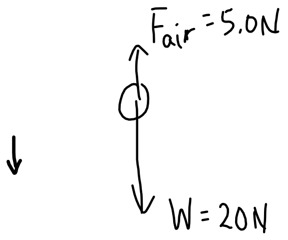
Resultant Forces

- A resultant force is just the sum of all forces acting on a body. You need to do vector addition!
- Sometimes it is referred to as the net force or total force.

Example

Determine the resultant force acting on a 20N weight which is falling through the air. The force of air resistance is 5.0N upwards.



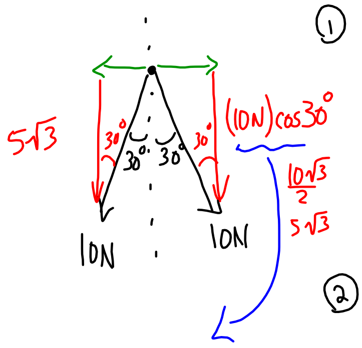
$\vec{F}_{net} = \vec{F}_{air} + \vec{W}$

$\vec{F}_{net} = 20N\,[down] + 5.0N\,[up]$

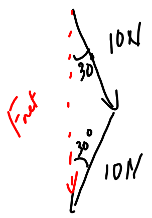
$\boxed{\vec{F}_{net} = 15N\,[down]}$

Example

Two forces, each 10N, act downwards on a nail. One force is inclined at 30° to the left of vertical and the other is inclined at 30° to the right of vertical. What is the resultant force?



① join vectors head to tail



② components (easier -> right triangles)

$\cos\theta = \frac{adj}{hyp}$

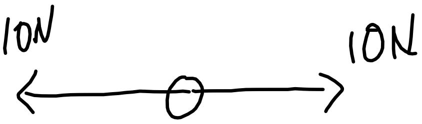
$adj = (10N)\cos 30°$

$5\sqrt{3} + 5\sqrt{3} = (10\sqrt{3})_N = 17N$

$\vec{F}_{net} = 17N\,[down]$

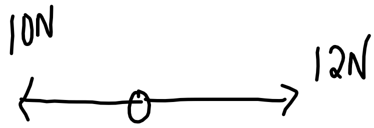
Balanced and Unbalanced Forces

Balanced: If two or more forces acting on a body add to zero, the forces are said to be balanced.



$$\vec{F}_{net} = 0$$

Unbalanced: If one or more forces acting on a body add to a non-zero force, the forces are said to be unbalanced.



$$\vec{F}_{net} = 2N \text{ [right]}$$

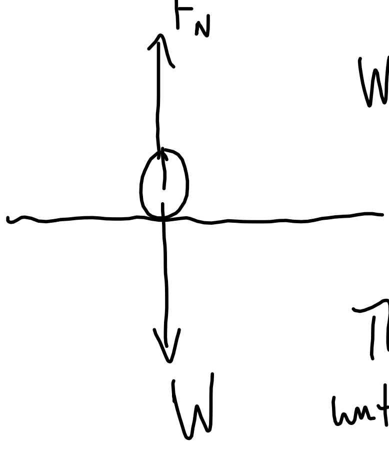
Newton's First Law of Motion

A body at rest will remain at rest, and a body which is moving will continue to move with a constant speed in a straight line, unless acted upon by an unbalanced force.

i.e. $\vec{F}_{net} = 0$ then $\vec{a} = 0$

(forces are balanced) (not moving or constant velocity)

Consider a ball resting on a table:



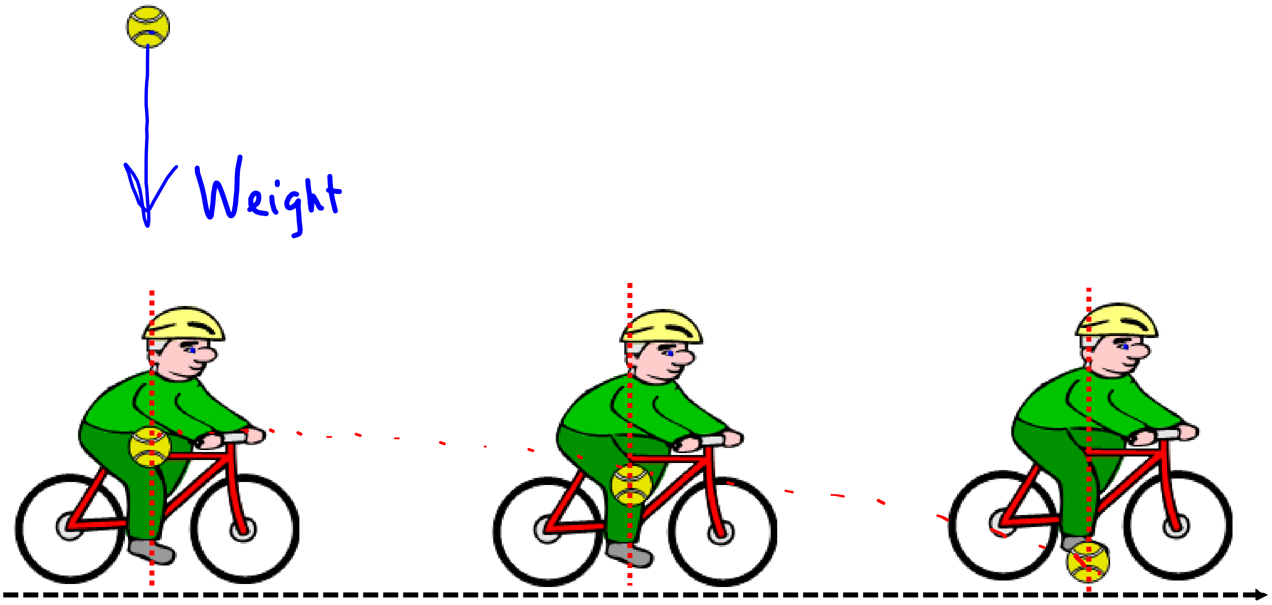
$W = F_N$ ∴ the forces are balanced and $\vec{F}_{net} = 0$ and $\vec{a} = 0$

