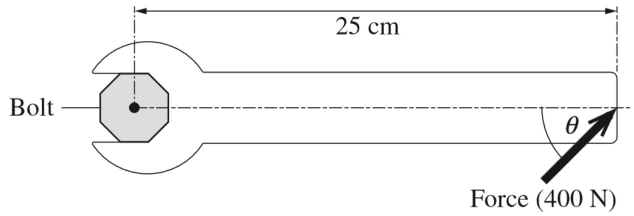
Compare the angular and instantaneous velocities of *X* with those of *Y*.

X and Y are situated on the same rotating plane, neither of which are on the centre. Therefore the angular velocities are the same. X is further away from the axis of rotation compared to Y, ∴ has a higher instaneous velocity.

2019

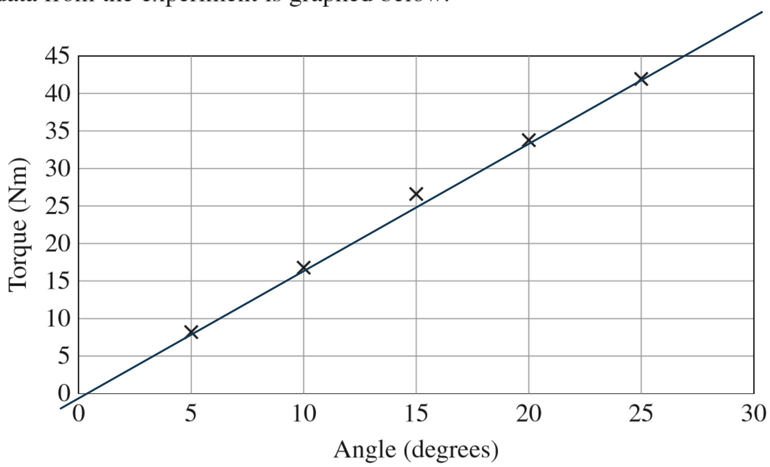
Question 26 (6 marks)

A student carried out an experiment to investigate the relationship between the torque produced by a force and the angle at which the force is applied. A 400 N force was applied to the same position on the handle of a spanner at different angles, as shown.



A high-precision device measured the torque applied to the bolt.

The data from the experiment is graphed below.



Question 26 continues on next page

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Question 26 (continued)

The student concluded that the torque (τ) was proportional to the angle (θ) and proposed the model

$$\tau = k\theta$$

where $k = 1.7$ Nm/degree.

(a) Justify the validity of the student's model using information from the graph. **3**

Based on the above graph, torque has a linear relationship to the angle θ indicated in the diagram. Using least squares regression, the graph has a gradient approx. equal to 1.71, therefore the student's model is correct based on the experimental data.

(b) What happens to the accuracy of this model's predictions as the angle increases beyond 25°? Justify your answer with reference to a different model. **3**

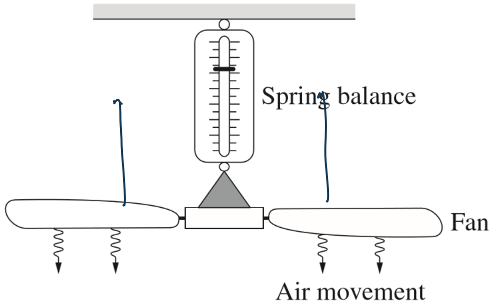
Beyond 25° the model becomes less accurate. $\tau = F_\perp r = F\sin\theta\, r$. Therefore for small θ values the relationship appears to be linear ($\lim_{x\to 0} \frac{\sin x}{x} = 1$), however is inaccurate.

End of Question 26

2019 Question 31

A student suspends an electric ceiling fan from a spring balance.

The fan is switched on, reaching a maximum rotational velocity after ten seconds.



(a) Explain the changes that would be observed on the spring balance in the first 15 seconds after the fan is switched on. **4**

When the fan is switched on, it pushes air down. Due to Newton's 3rd Law, an upwards force is exerted onto the fan. This force increases until the fan reaches maximum rotational velocity after 10 seconds. This force is indicated as the spring balance will return less force.

