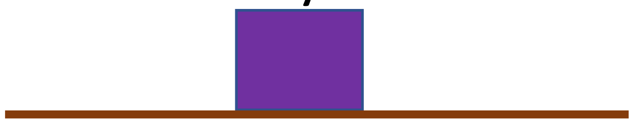
Chapter 5

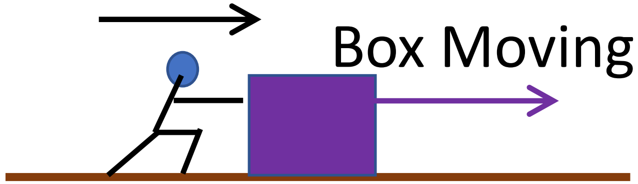
Introduction to Force

Force and Motion

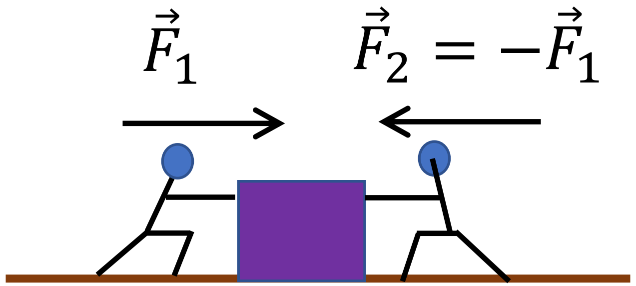
- To move an object a Force, $\vec{F}_{human}$ must be applied

Stationary $\vec{v} = 0$



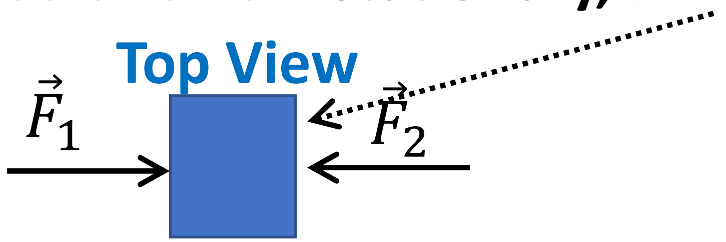


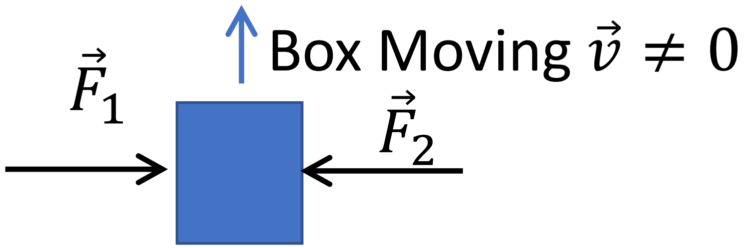
Box Moving $\vec{v} \neq 0$



Effect (**reaction**) of the **forces** (**actions**) on the box?

It could remain **stationary**, $\vec{v} = 0$.



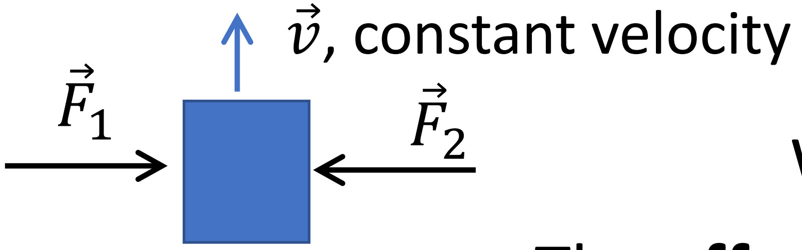


Is it possible that the box will be moving as shown on the left?

Yes. This is allowed by **Newton's First Law**

Simple view of Newton's First and second law

- **Newton's first Law** states that if there is no applied force on an object will move in a straight line at constant speed. **Constant Velocity**

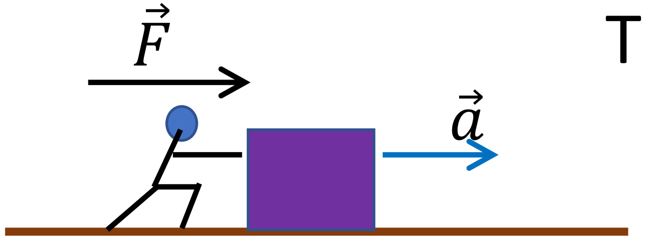


Scenario on left is allowed if **constant velocity**

What is the **effect** of the **force** (an **action**)?

The **effect** (**reaction**) of a force is to **change** the **velocity**!

