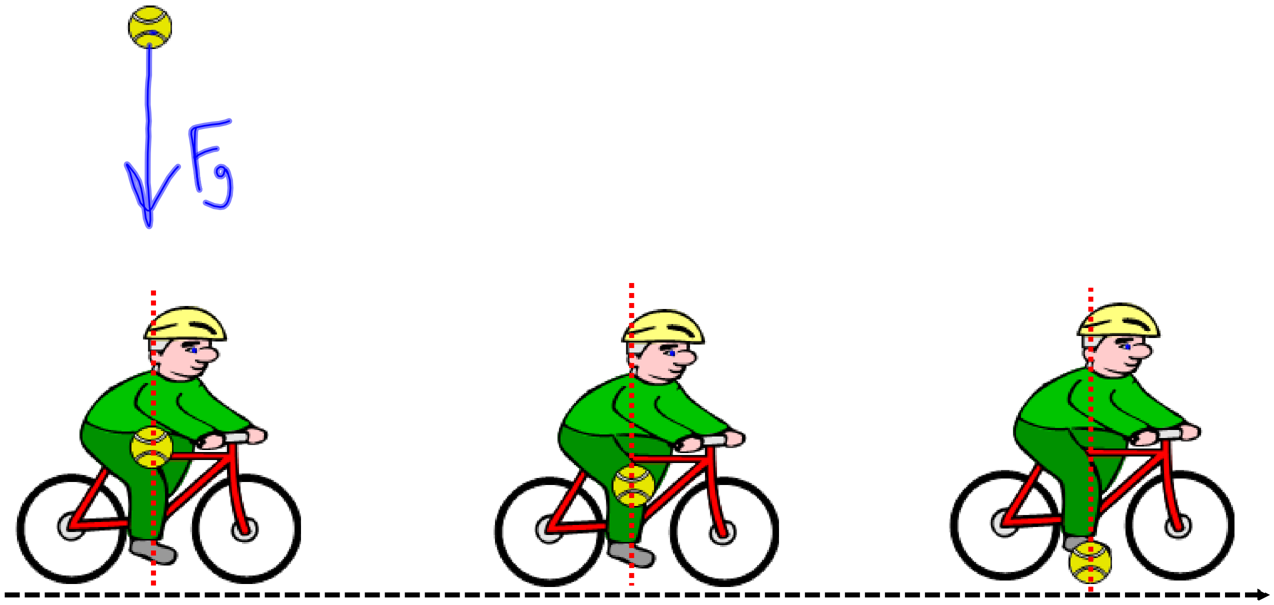
Newton's First Law

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

(neglect air resistance)



Translational Equilibrium

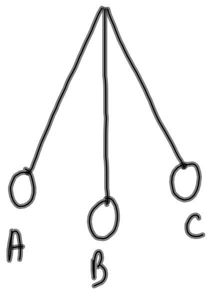
A body is in translational equilibrium if its linear acceleration is zero. That is, the body is at rest or it is moving with uniform motion in a straight line.

Condition for Translational Equilibrium

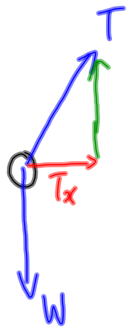
It is a consequence of Newton's First Law of motion that the condition for translational equilibrium is that the resultant of all the forces acting on the body in any direction is zero.

Example

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

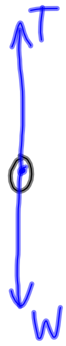


- Draw a FBD for the pendulum bob in each position.
- State whether the pendulum is in translation equilibrium at A, B or C.



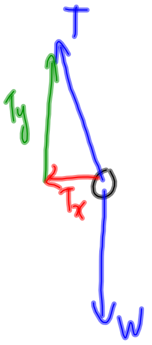
Not in translational equilibrium

($F_{net} \neq 0$)



In translational equilibrium

($F_{net} = 0$)



Not in translational equilibrium

($F_{net} \neq 0$)

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

$$\Rightarrow \text{ if } F_{net} = 0, \; a = 0$$

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

$$\Rightarrow \text{ if } F_{net} \neq 0, \; a \neq 0$$

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 forc
- the acceleration is proportional to the net force
- the acceleration is inversely proportional to the mas of the bod

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

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

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

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

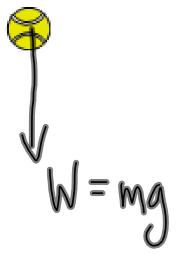
$$a = \frac{F_{net}}{m}$$

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

So what is a Newton?

