The following list of formulae may be found useful :

For uniformly accelerated motion $v = u + a t$

$s = u t + \frac{1}{2} a t^2$

$v^2 = u^2 + 2 a s$

Equation of a straight line $y = m x + c$

Use the following data wherever necessary :

Acceleration due to gravity $g = 9.81\ \text{m s}^{-2}$ (close to the Earth)

Part A : HKAL examination questions

1. **< HKAL 1981 Paper I - 34 >**

Two small balls A and B are launched simultaneously from the top of a building. A is projected horizontally with an initial velocity of 10 m s^{-1} and B is projected at an angle of 60° above the horizontal with an initial velocity of 20 m s^{-1}. The motion of both A and B is in the same plane and air resistance is negligible. Which of the following statements is/are correct when they are travelling in air ?

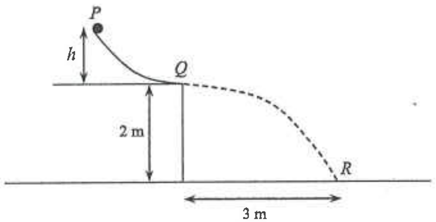
(1) Balls A and B travel equal vertical distances in equal times.

(2) Balls A and B travel equal horizontal distances in equal times.

(3) Balls A and B never meet.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

2. **< HKAL 1983 Paper I - 7 >**



A small particle is released from P and slips down a smooth curve to Q, at the edge of a table 2 m high, where it travels horizontally. It then leaves the table and travels freely under gravity until it hits the ground at R, at a horizontal distance of 3 m from Q. What is the vertical distance h of P above Q ?

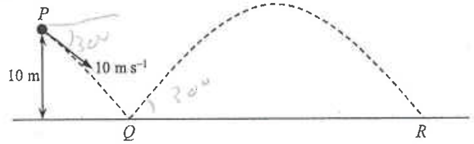
A. 1.13 m
B. 1.33 m
C. 2.50 m
D. 3.00 m

3. **< HKAL 1984 Paper I - 2 >**

A ball is thrown horizontally from the top of a building at a speed of 20 m s^{-1}. What will be the speed of the object after 3 s ?

A. 20.0 m s^{-1}
B. 25.0 m s^{-1}
C. 30.0 m s^{-1}
D. 35.6 m s^{-1}

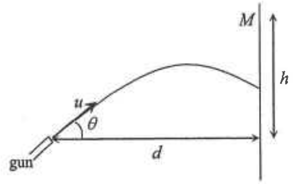
4. **< HKAL 1987 Paper I - 5 >**



A particle is projected with a speed of 10 m s^{-1} downwards from P at an angle of 30° to the horizontal. The particle rebounds from the ground at Q as shown in the above figure. If the collision is perfectly elastic, and assume the ground is smooth, what is the horizontal distance QR when it reaches the ground at R ? (Take g to be 10 m s^{-2})

A. 10.0 m.
B. 13.0 m.
C. 26.0 m.
D. 43.5 m.

5. **< HKAL 1990 Paper I - 4 >**



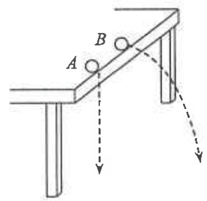
As shown in the above figure, a hunter aims his gun at a monkey which is at rest at the point M, and his gun makes an angle θ with the horizontal. When the gun is fired, the monkey releases itself from M with zero initial velocity. In order that the bullet can hit the monkey, the angle θ depends on

(1) u, the initial speed of the bullet.
(2) h, the vertical height of the monkey above the level of the gun.
(3) d, the horizontal distance of the gun from the monkey.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

6. **< HKAL 1993 Paper I - 4 >**

Two small balls A and B are placed at the edge of a table. When ball A is pushed slightly to fall vertically to the ground, ball B is projected horizontally at the same instant and it reaches the ground through a parabolic path. If air resistance is neglected, which of the following statements is/are correct ?



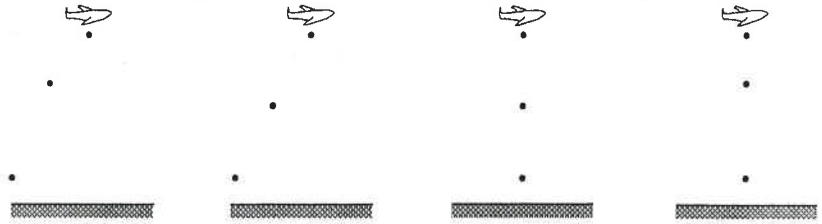
(1) Balls A and B reach the ground at the same time.
(2) Balls A and B have the same acceleration during their motion in air.
(3) Balls A and B have the same vertical velocity on reaching the ground.

A. (3) only
B. (1) & (2) only
C. (2) & (3) only
D. (1), (2) & (3)

7. < HKAL 1994 Paper IIA - 6 >

A bomber is flying horizontally to the right with constant velocity. It releases three bombs one by one at a constant time interval. If air resistance is neglected, which of the following diagrams best shows the positions of the bomber and the bombs at a certain time instant ?

A. B. C. D.



8. < HKAL 1997 Paper IIA - 3 >

A ball is projected horizontally from a table surface with an initial speed u. It hits the ground with a speed v. If air resistance is neglected, what is the time of flight of the ball in air ?

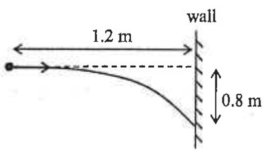
A. $\dfrac{v-u}{2g}$

B. $\dfrac{v-u}{g}$

C. $\dfrac{\sqrt{v^2-u^2}}{2g}$

D. $\dfrac{\sqrt{v^2-u^2}}{g}$

9. < HKAL 1998 Paper IIA - 6 >



A particle is projected horizontally towards a vertical wall at a horizontal distance of 1.2 m away. It hits the wall at a point which is 0.8 m below its initial horizontal level. If air resistance is neglected, what is the speed of the particle when it hits the wall ?

A. 2.65 m s^{-1}
B. 3.45 m s^{-1}
C. 3.95 m s^{-1}
D. 4.95 m s^{-1}

10. < HKAL 2001 Paper IIA - 3 >

A ball is projected at an elevation angle of 45° to the horizontal with an initial kinetic energy E_o. Neglecting air resistance, what is the kinetic energy of the ball when it is moving halfway up ?

A. $\frac{1}{4}E_o$

B. $\frac{1}{2}E_o$

C. $\frac{1}{3}E_o$

D. $\frac{3}{4}E_o$

11. < HKAL 2003 Paper IIA - 3 >

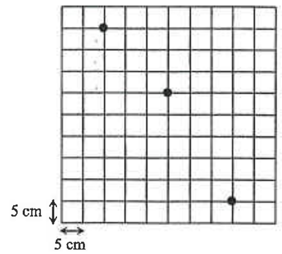
A small particle is projected horizontally into the air. The figure shows **part** of the stroboscopic picture. The side of each square of the grid is 5 cm long. Estimate the frequency of the stroboscopic lamp used. (Neglect air resistance and take g to be 10 m s^{-2}.)

A. 5.8 Hz

B. 7.1 Hz

C. 10.0 Hz

D. 12.5 Hz

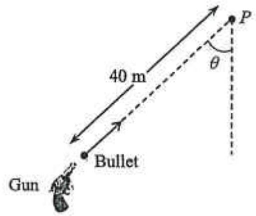


12. < HKAL 2004 Paper IIA - 3 >

As shown in the figure, a gun aims directly at a point P which is 40 m from the gun. The barrel of the gun makes an angle θ with the vertical. If the speed of the bullet is 50 m s^{-1}, what is the separation between the bullet and point P when the bullet is vertically below P ?

(Neglect air resistance and take g to be 10 m s^{-2}.)

