Newton's laws of motion

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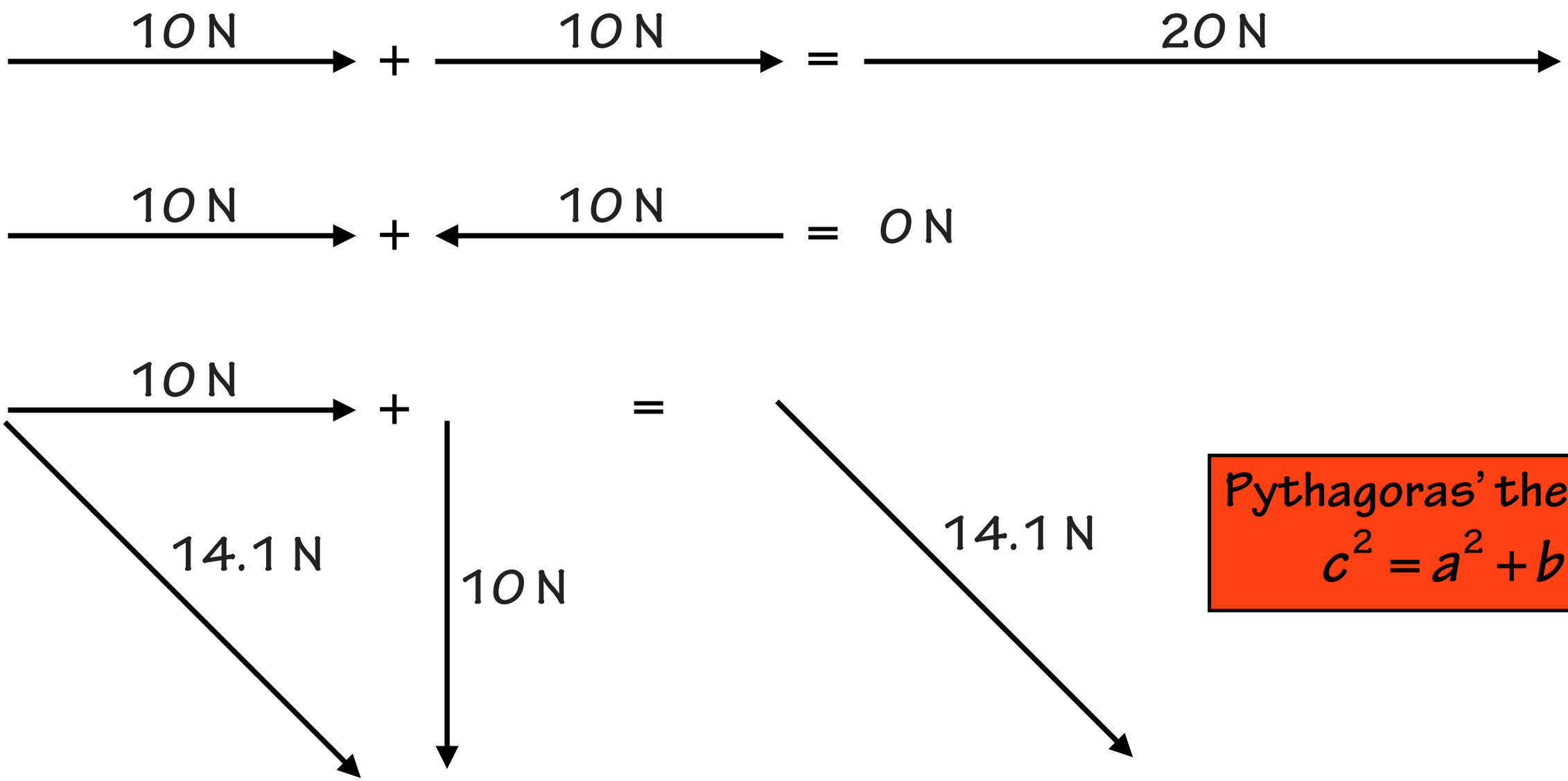
Forces

- Forces are **pushes** or **pulls** that act to change the shape or position of an object.
- Forces can be **contact forces**, such as: directly touching an object, friction between surfaces & drag as an object moves through a fluid.
- There are also **non-contact forces**, such as gravity, electrostatics & magnetism.
- Forces are vector quantities - having both a magnitude (measured in Newtons) & a direction.

