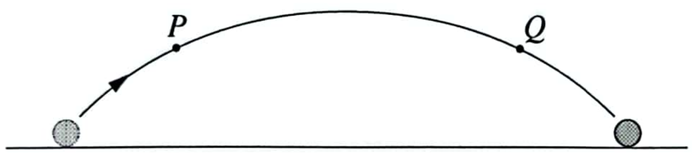
Questions

Module 5: Advanced Mechanics

5.1 Projectile Motion

Multiple-choice questions: 1 mark each

1. The diagram shows the trajectory of a golf ball.

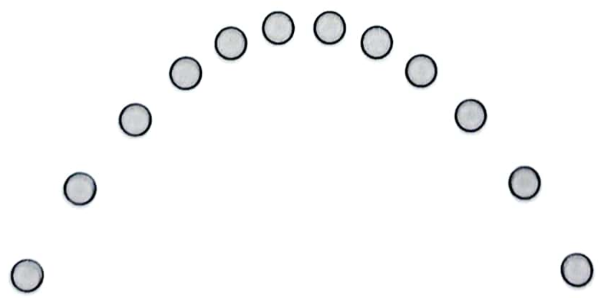


Which set of arrows shows the direction of the acceleration of the ball at points *P* and *Q* respectively?

	At P	*At Q*
(A)	↑	↓
(B)	↓	↓
(C)	↗	↘
(D)	↙	↘

2002 HSC Q1

2. A ball thrown in the air traces a path as shown below.



Which of the following statements is true?

(A) The velocity of the ball keeps changing.

(B) The acceleration of the ball keeps changing.

(C) The velocity of the ball at the top of its motion is zero.

(D) The acceleration of the ball at the top of its motion is zero.

2005 HSC Q1

3. A marble rolls off a 1.0 m high horizontal table with an initial velocity of 4.0 m s^{-1}.

How long will it take the marble to hit the floor?

(A) 0.20 s

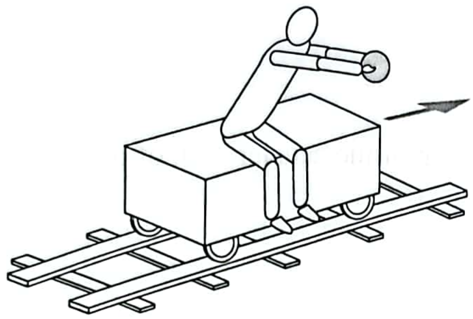
(B) 0.25 s

(C) 0.45 s

(D) 3.20 s

2011 HSC Q15

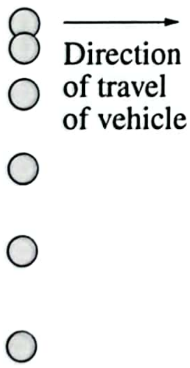
4. A ball is dropped by a person sitting on a vehicle that is accelerating uniformly to the right, as shown by the arrow.



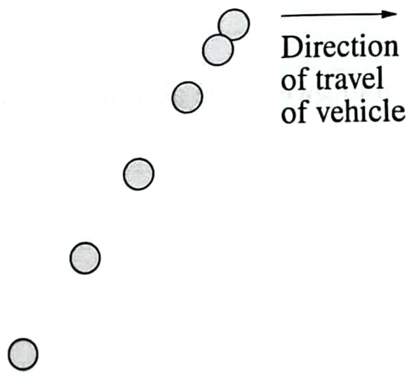
Ignore air resistance

Which of the following represents the path of the ball, shown at equal time intervals, observed from the frame of reference of the vehicle?

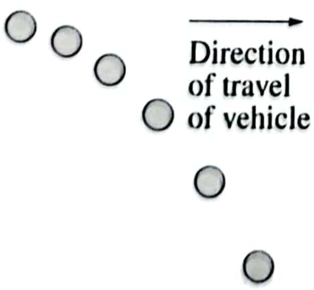
(A)



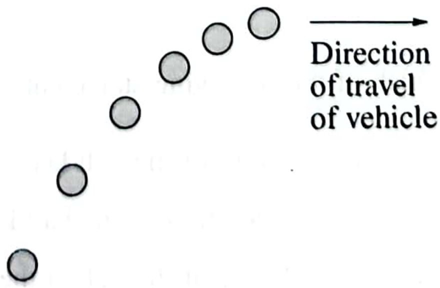
(B)



(C)

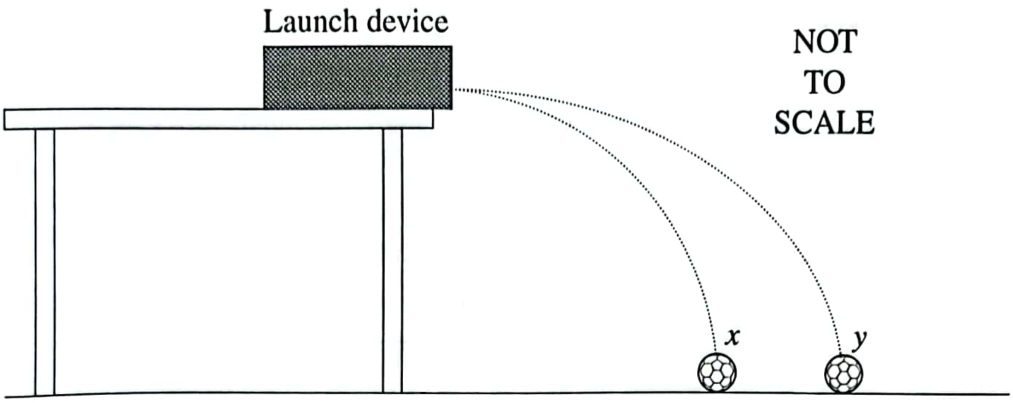


(D)



2004 HSC Q6

5. A device launches two identical balls (x and y) simultaneously in a horizontal direction from the same height. The results are shown.



Which statement correctly describes what happens?

(A) x hits the ground before y as it is closer to the launch site.

(B) y hits the ground before x as it has a higher launch velocity.

(C) x and y hit the ground simultaneously with the same velocity.

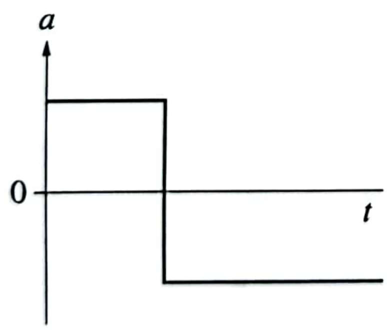
(D) x and y hit the ground simultaneously with different velocities.

2009 HSC Q4

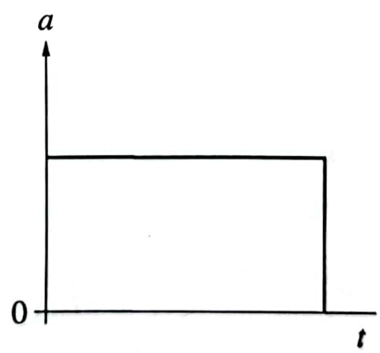
6. A stone is thrown horizontally from the top of a cliff and falls onto the beach below.

Which acceleration–time graph best describes the motion of the stone?

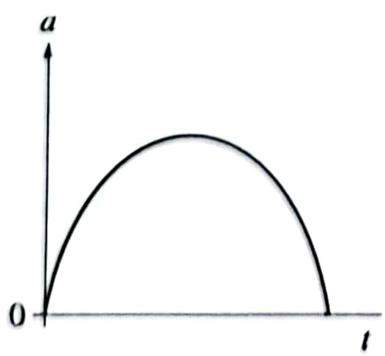
(A)



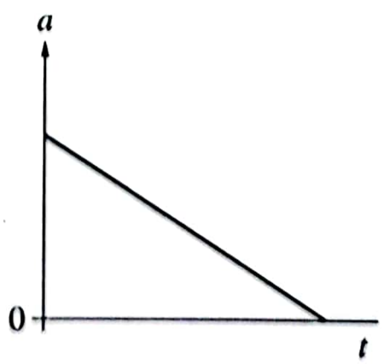
(B)



(C)



(D)

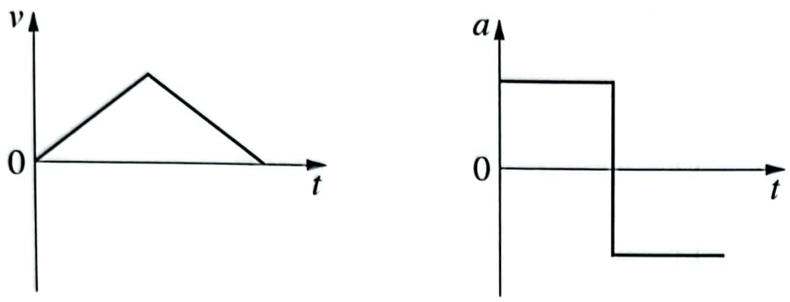


2006 HSC Q4

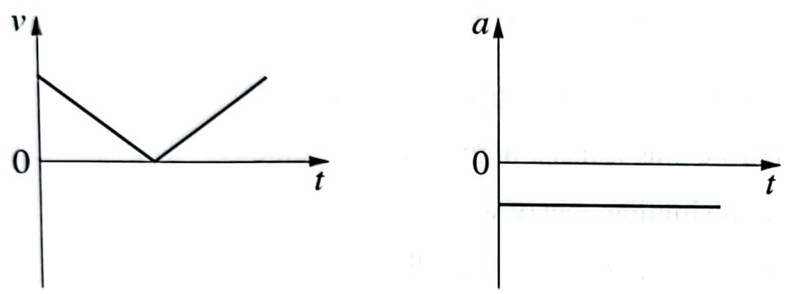
7. A cannon ball is fired vertically upward from a stationary boat.

Which pair of graphs best describes the velocity, v, and acceleration, a, of the cannon ball as functions of time, t? Ignore air resistance.

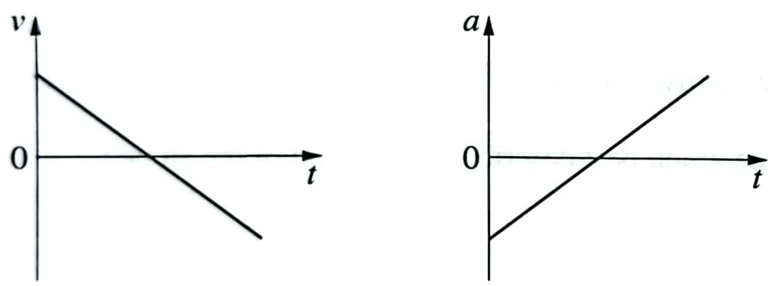
(A)



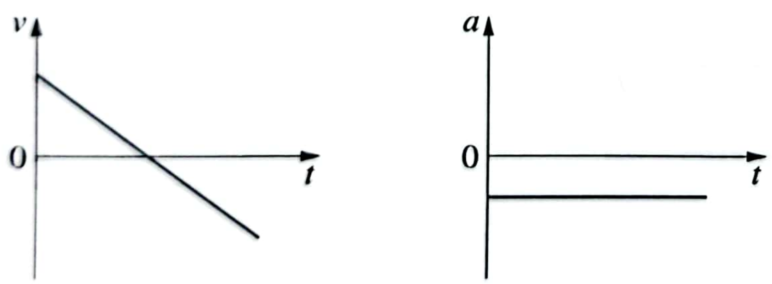
(B)



(C)



(D)



2007 HSC Q5

8. Which of the following best describes Galileo's analysis of projectile motion?

(A) A projectile launched with a great enough velocity would escape Earth's gravity.

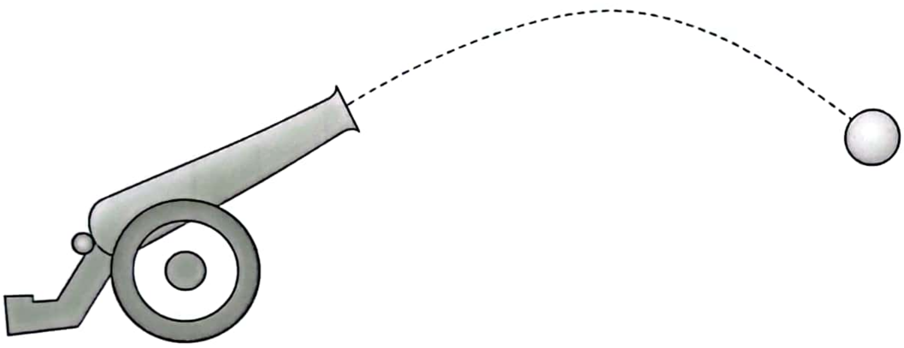
(B) A projectile would travel in a straight line until it ran out of momentum, then it would fall.

