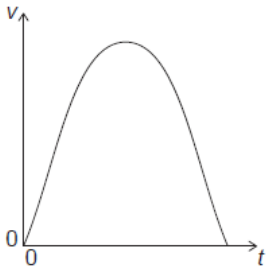
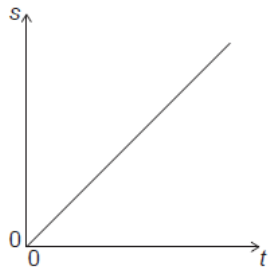
Circular motion and gravity *[162 marks]*

1. The graph shows the variation of speed v of an object with time t. *[1 mark]*

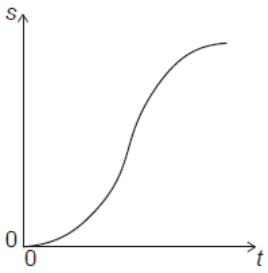


Which graph shows how the distance s travelled by the object varies with t?

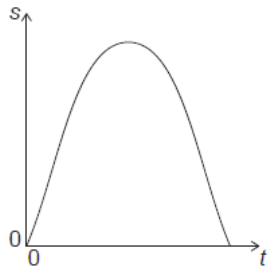
A.



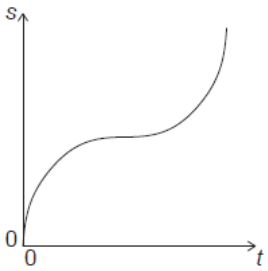
B.



C.



D.



2. A ball is tossed vertically upwards with a speed of 5.0 m s^{-1}. After how many seconds will the ball return to its initial position? *[1 mark]*

A. 0.50 s

B. 1.0 s

C. 1.5 s

D. 2.0 s

3. A projectile is fired horizontally from the top of a cliff. The projectile hits the ground 4 s later at a distance of 2 km from the base of the cliff. What is the height of the cliff? *[1 mark]*

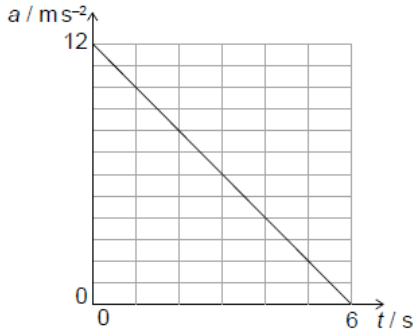
A. 40 m

B. 80 m

C. 120 m

D. 160 m

4. The graph shows the variation of the acceleration a of an object with time *t*. *[1 mark]*



What is the change in speed of the object shown by the graph?

A. 0.5 m s^{-1}

B. 2.0 m s^{-1}

C. 36 m s^{-1}

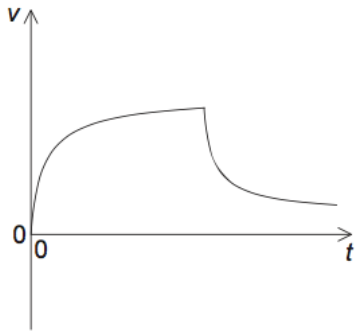
D. 72 m s^{-1}

5. An object of weight *W* is falling vertically at a constant speed in a fluid. What is the magnitude of the drag force acting on the object? *[1 mark]*

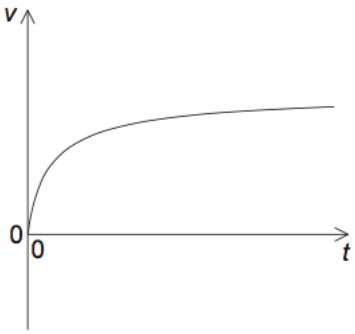
A. 0
B. $\frac{W}{2}$
C. *W*
D. 2*W*

6. An aircraft is moving horizontally. A parachutist leaves the aircraft and a few seconds later opens her parachute. Which graph shows the variation of the vertical speed *v* with time *t* for the parachutist from the time she leaves the aircraft until just before landing? *[1 mark]*

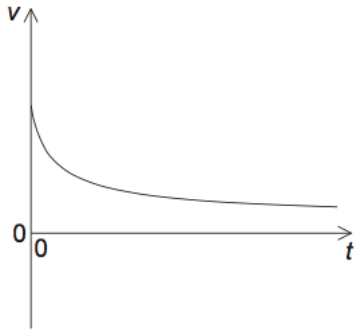
A.



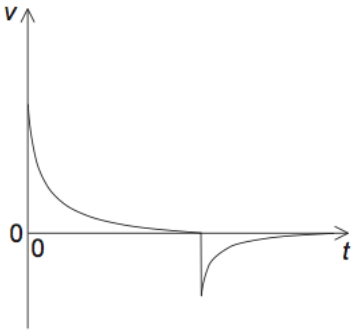
B.



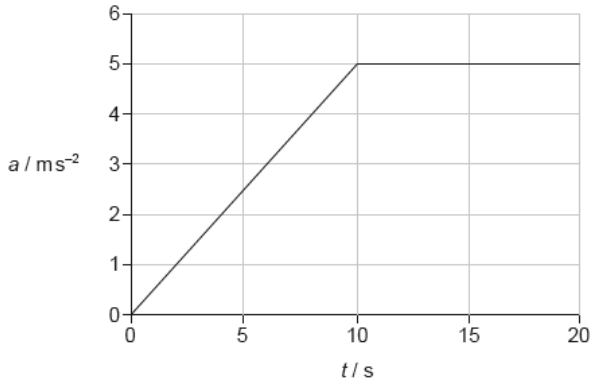
C.



D.



7. An object is at rest at time $t = 0$. The variation with t of the acceleration a of the object is shown from $t = 0$ to $t = 20$ s. *[1 mark]*



What is the speed of the object when $t = 15$ s?