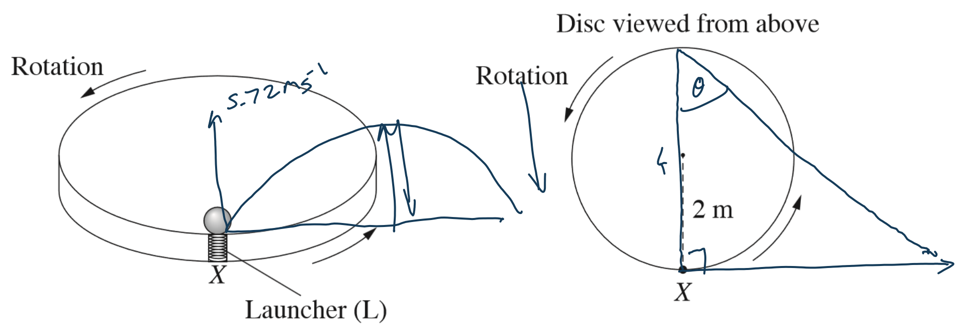
Do NOT write in this area.

2023

Question 32 (7 marks)

A horizontal disc rotates at 3 revolutions per second around its centre, with the top of the disc at ground level. **7**

At 2 m from the centre of the disc, a ball is held in place at ground level on the top of the disc by a spring-loaded projectile launcher. At position X, the launcher fires the ball vertically upward with a velocity of 5.72 m s^{-1}.



Calculate the ball's position relative to the launcher's new position, at the instant the ball hits the ground.

3 rev/s = 1/3 s/rev

$V_{horiz.} = 2\pi r / T$

$= 2\pi(2) / \tfrac{1}{3}$

$= 12\pi \ ms^{-1}$

V_{vert} : $v = u + at$

At same height, v is equal

$5.72 = -5.72 + (9.8)t$

$t = 2 \times 5.72 / 9.8$ sec

$S_{horiz} = 12\pi \times t$

$= 3432\pi / 245$ m

Number of revolutions

$t \times 3 \doteqdot 3.5$ revolutions

dist. from launcher at landing =

$= \sqrt{4^2 + S_{horiz.}^2}$

$\doteqdot 44.2$ m

$\theta = \tan^{-1}\left(\frac{S_{horiz.}}{4}\right)$

$\doteqdot 84° 48'$

∴ The ball lands 44.2m away from the launcher at 95° 10'

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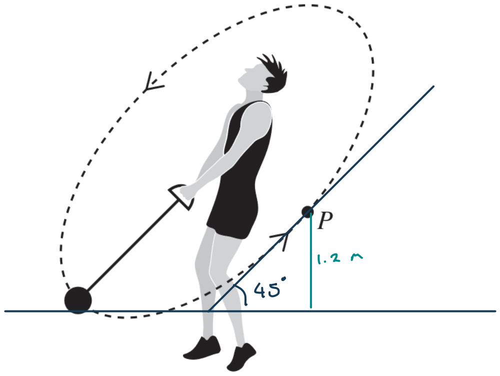
2022

Question 33 (6 marks)

In a hammer throw sport event, a 7.0 kg projectile rotates in a circle of radius 1.6 m, with a period of 0.50 s. It is released at point *P*, which is 1.2 m above the ground, where its velocity is at 45° to the horizontal.



(a) Show that the vertical component of the projectile's velocity at *P* is 14.2 m s^{-1}. **2**

$v = 2\pi r / T$
$= 2\pi(1.6) / 0.5$
$= 32\pi / 5$

$v_{vert} = \frac{32\pi}{5} \sin(45°)$
$= \frac{32\pi}{5} \times \frac{\sqrt{2}}{2}$
$\doteq 14.2 \text{ ms}^{-1}$