(C) A projectile launched from the equator towards the east with a great enough velocity would orbit Earth.

(D) A projectile would travel in a parabolic path because it has constant horizontal velocity and constant vertical acceleration.

2010 HSC Q2

9. This diagram shows the path of a cannonball, fired from a cannon.



Which set of vectors represents the horizontal and vertical components of the cannonball's velocity along the path?

	Horizontal				*Vertical*			
(A)	$\longrightarrow$	$\rightarrow$	$\rightarrow$	$\longrightarrow$	$\Big\downarrow$	$\Big\downarrow$	$\Big\downarrow$	$\Big\downarrow$
(B)	$\longrightarrow$	$\rightarrow$	$\rightarrow$	$\longrightarrow$	$\Big\uparrow$	$\uparrow$	$\downarrow$	$\Big\downarrow$
(C)	$\longrightarrow$	$\longrightarrow$	$\longrightarrow$	$\longrightarrow$	$\Big\uparrow$	$\uparrow$	$\downarrow$	$\Big\downarrow$
(D)	$\longrightarrow$	$\longrightarrow$	$\longrightarrow$	$\longrightarrow$	$\Big\downarrow$	$\Big\downarrow$	$\Big\downarrow$	$\Big\downarrow$

2013 HSC Q6

10. A ball is thrown vertically upwards with an initial speed u. It rises to a height h and falls back to the thrower. The time of flight is t.

An identical second ball is also thrown vertically, but with an initial speed $2u$. It rises to a height $4h$ and falls back to the thrower. What is the time of flight?

(A) $t/2$

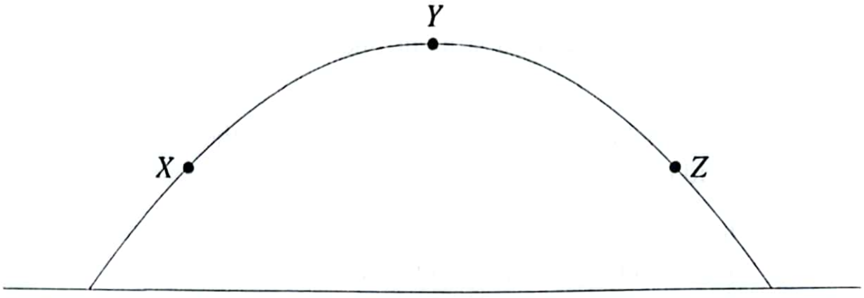
(B) t

(C) $2t$

(D) $4t$

Adapted 1982 HSC Q6

11. A ball is thrown from S at an angle to the horizontal as shown in the diagram below.



X, Y and Z are different positions along the ball's trajectory.

Which of the following best represents the velocity and acceleration of the ball?

	VELOCITY			ACCELERATION		
	X	Y	Z	X	Y	Z
(A)	↑	zero	↓	↓	zero	↓
(B)	↗	→	↘	↑	zero	↓
(C)	↗	→	↘	↓	↓	↓
(D)	↗	→	↘	↗	zero	↘

1995 HSC Q1

12. Napoleon attacked Moscow in 1812 with his cannon firing a shot at an elevation angle of 40°. Napoleon then decided to fire a second shot at the same speed but at an elevation angle of 50°.

Which of the following observations would Napoleon expect to be true about the second shot when compared with the first?

(A) Longer range

(B) Shorter range

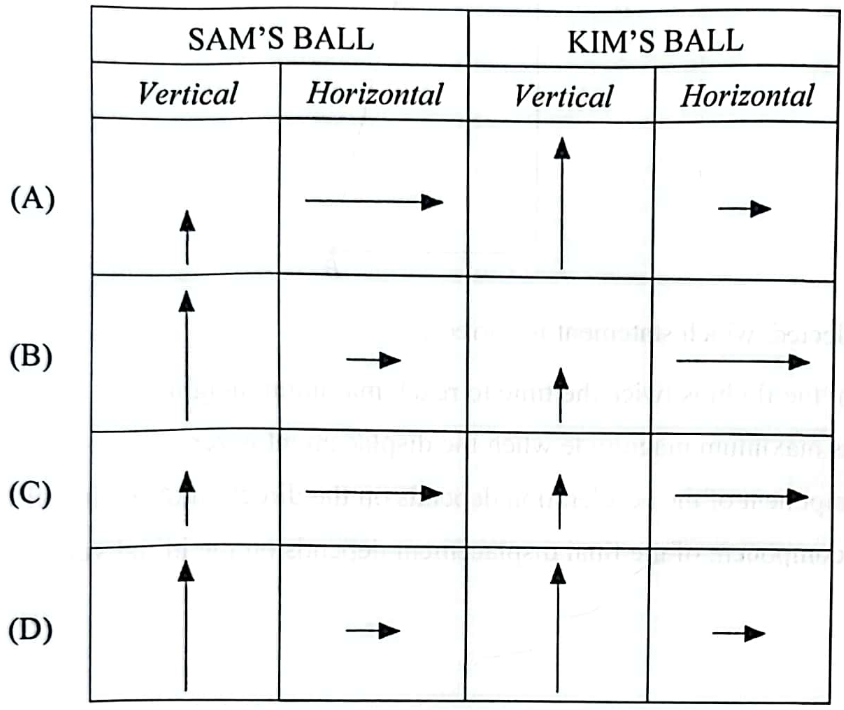
(C) Longer time of flight

(D) Shorter time of flight

2005 HSC Q5

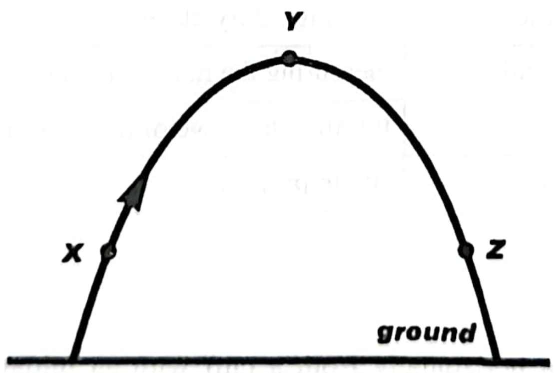
13. Two golfers, Sam and Kim, used different golf clubs to hit identical golf balls from the same place. Sam's ball went higher than Kim's ball, but both golf balls first hit the ground 100 m away.

Which set of vectors below best represents the horizontal and vertical components of the initial velocity of the two balls?



1997 HSC Q3

14. An object is projected upwards from the ground, and follows a path represented in the diagram below.



Which statement below correctly describes the object's acceleration?

(A) At point X, it is equal to that a point Y.

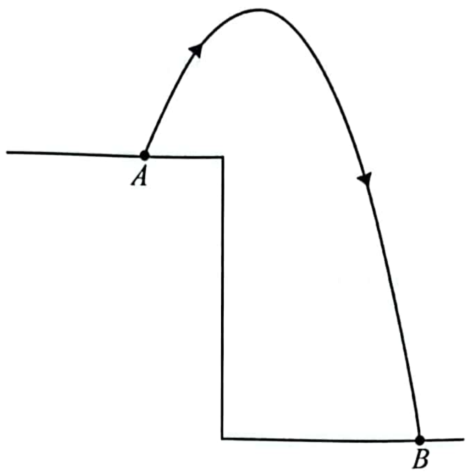
(B) At point X, it is less to that a point Z.

(C) At point Y, it is less to that a point X.

(D) At point Y, it is less to that a point Z.

1985 HSC Q1 (adapted)

15. A projectile follows a parabolic arc from point A to point B in the diagram below. The displacement of the projectile is measured from the launch point.



If air resistance is neglected, which statement is correct?

(A) The total time of the flight is twice the time to reach maximum height.

(B) The velocity has maximum magnitude when the displacement is zero.

(C) The vertical component of the acceleration depends on the direction of the initial velocity.

(D) The horizontal component of the final displacement depends on the initial velocity.

1998 HSC Q3

16. Students performed an investigation to determine the initial velocity of a projectile.

Which row correctly identifies a hazard of this investigation and a related precaution?

	Hazard	*Safety precaution*
(A)	flying projectile	wearing safety glasses
(B)	range of projectile	measuring the range with a tape measure
(C)	enclosed shoes	limiting the range of the projectile
(D)	safety glasses	flying projectile

2013 HSC Q4

17. A ball is launched horizontally from a cliff with an initial velocity of u m s^{-1}. After two seconds, the ball's velocity is in the direction 45° from the horizontal.

What is the magnitude of the velocity in m s^{-1} at two seconds?

(A) u

(B) $1.5u$

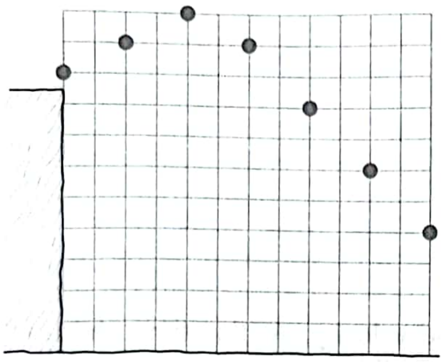
(C) 19.6

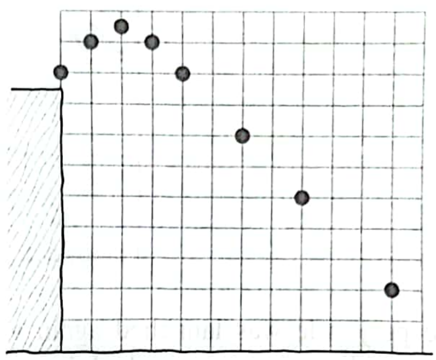
(D) 27.7

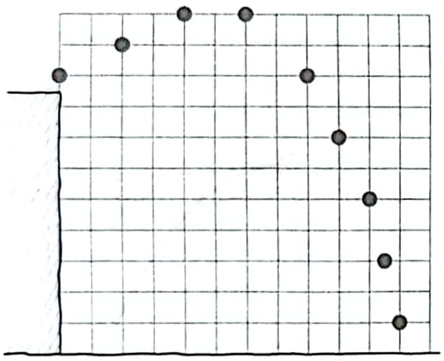
2014 HSC Q20

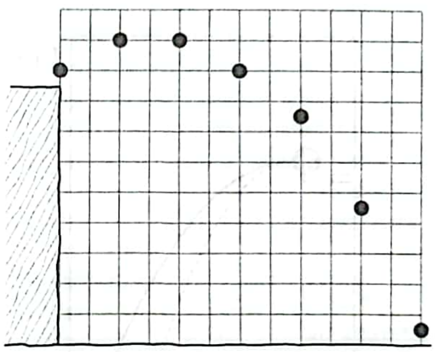
18. A projectile is launched from a cliff top. The dots show the position of the projectile at equal time intervals.

Assuming negligible air resistance, which diagram best shows the path of the projectile?

(A)


(B)


(C)


(D)


2015 HSC Q4

19. An aeroplane is flying horizontally over level ground. It has an altitude of 490 m and a velocity of 100 m s^{-1}. As the aeroplane passes directly above a cross marked on the ground, an object is released from the aeroplane.

How far away from the cross will this object land?

(A) 490 m

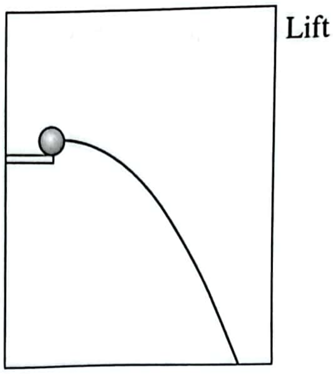
(B) 1000 m

(C) 10 000 m

(D) 49 000 m

2008 HSC Q3

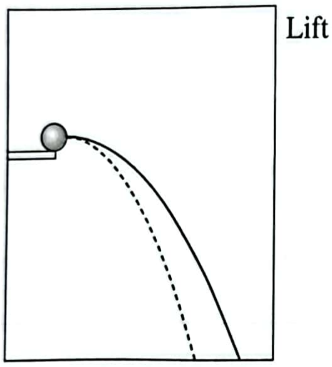
20. A projectile was launched horizontally inside a lift in a building. The diagram shows the path of the projectile when the lift was stationary.



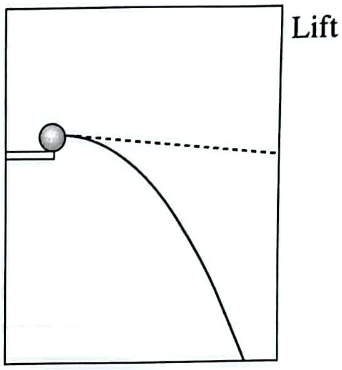
The projectile was launched again with the same velocity. At this time, the lift was slowing down as it approached the top floor of the building.