A. $25\ \mathrm{ms}^{-1}$

B. $50\ \mathrm{ms}^{-1}$

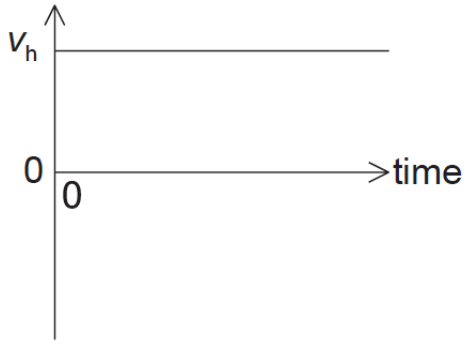
C. $75\ \mathrm{ms}^{-1}$

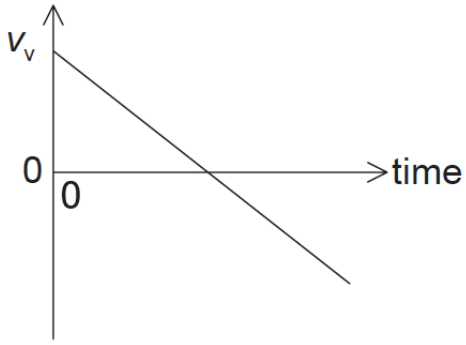
D. $100\ \mathrm{ms}^{-1}$

8. A tennis ball is released from rest and falls vertically through a small distance in air. What is the change in the speed of the ball and the change in the acceleration of the ball as it falls? *[1 mark]*

	Speed of the ball	Acceleration of the ball
A.	increases	decreases
B.	decreases	increases
C.	increases	increases
D.	decreases	decreases

9. The horizontal component v_h and the vertical component v_v of velocity of an object are shown on the graphs. Air resistance is negligible. *[1 mark]*





These graphs could represent the motion of an object fired from a cliff

A. vertically upwards.

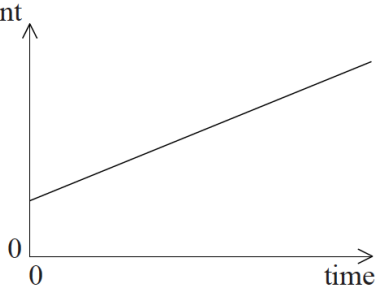
B. at an angle above the horizontal.

C. horizontally.

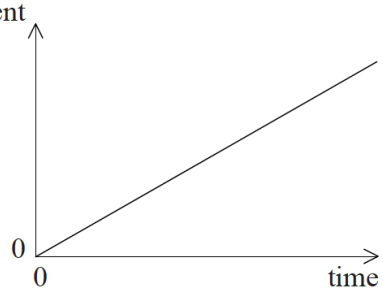
D. at an angle below the horizontal.

10. A body moves on a straight line. The graphs show the variation of displacement with time. Which graph shows motion with negative acceleration? *[1 mark]*

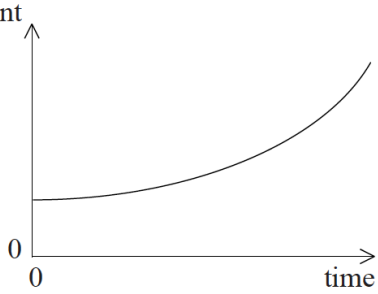
A. displacement



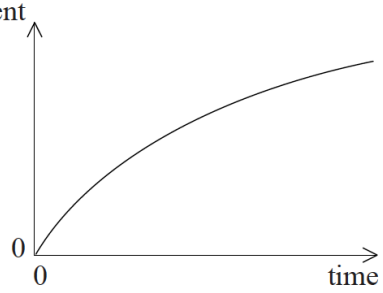
B. displacement



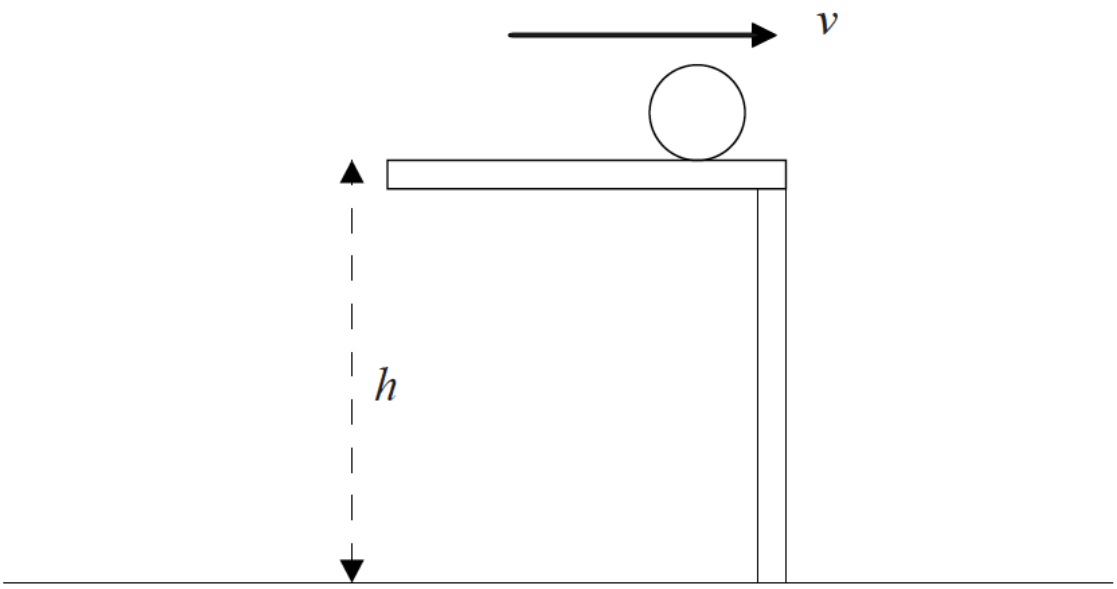
C. displacement



D. displacement



11. A ball of mass m is projected horizontally with speed v from a height h above the floor. Air resistance is negligible. *[1 mark]*



The horizontal distance travelled by the ball to the point where it lands on the floor depends on

A. m and h only.
B. m and v only.
C. h and v only.
D. m, h and v.

12. Two identical balls are dropped from a tall building, one a few seconds after the other. Air resistance is **not** negligible. As the balls fall, the distance between the balls will *[1 mark]*

A. decrease.
B. increase.
C. increase then remain constant.
D. remain constant.

13. An object, initially at rest, travels a distance d in a time t at a constant acceleration. What is the time taken for the object to travel $16d$ from rest at the same acceleration? *[1 mark]*

A. $16t$
B. $8t$
C. $4t$
D. $2t$

14. An object is thrown horizontally from the edge of a high crater on the Moon. The Moon has no atmosphere. Which of the following describes the changes, if any, to the horizontal and vertical components of the velocity of the object? *[1 mark]*

