Topic 1: Momentum and Energy

Forces

Newton's 3rd law (N3) states that **if body A exerts a force on body B, body B will exert an equal and opposite force on body A**. For example, a Physics teacher has a weight of 800N. This means the gravitational force of the Earth pulling the teacher is 800N, so there is also an 800N force pulling the Earth towards the teacher.

Impulse

Newton's 2nd law tells us that the force is equal to the rate of change of momentum.

$$F = \frac{\Delta p}{\Delta t}$$

Where **momentum** is defined according to this equation:

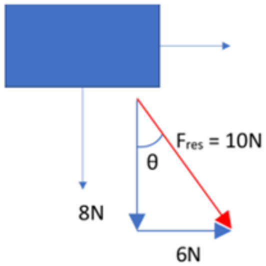
$p = mv$

As $p = mv$ and $a = {}^{\Delta v}/_{t}$ **Newton's 2nd law** can be written as follows:

$$\sum F = ma$$

Where $\sum F$ is the sum of the forces acting on the object.

Remember there may be multiple forces acting on an object so you must calculate the resultant force by adding vectors (see unit 1.1) before you can calculate the acceleration.



Momentum

Conservation of momentum:

The law of conservation of momentum states, **the vector sum of the momenta of bodies in a system stays constant even if forces act between the bodies, provided there is no external resultant force**. Which means the total momentum before an interaction must be equal to the total momentum after an interaction.

Consider this example:

Before colliding

The total momentum before is:

$p = mv$ = 2.0 × 8.0 + 1.5 × (-4.0)

= 10 kg m s^{-1}

Remember momentum is a vector quantity so the velocity of the green ball is -4.0 m s^{-1}

After colliding

The total momentum after must be 10 kg m s^{-1}.

10 = 2.0 × v + 1.5 × 2.0

Therefore, v = 3.5 m s^{-1}.

This is an example of an **inelastic collision** as the kinetic energy of before the collision is not equal to the kinetic energy after the collision, some **kinetic energy has been lost**.

In an **elastic collision** the kinetic energy before colliding is equal to the kinetic energy afterwards.

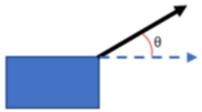
Energy

Work:

When a force is applied to an object that moves, work is done by that force.

$W = F\ x\ cos\theta$

Where θ is the angle between the force and the direction of movement.



The **work done is equal to the amount of energy transferred**. For example, if 100J of work is done to lift an object at a constant velocity, it will gain 100J of gravitational potential energy.

Gravitational potential energy:

Gravitational potential energy is the energy of an object due to its position above the surface of the Earth.

$$\Delta E = mg\Delta h$$

Kinetic energy:

Kinetic energy is the energy of an object due to its motion.

$$E = \frac{1}{2}mv^2$$

Power:

Power is the rate of transfer of energy, measured in Watts where 1 W = 1 J s^{-1}

$$P = \frac{E}{t}$$

W = Work done in Joules (J)

F = Force in N

E = Energy in J

m = mass in kg

x = extension of a spring in m

k = spring constant in N m^{-1}

v = speed or velocity in m s^{-1}

Δh = change in height in m

P = power in Watts (W)

t = time in s

d = distance travelled in the direction of the force in m

Elastic potential energy:

Elastic potential energy is the energy of an object due to it being deformed by a force.

It can be calculated in two ways, either using this equation:

$$E = \frac{1}{2}kx^2$$

Using Hooke's law (see unit 1.5), this equation can be converted to,

$$E = \frac{1}{2}Fx = \frac{F^2}{2k}$$

Efficiency:

Friction and other dissipative forces reduce the efficiency of a system as they reduce the useful energy transfer.
The efficiency can be calculated using this equation;

$$efficiency = \frac{useful\ energy\ transfer}{total\ energy\ input} \times 100\%$$

Energy

Conservation of energy:

The law of conservation of energy states that **energy cannot be created or destroyed**, it can only be **transferred** from one form to another.

This means that in any situation the **total energy of the system must remain constant**.

In reality, **friction and air resistance will cause some losses** during the transfer but the total energy must remain the same. Therefore, if the cannonball only gains 950J of gravitational energy the rest, 50J, must be **lost as heat due to the work done by air resistance**. The frictional forces can be calculated using the work equation,

$$Work = F\ d$$