Two dimensional kinematics

Projectile Motion
1. You throw a ball straight upwards with a velocity of 40m/s. How long before it returns to your hand?

A. 2s  
B. 4s  
C. 6s  
D. 8s  
E. 10s
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\[ v = v_0 - gt \]

\[ v_0 = 40 \text{ m/s} \]

\[ v = -40 \text{ m/s} \]

\[ g = 10 \text{ m/s}^2 \]
You throw a ball straight upwards with a velocity of 40m/s. At the highest point:

A. The acceleration changes direction
B. The acceleration is zero
C. The acceleration is negative
D. The acceleration is positive
2. You throw a ball straight upwards with a velocity of 40 m/s. At the highest point

A. The acceleration changes direction
B. The acceleration is zero
C. The acceleration is negative
D. The acceleration is positive

The acceleration is always the same: \(-g\)
3. You shoot a rocket from the ground in a trajectory. Ignore air resistance. At what point is the horizontal component of the velocity a maximum?

A. Immediately after launch
B. At the top
C. Just before landing
D. It is always the same
3. You shoot a rocket from the ground in a trajectory. Ignore air resistance. At what point is the horizontal component of the velocity a maximum?

A. Immediately after launch
B. At the top
C. Just before landing
D. It is always the same
4. You shoot a rocket from the ground in a trajectory. Ignore air resistance. At what point is the horizontal component of the **acceleration** a maximum?

A. Immediately after launch  
B. At the top  
C. Just before landing  
D. It is always the same
4. You shoot a rocket from the ground in a trajectory. Ignore air resistance. At what point is the horizontal component of the acceleration a maximum?

A. Immediately after launch
B. At the top
C. Just before landing
D. It is always the same

The horizontal component of acceleration is always 0.
5. You shoot a rocket from the ground in a trajectory. Ignore air resistance. At what point is the **vertical** component of the **velocity** a maximum?

A. Immediately after launch
B. At the top
C. Just before landing
D. It is always the same
5. You shoot a rocket from the ground in a trajectory. Ignore air resistance. At what point is the \textit{vertical} component of the \textit{velocity} a maximum?

A. Immediately after launch
B. At the top
C. Just before landing
D. It is always the same
6. You shoot a rocket from the ground in a trajectory. Ignore air resistance. At what point is the **vertical** component of the **acceleration** a maximum?

A. Immediately after launch
B. At the top
C. Just before landing
D. It is always the same
6. You shoot a rocket from the ground in a trajectory. Ignore air resistance. At what point is the **vertical** component of the **acceleration** a maximum?

A. Immediately after launch  
B. At the top  
C. Just before landing  
D. It is always the same
A projectile is launched from the ground at an angle of 30°. At what point in its trajectory does this projectile have the least speed?

1) just after it is launched
2) at the highest point in its flight
3) just before it hits the ground
4) halfway between the ground and the highest point
5) speed is always constant
A projectile is launched from the ground at an angle of 30°. At what point in its trajectory does this projectile have the least speed?

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The speed is **smallest** at the **highest point** of its flight path because the $y$-component of the velocity is zero.
You throw a ball horizontally off a tower with a speed of 25m/s. It takes 3s to reach the ground. How far does it travel horizontally?

A. 75m
B. Less than 75m
C. More than 75m
8. You throw a ball horizontally off a tower with a speed of 25m/s. It takes 3s to reach the ground. How far does it travel horizontally?

A. 75m  
B. Less than 75m  
C. More than 75m

\[ \Delta x = v_{0x} t \]
9. You throw a ball horizontally off a tower with a speed of 25m/s. It takes 3s to reach the ground. How high is the tower?

A. 5m  
B. 15m  
C. 25m  
D. 35m  
E. 45m
9. You throw a ball horizontally off a tower with a speed of 25 m/s. It takes 3 s to reach the ground. How high is the tower?

A. 5 m  
B. 15 m  
C. 25 m  
D. 35 m  
E. 45 m

\[
\Delta y = v_{0y} t - \frac{1}{2} gt^2
\]

But \( v_{0y} t = 0 \) so

\[
\Delta y = - \frac{1}{2} gt^2
\]

\[
|\Delta y| = \frac{1}{2} gt^2 = \frac{1}{2} \times 10 \times (3)^2 = 45 m
\]
ConcepTest 3.4a Firing Balls I

A small cart is rolling at constant velocity on a flat track. It fires a ball straight up into the air as it moves. After it is fired, what happens to the ball?

1) it depends on how fast the cart is moving
2) it falls behind the cart
3) it falls in front of the cart
4) it falls right back into the cart
5) it remains at rest
A small cart is rolling at constant velocity on a flat track. It fires a ball straight up into the air as it moves. After it is fired, what happens to the ball?