(b) Calculate the horizontal range of the projectile from point *P*. **4**

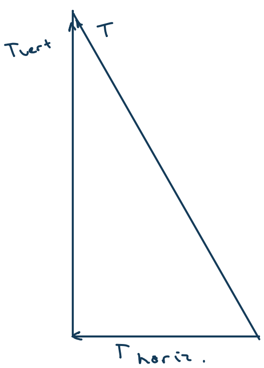
$S_{vert} = ut + \frac{1}{2} at^2$
$-1.2 = \frac{16\sqrt{2}\pi}{5} t + \frac{1}{2}(-9.8)t^2$
$4.9t^2 - \frac{16\sqrt{2}\pi}{5} t - 1.2 = 0$
$t = \frac{\frac{16\sqrt{2}\pi}{5} \pm \sqrt{\left(\frac{16\sqrt{2}\pi}{5}\right)^2 - 4(4.9)(-1.2)}}{2(4.9)}, \; t \geq 0$

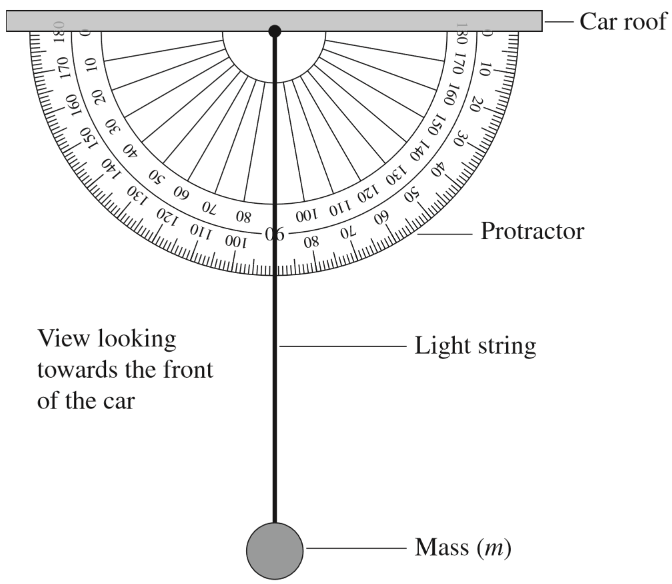
$v_{horiz.} = \frac{32\pi}{5} \cos(45°)$
$= \frac{16\sqrt{2}\pi}{5} \text{ ms}^{-1}$

$S_{horiz.} = v_{horiz.} \times t$
$\doteq 42.42 \text{ m}$ (4 s.f.)

2019 Question 35 (4 marks)

The apparatus shown is attached horizontally to the roof inside a stationary car. The plane of the protractor is perpendicular to the sides of the car. **4**





The car was then driven at a constant speed (v), on a horizontal surface, causing the string to swing to the right and remain at a constant angle (θ) measured with respect to the vertical.

Describe how the apparatus can be used to determine features of the car's motion. In your answer, derive an expression that relates a feature of the car's motion to the angle θ.

The mass swings to the right, implying a uniform circular acceleration in the anticlockwise direction.

$T_{vert} = T\sin\theta = mg$ ①

$T_{horiz} = T\cos\theta = \frac{mv^2}{r}$ ②

① ÷ ②:

$\frac{T\sin\theta}{T\cos\theta} = \frac{mg}{\frac{mv^2}{r}}$

$\tan\theta = \frac{rg}{v^2}$ ✓ , $\theta = \tan^{-1}\left(\frac{rg}{v^2}\right)$

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M5 Motion in Graviational Fields

2023

1 The gravitational field strength acting on a spacecraft decreases as its altitude increases.

This is due to a change in the

A. mass of Earth.

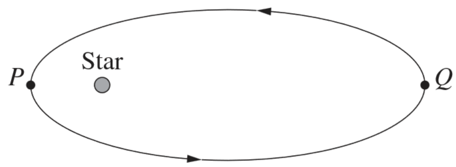
B. mass of the spacecraft.

C. density of the atmosphere.

D. distance of the spacecraft from Earth's centre.

2022

6 The elliptical orbit of a planet around a star is shown.



Which type of energy is greater at position P than at Q?