A. 3.2 m
B. 4.8 m
C. 7.8 m
D. It cannot be found as the value of θ is not known.



13. < HKAL 2005 Paper IIA - 4 >

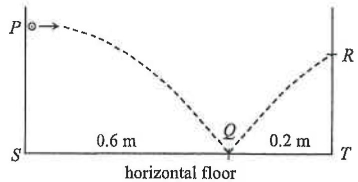
Five bombs are released from a bomber flying horizontally with a constant velocity. They are released one by one at one-second intervals. Neglecting air resistance, state

(1) the positions of the five bombs in the air at any instant before landing on the ground,

(2) the landing positions of the five bombs on the ground ?

	(1)	(2)
A.	They lie on a parabola.	They are evenly spaced.
B.	They lie on a parabola.	They are unevenly spaced.
C.	They lie on a straight line.	They are evenly spaced.
D.	They lie on a straight line.	They are unevenly spaced.

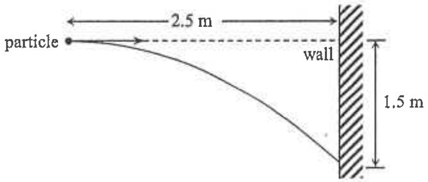
14. < HKAL 2006 Paper IIA - 3 >



As shown in the above figure, a small ball is projected horizontally with a speed of 1.6 m s^{-1} from the point P on a wall inside a room. The ball hits the smooth horizontal floor at Q and rebounds to the point R on the opposite wall. If air resistance is neglected, which of the following statements must be true ?

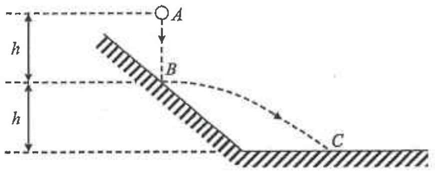
A. There is no loss of kinetic energy of the ball for the collision at Q.
B. The ball hits R with a horizontal velocity.
C. The total time of flight along the path PQR is 0.5 s.
D. If the ball is projected with the same horizontal speed at a point P', vertically above P, the total time of flight from P' to the opposite wall would be longer.

15. < HKAL 2008 Paper IIA - 7 >



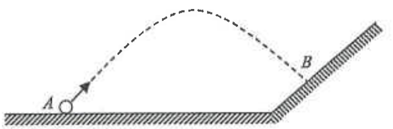
A small particle is projected horizontally towards a vertical wall 2.5 m away. It hits the wall 1.5 m below the initial horizontal level. At what angle to the vertical does the particle hit the wall ?
A. 34°
B. 40°
C. 53°
D. 56°

16. < HKAL 2009 Paper IIA - 7 >



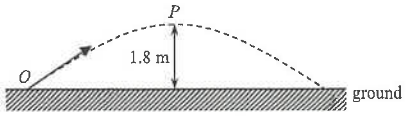
As shown in the above figure, a small ball is released from the point A. It makes a perfectly elastic collision at B on a slope and then rebounds horizontally. The ball finally reaches C on the ground. The vertical separation of AB and BC are both equal to h. If air resistance is neglected, which of the following statements is/are correct ?
(1) The acceleration of the ball is constant throughout the motion from A to C.
(2) The time for the ball to move from A to B is equal to that for it to move from B to C.
(3) The kinetic energy of the ball just before colliding at C is twice that at B.
A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

17. < HKAL 2010 Paper IIA - 4 >



As shown in the figure, a small ball is projected from the point A on the ground with an angle of elevation. It rebounds at B on the incline and travels back to A along the same path. Which statements about the ball must be correct ?
(1) The ball hits the incline at B normally.
(2) The ball undergoes perfectly elastic collision at B.
(3) The time taken for the ball to go from A to B is equal to that for it to return from B to A.
A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

18. < HKAL 2012 Paper IIA - 7 >



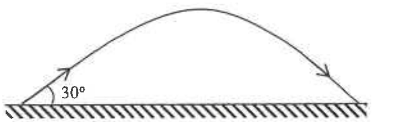
A small ball of mass 0.2 kg is projected from point O on the ground with a certain initial velocity as shown. It reaches a maximum height of 1.8 m at point P. Find the magnitude of the change in momentum, in N s, of the ball from O to P. Neglect air resistance and take g to be 10 m s^{-2}.
A. 1.2
B. 1.6
C. 2.4
D. It cannot be determined since the angle of projection is not given.

19. < HKAL 2013 Paper IIA - 6 >

A small ball is released from rest at the top of a building. After a while another ball is projected horizontally from the same position. Before reaching the ground, which quantity of the two balls will remain unchanged ? Neglect air resistance.
(1) their acceleration
(2) the difference in the vertical component of their velocities
(3) the difference in their heights above the ground
A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

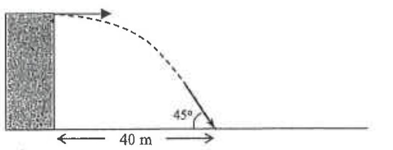
Part B : Supplemental exercise

20.



A ball of mass 2 kg is projected upwards with an angle of 30° inclined with the horizontal. It was found that the kinetic energy of the ball at the maximum height is 108 J. What is the initial speed of the ball ?
A. 8 m s^{-1}
B. 12 m s^{-1}
C. 15 m s^{-1}
D. 18 m s^{-1}

21.



A ball is projected horizontally from the top of a building. It reaches the ground at a point 40 m from the building, making an angle of 45° with the horizontal as shown in the above figure. What is the height of the building ? Take the acceleration due to gravity g to be 10 m s^{-2}.
A. 20 m
B. 30 m
C. 40 m
D. 80 m

22. An angry bird is at a height of 10 m above the ground. A green pig is at a horizontal distance of 55 m from the angry bird with a height of 12 m above the ground. In order that the angry bird can hit the green pig, what should be the launch angle (made with the horizontal) of the shot if the time of flight is 2.5 s ?

A. 28.5°
B. 30.7°
C. 32.5°
D. 35.2°

23. A ball is projected horizontally with an initial speed of u at a certain height above the ground. It then reaches the ground after a time t and the landing position is at a horizontal distance R from the starting point. What would the corresponding values be if the initial speed of the ball is changed to $2u$?

	Time taken to reach the ground	Horizontal distance travelled
A.	$2t$	$2R$
B.	$2t$	R
C.	t	$4R$
D.	t	$2R$

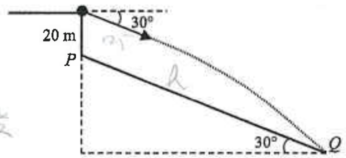
24. A particle is projected from the ground with a certain speed making an angle of 35° with the ground. After 4.5 s, it reaches the ground. Determine the horizontal distance moved by the particle.

A. 128 m
B. 142 m
C. 164 m
D. 186 m

25. A heavy ball is projected horizontally from top of a building with an initial speed of 10 m s^{-1}. It hits the ground with a speed of 15 m s^{-1}. If air resistance is neglected, what is the height of the building ?

A. 3.09 m
B. 6.37 m
C. 8.15 m
D. 9.28 m

26.



A particle is projected with speed 25 m s^{-1} at an angle of dip of 30° on the edge of a vertical cliff 20 m above point P as shown in the above figure. The particle then follows a parabolic path to reach the point Q at the bottom of an incline which makes an angle of 30° with the horizontal. Calculate the distance PQ of the incline. Take g to be 10 m s^{-2}.

A. 40 m
B. 50 m
C. 60 m
D. 70 m

27. A ball is projected horizontally at the top of a building with a speed of 12 m s^{-1}. The height of the building above the ground is 18 m. What is the speed of the ball when it lands on the ground if air resistance is negligible ?

A. 15.6 m s^{-1}
B. 22.3 m s^{-1}
C. 25.6 m s^{-1}
D. 28.9 m s^{-1}

Part C : HKDSE examination questions

28. **< HKDSE Practice Paper IA - 11 >**

A football player kicks a ball on the ground. The ball leaves the ground with speed v and hits the bar at X with a speed of 17 m s^{-1}. X is 2 m above the ground. Neglect air resistance, what is the value of v ?

