PRACTICE PROBLEMS

PROJECTILE MOTION

1D projectile motion

1. A basketball is thrown directly upwards. As the ball rises through the air its speed is
   - A increasing
   - B decreasing
   - C constant
   - D cannot be determined

2. A basketball is thrown directly upwards. When the ball reaches its maximum height its velocity is
   - A upwards
   - B downwards
   - C zero
   - D at the maximum velocity

3. A basketball is thrown directly upwards. When the ball is falling back down its speed is
   - A increasing
   - B decreasing
   - C constant
   - D cannot be determined

4. A tennis ball is dropped on the ground. If up is the positive direction, the acceleration of the ball as it falls is
   - A 9.8 m/s^2
   - B -9.8 m/s^2
   - C 0 m/s^2
   - D cannot be determined

5. A tennis ball is thrown upwards. If up is the positive direction, the acceleration of the ball as it rises in the air is
   - A 9.8 m/s^2
   - B -9.8 m/s^2
   - C 0 m/s^2
   - D cannot be determined

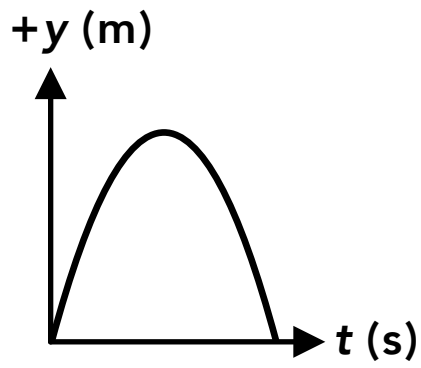
6. At the maximum height of the trajectory in projectile motion, which of the following is true? (Select all that apply)
   - A the acceleration is zero
   - B the acceleration reverses direction
   - C the vertical velocity is zero
   - D the vertical velocity reverses direction

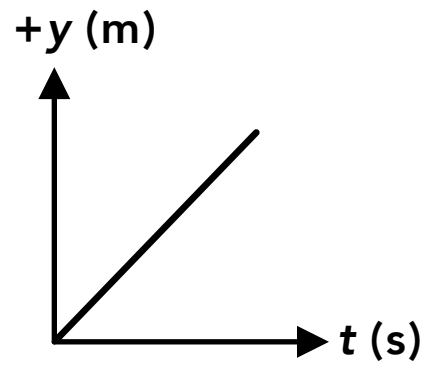
7. A cannon ball is launched upwards from an initial height of 1 m with a speed of 30 m/s. The ball rises and falls back down. What is the speed of the ball when it reaches a height of 1 m on its way down?
   - A 0 m/s
   - B 1 m/s
   - C 30 m/s
   - D cannot be determined

8. A rock is launched vertically using a slingshot. After 6 seconds, the rock falls down and is at the same height that it was launched from. How long did it take the rock to reach its maximum height?
   - A 2 seconds
   - B 3 seconds
   - C 6 seconds
   - D 12 seconds

9. An arrow is shot directly upwards. During the period between 1 second and 2 seconds, the arrow moves upwards a distance of Δy_1. During the period between 2 seconds and 3 seconds, the arrow moves upwards a distance of Δy_2. How do Δy_1 and Δy_2 compare?
   - A $\Delta y_1 < \Delta y_2$
   - B $\Delta y_1 = \Delta y_2$
   - C $\Delta y_1 > \Delta y_2$
   - D cannot be determined

10. A coin is flipped up into the air from an initial height and allowed to land on the ground. Which of these graphs best represents the motion of the coin?

A


B


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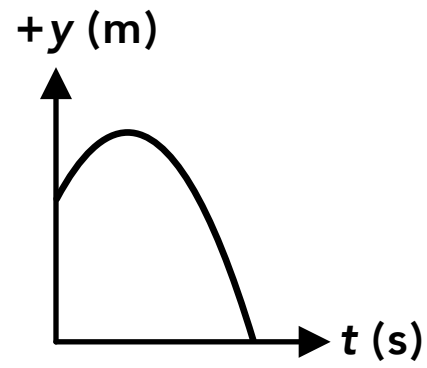

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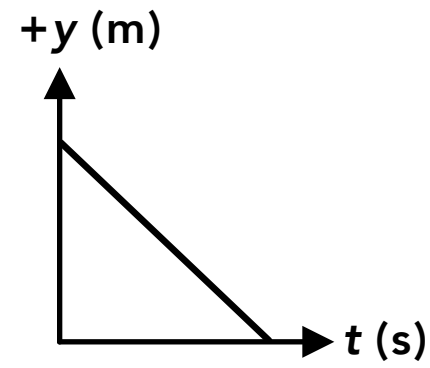
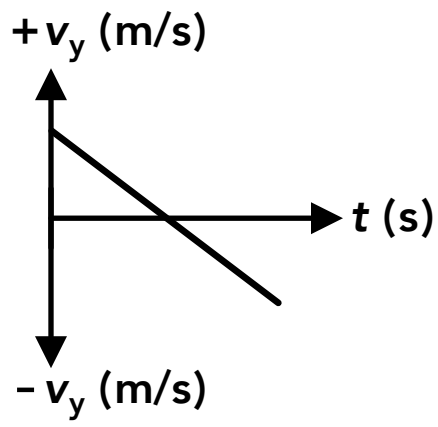


11. A cannon ball is shot directly upwards and eventually falls back down to the same height. Which of these graphs best represents the motion of the cannon ball (if up is the positive direction)?

