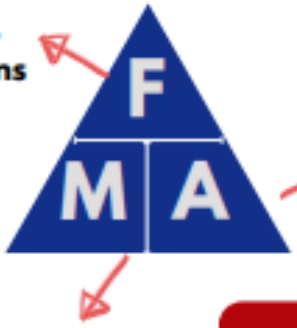
Biomechanics

Newton's Three Laws of Motion

- The Law of Inertia
- The Law of Acceleration
- The Law of Action/Reaction

The law of inertia - unless acted upon by an external force, an object at rest remains at rest, or if in motion, it continues to move in a straight line with constant speed.

The law of acceleration - a force upon an object causes it to accelerate according to the formula
Force = Mass x Acceleration



The law of action/reaction - for every action (force) there is an equal and opposite reaction.

Distance = Speed x Time

Speed = Distance ÷ Time

Time = Distance ÷ Speed

Scalar Quanity - a measurement which is described in size or magnitude without taking into account direction.

Acceleration - rate of change in momentum.

Acceleration =
(final velocity - initial velocity) / time taken

Acceleration =
(final momentum - initial momentum) / time taken

Momentum is closely linked to acceleration

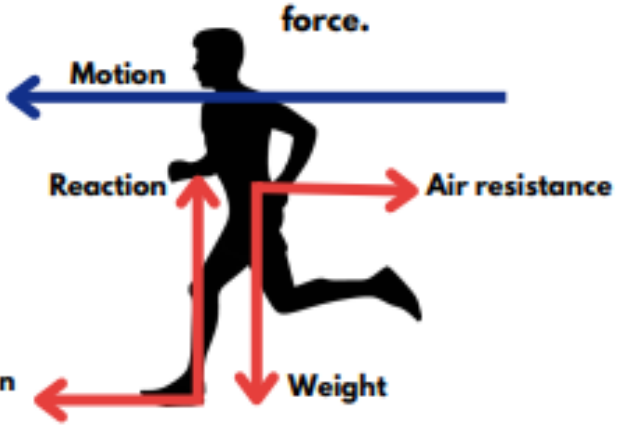
Force (Newtons, N) - a push or pull that tends to change the state of motion.
The **net force** determines the overall motion and is the sum of all forces acting on a body.

Centre of Mass (COM) - where an object's mass is considered to be concentrated.

Factors that affect stability

- Height of the COM
- Area of base of support
- Position of the line of gravity
- Mass of performer

Free body diagrams - show where forces are applied, and the relative size of the force.



Biomechanics - Lever Systems

Levers - something that generates movement, involving a pivot.

Joints in our bodies allow movement, with muscles producing the force required.

Fulcrum - the axis around which the lever rotates.

Load - the force of the thing that you want to move.

Effort - the force that is applied by the user of the lever system.

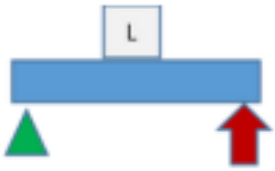
Lever systems can be classed as 1st class, 2nd class or 3rd class.
The class of a lever system depends on what can be found in the middle

- 1st Class = Fulcrum in the Middle
- 2nd Class = Load in the Middle
- 3rd Class = Effort in the Middle

First Class

- Rowing
- Tricep Dip
- Nodding

Second Class



- Calf Raise

Third Class

- Kicking a ball
- Bicep Curl

First class - can have a mechnical advantage or disadvantage.

Second class - mechanical advantage.

Third class - mechanical disadvantage.

Mechanical advantage - when a large load can be lifted with relatively little effort.

Mechanical disadvantage - when it takes a lot of effort to lift a relatively small load.

Mechanical Advantage =
Effort Arm ÷ Resistance Arm

First and Second class lever systems have slower movement.

Biomechanics - Linear Motion

Forces that act on an object during linear motion

Linear Motion

→ Describes a one-dimensional motion along a straight line

Gravity

→ The force that attracts a body towards the centre of the Earth

Air Resistance

→ A force that in the opposite direction to the motion of body moving through the air

→ Changing technique can decrease this and increase speed

Frictional Force

→ **Static frictional force** - force exerted on one surface by another when there is **no motion** between the two surfaces

→ **Sliding frictional force** - dry friction acts between two surfaces **moving relative** to one another

→ Appropriate footwear can decrease this.