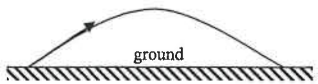
A. 15.8 m s^{-1}
B. 18.1 m s^{-1}
C. 19.0 m s^{-1}
D. 23.3 m s^{-1}

29. **< HKDSE 2012 Paper IA - 12 >**

A bomber aircraft is 1 km above the ground and is flying horizontally at a speed of 200 m s^{-1}. The aircraft is going to release a bomb to destroy a target on the ground. How long before flying over the target should the bomb be released ? Assume that the bomber aircraft and the target are in the same vertical plane and neglect air resistance.

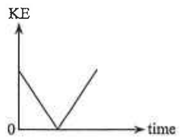
A. 5.6 s
B. 10.1 s
C. 14.3 s
D. It cannot be calculated as the horizontal distance between the aircraft and the target is not known.

30. **< HKDSE 2013 Paper IA - 13 >**

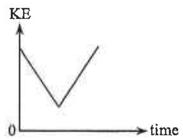


A particle is projected into the air at time t = 0 and it performs a parabolic motion before landing on the ground as shown. Which graph represents the variation of the kinetic energy (KE) of the particle with time before landing ? Neglect air resistance.

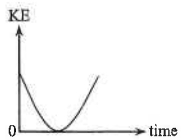
A.



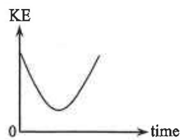
B.



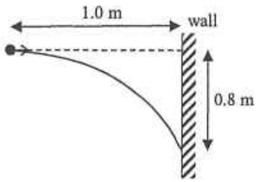
C.



D.



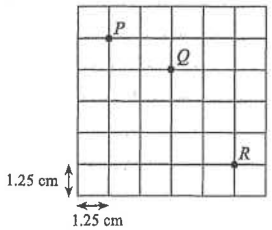
31. < HKDSE 2014 Paper IA - 10 >



A particle is projected horizontally towards a vertical wall 1.0 m away. It hits the wall at a position 0.8 m vertically below its point of projection. At what speed is it projected ? Neglect air resistance.

A. 2.0 m s^{-1}
B. 2.5 m s^{-1}
C. 5.0 m s^{-1}
D. 6.3 m s^{-1}

32. < HKDSE 2016 Paper IA - 10 >

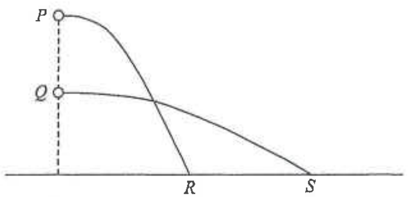


The above stroboscopic picture shows a particle projected horizontally at position P into the air in a vertical plane. Subsequently the particle reaches positions Q and R such that the time interval between P and Q is equal to that between Q and R. Each square of the grid measures 1.25 cm × 1.25 cm. Find the particle's speed of projection at P. Neglect air resistance.

A. 0.3 m s^{-1}
B. 0.4 m s^{-1}
C. 0.5 m s^{-1}
D. 0.6 m s^{-1}

33. < HKDSE 2017 Paper IA - 9 >

Marbles P and Q of the same mass are shot horizontally. They hit the horizontal ground at points R and S respectively as shown. Neglect air resistance.



Which of the following statements is **INCORRECT** ?

A. The initial speed of marble P is smaller than that of marble Q.
B. The time of flight of marble P is shorter than that of marble Q.
C. The potential energy loss of marble P is greater than that of marble Q.
D. The acceleration of marbles P and Q is the same during the flight.

There is question in next page

M.C. Answers

1. D	11. C	21. A	31. B
2. A	12. A	22. B	32. C
3. D	13. C	23. D	33. B
4. C	14. C	24. B	**34. C**
5. D	15. B	25. B	**35 C**
6. D	16. D	26. B	
7. D	17. D	27. B	
8. D	18. A	28. B	
9. D	19. C	29. C	
10. D	20. B	30. D	

M.C. Solution

1. D

× (1) Vertical speed of A = 0 m s^{-1} ; Vertical speed of B = 20 × sin 60° = 17.3 m s^{-1}
Different initial vertical speed ⇒ travel different vertical distance in equal times

✓ (2) Horizontal speed of B = 20 × cos 60° = 10 m s^{-1} = Horizontal speed of A.
Same initial horizontal speed ⇒ travel same horizontal distance in equal times

✓ (3) Balls A and B experience same acceleration due to gravity but different initial speed
⇒ B is always above A ∴ they never meet

2. A

From Q to R :

$y = u_y t + \frac{1}{2} a_y t^2$ ∴ $(2) = (0) + \frac{1}{2}(9.81)t^2$ ∴ $t = 0.6386$ s

$x = u_x t$ ∴ $(3) = u(0.6386)$ ∴ $u = 4.70$ m s^{-1}

From P to Q :

loss of $P.E.$ = gain of $K.E.$

∴ $mgh = \frac{1}{2}mu^2$ ∴ $(9.81)h = \frac{1}{2}(4.70)^2$ ∴ $h = 1.13$ m

3. D

Vertical direction : $v_y = u_y + gt = (0) + (9.81)(3) = 29.43$ m s^{-1}

Horizontal direction : $v_x = u = 20$ m s^{-1}

Speed : $v = \sqrt{29.43^2 + 20^2} = 35.6$ m s^{-1}

4. C

From P to Q :

$v_y^2 = u_y^2 + 2\,a_y\,y$ $\quad\therefore\ v_y^2 = (10\sin 30°)^2 + 2\,(10)\,(10)$ $\quad\therefore\ v_y = 15\ \text{m s}^{-1}$

Since the collision at Q is perfectly elastic, the vertical velocity of the sphere just after collision is also 15 m s^{-1}.

From Q to R, the vertical displacement is zero.

By $y = u_y t + \frac{1}{2} a_y t^2$ $\quad\therefore\ (0) = (15)\,t + \frac{1}{2}(-10)\,t^2$ $\quad\therefore\ t = 3\ \text{s}$

Horizontal distance $QR = v_x t = (10 \times \cos 30°)\,(3) = 26.0\ \text{m}$

5. D

In order to hit the monkey, the angle θ of projection must satisfy : $\tan\theta = \dfrac{h}{d}$ $\quad\therefore\ \theta$ depends on h and d.

Since both the bullet and the monkey have the same acceleration due to gravity,

thus, the bullet and the monkey must meet irrespective of the value of the initial speed u.

6. D

✓ (1) Both A and B have zero initial vertical velocity and both have same acceleration due to gravity,
∴ they reach the ground at the same time.

✓ (2) Both A and B experience the same acceleration due to gravity g since the net force is the weight mg.

✓ (3) Both A and B have zero initial vertical velocity and both have same acceleration due to gravity,
they have the same final vertical velocity.

7. D

Bomber moves with constant velocity

∴ bombs and bomber always move with the same horizontal displacement

∴ all the bombs must always be vertically below the bomber

∴ all the bombs and the bomber must be in a vertical line

Gravitational acceleration exists ⇒ bombs move for a longer vertical distance as time increases

∴ D is the correct answer.

8. D

The horizontal component of velocity is constant and is equal to u.