A. Kinetic

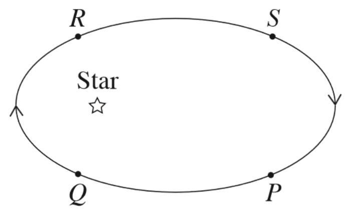
B. Nuclear

C. Potential

D. Total

2023

5 An exoplanet is in an elliptical orbit, moving in the direction shown. The distances between consecutive positions P, Q, R and S are equal.



Between which two points is the exoplanet's travel time the greatest?

A. P and Q

B. Q and R

C. R and S

D. S and P

2019

Q9 Two satellites have the same mass. One (LEO) is in low-Earth orbit and the other (GEO) is in a geostationary orbit.

The total energy of a satellite is half its gravitational potential energy.

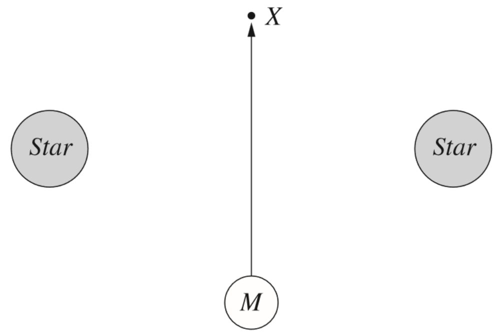
Which row of the table correctly identifies the satellite with the greater orbital period and the satellite with the greater total energy?

	Greater orbital period	*Greater total energy*
A.	LEO	LEO
B.	LEO	GEO
C.	GEO	LEO
D.	GEO	GEO

2021

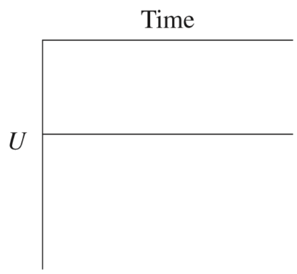
9 A mass, M, is positioned at an equal distance from two identical stars as shown.

The mass is then moved to position X.

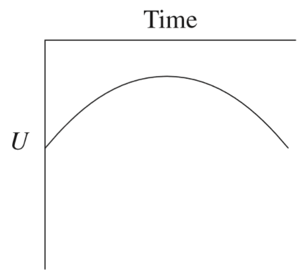


Which graph best represents the gravitational potential energy, U, of the mass during this movement?

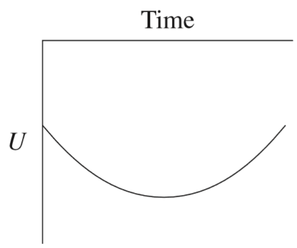
A.



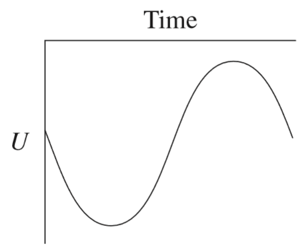
B.



C.



D.

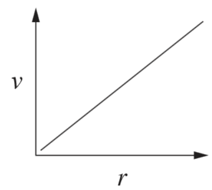


2022

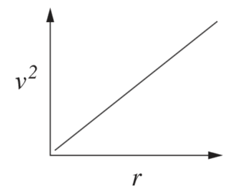
10 The orbital velocity, v, of a satellite around a planet is given by $v = \sqrt{\frac{GM}{r}}$.

Which graph is consistent with this relationship?

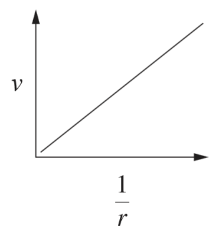
A.



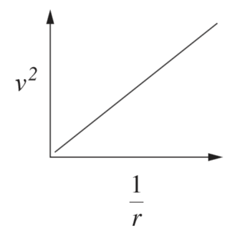
B.



C.



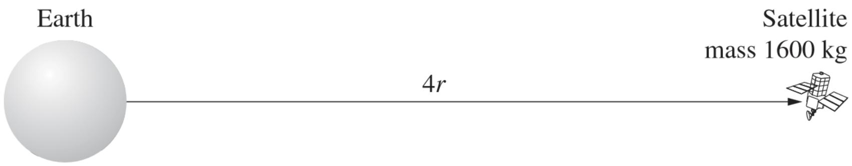
D.