A


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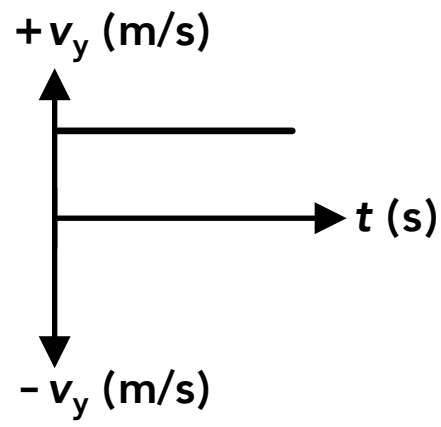

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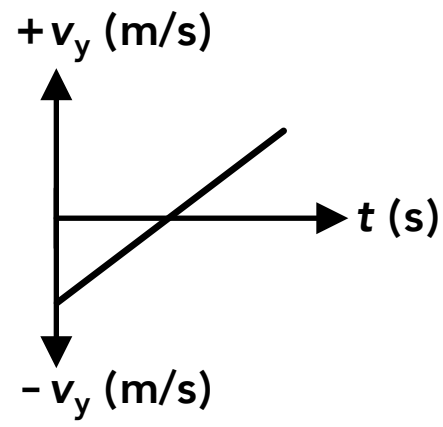

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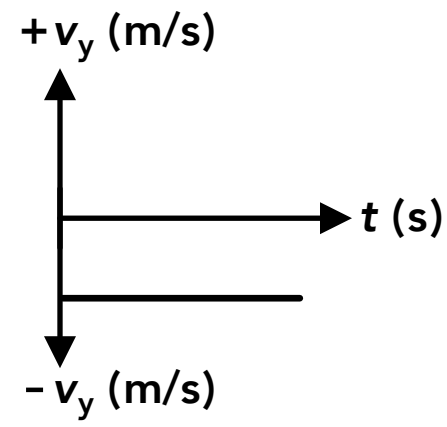
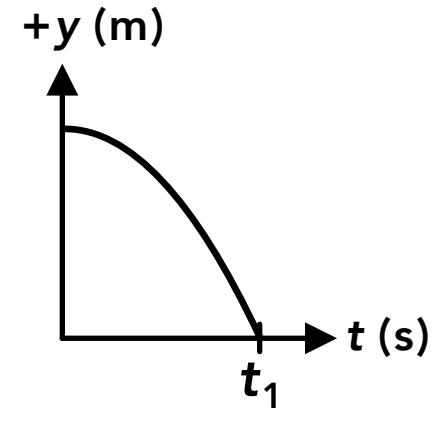
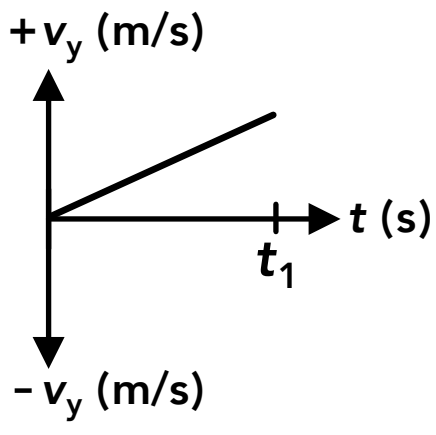


12. Which of these velocity graphs could represent the projectile motion of an object which has a position graph as shown on the right?



A


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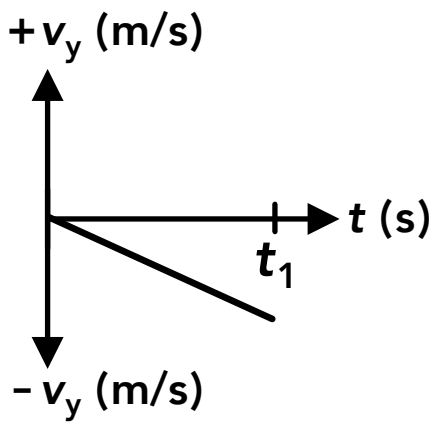

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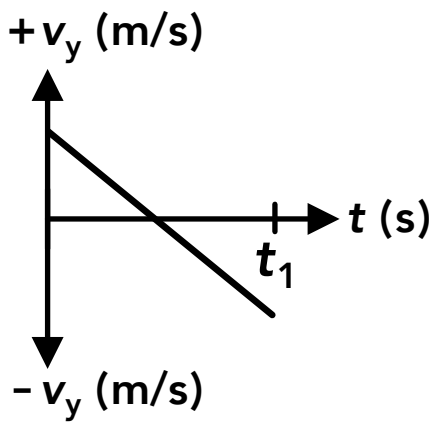

