

Today : section 3.2 & 3.3

18



Today : section 3.2 & 3.3

[18]

acceleration
vector

Today : section 3.2 & 3.3

L8

acceleration
vector

projectile
motion

Today : section 3.2 & 3.3

18

NW#3 : Due Friday

Today : section 3.2 & 3.3

[18]

HW#3 : Due Friday

HW#4 : Due Wednesday Sept 16

Today : section 3.2 & 3.3

[L8]

HW#3 : Due Friday

HW#4 : Due Wednesday Sept 16

Date of Exam #1

Acceleration Vector

Acceleration Vector

Instead of x, y & z components it is sometimes useful to use parallel & perpendicular components

Acceleration Vector

Parallel & Perpendicular

Acceleration Vector

Parallel & Perpendicular

parallel to
path

Acceleration Vector

Parallel & Perpendicular

parallel to
path

perpendicular
to path

Acceleration Vector

Parallel & Perpendicular

parallel to
path

$a_{||}$

perpendicular
to path

Acceleration Vector

Parallel & Perpendicular

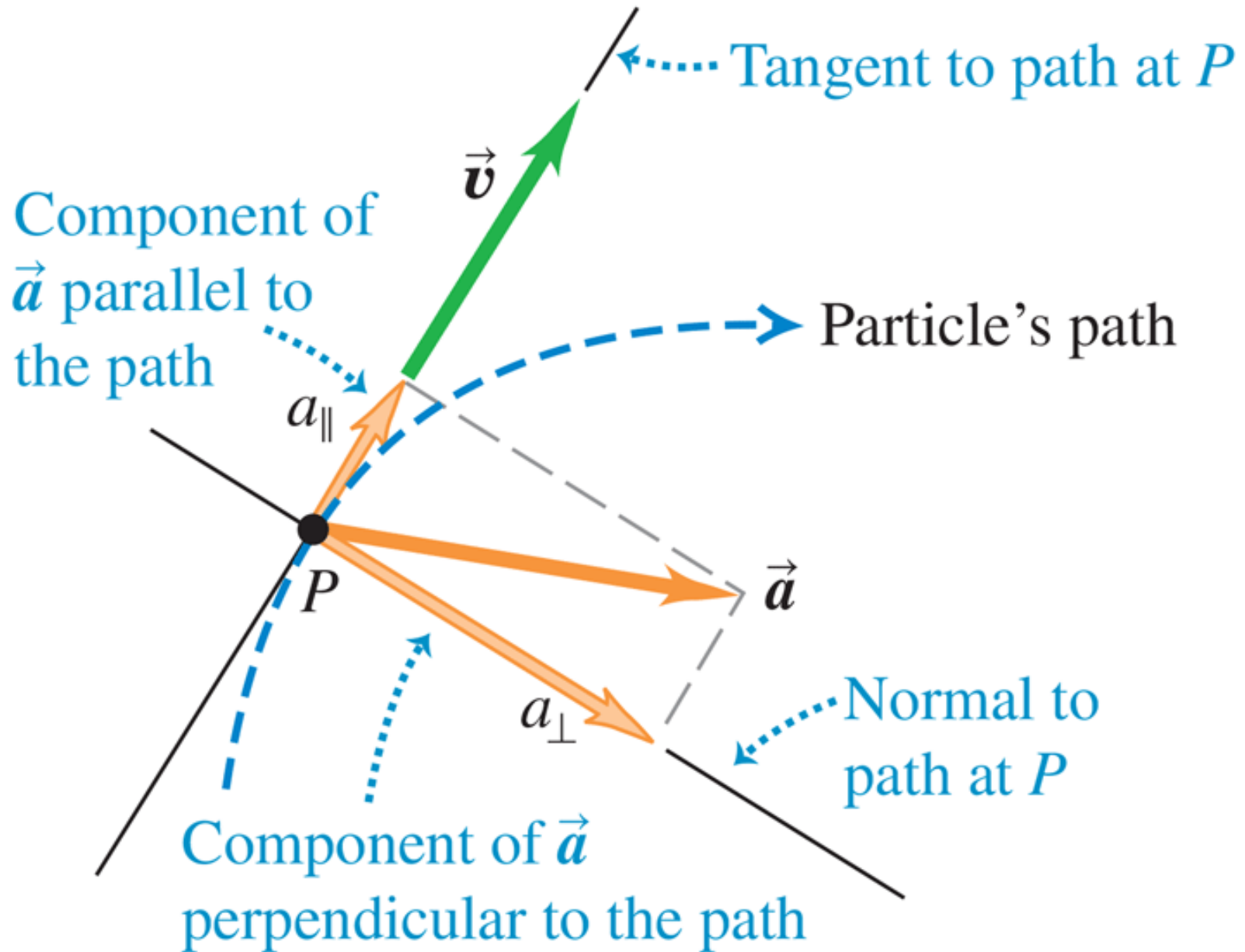
parallel to
path

a_{\parallel}

perpendicular
to path

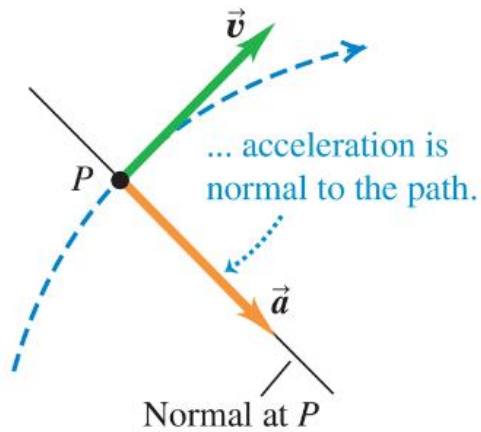
a_{\perp}

Acceleration Vector



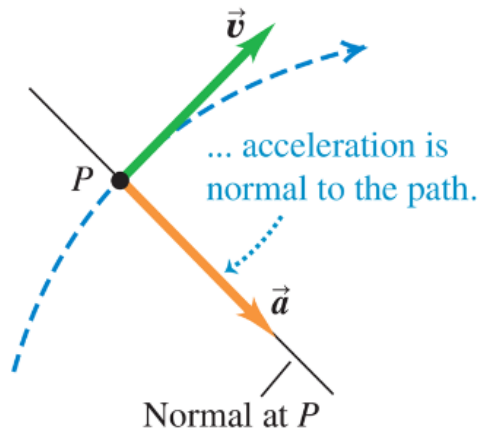
Acceleration Vector

(a) When speed is constant along a curved path ...

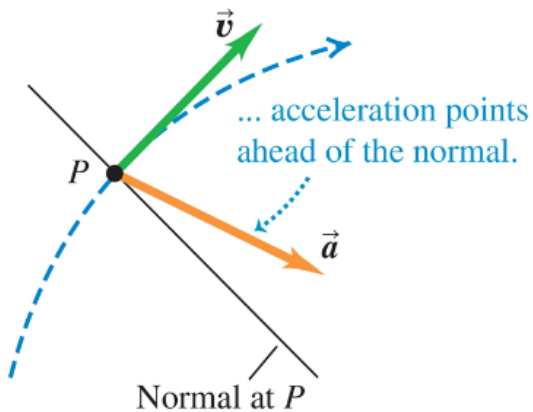


Acceleration Vector

(a) When speed is constant along a curved path ...

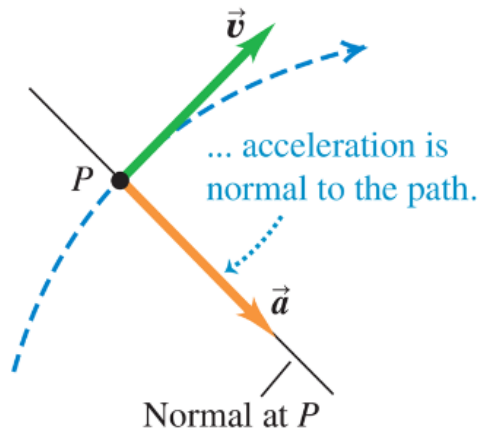


(b) When speed is increasing along a curved path ...

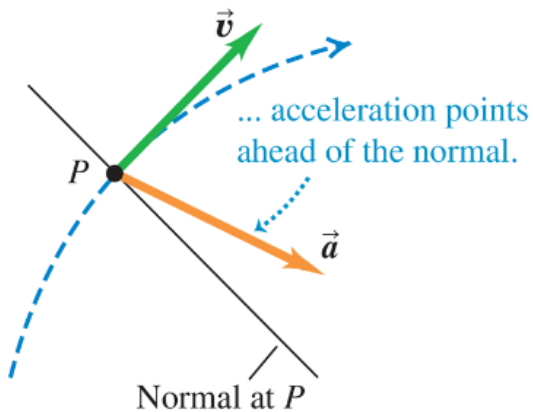


Acceleration Vector

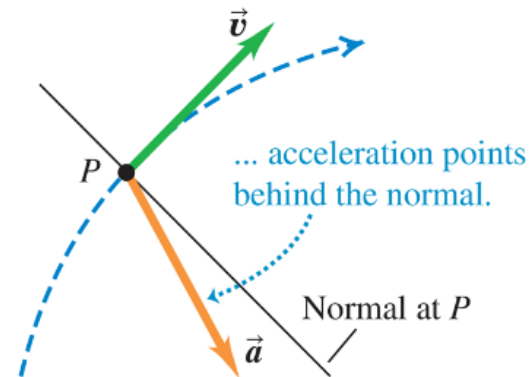
(a) When speed is constant along a curved path ...



(b) When speed is increasing along a curved path ...



(c) When speed is decreasing along a curved path ...



Example:

Given: $\vec{a} = 0.58 \text{ m/s}^2$ at $\theta = 149^\circ$
& \vec{v} has $\theta = 128^\circ$, where
 θ is measured from the x-axis.

Example:

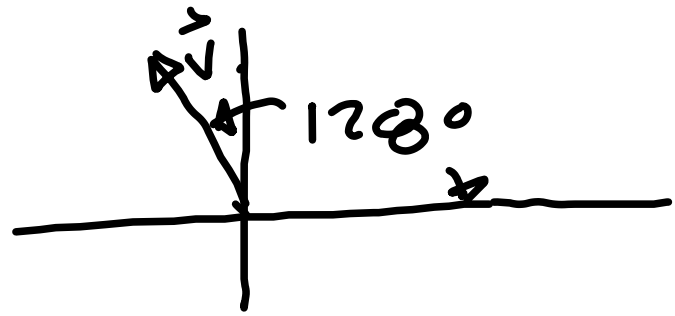
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& \vec{v} has $\theta = 128^\circ$, where
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Find $a_{||}$ & a_{\perp} :

Example:

Given: $\vec{a} = 0.58 \text{ m/s}^2$ at $\theta = 149^\circ$
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Find a_{\parallel} & a_{\perp} :



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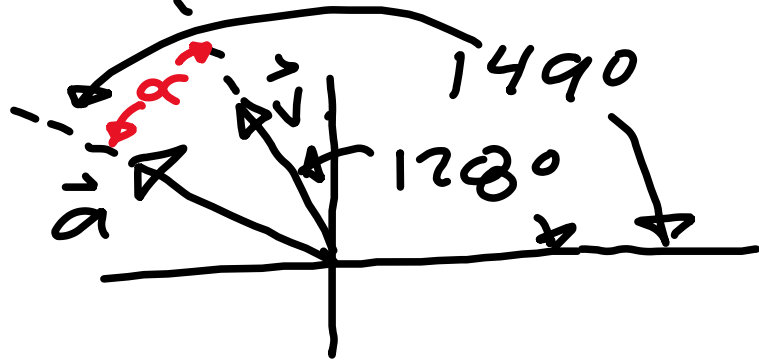
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Find $a_{||}$ & a_{\perp} :

$$\alpha + 128^\circ = 149^\circ$$



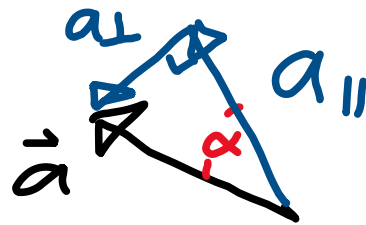
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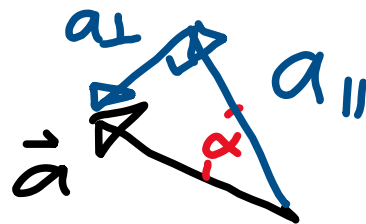
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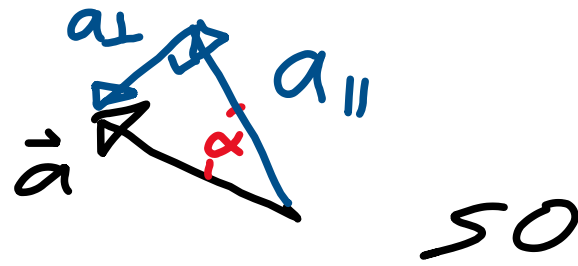
$$a_{||} = a \cos \alpha$$

50

Example:

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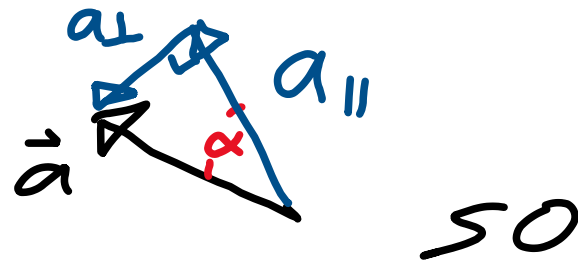
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$$a_{\parallel} = a \cos \alpha \quad \& \quad a_{\perp} = a \sin \alpha$$

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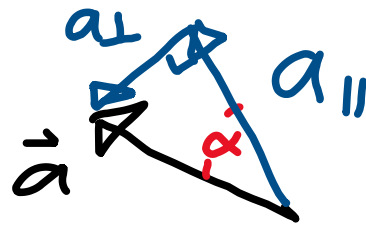
$$a_{||} = a \cos \alpha \quad \& \quad a_{\perp} = a \sin \alpha \Rightarrow$$

$$a_{||} = (0.58 \text{ m/s}^2) \cos(21^\circ)$$

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Given: $\vec{a} = 0.58 \text{ m/s}^2$ at $\theta = 149^\circ$
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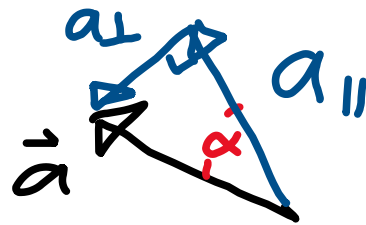
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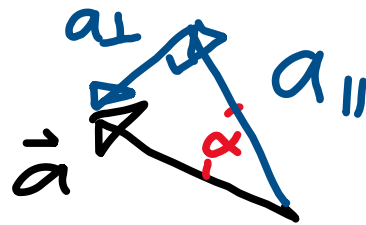
$$\Rightarrow a_{||} = 0.54 \text{ m/s}^2$$

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Given: $\vec{a} = 0.58 \text{ m/s}^2$ at $\theta = 149^\circ$

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Find $a_{||}$ & a_{\perp} :



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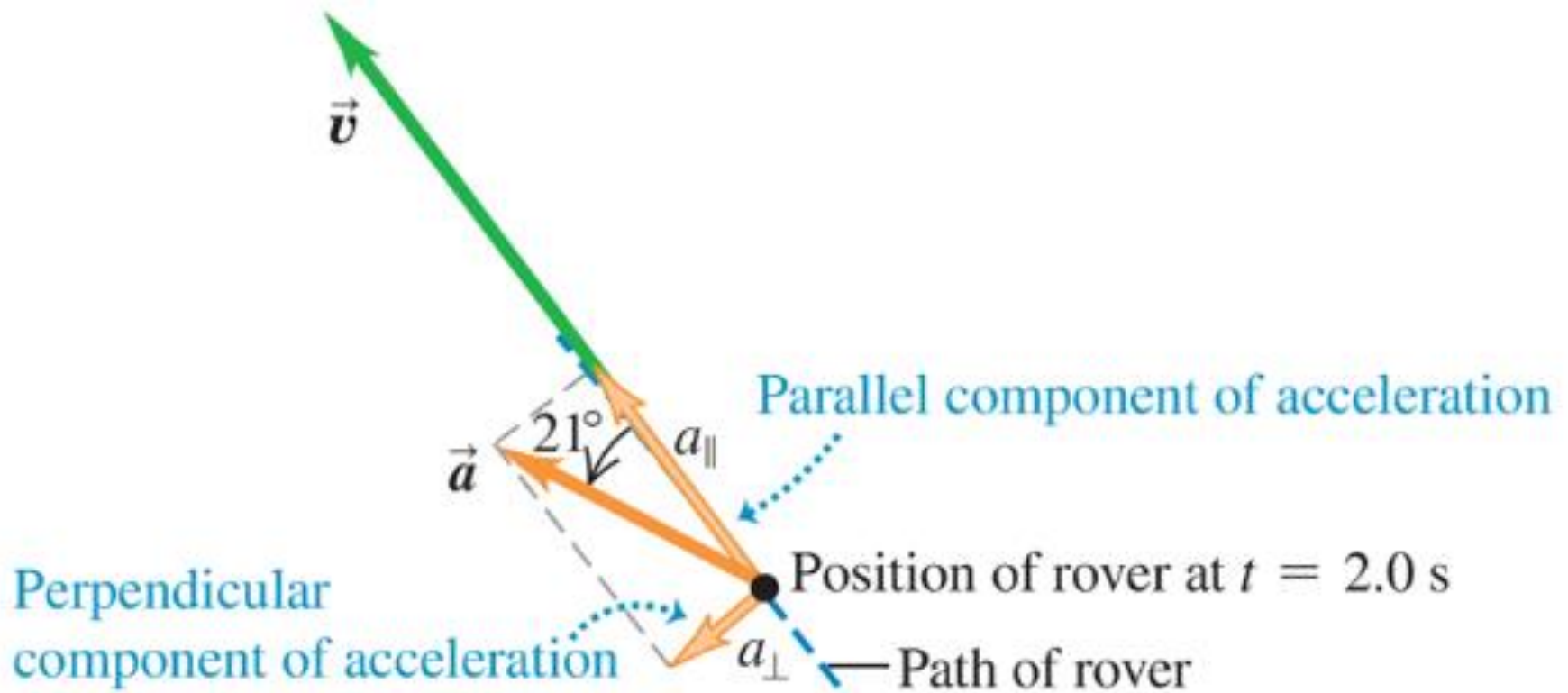
so

$$a_{||} = a \cos \alpha \quad \& \quad a_{\perp} = a \sin \alpha \Rightarrow$$

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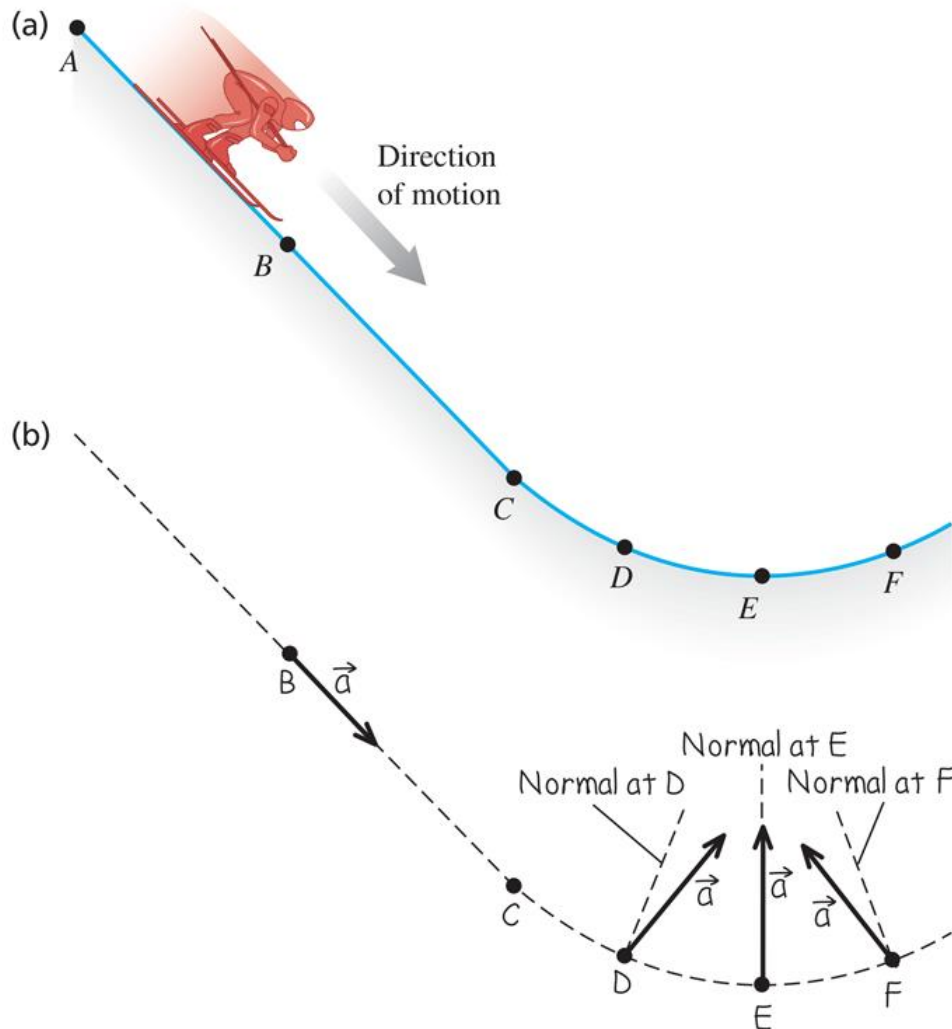
$$\Rightarrow a_{||} = 0.54 \text{ m/s}^2 \quad \& \quad a_{\perp} = 0.21 \text{ m/s}^2$$