Which diagram correctly shows the new path of the projectile (dotted line) relative to the path created in the stationary lift (solid line)?

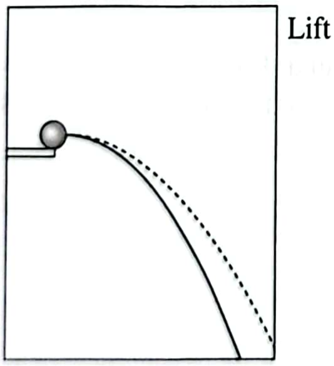
(A)



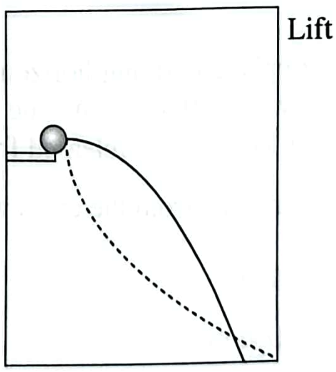
(B)



(C)



(D)



2016 HSC Q17

21. A projectile was launched from the ground. It had a range of 70 metres and was in the air for 3.5 seconds.

At what angle to the horizontal was it launched?

(A) 30°

(B) 40°

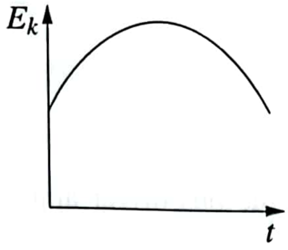
(C) 50°

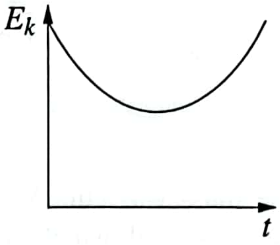
(D) 60°

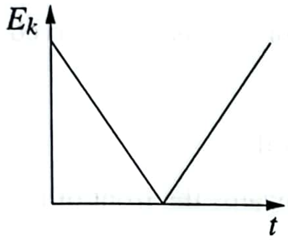
2015 HSC Q20

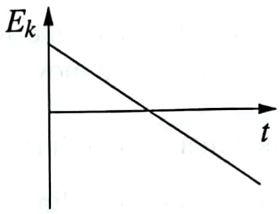
22. A ball was thrown upward at an angle of 45°. It landed at the same height as thrown.

Which graph best represents the kinetic energy of the ball during its time of flight?

(A) 

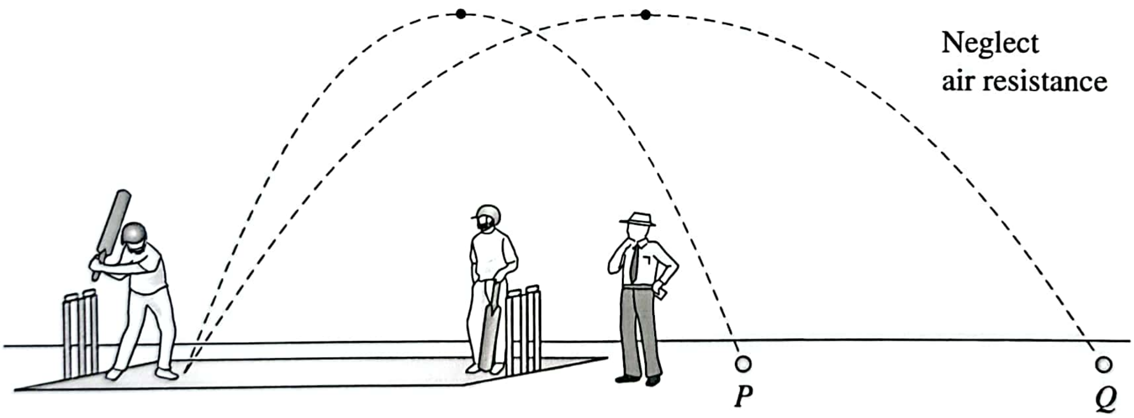
(B) 

(C) 

(D) 

2010 HSC Q4

23. The picture shows a game of cricket.



The picture shows two consecutive shots by the batsman. Both balls reach the same maximum height above the ground but ball Q travels twice as far as ball P.

Which of the following is DIFFERENT for balls P and Q?

(A) Time of flight

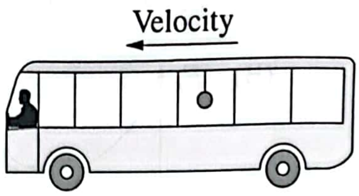
(B) Initial velocity

(C) Gravitational force

(D) Gravitational acceleration

2004 HSC Q1

24. A mass was hanging from the roof of a bus that was travelling forward on a horizontal road at a constant velocity.



The string holding the mass was cut. At the same instant, the bus driver applied the brakes, causing the bus to slow down at a rate of 3 m s^{-2}.

To an observer outside the bus, the mass follows a parabolic trajectory.

Which statement correctly describes the resulting motion of the mass observed from within the frame of reference of the moving bus?

A. The mass travelled in a straight line vertically downwards.

B. The mass travelled in a straight line downwards and towards the front of the bus.

C. The mass travelled in a parabolic path downwards and towards the back of the bus.

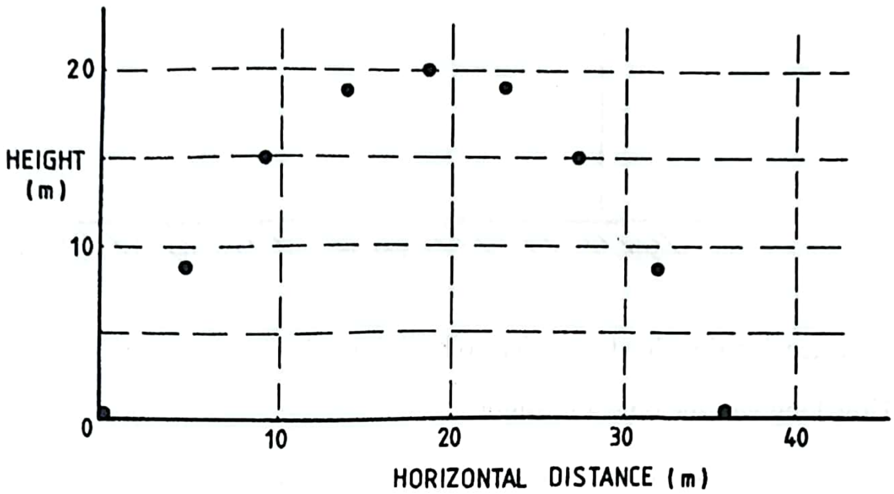
D. The mass travelled in a parabolic path downwards and towards the front of the bus.

2018 HSC Q19

Short-answer questions

25. The diagram below is a record of a stroboscopic photograph of the motion of a projectile fired from a horizontal surface. The time interval between images is 0.5 seconds.

Take the acceleration due to gravity as 10 m s^{-2}.



When the horizontal distance travelled by the projectile is 18 m, the vertical component of its velocity is zero.

(a) What was the horizontal component of the velocity of the projectile immediately before impact with the horizontal surface?

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(b) What was the vertical component of its initial velocity?

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(c) At what angle to the horizontal was the projectile fired?

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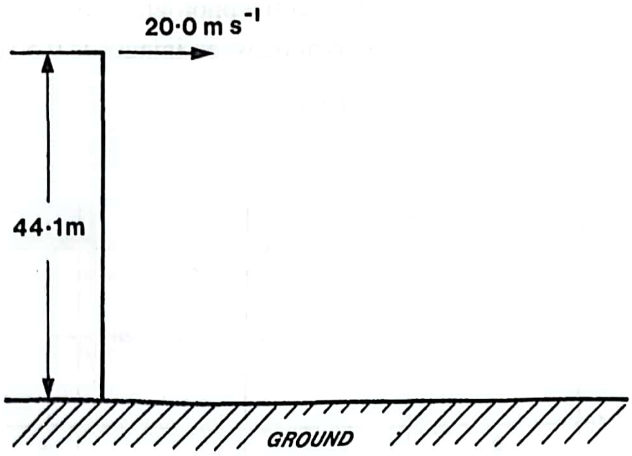
1984 HSC Q19 – 2 + 2 + 2 = 6 marks

26. An object of mass 2.0 kg is projected horizontally with a speed of 20.0 m s^{-1} from the top of a cliff. The height of the cliff is 44.1 m.



Take g, the acceleration due to gravity, to be 9.8 m s^{-1}.

(a) How long was the object in flight?

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(b) How far horizontally from the base of the cliff does the object land?

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1985 HSC Q14 – 2 + 2 = 4 marks

27. On the planet Zircon an astronaut throws a stone horizontally at 8.0 m s^{-1} from a vertical cliff 87.5 m high. The stone lands on the horizontal plain below, 40.0 m from the base of the cliff.

(a) Calculate:

(i) the time it takes for the stone to reach the plain

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(ii) the magnitude of the acceleration due to gravity on Zircon

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(b) Would a stone projected from a similar cliff on Earth at the same horizontal speed also land 40.0 m from the base of the cliff? Explain your answer.

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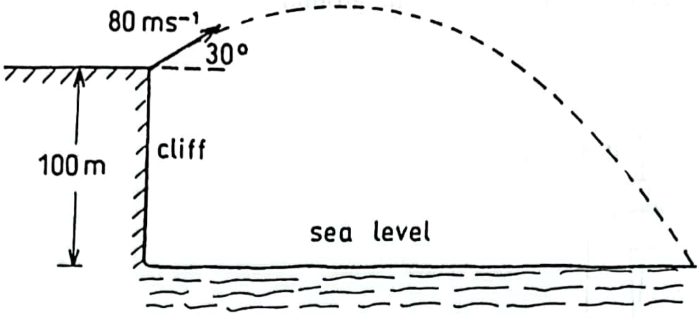
1992 HSC Q13 – 1 + 1 + 3 = 5 marks

28. As shown in the diagram below, a projectile is fired from the top of a cliff with a velocity of 80 m s^{-1} at an angle of 30° to the horizontal. The cliff is 100 m above sea level.



Ignoring air resistance, calculate:

(a) the time taken for the projectile to reach its maximum height.

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(b) the maximum height above sea level reached by the projectile.

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(c) the speed of the projectile at its maximum height.

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(d) the horizontal distance from the base of the cliff that the projectile enters the sea.

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1990 HSC Q20 – 2 + 2 + 2 + 2 = 8 marks

29. A projectile is fired at a velocity of 50 m s^{-1} at an angle of 30° to the horizontal.

Determine the range of the projectile.

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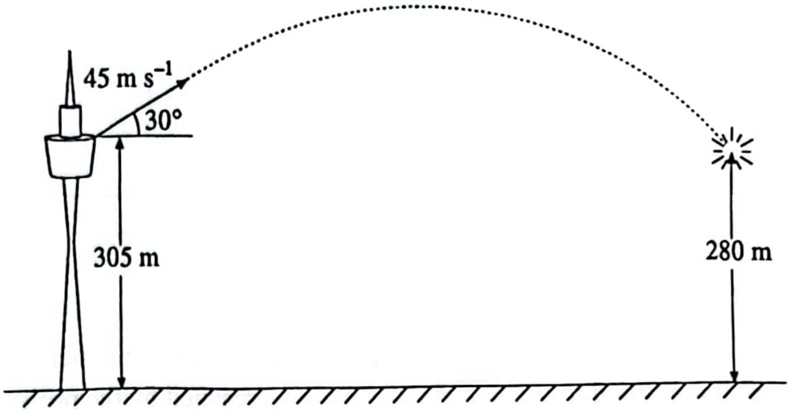
2004 HSC Q16 – 4 marks

30. A bundle of fireworks is launched from Centrepoint Tower in Sydney, 305 m above the ground. It is launched with a velocity of 45 m s^{-1} at an angle of 30° above the horizontal. The fireworks explode at a safe height of 280 m above the ground.



(a) What is the initial vertical component of the velocity?

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(b) What is the maximum height reached by the fireworks before they explode?

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(c) How long after the launch do the fireworks explode?

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(d) What is the horizontal distance from the tower to the fireworks when they explode?

