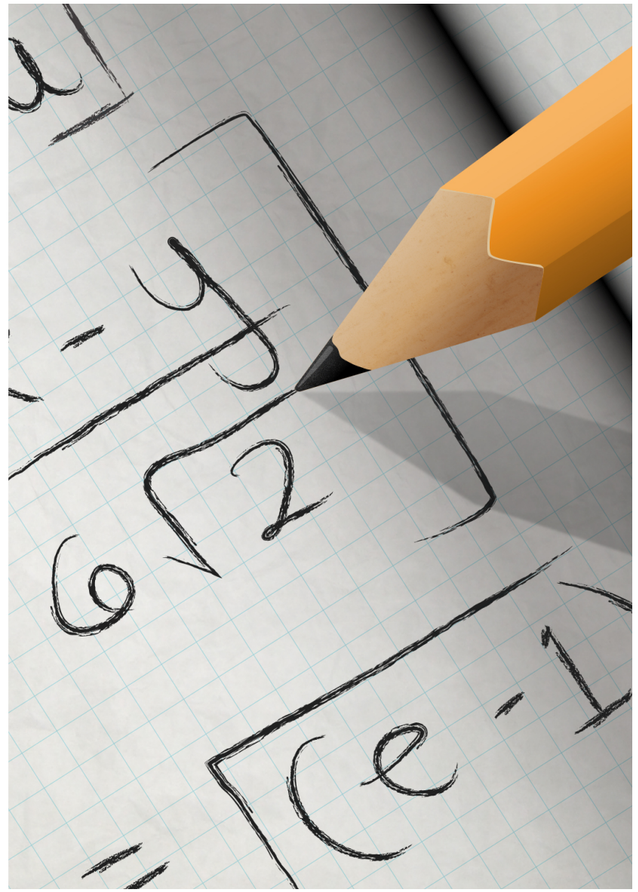
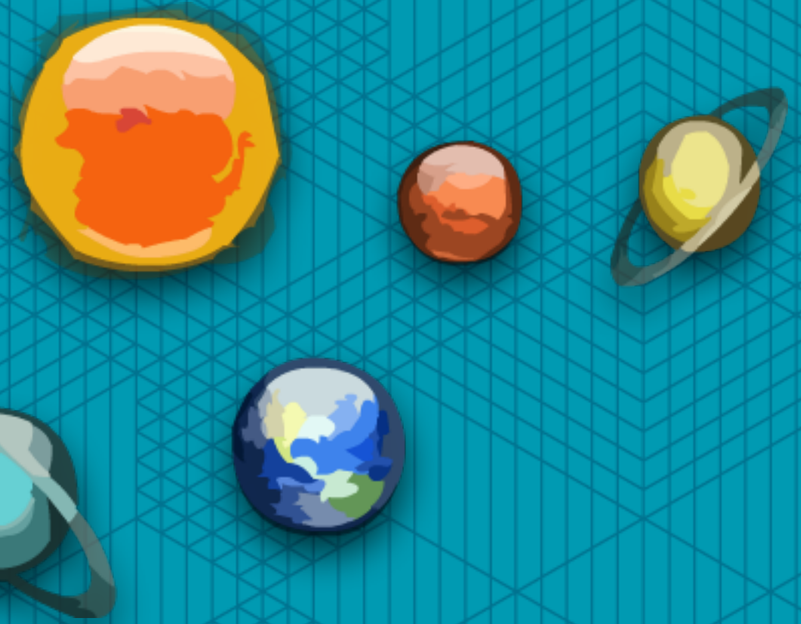
FUNDAMENTALS OF PHYSICS

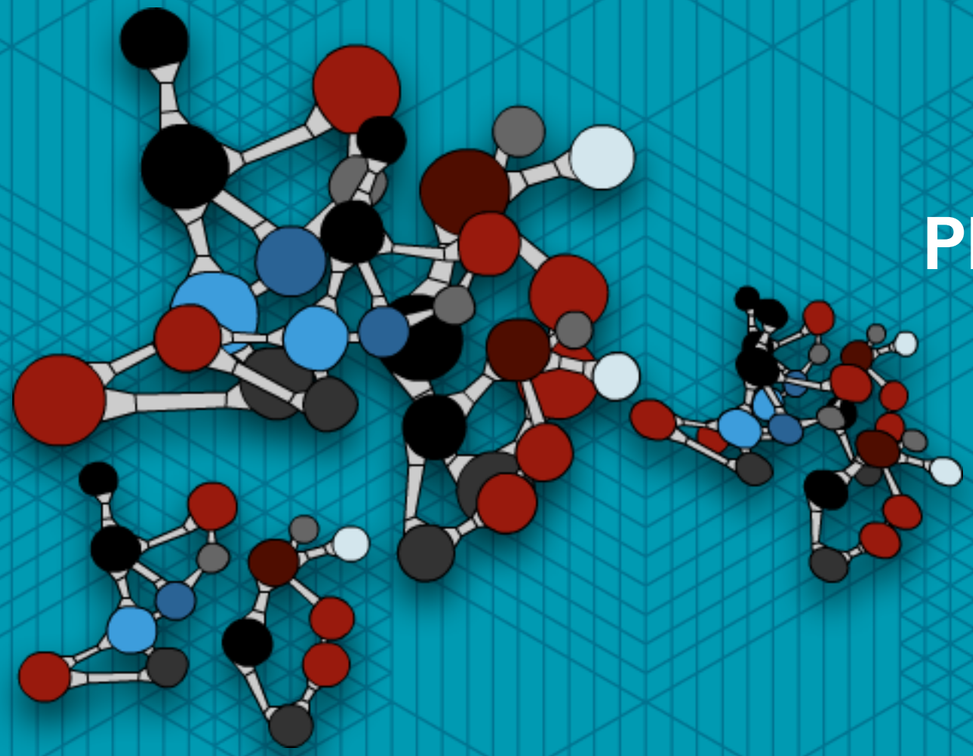
What is Physics?



Physics is our explanation of how the universe works.

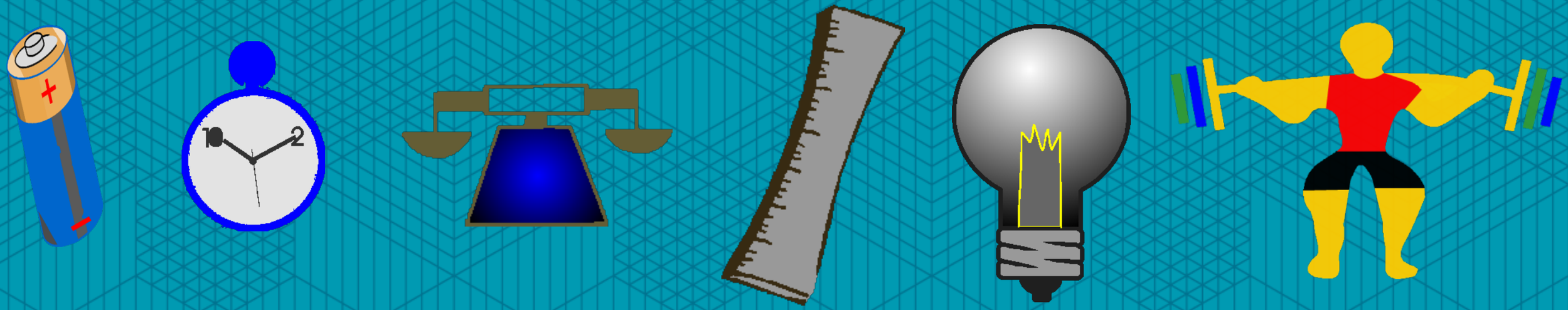


A collection of laws and equations that allow us to understand the world around us.



Physics applies to the largest and smallest objects in our universe.

Including you!

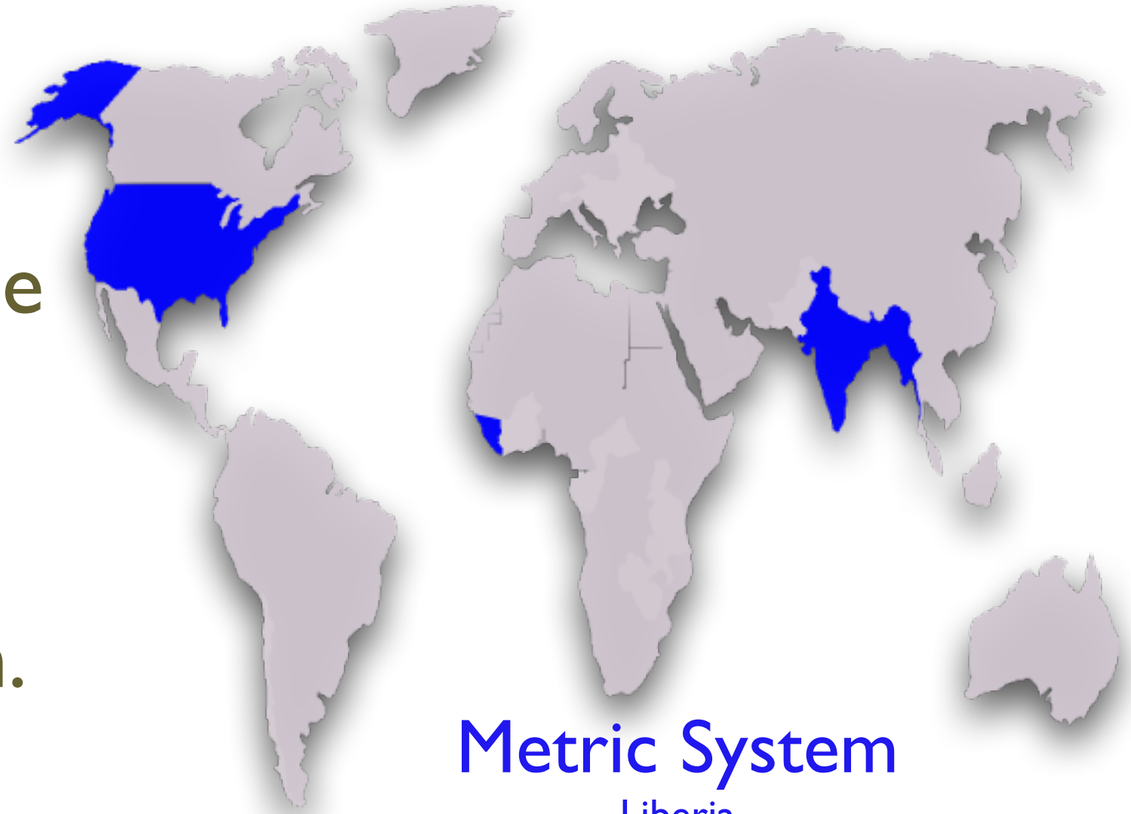


MEASUREMENT

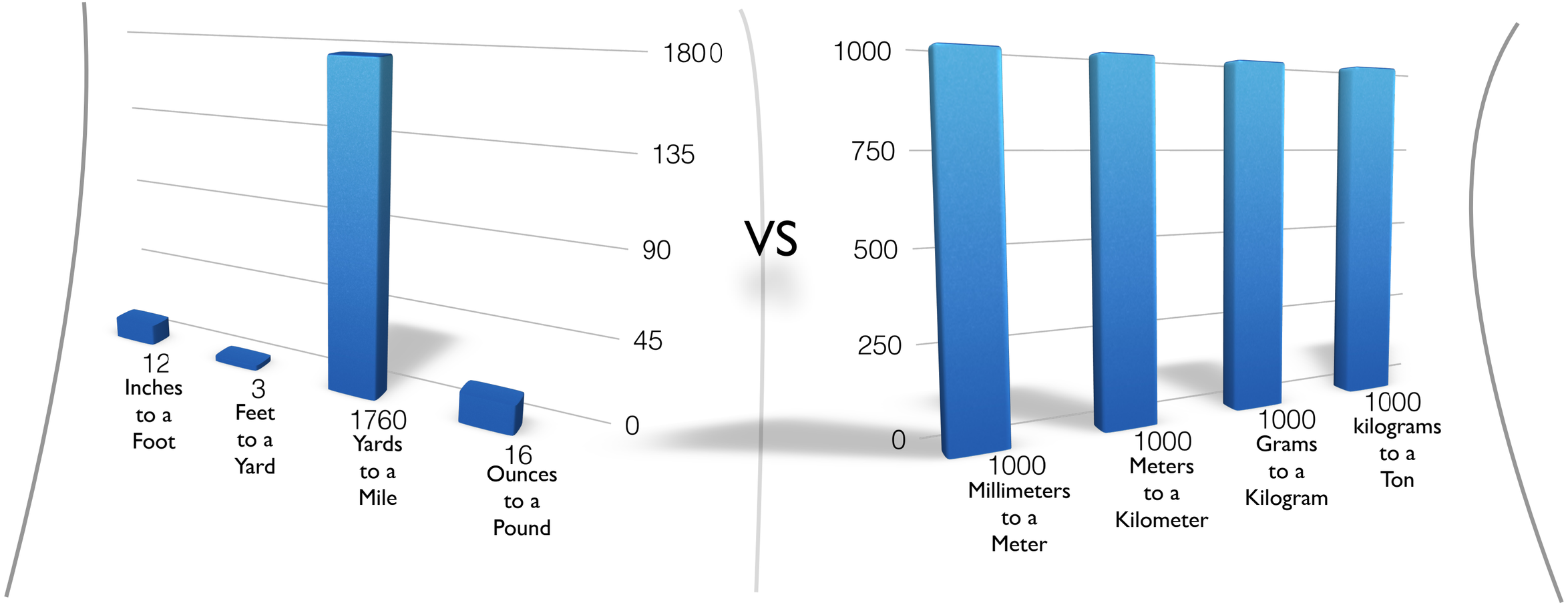
SCIENTIFIC UNITS

METRIC VS. ENGLISH

- The majority of the world uses the metric system.
- Since physics is a world-wide science, we use the metric system.



METRIC VS. ENGLISH



Distance is measured in **meters** (m).