Example :

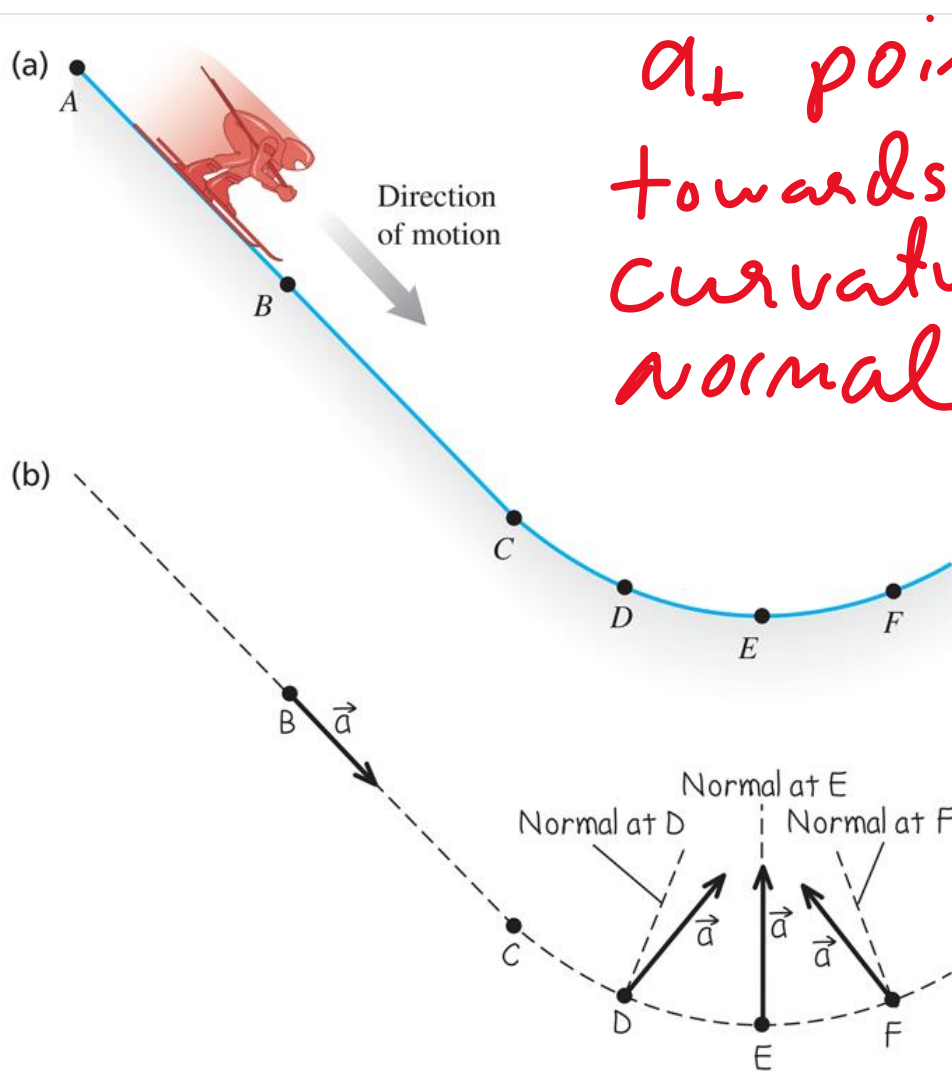


$$a_{\parallel} = 0.54 \text{ m/s}^2 \quad \& \quad a_{\perp} = 0.21 \text{ m/s}^2$$

A skier moves along a ski-jump ramp (Fig. 3.14a). The ramp is straight from point A to point C and curved from point C onward. The skier speeds up as she moves downhill from point A to point E , where her speed is maximum. She slows down after passing point E . Draw the direction of the acceleration vector at each of the points B , D , E , and F .

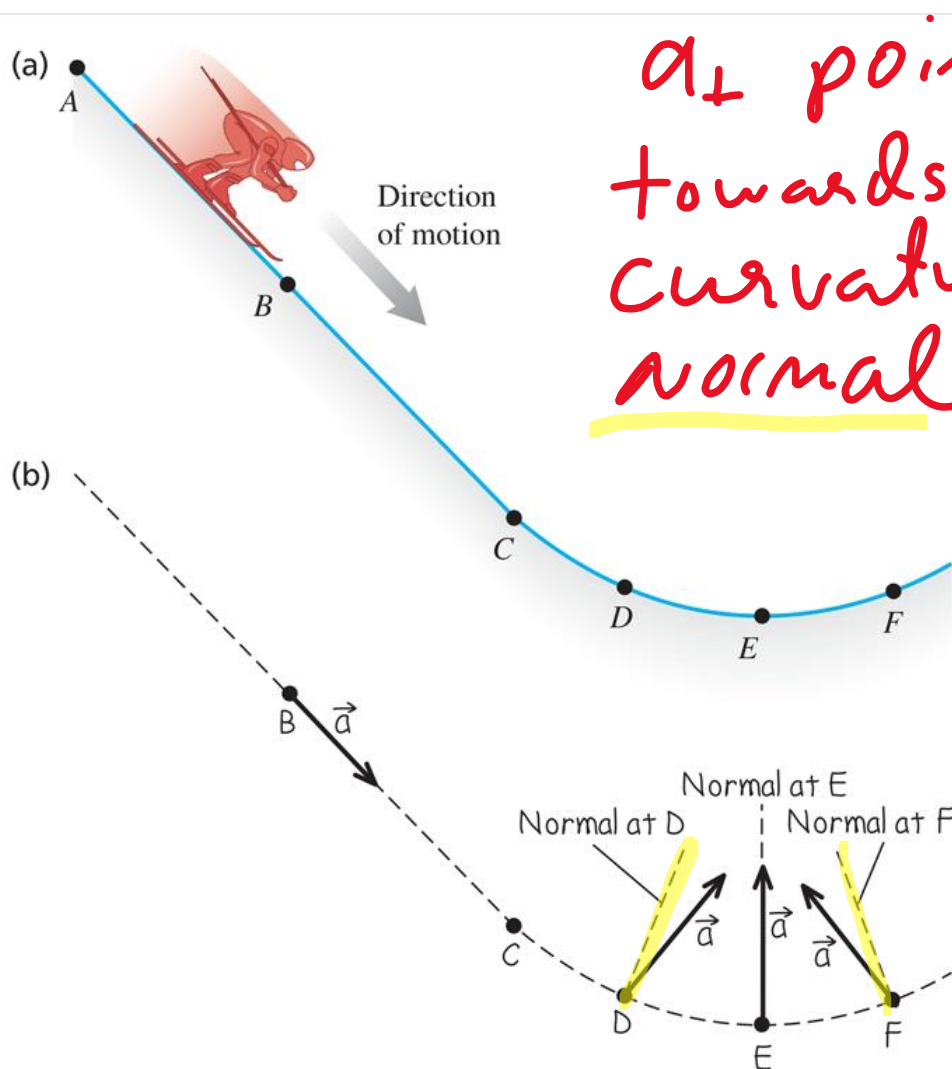


A skier moves along a ski-jump ramp (Fig. 3.14a). The ramp is straight from point A to point C and curved from point C onward. The skier speeds up as she moves downhill from point A to point E , where her speed is maximum. She slows down after passing point E . Draw the direction of the acceleration vector at each of the points B , D , E , and F .



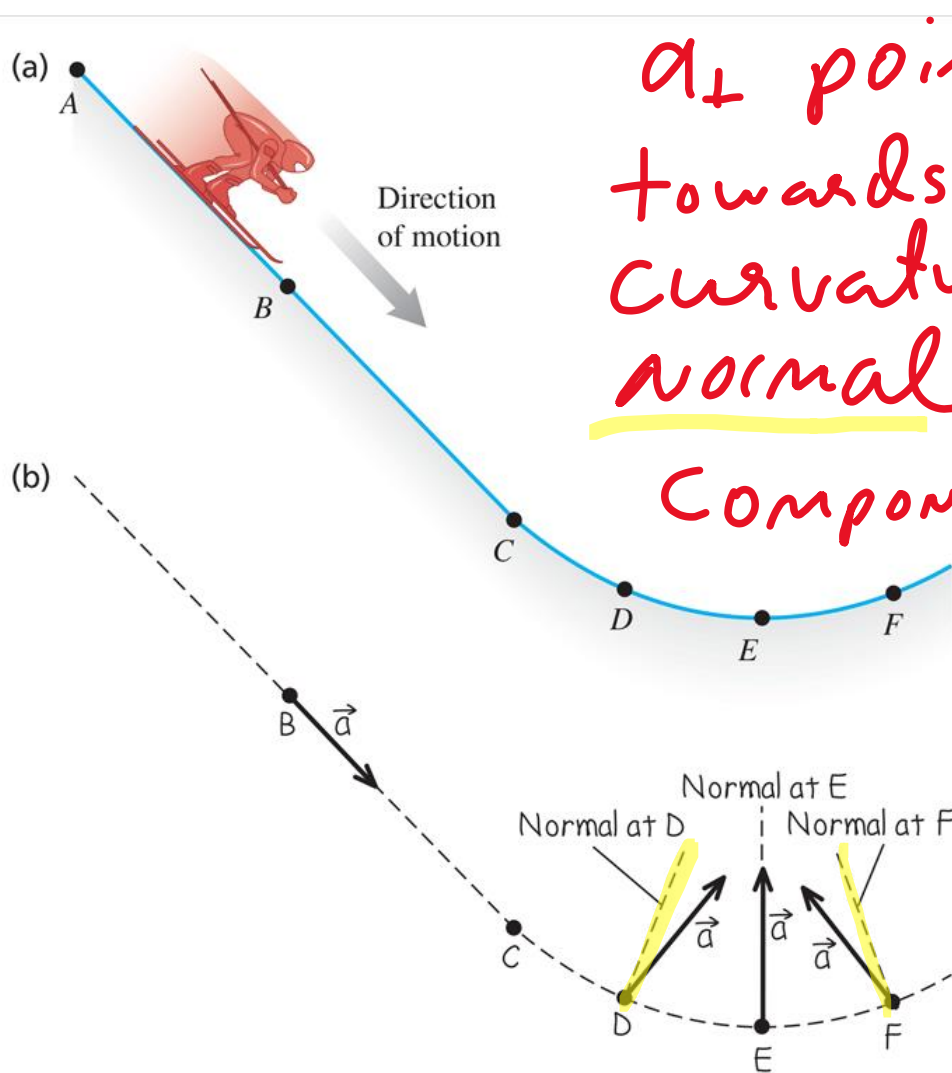
a_{\perp} points towards radius of curvature along normal

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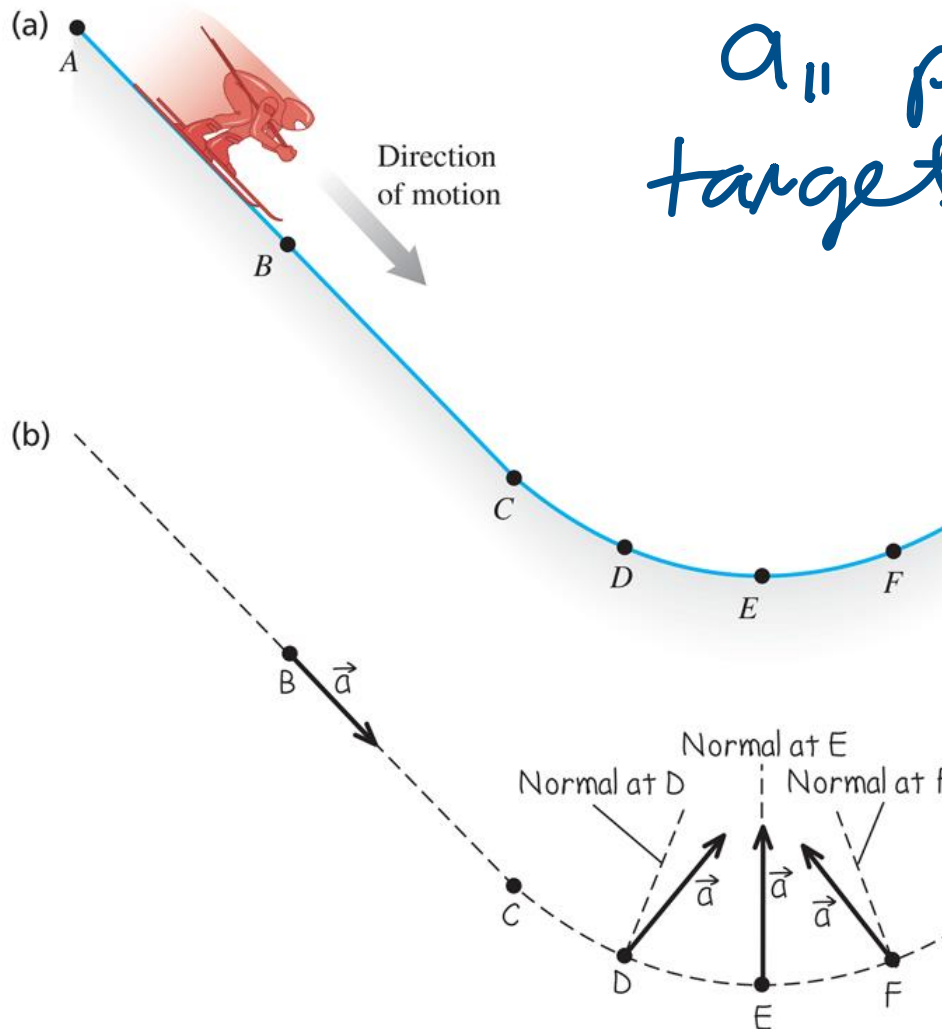
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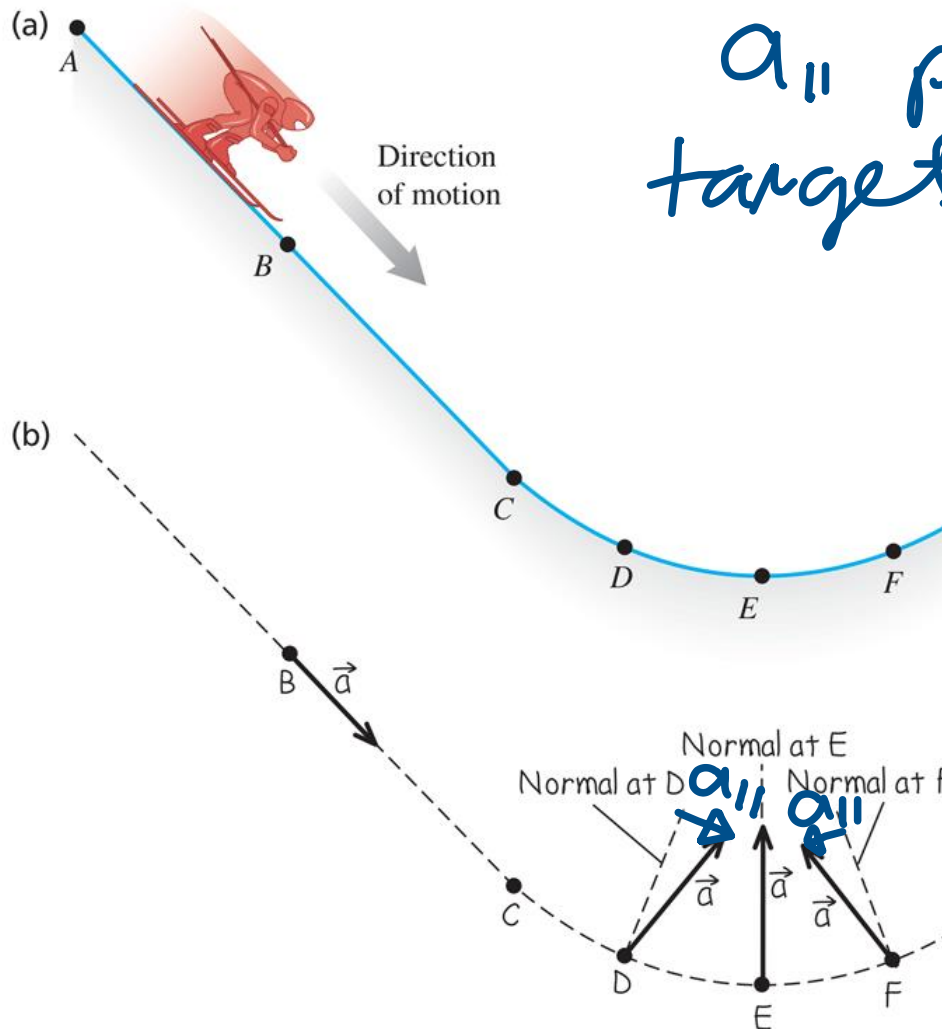
a_{\perp} points towards radius of curvature along normal. The a_{\perp} component allows for curved motion

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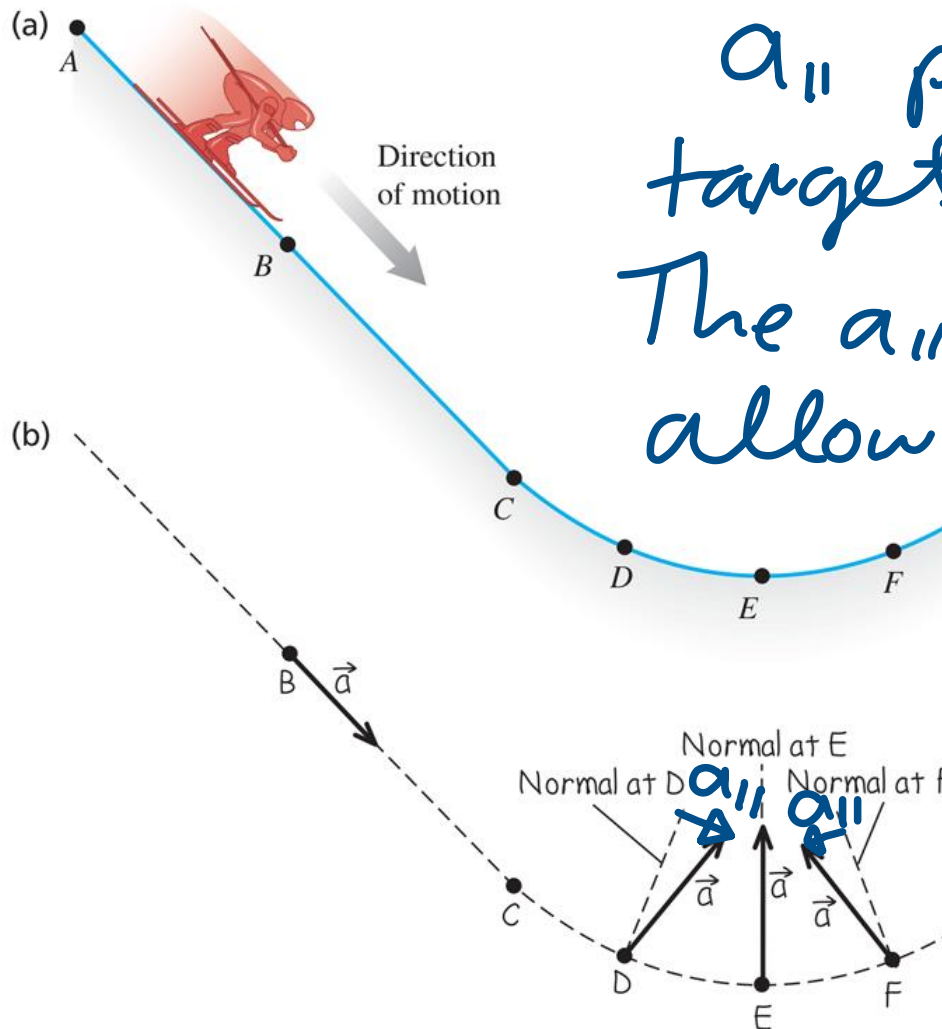
a_{\parallel} points along target to path

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$a_{||}$ points along
tangent to path
The $a_{||}$ components
allows speed to
change

Projectile motion

Projectile motion

"A projectile is any object that is given an initial velocity and then follows a path determined entirely by the effects of gravitational acceleration & air resistance"