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4) it falls right back into the cart
5) it remains at rest

In the frame of reference of the cart, the ball only has a **vertical** component of velocity. So it goes up and comes back down. To a ground observer, both the cart and the ball have the **same horizontal velocity**, so the ball still returns into the cart.
ConcepTest 3.5

Dropping a Package

You drop a package from a plane flying at constant speed in a straight line. Without air resistance, the package will:

1) quickly lag behind the plane while falling
2) remain vertically under the plane while falling
3) move ahead of the plane while falling
4) not fall at all
**ConcepTest 3.5**

**Dropping a Package**

You drop a package from a plane flying at constant speed in a straight line. Without air resistance, the package will:

1) quickly lag behind the plane while falling
2) remain vertically under the plane while falling
3) move ahead of the plane while falling
4) not fall at all

Both the plane and the package have the **same horizontal velocity** at the moment of release. They will **maintain** this velocity in the x-direction, so they stay aligned.

**Follow-up:** What would happen if air resistance is present?
Which of the 3 punts has the longest hang time?

4) all have the same hang time
ConcepTest 3.7a

Which of the 3 punts has the longest hang time?

4) all have the same hang time

The time in the air is determined by the vertical motion! Since all of the punts reach the same height, they all stay in the air for the same time.

Follow-up: Which one had the greater initial velocity?
A battleship simultaneously fires two shells at two enemy submarines. The shells are launched with the same initial velocity. If the shells follow the trajectories shown, which submarine gets hit first? 

3) both at the same time
A battleship simultaneously fires two shells at two enemy submarines. The shells are launched with the same initial velocity. If the shells follow the trajectories shown, which submarine gets hit first?

The flight time is fixed by the motion in the y-direction. The higher an object goes, the longer it stays in flight. The shell hitting ship #2 goes less high, therefore it stays in flight for less time than the other shell. Thus, ship #2 is hit first.

3) both at the same time
14. Rolling a ball off the table

Increasing the velocity will increase...

A. x
B. t
C. both
D. neither
14. Rolling a ball off the table

Increasing the velocity will increase...

A. $x$
B. $t$
C. both
D. neither

Since the time is determined only by the height, $h$, increasing the speed means that it will go further. \[ \Delta x = v_{0x} t \]
15. Rolling a ball off the table

Increasing the height, $h$ will increase...

A. $x$
B. $t$
C. both
D. neither
Increasing the height, $h$ will increase...

A. $x$
B. $t$
C. both
D. neither

Increasing the height increases the time until landing. The $x$-component of the position varies at a constant rate.

$$\Delta x = v_{0x} t$$
16. Rolling a ball off the table

Doubling $v$ will increase the landing distance to

A. 2x
B. More than 2x
C. Less than 2x
16. Rolling a ball off the table

Doubling $v$ will increase the landing distance to

A. $2x$
B. More than $2x$
C. Less than $2x$

Since the time is determined only by the height, $h$, doubling the speed means that it will go twice as far. $\Delta x = v_0x \cdot t$
17. Which of the following is true about projectiles?

A. The vertical component of a projectile's velocity is a constant value of 10.0 m/s.
B. The vertical component of a projectile's velocity is constant.
C. The vertical component of a projectile's velocity is changing at a constant rate.
D. All of the above
E. None of the above
17. Which of the following is true about projectiles?

A. The vertical component of a projectile's velocity is a constant value of 10.0 m/s.
B. The vertical component of a projectile's velocity is constant.
C. The vertical component of a projectile's velocity is changing at a constant rate.
D. All of the above
E. None of the above

The acceleration is always downward and has a magnitude of g.
18. Which of the following is true about projectiles?

A. A projectile with an upward component of motion will have a upward component of acceleration.

B. A projectile with a downward component of motion will have a downward component of acceleration.

C. Both are true

D. Neither are are true
18. Which of the following is true about projectiles?

A. A projectile with an upward component of motion will have a upward component of acceleration.

B. A projectile with a downward component of motion will have a downward component of acceleration.

C. Both are true

D. Neither are true

The acceleration is always downward and has a magnitude of g.
19. Which of the following statements about projectiles is FALSE

A. The magnitude of the vertical velocity of a projectile changes by 10.0 m/s each second.
B. The vertical velocity of a projectile is 0 m/s at the peak of its trajectory.
C. The vertical velocity of a projectile is unaffected by the horizontal velocity; these two components of motion are independent of each other.
D. The vertical acceleration of a projectile is 0 m/s$^2$ when it is at the peak of its trajectory.
E. None. They are all true.
19. Which of the following statements about projectiles is FALSE

A. The magnitude of the vertical velocity of a projectile changes by 10.0 m/s each second.
B. The vertical velocity of a projectile is 0 m/s at the peak of its trajectory.
C. The vertical velocity of a projectile is unaffected by the horizontal velocity; these two components of motion are independent of each other.
D. The vertical acceleration of a projectile is 0 m/s\(^2\) when it is at the peak of its trajectory.
E. None. They are all true.

The vertical acceleration is the acceleration of gravity (-g). It is constant.
20. Which of the following statements is false

A. The time that a projectile is in the air is dependent upon the horizontal component of the initial velocity.

B. The time that a projectile is in the air is dependent upon the vertical component of the initial velocity.

C. For a projectile which lands at the same height that it is projected from, the time to rise to the peak is equal to the time to fall from its peak to the original height.