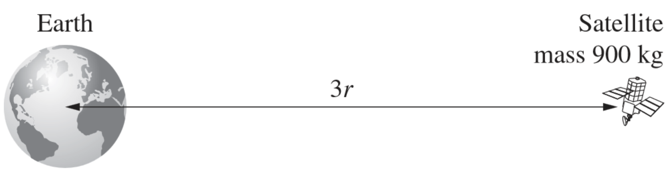
2020

12 In which of the following would the satellite have the greatest escape velocity from Earth?

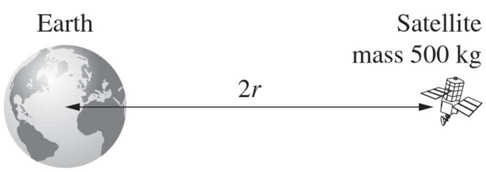
A.



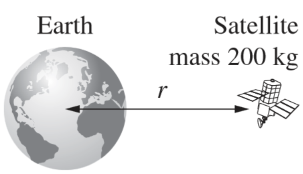
B.



C.

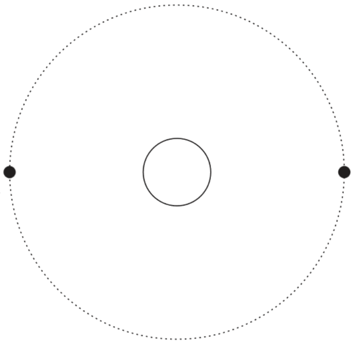


D.



2022

13 Two satellites share an orbit around a planet. One satellite has twice the mass of the other.



Which quantity would be different for the two satellites?

A. Speed

B. Momentum

C. Orbital period

D. Centripetal acceleration

2023

14 Planet X has a mass 4 times that of Earth and a radius 3 times that of Earth. The escape velocity at the surface of Earth is $11.2\ \text{km s}^{-1}$.

What is the escape velocity at the surface of planet X?

A. $8.40\ \text{km s}^{-1}$

B. $9.70\ \text{km s}^{-1}$

C. $12.9\ \text{km s}^{-1}$

D. $14.9\ \text{km s}^{-1}$

2023

Question 23

The James Webb Space Telescope (JWST) has a mass of 6.1×10^3 kg and orbits the Sun at a distance of approximately 1.52×10^{11} m.

(a) The Sun has a mass of 1.99×10^{30} kg. **2**

Calculate the magnitude of gravitational force the Sun exerts on the JWST.

$F = GMm/r^2$

$= G(1.99\times10^{30})(6.1\times10^3)/(1.52\times10^{11})^2$

$= 35$ N (2 s.f.)

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2022

Question 25 (5 marks)

A rocket is launched vertically from a planet of mass M. After it leaves the atmosphere, the rocket's engine is turned off and it continues to move away from the planet. From this time the rocket's mass is 200 kg. The rocket's speed, v, at two different distances from the planet's centre, R, is shown.

Point	R (m)	v (m s^{-1})
1	4.3×10^6	5500
2	2.5×10^7	2900

(a) Show that the magnitude of the change in kinetic energy from point 1 to point 2 is 2.2×10^9 J. **2**

$KE_1 = \frac{1}{2} mv^2 = \frac{1}{2}(200)(5500)^2 = 3.025 \times 10^9$

$KE_2 = \frac{1}{2}(200)(2900)^2 = 8.41 \times 10^8$

$KE_1 - KE_2 \doteq 2.2 \times 10^9$ J (2 s.f.)

(b) Determine the mass M of the planet using the law of conservation of energy. **3**

$|\Delta KE| = |\Delta U|$

$U = GMm / r$

$2.2 \times 10^9 = \frac{(6.67\times10^{-11})(200)M}{R_1 - R_2}$

$M \doteq 8.6 \times 10^{23}$ kg

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2021

Question 25 (5 marks)

A satellite is launched from the surface of Mars into an orbit that keeps it directly above a position on the surface of Mars.