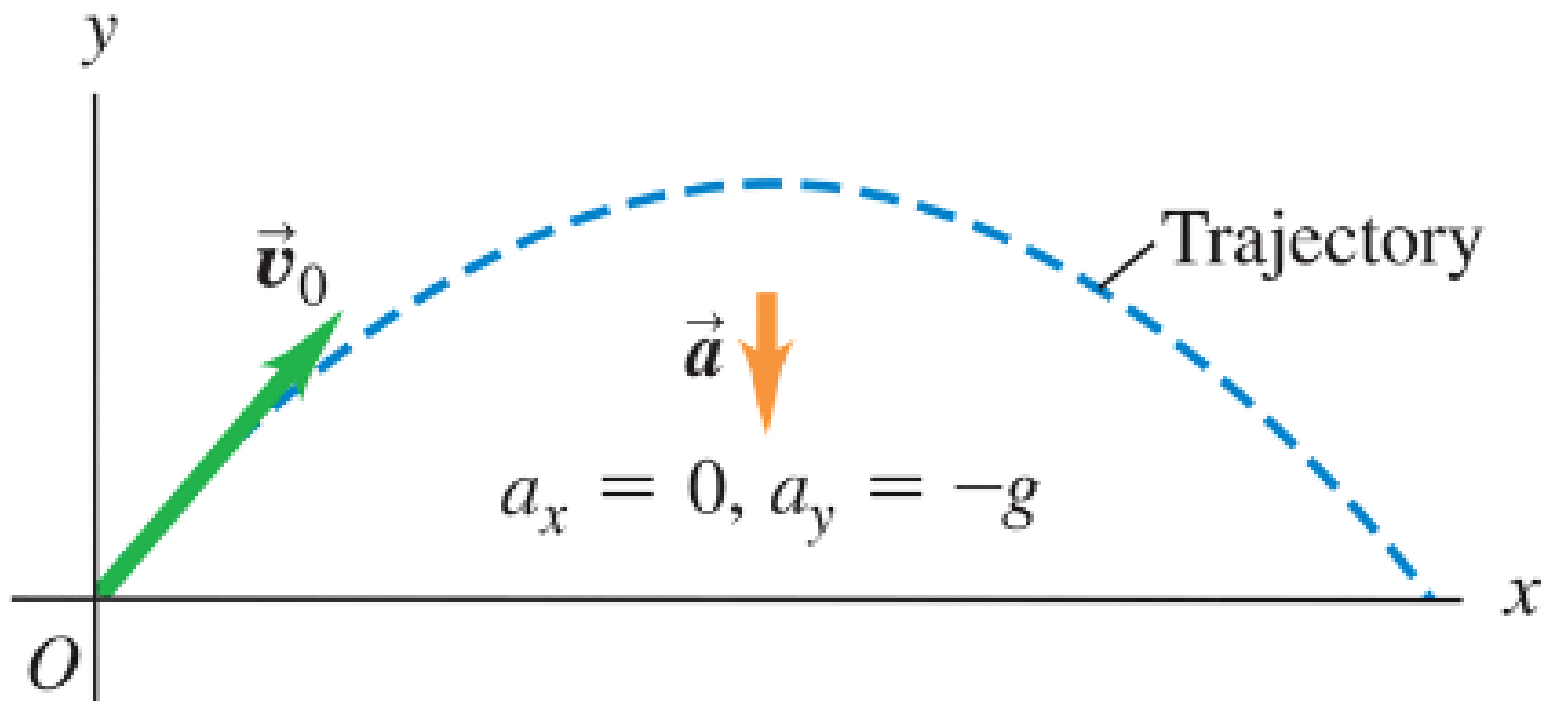
Projectile motion

"A projectile is any object that is given an initial velocity and then follows a path determined entirely by the effects of gravitational acceleration & air resistance"

we will ignore the
air resistance

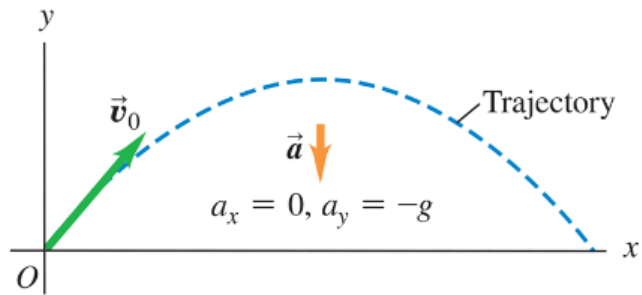
Projectile motion

- A projectile moves in a vertical plane that contains the initial velocity vector \vec{v}_0 .
- Its trajectory depends only on \vec{v}_0 and on the downward acceleration due to gravity.



Projectile motion

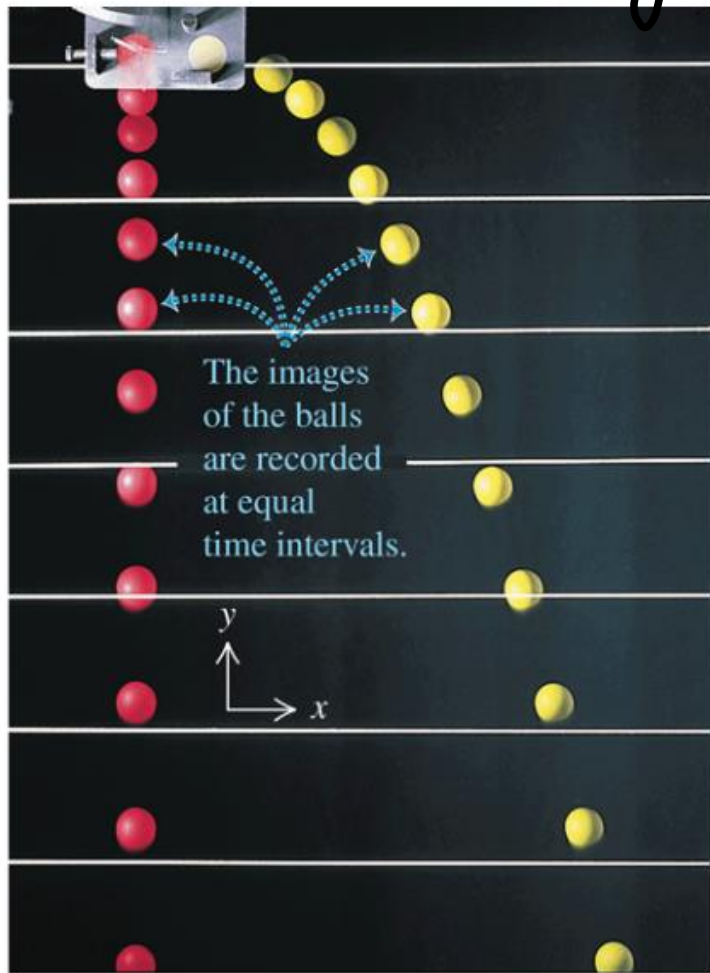
- A projectile moves in a vertical plane that contains the initial velocity vector \vec{v}_0 .
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Key is to treat x -
and y -coordinates
separately

Projectile motion

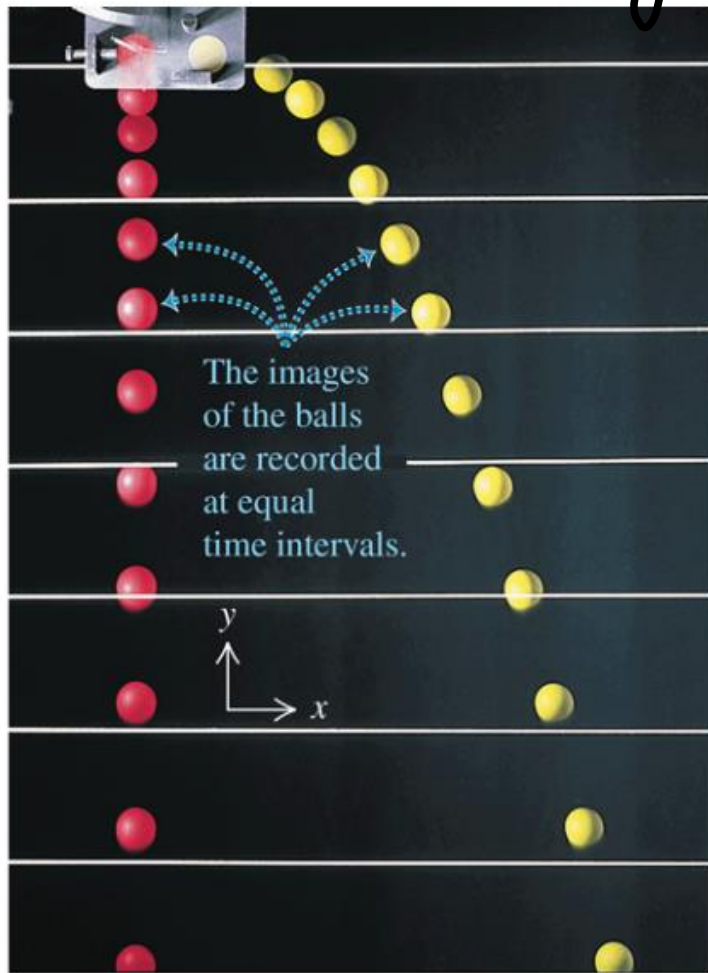
$$a_x = 0$$



- At any time the two balls have different x -coordinates and x -velocities but the same y -coordinate, y -velocity, and y -acceleration.
- The horizontal motion of the yellow ball has no effect on its vertical motion.

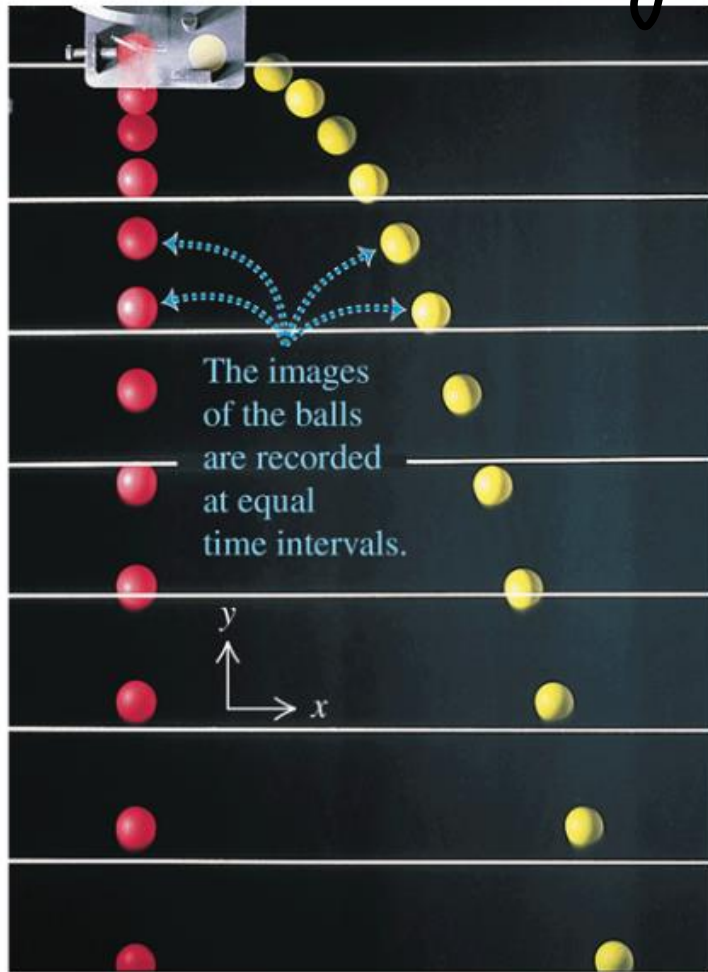
Projectile motion

$$a_x = 0 \quad \& \quad a_y = -g$$



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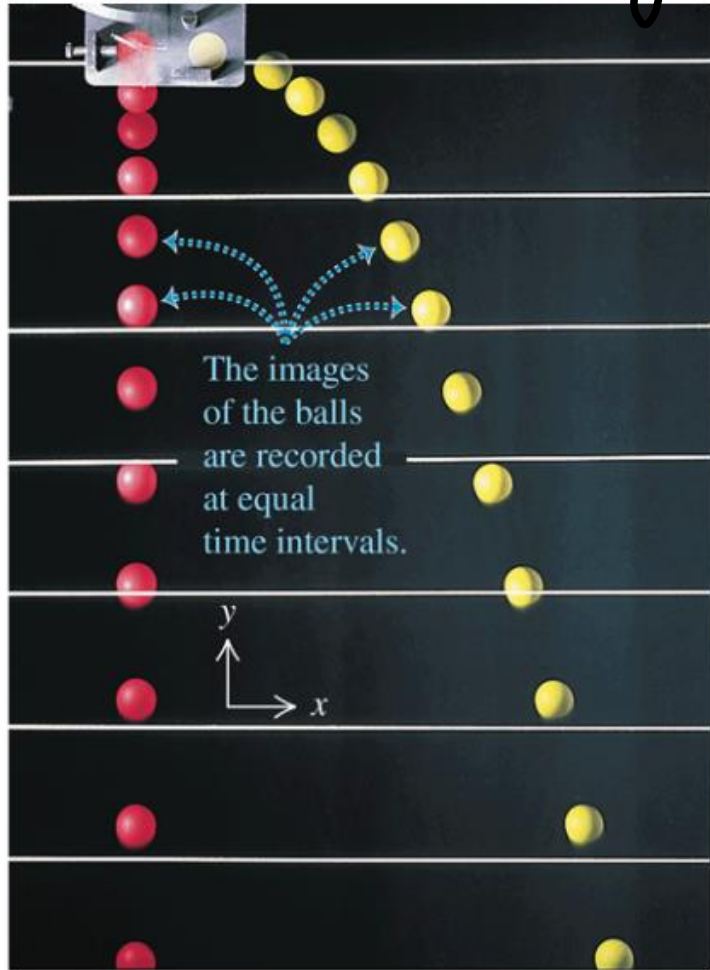
Projectile motion



$$a_x = 0 \quad \& \quad a_y = -g$$
$$\Rightarrow v_x = v_{0x}$$

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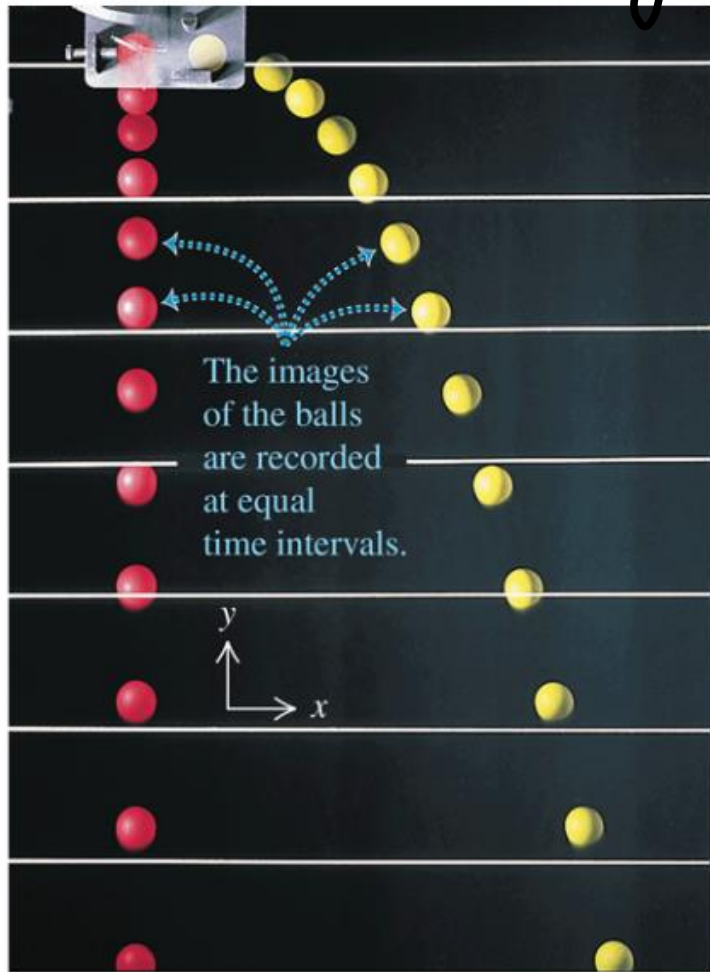
Projectile motion



$$a_x = 0 \quad \& \quad a_y = -g$$
$$\Rightarrow v_x = v_{0x} \quad \& \quad v_y = -gt + v_{0y}$$

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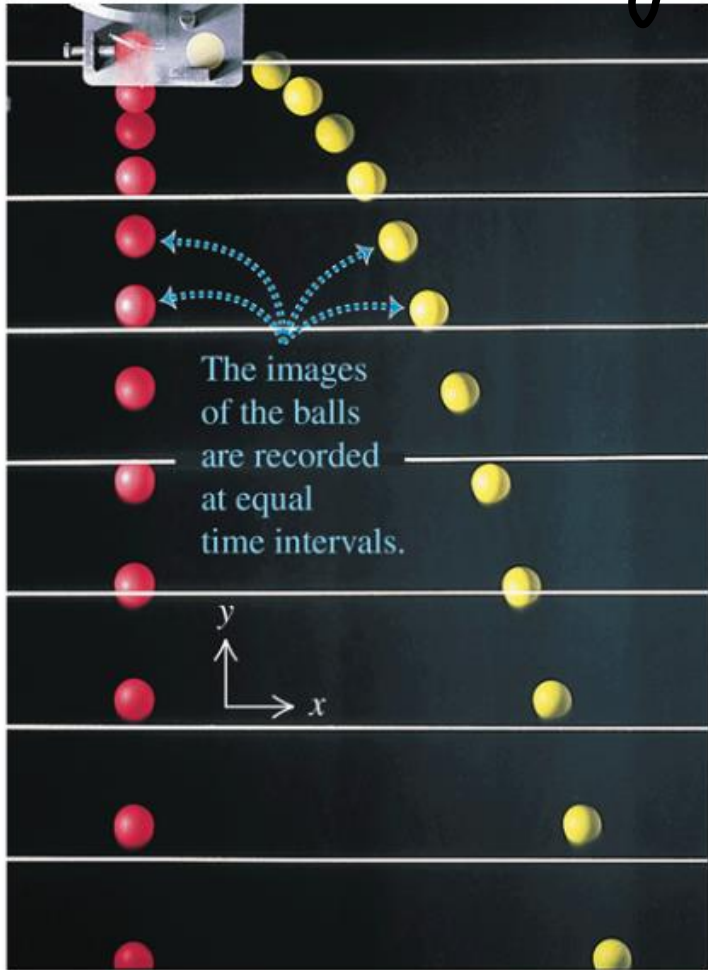
Projectile motion



$$a_x = 0 \quad \& \quad a_y = -g$$
$$\Rightarrow v_x = v_{0x} \quad \& \quad v_y = -gt + v_{0y}$$
$$\Rightarrow X = v_{0x}t + X_0$$

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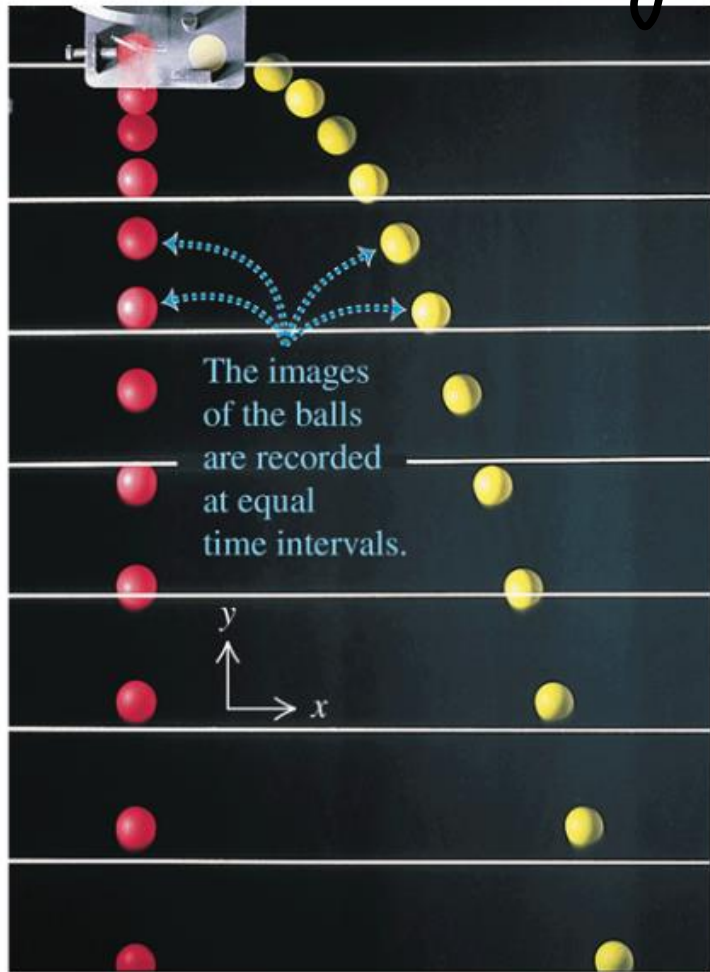
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$$\Rightarrow v_x = v_{0x} \quad \& \quad v_y = -gt + v_{0y}$$
$$\Rightarrow x = v_{0x}t + x_0 \quad \& \quad y = -\frac{g}{2}t^2 + v_{0y}t + y_0$$