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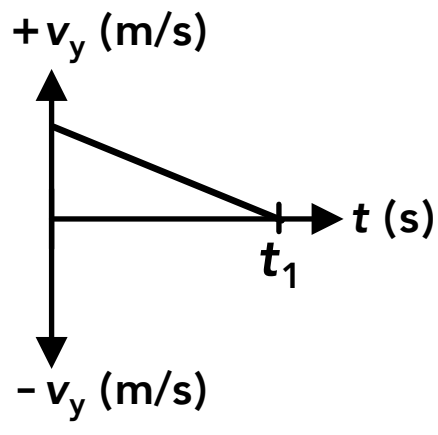
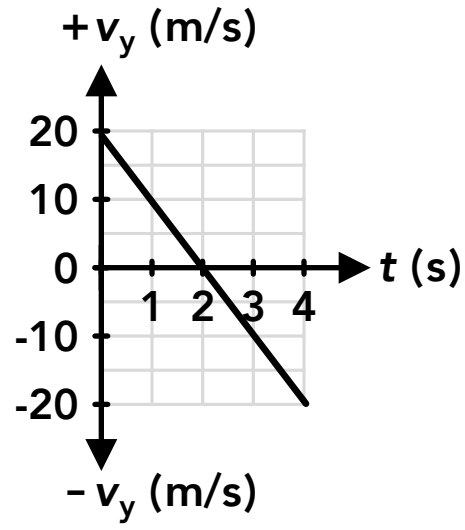


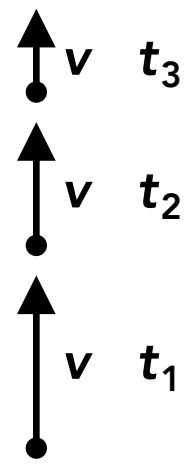
13. A ball is thrown directly upwards into the air. A graph of the ball's velocity over time is shown on the right. When is the ball at its maximum height?



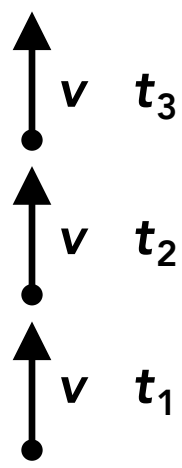
A 1 s
B 0 s
C 4 s
D 2 s

14. A rubber ball is dropped on the ground and it bounces back up. Which of the following shows the ball's velocity vector as it moves upwards (after it leaves the ground)?

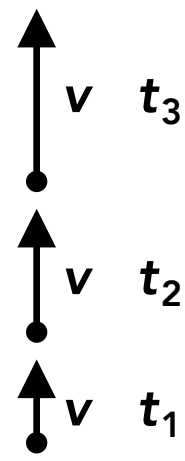
A



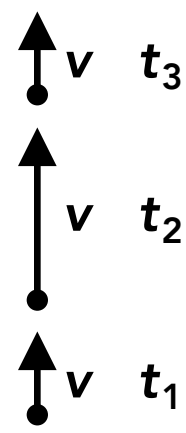
B



C



D



15. A person leans out of a window on the top floor of a building and throws two balls. They throw ball A directly upwards and they throw ball B directly downwards with the same speed as ball A. Ball A hits the ground with a speed of v_{Af} and ball B hits the ground with a speed of v_{Bf}. Which of the following is true?

A $v_{Af} < v_{Bf}$
B $v_{Af} = v_{Bf}$
C $v_{Af} > v_{Bf}$
D cannot be determined

16. A slingshot is used to shoot a rock directly upwards at 9 m/s from a height of 1 m. How high does it go?

17. A plane is flying at a constant altitude of 8,500 m when it drops a heavy box. What is the altitude of the box after 5 seconds?

18. A tennis player bounces a ball on the ground before serving. The ball is released at 0 seconds, it hits the ground at 0.5 seconds, it bounces up to a maximum height and hits the ground again at 2.5 seconds. At what time does the ball reach the maximum height?

19. A person is jumping up and down on a trampoline. During one jump, they're in the air for 2.2 seconds. What was their initial upwards speed at the start of the jump?

20. A water balloon is thrown straight down from a 12 m high balcony with a speed of 2 m/s. What is the speed of the water balloon when it hits the ground?

21. A person is riding in a hot air balloon that is rising at a constant 4 m/s. When the balloon is 30 m high they drop a rock over the side (the rock is released from rest relative to the hot air balloon). How long does it take the rock to hit the ground?

22. During the Apollo 15 mission in 1971, NASA astronaut David Scott dropped a hammer and a feather on the surface of the moon to demonstrate that all objects fall at the same rate if there's no air resistance. If the objects were dropped from rest from a height of 1.6 m and hit the ground in 1.4 seconds, what is the acceleration due to gravity on the moon as a percent of the acceleration due to gravity on Earth?

2D projectile motion

23. A tennis ball is hit at an angle of 20° relative to the ground at a speed of 12 m/s. After the ball is hit, what is the vertical acceleration of the ball (assuming up is positive)?
    - **A** 12 m/s
    - **B** 9.8 m/s²
    - **C** -4.1 m/s²
    - **D** -9.8 m/s²

24. A tennis ball is hit at an angle of 20° relative to the ground at a speed of 12 m/s. After the ball is hit, what is the horizontal acceleration of the ball?
    - **A** 12 m/s
    - **B** -9.8 m/s²
    - **C** 11.3 m/s
    - **D** 0 m/s²

25. A cannon ball is launched into the air at an angle. When the ball is at the maximum height, the velocity is
    - **A** zero
    - **B** the same as the vertical velocity component
    - **C** the same as the horizontal velocity component
    - **D** none of the above

26. A cannon ball is launched into the air at an angle. As the ball rises, the magnitude of the vertical velocity
    - **A** increases
    - **B** decreases
    - **C** stays the same
    - **D** is zero

27. A cannon ball is launched into the air at an angle with initial horizontal and vertical velocities v_{xi} and v_{yi} . After a period of time (but before the ball reaches the maximum height), the horizontal velocity is

A the same as v_{xi}
B greater than v_{xi}
C less than v_{xi}
D cannot be determined

28. A cannon ball is launched into the air at an angle. If the ball starts and ends at the same height, which launch angle will result in the longest range?