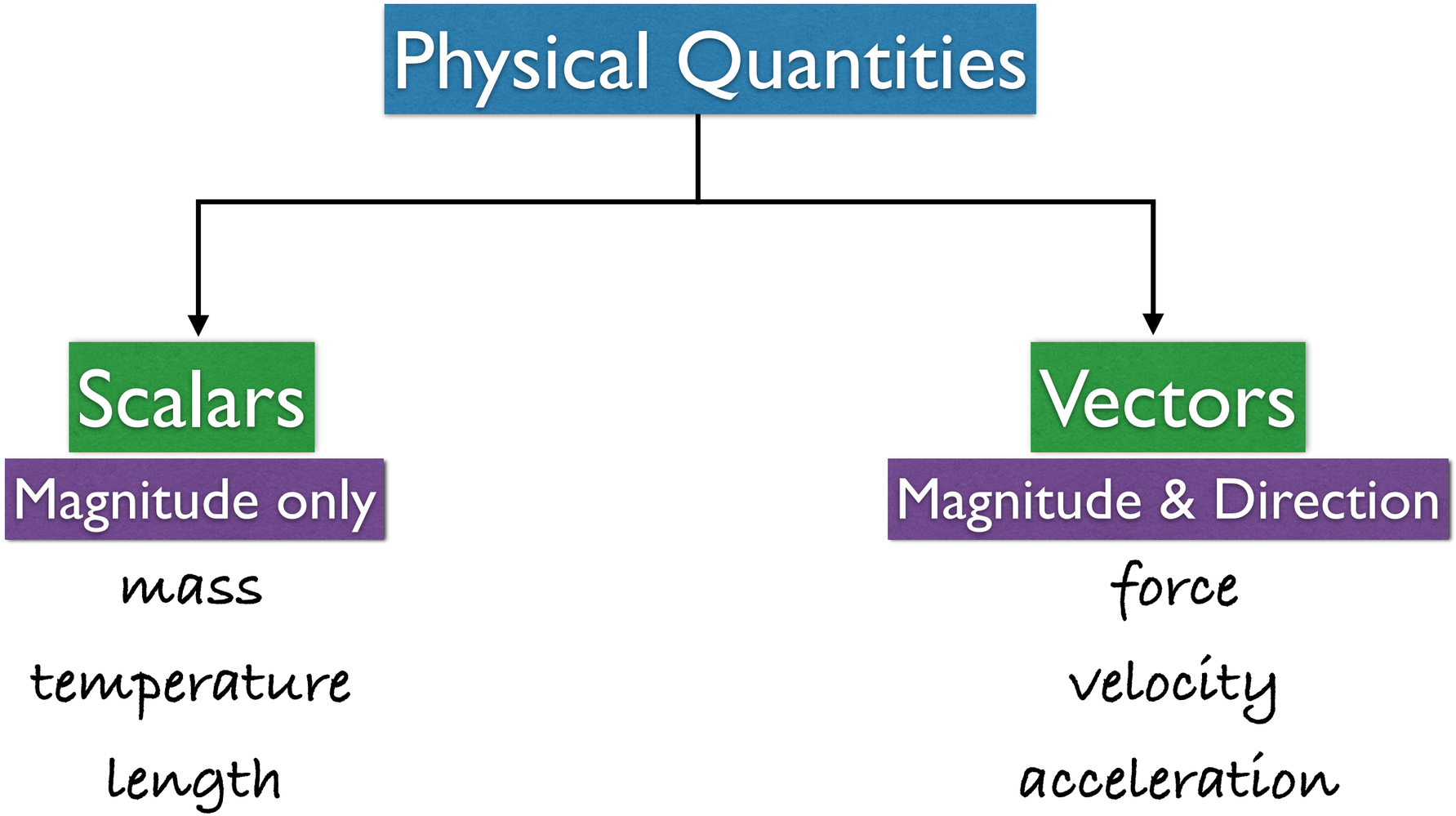
Mass is measured in **grams** or **kilograms** (g or kg).

Time is measured in **seconds** (s).

Force is measured in **Newtons** (N).

Energy is measured **Joules** (J).

Power is measured in **Watts** (W).


Physical Quantities
Scalars
Magnitude only
mass
temperature
length
Vectors
Magnitude & Direction
force
velocity
acceleration

DESCRIBING MOTION

Fundamentals of Physics

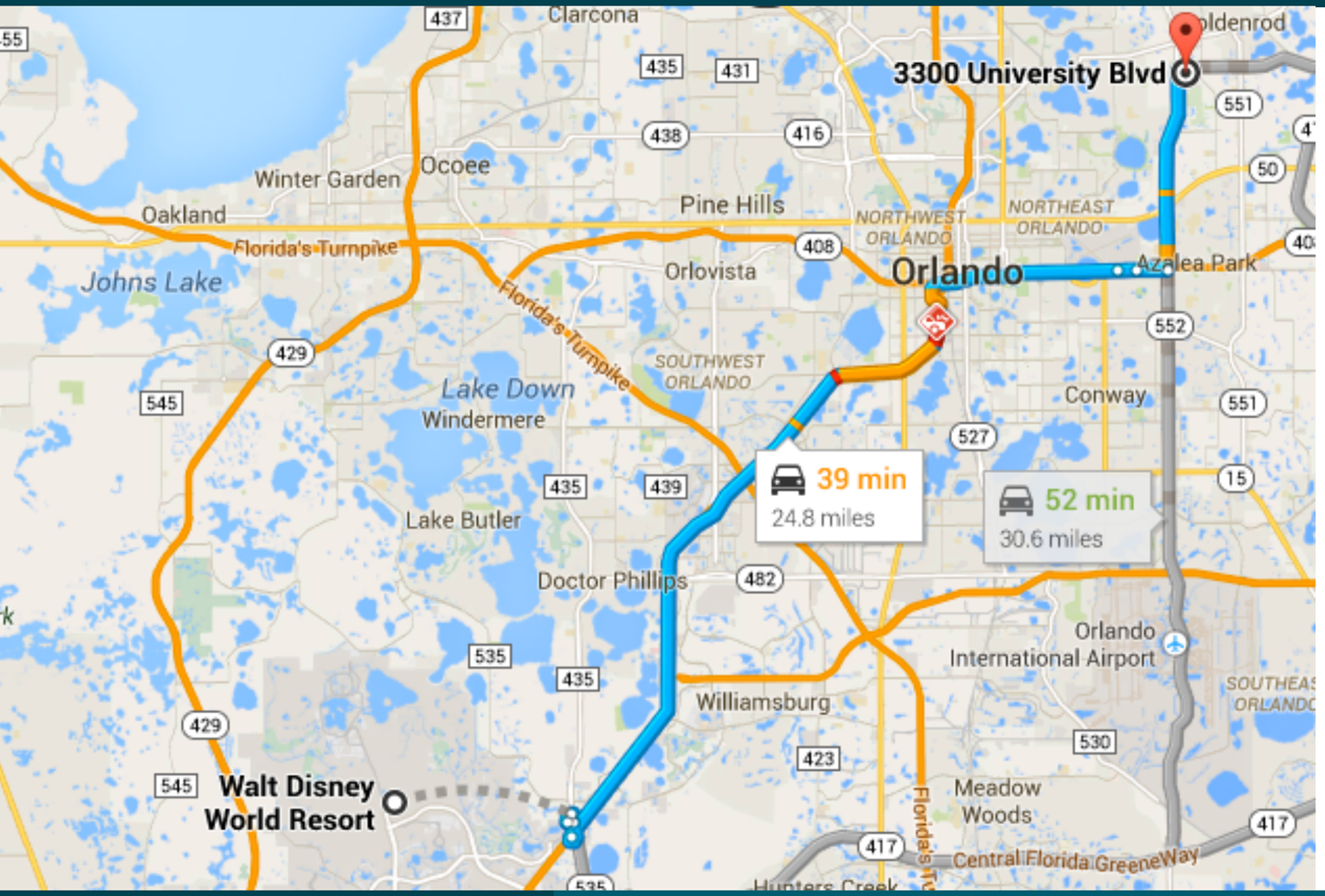
AVERAGE SPEED

The distance traveled divided by the time of travel.

$$s = \frac{d}{t}$$

s = speed (m/s) **d** = distance (m) **t** = time (s)

AVERAGE SPEED

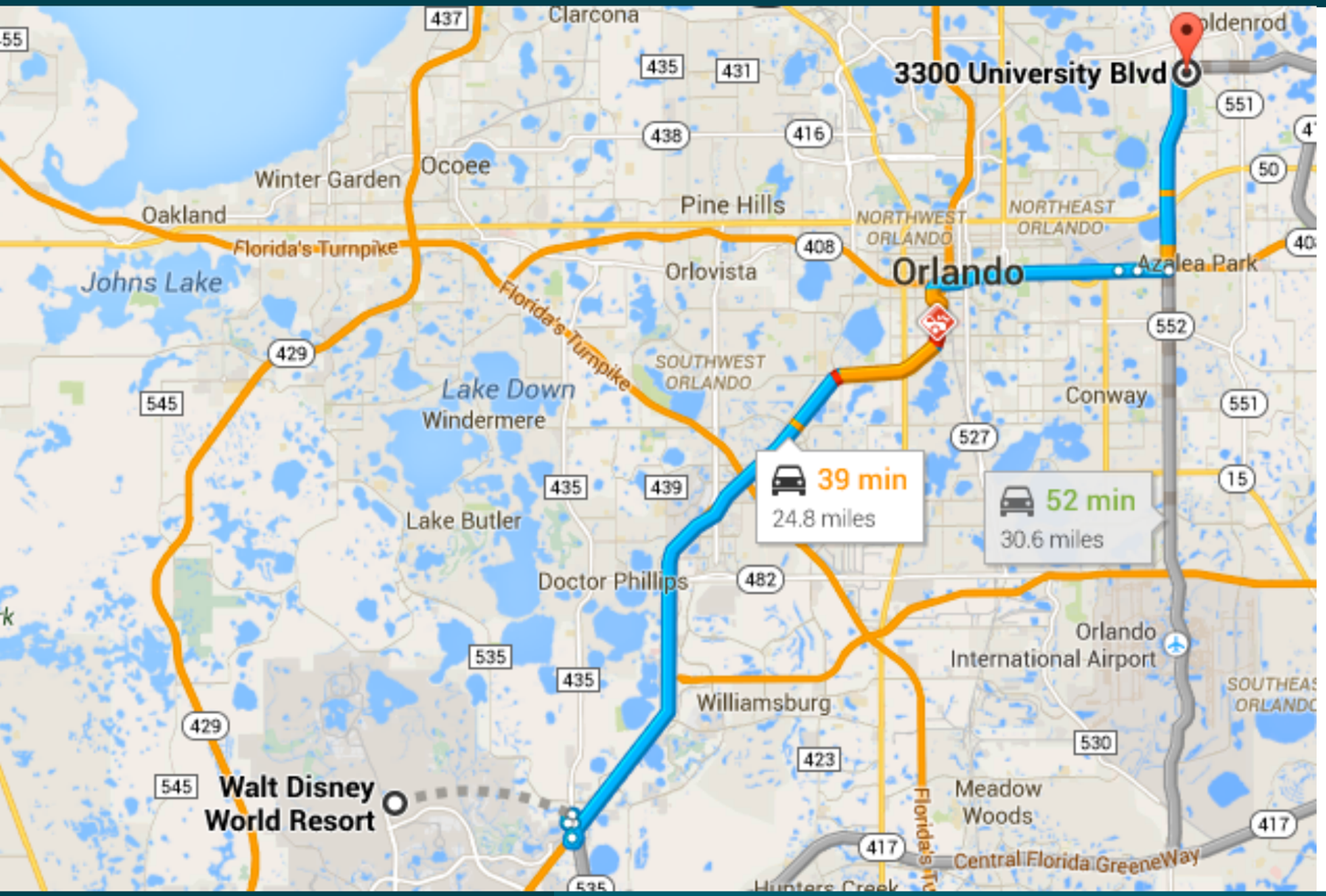


Time of travel = 0.65 hrs

Distance traveled = 24.8 miles

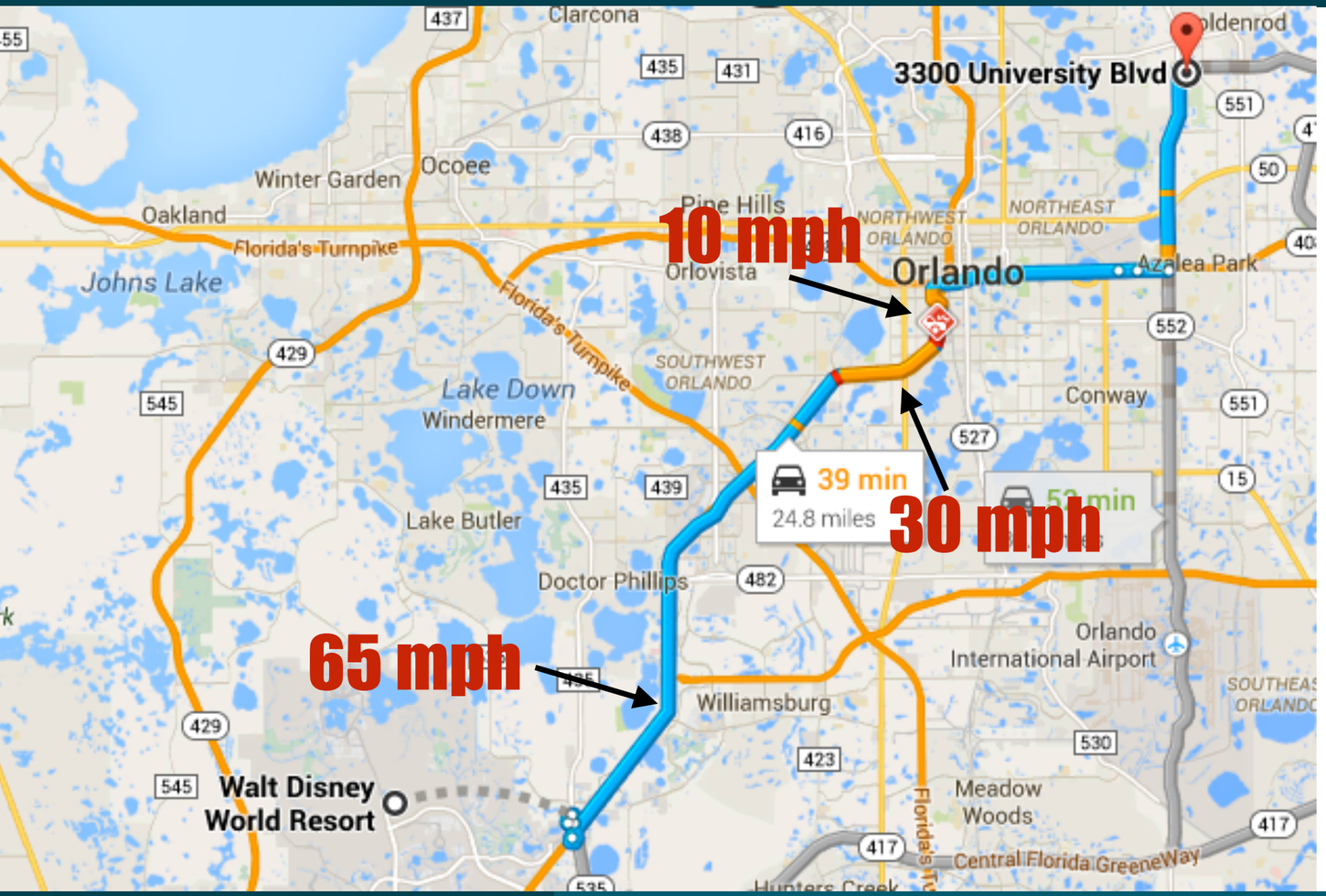
Average Speed = 38 mph

INSTANTANEOUS SPEED



How fast we are going at a given instant in time.

INSTANTANEOUS SPEED



How fast we are going at a given instant in time.