Projectile motion

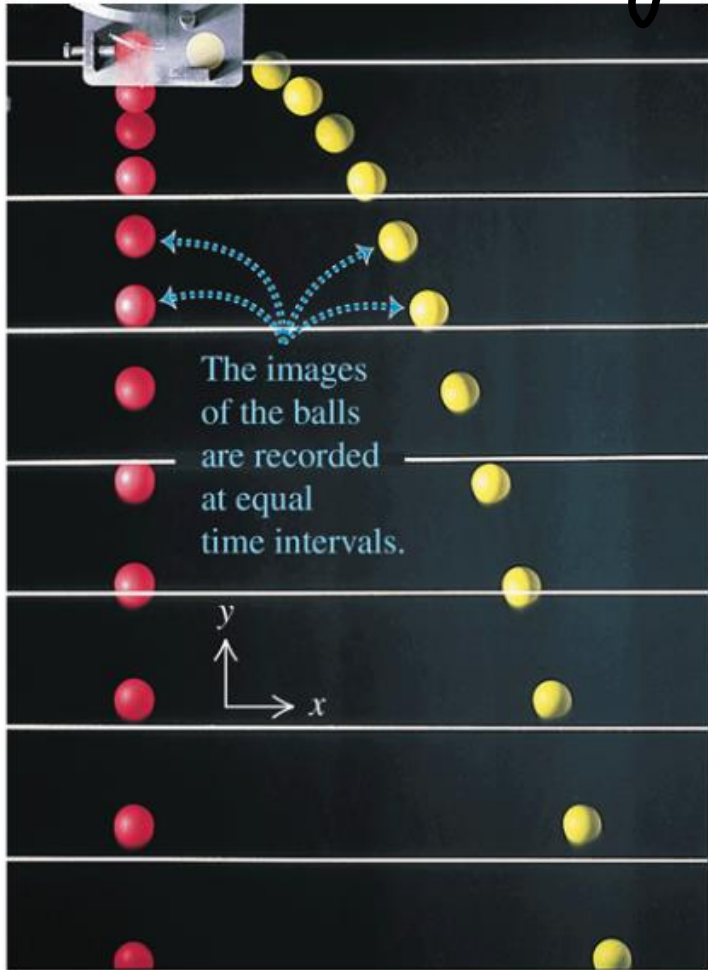


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for either ball

Projectile motion



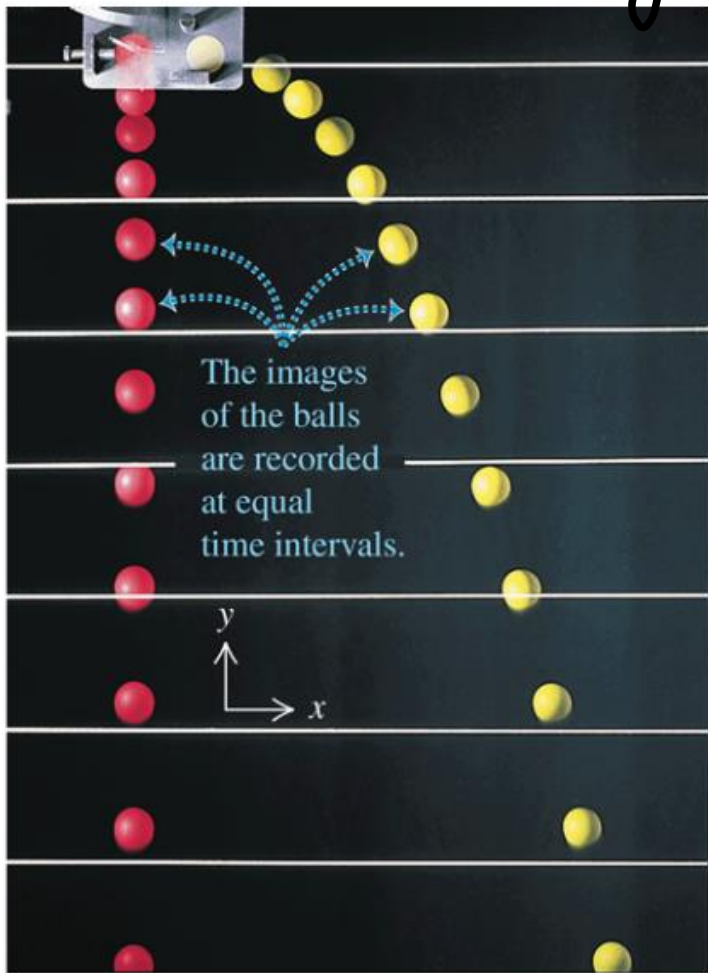
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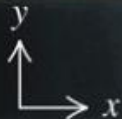
for either ball

Only difference is that yellow ball has different value of v_{0x}

Projectile motion



The images of the balls are recorded at equal time intervals.



- At any time the two balls have different x -coordinates and x -velocities but the same y -coordinate, y -velocity, and y -acceleration.
- The horizontal motion of the yellow ball has no effect on its vertical motion.

$$a_x = 0 \quad \& \quad a_y = -g$$
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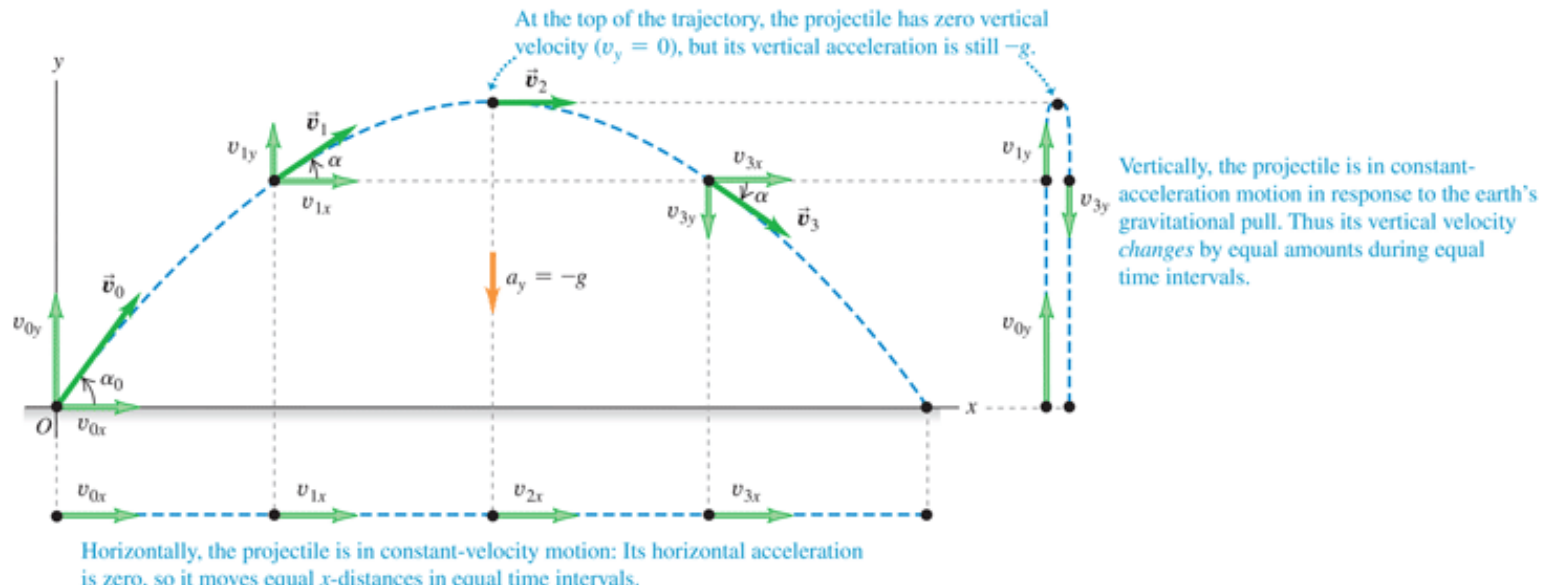
for either ball

Only difference is that yellow ball has different value of $v_{0x} \Rightarrow$ different $x(t)$

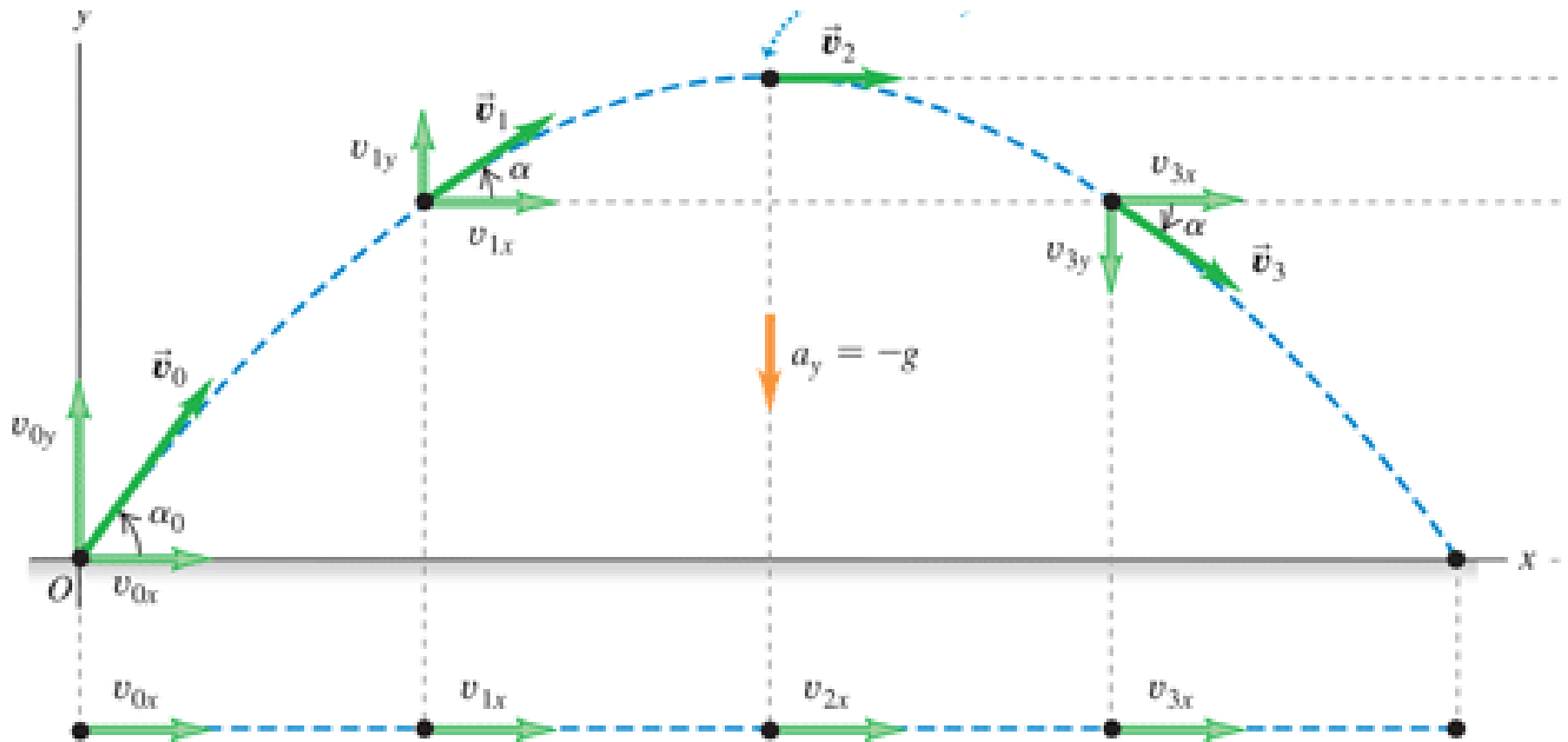
Projectile motion

Figure 3.17 shows the trajectory of a projectile that starts at (or passes through) the origin at time $t = 0$, along with its position, velocity, and velocity components at equal time intervals. The x -velocity v_x is constant; the y -velocity v_y changes by equal amounts in equal times, just as if the projectile were launched vertically with the same initial y -velocity.

Figure 3.17



Projectile motion



Horizontally, the projectile is in constant-velocity motion: Its horizontal acceleration is zero, so it moves equal x -distances in equal time intervals.

Acceleration Vector

Since \vec{v} is a vector we can write

$$v_{ox} = v_0 \cos \alpha_0 \quad \& \quad v_{oy} = v_0 \sin \alpha_0$$



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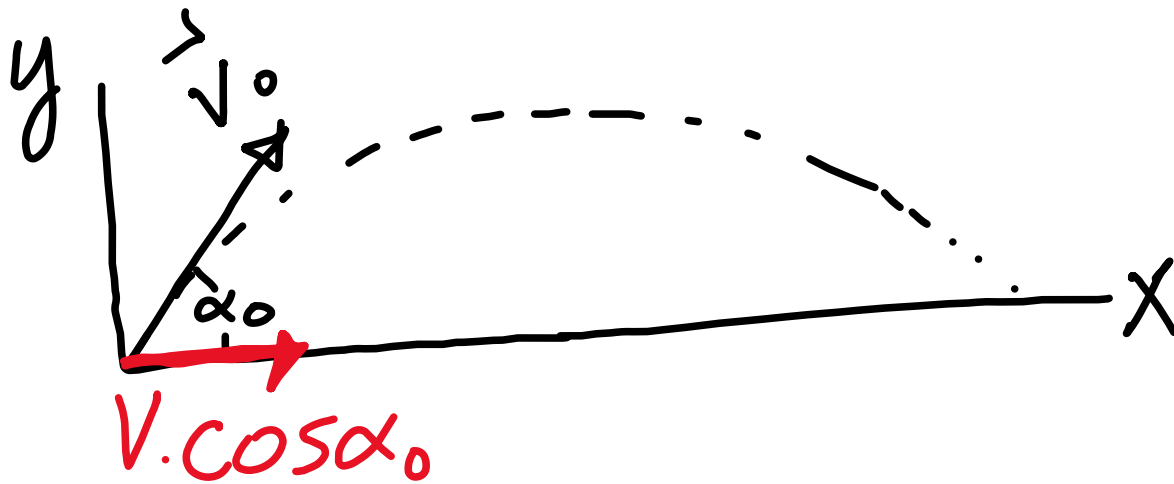
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Acceleration Vector

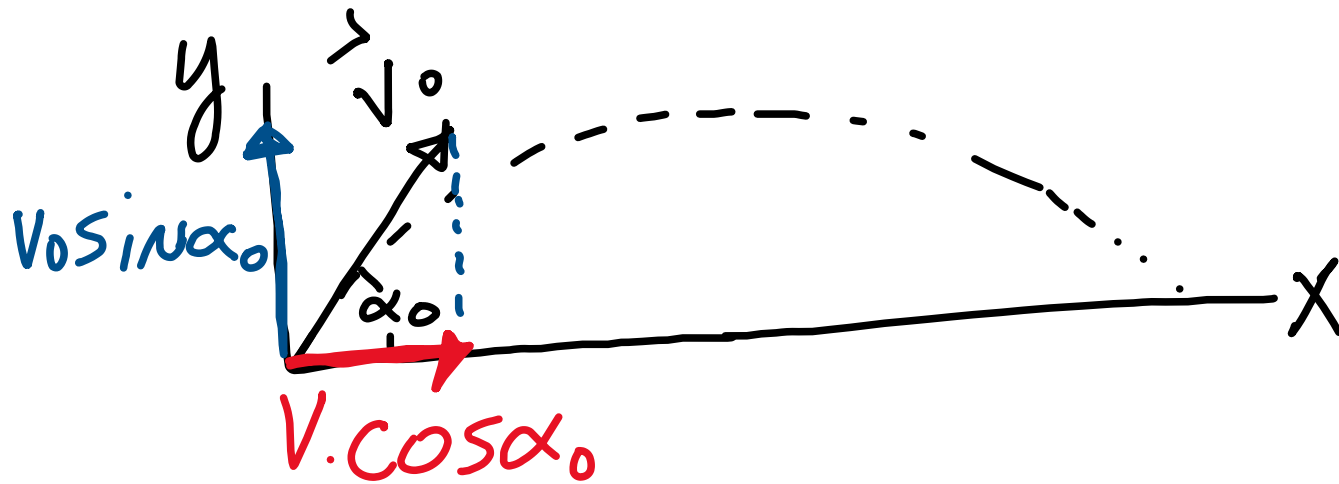
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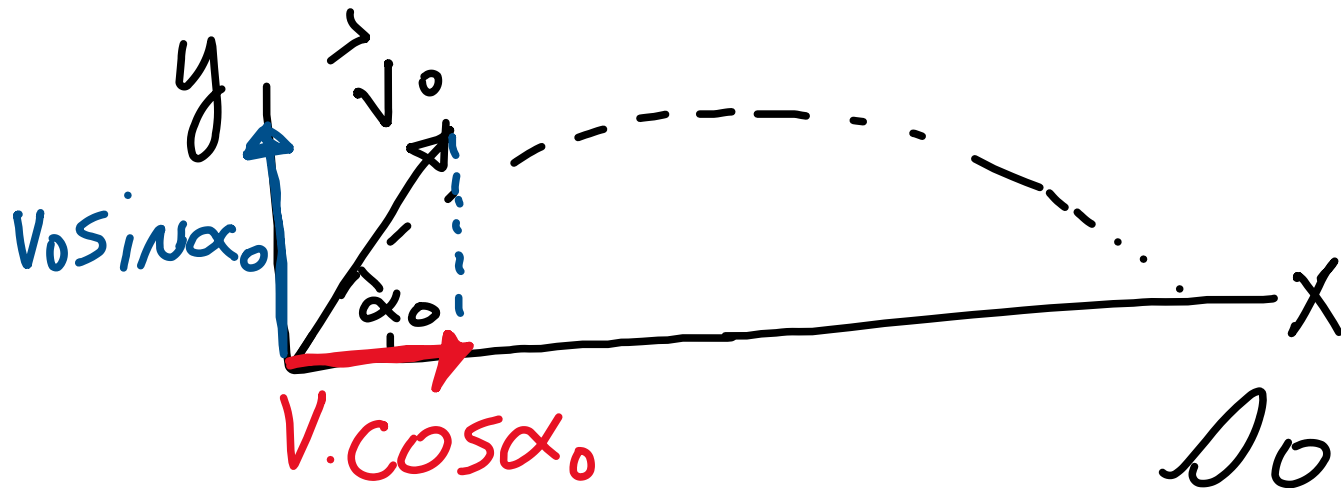
Acceleration Vector

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 $V_{ox} = V_0 \cos \alpha_0$ & $V_{oy} = V_0 \sin \alpha_0$



Acceleration Vector

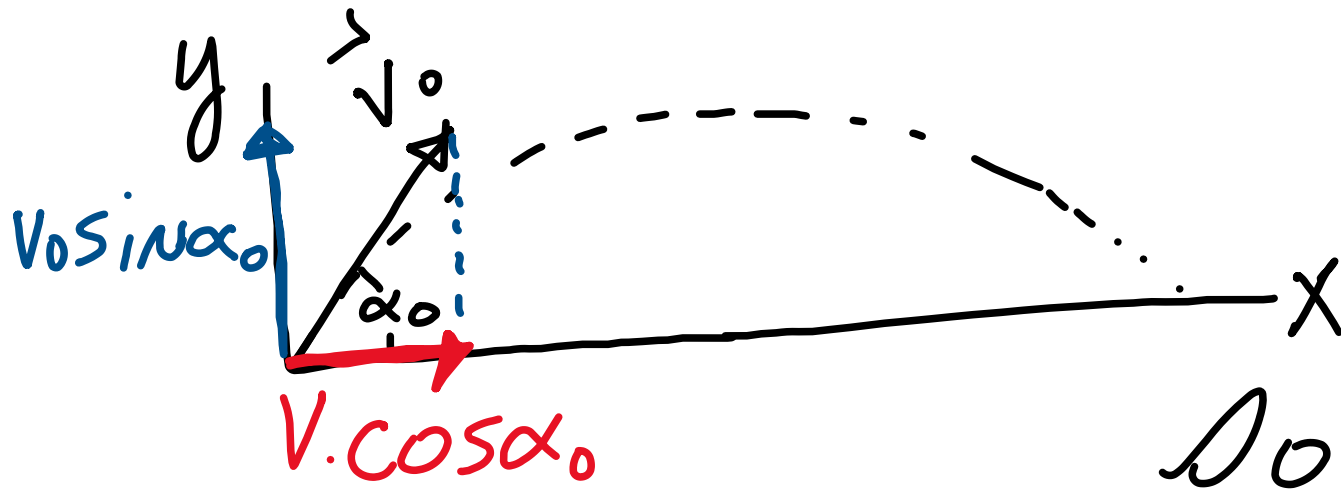
Since \vec{v} is a vector we can write
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$$X = V_{ox}t$$