Internal Muscular Force

→ Force generated by skeletal muscles

→ Weight training can increase this

Weight (measured in newtons)

→ = Mass x Gravity

Scalar quantity

→ Describes magnitude, not direction

Vector quantity → Describes magnitude and direction (+/-)

Describing accurate scalars/vectors

Weight- Mass x Gravity (measured in newtons)

Displacement - shortest route in a straight line between start and finish (m)

Velocity - how fast a body travels in a given direction (m/s)

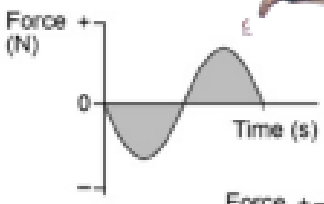
Acceleration - rate of change in velocity (m/s)

Momentum - product of mass and velocity of an object

Impulse

The time it takes for a force to be applied to an object or body

I - Impulse, Ns
F - Force (N)
T - Time (s)



Constant speed

Equal positive and negative impulse

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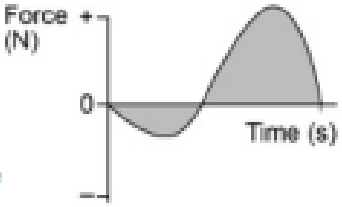
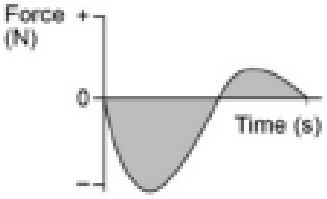


Acceleration

Large positive impulse



Deceleration

Large negative impulse

Biomechanics - Angular & Projectile Motion

Applying Newton's laws to angular motion

First Angular Law
→ A rotating body will continue with constant torque until a large enough external force is acted up upon it.

Angular Motion
→ Movement that takes place around an axis on a fixed point.

Torque
→ Force created that turns the body around an axis

Second Angular Law
→ The rate of change of angular motion is proportional to the force changing it, often down to position

Angular momentum = moment of inertia x angular velocity

Changing angular motion

Slow Down	Increase
↓	↓
Increase moment of inertia	Decrease moment of inerita
↓	↓
Opening out limbs and body	Tucking in body, bring arms together

Third Angular Law
→ When torque is applied, there will be always be an equal and opposite force.

Angular Displacement - smallest change in angle between the start and finish points of a **rotation**. It is measured in **degrees** and **radians**

Angular Velocity - rotational speed of an **object** (rate of change of angular displacement)

Angular Acceleration - rate of **change** of angular **velocity**.

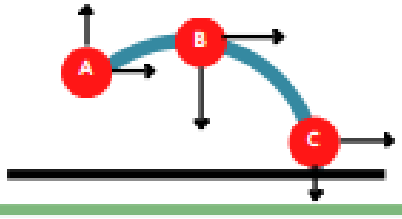
Projectile motion refers to factors affecting objects through into the air, such as shot put, discus and javelin

Horizontal displacement
→ Shortest distance from starting to finish point

Flight Path (parabola) in shot put and badminton

Remember:
1. Height - the **higher**, the better
2. Speed - the **faster**, the better
3. Angle of release - **45 degrees** is optimum

Example of horizontal and vertical vectors on a shot put flight path:



Factors affecting horizontal displacement
→ Gravity
→ Air resistance

Biomechanics - Fluid Mechanics

Dynamic Fluid Force

- The study of an object that travel through a liquid or gas
- Main principles are drag and lift

Drag

Acts opposite to motion and slows something or someone down

- **Surface Drag** - Refers to friction.
  E.g. when a football rolls across the grass
- **Form Drag** - Refers to streamlining.
  E.g. cyclist gets low to maximise this and increase speed

Lift - Explained by the Bernoulli Principle.

The more lift a sporting object has, the longer and further it will fly.

Bernoulli Principle - The angle of release of an object affects how air passes over the top and bottom of an object. Air molecules exert less pressure when they travel faster and more pressure when they travel slower.

Upward Lift

E.g. the flight of a discus

1. The performer should aim to release the discus at the optimal angle (45 degrees)
2. Air travels faster above the discus, creating low pressure
3. Air travels slower below the discus, creating high pressure
4. Pressure moves from high to low pressure, so the discus lifts higher into the air, travelling further.

Downward Lift

E.g. Cyclists

1. Cyclists gets in a low, streamlined position
2. Air travels slower above the cyclist, creating high pressure
3. Air travels faster against the cyclist, creating low pressure
4. Pressure moves from high to low pressure, enabling cyclist to maintain speed at corner