When a force is applied to an object of **inertia mass M**, it accelerates in the same direction of the force according to $\vec{F} = M\vec{a}$

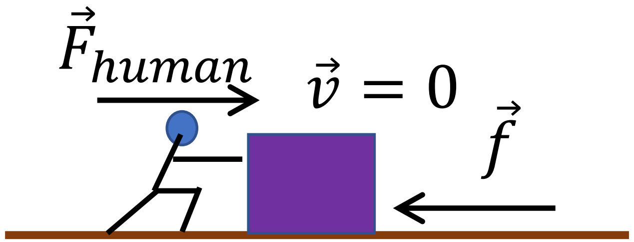


The above is **Newton's Second Law**.

The Principle of Superposition of Forces

Why is it that when you push a heavy object it does not move?

Is it because it is too heavy (its mass too large)?



The answer is yes and no!

The Box does not move because of friction, $\vec{f}$

The force of friction due to the ground on the box cancels the applied force:

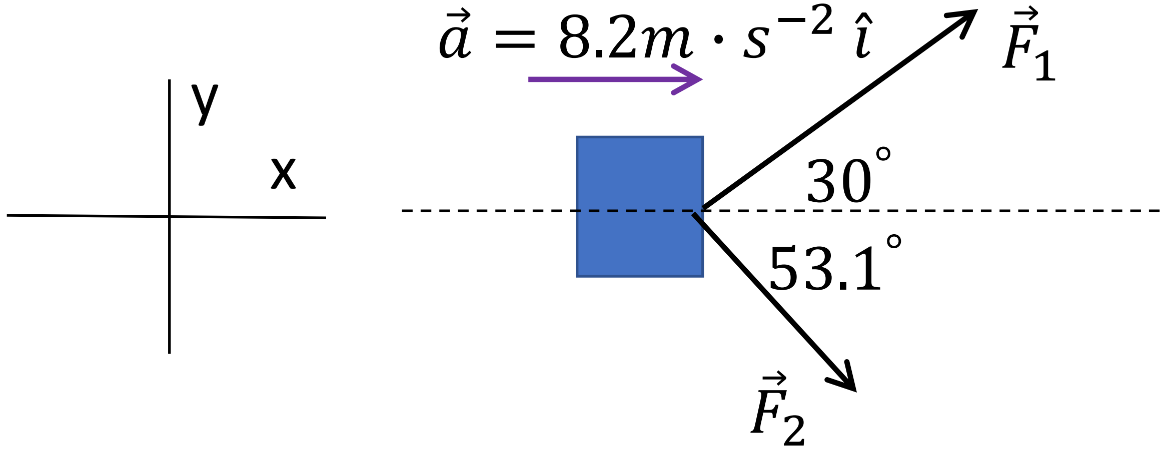
$\vec{f} = -\vec{F}_{human}$

The **Principle** of **Superposition** of **Forces**: The net effect of multiple forces on an object is the same as the **vector sum** of the forces, also called the **net force**, $\vec{F}_{net} = \sum_i \vec{F}_i$

In the above, the net force is zero, $\vec{F}_{net} = \sum_i \vec{F}_i = \vec{F}_{human} + \vec{f} = 0$

