PHYSICS 203

5/30/2019
Lecture 2

- Review: Motion at Constant Acceleration
- Review: Projectile Motion
- Solving Projectile Motion Problems
- Relative velocities (Galilean Relativity)
At time \( t = 0 \) s, an object is observed at \( x = 0 \) m; and its position along the \( x \) axis follows this expression: \( x = 4.0t + t^2 \), where the units for distance and time are meters and seconds, respectively. What is the object's displacement \( \Delta x \) between \( t = 1.0 \) s and \( t = 3.0 \) s?

A) +16 m
B) –21 m
C) +10 m
D) +2 m
E) –5 m
If $\vec{A} = 12\hat{x} - 16\hat{y}$ and $\vec{B} = -24\hat{x} + 10\hat{y}$, what is the direction of the vector $\vec{C} = 2\vec{A} - \vec{B}$?

A) $49^\circ$ below the positive $x$ – axis
B) $41^\circ$ below the positive $x$ – axis
C) $90^\circ$ below the $x$ – axis
D) $49^\circ$ above the $x$ – axis
E) $21^\circ$ degrees above the $x$ – axis
F) None of the other answers.
Motion at Constant Acceleration

General Solution (in x)

Position as a function of time:

\[ x(t) = x_0 + v_{x_0} t + \frac{1}{2} a_x t^2 \]

Velocity as a function of time:

\[ v_x(t) = v_0 + at \]

Velocity from displacement:

\[ v_x^2 = v_{x_0}^2 + 2a\Delta x \]

Average velocity:

\[ v_{x\text{average}} = \frac{v_x + v_{x_0}}{2} \]
A bullet is fired through a board, 14.0 cm thick, with its line of motion perpendicular to the face of the board. If it enters with a speed of 450 m/s and emerges with a speed of 220 m/s, what is the bullet's acceleration as it passes through the board?

a) $-500 \ km/s^2$

b) $-550 \ km/s^2$

c) $-360 \ km/s^2$

d) $-520 \ km/s^2$

e) $-275 \ km/s^2$

f) None of the other answers
Motion at Constant Acceleration

General Solution (in y)

Position as a function of time:

\[ y(t) = y_0 + v_{y0} t + \frac{1}{2} a_y t^2 \]

Velocity as a function of time:

\[ v_y(t) = v_{y0} + a_y t \]

Velocity from displacement:

\[ v_y^2 = v_{y0}^2 + 2a_y \Delta y \]

Average velocity:

\[ v_{y\text{average}} = \frac{v_y + v_{y0}}{2} \]
Motion at Constant Acceleration

General Solution (in $z$)

Position as a function of time:

$$z(t) = z_0 + v_{z_0} t + \frac{1}{2} a_z t^2$$

Velocity as a function of time:

$$v_z(t) = v_{z_0} + a_z t$$

Velocity from displacement:

$$v_z^2 = v_{z_0}^2 + 2a_z \Delta z$$

Average velocity:

$$v_{z,\text{average}} = \frac{v_z + v_{z_0}}{2}$$
Vector Kinematics

Displacement is a vector:

$$\Delta \vec{r} = \vec{r}_2 - \vec{r}_1.$$

$$\Delta \vec{r} = \Delta x \hat{x} + \Delta y \hat{y} + \Delta z \hat{z}$$

Velocity and acceleration are also vectors so we can write them using unit vectors:

$$\vec{v} = v_x \hat{x} + v_y \hat{y} + v_z \hat{z}$$

$$\vec{a} = a_x \hat{x} + a_y \hat{y} + a_z \hat{z}$$
If an object is launched at an initial angle of $\theta_0$ with the horizontal, the analysis is similar except that the initial velocity has a vertical component.
Solving Projectile Motion Problems