VELOCITY

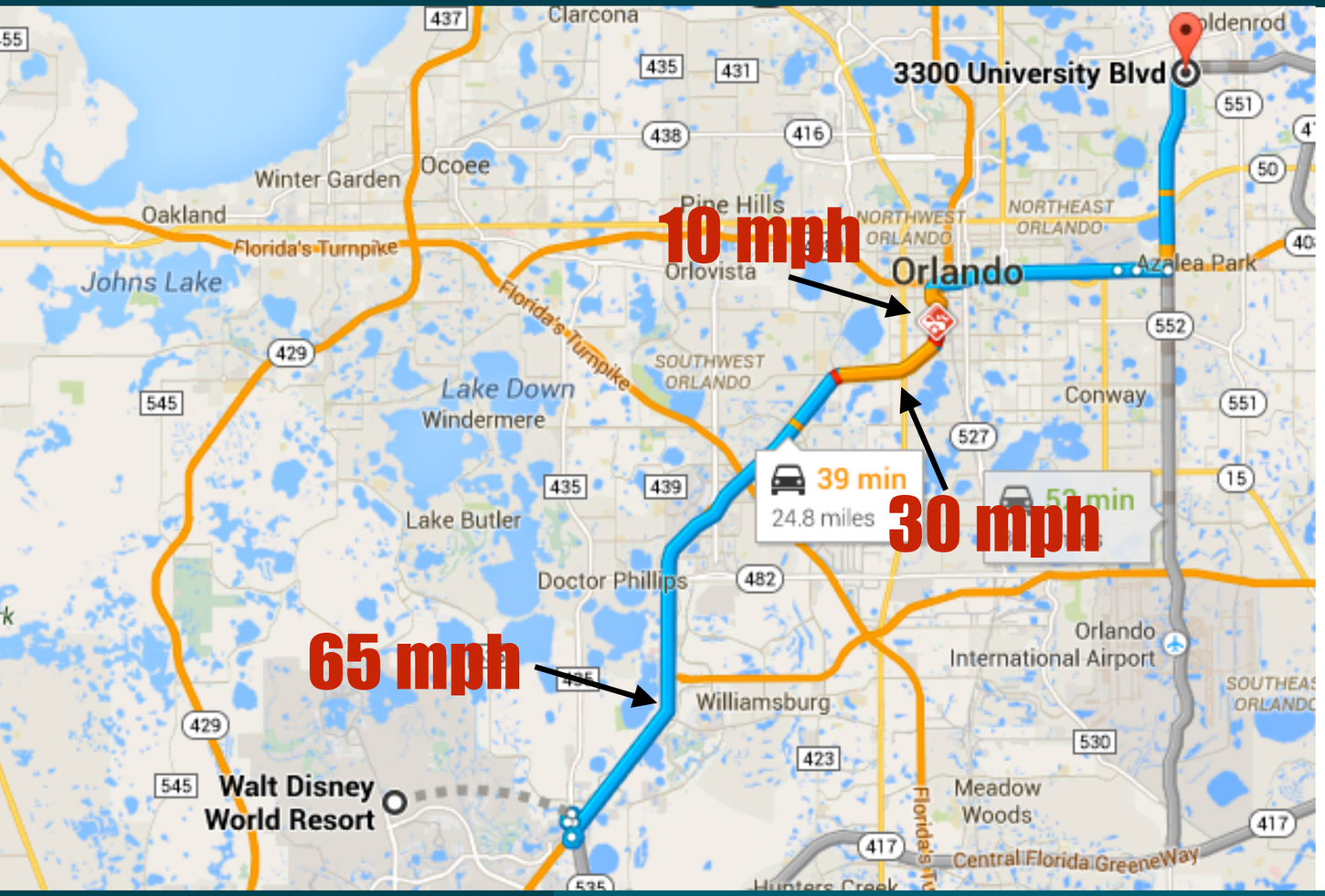
A **vector** quantity that describes how fast an object is moving and in what direction it is moving.

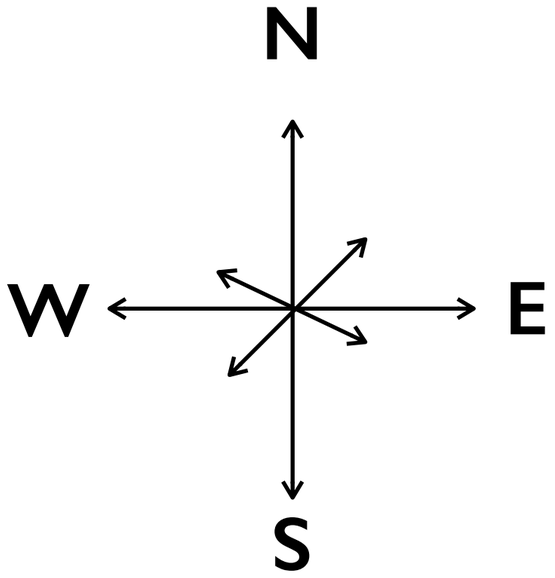
$$v = \frac{d}{t}$$

v = velocity (m/s) **d** = distance (m) **t** = time (s)

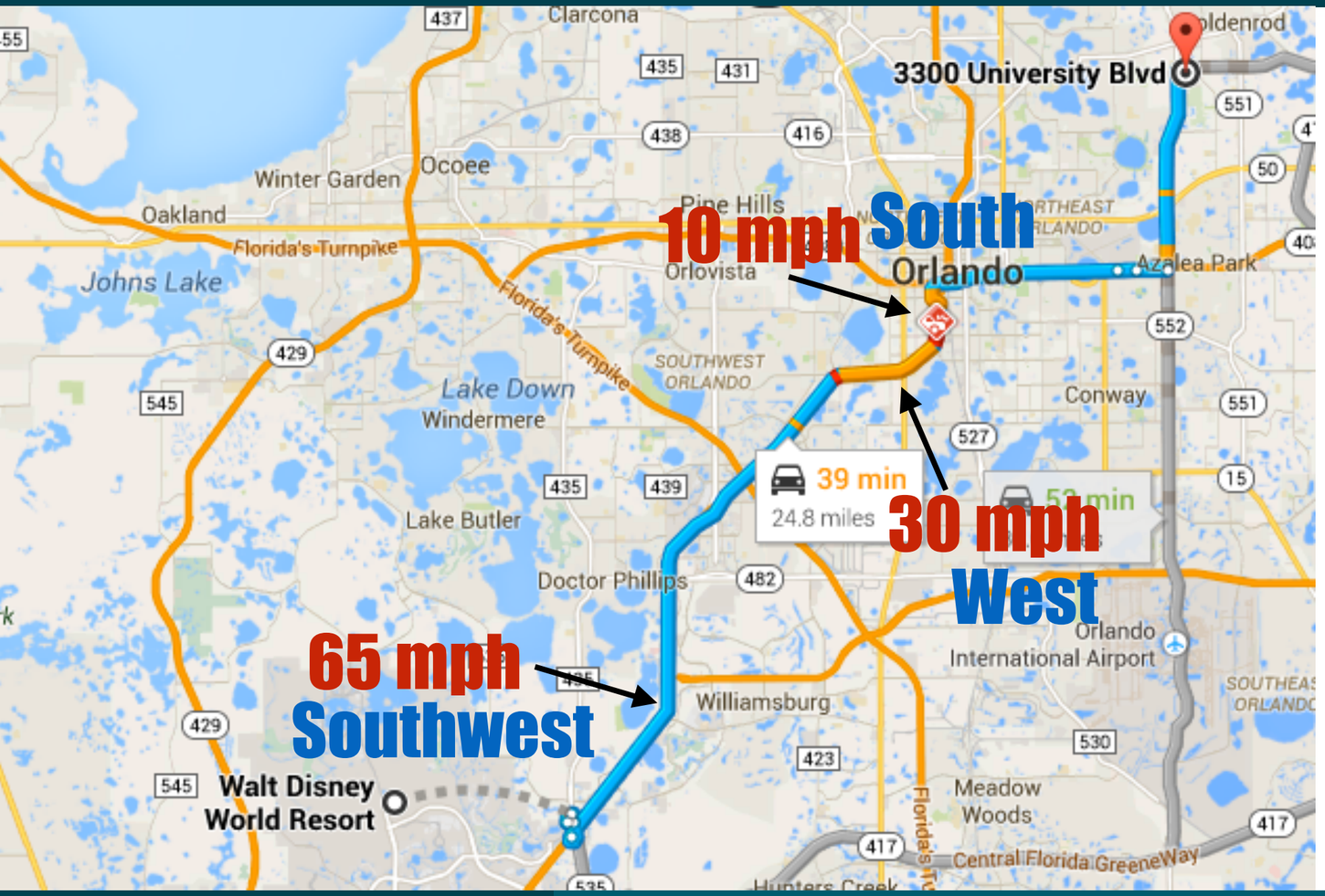
"Speed and Velocity" - They Might Be Giants

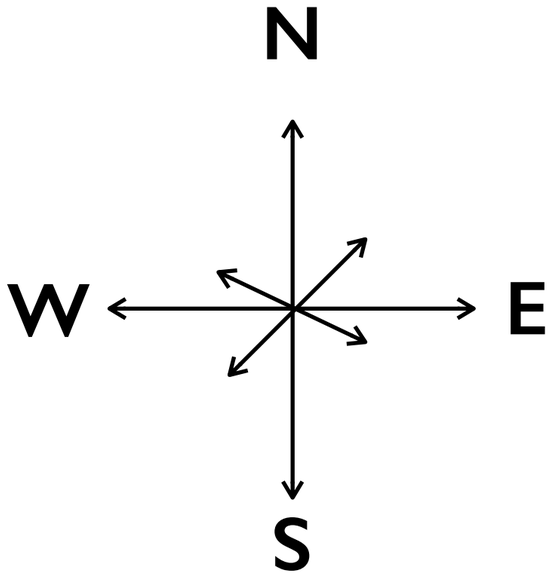
VELOCITY


3300 University Blvd
10 mph
30 mph
65 mph
39 min
24.8 miles
Orlando
Orlovista
Pine Hills
Winter Garden
Ocoee
Oakland
Johns Lake
Lake Down
Windermere
Lake Butler
Doctor Phillips
Conway
Azalea Park
Orlando International Airport
Williamsburg
Meadow Woods
Walt Disney World Resort
Florida's Turnpike
Central Florida GreeneWay
NORTHWEST ORLANDO
NORTHEAST ORLANDO
SOUTHWEST ORLANDO

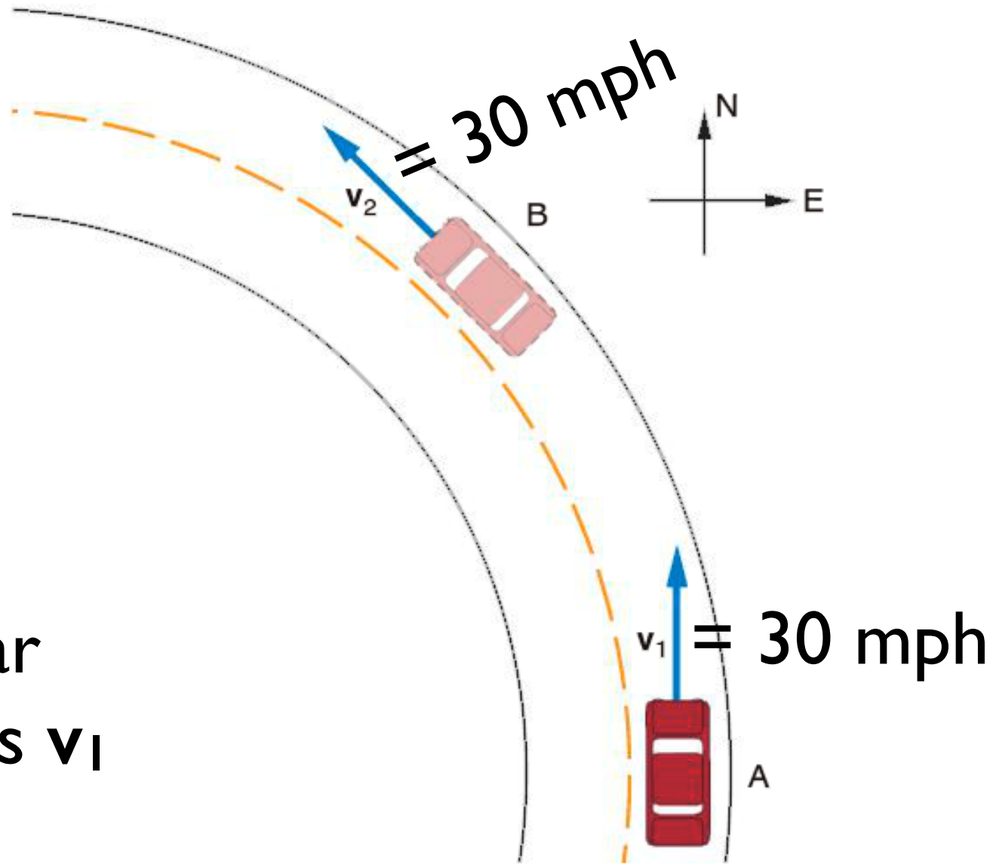

N
W
E
S

VELOCITY


3300 University Blvd
10 mph South
30 mph West
65 mph Southwest
39 min
24.8 miles
Walt Disney World Resort
Orlando
Winter Garden
Ocoee
Oakland
Johns Lake
Florida's Turnpike
Pine Hills
Orlovista
Azalea Park
Lake Down
Windermere
Conway
Lake Butler
Doctor Phillips
Orlando International Airport
Williamsburg
Meadow Woods
Central Florida GreeneWay
Clarcona
Goldenrod


N
W
E
S

SPEED VS. VELOCITY



The direction of the velocity changes as the car moves around the curve, so v_2 is not the same as v_1 even though the speed has not changed.

Variables are **directly proportional** to one another if one variable increases as the other increases, or if one variable decreases as the other decreases.

$$v = \frac{d}{t}$$

If you go faster, you cover more distance in the same amount of time!

v increases as **d** increases & **v** decreases as **d** decreases

Variables are **inversely proportional** to one another if one variable increases as the other decreases, or if one variable decreases as the other increases.

$$v = \frac{d}{t}$$

If you go faster, it takes less time to cover the same distance!

v increases as **t** decreases & **v** decreases as **t** increases

What is the velocity of a car that travels 150 meters East in 2 seconds?

STEP 1:

Define what you know.

d = 150 m

t = 2 s

What is the velocity of a car that travels 150 meters East in 2 seconds?

STEP 1:
Define what you know.

STEP 2:
Figure out what are solving for.

d = 150 m
t = 2 s

v = ?

What is the velocity of a car that travels 150 meters East in 2 seconds?

STEP 1: Define what you know.

STEP 2: Figure out what are solving for.

STEP 3: Decide which equation to use.

NAME	SYMBOL	UNIT	FORMULA
Velocity			
velocity	v	m/s (meters per second)	$v = \frac{d}{t}$
distance	d	m (meters)	
time	t	s (seconds)	
Acceleration			
acceleration	a	m/s² (meters per seconds squared)	$a = \frac{v_f - v_i}{t}$
final velocity	v_f	m/s (meters per second)	
initial velocity	v_i	m/s (meters per second)	
time	t	s (seconds)	
Distance fallen in free fall			
distance	d	m (meters)	$d = \frac{1}{2}gt^2 \quad \left(g = 9.8\frac{m}{s^2}\right)$
gravity	g	m/s² (meters per seconds squared)	
time	t	s (seconds)	
Weight			
weight	w	N (Newtons)	$w = mg \quad \left(g = 9.8\frac{m}{s^2}\right)$
mass	m	kg (kilograms)	
gravity	g	m/s² (meters per seconds squared)	
Force (Newton's 2nd Law)			
force	F	N (Newtons)	$F = ma$
mass	m	kg (kilograms)	
acceleration	a	m/s² (meters per seconds squared)	
Momentum			
momentum	p	kgm/s (kilograms meters per second)	$p = mv$

d = 150 m
t = 2 s

v = ?

v = d / t

What is the velocity of a car that travels 150 meters East in 2 seconds?

