MOTION

Aristotle's Study

Aristotle's Law of Motion
This law of motion was based on false assumptions. He believed that an object moved only if something was pushing it. His arguments were based on everyday observations, rather than scientific experiments.

Argument:

(i) Forces are needed to keep things moving, because they stop when the forces are taken away (evidence – horse pulling a carriage).

(ii) The speed of the object depends on the size of the force (evidence – two horses pull a carriage faster than one horse).

Aristotle's Law of Motion:

The speed of an object is proportional to the force applied, $V \propto F$.

Problems with Aristotle's Explanation:

(i) Aristotle could not explain why objects fell to the ground without any visible force.

(ii) He could not explain why the moon and planets move for no apparent reason, so he invented explanations without scientific evidence.

Galileo's Achievements

Born: 1564
Died: 1642

He invented the scientific instrument, the telescope, which allowed him to make/ take accurate measurements, which supported his theories. He was the first to discover the Earth was not the center of the Universe, but in actual fact it circled around the Sun. His beliefs were against those preached by the church, and he was sentenced to house arrest for the remainder of his life. He also invented the scientific method, which we presently use when carrying out experiments.

Galileo's Study:

a) Pendulum
b) Motion and falling objects
c) The effect of friction on moving objects

Sir Isaac Newton

Born: 1642
Died: 1727

Achievements:

1. He studied the nature of light, and demonstrated that white light is made up of many colours.
2. Newton's Law of Gravitation.
3. Newton's New Law of Calculation.
4. He invented the first reflective telescope.
5. He invented new Mathematics, to handle data produced by scientific observations.
6. Newton's Laws of Motion.

Newton's First Law

Every body remains in a state of rest or continues to move in a uniform motion, in a straight line, unless acting on by an external force.

Inertia (Newton's 1^{st} Law can be used to explain "inertia")

This is the laziness or tendency of matter to resist changes in its motion. Inertia makes difficult for an object to start or stop moving, change direction or accelerate.

Example:
A passenger standing on a bus observes the effects of inertia, especially when the bus moves off and stops suddenly.

Newton's Second Law

When a force acts on a body, the rate of change on momentum is proportional to the applied force, and takes place in the direction on the force.

force = mass × acceleration

$$F = ma$$

1N is defined as the force needed to give a mass of 1kg an acceleration of $1m/s^2$

Newton's Third Law

If body A exerts a force on body B, then body B exerts an equal but opposite force.

Momentum (Newton's 1st and 2nd Laws can be used to explain Momentum)

momentum = mass × velocity

$$p = mv$$

units of momentum = kgm/s

Note:
Momentum is a vector quantity.

When a force acts on a body, it causes the velocity to change, and hence the momentum changes.

We can determine the force applied by measuring the rate of change of momentum.

$$F = \frac{m\Delta v}{t}$$

where: Δv = *change in velocity*
= *v – u (final velocity – initial velocity)*

Therefore:

$$F = \frac{m(v - u)}{t}$$

Impulse

We can calculate the impulse, which is equal to change of momentum. It is determined by multiplying the force by time.

$$Ft = mv - mu$$

units = Ns

Law of Conservation of Momentum

When two or more objects interact, the total momentum remains constant, provided that no external force acts on them.

total momentum before collision = total momentum after collision

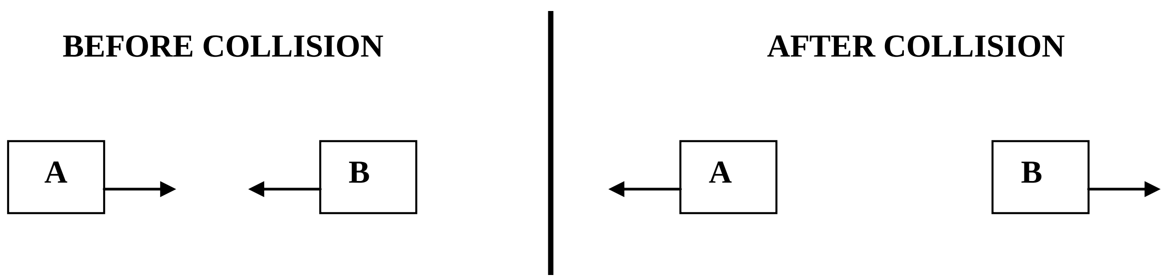
We use this law when dealing with collisions. There are two types of collisions: elastic or inelastic collision.

(N.B. Momentum is a vector quantity, and direction must be always taken into account, when doing calculations)

Elastic Collisions

An elastic collision is when two or more objects collide, and move apart, having lost little or none of their motion energy.