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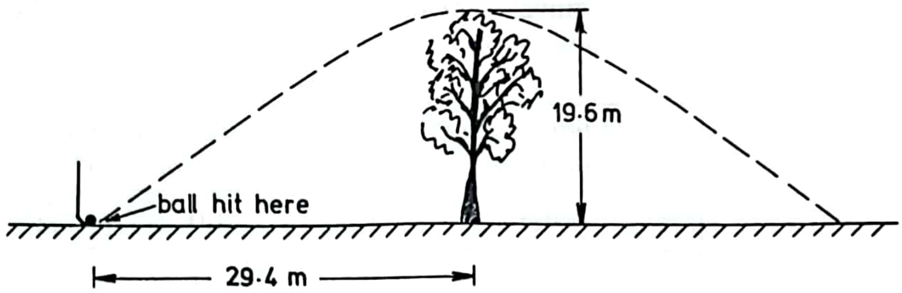
1995 HSC Q27 – 2 + 2 + 2 + 2 = 8 marks

31. A golfer hits a golf ball from 29.4 m in front of a large tree. The tree is 19.6 m high.



Take g, the acceleration due to gravity, to be 9.8 m s^{-1}.

(a) With what vertical component of velocity must the golfer hit the ball so that it will pass over the top of the tree?

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(b) How long will it take the ball to travel the horizontal distance of 29.4 m?

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(c) At what angle to the horizontal did the golfer hit the ball?

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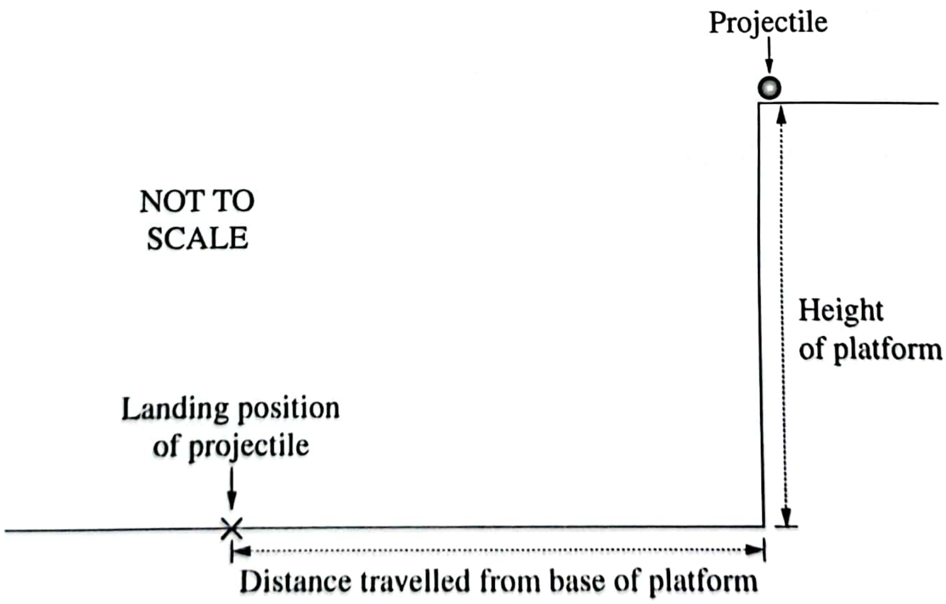
1986 HSC Q20 – 2 + 2 + 2 = 6 marks

32. A projectile is fired horizontally from a platform.

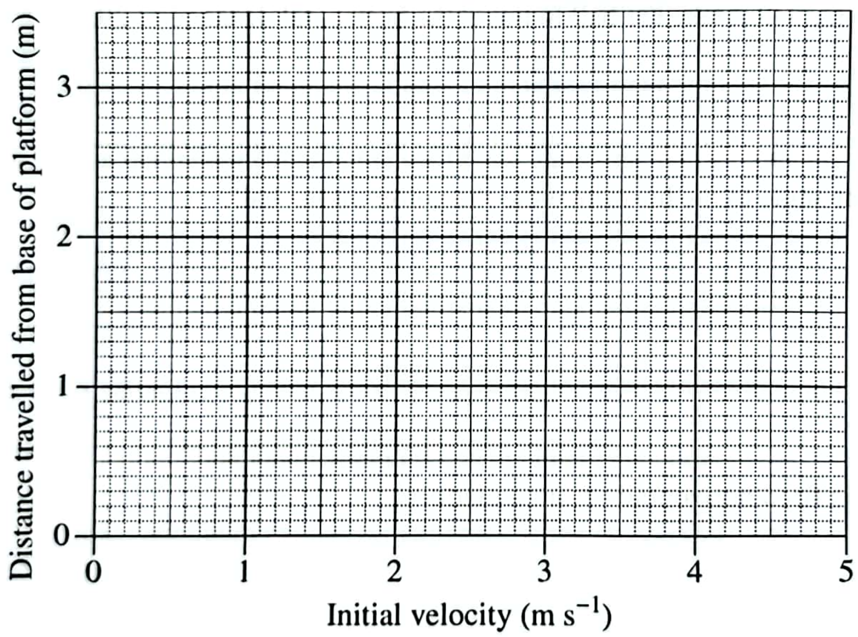


Question 32 continues

Measurements of the distance travelled by the projectile from the base of the platform are made for a range of initial velocities.

Initial velocity of projectile (m s^{-1})	*Distance travelled from base of platform* (m)
1.4	1.0
2.3	1.7
3.1	2.2
3.9	2.3
4.2	3.0

(a) Graph the data on the grid provided and draw the line of best fit.



(b) Calculate the height of the platform.

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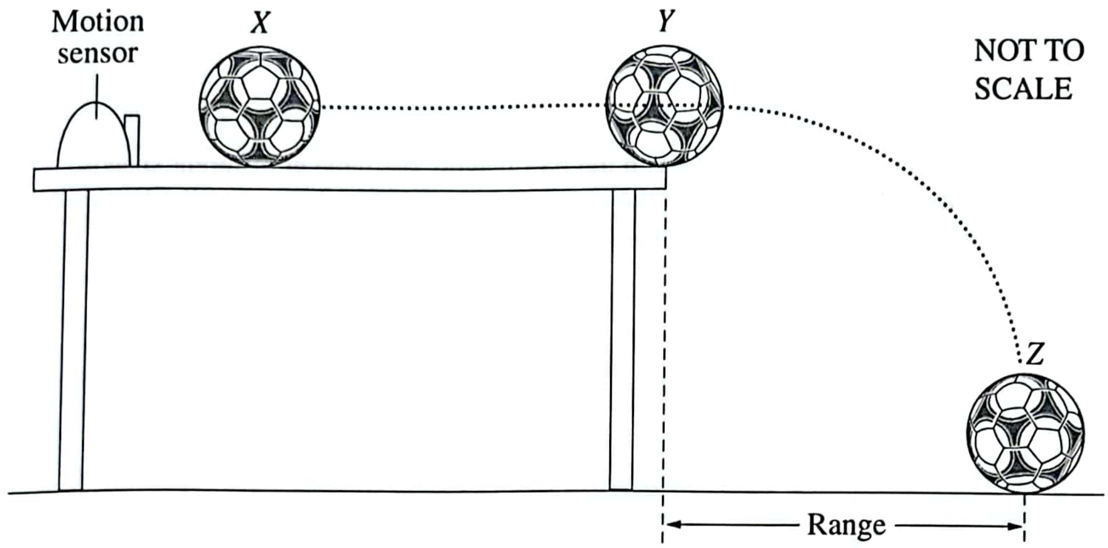
End of Question 32

2015 HSC Q21 – 2 + 2 = 4 marks

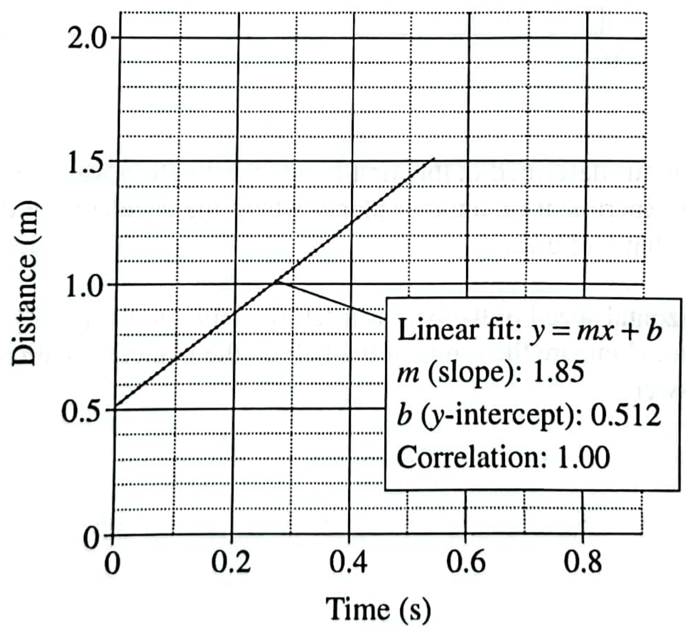
33. A student performed a first-hand investigation to examine projectile motion.

A ball resting on a horizontal table was given an initial push at X, resulting in the ball following the path XYZ as shown.



A data logger used the motion sensor to measure the horizontal distance to the ball. When the ball was at position Y, a distance of 1.50 m from the motion sensor, it left the edge of the table.

In the first trial, the range was 0.60 m. The graph below was obtained from the data logger.

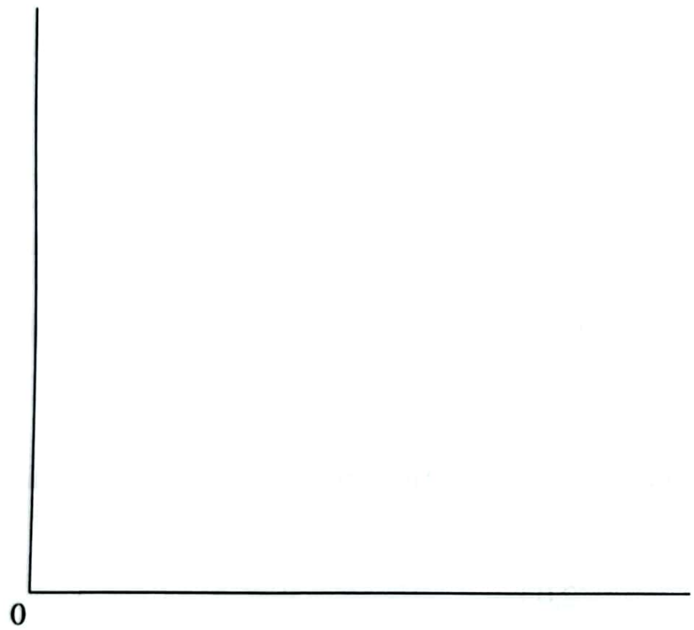


Question 33 continues

Question 33 (continued)

(a) For this trial, determine the horizontal speed of the ball as it left the edge of the table.

(b) The experiment was repeated with the ball leaving the table at different speeds. Graph the relationship between the range and the horizontal speed at *Y*. Identify on your graph the results from the first trial.



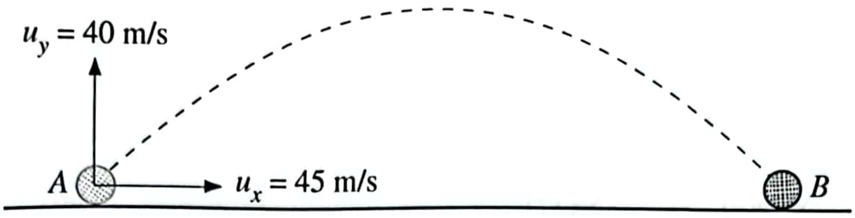
(c) The apparatus described in this first-hand investigation was used to carry out an identical experiment on another planet where the acceleration due to gravity is less than that on Earth.

The horizontal speed of the ball as it left the table on the planet was the same as in part (a). Compare the range of the ball on the planet to that on Earth. Explain your answer.

End of Question 33

2003 HSC Q16 – 1 + 3 + 2 = 6 marks

34. A projectile leaves the ground at point A with velocity components as shown in the diagram. It follows the path given by the dotted line and lands at point B.



(a) State the horizontal component of the projectile's velocity when it lands.

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(b) Find the magnitude of the initial velocity of the projectile.

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(c) Calculate the maximum height attained by the projectile.

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(d) Calculate the range of the projectile, if it lands level with its starting position.