1. **Read** the problem carefully, and choose the object(s) you are going to analyze.
2. **Draw** a diagram.
3. **Choose** an origin and a coordinate system.
4. **Decide** on the **time interval**; this is the **same in both directions**, and includes only the time the object is moving with constant acceleration $g$.
5. **Examine** the $x$ and $y$ motions separately.
6. **List** known and unknown quantities. Remember that $v_x$ never changes, and that $v_y = 0$ at the highest point.
7. **Plan** how you will proceed. Use the appropriate equations; you may have to combine some of them.
Observation: Projectile Motion Is Parabolic

In order to demonstrate that projectile motion is parabolic, we need to write $y$ as a function of $x$. When we do, we find that it has the form:

$$y = Ax - Bx^2$$

This is indeed the equation for a parabola.
A kicked football.

A football is kicked at an angle $\theta_0 = 37.0^\circ$ with a velocity of 15.0 m/s, as shown. Calculate,

(a) the maximum height

(b) the time of elapsed before the football hits the ground

(c) how far away it hits the ground
You drop a package from a plane flying at constant speed in a straight line. Without air resistance, the package will:

a) quickly lag behind the plane while falling
b) remain vertically under the plane while falling
c) move ahead of the plane while falling
d) not fall at all
Example

If the airplane in the image below is traveling horizontally at 85.0 m/s. At what distance “x” should a package be dropped to that it falls on the intended target?
A ball is hit at ground level. The ball is observed to reach its maximum height above ground level 3.00 s after being hit. And 2.50 s after reaching this maximum height, the ball is observed to barely clear a fence that is 97.5 m from where it was hit. How tall is the fence? ($|\vec{g}| = 9.8 \text{ m/s}^2$)

a) 8.2 m  
b) 15.8 m  
c) 13.5 m  
d) 4.9 m  
e) None of the other answers
Galilean Relativity

Observers in different reference frames may measure different positions, velocities and accelerations for a given particle or object.

Galilean Relativity describes how observations made by different observers in different frames of reference relate to each other.

Example: Consider two observers watching a man walking on a moving beltway at an airport. Observer 1 will observe the man moving at a slower speed.
Galilean Relativity
Relative Velocity (Galilean Relativity)

S (static frame of reference) M (frame moving at a constant velocity)

At time $t=0$, both reference frames coincide at the same origin.

At time $t \neq 0$. 

At time $t \neq 0$. 

$\vec{v}_{MS}$ (constant)
Relative Velocity

\[
\vec{r}_S \quad \vec{r}_M
\]

Object "O"

\[
\vec{v}_{MS} \text{ (constant)}
\]

\[
\vec{v}_{MS}\Delta t
\]
Relative Velocities

\[ \vec{v}_{FS} \Delta t = \vec{r}_S - \vec{r}_M \]
\[ \vec{v}_{MS} = \frac{\vec{r}_S}{\Delta t} - \frac{\vec{r}_M}{\Delta t} \]
\[ \vec{v}_{MS} = \vec{v}_{OS} - \vec{v}_{OM} \]

Relative Velocities

\[ \vec{v}_{OS} = \vec{v}_{OM} + \vec{v}_{MS} \]

\( \vec{v}_{OS} \rightarrow \) Velocity of the object measured from the static frame
\( \vec{v}_{OM} \rightarrow \) Velocity of the object as measured in the Moving frame.
\( \vec{v}_{MS} \rightarrow \) Velocity of the moving Moving frame with respect to the Static frame.
Example

The pilot of an aircraft flies due north relative to the ground in a wind blowing 40 km/h toward the east. If his speed relative to the ground is 80 km/h, what is the speed of his airplane relative to the air?

\[ \vec{v}_{OS} = \vec{v}_{OM} + \vec{v}_{MS} \]
A river has a steady speed of 0.30 m/s. A student swims downstream a distance of 1.2 km and returns to the starting point. If the student swims with respect to the water at a constant speed and the downstream portion of the swim requires 20 minutes, how much time is required for the entire swim?

a) 50 minutes
b) 80 minutes
c) 90 minutes
d) 70 minutes
e) 60 minutes
f) It cannot be determined with given information.