Acceleration due to gravity

Now consider Newton's second law



$$F_{net} = ma$$

$$a = \frac{F_{net}}{\underset{\text{inertial mass}}{\textcircled{m}}} = \frac{W}{\underset{\text{gravitational mass}}{\textcircled{m}}}$$

* 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

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

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

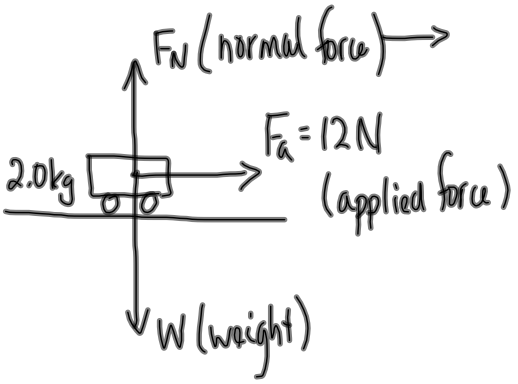
$$\boxed{a = g}$$

$$\mathrm{m\,s^{-2}} \qquad \mathrm{N\,kg^{-1}}$$

$$\mathrm{m\,s^{-2}} \longleftarrow \cancel{\mathrm{kg}}\,\textcircled{\mathrm{m\,s^{-2}}}\,\cancel{\mathrm{kg^{-1}}}$$

Example

A force of 12 N acts horizontally to the right on a frictionless cart of mass 2.0 kg Determine the acceleration of the car.



$F_a = 12\text{N}$

$m = 2.0\text{kg}$

$a = ??$

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

$$F_a = ma$$

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

$$a = \frac{12\bigcirc\!\!\!\!\text{N}}{2.0\cancel{\text{kg}}} \quad \cancel{\text{kg}}\cdot\text{ms}^{-2}$$

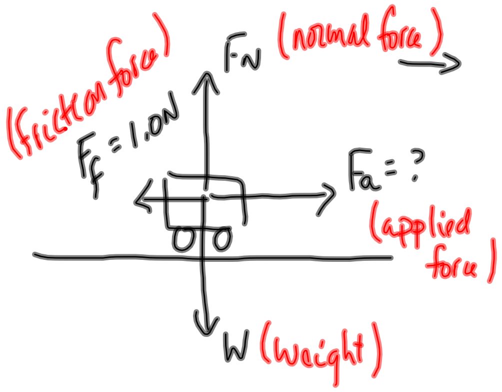
$$a = 6.0\ \text{ms}^{-2}$$

horizontally

$$\boxed{\vec{a} = 6.0\ \text{ms}^{-2}\ [\text{right}]}$$

Example

The cart (mass 2.0 kg) is to be accelerated horizontally to the right by 6.0 m s^{-2} againts a constant friction force of 1.0 N. What force is required?



$F_f = 1.0\text{N}$

$m = 2.0\text{kg}$

$a = 6.0\ \text{ms}^{-2}$

$F_a = ?$

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

$$F_a - F_f = ma$$

$$F_a = \overset{F_{net}}{\bigcirc\!\!\!\!\!\!\;ma} + F_f$$

$$F_a = (2.0\text{kg})(6.0\text{ms}^{-2}) + 1.0\text{N}$$

$$F_a = 12\text{N} + 1.0\text{N}$$

$$F_a = 13\text{N}$$

$$\boxed{\vec{F}_a = 13\text{N}\ [\text{right}]}$$

Example

The diagram shows a dynamics trolley of mass 1.5 kg on a board which is inclined at 20° to the horizontal. A friction force of 0.25 N acts between the trolley and the board. Draw and label a FBD. Calculate the acceleration of the trolley down the incline.

Example

A trolley of mass 0.20 kg is on a horizontal surface and is connected by a string to a mass of 0.10 kg. The string passes over a pulley such that the weight of the 0.10 kg mass causes the trolley to accelerate. There is a friction force of 0.10 N in the pulley and a friction force of 0.30 N in the wheels of the trolley. Calculate the acceleration of the trolley along the surface.

Example

A billiard ball of mass 0.15kg moving with a velocity of 10 m s^{-1} inclined at 45^{o} to the edge of the table bounces off the edge of the table at the same angles but with no change in speed. The ball is in contact with the edge of the table for 5.0 x 10^{-2} s. Determine the force acting on the ball during its collision with the edge of the table.