Consider the final velocity v :

By $v_x^2 + v_y^2 = v^2$

$\therefore\ u^2 + v_y^2 = v^2$ $\quad\therefore\ v_y = \sqrt{v^2 - u^2}$

Consider the vertical component :

By $v_y = u_y + a\,t$ $\quad\therefore\ \sqrt{v^2 - u^2} = (0) + (g)\,t$

$\therefore\ t = \dfrac{\sqrt{v^2 - u^2}}{g}$

9. D

Vertically : $y = u_y t + \frac{1}{2} a_y t^2$ $\quad\therefore\ (0.8) = (0)\,t + \frac{1}{2}(10)\,t^2$ $\quad\therefore\ t = 0.404\ \text{s}$

Vertically : $v_y = u_y + g\,t = (0) + (9.81)\,(0.404) = 3.96\ \text{m s}^{-1}$

Horizontally : $x = v_x t$ $\quad\therefore\ (1.2) = v_x\,(0.404)$ $\quad\therefore\ v_x = 2.97\ \text{m s}^{-1}$

Final speed : $v = \sqrt{v_x^2 + v_y^2} = \sqrt{(2.97)^2 + (3.96)^2} = 4.95\ \text{m s}^{-1}$

10. D

As $E_o = \frac{1}{2} m u^2$

∴ kinetic energy of the horizontal component $= \frac{1}{2} m\,(u\cos 45°)^2 = \frac{1}{2} m u^2 \times \frac{1}{2} = \frac{1}{2} E_o$

∴ initial kinetic energy of the vertical component $= \frac{1}{2} E_o$

When the ball is moving halfway up, half of the initial kinetic energy of vertical component is changed into $P.E.$

∴ kinetic energy of the vertical component at halfway up $= \frac{1}{4} E_o$

∴ total kinetic energy at halfway up $= \frac{1}{2} E_o + \frac{1}{4} E_o = \frac{3}{4} E_o$

OR

potential energy of the stone at halfway up $= \frac{1}{2} E_o \times \frac{1}{2} = \frac{1}{4} E_o$

∴ total kinetic energy at halfway up $= E_o - \frac{1}{4} E_o = \frac{3}{4} E_o$

11. C

Assume T is the period of the strobe lamp, which is the time interval between two images of the particle.

By $y = u_y t + \frac{1}{2} a_y t^2$

① $(0.15) = u_y\,(T) + \frac{1}{2}(10)\,(T)^2$

② $(0.40) = u_y\,(2\,T) + \frac{1}{2}(10)\,(2\,T)^2$

Eliminate u_y : $T = 0.1\ \text{s}$

Frequency of the strobe lamp : $f = \dfrac{1}{0.1} = 10\ \text{Hz}$

12. A

Assume the bullet takes time t to reach the point vertically below P.

Consider the horizontal motion of the bullet : $x = v_x t$ $\quad\therefore\ (40\sin\theta) = (50\sin\theta)\,t$ $\quad\therefore\ t = 0.8\ \text{s}$

Method ① : By the concept of Monkey and hunter experiment, the displacement of the monkey dropped from P is

$s = \frac{1}{2} g t^2 = \frac{1}{2}(10)\,(0.8)^2 = 3.2\ \text{m}$

Method ② : Consider the vertical motion of the bullet :

$y = u_y t + \frac{1}{2} g t^2 = (50\cos\theta) \times (0.8) + \frac{1}{2}(-10)\,(0.8)^2 = 40\cos\theta - 3.2$

Vertical separation between P and the bullet : $s = (40\cos\theta) - (40\cos\theta - 3.2) = 3.2\ \text{m}$

13. C

(1) Since every bomb has the same horizontal velocity as the aircraft, it must always be vertically under the aircraft. Thus, at any instant, they lie on a vertical straight line.

(2) The spacing between the landing position of any two bombs is $\Delta x = v_x \times \Delta t$. Thus, Δx is a constant.

14. C

× A. Since the collision may be elastic or not elastic, kinetic energy may or may not be conserved.

× B. The ball may or may not hit R at the topmost point, thus it may or may not hit R with a horizontal velocity.

✓ C. Since the horizontal component of the velocity remains unchanged

$\therefore \ t = \dfrac{(0.6+0.2)}{(1.6)} = 0.5 \text{ s}$

× D. If the horizontal projected velocity is the same, the time of flight should remain unchanged.

15. B

Time taken to hit the wall : $y = \frac{1}{2} g t^2$ $\therefore (1.5) = \frac{1}{2}(9.81) t^2$ $\therefore t = 0.553 \text{ s}$

Horizontal motion : $x = v_x t$ $\therefore (2.5) = v_x (0.553)$ $\therefore v_x = 4.52 \text{ m s}^{-1}$

Vertical motion : $v_y^2 = 2 g y$ $\therefore v_y^2 = 2(9.81)(1.5)$ $\therefore v_y = 5.42 \text{ m s}^{-1}$

$\therefore \tan\theta = \dfrac{v_x}{v_y} = \dfrac{4.52}{5.42}$ $\therefore \theta = 40°$

16. D

× (1) From A to B and from B to C, the acceleration is equal to g and is constant. However, during the impact with the slope at B, the acceleration is not equal to g due to the normal reaction force acting on the ball by the slope.

✓ (2) Time taken from A to B is found by $h = \frac{1}{2} g t^2$
and time taken from B to C is also found by $h = \frac{1}{2} g t^2$
as the initial vertical velocity is zero in both cases, thus the times taken are the same.

✓ (3) KE just before colliding B = loss of PE from A to B = $m g h$
KE just before colliding C = loss of PE from A to C = loss of PE from A to $B \times 2 = m g \times 2h$

17. D

✓ (1) As the ball rebounds along the same path, it must hit the incline at B normally, i.e. perpendicular to the incline.

✓ (2) As the ball can reach the original position, the collision must be perfectly elastic. If it is not perfectly elastic, some KE is lost, the ball cannot reach the same maximum height.

✓ (3) As the distance of the path is the same and the speed at corresponding points are the same, the time taken must be the same.

18. A

Consider the vertical component. At the maximum height, $v_y = 0$.

By $v_y^2 = u_y^2 + 2 a_y y$ $\therefore (0) = u_y^2 + 2(-10)(1.8)$ $\therefore u_y = 6 \text{ m s}^{-1}$

Since there is no change of horizontal component of velocity, there is no change of horizontal momentum.

The change in momentum = change in vertical momentum

Initial vertical momentum = $m u_y$ = (0.2) (6) = 1.2 N s

At highest point, the vertical momentum is zero, thus the change in vertical momentum = 1.2 N s

19. C

✓ (1) Both the vertical fall and the projectile motion have the same acceleration due to gravity.

✓ (2) Since the projected ball starts the motion later, their vertical velocities would differ by a constant value.

× (3) The difference in their vertical heights would increase with time.

20. B

At maximum height, the vertical component of the velocity is zero.

$\therefore KE = \frac{1}{2} m u^2 \cos^2\theta$

$\therefore (108) = \frac{1}{2}(2) u^2 \cos^2 30°$ $\therefore u = 12 \text{ m s}^{-1}$

21. A

$\dfrac{v_y}{v_x} = \tan 45° = 1$ $\therefore v_y = v_x = u$

Vertical component : $v_y = g t = (10) t = 10 t$

Horizontal component : $x = v_x t$ $\therefore (40) = (10 t) t$ $\therefore t = 2 \text{ s}$

$\therefore y = \frac{1}{2} g t^2$ $\therefore h = \frac{1}{2}(10)(2)^2 = 20 \text{ m}$

22. B

Horizontal component :

$x = u_x t$ $\therefore (55) = u_x (2.5)$ $\therefore u_x = 22 \text{ m s}^{-1}$

Vertical component :

$y = u_y t + \frac{1}{2} a_y t^2$ $\therefore (12 - 10) = u_y (2.5) + \frac{1}{2}(-9.81)(2.5)^2$ $\therefore u_y = 13.06 \text{ m s}^{-1}$

$\tan\theta = \dfrac{u_y}{u_x} = \dfrac{13.06}{22}$ $\therefore \theta = 30.7°$

23. D

① Time taken to reach the ground depends on the height of projection and is independent of the initial speed. Thus the time taken is still t.

② Horizontal distance travelled is $R = u\,t$.
If $u \to 2u$, then $R \to 2R$.

24. B

By $y = u_y t + \frac{1}{2} a_y t^2$

$\therefore$ $(0) = (u \sin 35°) \times (4.5) + \frac{1}{2}(-9.81) \times (4.5)^2$ $\therefore$ $u = 38.48 \text{ m s}^{-1}$

Horizontal range : $x = u_x t = (38.48 \cos 35°) \times (4.5) = 142 \text{ m}$

25. B

The horizontal component of velocity is constant and is equal to 10 m s^{-1}.