A 30°
B 45°
C 60°
D cannot be determined

29. A paintball is shot horizontally out of a window at 90 m/s and lands on the ground in 2.5 seconds. If a second paintball is dropped from rest from the same height (ignoring air resistance), it will land on the ground in

A less than 2.5 seconds
B 2.5 seconds
C more than 2.5 seconds
D cannot be determined

30. Ball A is kicked into the air at an angle of 35°. Ball B is kicked into the air with the same speed as ball A but at an angle greater than 35°. If ball A and ball B travel the same horizontal distance, what angle was ball B kicked into the air?

A 35°
B 45°
C 55°
D cannot be determined

31. An arrow is shot at 20 m/s at an angle of 15° above the horizontal. The initial velocity components are

A $v_{xi} = (20\text{ m/s})\cos(15°)$ $v_{yi} = (20\text{ m/s})\sin(15°)$
B $v_{xi} = (20\text{ m/s})\sin(15°)$ $v_{yi} = (20\text{ m/s})\cos(15°)$
C $v_{xi} = 20\text{ m/s}$ $v_{yi} = 0\text{ m/s}$
D $v_{xi} = 0\text{ m/s}$ $v_{yi} = 20\text{ m/s}$

32. A projectile starts at the ground and is launched into the air at an angle of 60°. It lands on the ground 7 seconds later. How long did it take to reach the maximum height of the trajectory?

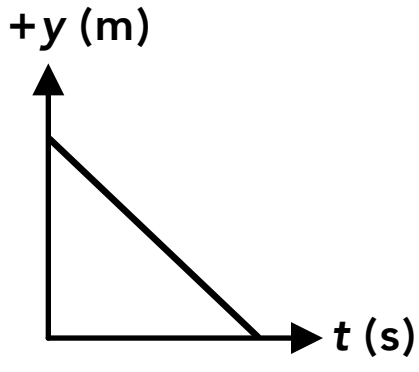
A 0 seconds
B 3.5 seconds
C 7 seconds
D cannot be determined

33. Ball A and B are thrown with the same speed from the same initial height. Ball A is thrown at 30° above the horizontal and ball B is thrown at 30° below the horizontal. Which ball will hit the ground with a greater speed?

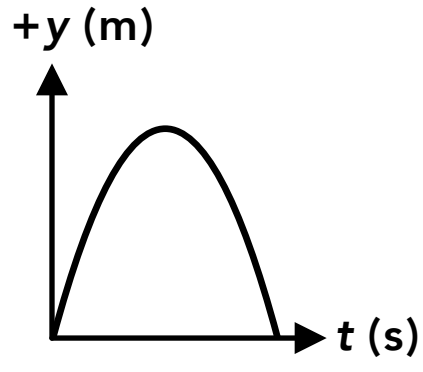
A ball A
B ball B
C the speeds will be the same
D cannot be determined

34. A ball is thrown from a height of 4 m above the ground at an angle of 60°. If the origin is placed at the ground directly below the ball and up is the positive ***y*** direction, which of these graphs could represent the motion?

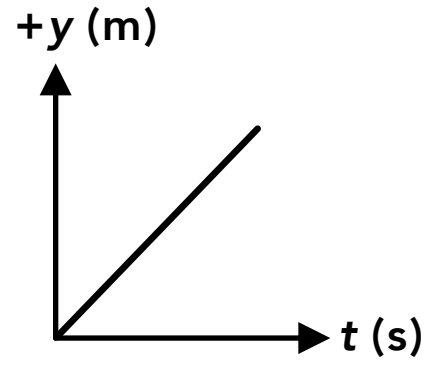
A



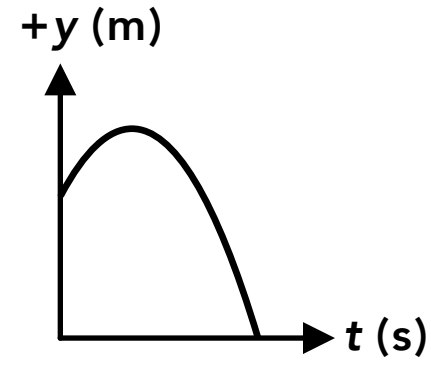
B



C

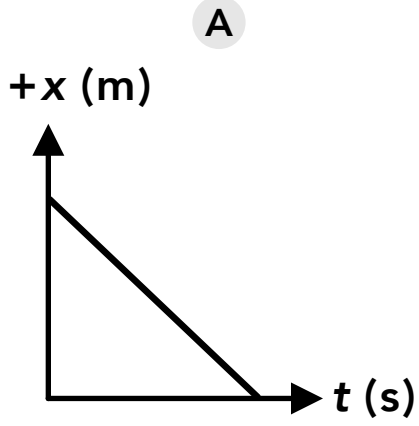


D

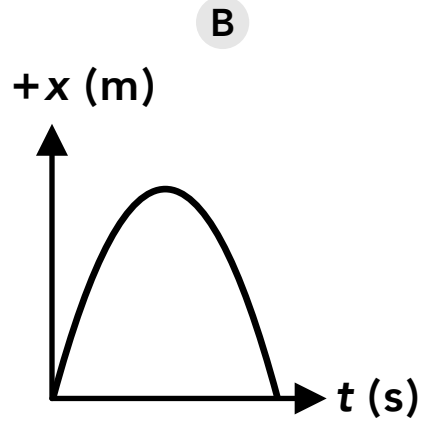


35. A ball is thrown from a height of 4 m above the ground at an angle of 60°. If the origin is placed at the ground directly below the ball and up is the positive ***y*** direction, which of these graphs could represent the motion?