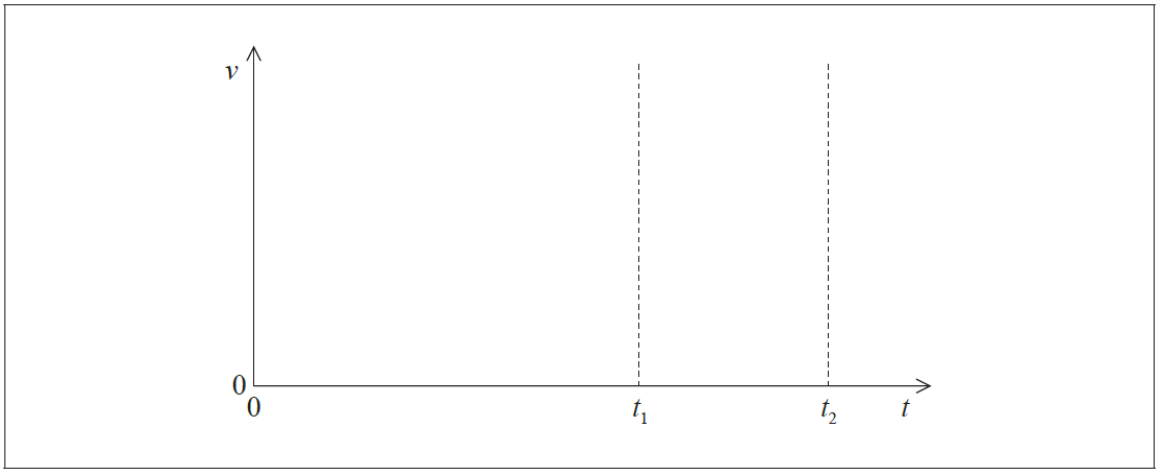
	Horizontal velocity	Vertical velocity
A.	stays constant	increases at a constant rate
B.	decreases	increases at a constant rate
C.	stays constant	increases at a non-constant rate
D.	decreases	increases at a non-constant rate

15a. Fiona drops a stone from rest vertically down a water well. She hears the splash of the stone striking the water 1.6 s after the stone leaves her hand. Estimate the *[3 marks]*

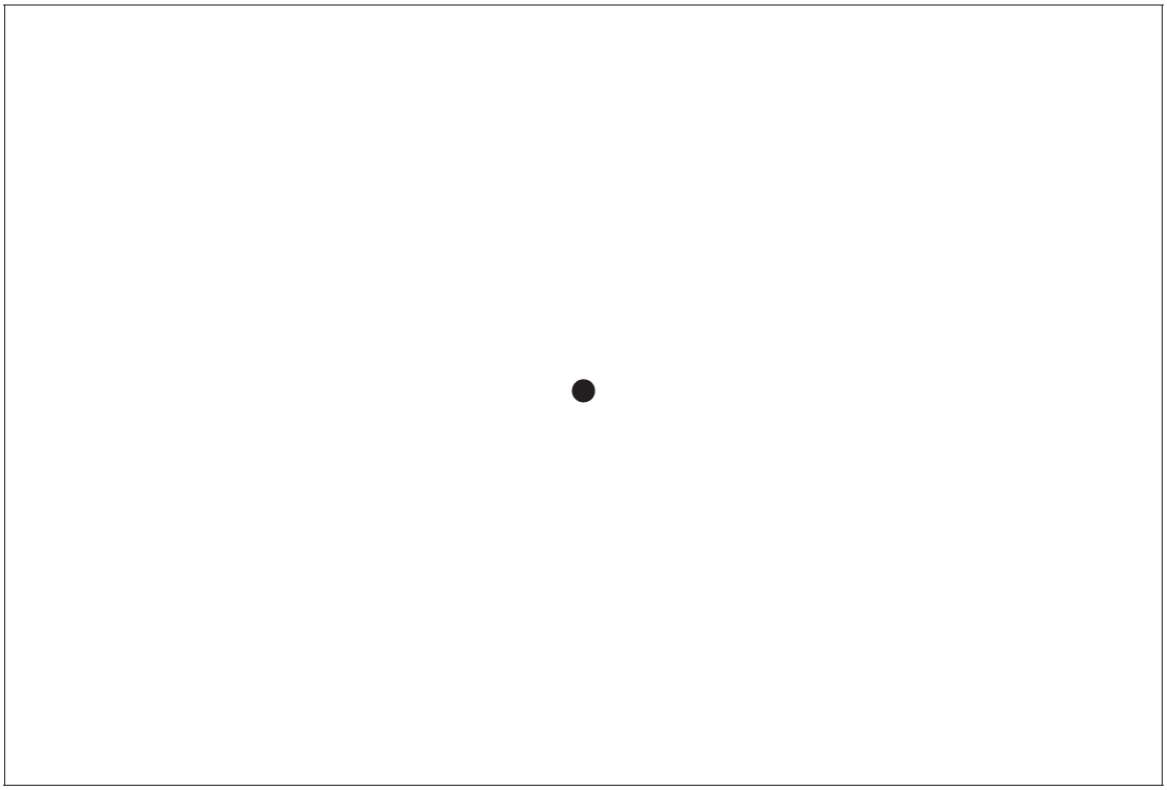
(i) distance between Fiona's hand and the water surface.

(ii) speed with which the stone hits the water.

15b. After the stone in (a) hits the water surface it rapidly reaches a terminal speed as it falls through the water. The stone leaves Fiona's hand at time $t = 0$. It hits the water surface at t_1 and it comes to rest at the bottom of the water at t_2. Using the axes below, sketch a graph to show how the speed v of the stone varies from time $t = 0$ to just before $t = t_2$. (There is no need to add any values to the axes.) *[3 marks]*

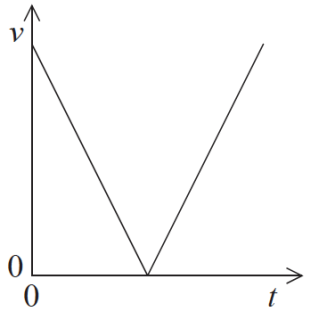


15c. Draw and label a free-body diagram representing the forces acting on the stone as it falls through the water at its terminal speed. *[2 marks]*

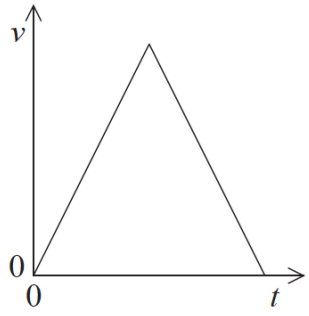


16. An object is thrown upwards leaving the thrower's hand at time t=0. Which graph shows how speed v varies with t as the object rises and falls? *[1 mark]*

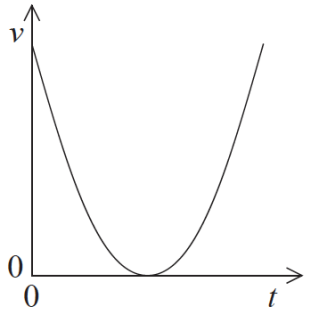
A.