Forces & vectors

- Two forces acting on an object are added as **vectors**.
- Vector addition - use the **head to tail rule**.

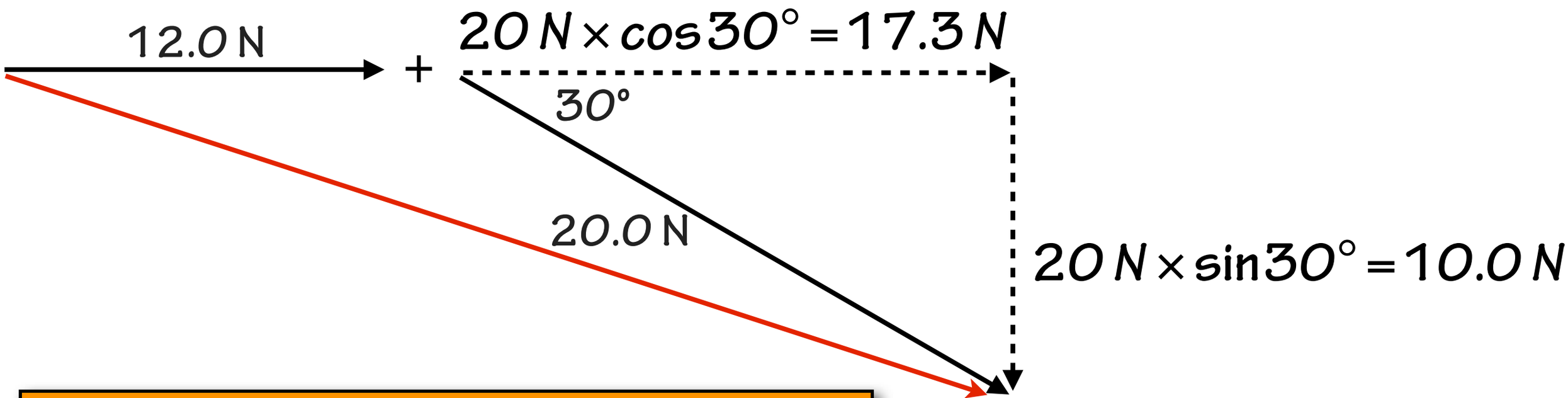


Pythagoras' theorem:

$$c^2 = a^2 + b^2$$

Resolving vectors

- Vectors at angles to each other or a surface can be resolved into parallel & perpendicular components.
- Parallel components of vectors can be added together.



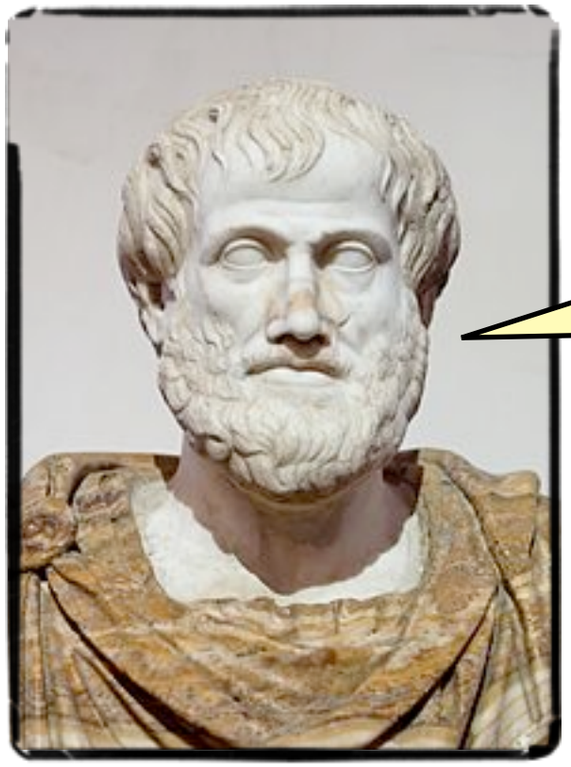
Parallel components : $F \times \cos\theta$
Perpendicular components : $F \times \sin\theta$