Consider the final velocity v :

$v^2 = v_x^2 + v_y^2$

$\therefore$ $(15)^5 = (10)^2 + v_y^2$ $\therefore$ $v_y = 11.18 \text{ m s}^{-1}$

Consider the vertical component :

$v_y^2 = u_y^2 + 2 a_y y$

$\therefore$ $(11.18)^2 = (0) + 2(9.81) y$ $\therefore$ $y = 6.37 \text{ m}$

26. B

Let the distance PQ be d.

Consider the horizontal component :

$x = u_x t$

$\therefore$ $(d \cos 30°) = (25 \cos 30°) \times t$ $\therefore$ $d = 25 t$

Consider the vertical component :

$y = u_y t + \frac{1}{2} a_y t^2$

$\therefore$ $(20 + d \sin 30°) = (25 \sin 30°) t + \frac{1}{2}(10) t^2$

$\therefore$ $(20 + 25 t \times \sin 30°) = (25 \sin 30°) t + \frac{1}{2}(10) t^2$

$\therefore$ $20 = \frac{1}{2}(10) t^2$

$\therefore$ $t = 2 \text{ s}$

Distance PQ : $d = 25 \times 2 = 50 \text{ m}$

27. B

By Conservation of energy :

$\frac{1}{2} m u^2 + m g h = \frac{1}{2} m v^2$

$\therefore$ $\frac{1}{2}(12)^2 + (9.81)(18) = \frac{1}{2} v^2$ $\therefore$ $v = 22.3 \text{ m s}^{-1}$

28. B

Let v_x be the speed of the ball at position X.

By Conservation of energy :

$\frac{1}{2} m v^2 = \frac{1}{2} m v_x^2 + m g h$

$\therefore$ $\frac{1}{2} v^2 = \frac{1}{2}(17)^2 + (9.81)(2)$ $\therefore$ $v = 18.1 \text{ m s}^{-1}$

29. C

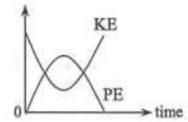
Consider the vertical component :

$y = \frac{1}{2} g t^2$ $\therefore$ $(1 \times 10^3) = \frac{1}{2}(9.81) t^2$

$\therefore$ $t = 14.3 \text{ s}$

30. D

As the time variation of PE is a quadratic curve,
the time variation of KE should also be a quadratic curve.
At the highest point, the speed is equal to $u \cos \theta$ which is not zero,
thus the KE at the highest point is not zero.



31. B

Vertical component : $y = \frac{1}{2} g t^2$ $\therefore$ $(0.8) = \frac{1}{2}(9.81) t^2$ $\therefore$ $t = 0.404 \text{ s}$

Horizontal component : $x = u t$ $\therefore$ $(1.0) = u(0.404)$ $\therefore$ $u = 2.5 \text{ m s}^{-1}$

32. C

As the particle is projected horizontally at P, the initial vertical velocity is zero.

Assume the time interval between two images be T.

For the first two images, vertical displacement y is 1.25 cm and horizontal displacement x is 2.5 cm.

By $y = \frac{1}{2} g t^2$ $\therefore$ $(0.0125) = \frac{1}{2}(9.81) T^2$ $\therefore$ $T = 0.0505 \text{ s}$

By $x = u t$ $\therefore$ $(0.025) = u(0.0505)$ $\therefore$ $u = 0.5 \text{ m s}^{-1}$

33. B

✓ A. By $x = u t$, since the horizontal range x of P is shorter and the time of flight t of P is longer, the initial speed u of P must be smaller.

✗ B. By $y = \frac{1}{2} g t^2$, as the vertical displacement y of P is greater, the time of flight t of P should be longer.

✓ C. Since P is at a higher height, by $PE = mgh$, P has a greater potential energy.

✓ D. During the projectile motion in air, both of them experience the same acceleration due to gravity.

The following list of formulae may be found useful :

For uniformly accelerated motion $v = u + at$

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

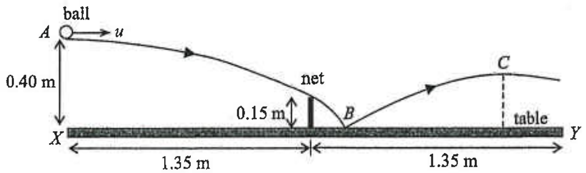
$v^2 = u^2 + 2as$

Use the following data wherever necessary :

Acceleration due to gravity $g = 9.81 \text{ m s}^{-2}$ (close to the Earth)

Part A : HKAL examination questions

1. < HKAL 1996 Paper I - 1 >

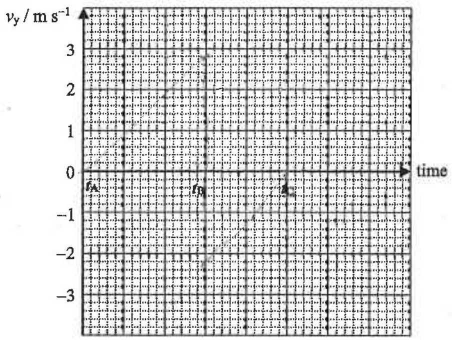


A ping-pong ball is struck at the point A, which is 0.40 m vertically above the edge X of the table. The ball then moves with a horizontal velocity u. It then just passes the net to reach the table at point B. After rebounding from the table, it reaches the highest point C, which is 0.25 m above the table. The length of the table XY is 2.70 m. The net is 0.15 m high and it is placed exactly at the middle of the table. Take g to be 10 m s^{-2}. Neglect the effect of air resistance.

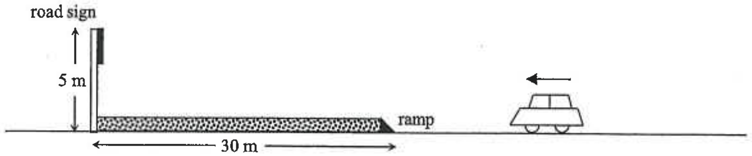
(a) Calculate the initial velocity u of the ping-pong ball. (2 marks)

(b) Calculate the speed of the ball just before it hits the table at B. (2 marks)

(c) If point C is at 0.25 m above the table, draw the graph of vertical velocity, v_y, of the ball against time from A to C. Take downward direction as positive. (t_A, t_B and t_C on the time axis are the times when the ball is at A, B and C respectively.) (3 marks)



2. < HKAL 2000 Paper I - 1 >



As shown in the above figure, a car travels on a horizontal road towards the left. When it hits the ramp, it takes off from the ramp with an initial speed u and follows a projectile path to hit the top of the road sign which is 5 m high above the road and 30 m away from the ramp. Take the acceleration due to gravity to be 10 m s^{-2}.

(a) Sketch the possible trajectories of the car in the air for a certain take-off speed in the above figure. (2 marks)

(b) Assume that the car hit the road sign at the highest point in its trajectory. Neglect air resistance and the size of the car.

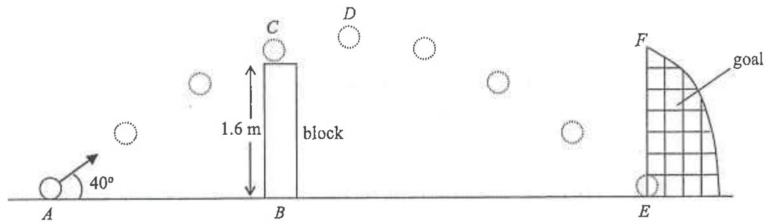
(i) Calculate the time t of flight before the car hit the road sign. (2 marks)

(ii) Calculate the take-off speed u and the projection angle θ of the car. (3 marks)

(c) Braking marks of 39 m long was found on the road in front of the ramp. Forensic measurements on the marks by the police indicated that the braking force was about 8000 N on the car of mass 1000 kg. Estimate the speed of the car just before applying the brakes. Assume that the speed of the car on hitting the ramp is equal to the projection speed of the car from the ramp. (2 marks)

3. < HKAL 2003 Paper I - 7 >

A ball is kicked to move with an initial velocity of 10 m s^{-1}, making an angle of 40° with the horizontal. The ball then just passes a block of height 1.6 m, reaching the highest point D, and finally hits the ground at E as shown in the below figure. Neglect air resistance and the size of the ball.



