Forces: A force is a manifestation of energy that moves / reshapes or tends to move /reshape an object or in plain language, "A push, pull, squeeze, or stretch"

- Forces are vectors $\vec{F}$
- Forces are measured in **Newtons** (N), named after the English physicist, Sir Isaac Newton.
- $1N = 1kg \cdot m/s^2$
- Forces are often measured with a spring scale. The greater the force, the greater the compression or extension (stretch) on the spring.

Weight vs. Mass

A common misconception is that **weight** and **mass** are the same. **They are not**!

- **Mass:** is the measurement that specifies the amount of material in an object. Mass is measured using a balance scale against a standardized mass. The standard unit is the $\boldsymbol{kg}$.
- **Weight:** represents the force gravity on a mass. Hence in space, one is weightless not massless. In physics, weight is measured in Newtons. Therefore weight is the force of gravity on an object

$$Weight = F_g$$ (**F**orce of **g**ravity)

The formula for the **force of gravity** / **weight** is

$$F_g = mg$$

Where F_g is the force of gravity is in Newtons (N), m is the mass of the object In kg , and g is the acceleration due to gravity which is 9.8 N/kg or 9.8 m/s^2. **Note: $\boldsymbol{g}$ is not negative**. This is an important distinction to make. The force of gravity always acts downward so $F_g = mg$ only calculates the **magnitude** of the force.

Example: Find the weight of a $20.0kg$ mass

$$\begin{aligned} F_g &= mg \\ &= (20kg)(9.8N/kg) \\ &= 196kg \cdot \frac{N}{kg} \\ &= 196N \end{aligned}$$

or

$$\begin{aligned} F_g &= mg \\ &= (20kg)(9.8m/s^2) \\ &= 196kg \cdot \frac{m}{s^2} \\ &= 196kg \cdot m/s^2 \end{aligned}$$

Note: $1N = 1kg \cdot m/s^2$

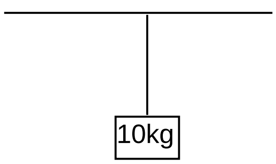
<u>Free Body Diagrams (FBD)</u>

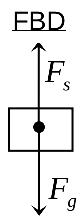
Free body diagrams are used to graphically represent all the forces acting on an object. Free body diagrams are intended to be simplified representation of the force configuration so free body diagrams only work with one object at a time.

<u>Rules for drawing FBDs</u>

- Draw a diagram of the object, isolated from its surroundings
- Draw a point in the approximate location of the object's centre of mass.
- From the point, draw all the forces acting on the object
- Do not include forces that the object exerts on other objects
- Label it as a FBD

Ex: Consider a $10\ kg$ mass hanging from a string.



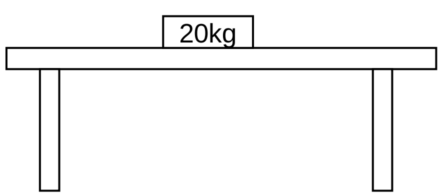


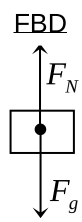
Note:

- Since the mass is in equilibrium (not accelerating), the forces balance and are hence the same length.
- F_s and F_g represent the force of the string and gravity respectively. Notice, it is not necessary to include the vector notation on the diagram because the force arrows clearly indicate the direction of the force.

<u>The Normal Force</u>

The **normal force** is the force that all **surfaces produce** in order to **oppose gravity**. The normal force is a **reactionary** force, meaning that the **normal force** immediately compensates for any change in the force of gravity. Without the normal force, all objects would fall straight to the centre of the earth. Since this does not happen then things like the ground, the floors, tabletops all produce a normal force.





Note: if the force of gravity is too large, then the surface supporting the object will bend, break or deform. This implies there is a limit to the normal force. St. Mary's is good example of what happens when the normal force cannot compensate for the force of gravity, as we slowly sink. Eventually the ground beneath the school will become sufficiently packed in order to compensate for the force of gravity. However by that time, damage to the property has already occurred. Apparently the soil engineers slept through that lesson during first year physics for architects.

<u>Net Force</u>

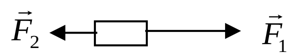
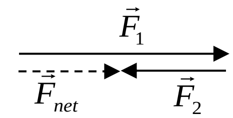
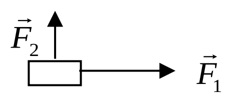
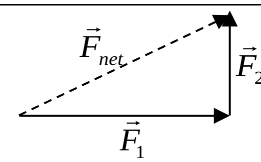
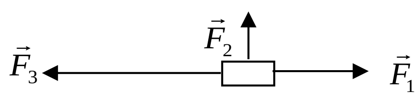
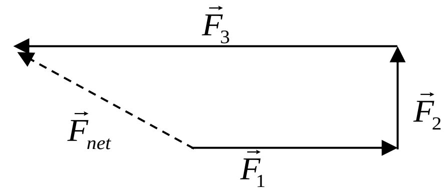
The net force is the sum of all the forces acting on an object. Since forces are vectors, finding the net forces follows the rules for vector addition and subtraction.

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \cdots + \vec{F}_n$$

Facts About the Net Force:

- If $\vec{F}_{net} = \vec{0}$ then acceleration is **zero**. In this situation objects are said to be in **equilibrium**.
- **Balanced forces**: When $\vec{F}_{net} = \vec{0}$, the object may be **at rest** OR moving with **constant velocity.**
- **Unbalanced forces**: Acceleration only occurs when $\vec{F}_{net} > \vec{0}$ or $\vec{F}_{net} < \vec{0}$
- Acceleration is calculated using $\vec{F}_{net}$ ONLY!
- $\vec{F}_{net} < \vec{0}$, object accelerates forward (increases velocity in the positive direction)
- $\vec{F}_{net} < \vec{0}$, object accelerates backwards (decreases velocity in the positive direction)

Examples: Which way will the object move? Consider both the size and direction of all the forces. It's like a tug-o-war, the net force $\vec{F}_{net}$ is the resulting overall force acting on the object. The object will also move in the same direction of net force. If all the forces cancel out, the object either stays at rest or keeps moving in the same direction that it has been moving, but at a constant speed.

FBD	Vector Equation	Vector Diagram
	$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2$	
	$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2$	
	$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3$	

Sample problems

1) Find the weight of the following objects
   a) 10.0 kg
   b) 50.0 kg

2) What would be the magnitude and direction of normal force acting on each mass in question 1) if they were sitting on a flat surface. Include an FBD

3) Find the net force on an object that is experiencing the following forces include the FBDs
   a) $20.0N\ [N], 40.0N\ [S]$
   b) $15.0N\ [U], 30.0N\ [D], 35.0N\ [U]$
   c) $100.0N\ [N], 40.00N\ [W]$
   d) $50.0N\ [W], 30.0N\ [E30.0°N]$

4) What would be the magnitude and direction of an additional force that would make F_{net} = zero in each case in questions 3).