Horizontal forces: 12.0 N + 17.3 N = 29.3 N

Vertical forces: 10.0 N + 0 N = 10 N

Explaining motion - Aristotle vs Newton

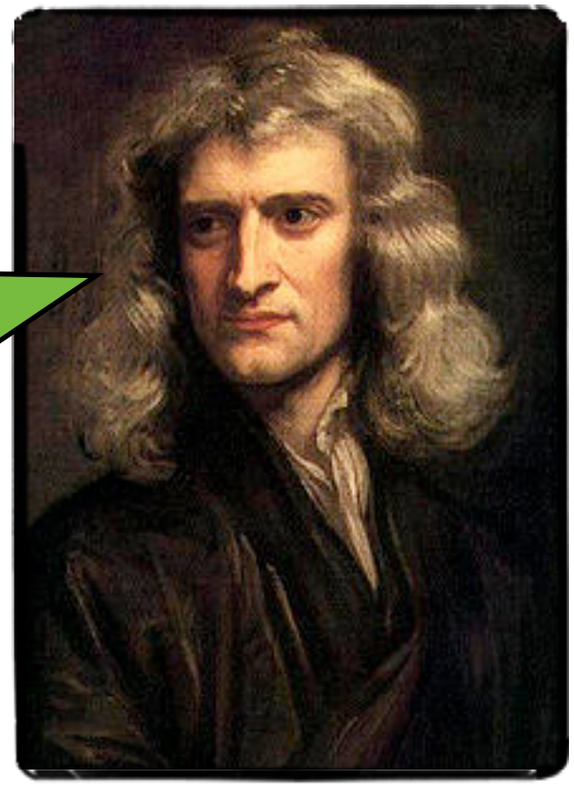
- For around 2000 years, Aristotle's idea that motion needs forces prevailed.
- Sir Isaac Newton used Gallileo's thought experiments about rolling balls to state that the forces are required to change the motion of an object.



Objects have a natural state of rest. Forces are needed to keep objects moving.

Aristotle
(384 - 322 BC)

Objects will keep moving unless there is an overall force acting upon them.



Sir Isaac newton
(1642 - 1727)