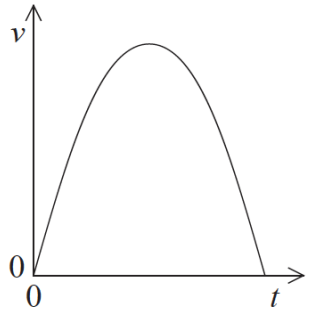
B.



C.



D.



17. A gun fires a bullet of mass m at a horizontal velocity of v. Air resistance on the bullet is negligible. A change in which of the following will affect the time for the bullet to hit the ground? *[1 mark]*

A. m only

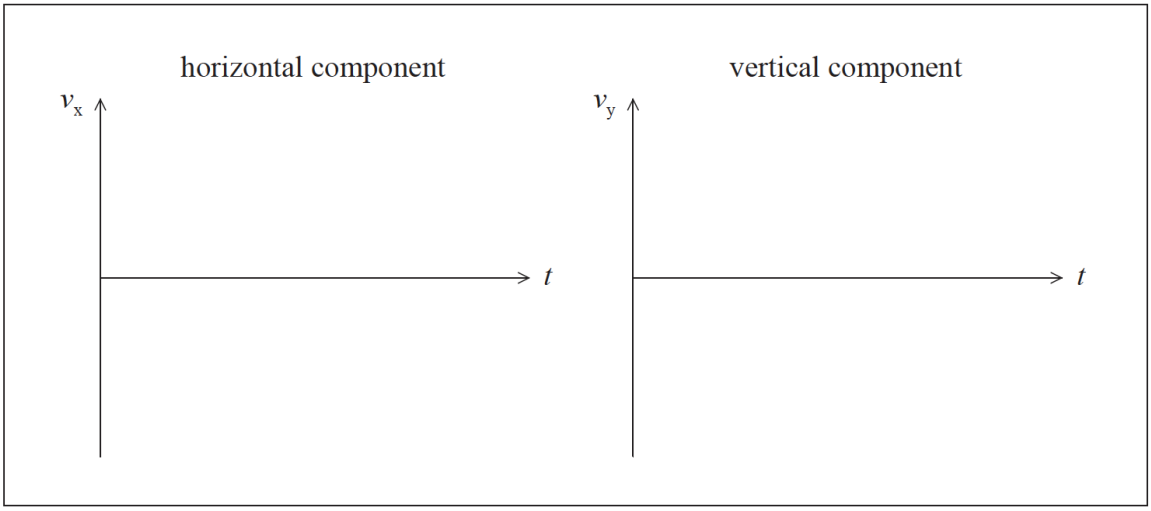
B. v only

C. m and v

D. neither m nor v

18a. (i) State the magnitude of the horizontal component of acceleration of the ball after it leaves the cliff. *[3 marks]*

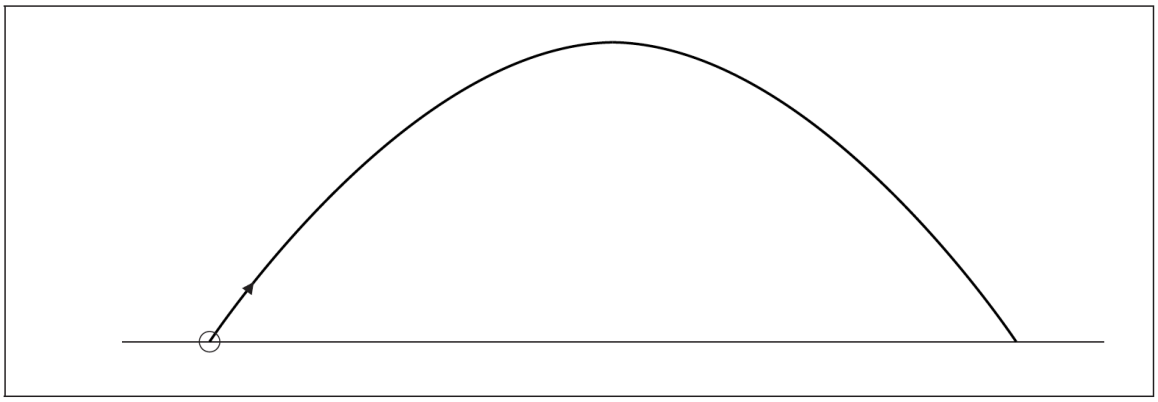
(ii) On the axes below, sketch graphs to show how the horizontal and vertical components of the velocity of the ball, v_x and v_y , change with time t until just before the ball hits the ground. It is not necessary to calculate any values.



18b. (i) Calculate the time taken for the ball to reach the ground. *[4 marks]*

(ii) Calculate the horizontal distance travelled by the ball until just before it reaches the ground.

18c. Another projectile is launched at an angle to the ground. In the absence of air resistance it follows the parabolic path shown below. *[3 marks]*



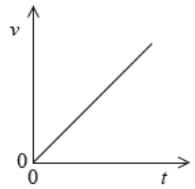
On the diagram above, sketch the path that the projectile would follow if air resistance were not negligible.

19a. Calculate the maximum height reached by the stone as measured from the point where it is thrown. *[2 marks]*

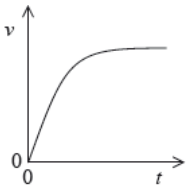
19b. Determine the time for the stone to reach the surface of the sea after leaving Lucy's hand. *[3 marks]*

20. A raindrop falling from rest at time $t = 0$ reaches terminal velocity. Which graph best represents how the speed v varies with time t? *[1 mark]*

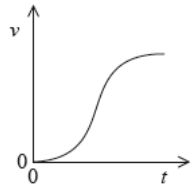
A.



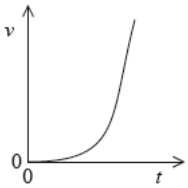
B.



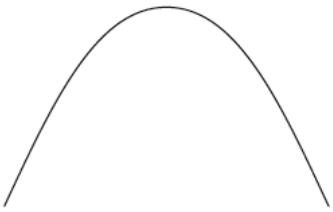
C.



D.

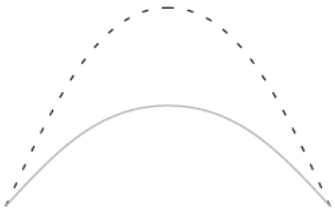


21. The diagram shows the path of a projectile that is launched with velocity v. Air resistance is negligible. *[1 mark]*



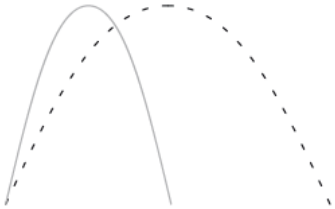
A second projectile has double the mass of the first projectile and is launched with the same velocity. Air resistance is still negligible. Which of the following paths best represents the path of the projectile? *(The original path is shown as a dotted line)*

A.

