Two Dimensional Kinematics
Concept Questions

Question1

A batter hits a baseball into the air with an initial speed, $v_0 = 50\ \mathrm{m \cdot s^{-1}}$, and makes an angle $\theta_0 = 30^\circ$ with respect to the horizontal. How long does it take to get to its highest point? When the ball is in flight, ignore all forces acting on the ball except for gravitation. Let $g = 10\ \mathrm{m \cdot s^{-2}}$.

1. 2.0 s
2. 2.5 s
3. 3.0 s
4. 4.0 s
5. 5.0 s
6. 6.0 s

Answer 2. If we choose the origin at the point where the ball was hit, and the positive y-direction upwards, then the y-component of the velocity as a function of time is given by the expression

$$v_y(t) = v_{y0} - gt = v_0 \sin\theta_0 - gt\ .$$

At the highest point of its flight

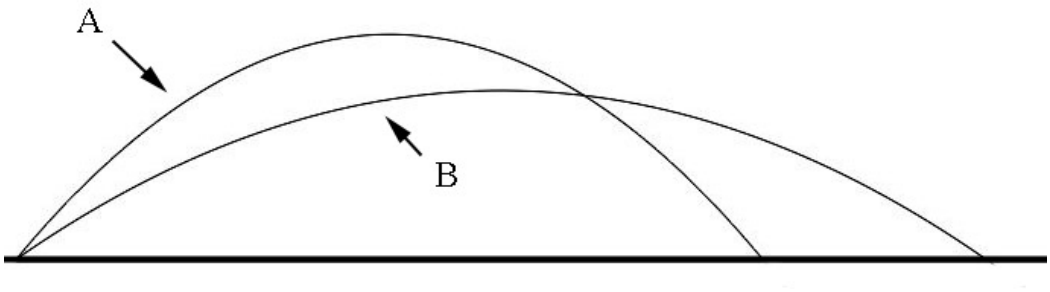
$$0 = v_y(t = t_{top}) = v_0 \sin\theta_0 - gt_{top}\ .$$

Therefore

$$t_{top} = \frac{v_0 \sin\theta_0}{g} = \frac{(50\ \mathrm{m \cdot s^{-1}})(\sin 30^\circ)}{(10\ \mathrm{m \cdot s^{-2}})} = \frac{(50\ \mathrm{m \cdot s^{-1}})(0.5)}{(10\ \mathrm{m \cdot s^{-2}})} = 2.5\ \mathrm{s}\,.$$

Question 2 Which Hits First

A person simultaneously throws two objects in the air. The objects leave the person's hands at different angles and travel along the parabolic trajectories indicated by A and B in the figure below. Which of the following statements best describes the motion of the two objects?



1. The object moving along the trajectory A hits the ground before the object moving along the trajectory B.

2. The object moving along the higher trajectory A hits the ground after the object moving along the lower trajectory B.

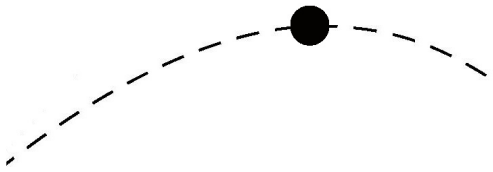
3. Both objects hit the ground at the same time.

4. There is not enough information specified in order to determine which object hits the ground first.

Answer: 2. Begin by assuming that we can ignore the effects of air resistance. Then it will take the same amount of time to reach the top of the trajectory as it takes to return to the starting height (in this case approximately the ground). If you drop two objects at the same time from two different heights, the object released from the higher height will reach the ground later. Therefore object A that is moving along the higher trajectory will hit the ground after object B which is traveling along the lower trajectory.

Question 3 Highest Point

Consider the path of a ball moving along a path through the air under the action of the gravitational force. You may neglect the effects of air friction. As it reaches the highest point in its arc, which of the following statement is true?



1. The magnitudes of the velocity and acceleration are zero.

2. The magnitude of the velocity is at a minimum but not equal to zero.

3. The magnitude of the velocity is equal to zero, and the magnitude of the acceleration is constant and not equal to zero.

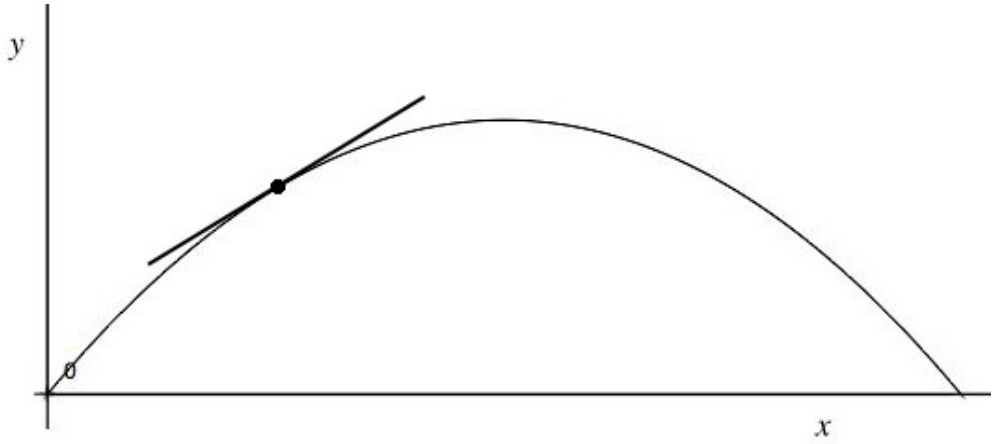
4. The magnitude of the velocity is at a minimum but not equal to zero and the magnitude of the acceleration is zero.

5. Neither the magnitudes of acceleration or velocity has yet attained its minimum value.

Answer: 2. The velocity has a non-zero horizontal component which remains constant throughout the flight. The vertical component of the velocity is zero at the top of the orbit so the magnitude of the velocity is minimum at the top of the orbit. The acceleration is constant and nonzero throughout the orbit and points downwards.

Question 4 Orbit Information

An object moves along a parabolic orbit under the influence of gravity. At each point along the orbit,



1. the magnitude of the velocity can be determined from the slope of the tangent line to the graph of y vs. x but not the direction

2. the magnitude and direction of the velocity can be determined from the slope of the tangent line to the graph of y vs. x

3. the magnitude and direction of the velocity cannot be determined from the slope of the tangent line to the graph of y vs. x

4. the direction of the velocity can be determined from the slope of the tangent line to the graph of y vs. x but not the magnitude.

Answer: 4. The direction is the velocity is always tangent to the spatial orbit but the magnitude cannot be determined. The magnitude of the slope is $|dy/dx|$ which is not the magnitude of the velocity

$$v = \sqrt{v_x^2 + v_y^2} = \sqrt{(dx/dt)^2 + (dy/dt)^2}\ .$$

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