Example

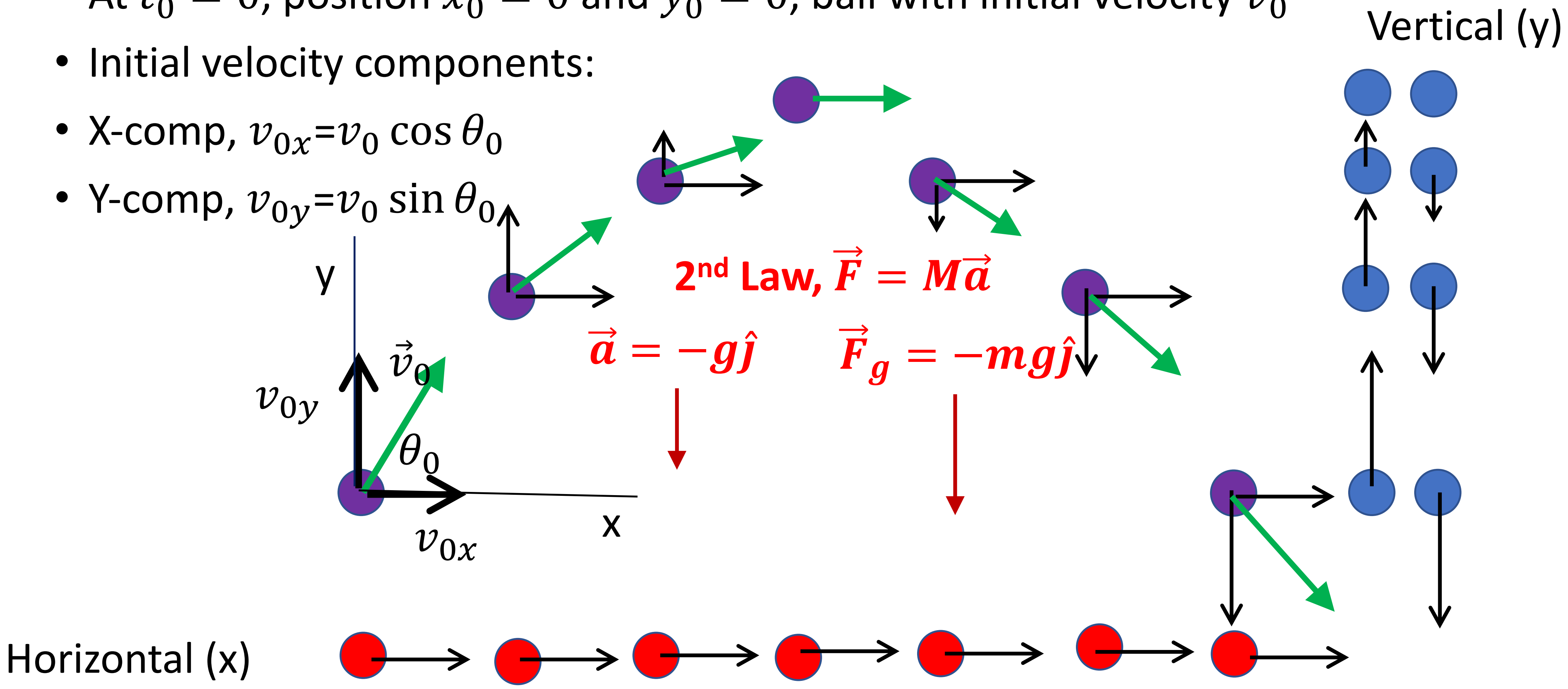
- An object of mass m = 2kg is acted on by forces, $\vec{F}_1$ $(F_1 = 12N, 30^{\circ})$ and $\vec{F}_2$ $(F_2 = 10N, 53.1^{\circ})$. Find the Acceleration.



- The **Principle** of **Superposition** of **Forces**: $\vec{F}_{net} = \sum_i \vec{F}_i$
- X-component: $F_{Net,x} = F_{1x} + F_{2x} = 12N\cos 30^{\circ} + 10N\cos 53.1^{\circ} = 16.4N$
- Y-component: $F_{Net,y} = F_{1y} + F_{2y} = 12N\sin 30^{\circ} - 10N\sin 53.1^{\circ} = 0$
- $\vec{F}_{net} = 16.4\ N\hat{\imath}$
- **Newton's second Law**: $\vec{F}_{net} = M\vec{a} \rightarrow \vec{a} = 8.2m \cdot s^{-2}\,\hat{\imath}$

Newton's Law and Projectile: Gravity affects only the Vertical Component, v_y, of the velocity.

- At $t_0 = 0$, position $x_0 = 0$ and $y_0 = 0$, ball with initial velocity $\vec{v}_0$
- Initial velocity components:
- X-comp, v_{0x}=$v_0 \cos\theta_0$
- Y-comp, v_{0y}=$v_0 \sin\theta_0$



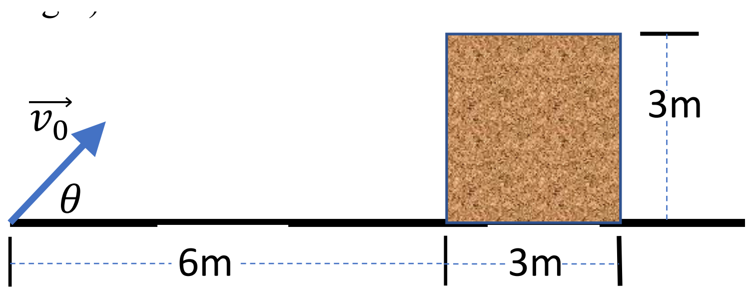
Another Projectile Example

In diagram below a ball is launched at a building with a speed of $v_0 = 20\frac{m}{s}$, at an angle of $\theta = 53.1^{\circ}$. (counterclockwise wrt +x axis, defined as being to the right). Assume that $\theta = 53.1^{\circ}$.

A) Using kinematics equations determine whether the ball will hit the wall, land on top of the building, or fall to the ground.

<u>Preamble:</u> Let's find the **components** of the **initial velocity**: x-com, $v_0 cos\theta = 20\frac{m}{s} cos53.1^{\circ} = 12\frac{m}{s}$; y-com, $v_{0y} = v_0 sin\theta = 20\frac{m}{s} sin53.1^{\circ} = 16\frac{m}{s}$

There are 4 possibilities: 1) It will fall before the building; 2) It will hit the front of the building; 3) It will fall on the top of the building; 4) It will fall behind the building.