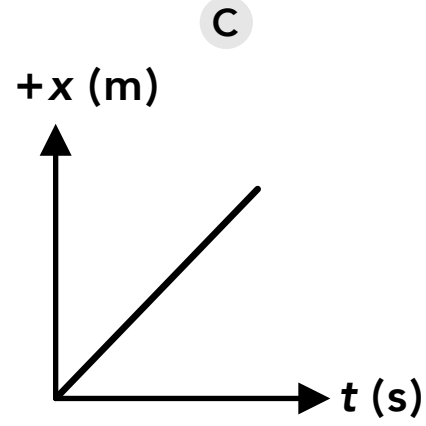
A



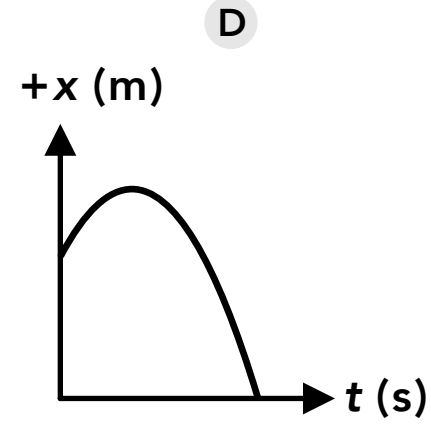
B



C

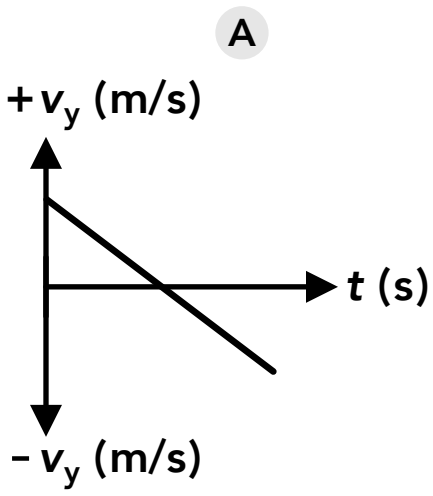


D

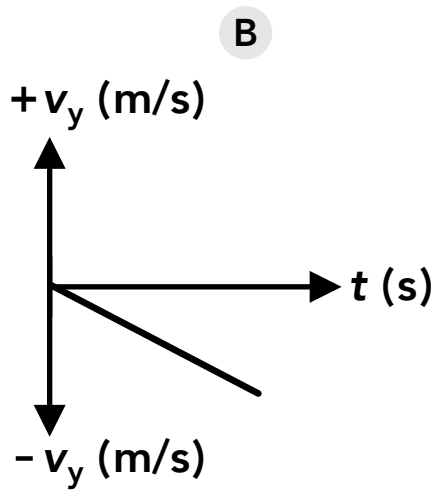


36. A ball is thrown from a height of 4 m above the ground at an angle of 60°. If the origin is placed at the ground directly below the ball and up is the positive ***y*** direction, which of these graphs could represent the motion?

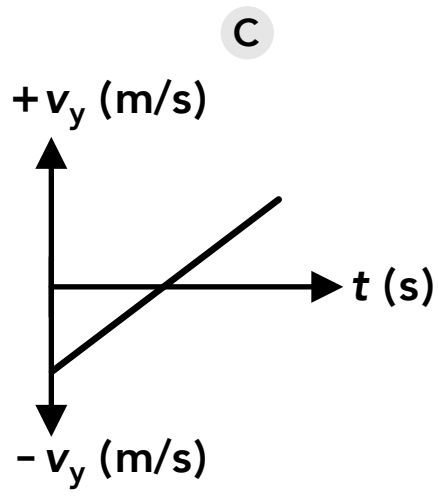
A



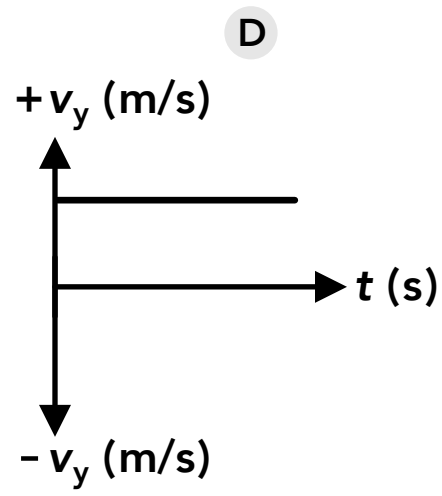
B



C

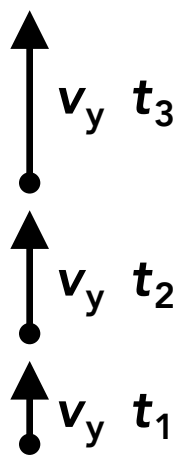


D

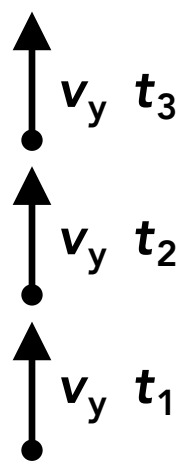


37. A ball is kicked into the air at an angle of 45°. Which of the following shows the ball's vertical velocity before it reaches the maximum height?