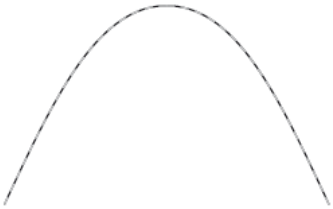


B.

C.



D.



22a. average acceleration of the car in stage 1. *[1 mark]*

22b. average net force required to accelerate the car in stage 2. *[3 marks]*

22c. total distance travelled by the car in 12 s. *[2 marks]*

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23. What is the acceleration of an object rotating with constant speed *v* in a circle of radius *r*? *[1 mark]*

A. Zero

B. $\frac{v^2}{r}$ towards the centre of the circle

C. $\frac{v^2}{r}$ away from the centre of the circle

D. $\frac{v^2}{r}$ along a tangent to the circle

24. The centres of two planets are separated by a distance *R*. The gravitational force between the two planets is *F*. What will be the force between the planets when their separation increases to 3*R*? *[1 mark]*

A. $\frac{F}{9}$

B. $\frac{F}{3}$

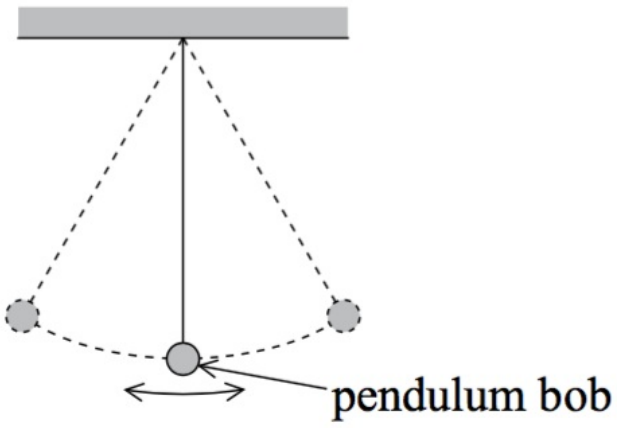
C. *F*

D. 3*F*

25. The acceleration of free fall of a mass of 2.0 kg close to the surface of Mars is 3.6 ms^{-2}. What is the gravitational field strength at the surface of Mars in N kg^{-1}? *[1 mark]*

A. 1.8
B. 3.6
C. 7.2
D. 9.8

26. A pendulum bob is attached to a light string and is swinging in a vertical plane. *[1 mark]*



At the lowest point of the motion, the magnitude of the tension in the string is

A. less than the weight of the mass of the pendulum bob.
B. zero.
C. greater than the weight of the mass of the pendulum bob.
D. equal to the weight of the mass of the pendulum bob.

27. A spherical planet of uniform density has three times the mass of the Earth and twice the average radius. The magnitude of the gravitational field strength at the surface of the Earth is *g*. What is the gravitational field strength at the surface of the planet? *[1 mark]*

A. 6 *g*
B. $\frac{2}{3}g$
C. $\frac{3}{4}g$
D. $\frac{3}{2}g$

28a. (i) On the diagram above, draw and label arrows to represent the forces on the ball in the position shown. *[4 marks]*

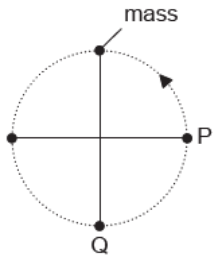
(ii) State and explain whether the ball is in equilibrium.

28b. Determine the speed of rotation of the ball. *[3 marks]*

29. The mass of a planet is twice that of Earth. Its radius is half that of the radius of Earth. The gravitational field strength at the surface of Earth is *g*. The gravitational field strength at the surface of the planet is *[1 mark]*

A. $\frac{1}{2}g$.
B. g.
C. $2g$.
D. $8g$.

30. A mass attached to a string rotates in a gravitational field with a constant period in a vertical plane. *[1 mark]*



How do the tension in the string and the kinetic energy of the mass compare at P and Q?

	Tension in the string	Kinetic energy of mass
A.	greater at P than Q	greater at Q than P
B.	greater at Q than P	greater at Q than P
C.	greater at P than Q	same at Q and P
D.	greater at Q than P	same at Q and P

31. A satellite X of mass *m* orbits the Earth with a period *T*. What will be the orbital period of satellite Y of mass *2m* occupying the same orbit as X? *[1 mark]*

A. $\frac{T}{2}$

B. T

C. $\sqrt{2T}$

D. $2T$

32a. Determine the orbital period for the satellite. *[3 marks]*

Mass of Earth = 6.0×10^{24} kg

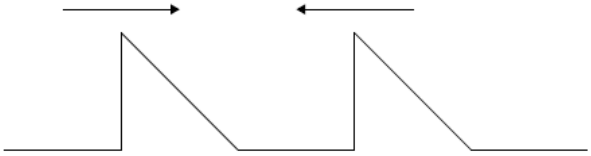
32b. Determine the mean temperature of the Earth. *[2 marks]*

32c. Suggest how the difference between λ_S and λ_E helps to account for the greenhouse effect. *[3 marks]*

32d. Not all scientists agree that global warming is caused by the activities of man. *[1 mark]*

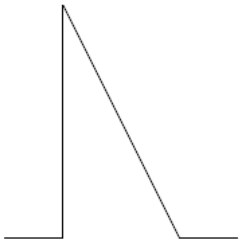
Outline how scientists try to ensure agreement on a scientific issue.

33. Two pulses are travelling towards each other. *[1 mark]*

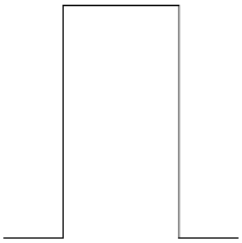


What is a possible pulse shape when the pulses overlap?

A.

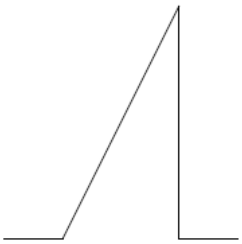


B.

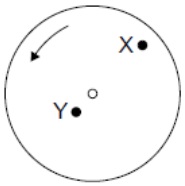


C.

D.



34. A horizontal disc rotates uniformly at a constant angular velocity about a central axis normal to the plane of the disc. *[1 mark]*



Point X is a distance 2*L* from the centre of the disc. Point Y is a distance *L* from the centre of the disc. Point Y has a linear speed *v* and a centripetal acceleration *a*.