STEP 1:
Define what you know.

STEP 2:
Figure out what are solving for.

STEP 3:
Decide which equation to use.

STEP 4:
Place values from Step 1 into equation.

d = 150 m
t = 2 s

v = d / t

v = /

What is the velocity of a car that travels 150 meters East in 2 seconds?

STEP 1:
Define what you know.

STEP 2:
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STEP 3:
Decide which equation to use.

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Place values from Step 1 into equation.

d =
t = 2 s

v = d / t

v = 150 m/

What is the velocity of a car that travels 150 meters East in 2 seconds?

STEP 1:
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STEP 2:
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STEP 3:
Decide which equation to use.

STEP 4:
Place values from Step 1 into equation.

d =
t =

v = d / t

v = 150 m/ 2 s

What is the velocity of a car that travels 150 meters East in 2 seconds?

STEP 1: Define what you know.

STEP 2: Figure out what are solving for.

STEP 3: Decide which equation to use.

STEP 4: Place values from Step 1 into equation.

STEP 5: Solve.

$v = d / t$

$v = 150\ m / 2\ s$

What is the velocity of a car that travels 150 meters East in 2 seconds?

STEP 1: Define what you know.

STEP 2: Figure out what are solving for.

STEP 3: Decide which equation to use.

STEP 4: Place values from Step 1 into equation.

STEP 5: Solve.

$$v = d / t$$

$$v = 150\ m / 2\ s$$

What is the velocity of a car that travels 150 meters East in 2 seconds?

STEP 1: Define what you know.

STEP 2: Figure out what are solving for.

STEP 3: Decide which equation to use.

STEP 4: Place values from Step 1 into equation.

STEP 5: Solve.

$$v = d / t$$

$$v = 150 \text{ m} / 2 \text{ s}$$

$$v = 75 \text{ m/s}$$

ACCELERATION

The rate at which velocity changes over time.

$$a = \frac{v_f - v_i}{t}$$

a = acceleration (m/s^2) $\quad$ $\mathbf{v_f}$ = final velocity (m/s)

$\mathbf{v_i}$ = initial velocity (m/s) $\quad$ **t** = time (s)

ACCELERATION

- **Positive acceleration** means an object is speeding up.
- **Negative acceleration** means an object is slowing down.
- **Zero acceleration** means an object is either at rest or moving at a constant velocity.

An object goes from rest to 50 m/s in 10 seconds.
What acceleration is the object experiencing?

STEP 1: Define what you know.

STEP 2: Figure out what are solving for.

STEP 3: Decide which equation to use.

STEP 4: Place values from Step 1 into equation.

STEP 5: Solve.

$v_f = 50 \text{ m/s}$

$v_i = 0 \text{ m/s}$

$t = 10 \text{ s}$

$a = ?$

$$a = \frac{v_f - v_i}{t} = \frac{50 \text{ m/s} - 0 \text{ m/s}}{10 \text{ s}}$$

$$a = 5 \text{ m/s}^2$$

A car traveling at 30 m/s crashes into a wall and stops in 0.1 seconds. What acceleration is the car experiencing?

STEP 1: Define what you know.

STEP 2: Figure out what are solving for.

STEP 3: Decide which equation to use.

STEP 4: Place values from Step 1 into equation.

STEP 5: Solve.

$v_f = 0 \text{ m/s}$

$v_i = 30 \text{ m/s}$

$t = 0.1 \text{ s}$

$a = ?$

$$a = \frac{v_f - v_i}{t} = \frac{0 \text{ m/s} - 30 \text{ m/s}}{0.1 \text{ s}}$$

$$a = -300 \text{ m/s}^2$$

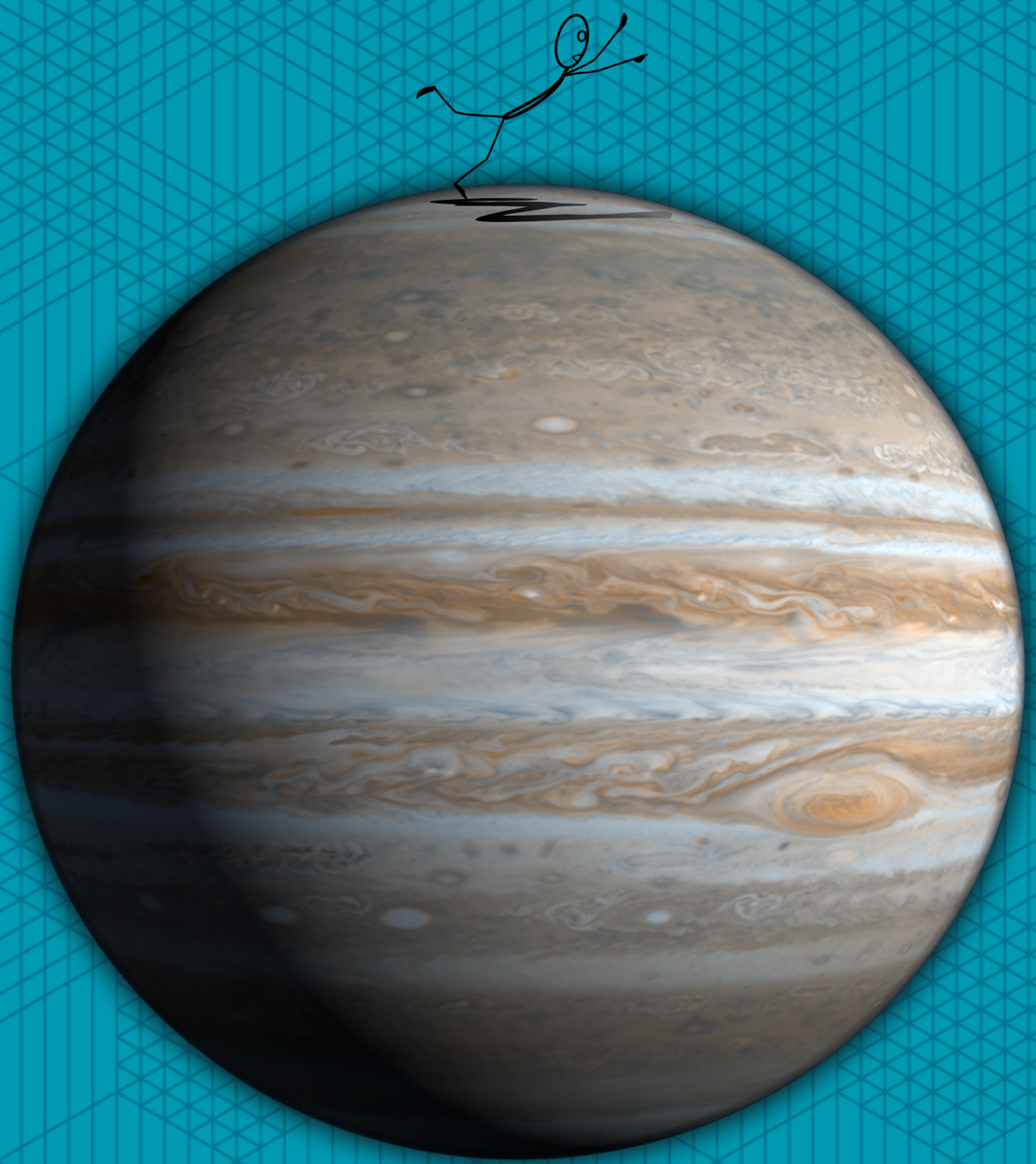
Acceleration of Gravity

All objects fall toward the surface of the Earth with an acceleration of **9.8 m/s^2**.

This number (**g = 9.8 m/s^2**) is a constant on Earth due to Earth's mass.

If Earth was more massive, objects would accelerate faster toward the surface.

Acceleration of Gravity



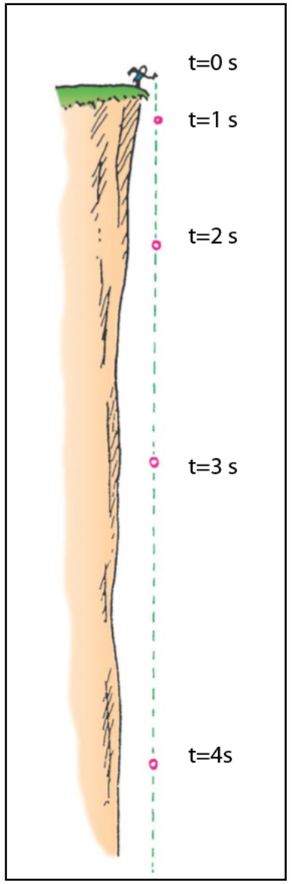
Jupiter is 318 times more massive than Earth, so all object's on Jupiter accelerate at a rate of **24.5 m/s²**.

FREE FALL

An object is in **free fall** when:

1. the only force acting on a falling object is gravity.

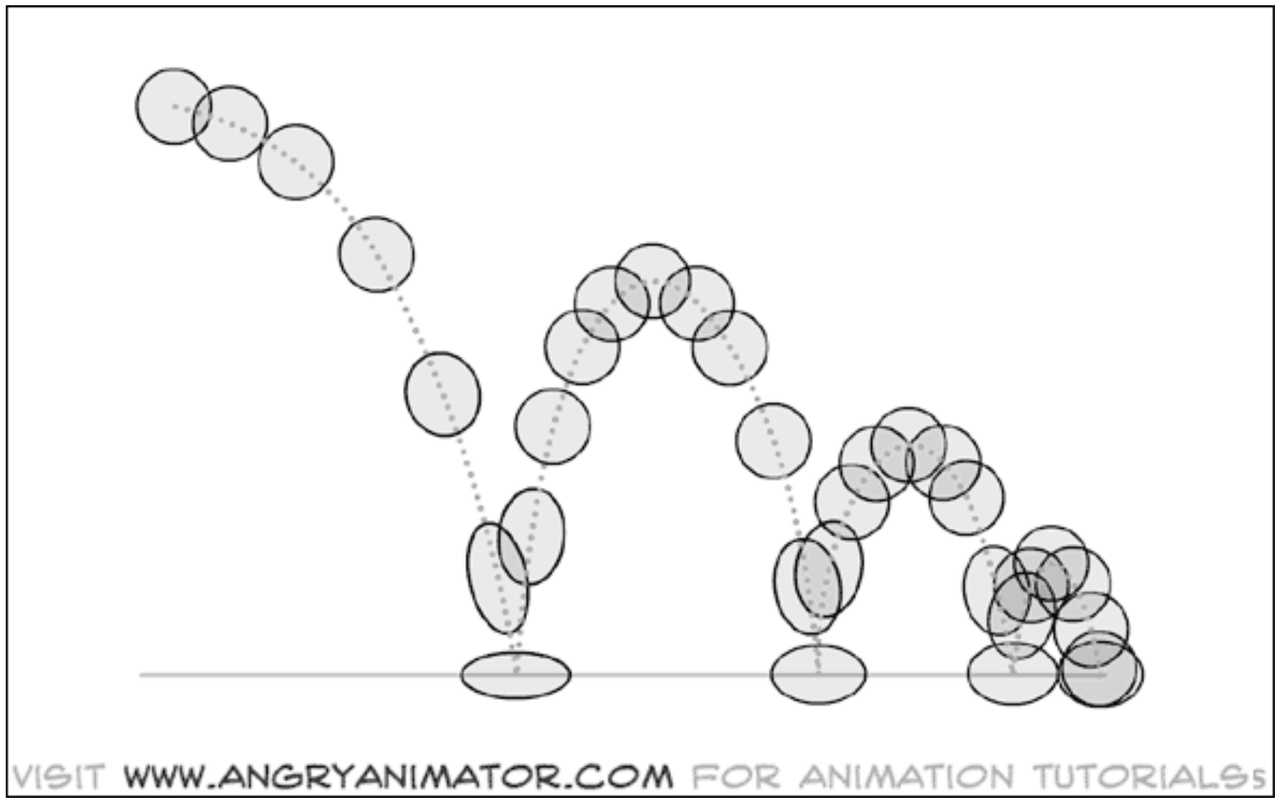
2. there is zero or negligible air resistance.



REAL WORLD FREE FALL

- On Earth, we have a thick atmosphere which makes zero to negligible air resistance difficult to obtain.
- The following free fall equations are good estimations for heavy objects falling over a short distance.

"You have to know what the rules are in order to break them, to advance the story successfully and [to] keep the audience believing what they're seeing on screen."
- Courtney Granner (Illustrator, San Jose State)



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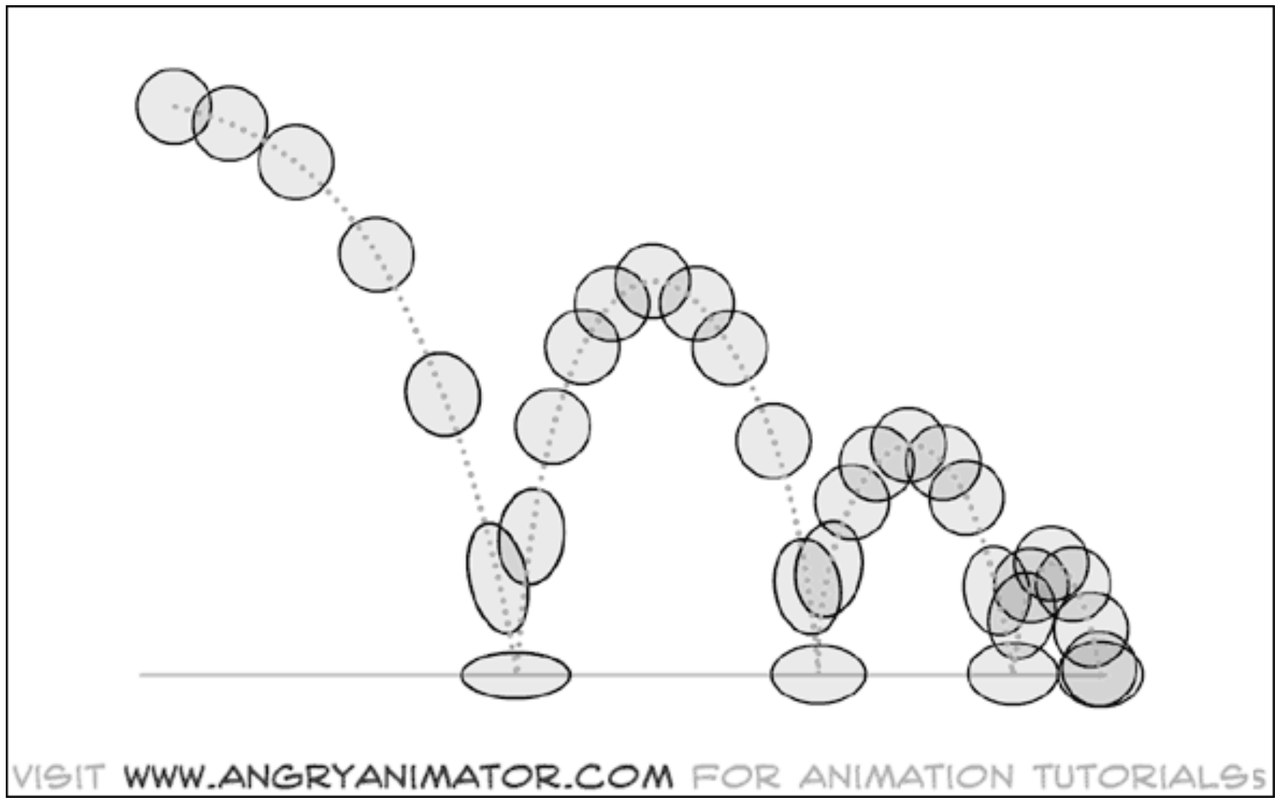
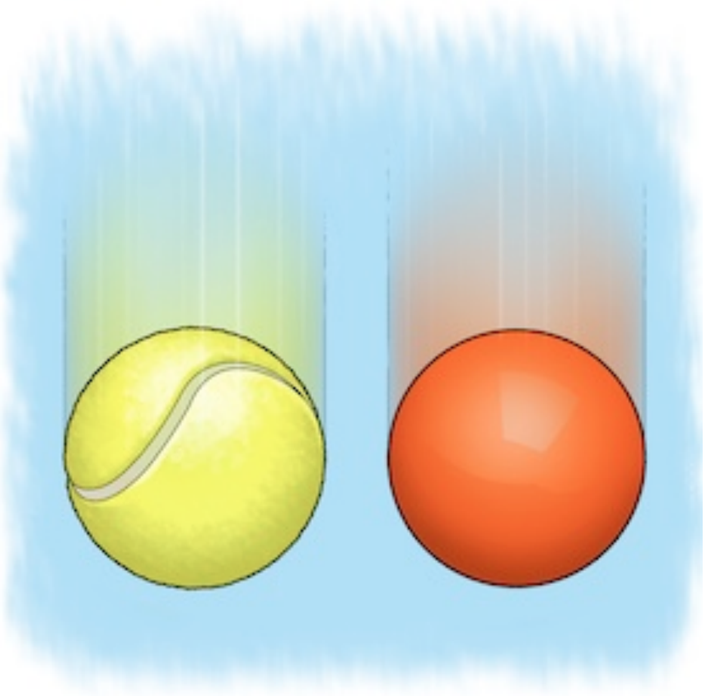