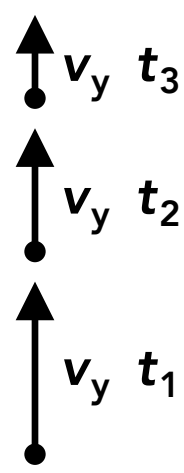
A



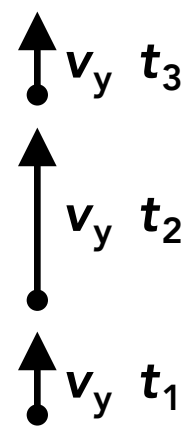
B



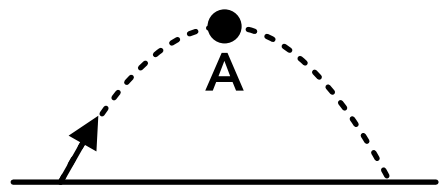
C

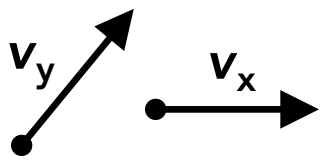


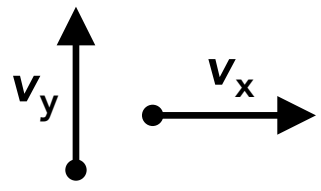
D

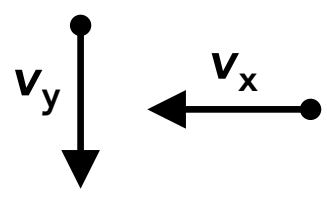


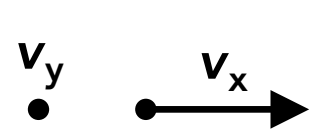
38. A object is launched at an angle as shown on the right. Which of the following show the direction of the vectors when the object is at point A in the trajectory?



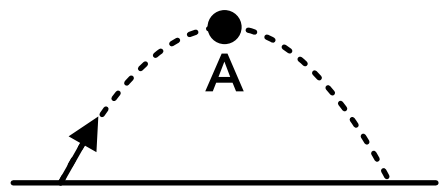
A 

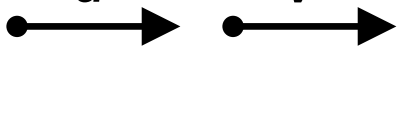
B 

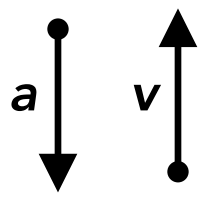
C 

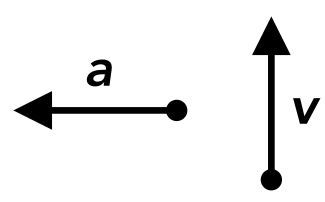
D 

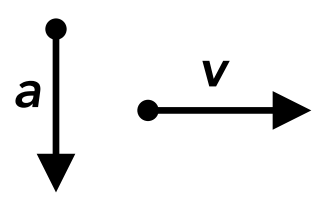
39. A object is launched at an angle as shown on the right. Which of the following show the direction of the vectors when the object is at point A in the trajectory?



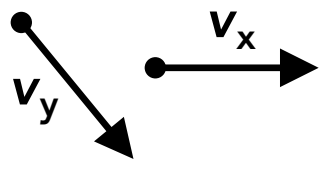
A 

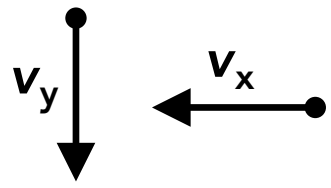
B 

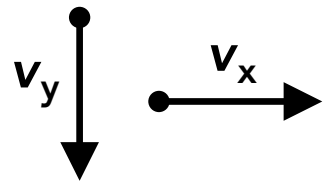
C 

D 

40. A object is launched at an angle as shown on the right. Which of the following show the direction of the vectors when the object is at point A in the trajectory?

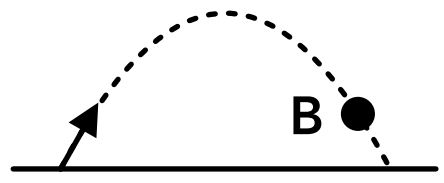
A 

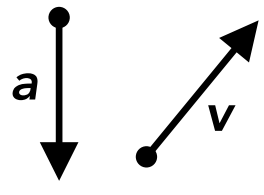
B 

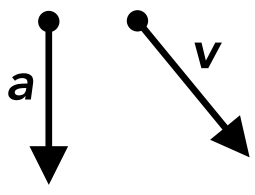
C 

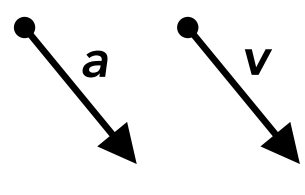
D 

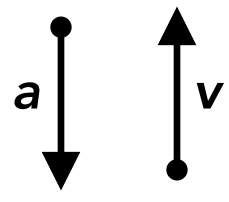
41. A object is launched at an angle as shown on the right. Which of the following show the direction of the vectors when the object is at point A in the trajectory?