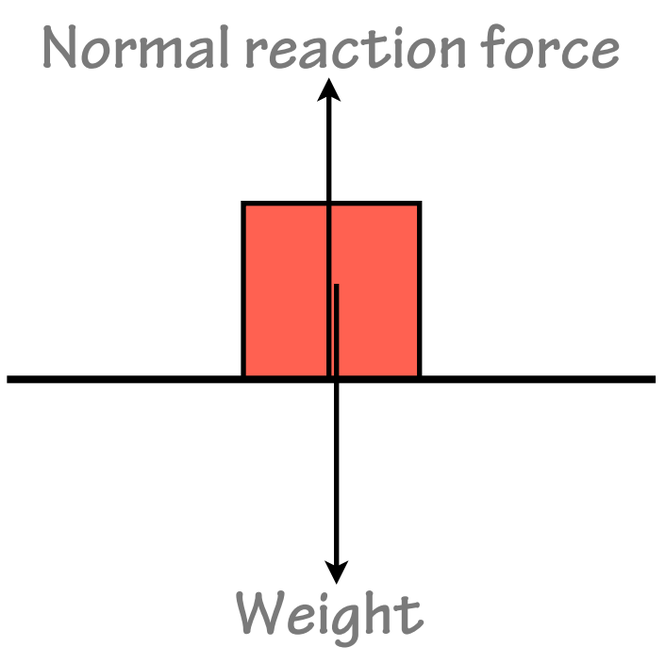
Newton's first law

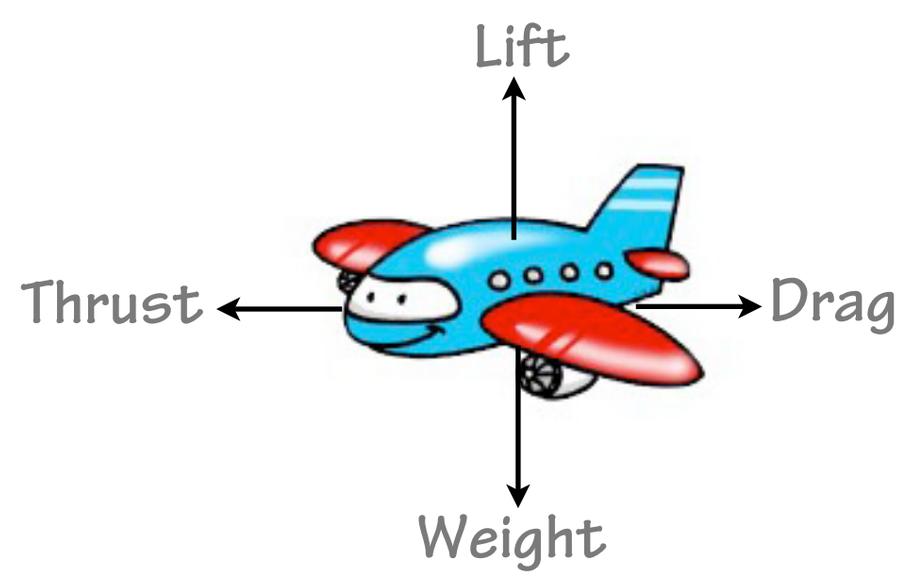
- **An object will keep a constant velocity (unless there is a non-zero net force acting on it).**

$$\sum F = 0$$

Examples include:

- Ice-skaters (pretty close to zero friction gliding forward)
- Objects at rest
- Falling at a constant speed
- Flying straight & level

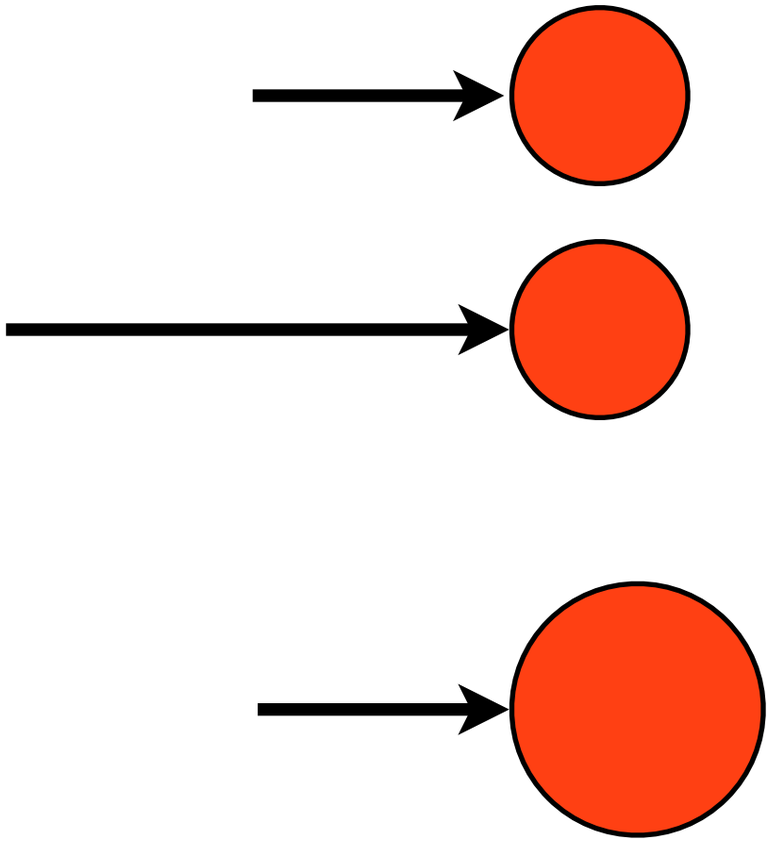




Newton's second law

- If there is a net force acting on an object, the motion of the object will change. This is an **acceleration**.
- **Acceleration increases with the net force, but decreases if acting over a larger mass.**
- For example, a hard kick of a soccer ball.
- Try kicking a medicine ball!

$$a = \frac{\Sigma F}{m}$$



Weight

- The **weight** of an object is the **force** that gravity exerts on it.
- The **mass** of the object is constant, but weight depends on gravity.
- Our feeling of weight comes from objects pushing up on us.

$$F = ma$$

$$W = mg$$

g = gravitational field strength (N/kg)
g = 9.8 N/kg on Earth (~ 10 N/kg)

What is the weight of a 60 kg person on the Earth?
What is it on the Moon?