Mass of Mars = 6.39×10^{23} kg

Length of Martian day = 24 hours and 40 minutes

(a) Identify TWO energy changes as the satellite moves from the surface of Mars into orbit. **2**

As the satellite moves into orbit, its gravitational potential and kinetic energies both increase

(b) Calculate the orbital radius of the satellite. **3**

Orbital period (T) = 88800 sec

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

$$r = \sqrt[3]{\frac{GMT^2}{4\pi^2}}$$

$$= \sqrt[3]{\frac{6.67 \times 10^{-11} \times 6.39 \times 10^{23} \times 88800^2}{4\pi^2}} \doteq 2.0 \times 10^7 \text{ m}$$

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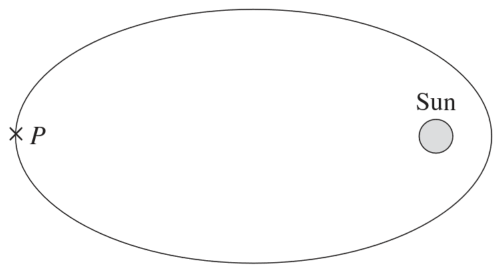
2020

Question 31 (6 marks)

(a) The orbit of a comet is shown. **3**



Account for the changes in velocity of the comet as it completes one orbit from position *P*.

At position P, the comet is furthest from the sun, therefore has the highest GPE and lowest KE, hence is at its slowest. As it approaches the Sun, gravitational energy is converted into KE, causing the comet to accelerate. After reaching the opposite point of the major axis, the comet decelerates as it gains GPE.

(b) Two stars, *A* and *B*, of equal mass *m*, separated by a distance *x*, interact gravitationally such that the speed of *A* is constant. **3**

Derive an expression for the speed of *B*.

Speed of A is constant, therefore A and B are in circular orbit with each other, around an axis in the middle.

$F = \frac{GMm}{r^2} = \frac{Gm^2}{x^2}$ ①

$F = \frac{mv^2}{r} = \frac{mv^2}{x/2} = \frac{2mv^2}{x}$ ②

① = ② : $\frac{Gm^2}{x^2} = \frac{2mv^2}{x}$

$v = \sqrt{\frac{Gm}{2x}}$

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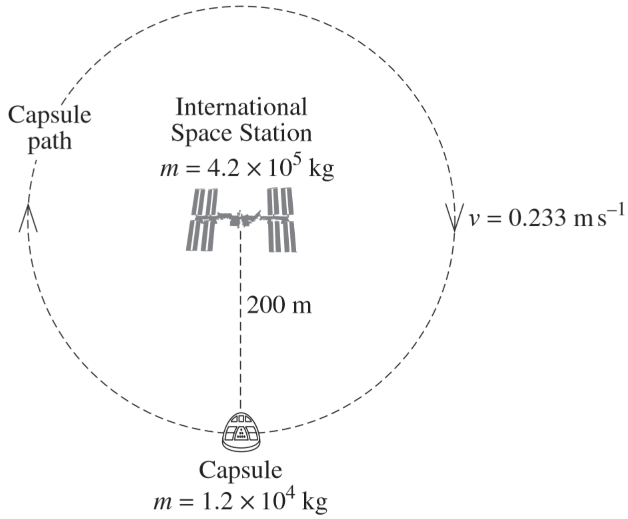
2022

Question 35 (5 marks)

A capsule travels around the International Space Station (ISS) in a circular path of radius 200 m as shown. **5**



Analyse this system to test the hypothesis below.

The uniform circular motion of the capsule around the ISS can be accounted for in terms of the gravitational force between the capsule and the ISS.