BEFORE COLLISION | **AFTER COLLISION**



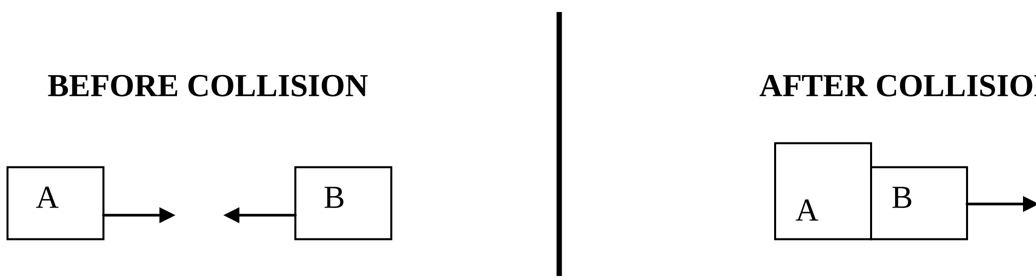
total momentum before collision = total momentum after collision

$$M_AU_A + M_BU_B = M_AV_A + M_BV_B$$

Inelastic Collisions

An inelastic collision is when two or more objects collide, stick together, and move off in one direction after the collision.

BEFORE COLLISION | **AFTER COLLISION**



total momentum before collision = total momentum after collision

$$M_AU_A + M_BU_B = (M_A + M_B)V$$

Examples:

A trolley A, 5kg, is traveling at 3m/s. Trolley B, 6kg, is traveling in the opposite direction at 5m/s. An elastic collision occurs, and trolley A moves opposite to the original direction at 4m/s. Calculate the speed of trolley B, after the collision.

A bullet of 100g was fired into a stationary target, of mass 4kg, the target and bullet moves off with a velocity of 5m/s. Calculate the velocity of the bullet before it hits the target.

<u>Terminal Velocity (Free Fall)</u>

When a fallen object has gained a velocity, a friction force ***(F_R)*** opposes its weight ***(W),*** the resultant downward force ***(F)*** can be calculated by

$$F = W - F_R$$

We can use this equation to calculate the acceleration of the object.

Since we know that

$$F = ma$$

And

$$F = W - F_R$$

We can therefore state

$$ma = W - F_R$$

Hence

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

As the velocity of an object increases so does the magnitude of the frictional force, this continues until the friction force reaches the same value as the weight. Since it acts in an opposite direction to the frictional force, the resultant force is zero,

$$W = F_R$$

$$W - F_R = 0$$

$$F = 0$$

At this point the acceleration is also zero so the object is falling at a constant speed. This constant speed is called terminal velocity, and it is the maximum speed for particular objects, free falling through liquids.

Example: **A marble falling through a viscous fluid.**

Stage A: When the marble is first released from rest, there's no frictional force ($F_R = 0$). Therefore $F = W$

Stage B: Velocity increases as the marble falls hence frictional force increases, but is less than the weight ($F_R < W$). The F which acts downwards is now $W - F_R$ ($F = W - F_R$)

Stage C: Terminal velocity is reached when the frictional force is equal to the weight of the marble ($W = F_R$). Therefore the resultant force is equal to zero, no acceleration ($F = 0$).

Example:

A woman of 70kg jumps out of an aeroplane, and before she could open her parachute she was falling at an acceleration of $7 m/s^2$. Calculate the frictional drag, if g = 10N/kg.

<u>Kinetic and Potential Energy</u>

Kinetic Energy

When work is done pushing an object (which accelerates) it gains motion energy, which we call kinetic energy. A resultant, or unbalanced, force applied to an object makes it accelerate and increases its kinetic energy. Therefore kinetic energy is the energy a body possesses because of its motion.

$$\mathbf{KE = \tfrac{1}{2}mv^2}$$

where: m is the mass of the object (kg)
v is the velocity of the object (m/s)

Potential Energy

This is stored energy which an object possesses because of its position or condition, like a stretched piece of string or rope. An object can have stored energy if it is held in a position where it can be influenced by gravity; this potential energy can be called gravitational potential energy.

$$\mathbf{PE = mgh}$$

where: m is the mass of the object (kg)
g is the gravity (N/kg)
h is the vertical distance (m)

Linking Potential and Kinetic Energy

Change of Kinetic Energy E = Change of Potential Energy E gain of E = loss of E
loss of E = gain of E

Motion in A Circle

Many objects move in circular paths or orbits. Examples can be a car turning a corner or a person riding on a roundabout. But for every case there must be an unbalanced or resultant force producing the motion in a circle, or else the objects would not move in a straight line, as described by Newton's first law of motion.

Centripetal Force

This is the external force required to make a body follow a circular path at constant speed. Hence centripetal force is a force requirement, not a particular kind of force. Any force can act as a centripetal force. The centripetal force always acts perpendicular to the direction of motion of the body.

$$\mathbf{F = \frac{mv^2}{r}}$$

where: m is the mass of the object (kg)
v is the velocity of the object (m/s)
r orbit radius (m)