Earth: $W = (60\ \text{kg}) \times (10\ \text{N/kg})$

$W = 600\ \text{N}$

Moon: $W = (60\ \text{kg}) \times (1.6\ \text{N/kg})$

$W = 96\ \text{N}$

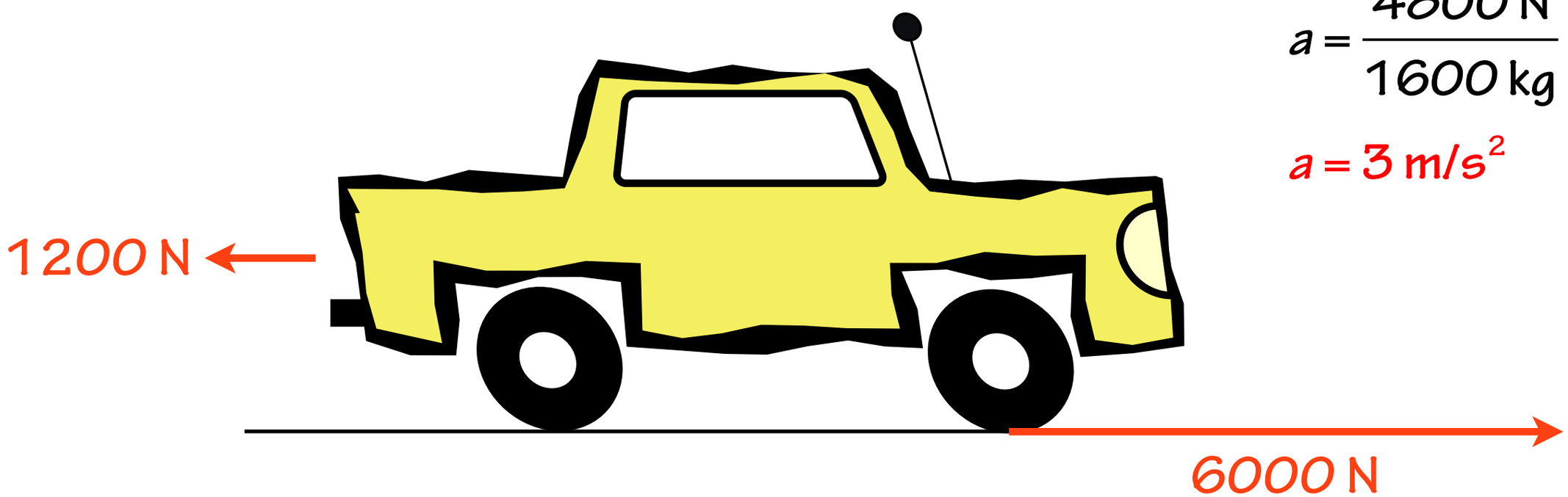
Calculating acceleration

- The engine of a 1600 kg car is apply to produce a force of 6000 N. There is 1200 N of friction and air resistance acting against the car. What is the acceleration of the car?

$$a = \frac{6000\ \text{N} - 1200\ \text{N}}{1600\ \text{kg}}$$

$$a = \frac{4800\ \text{N}}{1600\ \text{kg}}$$

$$a = 3\ \text{m/s}^2$$



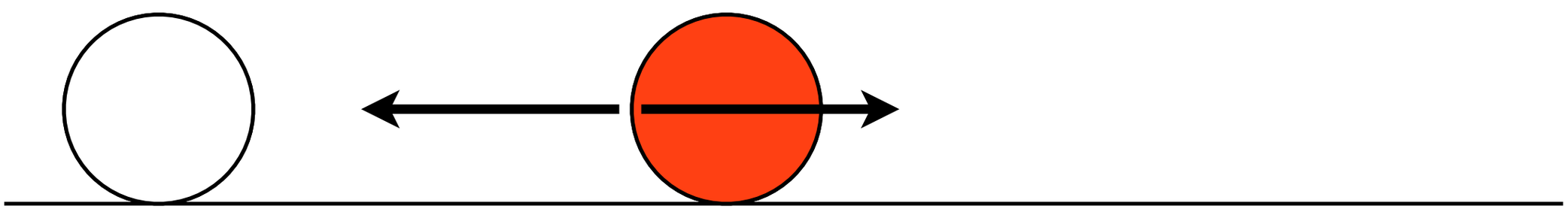
Net force = 4800 N

Newton's third law

- "Action & reaction forces".
- If one object applies a force to a second, the second object applies an equal force back onto the first.

