Newton's laws of motion

- Forces
- Forces as vectors
- Resolving vectors
- Explaining motion - Aristotle vs Newton
- Newton’s first law
- Newton’s second law
- Weight
- Calculating acceleration
- Newton’s third law
- Moving forward
- Gravity & Newton’s third law
• 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.

\[ 10 \text{ N} + 10 \text{ N} = 20 \text{ N} \]

\[ 10 \text{ N} + 10 \text{ N} = 0 \text{ N} \]

\[ 10 \text{ N} + 14.1 \text{ N} = 14.1 \text{ N} \]

Pythagoras’ theorem:
\[ c^2 = a^2 + b^2 \]
Vectors at angles to each other or a surface can be resolved into parallel & perpendicular components.

Parallel components of vectors can be added together.

Horizontal forces: $12.0\,\text{N} + 17.3\,\text{N} = 29.3\,\text{N}$

Vertical forces: $10.0\,\text{N} + 0\,\text{N} = 10\,\text{N}$
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.
Newton’s first law

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

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

\[ \sum F = 0 \]
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!

\[
a = \frac{\sum F}{m}
\]
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.

\[ F = ma \]
\[ W = mg \]

\[ g = \text{gravitational field strength (N/kg)} \]
\[ g = 9.8 \text{ N/kg on Earth (} \sim 10 \text{ N/kg)} \]

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: \[ W = (60 \text{ kg}) \times (1.6 \text{ N/kg}) \]
\[ W = 96 \text{ N} \]
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.

Foot pushes down & back on the ground.

Ground pushes up & forward on the foot.

Rocket pushes gas backwards.

Gas pushes rocket forwards.
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.

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

What if the ball weighed the same as the Earth?