DISTANCE IN FREE FALL



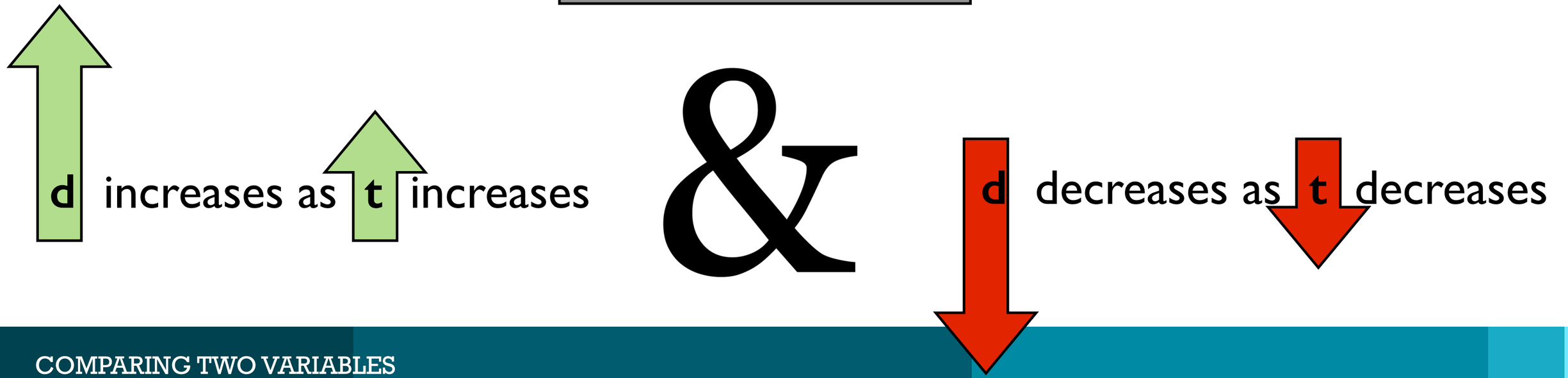
A calculation of distance covered over a change in time when object is in free fall.

$$d = \frac{1}{2} g t^2$$

d = distance (m) **g** = gravity (m/s^2) **t** = time (s)

Variables are **exponentially proportional** to one another if one variable increases as the other increases, or if one variable decreases as the other decreases by a power of the variable (such as a square).

$$d = \frac{1}{2} g t^2$$



An object is dropped and in free fall. How far does the object travel in 3 seconds?

How far does it travel in twice as much time (6 seconds)?

$$d = \frac{1}{2} g t^2$$

$$d = \frac{1}{2}(9.8\ \text{m/s}^2)(3\ \text{s})^2$$

$$d = (4.9\ \text{m/s}^2)(9\ \text{s}^2)$$

$$d = 44.1\ \text{m}$$

The time increased by a factor of 2 (doubles), so the distance fallen increased by a factor of 4 (quadrupled) because of the exponential relationship between time and distance in free fall.

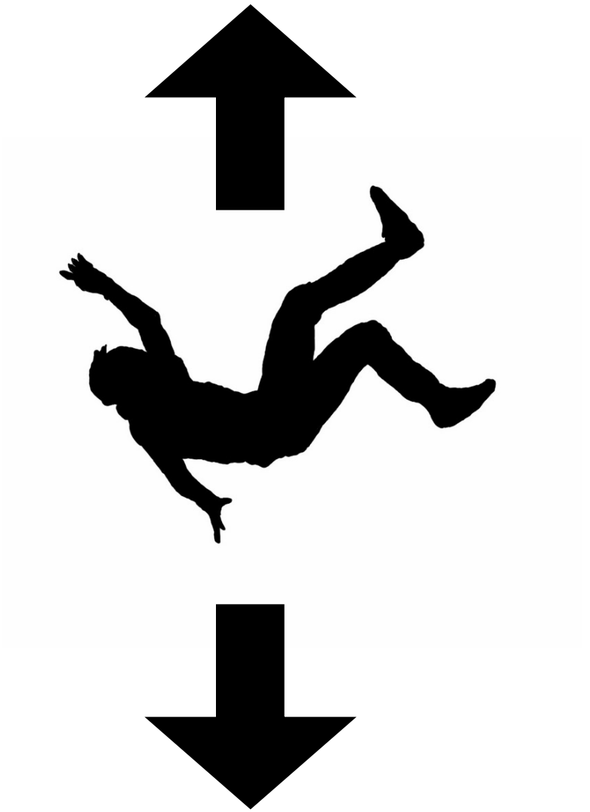
$$d = \frac{1}{2} g t^2$$

$$d = \frac{1}{2}(9.8\ \text{m/s}^2)(6\ \text{s})^2$$

$$d = (4.9\ \text{m/s}^2)(36\ \text{s}^2)$$

$$d = 176.4\ \text{m}$$

Terminal velocity occurs when the upward force of air resistance equals the downward force of gravity for a falling object.



When an object reaches terminal velocity, it is no longer accelerating.

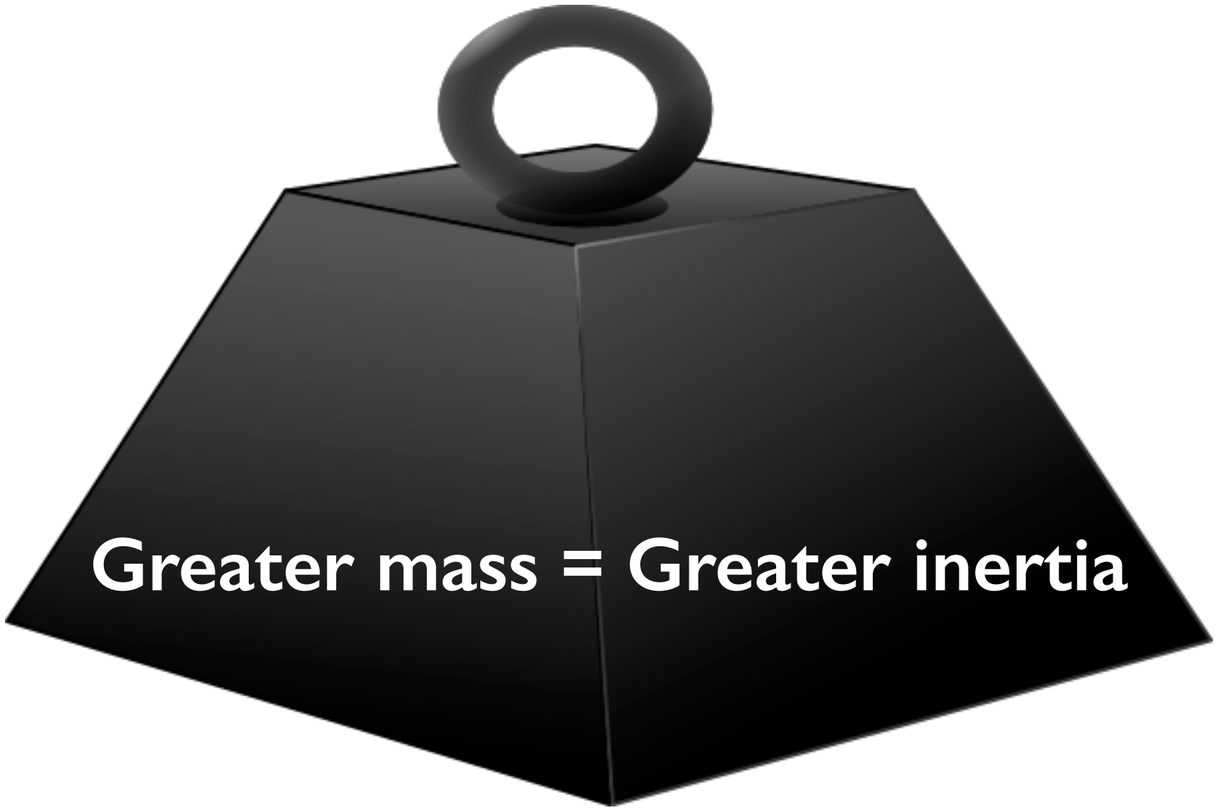
Inertia

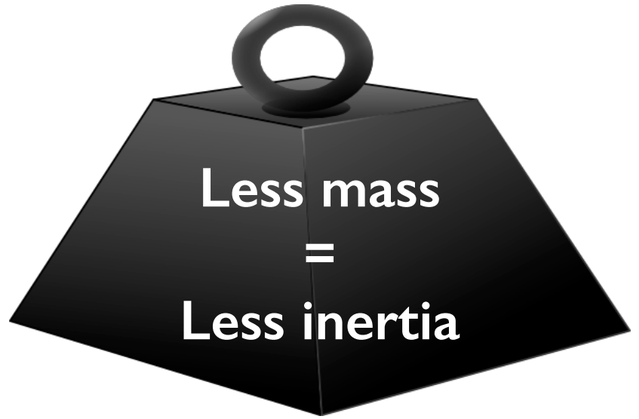
An object **in motion stays in motion** unless acted upon by an outside force.

An object **at rest stays at rest** unless acted upon by an outside force.

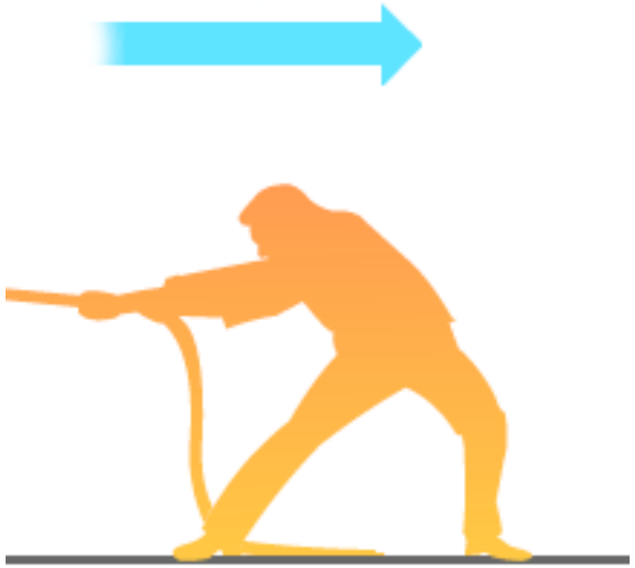
Inertia is an object's natural resistance to change.

The amount of inertia possessed by an object depends on the amount of matter that composes it - its mass.





FORCE



A push or a pull on an object.

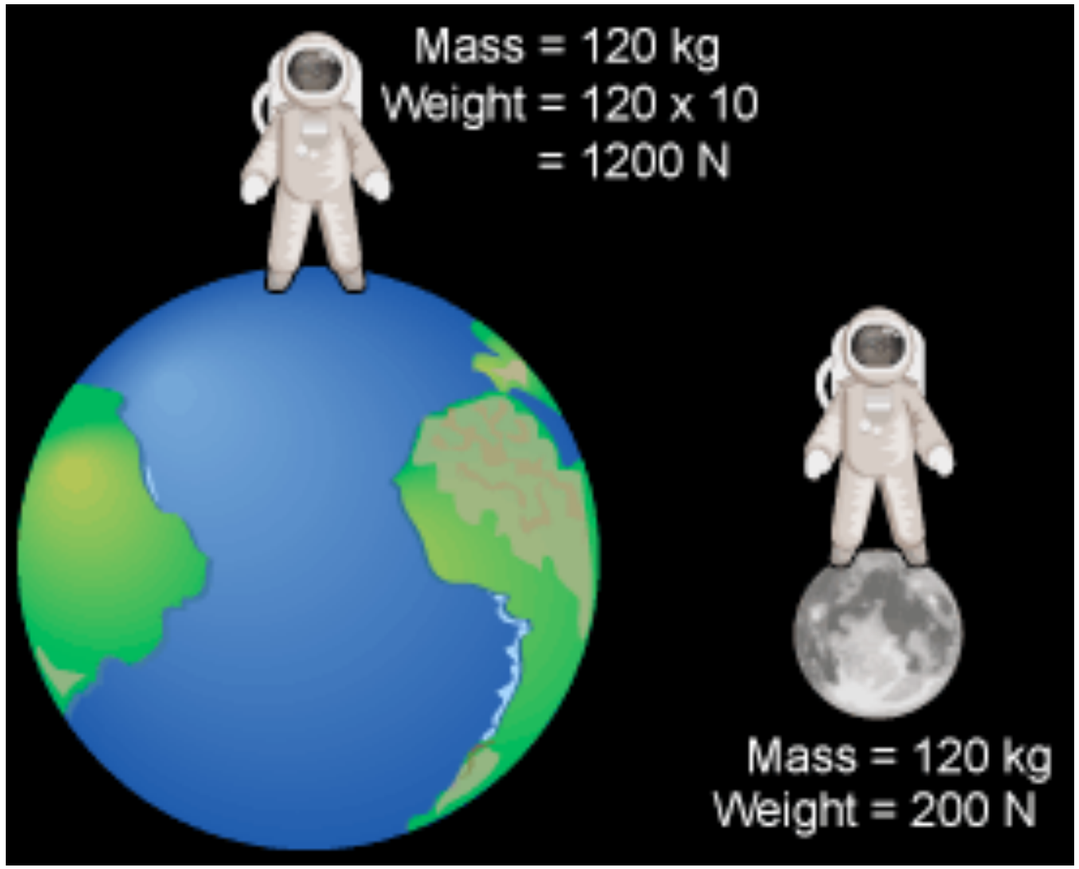
$$F = ma$$

F = Force (N) **m** = mass (kg) **a** = acceleration (m/s^2)

WEIGHT VS. MASS

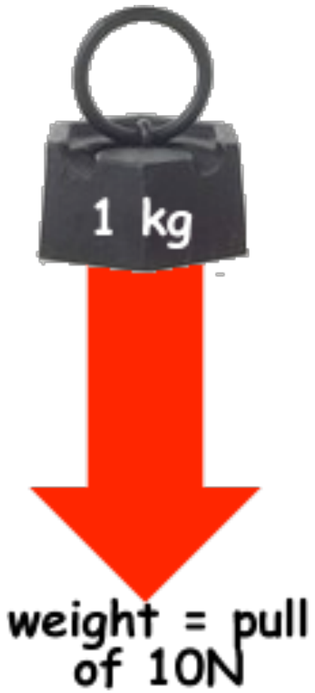
Mass is the amount of matter an object contains and is measured in kilograms (kg).