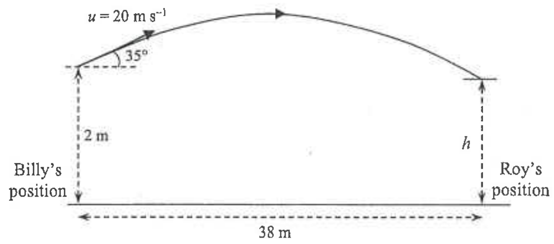
(a) Draw an arrow to indicate the direction of acceleration of the ball at C. (1 mark)

(b) Calculate the speed of the ball at C. (2 marks)

(c) Calculate the height of the ball at D. (2 marks)

(d) The ball finally reaches the point E. Calculate the distance between A and E. (3 marks)

4. < HKAL 2007 Paper I - 1 >



As shown in the above figure, Billy tries to pass a ball to Roy, standing 38 m away from him. Billy throws the ball from a point 2 m above the ground with an initial speed of 20 m s^{-1} at an angle of elevation of 35°. The mass of the ball is 0.42 kg. Take the acceleration due to gravity to be 10 m s^{-2}. Neglect air resistance and the size of the ball.

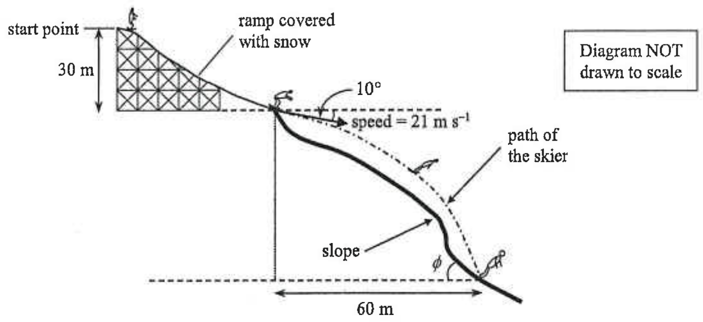
(a) Assume the throwing action of Billy starts from rest and the gain in gravitational potential energy of the ball during the throwing action can be neglected.

(i) Find the work done on the ball by Billy in the throwing action. (2 marks)

(ii) If the throwing action lasts for 0.15 s, calculate the average power that Billy delivers to the ball. (2 marks)

(b) Determine the height h that Roy should place his hands there so as to catch the ball. (3 marks)

5. < HKAL 2009 Paper I - 2 >



As shown in the above figure, a skier of mass 84 kg slides down a ramp from rest at the start point which is 30 m above the end of the ramp. The skier attains a speed of 21 m s^{-1} when he leaves the ramp and makes the ski jump at an angle 10° below the horizontal. He eventually lands on a slope at horizontal distance of 60 m from the lower end of the ramp. Neglect air resistance and take the acceleration due to gravity to be 10 m s^{-2}.

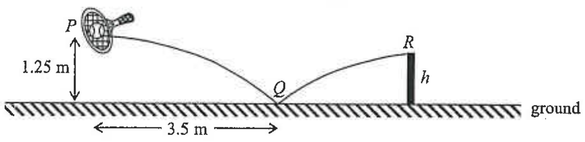
(a) Find the work done against friction by the skier when he slides down the ramp. (3 marks)

(b) Calculate the skier's time of flight in air after he leaves the ramp. (2 marks)

(c) Find the magnitude and direction of the skier's velocity at landing. (3 marks)

(d) For safety reasons, the direction of the skier's velocity just before landing and the slope there should differ by no more than 5°. Find the minimum value of the angle of inclination ϕ of the slope there. (1 mark)

6. < HKAL 2011 Paper I - 1 >



In the above figure, a player strikes a tennis ball of mass 60 g horizontally with a racket at P at a height of 1.25 m above the ground. The ball then hits the ground at Q and rebounds to that it just goes over an obstacle at R at its highest point of its path. The horizontal distance between PQ is 3.5 m. Neglect air resistance and take g to be 10 m s^{-2}.

(a) Calculate the time of flight of the ball from P to Q. (2 marks)

(b) Find the horizontal and vertical components of the velocity of the ball at Q just before it hits the ground. (2 marks)

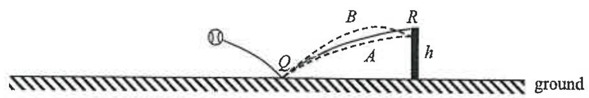
(c) During the impact with the ground at Q, the vertical component of the ball's velocity is reduced by 20%.

(i) Assume that the ground is smooth, calculate the speed of the ball just after impact at Q. (2 marks)

(ii) Find the magnitude of the average force exerted by the ground on the ball during the impact at Q if the contact time of the ball and the ground is 0.04 s. (3 marks)

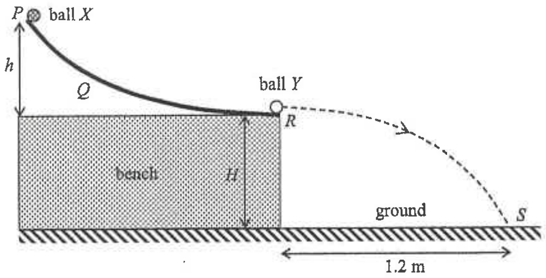
(d) Estimate the height h of the obstacle. (2 marks)

(e) If friction exists between the ball and the ground, decide whether the ball would take path A or B as shown in the Figure below. Explain your answer. (2 marks)



Part B : HKDSE examination questions

7. **< HKDSE Practice Paper IB - 3 >**



A smooth curved rail PQR is fixed on a horizontal bench as shown. P is at a height h above the bench surface. A small metal ball X of mass 0.03 kg is released from rest at P. When the ball X reaches R, it moves horizontally and collides head-on with another metal ball Y of mass 0.04 kg which is initially at rest on the rail. Immediately after the collision, ball X comes to rest while ball Y moves off the bench horizontally with a speed of 3 m s^{-1}. Neglect air resistance.

(a) What is the speed of ball X just before it collides with ball Y? (1 mark)

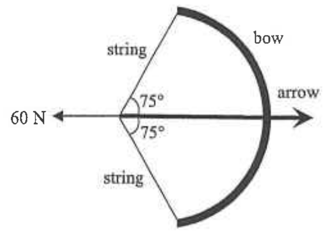
(b) Find the value of h. (2 marks)

(c) Ball Y lands on the ground at S which is at a horizontal distance of 1.2 m from the bench. Find the height H of the bench. (3 marks)

(d) Ball X is now released at Q such that ball Y moves off the bench horizontally with a smaller speed after collision. Would the time of flight of ball Y change ? Explain briefly. (2 marks)

8. **< HKDSE 2012 Paper IB - 5 >**

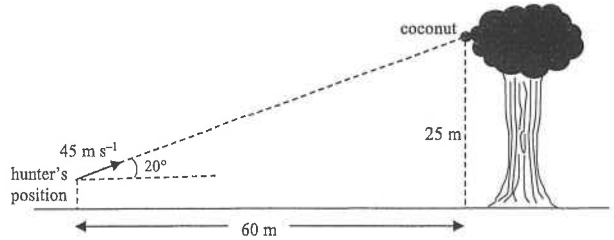
(a) A bow and arrow is a kind of projectile weapon. The string of a bow is drawn taut by a hunter with a force of 60 N and an arrow of mass 0.2 kg is held stationary as shown in the Figure below.



(i) Find the tension of the string. Neglect the weight of the arrow. (2 marks)

(ii) Estimate the energy stored in the taut string if the initial speed of the arrow is 45 m s^{-1} when released. Assume that the bow is rigid and neglect the mass of the string. (2 marks)

(b) The hunter stands at about 60 m away from a tree as shown in the Figure below. He uses the bow to release the arrow in order to shoot a coconut held by a monkey (not shown in the figure) in the tree. The coconut is at a height of 25 m from the ground. The hunter aims directly at the coconut and the arrow leaves the bow at a speed of 45 m s^{-1} making an angle of 20° to the horizontal. At the moment the hunter releases the arrow, the monkey drops the coconut such that it falls vertically from rest. Neglect air resistance and the arrow's size.