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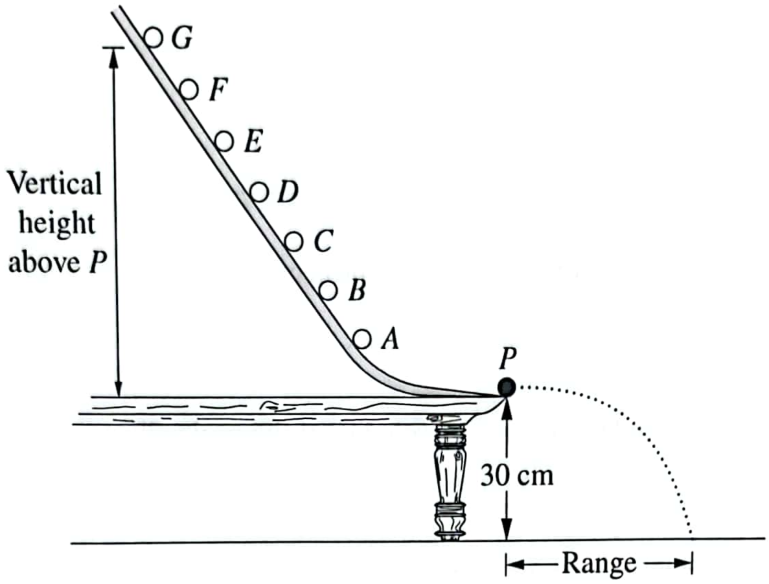
2006 HSC Q16 – 1 + 1 + 2 + 2 = 6 marks

35. A group of students conducted an investigation in which ball bearings were released from various points on a ramp. The ball bearings rolled down the ramp to the edge of a table at point *P* as shown. Their ranges were measured.

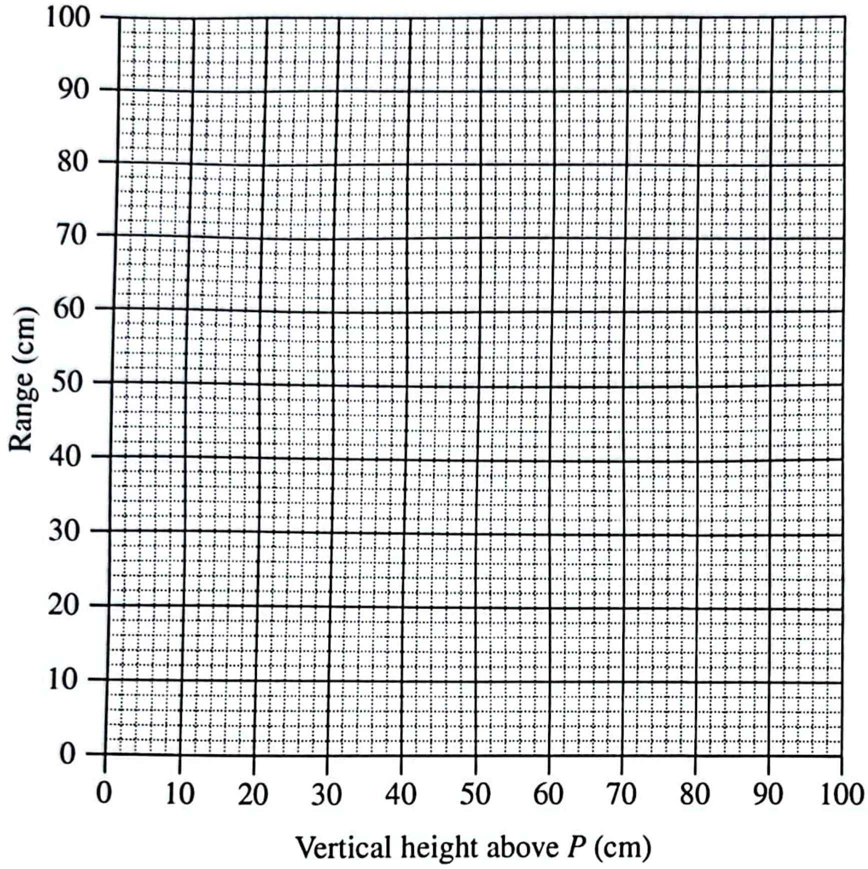


The results are shown in the table.

Point of release	*Vertical height above P* (cm)	*Range* (cm)
A	10	32
B	20	44
C	30	58
D	40	66
E	50	76
F	60	82
G	70	87

Question 35 continues

(a) Plot the data from the table and draw a curve of best fit.



(b) (i) Using your graph, predict the range of a ball bearing released from a height of 80 cm above point P.

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(ii) Calculate the horizontal velocity of the ball bearing released from a height of 80 cm above point P.

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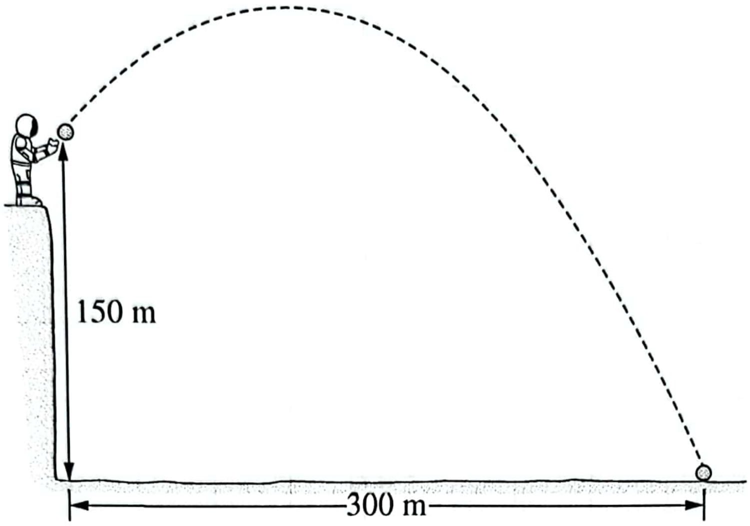
End of Question 35

2007 HSC Q16 – 2 + 1 + 2 = 5 marks

36. An astronaut on the Moon throws a stone from the top of a cliff. The stone hits the ground below 21.0 seconds later. The acceleration due to gravity on the moon is 1.6 m s^{-2}.



(a) Calculate the horizontal component of the stone's initial velocity. Show your working.

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(b) Calculate the vertical component of the stone's initial velocity. Show your working.

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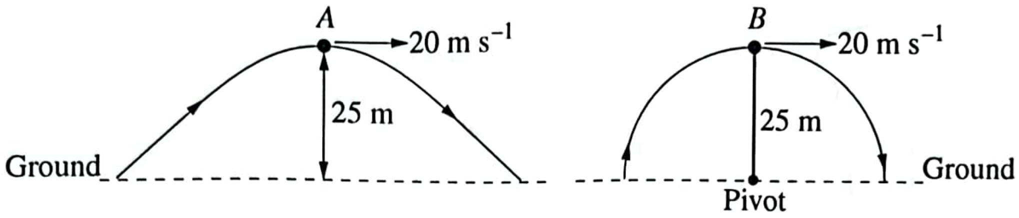
(c) On the diagram, sketch the path that the stone would follow if the acceleration due to gravity was higher. The initial velocity is the same.

2010 HSC Q22 – 1 + 2 + 2 = 5 marks

37. A 30 kg object, *A*, was fired from a cannon in projectile motion. When the projectile was at its maximum height of 25 m, its speed was 20 m s^{-1}.

An identical object, *B*, was attached to a mechanical arm and moved at a constant speed of 20 m s^{-1} in a vertical half-circle. The length of the arm was 25 m.



(a) Calculate the force acting on object *A* at its maximum height.

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(b) Calculate the time it would take object *A* to reach the ground from its position of maximum height.

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(c) Describe and compare the vertical forces acting on objects *A* and *B* at their maximum heights.

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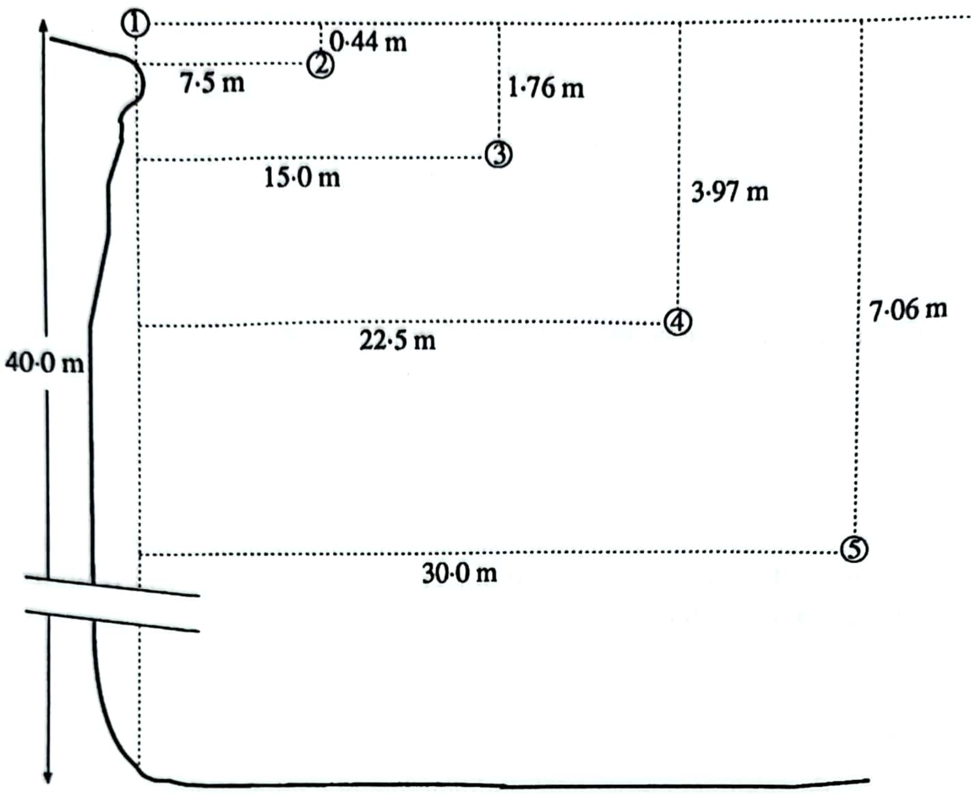
2001 HSC Q18 – 1 + 2 + 3 = 6 marks

38. A ball is thrown horizontally from the top of a cliff 40.0 high. The position of the ball is shown at five points on its path. Position 1 is the point where it leaves the thrower's hand. The time interval in moving from any position to the next is 0.3 seconds.
The diagram is not to scale. Air resistance is negligible.



(a) Explain why the horizontal displacement of the ball changes as it does.

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(b) Explain why the vertical displacement of the ball changes as it does.

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Question 38 continues

Question 38 (continued)

(c) How far from the bottom of the cliff does the ball land?

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(d) Determine the magnitude of the velocity of the ball immediately before it hits the ground.

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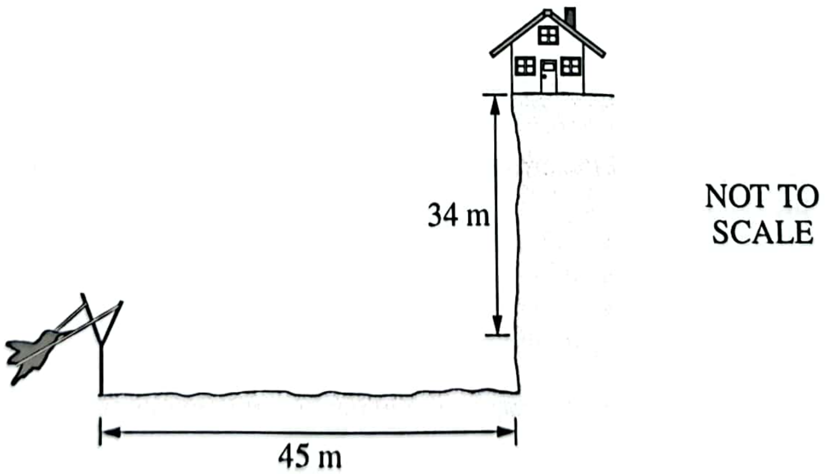
End of Question 38

1996 HSC Q26 – 2 + 2 +3 + 2 = 9 marks

39. A toy bird is launched at 60° to the horizontal, from a point 45 m away from the base of a cliff.



Question 39 continues

Question 39 (continued)

Calculate the magnitude of the required launch velocity such that the toy bird strikes the base of the wooden building at the top of the cliff, 34 m above the launch height.

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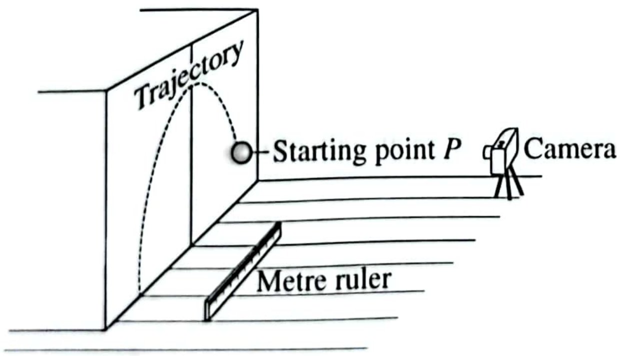
End of Question 39

2012 HSC Q27 – 4 marks

40. (a) The diagram shows a camera and a ruler set up to obtain data about a projectile's motion along the trajectory shown. The entire trajectory is visible through the camera.