$$F_{AB} = -F_{BA}$$

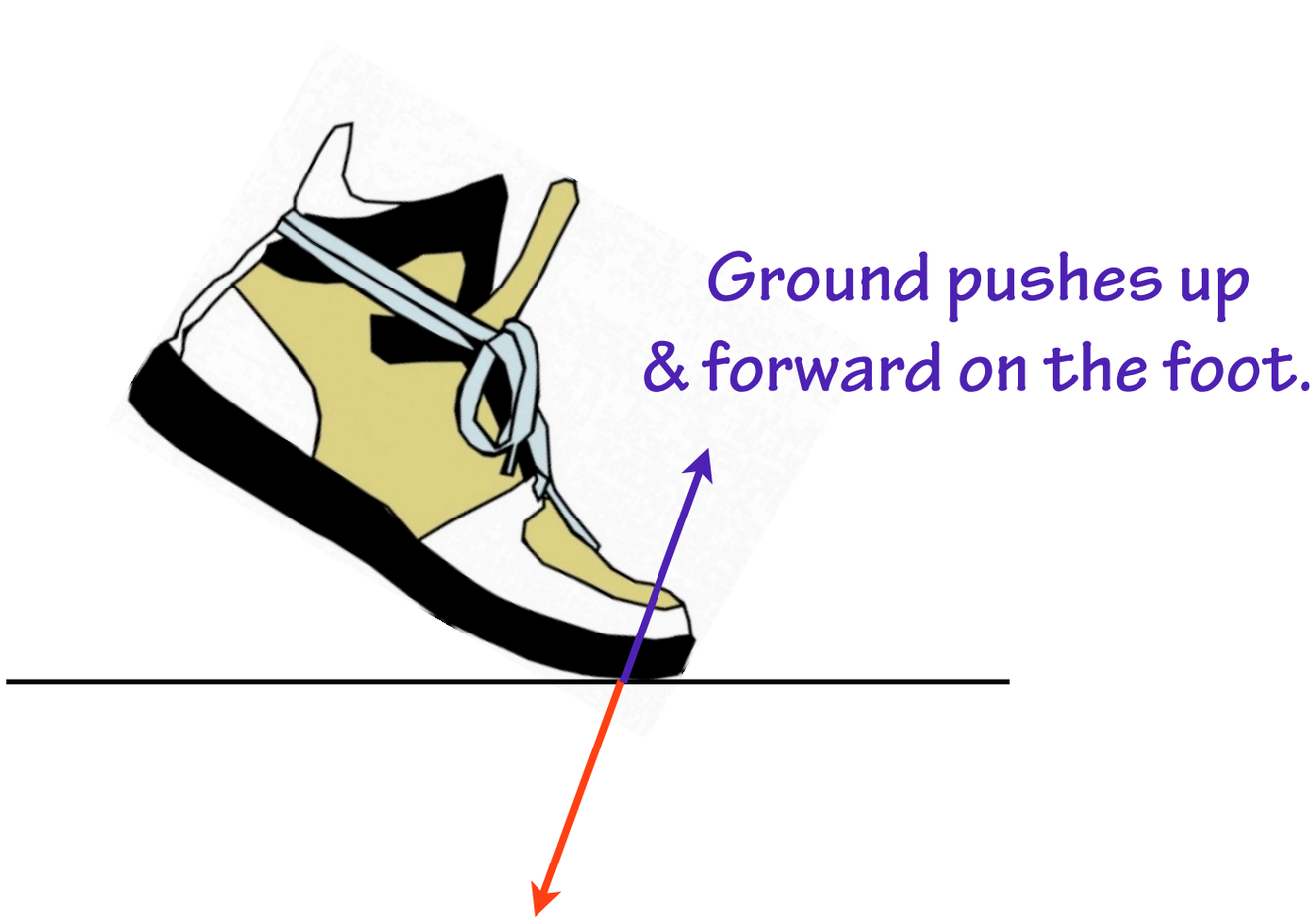
Red ball has been accelerated forward by force.