What is the linear speed and centripetal acceleration of point X?

	Linear speed of X	Centripetal acceleration of X
A.	*v*	*a*
B.	2v	2*a*
C.	*v*	2*a*
D.	2v	4*a*

35. An object of constant mass is tied to the end of a rope of length l and made to move in a horizontal circle. The speed of the object is increased until the rope breaks at speed v. The length of the rope is then changed. At what other combination of rope length and speed will the rope break? *[1 mark]*

	Rope length	Speed
A.	$4l$	$2v$
B.	$2l$	v
C.	$2l$	$\frac{v}{2}$
D.	$4l$	$\frac{v}{2}$

36. Two satellites of mass m and $2m$ orbit a planet at the same orbit radius. If F is the force exerted on the satellite of mass m by the planet and a is the centripetal acceleration of this satellite, what is the force and acceleration of the satellite with mass $2m$? *[1 mark]*

	Force	Acceleration
A.	$2F$	a
B.	$2F$	$\frac{a}{2}$
C.	F	a
D.	F	$\frac{a}{2}$

37. The gravitational field strength at the surface of Earth is g. Another planet has double the radius of Earth and the same density as Earth. What is the gravitational field strength at the surface of this planet? *[1 mark]*

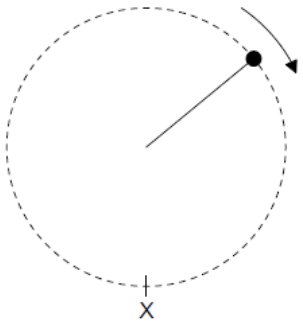
A. $\frac{g}{2}$

B. $\frac{g}{4}$

C. $2g$

D. $4g$

38. A small ball of weight W is attached to a string and moves in a vertical circle of radius R. *[1 mark]*



What is the smallest kinetic energy of the ball at position X for the ball to maintain the circular motion with radius R?

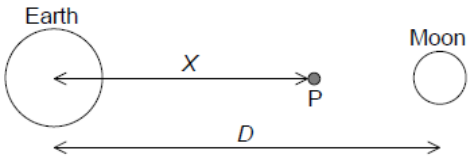
A. $\frac{WR}{2}$

B. WR

C. $2WR$

D. $\frac{5WR}{2}$

39. The centre of the Earth is separated from the centre of the Moon by a distance *D*. Point P lies on a line joining the centre of the Earth and the centre of the Moon, a distance *X* from the centre of the Earth. The gravitational field strength at P is zero. *[1 mark]*



What is the ratio $\frac{\text{mass of the Moon}}{\text{mass of the Earth}}$?

A. $\frac{(D-X)^2}{X^2}$

B. $\frac{(D-X)}{X}$

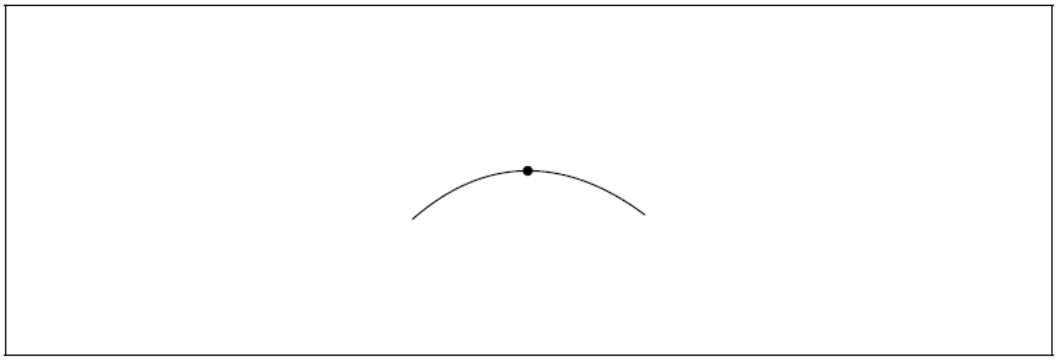
C. $\frac{X^2}{(D-X)^2}$

D. $\frac{X}{D-X}$

40a. From A to B, 24 % of the gravitational potential energy transferred to kinetic energy. Show that the velocity at B is 12 m s $^{-1}$. *[2 marks]*

40b. Some of the gravitational potential energy transferred into internal energy of the skis, slightly increasing their temperature. Distinguish between internal energy and temperature. *[2 marks]*

40c. The dot on the following diagram represents the skier as she passes point B. Draw and label the vertical forces acting on the skier. *[2 marks]*



40d. The hill at point B has a circular shape with a radius of 20 m. Determine whether the skier will lose contact with the ground at point B. *[3 marks]*

40e. The skier reaches point C with a speed of 8.2 m s^{-1}. She stops after a distance of 24 m at point D. *[3 marks]*

Determine the coefficient of dynamic friction between the base of the skis and the snow. Assume that the frictional force is constant and that air resistance can be neglected.

40f. Calculate the impulse required from the net to stop the skier and state an appropriate unit for your answer. *[2 marks]*

40g. Explain, with reference to change in momentum, why a flexible safety net is less likely to harm the skier than a rigid barrier. *[2 marks]*

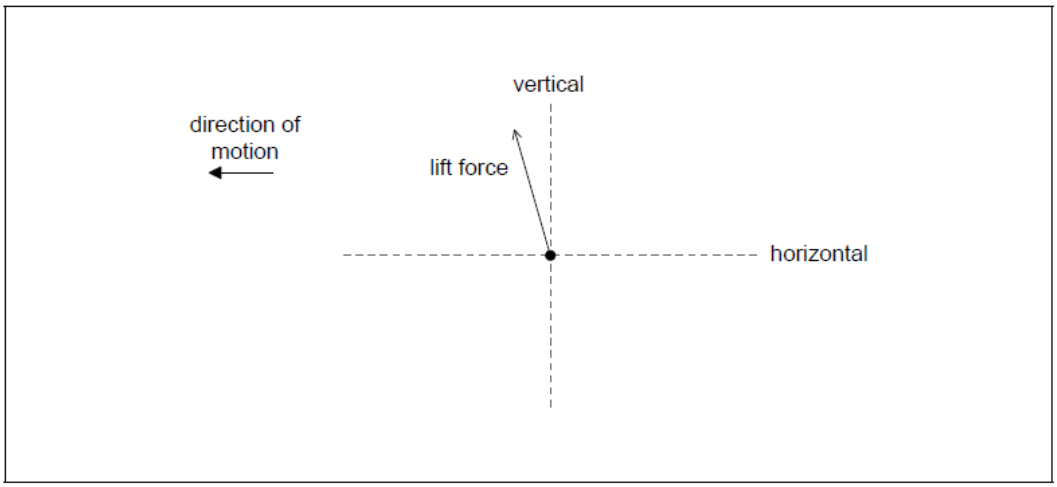
41a. The glider reaches its launch speed of 27.0 m s^{-1} after accelerating for 11.0 s. Assume that the glider moves horizontally until it leaves the ground. Calculate the total distance travelled by the glider before it leaves the ground. *[2 marks]*