Identify ONE of the errors in this set-up and describe the effect of this error on the results.

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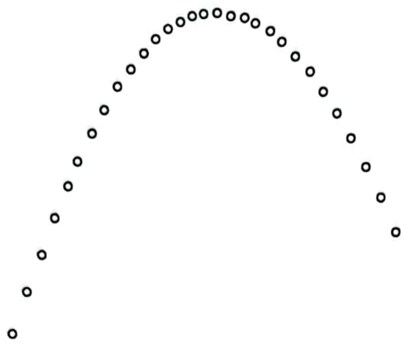
Question 40 continues

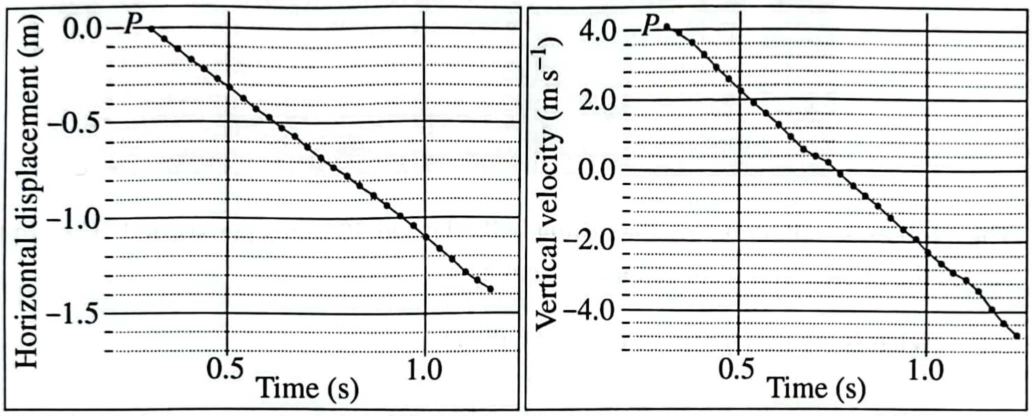
Question 40 (continued)

(b) An experiment was set up based on the method described in part (a), but conducted so that the data obtained were valid.

The image shows the trajectory of the ball.



The graphs show data from this experiment.



Using the graphs, describe the velocity and acceleration of the ball quantitatively and qualitatively.

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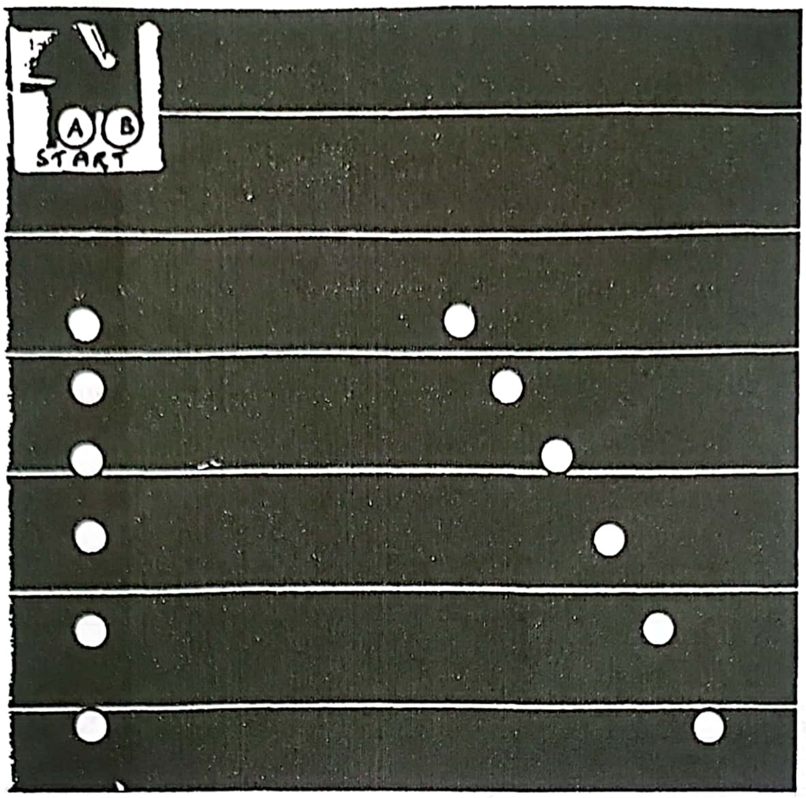
End of Question 40

2018 HSC Q27 – 3 + 3 = 6 marks

41. The photograph below was taken when a ball A was dropped from rest while ball B was simultaneously projected horizontally.



The stroboscope illuminating the falling balls flashed 30 times per second. The white lines across the photograph were actually 15 cm apart.

(a) What is the horizontal velocity of ball B?

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(b) How many images of the horizontally projected ball B are not shown on the photograph?

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(c) How many images of the vertically dropped ball A are not shown on the photograph?

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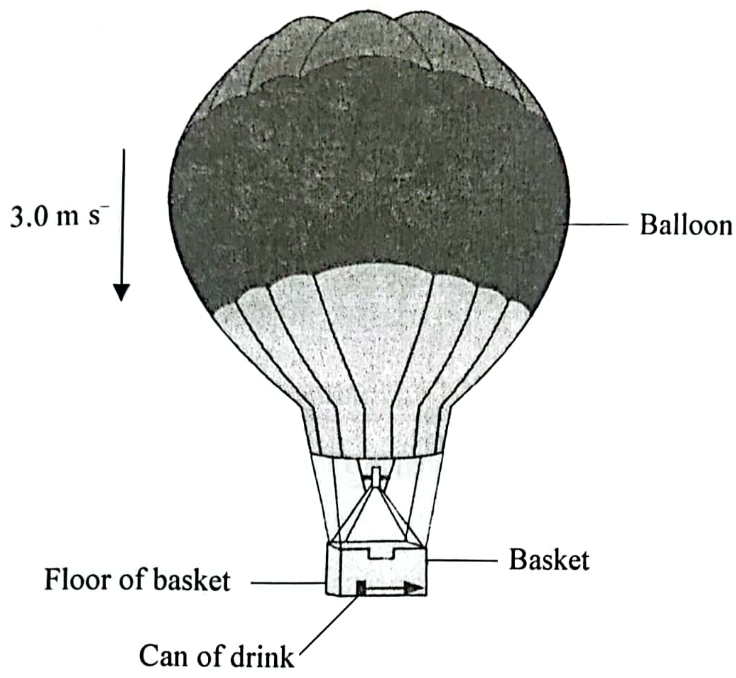
1988 HSC Q20 – 2 + 2 + 2 = 6 marks

42. A balloon with a basket attached moves vertically towards the ground. As it descends it maintains a constant velocity of 3.0 m s^{-1}.

A can of drink slides across the horizontal floor of the basket at 1.2 m s^{-1}. It slides out of a gap in the side of the basket 10.0 seconds before the basket hits the ground.



(a) How high is the floor of the basket above the ground when the can leaves the basket?

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(b) What is the vertical component of the can's velocity as it leaves the basket?

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(c) How long does it take the can of drink to hit the ground once it leaves the balloon? (Ignore air resistance on the can)

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(d) How far apart will be the initial impact sites of the basket and the can of drink?

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1997 HSC Q26 – 2 + 1 + 2 + 2 = 7 marks

Answers

Module 5: Advanced Mechanics

5.1 Projectile Motion

Multiple choice: 1 mark each

1. B	**2.** A	**3.** C	**4.** B	**5.** D	**6.** B	**7.** D	**8.** D
9. C	**10.** C	**11.** C	**12.** C	**13.** B	**14.** A	**15.** D	**16.** A
17. D	**18.** D	**19.** B	**20.** C	**21.** B	**22.** B	**23.** B	**24.** B

Explanations:

1. B The only forces acting on the moving golf ball are gravity, which always acts vertically downwards, and air resistance that always acts to oppose the motion. Ignoring air resistance, acceleration is always 'downwards'. So (B) is the answer. Acceleration is about *change* in velocity, not the actual value of the velocity. So (C) is incorrect. There is no upward force, so (A) is incorrect. (D) is incorrect as it suggests the net force opposes the motion at P and promotes the motion at Q.

[Note: If air resistance is considered, the net (total) force is downwards and to the left at both P and Q – no answer gives this combination.]

2. A The ball has a constant horizontal component to its velocity, while the vertical component varies due to gravity. So its overall velocity keeps changing, as in (A). Acceleration, g, is constant downwards at 9.8 m s^{-2}, so (B) and (D) are incorrect. Only the vertical component of velocity becomes zero at the top of its motion, so (C) is incorrect.

3. C $\Delta y = u_y t + \frac{1}{2} a_y t^2$ $\quad \Delta y = 1,\ u_y = 0$ $\quad$ [Note: The initial velocity of 4.0 m s^{-1} is horizontal.]

$1 = \frac{1}{2} \times 9.8 \times t^2 \quad \therefore t = \sqrt{\frac{1}{4.9}} = 0.45$ ... as in (C)

4. B The ball is accelerating downwards as a result of gravity. It is not accelerating with the vehicle, as would be required for path (A) to be observed from the vehicle. As observed from the vehicle, the ball will appear to accelerate to the left, and downwards, as in (B). A parabola is the path followed by an object with uniform velocity in one direction, and accelerating in another direction. The ball is accelerating in two directions and so its path is not a parabola, as in (C) or (D).

5. **D** Both x and y are launched with zero velocity in the vertical direction. Both will be acted on by gravity and accelerate towards the floor with acceleration, g. Since x and y take the same time to hit the floor, they have equal velocities in the vertical direction. However, ball y must have a higher velocity in the horizontal direction than ball x, since ball y travels further from the table than ball x in the same period of time. The horizontal component of each ball's velocity remains constant, so both will hit the floor simultaneously but with different velocities, as in (D).

6. **B** The stone is an example of a projectile. All projectiles have constant acceleration ($g = 9.8$ m s^{-2}) because the only force acting on them is gravity downwards. The stone has constant acceleration (shown by a horizontal line) until it lands on the beach below, at which point the acceleration instantly drops to 0 m s^{-2} (shown by a vertical line). Only graph (B) illustrates this.

7. **D** The cannon ball experiences a constant downward acceleration due to gravity. Only (B) and (D) show a constant acceleration. The velocity of the cannon ball will initially be upwards and will decrease to zero before increasing in the downwards direction. Since only (D) shows this, (D) is the answer.

8. **D** After it had been realised that a projectile followed a curved path, Galileo analysed the motion as a horizontal and vertical component producing a parabolic path. Thus (D) is the answer. An earlier idea (by Aristotle) held that a projectile followed a straight-line path until it lost its momentum and fell abruptly to the ground, so (B) is incorrect. It was Newton, nearly a century after Galileo, whose thought experiment about the ever more powerful cannon led to the two concepts in (A) and (C), so while these are true statements, they are incorrect answers.

9. **C** Once the cannon ball leaves the cannon, it is acted on by the force of gravity in a vertically downwards direction (ignoring the effects of air resistance). So the horizontal component of velocity will remain constant, as in either (C) or (D). The vertical component of velocity is initially upward, but will be decreased by the force of gravity until it becomes a downward velocity increasing with time, as in (C). (D) is incorrect as it shows a constant velocity downward. Both (A) and (B) show a horizontal velocity component that firstly decreases and then increases.

10. **C** At the maximum height reached, $v = 0$ in both cases. Using $v = u + at$, if u is doubled, then t must be doubled, as in (C).

11. **C** The ball is affected by the force of gravity ONLY. Its constant acceleration is g downwards. Only (C) has this option.

12. **C** Ignoring air resistance, the maximum range requires an elevation of 45°. At elevations of $(45 \pm 5)°$, i.e. 40° and 50°, the range will be the same. So (A) and (B) are incorrect. At an elevation of 50°, the vertical component of velocity will be greater, so the time of flight will be longer, as in (C) and not shorter, as in (D).

13. **B** Sam's ball went higher than Kim's ball. So Sam's ball had a greater component of vertical initial velocity than Kim's, as in (B), but not in (A), (C) or (D). Kim's ball was not in the air as long as Sam's. So it must have had a greater horizontal component of initial velocity than Sam's ball, thus confirming (B) is the answer.

14. **A** The object's acceleration is acceleration due to gravity. This is always a constant, downwards. So it is the same at points *X*, *Y* and *Z*. Only (A) is correct.

