WJEC (Wales) Physics GCSE

2.4: Further Motion Concepts

Detailed Notes

(Content in **bold** is for higher tier **only**)

Momentum

Moving objects have **momentum**, which means it is likely to **continue** travelling in the direction it is current heading in. The greater an object's momentum, the harder it is to change its direction. Momentum depends on **velocity** and **mass**.

$$p = mv$$

p is momentum (kg m/s), m is mass (kg) and v is velocity (m/s).

Newton's 2nd Law

In Newton's second law, **resultant forces** and **acceleration** of an object are related ($F=ma$). This law can also be used with the concept of momentum. The **force experienced** is related to the **change in momentum** over time.

$$F = \Delta p / t$$

F is force (N), ∆p is the change in momentum (kg m/s) and t is time (s).

The **faster** the momentum is changed, the **greater** the force experienced as the time over which the momentum change takes place has been reduced.

Conservation of Momentum

In a **closed system**, where no external forces act, the total momentum **before** and **after** an event remains the **same**. This includes explosions and collisions. Momentum is **conserved**.

$$momentum\ before = momentum\ after$$
$$m_1v_1 = m_2v_2$$

This concept can be used in calculations to find the **velocity** of objects after a collision or explosion.

Example 1:

*Two railway carriages collide and join to move off together afterwards. Carriage A has a mass of **12,000 kg** and moves at **5 m/s** before the collision. Carriage B has a mass of **8,000 kg** and is **stationary** before the collision. What is the velocity of the two carriages together after the collision?*

$$momentum\ before = momentum\ after$$
$$m_1v_1 = m_2v_2$$
$$(12000)(5) + (8000)(0) = (12000)(v) + (8000)(v)$$
$$60000 = 20000v$$

$$\Rightarrow v = 60000 / 20000$$
$$v = 3\ m/s$$

Example 2:

A 5kg cannonball sits stationary inside a 100 kg cannon. When fired, the cannonball moves forwards with a velocity of 40 m/s. What is the recoil velocity of the cannon?

$$momentum\ before = momentum\ after$$
$$m_1v_1 = m_2v_2$$
$$(5)(0) + (100)(0) = (5)(40) + (100)(v)$$
$$0 = 200 + 100v$$
$$-200 = 100v$$

$$\Rightarrow v = -200 / 100$$
$$v = -2\ m/s$$

The negative sign indicates that the canon moves in the opposite direction to the fired cannonball.

Newton's 3rd Law

Newton's third law describes how every action has an **equal and opposite** reaction. Momentum and **kinetic energy** can be considered in the same way and can indicate the **type of collision** occurring.

Elastic Collisions

In an elastic collision, kinetic energy is conserved so kinetic energy before equals kinetic energy after. Interactions between molecules on an atomic level are elastic, meaning kinetic energy is conserved.

$$kinetic\ energy\ before = kinetic\ energy\ after$$
$$\tfrac{1}{2}m_1v^2{}_1 = \tfrac{1}{2}m_2v^2{}_2$$

Inelastic Collisions

Most collisions in the natural world are not perfectly elastic meaning some energy is converted to other forms, so kinetic energy is not conserved. These collisions are described as inelastic. Momentum is conserved and energy is conserved, but kinetic energy is not.

Equations of Motion

The movement of objects can be quantified and related through a set of equations known as the **SUVAT equations**. SUVAT stands for:

$$v = u + at \qquad s = (u+v) / 2t \qquad s = ut + \tfrac{1}{2}at^2 \qquad v^2 = u^2 + 2as$$

s = displacement (m) ***u*** = initial velocity (m/s) ***v*** = final velocity (m/s)
a = acceleration (m/s^2) ***t*** = time (s)

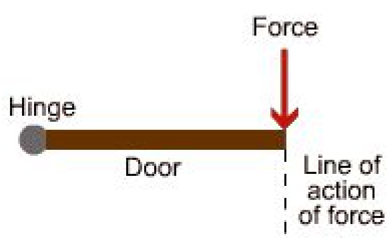
Moments

A moment is the **turning effect** of a force around a **fixed pivot** point. Moments can be utilised in things such as levers and hinges. The **size** of a moment (M) depends on the **force** applied and the **perpendicular distance** of the applied force from the pivot point.

$$M = Fd$$

M is the moment (Nm), F is the applied force (N) and d is perpendicular distance (m).

Moments help to understand why it is easier to do things like open a door at the handle rather than at the hinge. Increased distance from the hinge (pivot) means less force is required to unlock the door. This is because the moment is greater the further from the pivot a force is applied.



Moment acting on a door about a fixed hinge (s-cool.co.uk).

Balancing Moments

If **multiple moments** are acting at once, the **total** moment in that direction is the **sum** of the separate moments. Moments are **vectors**, so the **direction** they act in is important to consider.

$$M_T = M_1 + M_2 + \ldots$$

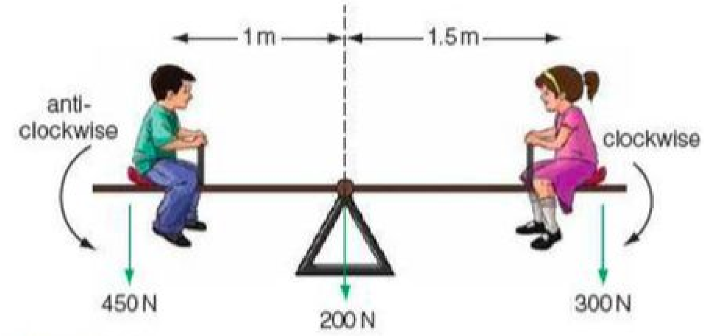
An object around a pivot can be **balanced** if two **equal** moments in **opposite** senses of rotation are applied. The **clockwise moment** will equal the **anticlockwise moment** so there is no overall resultant moment and the object remains stationary.

$$\textit{sum of clockwise moments} = \textit{sum of anticlockwise moment}$$

A see-saw is a good example of this, as the **weights** of the people sitting on it create **opposite moments** about the central pivot.

Here we see that the boy is heavier than the girl, but he is closer towards the pivot than she is. Consequently, in this scenario, the moments are balanced and so the seesaw remains in equilibrium.

anti-clockwise moment (boy) = 450 x 1 = 450Nm
clockwise moment (girl) = 300 x 1.5 = 450Nm



Moments on a seesaw around the central pivot (digestablenotes.com).