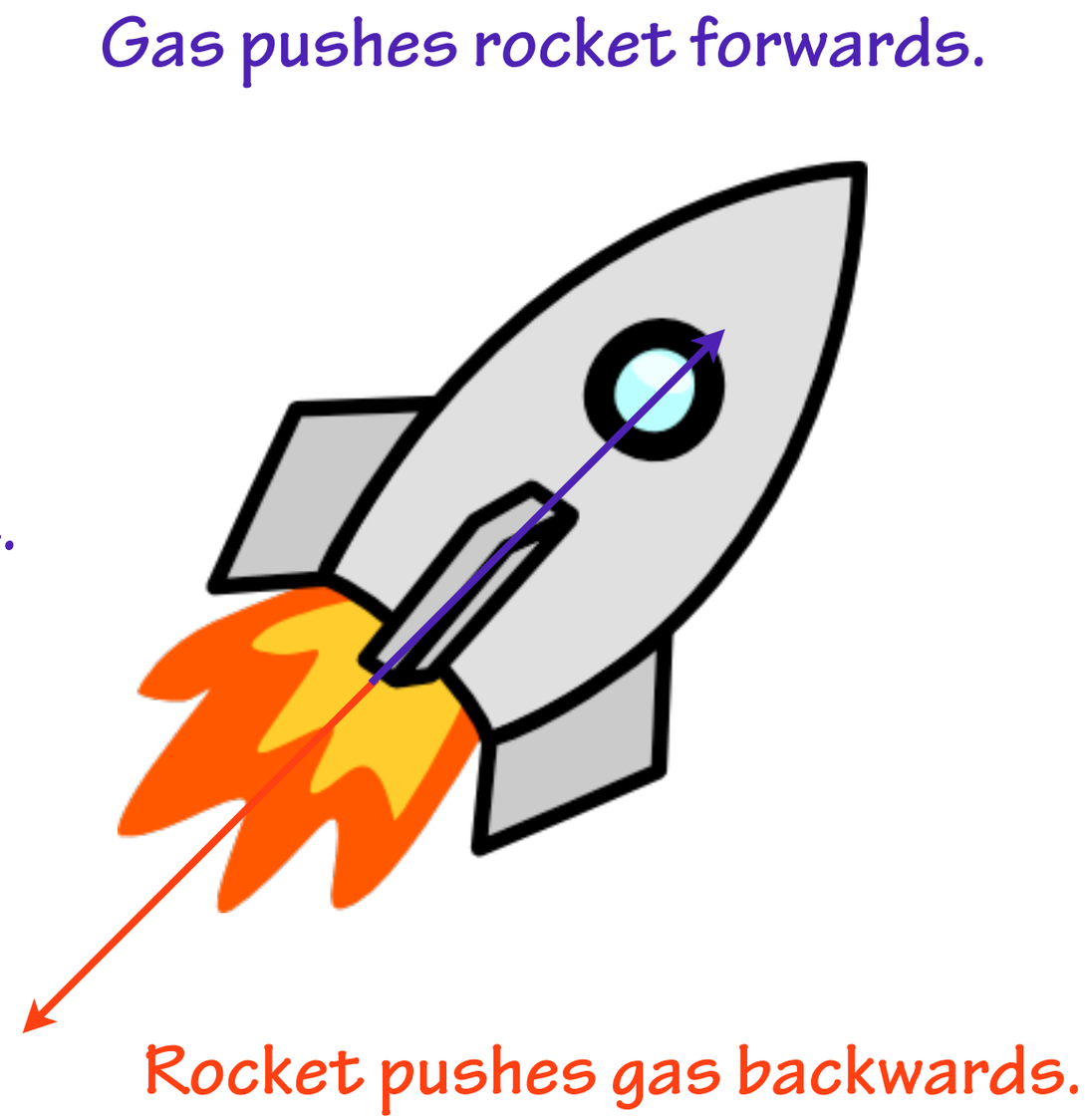


White ball has been stopped by force acting against the motion.

Moving forward

- To move forward, an object must push back onto another first.

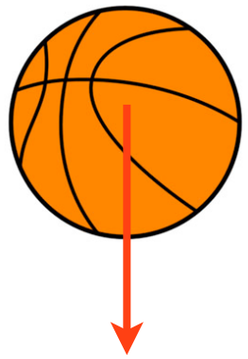




Gravity & Newton's third law

- The gravitational force of the Earth pulls the ball down.... what is the reaction to this force?
- **The ball pulls up on the Earth.**

Ground pulls the ball down.



But we don't notice this because the Earth has a far greater mass & less acceleration. (Newton's 2nd law)

Ball pulls the Earth up.

What if the ball weighed the same as the Earth?