Weight is the amount of force upon an object due to the pull of gravity and is measured in Newtons (N).



IMPORTANT! MASS AND WEIGHT ARE TWO DIFFERENT THINGS IN PHYSICS!

WEIGHT



A specific kind of force caused by gravity pulling on a mass.

$$w = mg$$

w = weight (N) **m** = mass (kg)

g = acceleration due to gravity (m/s^2)

What is the weight of a 10-kg object on Earth?

$$w = mg$$

$$w = (10\ \text{kg})(9.8\ \text{m/s}^2)$$

$$w = 98\ \text{N}$$

What is the weight of a 5-kg object on Earth?

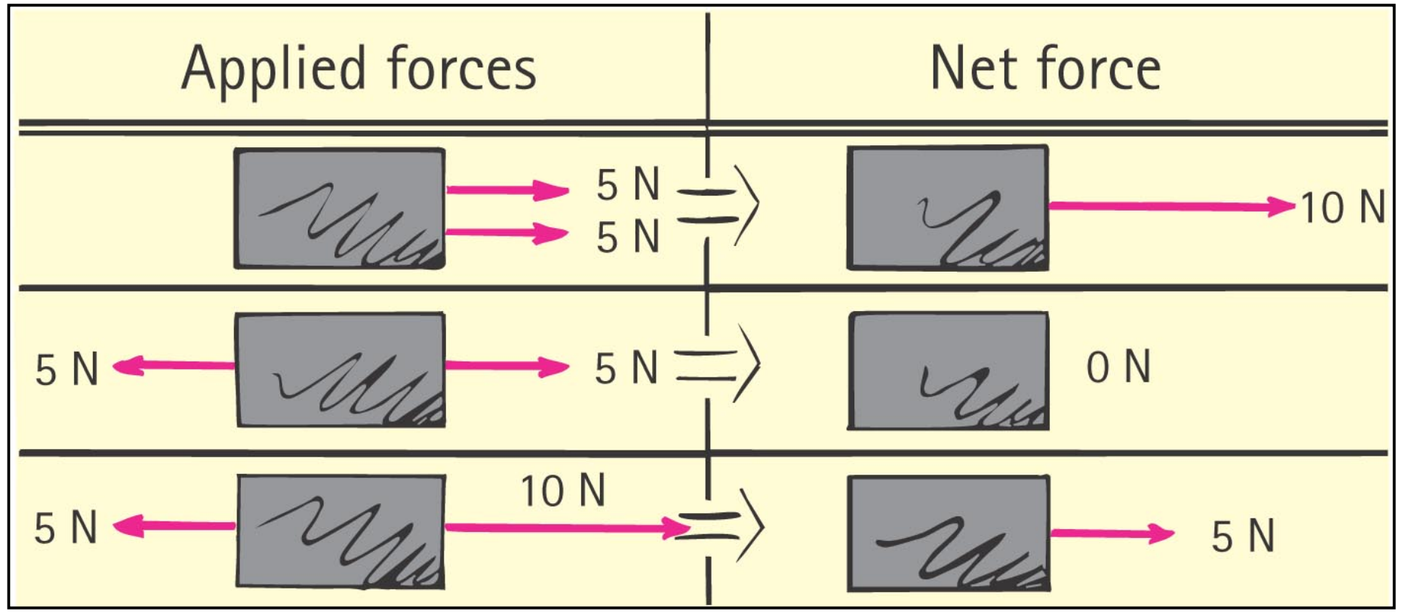
$$w = mg$$

$$w = (5\ \text{kg})(9.8\ \text{m/s}^2)$$

$$w = 49\ \text{N}$$

When the mass decreased by a factor of 2, the weight also decreased by a factor of 2 because weight and mass are directly proportional to each other.

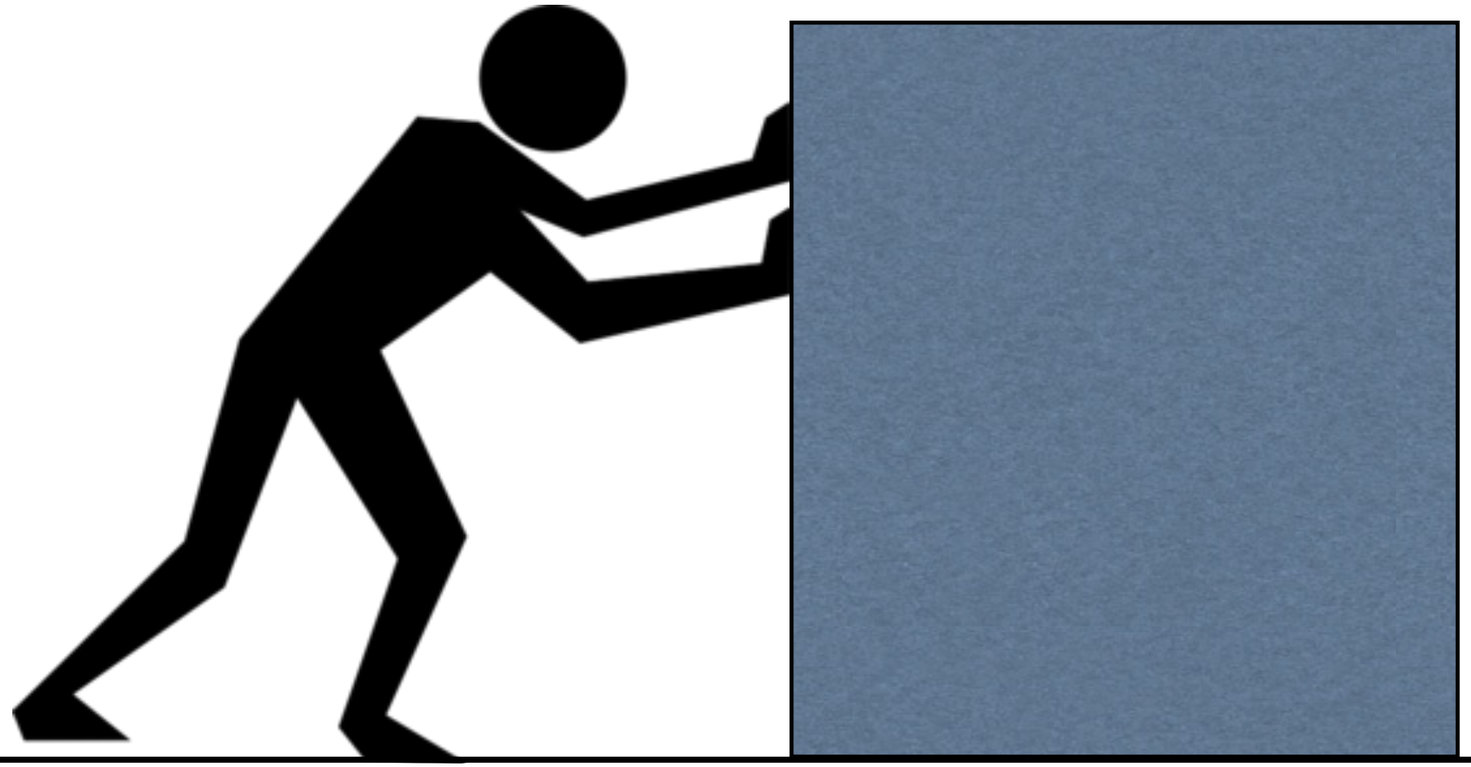
Net Force is the combination of all forces that act on an object.



Add forces acting in the **same direction**.

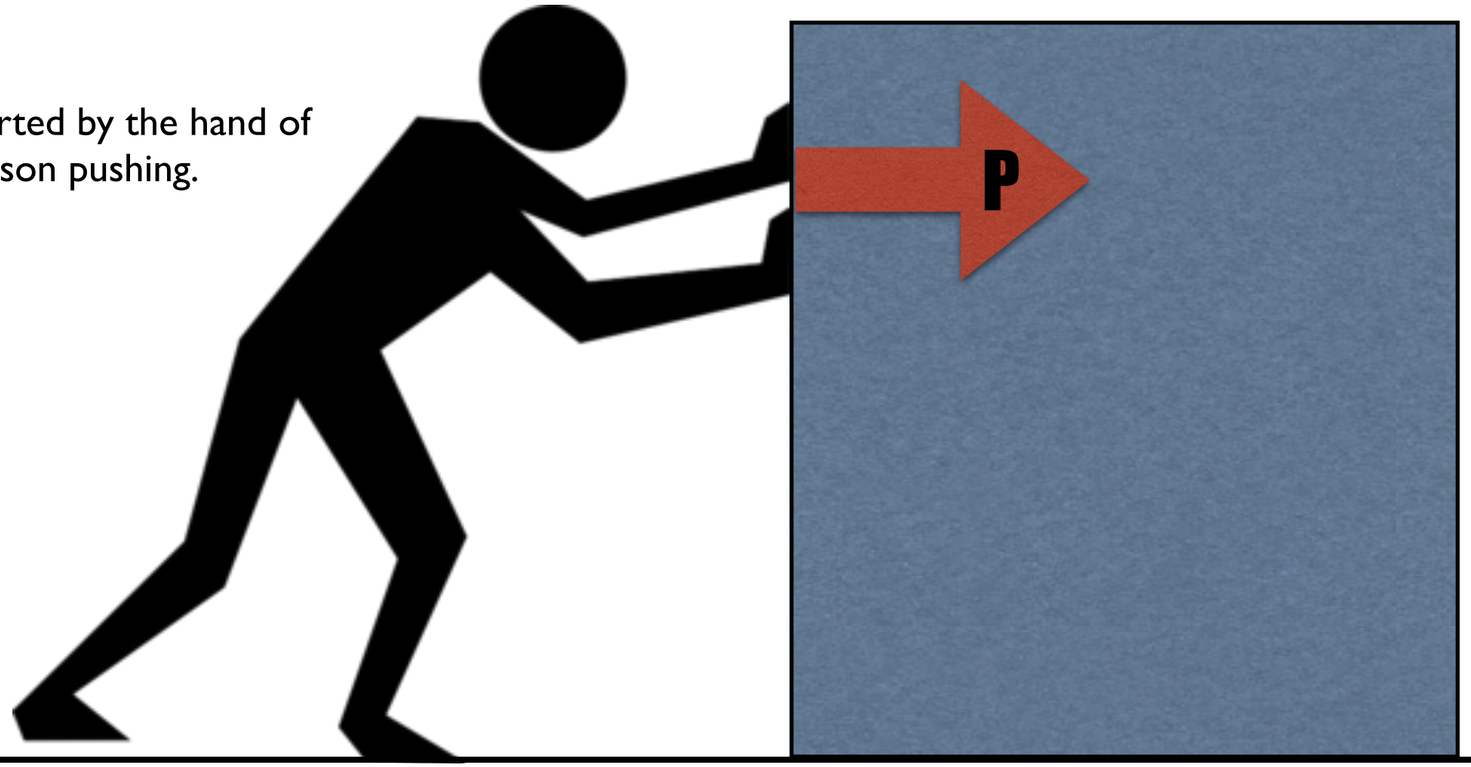
Subtract forces acting in the **opposite direction**.

The first step in any motion analysis is to identify forces acting on an object.



The first step in any motion analysis is to identify forces acting on an object.

The force exerted by the hand of the person pushing.



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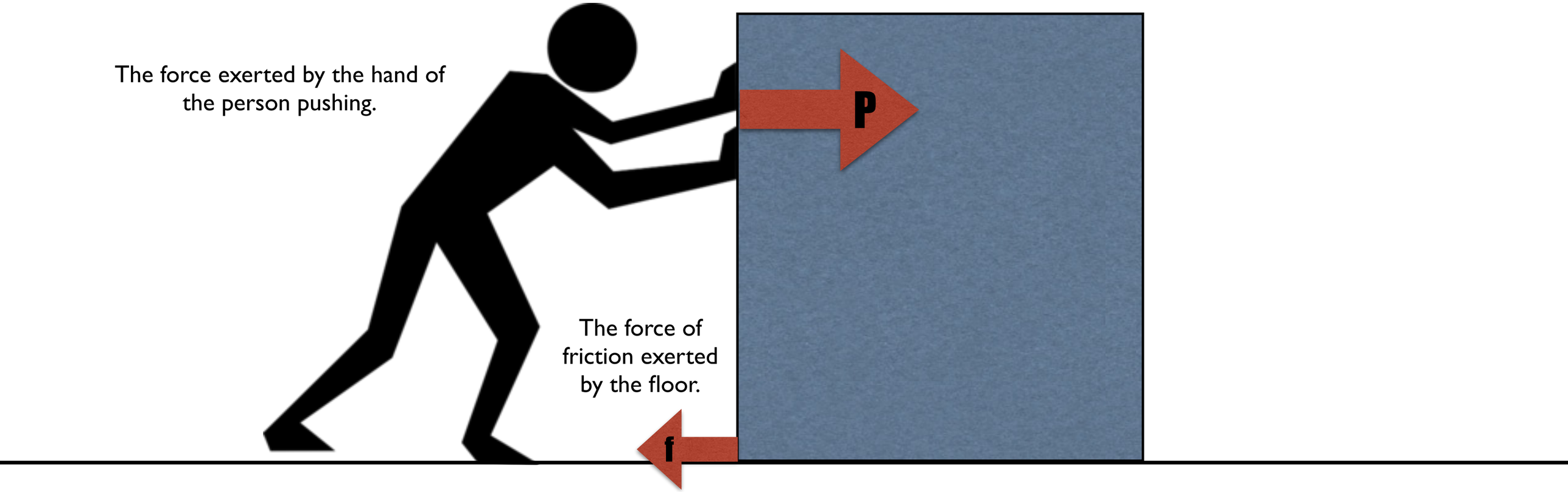