$v_{0x} = v_0 \cos\theta_0$ **E13**; $x = x_0 + v_{0x}t$ **E14**;
$v_{0y} = v_0 \sin\theta_0$ **E15**; $v_y = v_{0y} - gt$ **E16**;
$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$ **E17**; $v_y^2 = v_{0y}^2 - 2g(y - y_0)$ **E18**

Let's assume that we have already shown that possibility 1 and 2 will not occur. Let see whether it will fall on top of building. Let's check how long it takes to travel horizontally 9m to the far end of the top of the building

Use **E14**, find the time $x = x_0 + v_{0x}t \rightarrow 9m = 12\frac{m}{s}\times t \rightarrow t = 0.75s$

Use **E17** to find height at this time, $y = 0 + 16\frac{m}{s}(0.75s) - \frac{1}{2}\left(9.8\frac{m}{s^2}\right)(0.75s)^2 = 9.24m$

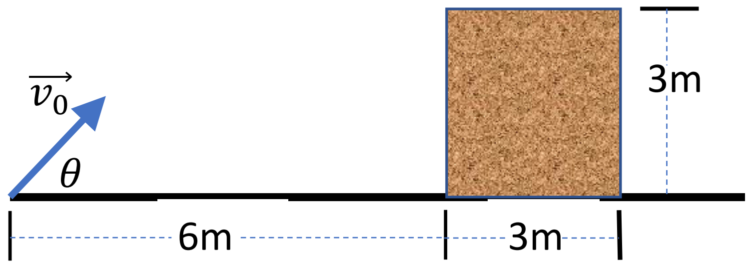
It will fall on the other side

Another Projectile Example

In diagram below a ball is launched at a building with a speed of $v_0 = 20\frac{m}{s}$, at an angle of $\theta = 53.1^{\circ}$. (counterclockwise wrt +x axis, defined as being to the right). Assume that $\theta = 53.1^{\circ}$.

B) Find where the Ball land.

When the ball is thrown, the initial vertical position is $y_0 = 0$, when it hits the ground its final vertical position is y = 0. Use **E17**.



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$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$ **E17**; $v_y^2 = v_{0y}^2 - 2g(y - y_0)$ **E18**

$$y = y_0 + v_{0y}t - \frac{1}{2}gt^2 \rightarrow 0 = 0 + v_{0y}t - \frac{1}{2}gt^2 \rightarrow t = \frac{2v_{0y}}{g} = \frac{2\times16\frac{m}{s}}{9.8\frac{m}{s^2}} = 3.27s.$$

Use **E14**, range = $x = v_{0x}t = 12\frac{m}{s}\times3.27s = 39m$

Another Projectile Example

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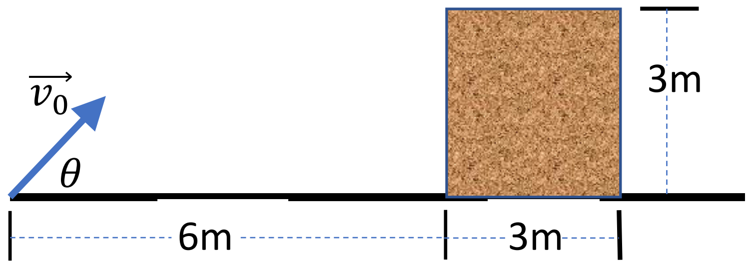
C) Find the final velocity when it hits the wall, land on top of the building, or hit the ground.

The x-comp of the velocity is constant, $v_x = v_{0x} = 12\frac{m}{s}$



$v_{0x} = v_0 \cos\theta_0$ **E13**; $x = x_0 + v_{0x}t$ **E14**;

$v_{0y} = v_0 \sin\theta_0$ **E15**; $v_y = v_{0y} - gt$ **E16**;

$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$ **E17**; $v_y^2 = v_{0y}^2 - 2g(y - y_0)$ **E18**

Use **E16**, The final y-com of velocity is found using, $v_y = v_{0y} - gt = 16\frac{m}{s} - 9.8\frac{m}{s^2}\times(3.27s) = -16\frac{m}{s}$

The final velocity in unit vector notation, $\vec{v} = 12\frac{m}{s}\hat{\imath} - 16\frac{m}{s}\hat{\jmath}$

In-Class Quiz Wednesday September 30, 2020

- 4:30 pm to 4:50 pm
- Based on last 3 slides
- Zoom Office Hours 11 am to noon, September 29, 2020. Make appointment at least one hour before 11 am tomorrow.