Acceleration Vector

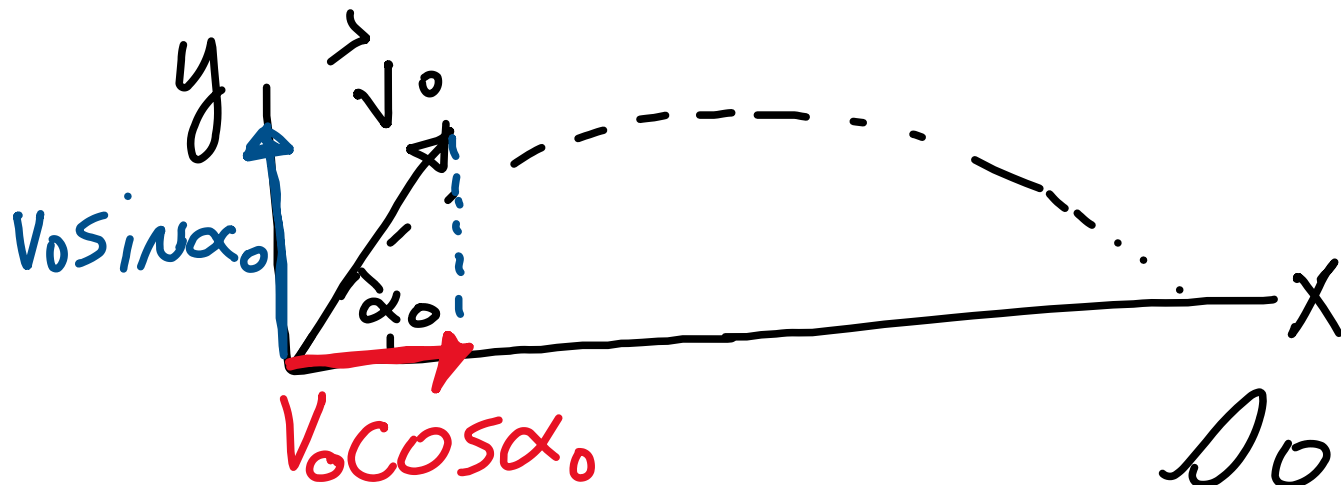
Since \vec{v} is a vector we can write
 $V_{ox} = V_0 \cos \alpha_0$ & $V_{oy} = V_0 \sin \alpha_0$



$$X = V_{ox}t \Rightarrow X = (V_0 \cos \alpha_0)t$$

Acceleration Vector

Since \vec{v} is a vector we can write
 $V_{ox} = V_0 \cos \alpha_0$ & $V_{oy} = V_0 \sin \alpha_0$

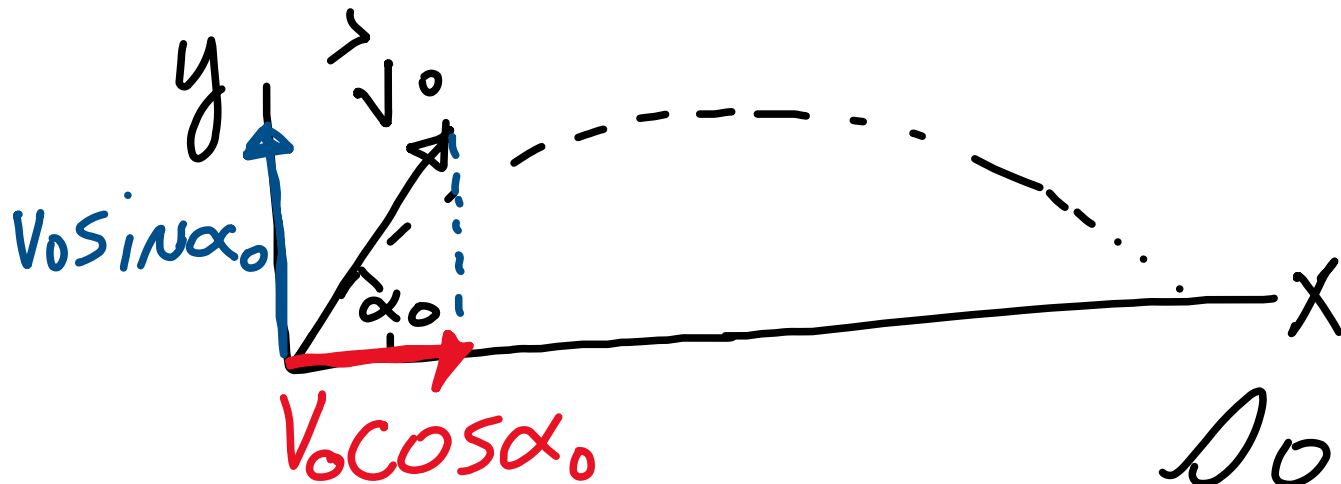


$$X = V_{ox}t \Rightarrow X = (V_0 \cos \alpha_0)t \quad \& \quad D_0$$

$$y = -\frac{g}{2}t^2 + V_{oy}t$$

Acceleration Vector

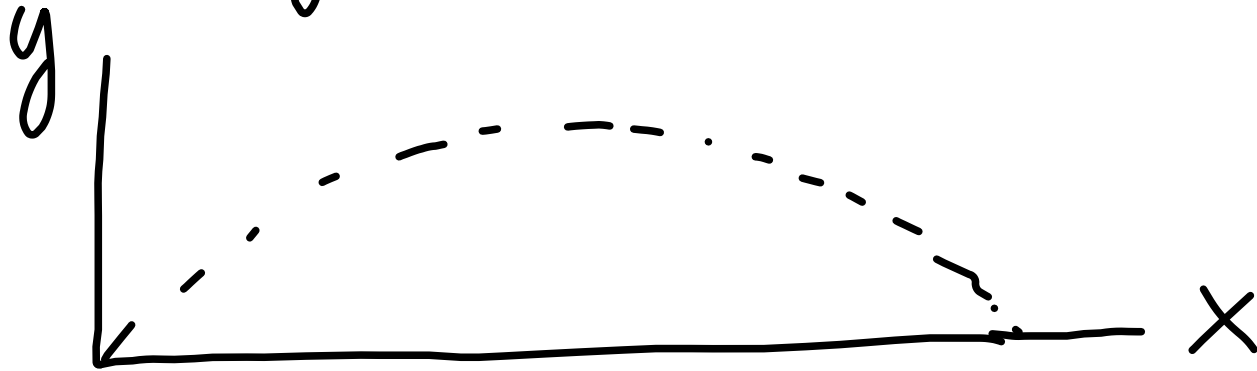
Since \vec{v} is a vector we can write
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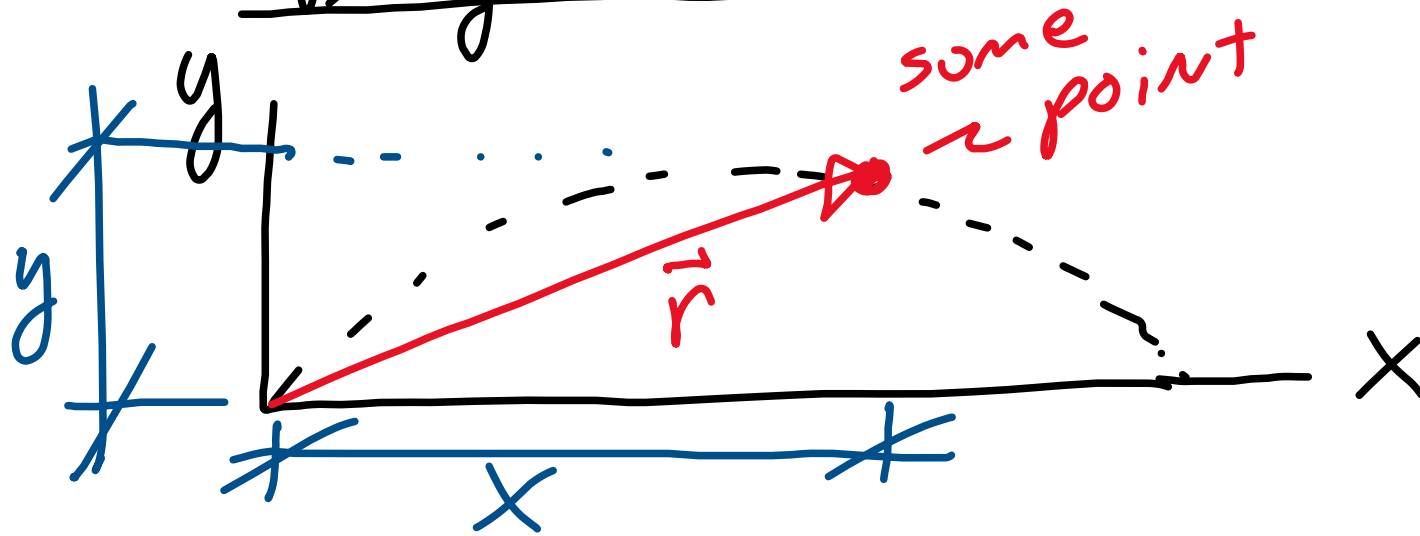
$$x = V_{ox}t \Rightarrow x = (V_0 \cos \alpha_0)t \quad \& \quad D_0$$

$$y = -\frac{g}{2}t^2 + V_{oy}t \Rightarrow y = -\frac{g}{2}t^2 + V_0 \sin \alpha_0 t$$