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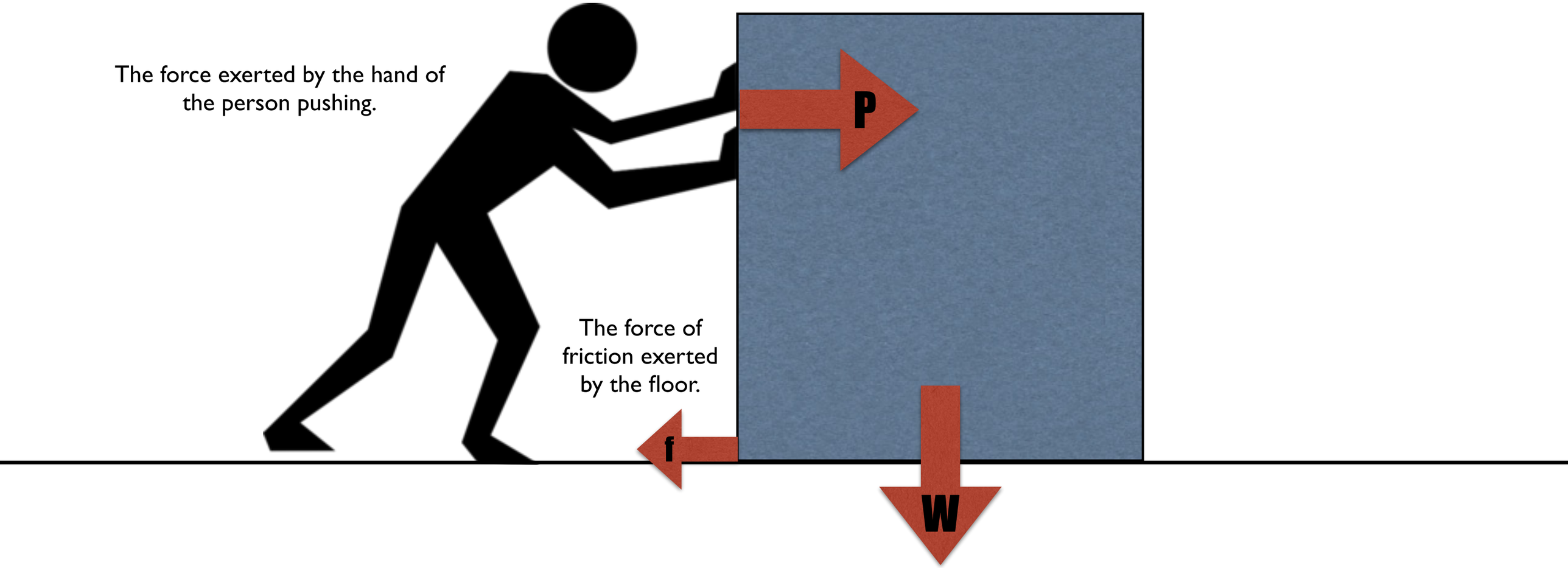
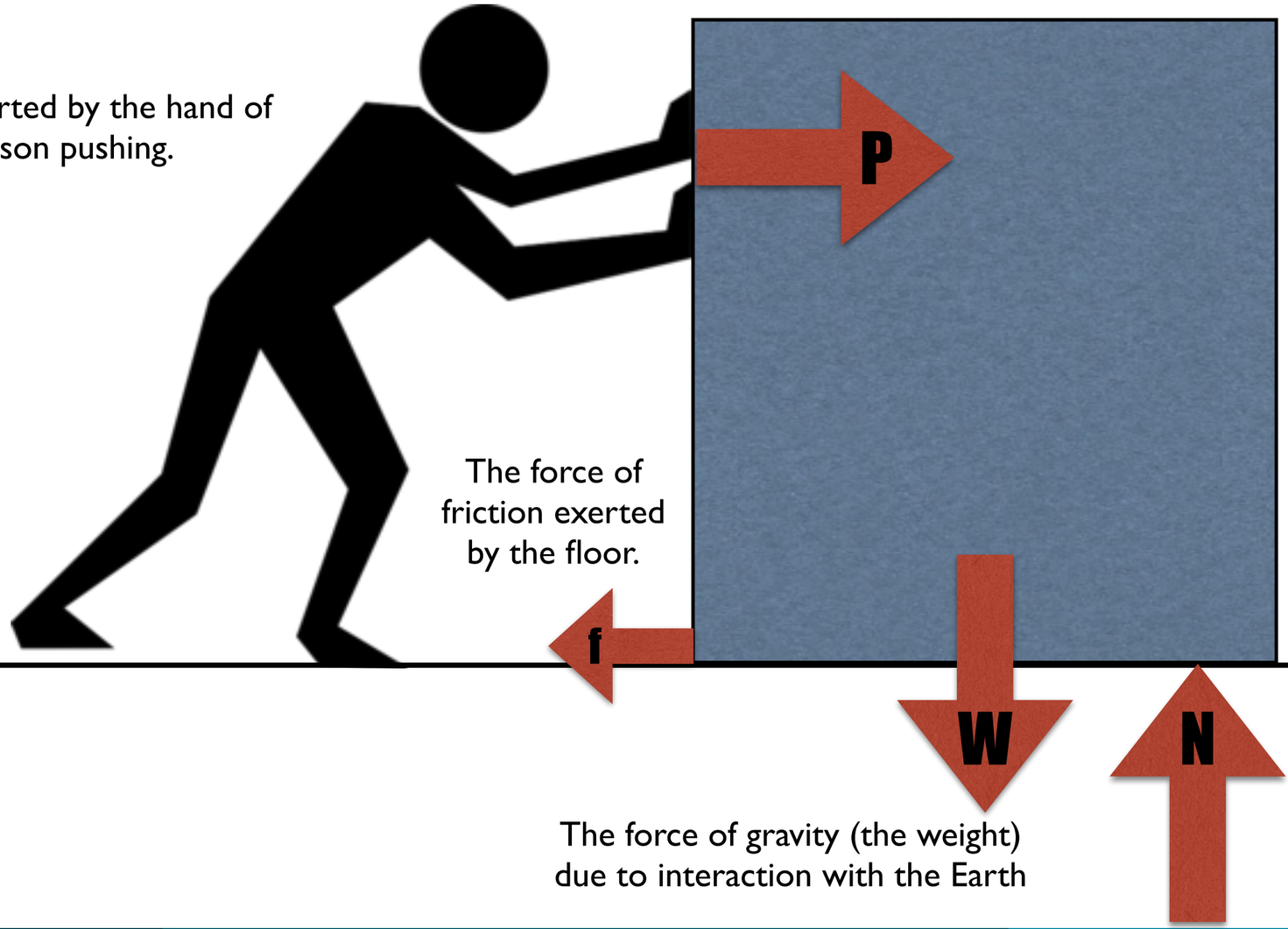


The first step in any motion analysis is to identify forces acting on an object.



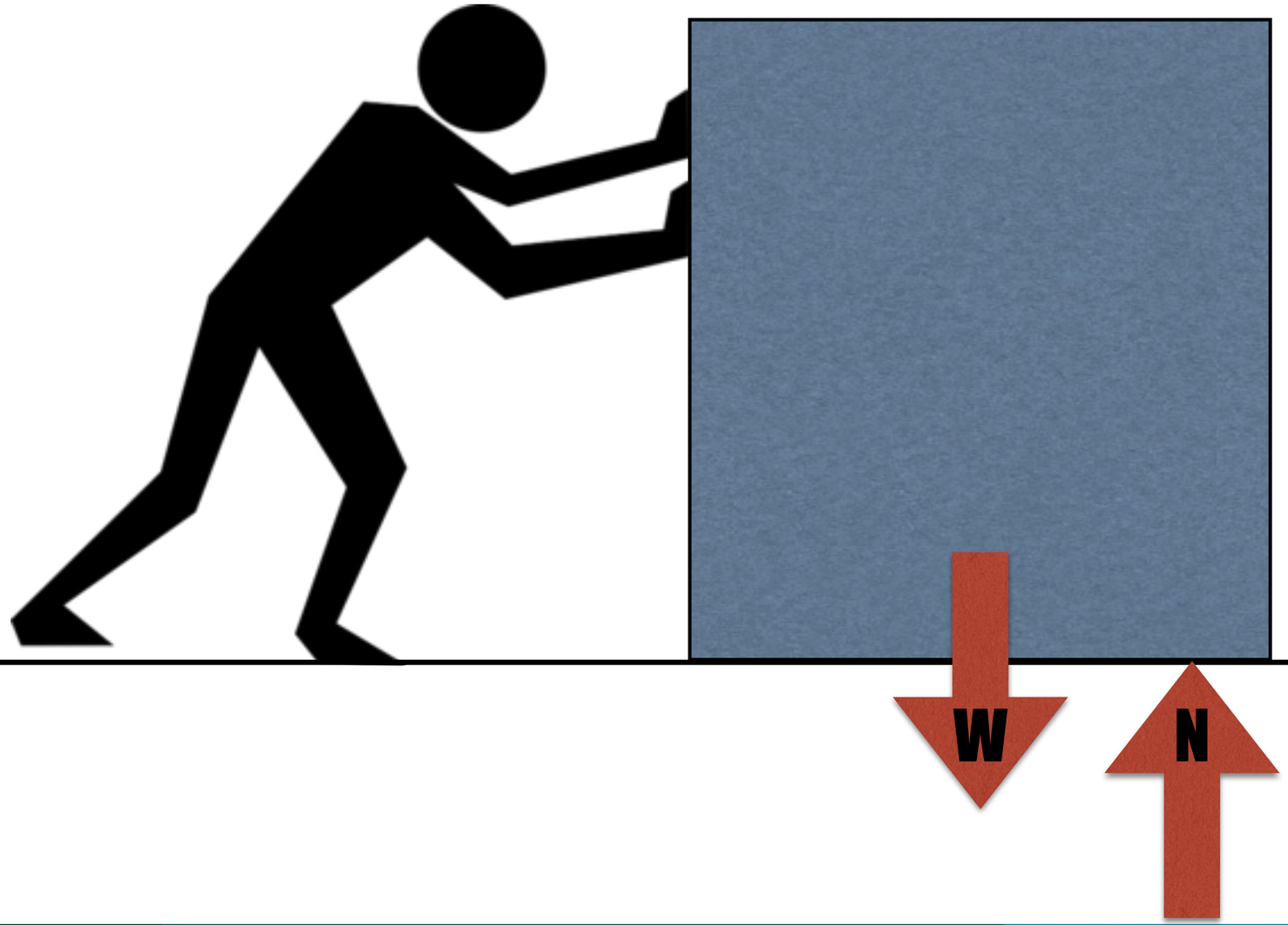
The force exerted by the hand of the person pushing.

The force of friction exerted by the floor.

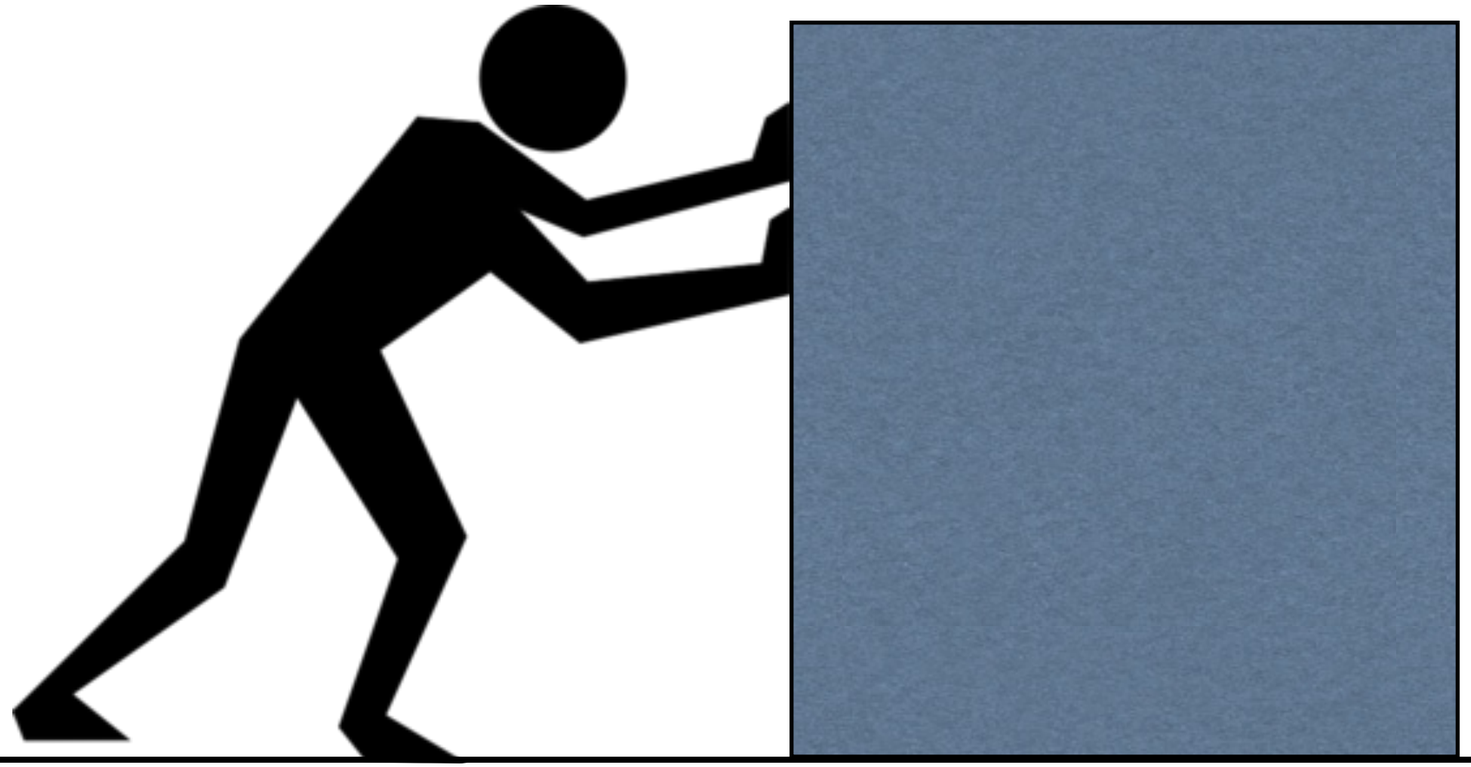
The force of gravity (the weight) due to interaction with the Earth

The upward (normal) force exerted by the floor due to the compression of the floor.

W and **N** are equal in magnitude, but opposite in direction, so they will cancel.