D. For the same upward launch angles, projectiles will stay in the air longer if the initial velocity is increased.
20. Which of the following statements is false

A. The time that a projectile is in the air is dependent upon the horizontal component of the initial velocity.

B. The time that a projectile is in the air is dependent upon the vertical component of the initial velocity.

C. For a projectile which lands at the same height that it is projected from, the time to rise to the peak is equal to the time to fall from its peak to the original height.

D. For the same upward launch angles, projectiles will stay in the air longer if the initial velocity is increased.

Only the vertical component determines the time in the air, because it helps to determine the time until the projectile hits the ground.
21. A football is kicked into the air at an angle of 45 degrees with the horizontal. At the very top of the ball's path, its velocity is ________.

A. entirely vertical  
B. entirely horizontal  
C. both vertical and horizontal  
D. not enough information given to know.
21. A football is kicked into the air at an angle of 45 degrees with the horizontal. At the very top of the ball's path, its velocity is _______.

A. entirely vertical
B. entirely horizontal
C. both vertical and horizontal
D. not enough information given to know.

At the top of the projectile the vertical component is zero and the horizontal component is the same as when the football was initially launched.
22. A football is kicked into the air at an angle of 45 degrees with the horizontal. At the very top of the ball's path, its acceleration is _______. (Neglect the effects of air resistance.)

A. entirely vertical
B. entirely horizontal
C. both vertical and horizontal
D. not enough information given to know.
22. A football is kicked into the air at an angle of 45 degrees with the horizontal. At the very top of the ball's path, its acceleration is _______. (Neglect the effects of air resistance.)

A. entirely vertical
B. entirely horizontal
C. both vertical and horizontal
D. not enough information given to know.

Neglecting air resistance, the acceleration is always only vertical. There is no acceleration in the horizontal direction.
23. At what point in its path is the horizontal component of the velocity \( (v_x) \) of a projectile the smallest?

A. The instant it is thrown.
B. Halfway to the top.
C. At the top.
D. As it nears the top
E. It is the same throughout the path.
23. At what point in its path is the horizontal component of the velocity \((v_x)\) of a projectile the smallest?

A. The instant it is thrown.
B. Halfway to the top.
C. At the top.
D. As it nears the top.
E. It is the same throughout the path.

The vertical speed has no effect on the horizontal speed. There is no acceleration in the horizontal direction.
24. At what point in its path is the magnitude of the vertical component of the velocity ($v_y$) of a projectile the smallest?

A. The instant it is thrown
B. Halfway to the top
C. At the top
D. As it nears the top
E. It is the same throughout the path.
24. At what point in its path is the magnitude of the vertical component of the velocity \( (v_y) \) of a projectile the smallest?

A. The instant it is thrown  
B. Halfway to the top  
C. At the top  
D. As it nears the top  
E. It is the same throughout the path.

At the top the vertical component of velocity is zero.
25. Roll a bowling ball off the edge of a table. As it falls, its horizontal component of velocity ___.

A. decreases
B. remains constant
C. increases
25. Roll a bowling ball off the edge of a table. As it falls, its horizontal component of velocity ___.

A. decreases
B. remains constant
C. increases

The vertical speed has no effect on the horizontal speed.
26. A bullet is fired horizontally and hits the ground in 0.5 seconds. If it had been fired with twice the speed in the same direction, it would have hit the ground in _____. (Assume no air resistance.)

A. less than 0.5 s.
B. more than 0.5 s.
C. 0.5 s.
26. A bullet is fired horizontally and hits the ground in 0.5 seconds. If it had been fired with twice the speed in the same direction, it would have hit the ground in _____. (Assume no air resistance.)

A. less than 0.5 s.
B. more than 0.5 s.
C. 0.5 s.

The horizontal speed has no effect on the vertical speed.
27. A projectile is launched at an angle of 15 degrees above the horizontal and lands down range. For the same speed, what other projection angle would produce the same downrange distance?

A. 30 degrees.
B. 45 degrees.
C. 50 degrees.
D. 75 degrees
E. 90 degrees
27. A projectile is launched at an angle of 15 degrees above the horizontal and lands down range. For the same speed, what other projection angle would produce the same downrange distance?

A. 30 degrees.
B. 45 degrees.
C. 50 degrees.
D. 75 degrees
E. 90 degrees

Because of \(\sin(2\theta)\) factor, the range of a projectile at angle \(\theta\) is the same as the range of a projectile at the compliment of \(\theta\).
28. Two projectiles are fired at equal speeds but different angles. One is fired at angle of 30 degrees and the other at 60 degrees. The projectile to hit the ground first will be the one fired at (neglect air resistance) ____.

A. 30 degrees
B. 60 degrees
C. both hit at the same time
28. Two projectiles are fired at equal speeds but different angles. One is fired at angle of 30 degrees and the other at 60 degrees. The projectile to hit the ground first will be the one fired at (neglect air resistance) ____.

A. 30 degrees
B. 60 degrees
C. both hit at the same time

Projectile fired at 60° has a larger initial vertical component of velocity.