A 

B 

C 

D 

42. A golf ball is hit into the air at an angle of 22° with a speed of 75 m/s. What maximum height does it reach?

43. An arrow is shot with a speed of 40 m/s at an angle of 38° from the roof of a building with a height of 16 m. How long is the arrow in the air before it hits the ground?

44. A plane is flying at an altitude of 500 m with a horizontal speed of 200 m/s. The moment it passes directly over a building it drops a box of cargo. How far from the building does the box land on the ground?

Answers - 1D projectile motion

1. Answer: B
   While the ball is moving upwards, the downwards acceleration due to gravity causes the speed to decrease.

2. Answer: C
   When an object moves upwards and reaches its maximum height, the vertical velocity is zero. At that moment, the velocity is reversing direction from upwards to downwards.

3. Answer: A
   While the ball is falling down, the velocity and acceleration are both downwards and the speed (the magnitude of the velocity) is increasing.

4. Answer: B
   The acceleration of an object in projectile motion is always 9.8 m/s² downwards. If up is the positive direction, the acceleration is -9.8 m/s².

5. Answer: B
   The acceleration of an object in projectile motion is always 9.8 m/s² downwards. If up is the positive direction, the acceleration is -9.8 m/s².

6. Answer: C, D
   The acceleration is always 9.8 m/s² downwards in projectile motion. At the maximum height, the velocity reverses direction (from upwards to downwards) and is zero at that moment.

7. Answer: C
   An object will have the same vertical speed at the same height (the magnitude of the velocity is the same but the direction is reversed).

8. Answer: B
   If an object starts and ends at the same height, the time at the maximum height is half of the total duration.

9. Answer: C
   As an object moves upwards, its velocity decreases due to the gravitational acceleration. During equal time intervals, it will move a smaller distance as it rises. The average velocity during the 1-2 second period is greater than the average velocity during the 2-3 period.

10. Answer: C
    These are all graphs of the ***y*** position (the height) of the coin over time. In projectile motion, the ***y*** position graph is a curved line due to the acceleration. The coin starts at an initial height above the ground, so the graph starts at a value above zero.

11. Answer: A
    These are all graphs of the ***y*** velocity of the cannon ball over time. In projectile motion, the slope of the ***y*** velocity graph is negative because the acceleration is negative (if up is the positive direction). The cannon ball starts with a positive velocity as it moves up, and a negative velocity as it falls down.

12. Answer: B
    The position graph starts with zero slope and the slope becomes more negative as time increases. The velocity graph is the slope of the position graph, so the velocity starts at zero and becomes more negative over time.

13. Answer: D
    When an object moves up, reaches a maximum height and then falls down, the vertical velocity is zero when the object is at the maximum height. The graph shows the vertical velocity is zero at 2 seconds.

14. Answer: A
    As an object moves upwards, the acceleration due to gravity causes the vertical velocity to decrease over time.

15. Answer: B
    Since the initial height and initial vertical speeds of ball A and ball B are the same, they will have the same vertical speeds at the same heights (including the ground), which can be found using this equation:
    $$v_{yf}^2 = v_{yi}^2 + 2a_y(y_f - y_i)$$
    Also, when ball A returns to the initial height it will have the same speed as when it was thrown up (but it's moving down) so it has the same motion as ball B after that point.

16. Answer: 5.13 m
    The maximum height can be found using the fact that the vertical velocity is 0 m/s at the maximum height.
    $$v_{yf}^2 = v_{yi}^2 + 2a_y(y_f - y_i)$$
    $$(0\text{ m/s})^2 = (9\text{ m/s})^2 + 2(-9.8\text{ m/s}^2)(y_f - 1\text{ m})$$
    $$y_f = y_{max\ h} = 5.13\text{ m}$$

17. Answer: 8378 m
    $$y_f = y_i + v_{yi}t + \frac{1}{2}a_y t^2$$
    $$y_f = (8{,}500\text{ m}) + (0\text{ m/s})(5\text{ s}) + \frac{1}{2}(-9.8\text{ m/s}^2)(5\text{ s})^2$$
    $$y_f = 8378\text{ m}$$

18. Answer: 1.5 s
    After hitting the ground the first time, the ball bounces up and is in the air for a duration of 2 seconds before it hits the ground a second time. It reaches the maximum height in half of that duration, which is 1 second after hitting the ground and 1.5 seconds after being released.

19. Answer: 10.8 m/s
    $$y_f = y_i + v_{yi}t + \frac{1}{2}a_y t^2$$
    $$(0\text{ m}) = (0\text{ m}) + v_{yi}(2.2\text{ s}) + \frac{1}{2}(-9.8\text{ m/s}^2)(2.2\text{ s})^2$$
    $$v_{yi} = 10.8\text{ m/s}$$

20. Answer: 15.5 m/s
    $$v_{yf}^2 = v_{yi}^2 + 2a_y(y_f - y_i)$$
    $$v_{yf}^2 = (-2\text{ m/s})^2 + 2(-9.8\text{ m/s}^2)(0 - 12\text{ m})$$
    $$v_{yf} = 15.5\text{ m/s}$$

21. Answer: 2.9 s
    The initial velocity of the rock relative to the ground is 4 m/s upwards:
    $$y_f = y_i + v_{yi}t + \frac{1}{2}a_y t^2$$
    $$(0\text{ m}) = (30\text{ m}) + (4\text{ m/s})t + \frac{1}{2}(-9.8\text{ m/s}^2)t^2$$
    $$t = 2.9\text{ s}$$

22. Answer: 16%

$$y_f = y_i + v_{yi}t + \frac{1}{2}a_y t^2$$

$$(0\text{ m}) = (1.6\text{ m}) + (0\text{ m/s})(1.4\text{ s}) + \frac{1}{2}a_y(1.4\text{ s})^2$$

$a_y = -1.6\text{ m/s}^2$ **(gravitational acceleration on the moon)**

$$\frac{1.6\text{ m/s}^2}{9.8\text{ m/s}^2} \times 100\% = 16\%$$

Answers - 2D projectile motion

23. Answer: D
When an object is in projectile motion (or free fall) the vertical acceleration is always 9.8 m/s² downwards. If up is the positive direction then the vertical acceleration is -9.8 m/s².