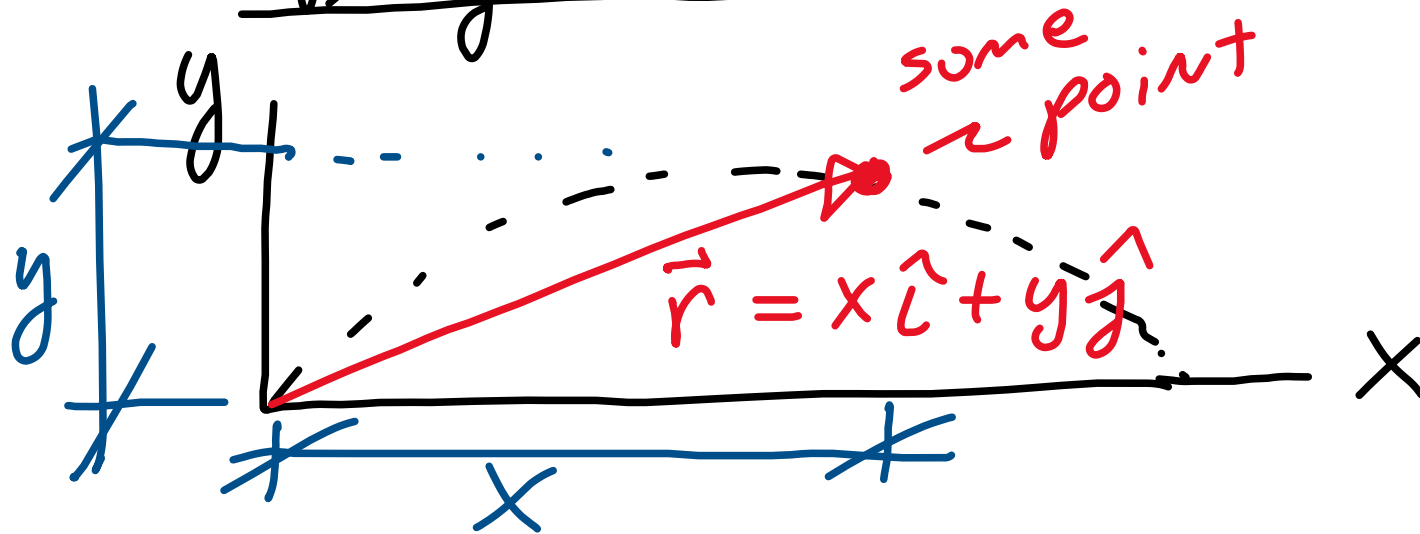
Projectile motion



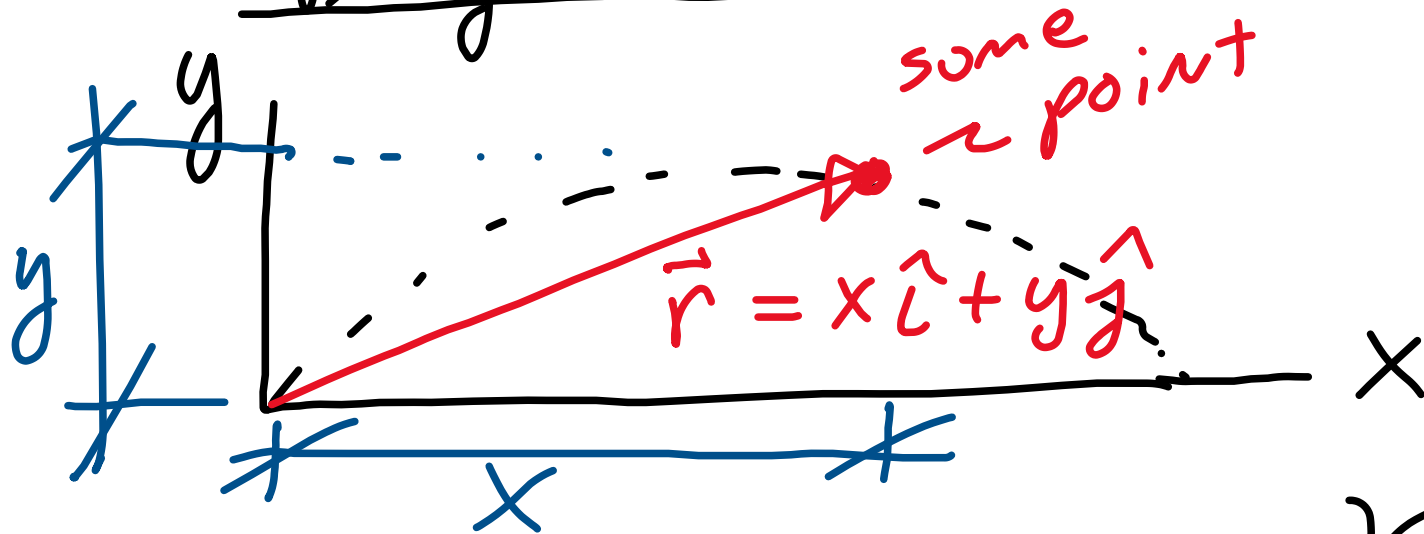
Projectile motion



Projectile motion

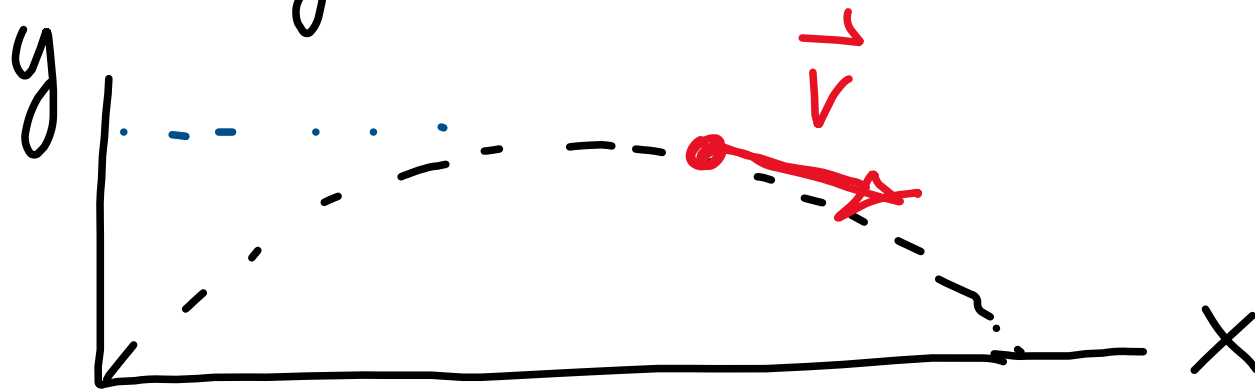


Projectile motion

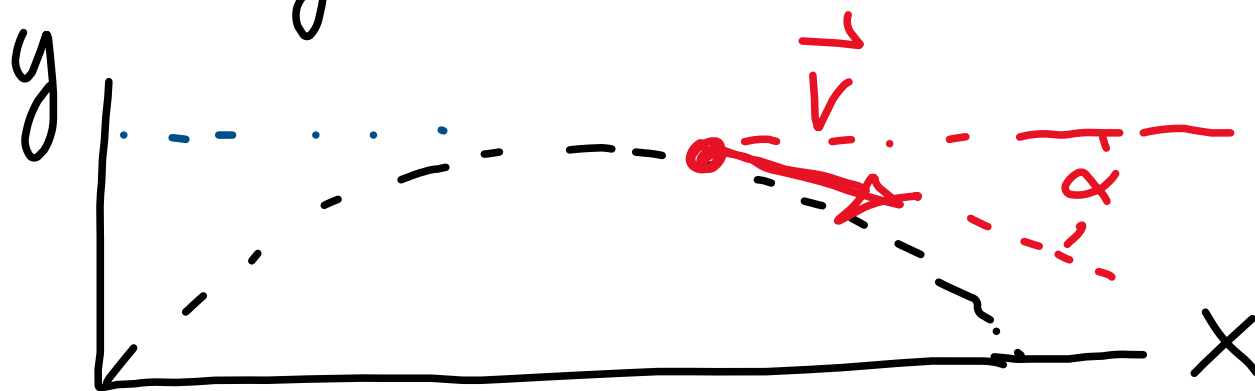


⇒ distance from origin = $r = \sqrt{x^2 + y^2}$

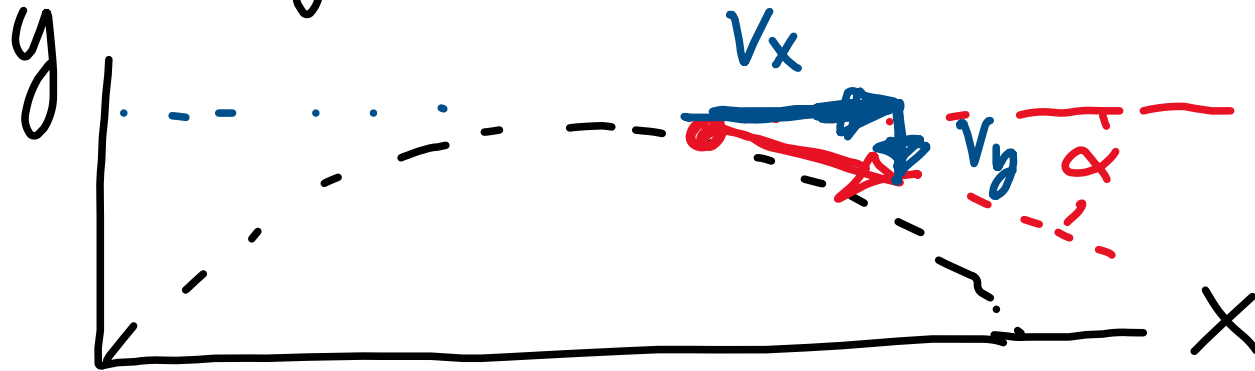
Projectile motion



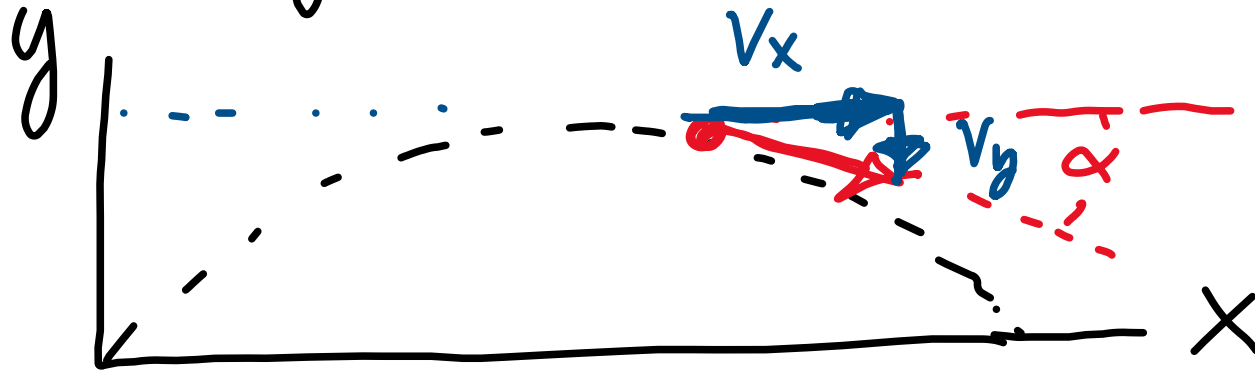
Projectile motion



Projectile motion

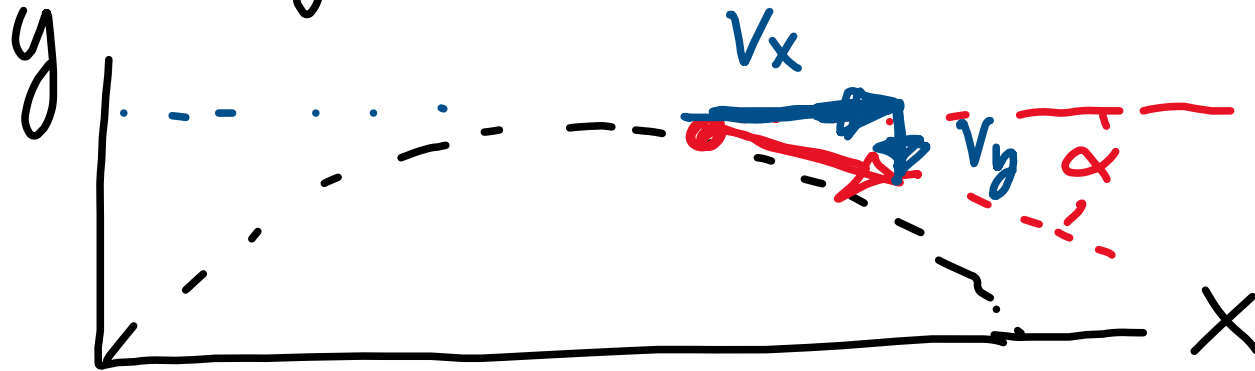


Projectile motion



$$V = \sqrt{V_x^2 + V_y^2}$$

Projectile motion



$$V = \sqrt{V_x^2 + V_y^2} \quad \&$$

$$\tan \alpha = \left(\frac{V_y}{V_x} \right)$$

Projectile motion

Let $x_0 = y_0 = 0$

Projectile motion

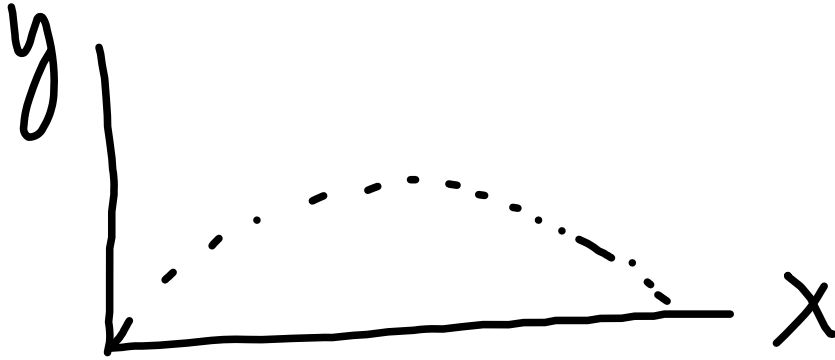
Let $x_0 = y_0 = 0$



Projectile motion

Let $x_0 = y_0 = 0$ so that

$$x = v_0 t$$



Projectile motion

Let $x_0 = y_0 = 0$ so that

$$x = v_{0x}t \quad \&$$

$$y = -\frac{g}{2}t^2 + v_{0y}t$$



Projectile motion

Let $x_0 = y_0 = 0$ so that

$$x = v_{0x}t \quad \&$$

$$y = -\frac{g}{2}t^2 + v_{0y}t$$

We want an

equation of y as a function of x



Projectile motion

Let $x_0 = y_0 = 0$ so that

$$x = v_0 t \quad \&$$

$$y = -\frac{g}{2} t^2 + v_0 t$$



We want an

equation of y as a function of x {instead of $y(t)$ }

Projectile motion

Let $x_0 = y_0 = 0$ so that

$$x = v_{0x}t \quad \&$$

$$y = -\frac{g}{2}t^2 + v_{0y}t$$



$$x = v_{0x}t \Rightarrow t = \frac{x}{v_{0x}}$$

Projectile motion

Let $x_0 = y_0 = 0$ so that

$$x = v_{0x}t \quad \&$$

$$y = -\frac{g}{2}t^2 + v_{0y}t$$



$$x = v_{0x}t \Rightarrow$$

$$t = \frac{x}{v_{0x}}$$

→ Sub this into

Projectile motion

Let $x_0 = y_0 = 0$ so that



$$x = v_{ox}t \quad \&$$

$$y = -\frac{g}{2}t^2 + v_{oy}t$$

$$x = v_{ox}t \Rightarrow t = \frac{x}{v_{ox}} \Rightarrow$$

$$y = -\frac{g}{2} \left(\frac{x^2}{v_{ox}^2} \right) + v_{oy} \frac{x}{v_{ox}}$$

Projectile motion

Let $x_0 = y_0 = 0$ so that



$$x = v_{0x}t \quad \&$$

$$y = -\frac{g}{2}t^2 + v_{0y}t$$

$$x = v_{0x}t \Rightarrow t = \frac{x}{v_{0x}} \Rightarrow$$

$$y = -\frac{g}{2} \left(\frac{x^2}{v_{0x}^2} \right) + v_{0y} \frac{x}{v_{0x}} = -\frac{g x^2}{2 v_{0x}^2} + \left(\frac{v_{0y}}{v_{0x}} \right) x$$

Projectile motion

Let $x_0 = y_0 = 0$ so that



$$x = v_{0x}t \quad \&$$

$$y = -\frac{g}{2}t^2 + v_{0y}t$$

$$x = v_{0x}t \Rightarrow t = \frac{x}{v_{0x}} \Rightarrow$$

$$y = -\frac{g}{2} \left(\frac{x^2}{v_{0x}^2} \right) + v_{0y} \frac{x}{v_{0x}} = -\frac{g x^2}{2 v_{0x}^2} + \left(\frac{v_{0y}}{v_{0x}} \right) x$$

$$\text{But } \underline{v_{0x} = v_0 \cos \alpha_0}$$

Projectile motion

Let $x_0 = y_0 = 0$ so that



$$x = v_{0x}t \quad \&$$

$$y = -\frac{g}{2}t^2 + v_{0y}t$$

$$x = v_{0x}t \Rightarrow t = \frac{x}{v_{0x}} \Rightarrow$$

$$y = -\frac{g}{2} \left(\frac{x^2}{v_{0x}^2} \right) + v_{0y} \frac{x}{v_{0x}} = -\frac{g x^2}{2 v_{0x}^2} + \left(\frac{v_{0y}}{v_{0x}} \right) x$$

$$\text{But } \underline{v_{0x} = v_0 \cos \alpha_0} \quad \& \quad \underline{\frac{v_{0y}}{v_{0x}} = \tan \alpha_0}$$

Projectile motion

Let $x_0 = y_0 = 0$ so that



$$x = v_{0x}t \quad \&$$

$$y = -\frac{g}{2}t^2 + v_{0y}t$$

$$x = v_{0x}t \Rightarrow t = \frac{x}{v_{0x}} \Rightarrow$$

$$y = -\frac{g}{2} \left(\frac{x}{v_{0x}} \right)^2 + v_{0y} \frac{x}{v_{0x}} = -\frac{gx^2}{2v_{0x}^2} + \left(\frac{v_{0y}}{v_{0x}} \right) x$$

So

$$y = \frac{-gx^2}{2v_0^2 \cos^2 \alpha_0} + (\tan \alpha_0)x$$

Projectile motion

Let $x_0 = y_0 = 0$ so that



$$x = v_{0x}t \quad \&$$

$$y = -\frac{g}{2}t^2 + v_{0y}t$$

$$x = v_{0x}t \Rightarrow t = \frac{x}{v_{0x}} \Rightarrow$$

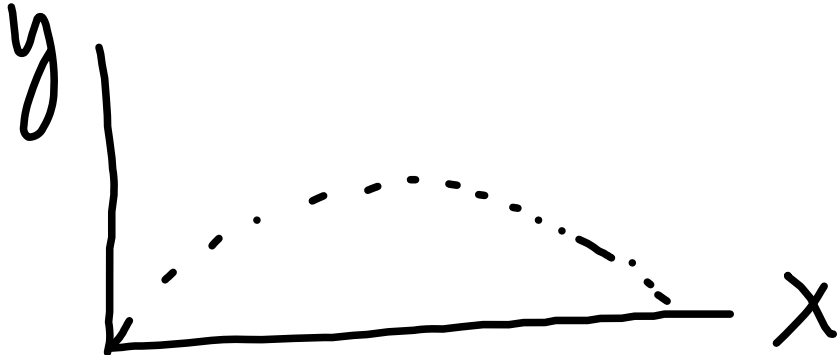
$$y = -\frac{g}{2} \left(\frac{x}{v_{0x}} \right)^2 + v_{0y} \frac{x}{v_{0x}} = -\frac{gx^2}{2v_{0x}^2} + \left(\frac{v_{0y}}{v_{0x}} \right) x$$

So

$$y = \frac{-gx^2}{2v_0^2 \cos^2 \alpha_0} + (\tan \alpha_0)x$$

Projectile motion

Let $x_0 = y_0 = 0$



Form $Ax^2 + Bx$

$$y = \frac{-gx^2}{2v_0^2 \cos^2 \alpha_0} + (\tan \alpha_0)x$$

Projectile motion

Let $x_0 = y_0 = 0$



Form $Ax^2 + Bx$, where

$$A = -\frac{g}{2v_0^2 \cos^2 \alpha_0}$$

$$y = \frac{-gx^2}{2v_0^2 \cos^2 \alpha_0} + (\tan \alpha_0)x$$

Projectile motion

Let $x_0 = y_0 = 0$

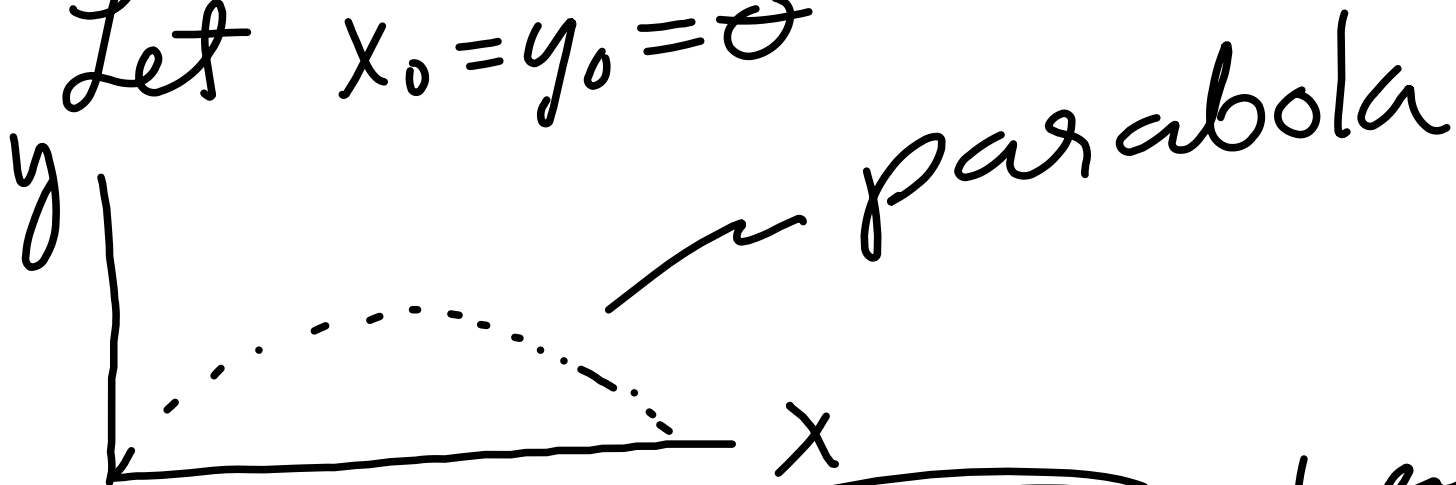


Form $Ax^2 + Bx$, where
 $A = -\frac{g}{2v_0^2 \cos^2 \alpha_0}$ & $B = \tan \alpha_0$

$$y = \frac{-gx^2}{2v_0^2 \cos^2 \alpha_0} + (\tan \alpha_0)x$$

Projectile motion

Let $x_0 = y_0 = 0$

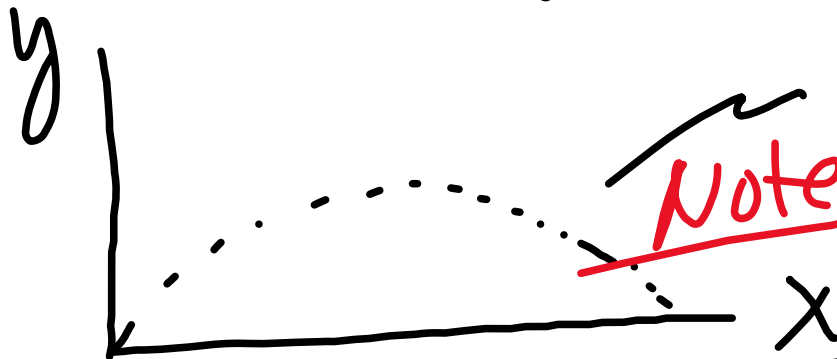


Form $Ax^2 + Bx$, where
 $A = -\frac{g}{2v_0^2 \cos^2 \alpha_0}$ & $B = \tan \alpha_0$

$$y = \frac{-gx^2}{2v_0^2 \cos^2 \alpha_0} + (\tan \alpha_0)x$$

Projectile motion

Let $x_0 = y_0 = 0$

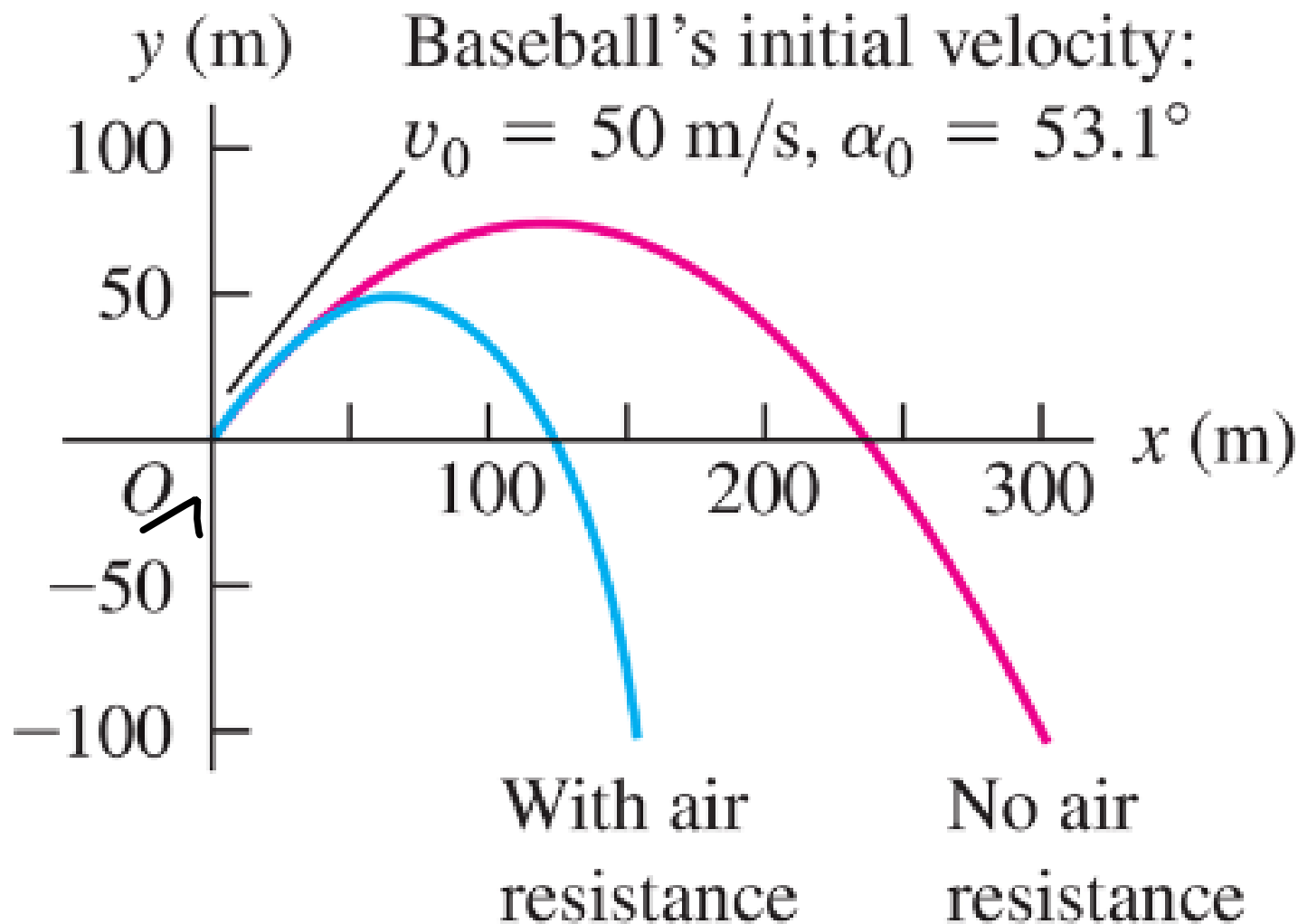


Note: Much more complicated if air resistance included

Form $Ax^2 + Bx$, where
 $A = -\frac{g}{2v_0^2 \cos^2 \alpha_0}$ & $B = \tan \alpha_0$

$$y = \frac{-gx^2}{2v_0^2 \cos^2 \alpha_0} + (\tan \alpha_0)x$$

Projectile motion



Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s . Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \underline{\text{Find } \vec{r}(0.5 \text{ s}):}$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \underline{\text{Find } \vec{r}(0.5 \text{ s}):}$$

$$x = v_{0x} t \Rightarrow$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \underline{\text{Find } \vec{r}(0.5 \text{ s}) :}$$

$$x = v_{0x} t \Rightarrow x(0.5 \text{ s}) = (9 \text{ m/s})(0.5 \text{ s})$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$v_{0x} = 9 \text{ m/s} \quad v_{0y} = 0 \quad \underline{\text{Find } \vec{r}(0.5 \text{ s}):}$$
$$x = v_{0x} t \Rightarrow x(0.5 \text{ s}) = (9 \text{ m/s})(0.5 \text{ s}) = 4.5 \text{ m}$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \underline{\text{Find } \vec{r}(0.5 \text{ s}):}$$

$$x = v_{0x} t \Rightarrow x(0.5 \text{ s}) = (9 \text{ m/s})(0.5 \text{ s}) = 4.5 \text{ m}$$

$$\cancel{\$} \quad y = -\frac{g}{2} t^2 + \cancel{V_{0y} t}$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \text{Find } \vec{r}(0.5 \text{ s}):$$

$$x = v_{0x} t \Rightarrow x(0.5 \text{ s}) = (9 \text{ m/s})(0.5 \text{ s}) = 4.5 \text{ m}$$

$$\cancel{y} \quad y = -\frac{g}{2} t^2 + \cancel{v_{0y}} t \Rightarrow y(0.5 \text{ s}) = \left(-\frac{9.8 \text{ m/s}^2}{2}\right) \left(\frac{5^2}{4}\right)$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \text{Find } \vec{r}(0.5 \text{ s}):$$

$$x = v_{0x} t \Rightarrow x(0.5 \text{ s}) = (9 \text{ m/s})(0.5 \text{ s}) = 4.5 \text{ m}$$

$$y = -\frac{g}{2} t^2 + v_{0y} t \Rightarrow y(0.5 \text{ s}) = \left(-\frac{9.8 \text{ m/s}^2}{2}\right) \left(\frac{5^2}{4}\right)$$

$$\Rightarrow y(0.5 \text{ s}) = -1.2 \text{ m}$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \text{Find } \vec{r}(0.5 \text{ s}):$$

$$x = v_{0x} t \Rightarrow x(0.5 \text{ s}) = (9 \text{ m/s})(0.5 \text{ s}) = 4.5 \text{ m}$$

$$y = -\frac{g}{2} t^2 + v_{0y} t \Rightarrow y(0.5 \text{ s}) = \left(-\frac{9.8 \text{ m/s}^2}{2}\right) \left(\frac{5^2}{4}\right)$$

$$\Rightarrow y(0.5 \text{ s}) = -1.2 \text{ m} \quad \text{Find } v(0.5 \text{ s}):$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \text{Find } \vec{r}(0.5 \text{ s}):$$

$$x = v_{0x} t \Rightarrow x(0.5 \text{ s}) = (9 \text{ m/s})(0.5 \text{ s}) = 4.5 \text{ m}$$

$$y = -\frac{g}{2} t^2 + v_{0y} t \Rightarrow y(0.5 \text{ s}) = \left(-\frac{9.8 \text{ m/s}^2}{2}\right)\left(\frac{5^2}{4}\right)$$

$$\Rightarrow y(0.5 \text{ s}) = -1.2 \text{ m} \quad \text{Find } r(0.5 \text{ s}):$$

$$r = \sqrt{x^2 + y^2}$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \text{Find } \vec{r}(0.5 \text{ s}):$$

$$x = v_{0x} t \Rightarrow x(0.5 \text{ s}) = (9 \text{ m/s})(0.5 \text{ s}) = 4.5 \text{ m}$$