$F_c = {mv^2}/{r}$

$= (1.2\times10^4)\times0.233 / 200$

$= 699/50$ N

$F_G = GMm/r^2$

$= (6.67\times10^{-11})(4.2\times10^5)(1.2\times10^4) / 200^2$

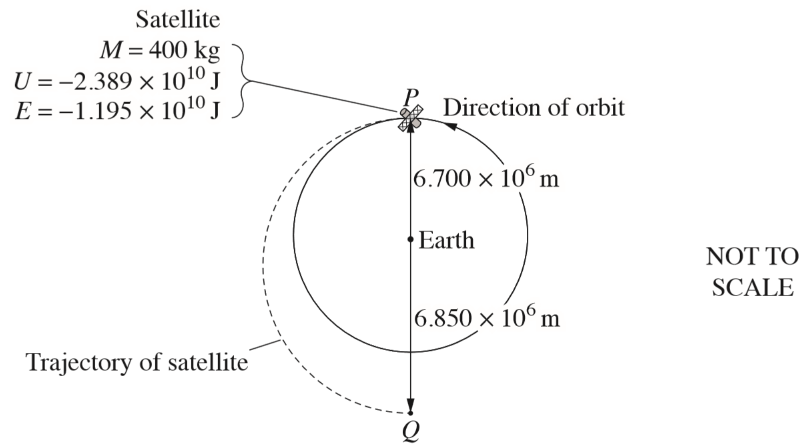
$= 8.4042\times10^{-6}$ N

The force due to gravity is significantly lower than the force required for circular motion, therefore the hypothesis is incorrect.

2023

Question 34 (9 marks)

A 400 kg satellite is travelling in a circular orbit of radius 6.700×10^6 m around Earth. Its potential energy is -2.389×10^{10} J and its total energy is -1.195×10^{10} J.



At point P, the satellite's engines are fired, increasing the satellite's velocity in the direction of travel and causing its kinetic energy to increase by 5.232×10^8 J. Assume that this happens instantaneously and that the engine is then shut down.

The satellite follows the trajectory shown, which passes through Q, 6.850×10^6 m from Earth's centre.

(a) Analyse qualitatively the energy changes as the satellite moves from P to Q. **2**

As the satellite moves from P to Q, its gravitational potential energy increases. Due to the law of conservation of energy, the satellite's kinetic energy must therefore decrease.

Question 34 continues on page 35

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Question 34 (continued)

(b) Show that the kinetic energy of the satellite at Q is 1.194×10^{10} J. **4**

At Q: $U = -GMm/r$

$= -(6.67\times10^{-11})(6\times10^{24})(400) / 6.85\times10^{6}$

$\doteqdot -2.34\times10^{10}$ J

$\sum E = -1.195\times10^{10} + 5.232\times10^{8}$

$KE_Q = \sum E - U$

$= -1.195\times10^{10} + 5.232\times10^{8} - (-2.34\times10^{10})$

$= 1.194\times10^{10}$ J

(c) Explain the motion of the satellite after it passes through Q. **3**

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

$V_Q = \sqrt{\frac{2KE_Q}{m}}$

$= \sqrt{\frac{2\times1.194\times10^{10}}{400}}$

$\doteqdot 7.727\times10^{3}$ ms^{-1}

To maintain circular orbit:

$V_{req} = \sqrt{GM/r}$

$\doteqdot 7.644\times10^{3}$ ms^{-1}

$V_Q > V_{req}$, ∴ satellite will continue on its trajectory, increasing dist. from Earth