41b. The glider and pilot have a total mass of 492 kg. During the acceleration the glider is subject to an average resistive force of 160 N. Determine the average tension in the cable as the glider accelerates. *[3 marks]*

41c. The cable is pulled by an electric motor. The motor has an overall efficiency of 23 %. Determine the average power input to the motor. *[3 marks]*

41d. The cable is wound onto a cylinder of diameter 1.2 m. Calculate the angular velocity of the cylinder at the instant when the glider has a speed of 27 m s^{-1}. Include an appropriate unit for your answer. *[2 marks]*

41e. After takeoff the cable is released and the unpowered glider moves horizontally at constant speed. The wings of the glider provide a lift force. The diagram shows the lift force acting on the glider and the direction of motion of the glider. *[2 marks]*



Draw the forces acting on the glider to complete the free-body diagram. The dotted lines show the horizontal and vertical directions.

41f. Explain, using appropriate laws of motion, how the forces acting on the glider maintain it in level flight. *[2 marks]*

41g. At a particular instant in the flight the glider is losing 1.00 m of vertical height for every 6.00 m that it goes forward horizontally. At this instant, the horizontal speed of the glider is 12.5 m s^{-1}. Calculate the **velocity** of the glider. Give your answer to an appropriate number of significant figures. *[3 marks]*

42. An object at the end of a wooden rod rotates in a vertical circle at a constant angular velocity. What is correct about the tension in the rod? *[1 mark]*

A. It is greatest when the object is at the bottom of the circle.
B. It is greatest when the object is halfway up the circle.
C. It is greatest when the object is at the top of the circle.
D. It is unchanged throughout the motion.

43. On Mars, the gravitational field strength is about $\frac{1}{4}$ of that on Earth. The mass of Earth is approximately ten times that of Mars. *[1 mark]*

What is $\frac{\text{radius of Earth}}{\text{radius of Mars}}$?

A. 0.4

B. 0.6

C. 1.6

D. 2.5

44a. (i) Define *gravitational field strength.* *[2 marks]*

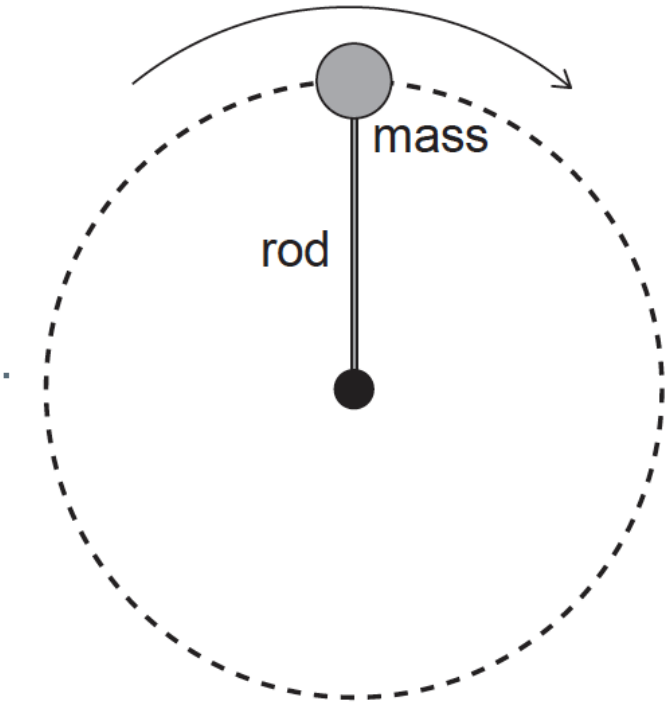
(ii) State the SI unit for gravitational field strength.

44b. A planet orbits the Sun in a circular orbit with orbital period *T* and orbital radius *R*. The mass of the Sun is *M*. *[4 marks]*

(i) Show that $T = \sqrt{\frac{4\pi^2 R^3}{GM}}$.

(ii) The Earth's orbit around the Sun is almost circular with radius 1.5×10^{11} m. Estimate the mass of the Sun.

45. A mass connected to one end of a rigid rod rotates at constant speed in a vertical plane about the other end of the rod. *[1 mark]*



The force exerted by the rod on the mass is

A. zero everywhere.

B. constant in magnitude.

C. always directed towards the centre.

D. a minimum at the top of the circular path.

46. Planet X has mass M and radius R. Planet Y has mass $2M$ and radius $3R$. The gravitational field strength at the surface of planet X is g. What is the gravitational field strength at the surface of planet Y? *[1 mark]*

A. $\frac{2}{9}g$

B. $\frac{2}{3}g$

C. $\frac{3}{2}g$

D. $\frac{9}{2}g$

47a. Show that the gravitational field strength at the position of the planet due to **one** of the stars is $g=3.7\times10^{-4}\text{Nkg}^{-1}$. *[1 mark]*

47b. Calculate the magnitude of the resultant gravitational field strength at the position of the planet. *[2 marks]*

48a. On the diagram above, draw **two** arrows to show the gravitational field strength at the position of the planet due to each of the stars. *[2 marks]*

48b. Calculate the magnitude and state the direction of the resultant gravitational field strength at the position of the planet. *[3 marks]*

49. What is the correct definition of gravitational field strength? *[1 mark]*

A. The mass per unit weight

B. The weight of a small test mass

C. The force acting on a small test mass

D. The force per unit mass acting on a small test mass

50. The Earth is a distance r_S from the Sun. The Moon is a distance r_M from the Earth. *[1 mark]*

The ratio $\frac{\text{gravitational field strength at the Earth due to the Sun}}{\text{gravitational field strength at the Earth due to the Moon}}$ is proportional to

A. $\frac{r_M}{r_S}$

B. $\frac{r_S}{r_M}$

C. $\frac{r_S^2}{r_M^2}$.

D. $\frac{r_M^2}{r_S^2}$

51a. Outline why Phobos moves with uniform circular motion. *[3 marks]*

51b. Show that the orbital speed of Phobos is about $2\ \text{km}\,\text{s}^{-1}$. *[2 marks]*