$$y = -\frac{g}{2} t^2 + v_{0y} t \Rightarrow y(0.5 \text{ s}) = \left(-\frac{9.8 \text{ m/s}^2}{2}\right)\left(\frac{5^2}{4}\right)$$

$$\Rightarrow y(0.5 \text{ s}) = -1.2 \text{ m} \quad \text{Find } r(0.5 \text{ s}):$$

$$r = \sqrt{x^2 + y^2} = \sqrt{4.5^2 + 1.2^2} \text{ m}$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \text{Find } \vec{r}(0.5 \text{ s}):$$

$$x = v_{0x} t \Rightarrow x(0.5 \text{ s}) = (9 \text{ m/s})(0.5 \text{ s}) = 4.5 \text{ m}$$

$$y = -\frac{g}{2} t^2 + v_{0y} t \Rightarrow y(0.5 \text{ s}) = \left(-\frac{9.8 \text{ m/s}^2}{2}\right)\left(\frac{5^2}{4}\right)$$

$$\Rightarrow y(0.5 \text{ s}) = -1.2 \text{ m} \quad \text{Find } r(0.5 \text{ s}):$$

$$r = \sqrt{x^2 + y^2} = \sqrt{4.5^2 + 1.2^2} \text{ m} = 4.7 \text{ m}$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \underline{\text{Find } v(0.5 \text{ s}) :}$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \underline{\text{Find } v(0.5\text{s}) :}$$

$$V_x = V_{0x}$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \underline{\text{Find } v(0.5 \text{ s}) :}$$

$$V_x = V_{0x} \quad \& \quad V_y = -gt + \cancel{V_{0y}}$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \underline{\text{Find } v(0.5 \text{ s}) :}$$

$$V_x = V_{0x} \quad \& \quad V_y = -gt + \cancel{V_{0y}} = -gt$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \underline{\text{Find } v(0.5s) :}$$

$$V_x = V_{0x} \quad \& \quad V_y = -gt + \cancel{V_{0y}} = -gt \quad \rightarrow$$

$$V_x(0.5s) = 9 \text{ m/s}$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \underline{\text{Find } v(0.5 \text{ s}) :}$$

$$V_x = V_{0x} \quad \& \quad V_y = -gt + \cancel{V_{0y}} = -gt \quad \rightarrow$$

$$V_x(0.5 \text{ s}) = 9 \text{ m/s} \quad \& \quad V_y = (-9.8 \text{ m/s}^2)(0.5 \text{ s})$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \underline{\text{Find } v(0.5 \text{ s}) :}$$

$$V_x = V_{0x} \quad \& \quad V_y = -gt + \cancel{V_{0y}} = -gt \quad \rightarrow$$

$$V_x(0.5 \text{ s}) = 9 \text{ m/s} \quad \& \quad V_y = (-9.8 \text{ m/s}^2)(0.5 \text{ s}) \\ = -4.9 \text{ m/s}$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \underline{\text{Find } v(0.5 \text{ s}) :}$$

$$V_x = V_{0x} \quad \& \quad V_y = -gt + \cancel{V_{0y}} = -gt \quad \rightarrow$$

$$V_x(0.5 \text{ s}) = 9 \text{ m/s} \quad \& \quad V_y = (-9.8 \text{ m/s}^2)(0.5 \text{ s}) \\ = -4.9 \text{ m/s}$$

$$\vec{v} = (9 \text{ m/s})\hat{i} - (4.9 \text{ m/s})\hat{j}$$

Projectile motion

A motorcycle stunt rider rides off the edge of a cliff. Just at the edge his velocity is horizontal, with magnitude 9.0 m/s. Find the motorcycle's position, distance from the edge of the cliff, and velocity 0.50 s after it leaves the edge of the cliff. Ignore air resistance.

$$V_{0x} = 9 \text{ m/s} \quad V_{0y} = 0 \quad \underline{\text{Find } v(0.5 \text{ s}) :}$$

$$V_x = V_{0x} \quad \& \quad V_y = -gt + \cancel{V_{0y}} = -gt \quad \rightarrow$$

$$V_x(0.5 \text{ s}) = 9 \text{ m/s} \quad \& \quad V_y = (-9.8 \text{ m/s}^2)(0.5 \text{ s}) \\ = -4.9 \text{ m/s}$$

$$\vec{v} = (9 \text{ m/s})\hat{i} - (4.9 \text{ m/s})\hat{j}, \quad v = \sqrt{9^2 + 4.9^2} \frac{\text{m}}{\text{s}}$$

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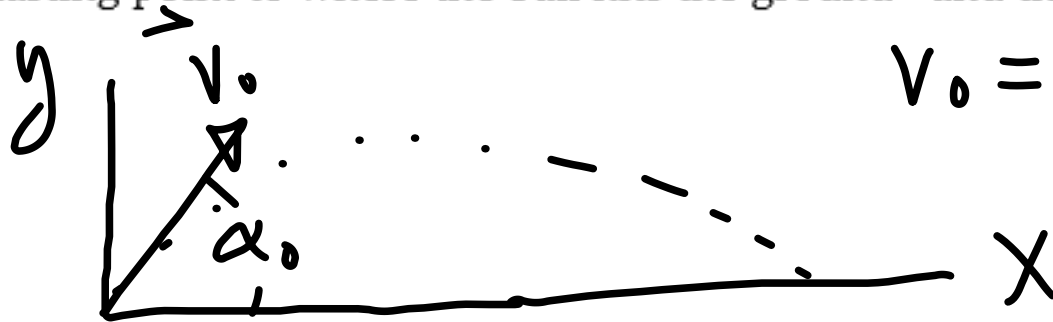
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$$\vec{v} = 10.2 \frac{\text{m}}{\text{s}} \text{ at } -29^\circ$$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0 \text{ m/s}$ at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00 \text{ s}$. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the *horizontal range* R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

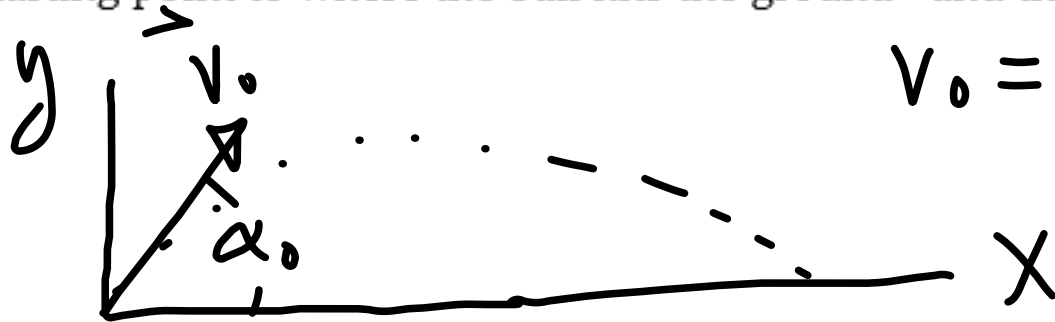


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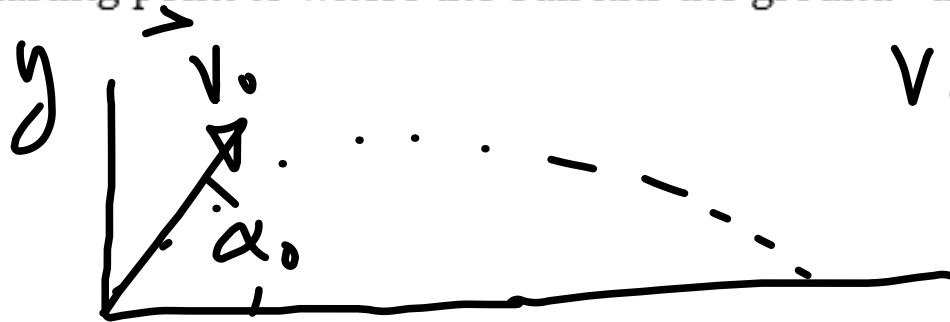
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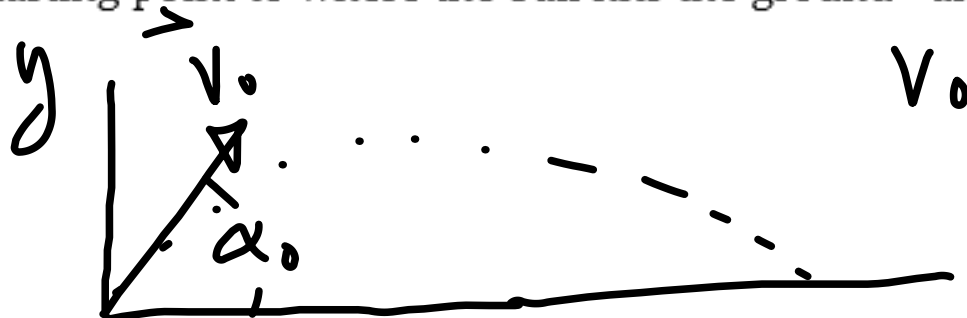


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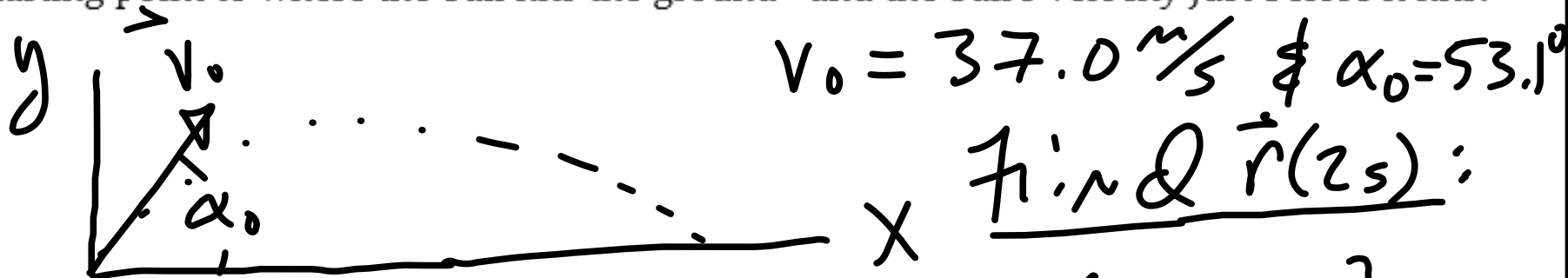


$v_0 = 37.0 \text{ m/s}$ & $\alpha_0 = 53.1^\circ$

Find $\vec{r}(2\text{s})$:

$$x = (v_0 \cos \alpha_0) t \Rightarrow x(2\text{s}) = (37 \frac{\text{m}}{\text{s}}) [\cos(53.1^\circ)] 2\text{s}$$

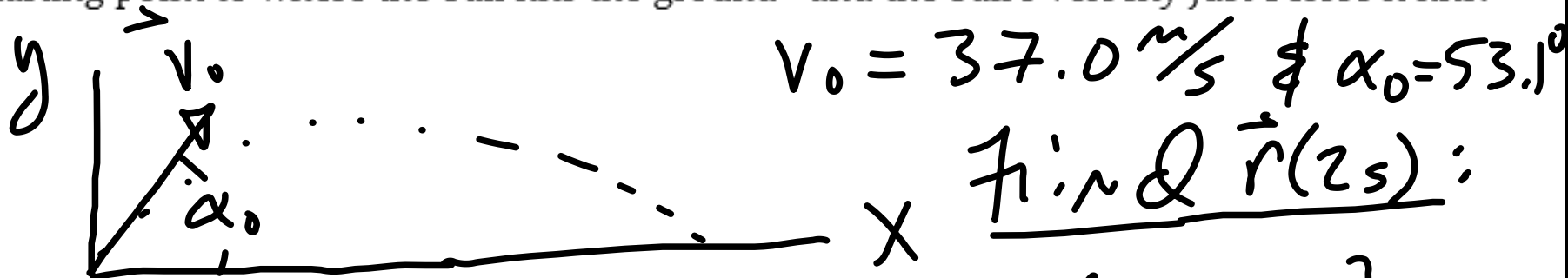
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$$x = (v_0 \cos \alpha_0) t \Rightarrow x(2s) = (37 \frac{\text{m}}{\text{s}}) [\cos(53.1^\circ)] 2s$$

$$= 44.4 \text{ m}$$

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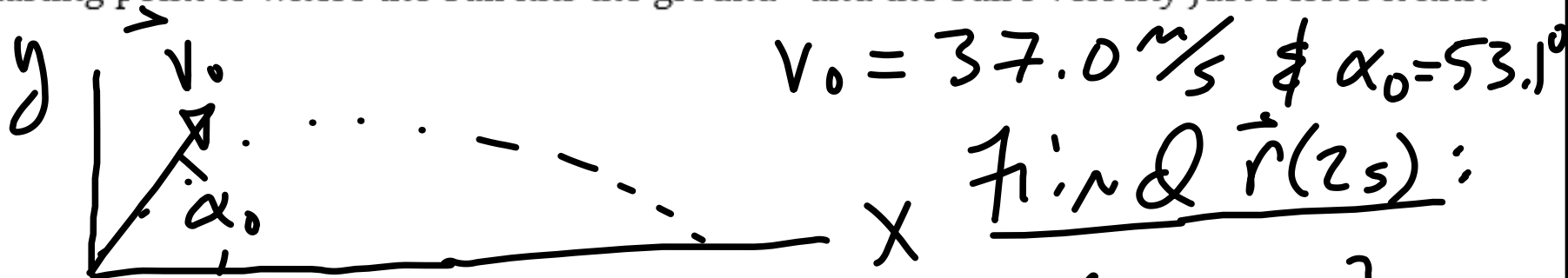


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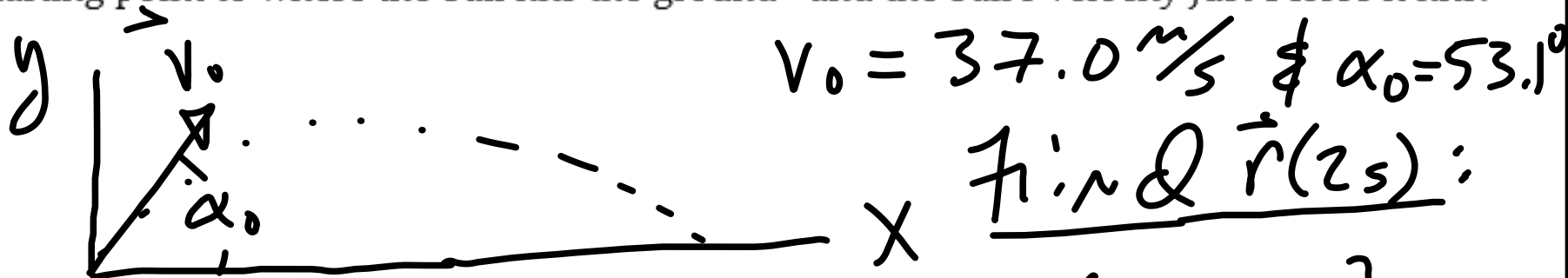
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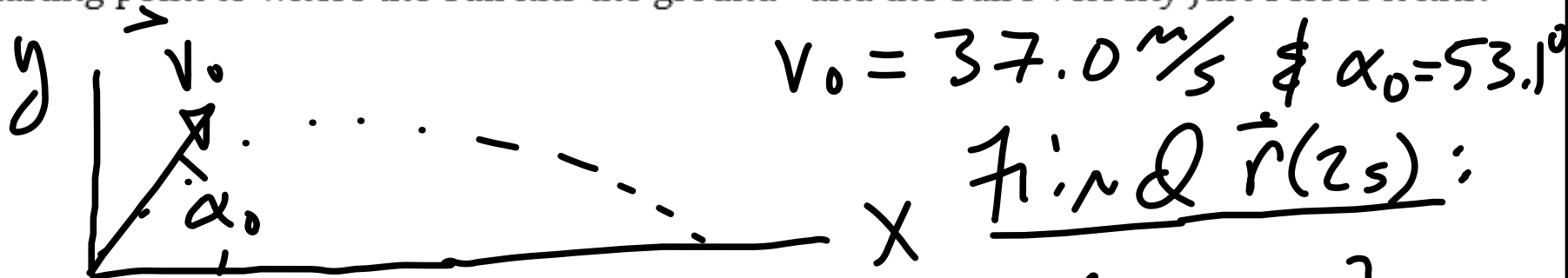
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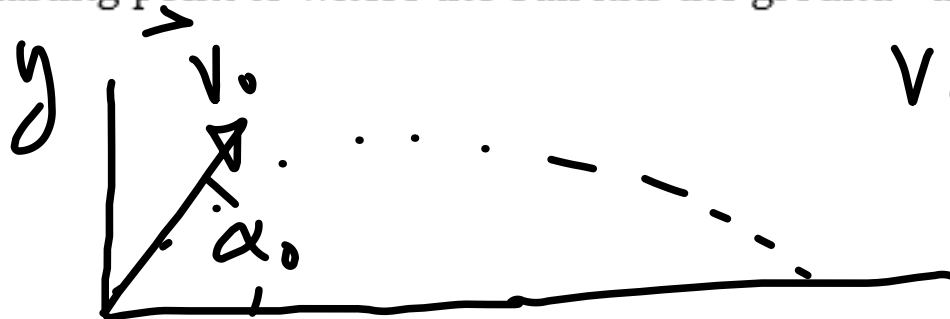
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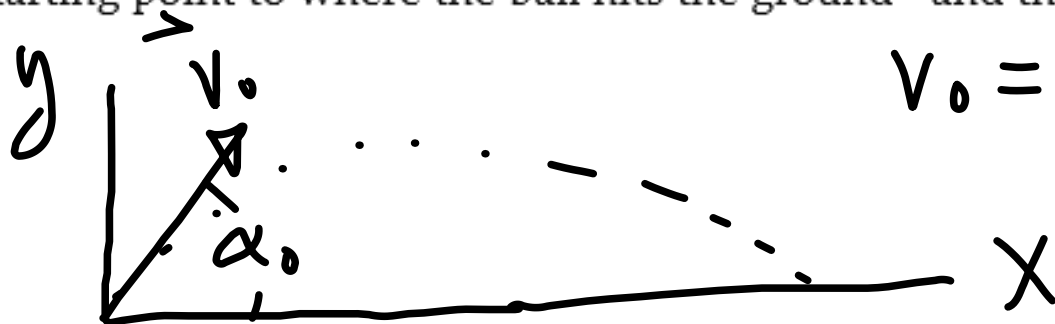
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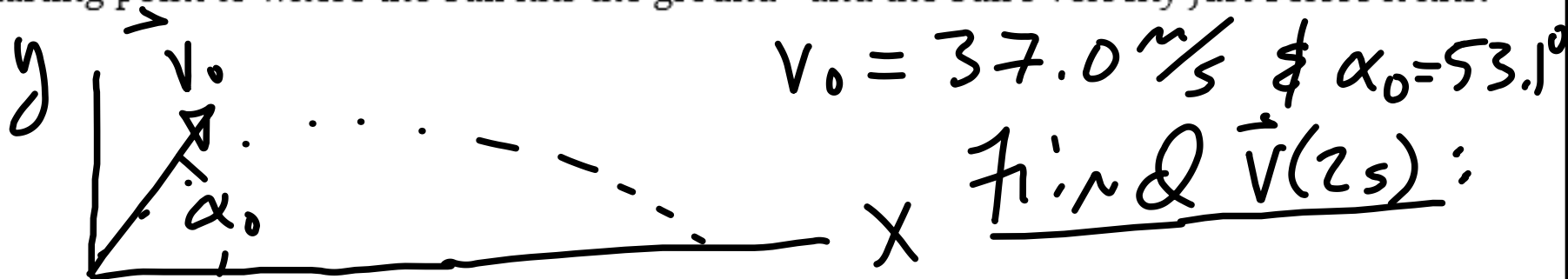