The ball will remain at rest until there is an unbalanced force acting on it.

Newton's First Law

Consider a moving object like a ball falling from a cyclist's pocket when he is travelling at a constant velocity:

(neglect air resistance)



Newton's First law describes the motion of a body that results when there is no net force acting on the body

$$\Rightarrow \text{ if } \vec{F}_{net} = 0 , \quad \vec{a} = 0$$

Newtons Second law describes the motion when there IS a net force acting on the body

$$\Rightarrow \text{ if } \vec{F}_{net} \neq 0 , \quad \vec{a} \neq 0$$

Empirically it is found that the body accelerates

- in the same direction as the net force
- acceleration is proportional to the net force
- acceleration is inversely proportional to the mass.

Newtons Second law of motion

When an unbalanced force acts on a body, the body accelerates such that

- the acceleration is in the same direction as the net force
- the acceleration is proportional to the net force
- the acceleration is inversely proportional to the mass of the body.

$$a \propto F_{net} \quad \text{and} \quad a \propto \frac{1}{m}$$

Combining proportionalities: $a \propto \frac{F_{net}}{m}$

$$a = k \frac{F_{net}}{m}$$

* k is "special" and has a value of $1 kg \cdot ms^{-2} N^{-1}$

$$a = \frac{F_{net}}{m}$$

The mathematical expression for Newton's second Law of motion → $\vec{F}_{net} = m\vec{a}$

So what is a Newton?

The newton is that force which, when acting alone, will produce an acceleration of $1 ms^{-2}$ in a body of mass 1kg

Unit: $1N = 1kg\, ms^{-2}$

Translational Equilibrium

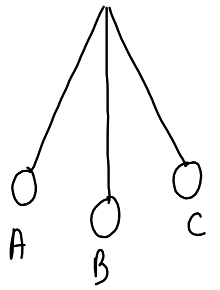
A body is in translational equilibrium if its linear acceleration is zero. That is, the body is at rest or it is moving with uniform motion in a straight line.

Condition for Translational Equilibrium

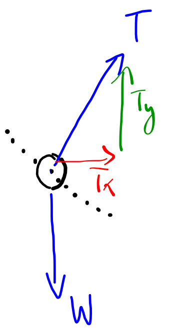
It is a consequence of Newton's First Law of motion that the condition for translational equilibrium is that the resultant of all the forces acting on the body in any direction is zero.

Example

Consider a pendulum in its maximum displacement at positions A and C and in its mean position B.

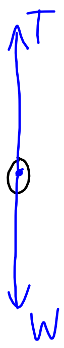


- Draw a FBD for the pendulum bob in each position.
- State whether the pendulum is in translational equilibrium at A, B or C.



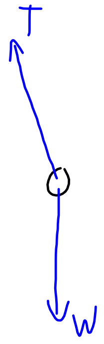
Not in translational equilibrium

$(F_{net} \neq 0)$



In translational equilibrium

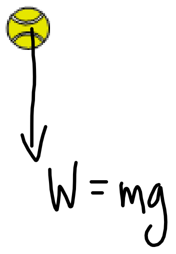
$(F_{net} = 0)$



Not in translational equilibrium

$(F_{net} \neq 0)$

Acceleration due to gravity



Now consider Newton's second law

$$\vec{F}_{net} = m\vec{a}$$

$$a = \frac{F_{net}}{m} = \frac{W}{m}$$

inertial mass

gravitational mass

$$a = \frac{W}{m}$$

$$a = \frac{\cancel{m}g}{\cancel{m}}$$

$$\boxed{a = g}$$

$\mathrm{ms^{-2}}$

$\mathrm{N\,kg^{-1}}$

$\cancel{\mathrm{kg}}\,\mathrm{ms^{-2}}\,\cancel{\mathrm{kg^{-1}}}$

* The acceleration due to gravity is numerically equal to the gravitational field strength

+ If we neglect air resistance, all falling bodies have the same acceleration