End of paper

2023 HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

DATA SHEET

Charge on electron, q_e	-1.602×10^{-19} C
Mass of electron, m_e	9.109×10^{-31} kg
Mass of neutron, m_n	1.675×10^{-27} kg
Mass of proton, m_p	1.673×10^{-27} kg
Speed of sound in air	340 m s^{-1}
Earth's gravitational acceleration, g	9.8 m s^{-2}
Speed of light, c	$3.00 \times 10^{8} \text{ m s}^{-1}$
Electric permittivity constant, ε_0	$8.854 \times 10^{-12} \text{ A}^2 \text{ s}^4 \text{ kg}^{-1} \text{ m}^{-3}$
Magnetic permeability constant, μ_0	$4\pi \times 10^{-7} \text{ N A}^{-2}$
Universal gravitational constant, G	$6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
Mass of Earth, M_E	6.0×10^{24} kg
Radius of Earth, r_E	6.371×10^{6} m
Planck constant, h	6.626×10^{-34} J s
Rydberg constant, R (hydrogen)	$1.097 \times 10^{7} \text{ m}^{-1}$
Atomic mass unit, u	1.661×10^{-27} kg $931.5 \text{ MeV}/c^2$
1 eV	1.602×10^{-19} J
Density of water, ρ	$1.00 \times 10^{3} \text{ kg m}^{-3}$
Specific heat capacity of water	$4.18 \times 10^{3} \text{ J kg}^{-1} \text{ K}^{-1}$
Wien's displacement constant, b	2.898×10^{-3} m K

FORMULAE SHEET

Motion, forces and gravity

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

$$\Delta U = mg\Delta h$$

$$P = \frac{\Delta E}{\Delta t}$$

$$\sum \frac{1}{2}mv^2_{\text{before}} = \sum \frac{1}{2}mv^2_{\text{after}}$$

$$\Delta\vec{p} = \vec{F}_{\text{net}}\Delta t$$

$$\omega = \frac{\Delta\theta}{t}$$

$$\tau = r_{\perp}F = rF\sin\theta$$

$$v = \frac{2\pi r}{T}$$

$$U = -\frac{GMm}{r}$$

$$v = u + at$$

$$\vec{F}_{\text{net}} = m\vec{a}$$

$$W = F_{||}s = Fs\cos\theta$$

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

$$P = F_{||}v = Fv\cos\theta$$

$$\sum m\vec{v}_{\text{before}} = \sum m\vec{v}_{\text{after}}$$

$$a_c = \frac{v^2}{r}$$

$$F_c = \frac{mv^2}{r}$$

$$F = \frac{GMm}{r^2}$$

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

Waves and thermodynamics

$$v = f\lambda$$

$$f = \frac{1}{T}$$

$$d\sin\theta = m\lambda$$

$$n_x = \frac{c}{v_x}$$

$$I = I_{\text{max}}\cos^2\theta$$

$$Q = mc\Delta T$$

$$f_{\text{beat}} = \left|f_2 - f_1\right|$$

$$f' = f\frac{\left(v_{\text{wave}} + v_{\text{observer}}\right)}{\left(v_{\text{wave}} - v_{\text{source}}\right)}$$

$$n_1\sin\theta_1 = n_2\sin\theta_2$$

$$\sin\theta_c = \frac{n_2}{n_1}$$

$$I_1r_1^2 = I_2r_2^2$$

$$\frac{Q}{t} = \frac{kA\Delta T}{d}$$

FORMULAE SHEET (continued)

Electricity and magnetism

$$E = \frac{V}{d}$$

$$V = \frac{\Delta U}{q}$$

$$W = qV$$

$$W = qEd$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$B = \frac{\mu_0 N I}{L}$$

$$\Phi = B_{\parallel} A = BA\cos\theta$$

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$$

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

$$\vec{F} = q\vec{E}$$

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$I = \frac{q}{t}$$

$$V = IR$$

$$P = VI$$

$$F = qv_{\perp}B = qvB\sin\theta$$

$$F = lI_{\perp}B = lIB\sin\theta$$

$$\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}$$

$$\tau = nIA_{\perp}B = nIAB\sin\theta$$

$$V_p I_p = V_s I_s$$

Quantum, special relativity and nuclear

$$\lambda = \frac{h}{mv}$$

$$K_{max} = hf - \phi$$

$$\lambda_{max} = \frac{b}{T}$$

$$E = mc^2$$

$$E = hf$$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$t = \frac{t_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

$$l = l_0\sqrt{\left(1 - \frac{v^2}{c^2}\right)}$$

$$p_v = \frac{m_0 v}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

$$N_t = N_0 e^{-\lambda t}$$

$$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$$

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.
Elements with no reported values in the table have no stable nuclides.
Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).
The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.