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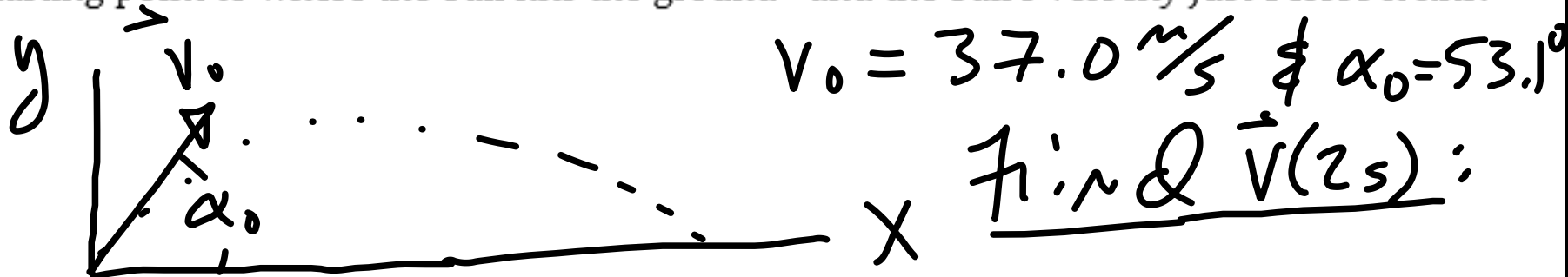
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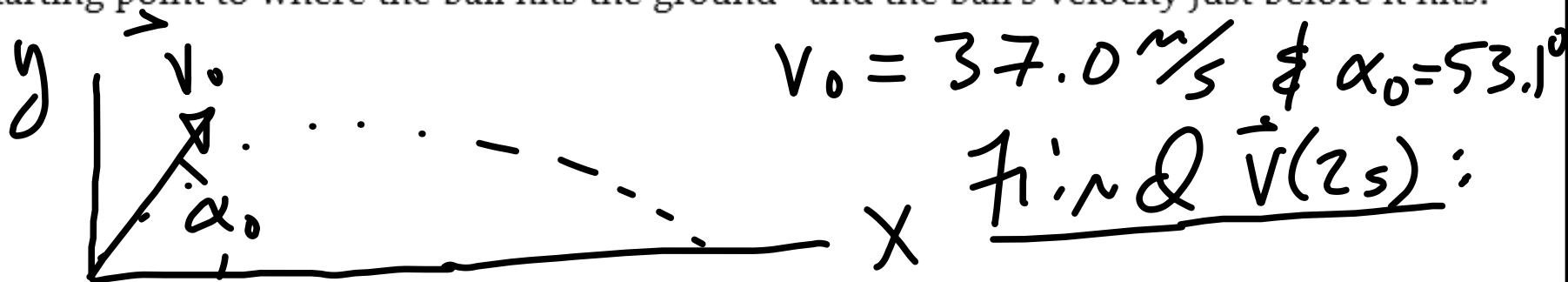
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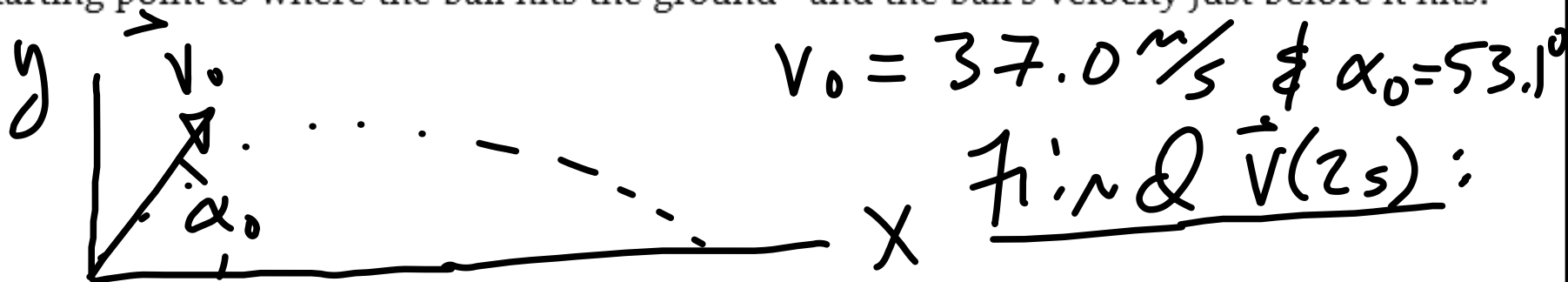
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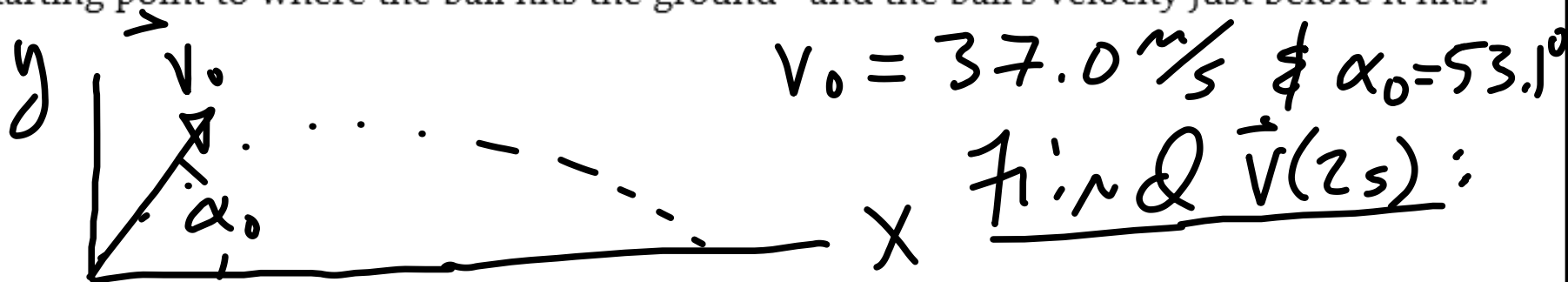
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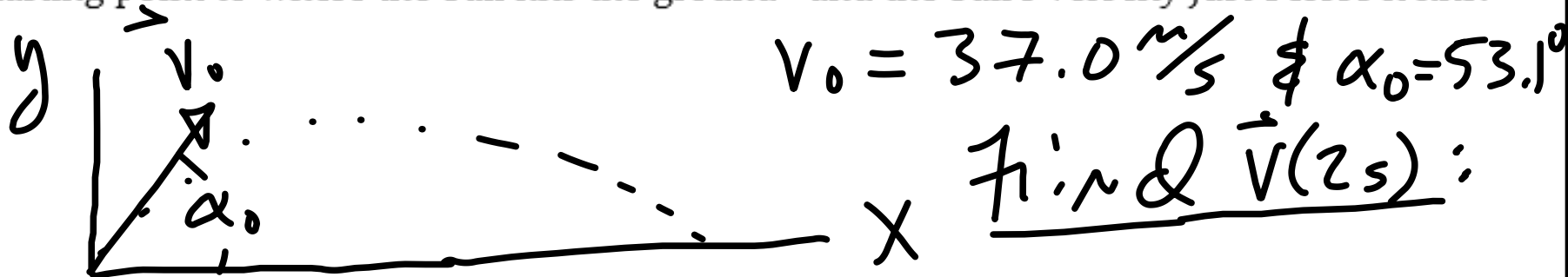
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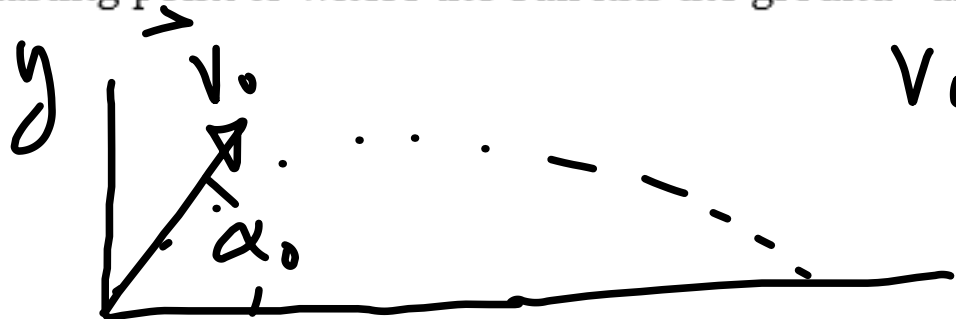
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$$\left(37 \frac{\text{m}}{\text{s}}\right) [\sin(53.1^\circ)] = 10 \frac{\text{m}}{\text{s}} \quad \rightarrow 0$$

$$v = \sqrt{22.2^2 + 100} \left(\frac{\text{m}}{\text{s}}\right)$$

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Find $\vec{v}(2s)$:

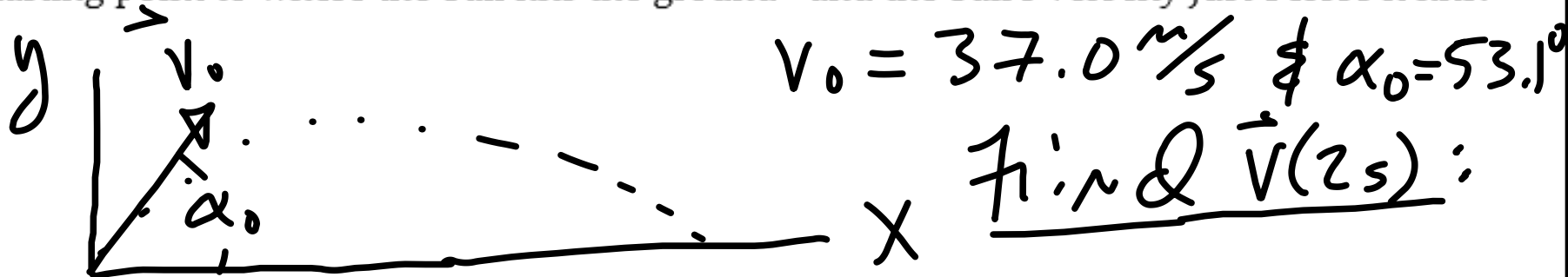
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$$v = \sqrt{22.2^2 + 100} \left(\frac{\text{m}}{\text{s}}\right) = 24.4 \text{ m/s}$$

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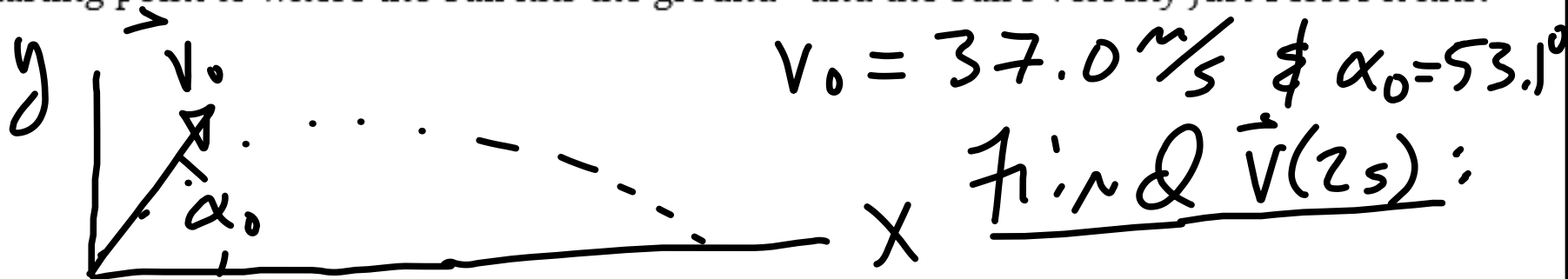
$$V_y = -gt + v_0 \sin \alpha_0 = (-9.8 \text{ m/s}^2)(2 \text{ s}) +$$

$$\left(37 \frac{\text{m}}{\text{s}}\right) [\sin(53.1^\circ)] = 10 \text{ m/s} \quad \rightarrow 0$$

$$v = \sqrt{22.2^2 + 100} \left(\frac{\text{m}}{\text{s}}\right) = 24.4 \text{ m/s}$$

$$\alpha = \tan^{-1}\left(\frac{V_y}{V_x}\right)$$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0 \text{ m/s}$ at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00 \text{ s}$. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the horizontal range R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.



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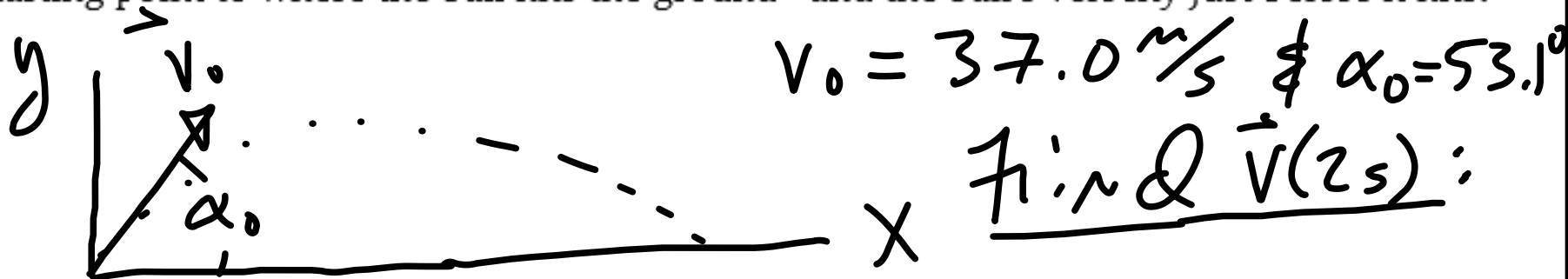
$$V_y = -gt + v_0 \sin \alpha_0 = (-9.8 \frac{\text{m}}{\text{s}^2})(2\text{s}) +$$

$$\left(37 \frac{\text{m}}{\text{s}}\right) [\sin(53.1^\circ)] = 10 \frac{\text{m}}{\text{s}} \quad \rightarrow 0$$

$$v = \sqrt{22.2^2 + 10^2} \left(\frac{\text{m}}{\text{s}}\right) = 24.4 \frac{\text{m}}{\text{s}}$$

$$\alpha = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{10}{22.2}\right)$$

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A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0$ m/s at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00$ s. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the *horizontal range* R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

y_{MAX} when $v_y = 0$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0 \text{ m/s}$ at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00 \text{ s}$. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the *horizontal range* R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

$$y_{\text{MAX}} \text{ when } v_y = 0 \Rightarrow v_y = -gt + v_{0y} = 0$$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0$ m/s at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00$ s. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the *horizontal range* R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

$$y_{\text{MAX}} \text{ when } v_y = 0 \Rightarrow v_y = -gt_1 + v_{0y} = 0$$
$$\Rightarrow t_1 = v_{0y}/g$$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0$ m/s at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00$ s. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the *horizontal range* R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

$$y_{\text{MAX}} \text{ when } v_y = 0 \Rightarrow v_y = -gt_1 + v_{0y} = 0$$
$$\Rightarrow t_1 = v_{0y}/g = \frac{29.6}{9.8} \text{ s}$$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0$ m/s at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00$ s. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the horizontal range R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

$$y_{\text{MAX}} \text{ when } v_y = 0 \Rightarrow v_y = -gt_1 + v_{0y} = 0$$
$$\Rightarrow t_1 = v_{0y}/g = \frac{29.6}{9.8} \text{ s} = 3.02 \text{ s}$$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0$ m/s at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00$ s. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the *horizontal range* R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

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$$y_{\text{MAX}} = h$$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0$ m/s at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00$ s. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the horizontal range R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

$$y_{\text{MAX}} \text{ when } v_y = 0 \Rightarrow v_y = -gt_1 + v_{0y} = 0$$
$$\Rightarrow t_1 = v_{0y}/g = \frac{29.6}{9.8} \text{ s} = 3.02 \text{ s}$$

$$y_{\text{MAX}} = h = -\frac{gt_1^2}{2} + v_{0y}t_1$$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0 \text{ m/s}$ at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00 \text{ s}$. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the *horizontal range* R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

$$y_{\text{MAX}} \text{ when } v_y = 0 \Rightarrow v_y = -gt_1 + v_{0y} = 0$$

$$\Rightarrow t_1 = v_{0y}/g = \frac{29.6}{9.8} \text{ s} = 3.02 \text{ s}$$

$$y_{\text{MAX}} = h = -\frac{gt_1^2}{2} + v_{0y}t_1 = \left(-\frac{9.8}{2}\right)(3.02)^2 \text{ m} + (29.6)(3.02) \text{ m}$$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0 \text{ m/s}$ at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00 \text{ s}$. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the horizontal range R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

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$$y_{\text{MAX}} = h = -\frac{gt_1^2}{2} + v_{0y}t_1 = \left(-\frac{9.8}{2}\right)(3.02)^2 \text{ m} + (29.6)(3.02) \text{ m} = 44.7 \text{ m}$$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0 \text{ m/s}$ at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00 \text{ s}$. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the *horizontal range* R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

$$y(t_2) = 0$$

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$$y(t_2) = 0 \Rightarrow -\frac{g}{2}t^2 + v_{0y}t = 0$$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0$ m/s at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00$ s. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the *horizontal range* R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

$$y(t_2) = 0 \Rightarrow -\frac{g}{2}t^2 + v_{0y}t = 0$$
$$\Rightarrow t = 2 \frac{v_{0y}}{g}$$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0$ m/s at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00$ s. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the *horizontal range* R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

$$y(t_2) = 0 \Rightarrow -\frac{g}{2}t^2 + v_{0y}t = 0$$
$$\Rightarrow t = 2 \frac{v_{0y}}{g} = 2 * 3.02 \text{ s}$$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0 \text{ m/s}$ at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00 \text{ s}$. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the *horizontal range* R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

$$y(t_2) = 0 \Rightarrow -\frac{g}{2}t^2 + v_{0y}t = 0$$
$$\Rightarrow t = 2 \frac{v_{0y}}{g} = 2 * 3.02 \text{ s} = 6.04 \text{ s}$$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0 \text{ m/s}$ at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00 \text{ s}$. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the *horizontal range* R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

$$y(t_2) = 0 \Rightarrow -\frac{g}{2}t^2 + v_{0y}t = 0$$
$$\Rightarrow t = 2 \frac{v_{0y}}{g} = 2 \times 3.02 \text{ s} = 6.04 \text{ s}$$

$$R = x(t = 6.04 \text{ s})$$

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$$y(t_2) = 0 \Rightarrow -\frac{g}{2}t^2 + v_{0y}t = 0$$
$$\Rightarrow t = 2 \frac{v_{0y}}{g} = 2 \times 3.02 \text{ s} = 6.04 \text{ s}$$
$$R = x(t = 6.04 \text{ s}) = (v_{0x}) 6.04 \text{ s}$$

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$$y(t_2) = 0 \Rightarrow -\frac{g}{2}t^2 + v_{0y}t = 0$$
$$\Rightarrow t = 2 \frac{v_{0y}}{g} = 2 \times 3.02 \text{ s} = 6.04 \text{ s}$$
$$R = x(t = 6.04 \text{ s}) = (v_{0x}) 6.04 \text{ s}$$
$$= (22.2 \text{ m/s})(6.04 \text{ s})$$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0 \text{ m/s}$ at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00 \text{ s}$. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the *horizontal range* R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

$$y(t_2) = 0 \Rightarrow -\frac{g}{2}t^2 + v_{0y}t = 0$$

$$\Rightarrow t = 2 \frac{v_{0y}}{g} = 2 \times 3.02 \text{ s} = 6.04 \text{ s}$$

$$R = x(t = 6.04 \text{ s}) = (v_{0x}) 6.04 \text{ s} \\ = (22.2 \text{ m/s})(6.04 \text{ s}) = 134 \text{ m}$$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0 \text{ m/s}$ at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00 \text{ s}$. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the *horizontal range* R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

$$V_x = 22.2 \text{ m/s}$$

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$$V_x = 22.2 \text{ m/s} \quad \& \quad V_y = -g * 6.04 \text{ s} + V_{0y}$$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0 \text{ m/s}$ at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00 \text{ s}$. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the *horizontal range* R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

$$V_x = 22.2 \text{ m/s} \quad \& \quad V_y = -g * 6.04 \text{ s} + V_{0y}$$
$$= -9.8 * 6.04 \frac{\text{m}}{\text{s}} + 29.6 \frac{\text{m}}{\text{s}}$$

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$$V_x = 22.2 \text{ m/s} \quad \& \quad V_y = -g * 6.04 \text{ s} + V_{0y}$$
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$$\begin{aligned}V_x &= 22.2 \text{ m/s} \quad \& \quad V_y = -g * 6.04 \text{ s} + V_{0y} \\ &= -9.8 * 6.04 \frac{\text{m}}{\text{s}} + 29.6 \frac{\text{m}}{\text{s}} = -29.6 \frac{\text{m}}{\text{s}} \\ \text{so} \quad V &= \sqrt{V_x^2 + V_y^2} = \sqrt{22.2^2 + 29.6^2} \frac{\text{m}}{\text{s}}\end{aligned}$$

A batter hits a baseball so that it leaves the bat at speed $v_0 = 37.0$ m/s at an angle $\alpha_0 = 53.1^\circ$. (a) Find the position of the ball and its velocity (magnitude and direction) at $t = 2.00$ s. (b) Find the time when the ball reaches the highest point of its flight, and its height h at this time. (c) Find the *horizontal range* R —that is, the horizontal distance from the starting point to where the ball hits the ground—and the ball's velocity just before it hits.

$$V_x = 22.2 \text{ m/s} \quad \& \quad V_y = -g * 6.04 \text{ s} + V_{0y}$$
$$= -9.8 * 6.04 \frac{\text{m}}{\text{s}} + 29.6 \frac{\text{m}}{\text{s}} = -29.6 \frac{\text{m}}{\text{s}}$$

$$\text{so} \quad v = \sqrt{V_x^2 + V_y^2} = \sqrt{22.2^2 + 29.6^2} \frac{\text{m}}{\text{s}}$$

$$\Rightarrow \quad v = 37 \frac{\text{m}}{\text{s}}$$



Projectile motion

Projectile motion