24. Answer: D
When an object is in projectile motion (or free fall) the horizontal acceleration is 0 m/s².

25. Answer: C
When an object is at the maximum height, the vertical velocity component is zero and the object's velocity is only the horizontal velocity component, which is constant throughout the motion.

26. Answer: B
As the ball rises, the vertical acceleration (due to gravity) acts in the opposite direction as the vertical velocity so the magnitude of the vertical velocity decreases.

27. Answer: A
The horizontal acceleration in projectile motion is zero so the horizontal velocity is constant and is always the same as the initial horizontal velocity.

28. Answer: B
If the initial and final height are the same, 45° will result in the maximum range.

29. Answer: B
In projectile motion, the amount of time in the air is determined by the vertical motion. Both paintballs have the same initial vertical velocity (0 m/s) so they travel the same vertical distance in the same amount of time.

30. Answer: C
Assuming the balls start and end at the same height (the ground), a launch angle of 45° results in the maximum range but two angles that are the same amount greater and less than 45° will have the same range as each other. 35° is 10° less than 45°, and 55° is 10° greater than 45°, so 35° and 55° will result in the same range.

31. Answer: A
v_{xi} is the component adjacent to the angle and v_{yi} is the opposite component.

32. Answer: B
If an object starts and ends at the same height, the time at the maximum height is half of the total time.

33. Answer: C
    Ball A and ball B have the same initial horizontal velocity so they have the same final horizontal velocity component. The magnitudes of the initial vertical velocities are the same (but in opposite directions) so the magnitudes of the vertical velocities will be the same at the same height (and at the ground), given by: $v_{yf}^2 = v_{yi}^2 + 2a_y(y_f - y_i)$. If ball A and ball B have the same final horizontal velocity and final vertical velocity components, then the magnitude (speed) of the final velocities are the same.

34. Answer: D
    All of these are graphs of the ***y*** position (height) of the ball over time. In projectile motion, the ***y*** position vs time graph is a curved line because there is acceleration in the ***y*** direction. The ball starts at an initial height so the curve starts at a ***y*** position greater than zero.

35. Answer: C
    All of these are graphs of the ***x*** (horizontal) position of the ball over time. In projectile motion, the ***x*** position vs time graph is a straight line because the horizontal velocity (the slope of the position graph) is constant. The graph starts at zero because the ball starts at the horizontal origin.

36. Answer: A
    All of these are graphs of the vertical velocity of the ball over time. In projectile motion, the v_y vs time graph is a straight line and the slope is the acceleration. Since up is the positive direction, the acceleration and the slope are negative. The initial vertical velocity component is upwards so the graph starts with a positive velocity.

37. Answer: C
    As an object moves upwards, the acceleration due to gravity causes the vertical velocity to decrease over time.

38. Answer: D
    At point A the object is at the maximum height in the trajectory. At that point the vertical velocity is zero. The horizontal velocity is always constant and points to the right for this motion.

39. Answer: D
    At point A the object is at the maximum height in the trajectory. At that point the vertical velocity component is zero and the velocity vector is horizontal. The acceleration vector in projectile motion is always downwards.

40. Answer: C
    At point B the object is falling down so the vertical velocity points down. The horizontal velocity is constant and always points to the right for this motion.

41. Answer: B
    At point B the object is falling down and moving to the right so the velocity vector points down and to the right. The acceleration vector in projectile motion is always downwards.

42. Answer: 40.3 m
    $v_{yi} = (75\text{ m/s})\sin(22°)$
    $v_{yf}^2 = v_{yi}^2 + 2a_y(y_f - y_i)$
    $(0\text{ m/s})^2 = ((75\text{ m/s})\sin(22°))^2 + 2(-9.8\text{ m/s}^2)(y_f - 0\text{ m})$
    $y_f = 40.3\text{ m} = y_{\text{max height}}$

43. Answer: 5.6 s

$v_{yi} = (40\text{ m/s})\sin(38°)$

$y_f = y_i + v_{yi}t + \frac{1}{2}a_y t^2$

$(0\text{ m}) = (16\text{ m}) + ((40\text{ m/s})\sin(38°))t + \frac{1}{2}(-9.8\text{ m/s}^2)t^2$

$t = 5.6\text{ s}$

44. Answer: 2020 m

$y_f = y_i + v_{yi}t + \frac{1}{2}a_y t^2 \quad (0\text{ m}) = (500\text{ m}) + (0\text{ m/s})t + \frac{1}{2}(-9.8\text{ m/s}^2)t^2 \quad t = 10.1\text{ s}$

$v_x = \frac{\Delta x}{\Delta t} \quad (200\text{ m/s}) = \frac{\Delta x}{(10.10\text{ s})} \quad \Delta x = 2020\text{ m}$