51c. Deduce the mass of Mars. *[3 marks]*

52. Which single condition enables Newton's universal law of gravitation to be used to predict the force between the Earth and the Sun? *[1 mark]*

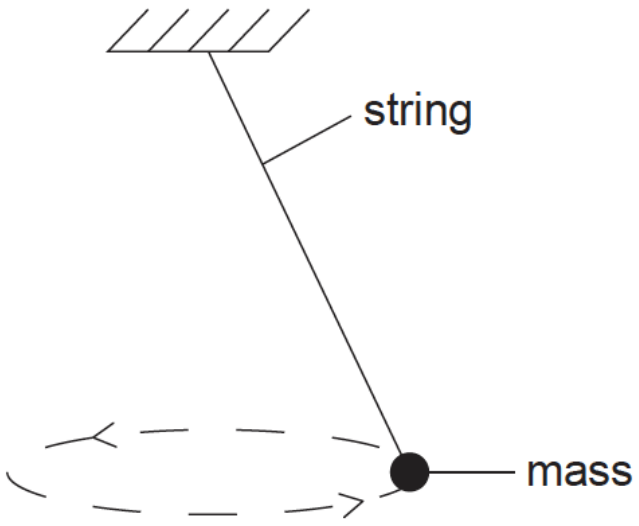
A. The Earth and the Sun both have a very large radius.

B. The distance between the Earth and the Sun is approximately constant.

C. The Earth and the Sun both have a very large mass.

D. The Earth and the Sun behave as point masses.

53. A mass is suspended by a string from a fixed point. The mass moves with constant speed along a circular path in a horizontal plane. *[1 mark]*



The resultant force acting on the mass is

A. zero.

B. directed upwards along the string.

C. directed towards the centre of the circular path.

D. in the same direction as the velocity of the mass.

54. A planet has half the mass and half the radius of the Earth. What is the gravitational field strength at the surface of the planet? The gravitational field strength at the surface of the Earth is 10 N kg^{-1}. *[1 mark]*

A. 2.5 N kg^{-1}

B. 5.0 N kg^{-1}

C. 10 N kg^{-1}

D. 20 N kg^{-1}

55a. Outline, with reference to the energy of the rocket, why the speed of the rocket is changing between P and Q. *[2 marks]*

55b. Estimate the average gravitational field strength of the planet between P and Q. *[2 marks]*

55c. A space station is in orbit at a distance *r* from the centre of the planet in (e)(i). A satellite is launched from the space station so as just to escape from the gravitational field of the planet. The launch takes place in the same direction as the velocity of the space station. Outline why the launch velocity relative to the space station can be less than your answer to (e)(i). *[1 mark]*

56. What is the definition of gravitational field strength at a point? *[1 mark]*

A. Force acting per unit mass on a small mass placed at the point.

B. Work done per unit mass on any mass moved to the point.

C. Force acting on a small mass placed at the point.

D. Work done on any mass moved to the point.

57. An object rotates in a horizontal circle when acted on by a centripetal force *F*. What is the centripetal force acting on the object when the radius of the circle doubles and the kinetic energy of the object halves? *[1 mark]*

A. $\frac{F}{4}$

B. $\frac{F}{2}$

C. *F*

D. 4*F*

58. An object rotates in a horizontal circle when acted on by a centripetal force *F*. What is the centripetal force acting on the object when the radius of the circle doubles and the kinetic energy of the object halves? *[1 mark]*

A. $\frac{F}{4}$

B. $\frac{F}{2}$

C. *F*

D. 4*F*

59. The maximum speed with which a car can take a circular turn of radius *R* is *v*. The maximum speed with which the same car, under the same conditions, can take a circular turn of radius 2*R* is *[1 mark]*

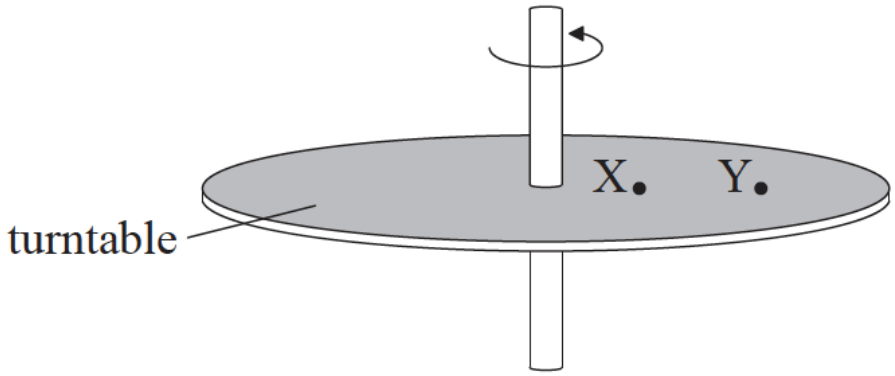
A. 2*v*.

B. $v\sqrt{2}$.

C. 4*v*.

D. $2v\sqrt{2}$.

60. Two particles, X and Y, are attached to the surface of a horizontally mounted turntable. *[1 mark]*



The turntable rotates uniformly about a vertical axis. The magnitude of the linear velocity of X is v and the magnitude of its acceleration is a. Which of the following correctly compares the magnitude of the velocity of Y and the magnitude of the acceleration of Y with v and a respectively?

	Magnitude of velocity of Y	Magnitude of acceleration of Y
A.	equal to v	less than a
B.	greater than v	less than a
C.	equal to v	greater than a
D.	greater than v	greater than a

61. A body moves with uniform speed around a circle of radius r. The period of the motion is T. What is the speed of the body? *[1 mark]*

A. $\frac{2\pi r}{T}$

B. $\frac{2\pi T}{r}$

C. Zero

D. $\frac{\pi r^2}{T}$

62. The magnitude of the gravitational field strength at the surface of a planet of mass M and radius R is g. What is the magnitude of the gravitational field strength at the surface of a planet of mass $2M$ and radius $2R$? *[1 mark]*

A. $\frac{g}{4}$

B. $\frac{g}{2}$

C. g

D. $2g$

63. A car on a road follows a horizontal circular path at constant speed. Which of the following correctly identifies the origin and the direction of the net force on the car? *[1 mark]*

	Origin	Direction
A.	car engine	toward centre of circle
B.	car engine	away from centre of circle
C.	friction between car tyres and road	away from centre of circle
D.	friction between car tyres and road	toward centre of circle

64a. Explain why the car is accelerating even though it is moving with a constant speed. *[2 marks]*

64b. On the diagram, draw and label the vertical forces acting on the car in the position shown. *[2 marks]*

64c. Calculate the maximum speed at which the car will stay in contact with the bridge. *[3 marks]*