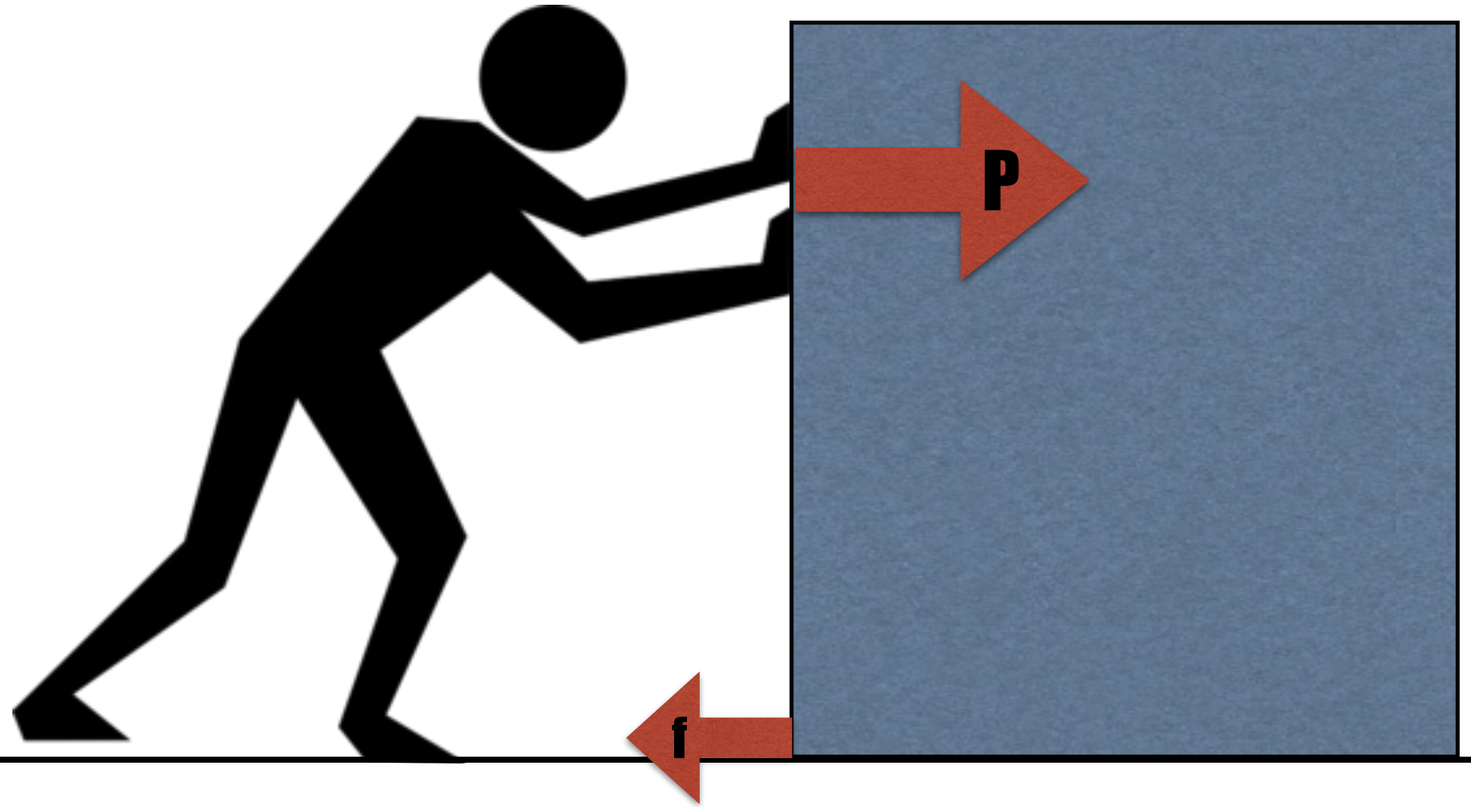


W and **N** are equal in magnitude, but opposite in direction, so they will cancel.

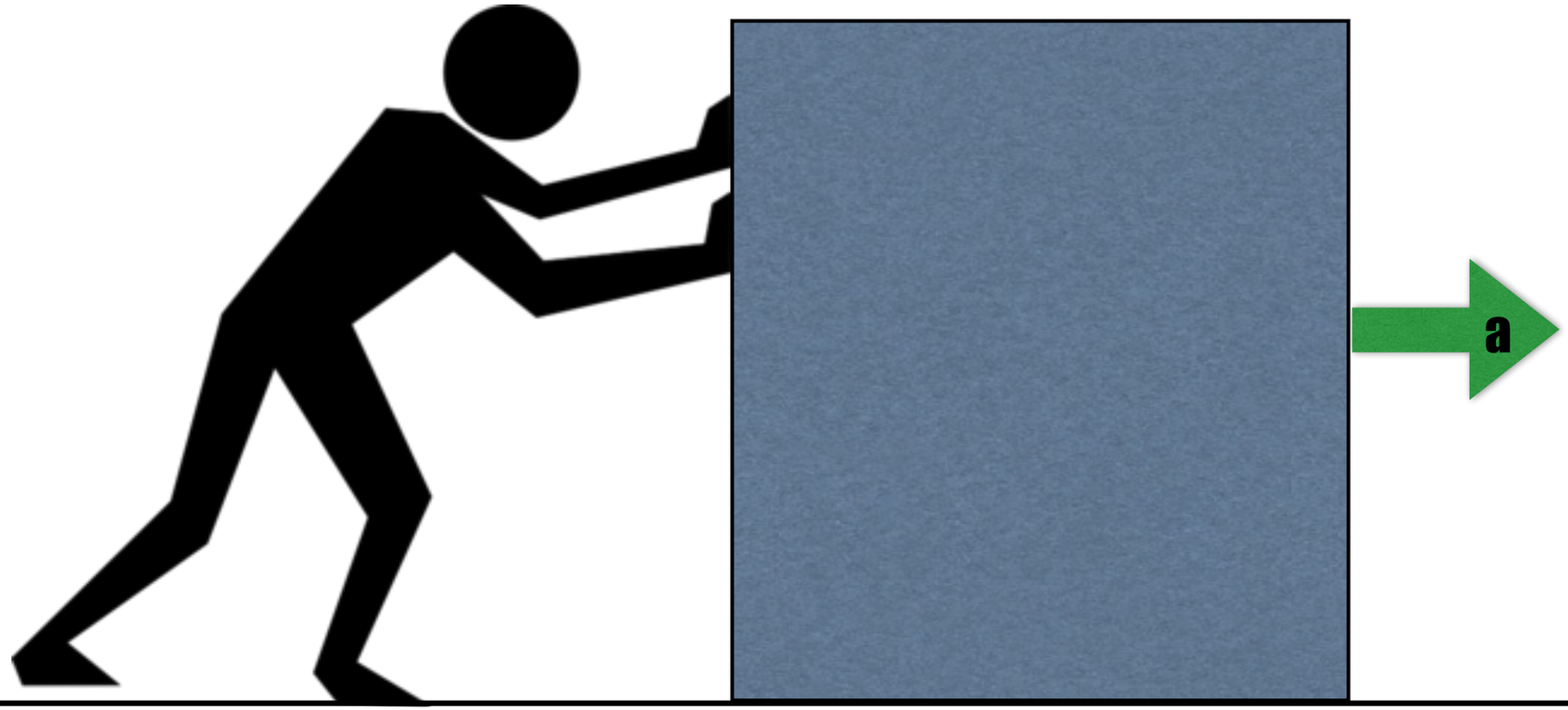


Therefore, there is no acceleration in the vertical direction.

P and **f** are opposite in direction, but unequal in magnitude, so they will not completely cancel.



P and **f** are opposite in direction, but unequal in magnitude, so they will not completely cancel.



Therefore, the box will accelerate in the direction of the greater force.

The Equilibrium Rule

The vector sum of forces acting on a non-accelerating object or system of objects equals zero.

When all the forces that act upon an object are balanced, then the object is said to be in a state of equilibrium.

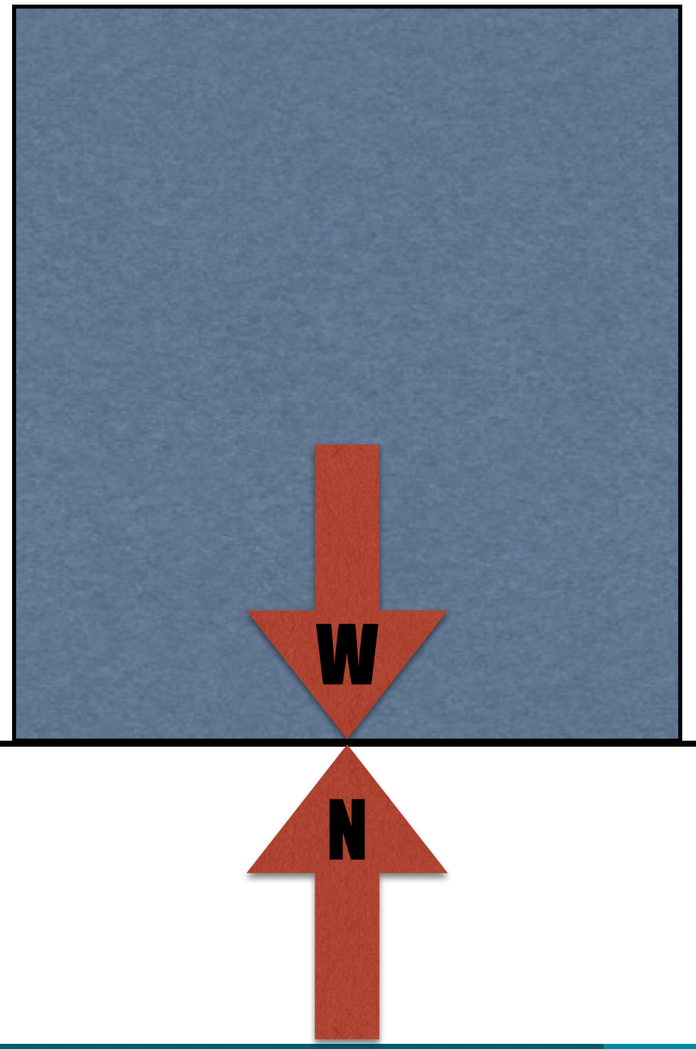
$$\Sigma F = 0$$

stands for "the sum," so this is read as "the sum of all Forces is equal to zero"

$$\Sigma F = F_1 + F_2 + F_3 + \ldots + F_n$$

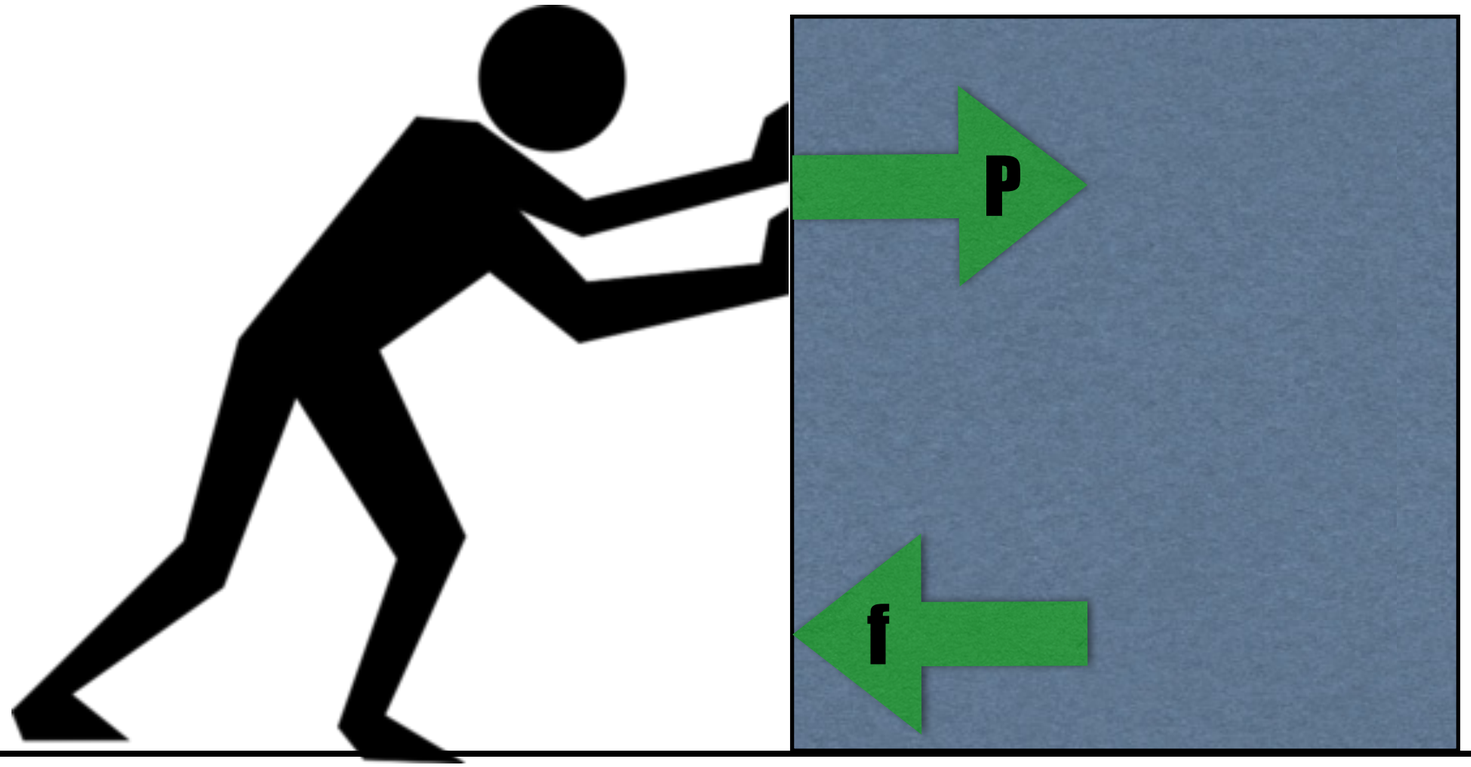
An object experiences static equilibrium at a state of rest.

W and **N** are equal in magnitude, but opposite in direction, so they will cancel.



Therefore, net force = zero and **acceleration** = zero.

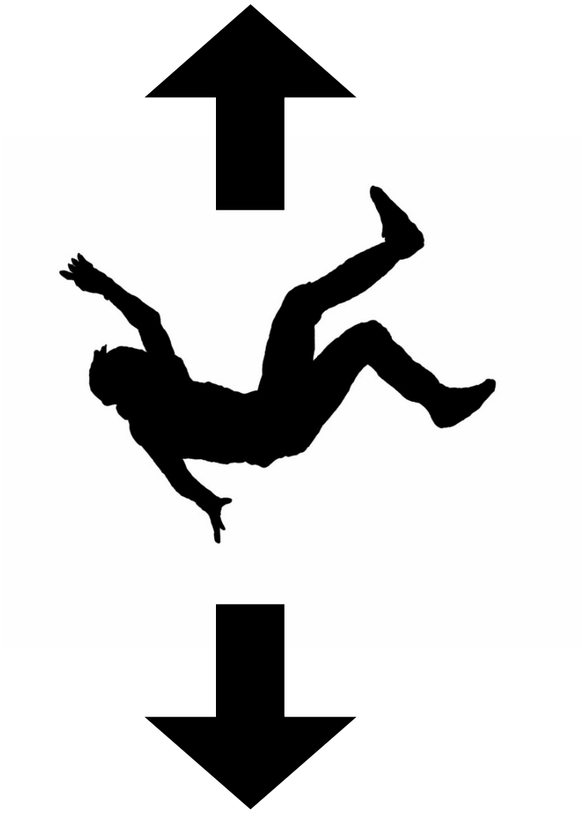
An object experiences dynamic equilibrium while moving at constant velocity.



If **P** and **f** are equal in magnitude, but opposite in direction, they will cancel.

Therefore, net force = zero and **acceleration** = zero even though the box is still moving!

Terminal velocity occurs when the upward force of air resistance equals the downward force of gravity for a falling object.



Dynamic Equilibrium

When an object reaches terminal velocity, it is no longer accelerating.