15. **D** $s_H = u_H t$ … so (D) is correct. (A) is incorrect because when $t = 2\times$ (time to reach maximum height), the projectile will have only dropped to a point equal in elevation to point A. (B) is incorrect because the velocity will be greatest just before it hits the ground. (C) is incorrect because the gravitational acceleration, *g* is constant, vertically downwards and independent of initial motion.

16. **A** A flying projectile is a hazard that could injure the eyes so wearing safety glasses is a related precaution. (A) is the answer. The range of the projectile could also be a hazard, but the precaution given is not related to it. Both enclosed shoes and safety glasses are safety precautions not hazards, so (B), (C) and (D) are incorrect.

17. **D** When the velocity is at 45° to the horizontal, both the vertical and horizontal components of velocity are equal. If the ball is launched horizontally, the vertical component of velocity is initially 0 m s^{-1}. After 2 s, it will be 19.6 m s^{-1} downwards. The horizontal component is constant and must also be 19.6 m s^{-1}.

$\therefore\ v = \sqrt{19.6^2 + 19.6^2} = 27.7\ \text{m s}^{-1}$. So (D) is the answer.

18. **D** In projectile motion, the horizontal velocity is always constant, i.e. uniform, while the vertical motion is subject to acceleration due to gravity. Projectiles follow a parabolic path, as shown best in (D). The downward motion follows a straight line in (A) and (B), not a parabolic path. So both are incorrect. (C) is incorrect as the downward motion shows non-uniform horizontal velocity.

19. **B** Assuming no air resistance: Let *t* be the time to fall 490 m.

$\Delta y = u_y t + \frac{1}{2} a_y t^2$, where $\Delta y = 490$ m, $u_y = 0$ m s^{-1}, $a_y = 9.8$ m s^{-2}

$$\therefore\ t = \sqrt{\frac{2\Delta y}{a_y}} = \sqrt{\frac{2 \times 490}{9.8}} = 10\ \text{s}$$

So horizontal displacement, $\Delta x = u_x \times t = 100 \times 10 = 1000\ m$, as in (B).

20. **C** The projectile will follow the same path if the lift is either stationary or moving with constant velocity. The lift is decelerating as it approaches the top floor. Hence the lift will be dropping behind the position it would have had if its motion remained constant. So the path of the ball in the lift will appear higher relative to the lift and the projectile will take longer before striking the floor of the lift … as shown in (C).

21. **B** Projectile travels 70 m in 3.5 s.

Horizontal velocity must be a constant: $\dfrac{70 \text{ m}}{3.5 \text{ s}} = 20 \text{ m s}^{-1} = u_x$

Initial vertical velocity: $\Delta y = u_y t + \frac{1}{2} a_y t$

Substituting: $0 = u_y \times 3.5 + \frac{1}{2} \times 9.8 \times 3.5^2$ So $u_y = 17.15 \text{ m s}^{-1}$

Angle of elevation, θ, is given by: $\tan^{-1} \theta = \dfrac{u_y}{u_x} = \dfrac{17.15}{20} = 0.8575$

$\therefore \theta = 40.6° \approx 40°$ ... as in (B).

22. **B** The ball was thrown at 45°. The ball's vertical velocity decreases due to gravity, while its horizontal velocity remains constant. The ball's kinetic energy (K or E_k) will decrease to a minimum at its highest altitude and then increase as the ball falls, as shown in (B). (A) is incorrect as it shows K (or E_k) increasing as the ball rises and decreasing as it falls. K (or E_k) is related to v^2, so it does not change linearly at a steady rate and since the ball never stops, K (or E_k) is never zero. So (C) is incorrect. (D) is incorrect because K (or E_k) is a scalar quantity and so cannot have negative values.

23. **B** Since they reach the same height, the vertical component of the velocity of both balls is the same and their time of flight will also be the same, so (A) is incorrect. The horizontal component for Q is twice that of P, so the initial velocities are different as in (B). Each ball has the same gravitational force and therefore the same gravitational acceleration, so (C) and (D) are incorrect.

24. **B** From the point of view of a passenger in the bus, the ball has an acceleration forward (due to the braking of the bus), a well as an acceleration downwards due to gravity. The resultant will be motion in a straight line downwards and towards the front of the bus, as in (B).

Short-answer questions

25. (a) $d_{(horizontal)} = 36$ m $\quad v = \frac{d}{t} = \frac{36}{4} = 9$ m s^{-1}

$t = 4$ s

$\therefore$ horizontal component of velocity is 9 m s^{-1}

(b) $d_{(vertical)} = 36$ m (until highest point reached) $\quad v = u + at$

$t = 2$ s $\quad 0 = u + (-10) \times 2$

$a = 10$ m s^{-2} $\quad u = 20$

$\therefore$ vertical component of velocity is 20 m s^{-1}

(c) $\tan\theta = \frac{u_{vertical}}{u_{horizontal}} = \frac{20}{9}$

$\therefore \theta = 65°$

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

$44.1 = 0 + ½ \times 9.8 \times t^2$

$\therefore t = 3.0$ s

(b) $s = v_{(horizontal)} \times t$

$= 20 \times 3$

$\therefore s = 60$ m

27. (a) (i) $v = \frac{s}{t}$

$t = \frac{40.0}{8.0}$

$\therefore t = 5.0$ s

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

$87.5 = 0 + ½ \times a \times 5^2$

$\therefore a = 7.0$ m s^{-2}

(b) No – acceleration due to gravity on Earth is different. At 9.8 m s^{-2}, it is greater than 7.0 m s^{-2}, and so the stone would fall more quickly. Hence it would not travel as far horizontally.

28. (a) $v_{(vertical)} = u_{(vertical)} + at$

$= 0$ [with up being positive]

$\therefore t = \frac{80 \sin 30°}{9.8} = 4.1$ s

(b) $v^2 = u^2 + 2as$

$s = \frac{v^2 - u^2}{2a}$

$= \frac{0 - (80 \sin 30)^2}{2 \times -9.8} = 82$ m

$\therefore$ height above sea level $= 100 + 82 = 182$ m

(c) Speed $= u \times \cos\theta = 80 \times \cos 30 = 69$ m s^{-1}

(d) Time up = 4.1 s ... from (a)

Time down = $\sqrt{\frac{2s}{a}} = \sqrt{\frac{2 \times 182}{9.8}} = 6.1$ s

So total time = 4.1 + 6.1 = 10.2 s

$\therefore\ d_{(horizontal)} = v_{(horizontal)} \times t = 69 \times 10.2 = 704$ m

29. The projectile is fired at 50 m s^{-1} at 30° elevation.
So the vertical and horizontal components of the velocity are:

$u_y = 50\sin 30$ m s^{-1} and $u_x = 50\cos 30$ m s^{-1}

Consider the vertical motion: $\Delta y = u_y t + \frac{1}{2} a_y t^2$

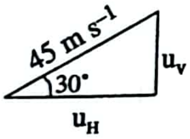
At the end of the trajectory, $\Delta y = 0 \text{ m} = (50\sin 30 \times t) - (\frac{1}{2} \times 9.8t^2)$

$4.9t^2 = 50\sin 30.t = 50 \times 0.5\ t = 25\ t$ $\therefore\ t = 0$ or $\frac{25}{4.9} = 5.1$ s

Consider the horizontal motion: $\Delta x = u_x t = 50\cos 30 \times \frac{25}{4.9} = 220.92$ m

$\therefore$ range of projectile is 221 m

30. (a)



$u_v = 45\sin 30°$

$= 22.5$

$\therefore\ u_v = 22.5$ m s^{-1}

(b) $v = 0$ m^{-1}

$u = 22.5$ m s^{-1}

$a = -9.8$ m s^{-2}

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

$0^2 = 22.5^2 + 2 \times (-9.8) \times s$

$s = \frac{22.5^2}{2 \times 9.8} = 25.83 = 26$ m = gain in altitude

$\therefore$ maximum height reached = 305 + 26 = 331 m

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

$= 22.5^2 + 2 \times (-9.8) \times (-25)$

$= 506.25 + 490$

v = 31.6 m s^{-1} (downwards)

$v = u + at$

$-31.6 = 22.5 + (-9.8)\ t$

$9.8\ t = 22.5 + 31.6 = 54.1$

$\therefore\ t = \frac{54.1}{9.8} = 5.52 \approx 5.5$ s

[Note: This could also be solved using s = ut + ½ at^2, however it involves solving a quadratic equation which would take longer. The problem can also be solved by other methods.]

(d) $u_H = 45\cos 30° = 38.97$ m s^{-1} $u_H = \frac{s_H}{t}$

$\therefore\ s_H = u_H\ t = 38.97 \times 5.52 = 215.1 \text{ m} \approx 215$ m

31. (a) $v = 0\ \text{m}^{-1}$ $\qquad v^2 = u^2 + 2as$

$s = 19.6\ \text{m}$ $\qquad u = \sqrt{v^2 - 2as}$

$a = -9.8\ \text{m s}^{-2}$ $\qquad = 19.6\ \text{m s}^{-1}$

$\therefore$ initial vertical velocity of ball = $19.6\ \text{m s}^{-1}$ to reach the top of the tree

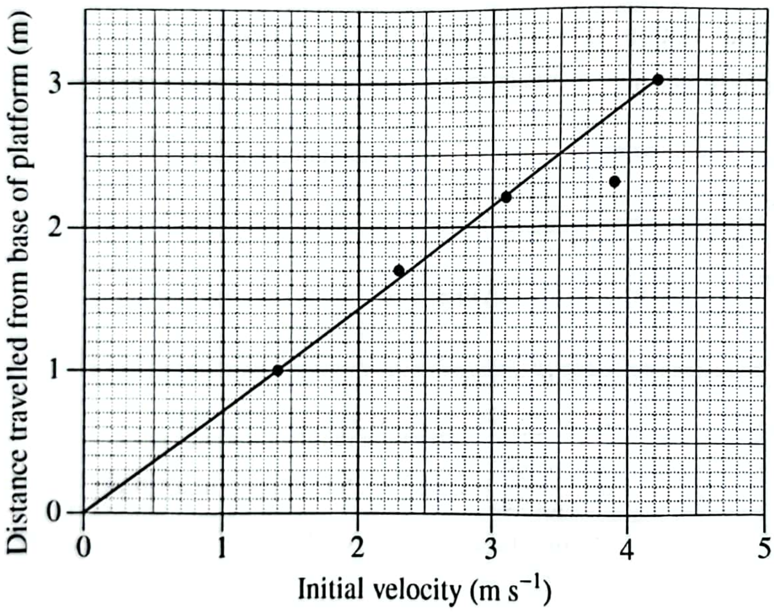
(b) $v = u + at$ $\qquad$ So, $t = \frac{v - u}{a} = \frac{0 - (-19.6)}{-9.8}$

$\therefore$ time taken = 2 s

(c) $s = ut + \frac{1}{2}at^2$ $\quad$ Since $a = 0$, $u = \frac{s}{t} = \frac{29.4}{2} = 14.7\ \text{m s}^{-1}$

$\therefore$ angle to hit ball = $\tan^{-1}\left(\frac{u_{(vertical)}}{u_{(horizontal)}}\right) = \tan^{-1}\left(\frac{19.6}{14.7}\right) = 53.1°$

32. (a)



[Note: The point x = 2.3, y = 3.9 is an outlier and should be ignored.]

(b) Time of flight, t = slope of graph = $\frac{\text{rise}}{\text{run}}$

$= \frac{3.0 - 1.0}{4.2 - 1.4} = \frac{2.0}{2.8} = 0.714\ \text{s}$

$\therefore$ height of platform, $\Delta y = u_y t + \frac{1}{2}a_y t$

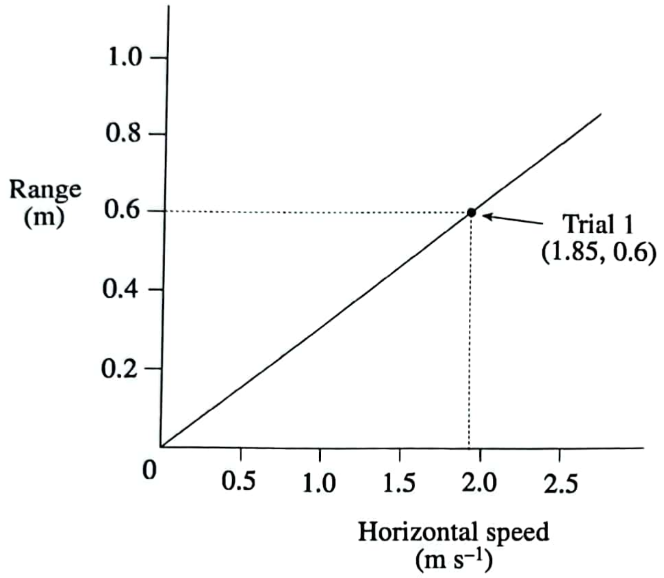
$= 0 + \frac{1}{2} \times 9.8 \times (0.714)^2$

$= 2.5\ \text{m}$

33. (a) Horizontal speed = slope of graph

$= 1.85\text{ m s}^{-1}$

(b) The relationship between range and horizontal speed



(c) $\Delta y = u_y t + \frac{1}{2} a_y t^2$

On both Earth and planet: Δy = height of table and $u_y = 0$ $\quad \therefore\ t \propto \sqrt{\frac{1}{g}}$

Since g on the planet is smaller than on Earth, t will be longer.