(i) Find the time taken for the arrow to hit the coconut. (2 marks)

(ii) Find the height of the coconut from the ground at the moment the arrow hits it. (2 marks)

9. < HKDSE 2017 Paper IB - 4 >

(a) A steel ball bearing is released from rest at time $t = 0$. A stroboscopic photo is taken at 0.05 s time intervals. The results are shown in Figure 1. Neglect air resistance.

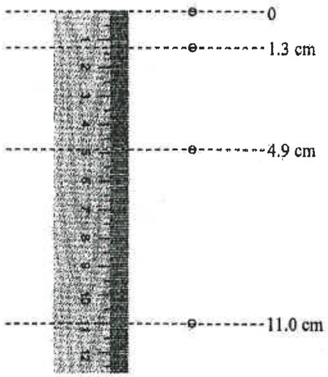


Figure 1

(i) Estimate the acceleration due to gravity using the data in Figure 1. (2 marks)

(ii) The bearing is now projected horizontally instead of released from rest. The bearing is projected at time $t = 0$, and a stroboscopic photo is taken at 0.05 s time intervals. The first and the last image of the stroboscopic photo are shown using circles (O) in Figure 2. For reference, the stroboscopic photo of the bearing released from rest is also shown in the figure using crosses (X).

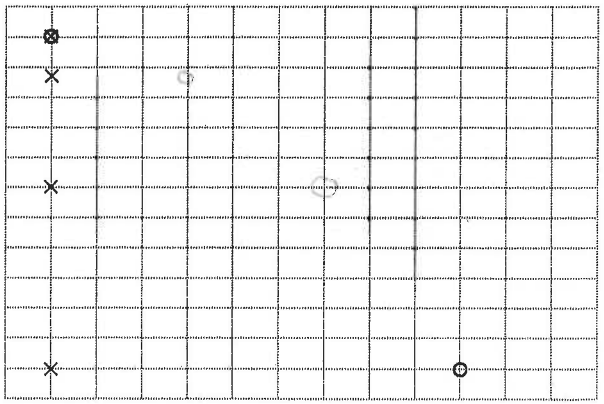


Figure 2

(1) In Figure 2, mark the positions of the projected bearing in the stroboscopic photo using circles (O). (2 marks)

9. (a) (ii) (2) Given that the bearing is projected horizontally with an initial speed of 1 m s^{-1}, use the results of (a)(i) to calculate the speed of the projected bearing when the last image was taken. (3 marks)

(b) If a small ball is released from rest from the top of a cliff, the speed of the ball becomes constant after a period of time. By considering the forces acting on the ball and using Newton's laws of motion, explain why the speed of the ball becomes constant. (3 marks)

Question Solution

1. (a) By $y = \frac{1}{2} g t^2$ (consider the motion from A to the net)

$\therefore$ $(0.40 - 0.15) = \frac{1}{2}(10) t^2$ [1]

$\therefore$ $t = 0.224$ s

By $x = u t$

$\therefore$ $(1.35) = u(0.224)$

$\therefore$ $u = 6.03$ m s^{-1} [1]

(b) Conservation of energy from A to B :

$\therefore$ $\frac{1}{2} m u^2 + m g h = \frac{1}{2} m v^2$ [1]

$\therefore$ $\frac{1}{2} m (6.03)^2 + m(10) \times (0.40) = \frac{1}{2} m v^2$ [1]

$\therefore$ $v = 6.66$ m s^{-1} [1]

OR

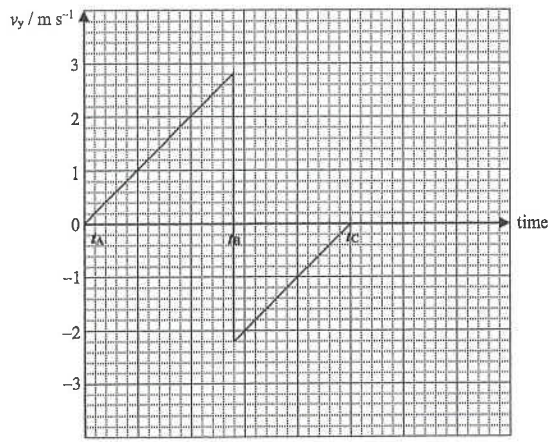
By $v_y^2 = u_y^2 + 2 a s$

$\therefore$ $v_y^2 = (0) + 2(10)(0.4)$

$\therefore$ $v_y = 2.828$ m s^{-1} [1]

$\therefore$ $v = \sqrt{(6.03)^2 + (2.828)^2} = 6.66$ m s^{-1} [1]

(c)



Before collision :

$v_y = \sqrt{2 \times 10 \times 0.4} = 2.8$ m s^{-1}

After collision :

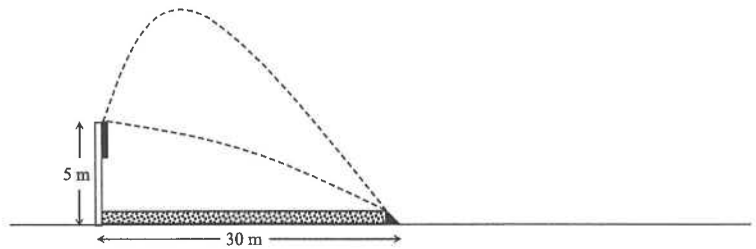
$v_y = \sqrt{2 \times 10 \times 0.25} = 2.2$ m s^{-1}

< uniform acceleration shown > [1]

< correct slope > [1]

< correct shape > [1]

2. (a)



< one trajectory hits the road sign at a shorter time > [1]

< one trajectory hits the road sign after reaching the highest point > [1]

(b) (i) At the highest point, $v_y = 0$

By $v_y^2 = u_y^2 + 2 a y$

$\therefore$ $(0) = u_y^2 + 2(-10)(5)$

$\therefore$ $u_y = 10$ m s^{-1} [1]

By $v_y = u_y + a t$

$\therefore$ $(0) = (10) + (-10) t$

$\therefore$ $t = 1$ s [1]

(ii) By $x = u_x t$

$\therefore$ $(30) = u_x (1)$

$\therefore$ $u_x = 30$ m s^{-1} [1]

$\therefore$ $u = \sqrt{(10)^2 + (30)^2} = 31.6$ m s^{-1} [1]

By $\tan\theta = \frac{u_y}{u_x} = \frac{10}{30}$

$\therefore$ $\theta = 18.4°$ [1]

(c) By $F = m a$

$\therefore$ $(8000) = (1000) a$

$\therefore$ $a = 8$ m s^{-2} < accept -8 m s^{-2} > [1]

By $v^2 = u^2 + 2 a s$

$\therefore$ $(31.6)^2 = u^2 + 2(-8) \times (39)$

$\therefore$ $u = 40.3$ m s^{-1} [1]

OR

Initial KE = Final KE + work done against the braking force

$\frac{1}{2} m u^2 = \frac{1}{2} m v^2 + F s$

$\frac{1}{2}(1000) u^2 = \frac{1}{2}(1000)(31.6)^2 + (8000)(39)$ [1]

$\therefore$ $u = 40.3$ m s^{-1} [1]

3. (a)

C

< arrow should be vertically downwards, as it is the acceleration due to gravity > [1]

(b) $\frac{1}{2} m u^2 = \frac{1}{2} m v^2 + m g h$

$\therefore \frac{1}{2} m (10)^2 = \frac{1}{2} m v^2 + m (9.81)(1.6)$ [1]

$\therefore v = 8.28 \text{ m s}^{-1}$ [1]

OR

$v_y^2 = (10 \sin 40°)^2 + 2(-9.81)(1.6)$ $\therefore v_y = 3.15 \text{ m s}^{-1}$ [1]

$v_x = 10 \cos 40° = 7.66 \text{ m s}^{-1}$

$v = \sqrt{(3.15)^2 + (7.66)^2} = 8.28 \text{ m s}^{-1}$ [1]

(c) $v_y^2 = u_y^2 + 2 a y$

$(0) = (10 \sin 40°)^2 + 2(-9.81) h$ [1]

$\therefore h = 2.11 \text{ m}$ [1]

(d) At E, the vertical displacement y is zero.

By $y = u_y t + \frac{1}{2} a t^2$

$\therefore (0) = (10 \sin 40°) t + \frac{1}{2}(-9.81) t^2$ [1]

$\therefore t = 1.31 \text{ s}$ [1]

Distance AE : $x = (10 \cos 40°) \times (1.31) = 10.0 \text{ m}$ [1]

4. (a) (i) $W = \frac{1}{2} m u^2 = \frac{1}{2}(0.42)(20)^2$ [1]

$= 84 \text{ J}$ [1]

(ii) $P = \frac{W}{t} = \frac{84}{0.15}$ [1]

$= 560 \text{ W}$ [1]

(b) Horizontally :

$x = u \cos \theta \times t$

$\therefore (38) = (20) \cos 35° \times t$ $\therefore t = 2.32 \text{ s}$ [1]

Vertically :

$y = u_y t + \frac{1}{2} a_y t^2$

$= (20 \sin 35°) \times (2.32) + \frac{1}{2}(-10)(2.32)^2 = -0.298 \text{ m}$ [1]

$\therefore h' = 2 - 0.298 = 1.70 \text{ m}$ [1]

5. (a) $m g h = \frac{1}{2} m v^2 + W$ [1]

$(84)(10)(30) = \frac{1}{2}(84)(21)^2 + W$ [1]

$W = 6678 \text{ J}$ < accept 6670 J to 6700 J > [1]

(b) $x = u_x \times t$

$\therefore (60) = (21 \cos 10°) \times t$ [1]

$\therefore t = 2.90 \text{ s}$ [1]

(c) $v_x = (21) \cos 10° = 20.7 \text{ m s}^{-1}$

$v_y = (21) \sin 10° + (10)(2.90) = 32.6 \text{ m s}^{-1}$ [1]

Resultant speed :

$v = \sqrt{(20.7)^2 + (32.6)^2} = 38.6 \text{ m s}^{-1}$ < accept 38.6 m s^{-1} to 39.1 m s^{-1} > [1]

By $\tan \theta = \frac{32.6}{20.7}$

$\therefore \theta = 57.6°$ < accept 57.5° to 58.0° > [1]

(d) $\phi = 57.6° - 5°$

$= 52.6°$ < accept 52.5° to 53.0° > [1]

6. (a) By $y = \frac{1}{2} g t^2$

$\therefore (1.25) = \frac{1}{2}(10) t^2$ [1]

$\therefore t = 0.5 \text{ s}$ [1]

(b) By $x = v_x t$

$\therefore (3.5) = v_x (0.5)$

$\therefore v_x = 7 \text{ m s}^{-1}$ [1]

By $v_y = g t$

$\therefore v_y = (10)(0.5) = 5 \text{ m s}^{-1}$ [1]

(c) (i) $v_y' = 5 \times 80\% = 4 \text{ m s}^{-1}$ [1]

$v = \sqrt{4^2 + 7^2} = 8.06 \text{ m s}^{-1}$ [1]

(ii) The average force acting on the ball by the ground is the normal reaction R.

By $R - m g = \frac{m v_y' - m v_y}{t}$ [1]

$\therefore R - (0.06)(10) = \frac{(0.06)(4) - (0.06)(-5)}{(0.04)}$ [1]

$\therefore R = 14.1 \text{ N}$ [1]

6. (d) By $v_y^2 = u_y^2 + 2\,a_y\,y$

$\therefore\ (0) = (4)^2 + 2\,(-10)\,h$ [1]

$\therefore\ h = 0.8$ m [1]

(e) Path *B*.

Horizontal speed is reduced after impact at *Q* due to friction.α [1]

Ball rebounds at a larger angle with the horizontal, thus the ball takes the path *B*. [1]

7. (a) Conservation of momentum :

$\therefore\ (0.03)\,v = (0.04)\,(3)$

$\therefore\ v = 4$ m s^{-1} [1]

(b) $m\,g\,h = \frac{1}{2}\,m\,v^2$ [1]

$(0.03)\,(9.81)\,h = \frac{1}{2}\,(0.03)\,(4)^2$

$\therefore\ h = 0.815$ m [1]

(c) By $x = u_x\,t$

$\therefore\ (1.2) = (3)\,t \qquad \therefore\ t = 0.4$ s [1]

By $y = \frac{1}{2}\,g\,t^2$ [1]

$\therefore\ H = \frac{1}{2}\,(9.81)\,(0.4)^2 = 0.785$ m [1]

(d) The time of flight remains unchanged [1]

as the time of flight is independent of the horizontal speed of the projectile. [1]

OR

as the vertical speed and the vertical displacement remain unchanged. [1]

8. (a) (i) $2\,T\cos 75° = 60$ [1]

$T = 116$ N [1]

(ii) Energy stored in the taut string = kinetic energy of the arrow = $\frac{1}{2}\,m\,v^2$ [1]

$= \frac{1}{2}\,(0.2)\,(45)^2 = 202.5$ J < accept 203 J > [1]

(b) (i) By $x = u_x\,t$

$\therefore\ (60) = (45\cos 20°)\,t$ [1]

$\therefore\ t = 1.42$ s [1]

(ii) For coconut : $s = \frac{1}{2}\,g\,t^2 = \frac{1}{2}\,(9.81)\,(1.42)^2 = 9.89$ m [1]

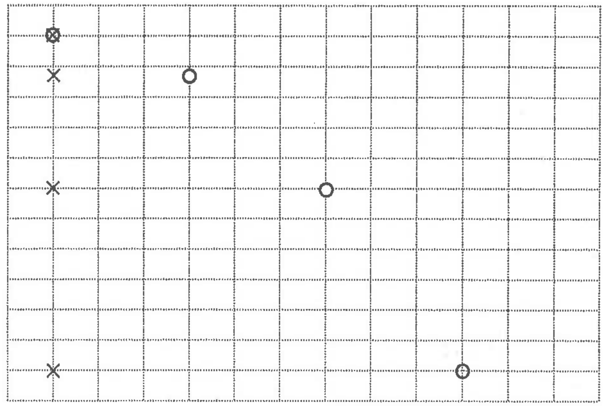
Height of coconut from the ground = 25 − 9.89 = 15.1 m [1]

9. (a) (i) By $s = u\,t + \frac{1}{2}\,a\,t^2$

$\therefore\ (0.11) = \frac{1}{2}\,g\,(0.05 \times 3)^2$ [1]

$\therefore\ g = 9.78$ m s^{-2} [1]

(ii) (1)



< correct horizontal positions > [1]

< correct vertical positions > [1]

(2) $v_x = 1$ m s^{-1}

$v_y = u_y + a\,t = (0) + (9.78) \times (0.05 \times 3) = 1.47$ m s^{-1} [1]

$v = \sqrt{(1)^2 + (1.47)^2}$ [1]

$\therefore\ v = 1.78$ m s^{-1} [1]

OR

By $\frac{1}{2}\,m\,u^2 + m\,g\,h = \frac{1}{2}\,m\,v^2$ [1]

$\therefore\ \frac{1}{2}\,(1)^2 + (9.78)\,(0.11) = \frac{1}{2}\,v^2$ [1]

$\therefore\ v = 1.78$ m s^{-1} [1]

(b) The air resistance acting on the ball increases as its speed increases. [1]

When the air resistance equals to the weight of the ball, net force on the ball is zero. [1]

By Newton's first law, the ball then travels with constant speed. [1]

OR

By Newton's second law, the ball will not accelerate and travels with constant speed. [1]