Since range = $\Delta x = u_x t$, then range is proportional to time (as u_x is constant).

$\therefore$ a larger range will be obtained on the planet than on Earth.

34. (a) 45 m s^{-1} to the right

(b) $u = \sqrt{u_x^{\,2} + u_y^{\,2}} = 45^2 + 40^2 \approx 60.21 \approx 60\text{ m s}^{-1}$

[Note: Magnitude only was required, so direction not needed.]

(c) $v_y^{\,2} = u_y^{\,2} + 2a_y \Delta y$

$0 = 40^2 + 2(-9.8)\Delta y$

$19.6\Delta y = 1600$

$\therefore$ maximum height, $\Delta y = \dfrac{1600}{19.6} = 81.6\text{ m}$

(d) $v_y = u_y + a_y t$

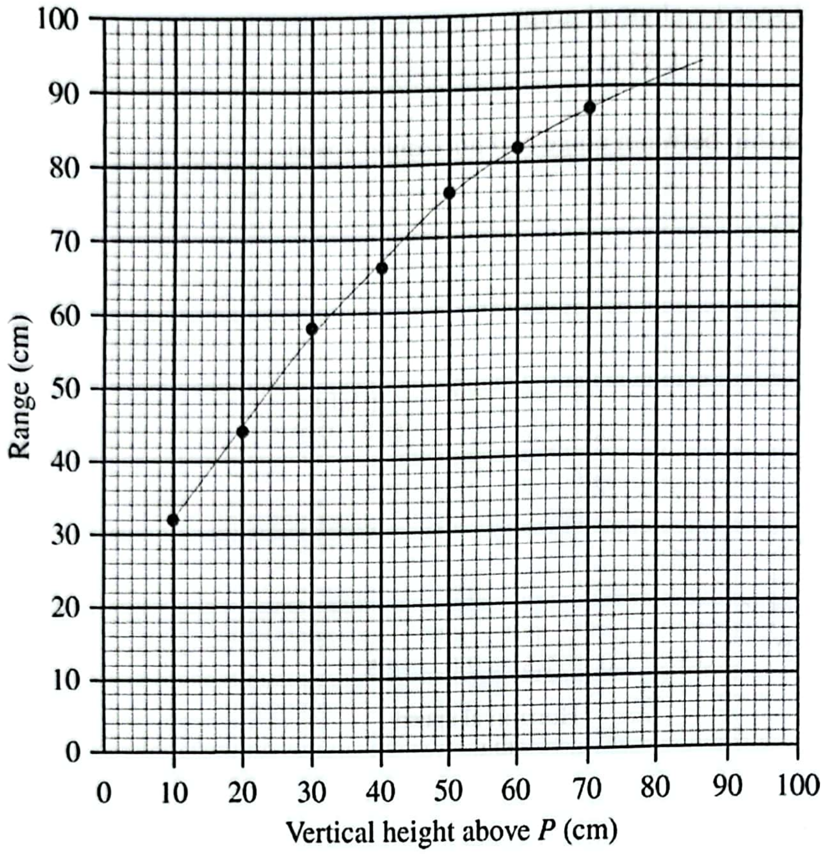
$0 = 40 + (-9.8)t$

Time to reach max height, $t = \dfrac{40}{9.8} = 4.08\text{ s}$

Time projectile in air $= 2t = 8.16\text{ s}$

$\therefore$ range, $\Delta x = u_x t = 45 \times 8.16 = 367.2 \approx 367\text{ m}$

35. (a)



(b) (i) 91 cm

(ii) $\Delta y = u_y t + \frac{1}{2} a_y t^2$, where $\Delta y = 30$ cm $= 0.3$ m, $u_y = 0$, $a_y = 9.8$ m s^{-2}

$\therefore\ t = \sqrt{\frac{2\Delta y}{a_y}} = \sqrt{\frac{2 \times 0.3}{9.8}}$ s Now $\Delta x = 91$ cm $= 0.91$ m

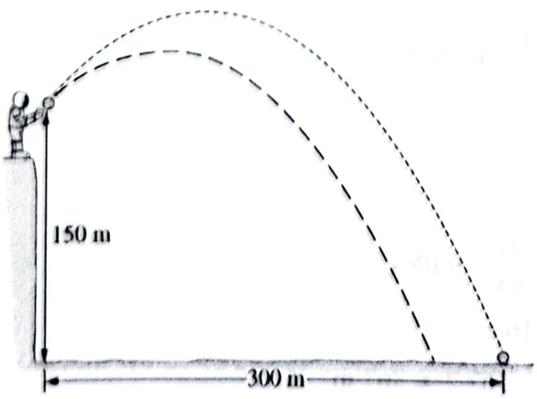
and so horizontal velocity, $u_x = \frac{\Delta x}{t} = 0.91 \times \sqrt{\frac{9.8}{0.6}} = 3.7$ m s^{-1}

36. (a) $\Delta x = u_x t$ $300 = u_x \times 21.0$ $\therefore u_x = \frac{300}{21.0} = 14.3$ m s^{-1}

(b) $\Delta y = u_y t + \frac{1}{2} a_y t^2$ $-150 = (u_y \times 21.0) + (\frac{1}{2} \times -1.6 \times 21.0^2)$

$u_y = \frac{(\frac{1}{2} \times 1.6 \times 21.0^2) - 150}{21.0} = \frac{202.8}{21.0} = 9.66$ m s^{-1}

(c)



37. (a) force = $ma = mg$ = 30 kg × 9.8 m s^{-2} = 294 N

(b) $\Delta y = u_y t + \frac{1}{2} a_y t^2$ [Note: This is on the Formulae sheet, but you could still use: $s = ut + \frac{1}{2}at^2$]

$t^2 = \frac{2\Delta y 2 u_y t}{a} = \frac{2 \times 252 \times 0 \times t}{9.8} = \frac{50}{9.8} = 5.1$

$\therefore t = \sqrt{5.1} = 2.3$ s

(c) On object *A*, the only vertical force acting is the weight force down (= 294 N)

On object *B*, there are two vertical forces acting:

- the weight force (*W*) down (= 294 N), and
- the tension force (*T*) down (due to the arm and directed towards the pivot)

B is executing uniform circular motion, so the net force acting on *B* is the centripetal force

$= \frac{mv^2}{r} = \frac{30 \times 20^2}{25} = 480$ N

∴ net force on *B* (= 480 N) is larger than the force on *A* (= 294 N).

38. (a) Since air resistance is negligible, the only force acting on the ball is the weight force due to gravity which acts at right angles to the ball's horizontal motion.
∴ ball travels with uniform horizontal velocity and its horizontal displacement varies by a constant value in equal time intervals.

(b) Initially, the ball is travelling in a horizontal direction, so its velocity in the vertical direction, $u_{vertical} = 0$ m s^{-1}.
The ball is accelerated downwards by gravity with a constant $a = 9.8$ m s^{-2}.
∴ its vertical displacement increases in each successive time interval.

(c) In one time interval:

$s_{horizontal} = u_{horizontal} \times t$

So, $7.5 = u_{horizontal} \times 0.3$

$\therefore u_{horizontal} = \frac{7.5}{0.3} = 25$ m s^{-1}

To find time of fall:

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

$40 = 0 + (\frac{1}{2} \times 9.8 \times t^2)$

$\therefore t = \sqrt{\frac{40}{4.9}} = 2.86$ s

$u_{vertical} = 0$
$a_{vertical} = 9.8$ m s^{-2}
$s_{vertical} = 40$ m

At bottom of cliff: $s_{horizontal} = u_{horizontal} \times t = 25 \times \sqrt{\frac{40}{4.9}} = 71.4$ m
∴ ball lands 71.4 m from the bottom of the cliff.

(d) $u_{horizontal} = v_{horizontal} = 25$ m s^{-1}

$v_{vertical} = u_{vertical} + at = 0 + 9.8 \times \sqrt{\frac{40}{4.9}} = 28$ m s^{-1}

$v_{absolute} = \sqrt{28^2 + 25^2} = 37.5$ m s^{-1}

[Note: Direction not required as this question only asked for magnitude of velocity.]

39. $\Delta x = u_x t$ So $45 = v \cos 60 \times t$ (where v = launch velocity) $\therefore t = \dfrac{45}{v_{launch} \cos 60}$

$\Delta y = u_y t + \frac{1}{2} a_y t^2$ So $34 = v \sin 60 . \frac{45}{v \cos 60} + \frac{1}{2}(-9.8)(\frac{45}{v \cos 60})^2$

$\therefore 34 = (\frac{\sin 60}{\cos 60} \times 45) + (-4.9 \times (\frac{45}{v \cos 60})^2) = 77.94 - \frac{39{,}690}{v^2}$

$\frac{39{,}690}{v^2} = 77.94 - 34 = 43.94$ So $v^2 = \frac{39{,}690}{43.94}$ $\therefore v = 30.055 \text{ m s}^{-1}$

$\therefore$ launch velocity, $v_{launch} = 30 \text{ m s}^{-1}$

40. (a) *Either ONE of the following:*

- ERROR: The camera is not centred on the projectile's trajectory path.

  EFFECT ON RESULTS: The measurement of the projectile's velocity will not be accurate, as the velocity will be greater when the object is closer to the camera compared to when they are further apart.

- ERROR: The ruler is not aligned correctly in the same plane as the projectile's trajectory path.

  EFFECT ON RESULTS: This means that an incorrect horizonal distance (range) will be measured and so the results will be inaccurate due to parallax error.

(b) Graph on left: This shows the ball is moving with a constant velocity, where:

$$\text{velocity, } v = \frac{-1.1 - (-0.3)}{0.5} = \frac{-0.8}{0.5} = -1.6 \text{ m s}^{-1}$$

Graph on right: This shows the ball accelerating downwards with a constant acceleration, where:

$$\text{acceleration, } a == \frac{-2.4 - 2.3}{0.5} = \frac{-4.7}{0.5} = -9.4 \text{ m s}^{-2}$$

41. (a) Each white line = 15 mm apart, so scale is 15 mm = 15 cm

$$v_{(horizontal)} = \frac{d_{(horizontal)}}{t}$$

$d_{(horizontal)}$ between 1st and last images = 34 mm = 0.34 m, $t = \frac{5}{30}$ s

$$\therefore v_{(horizontal)} = \frac{d}{t} = \frac{0.34}{\frac{5}{30}} = 2.04 \text{ m s}^{-1} = 2.0 \text{ m s}^{-1}$$

(b) 6 images produce 5 intervals, $\therefore$ number of missing images = number of intervals – 1

For ball B, d travelled to 1st image = 42 mm, then 34 mm more to the last image

d travelled per flash $= \frac{34}{5} = 6.8$ mm

$\therefore$ no. intervals not shown $= \dfrac{d_{(horizontal)} \text{ travelled by B to the 1st image}}{d \text{ travelled per flash}}$ (as $v_{(hor)}$ is constant)

$= \frac{42}{6.8} = 7.2 \approx 7$ intervals

(c) Same as (b).

42. (a) $u_{(vertical)}$ of balloon = 3.0 m s^{-1} down

Height when can drops = 3.0 m s^{-1} × 10 s = 30 m

(b) Initial vertical velocity of can is same as that of balloon, $\therefore$ $u_{(vertical)}$ = 3.0 m s^{-1} down

(c) $v^2 = u^2 + 2as = 3.0^2 + 2 \times 9.8 \times 30 = 59$

$\therefore$ $v = 24.43$ m s^{-1}

$v = u + at$ So $9.8\,t = 24.43 - 3.0 = 21.43$

$\therefore$ time to hit ground, $t = \frac{21.43}{9.8} = 2.187 \approx 2.2$ s

(d) Ground distance travelled by can, $s = u \times t$

$= 1.2 \times 2.187 = 2.624 \approx 2.6$ m

$\therefore$ initial impact sites of can and balloon are 2.6 m apart.