Biomechanics

- **Biomechanics –** The study of human movement and associated laws and principles
- **Linear Motion –** Motion in a straight or curved line, with all body parts moving the same distance at the same speed in the same direction

Newtons Laws of Motion – Newtons 1st Law (Intertia)

- **Newtons 1st Law –** A body or object has gravity that pulls the mass down to the ground

The greater the mass the greater the inertia to change its state of motion/rest

' a body will continue in its state of rest or uniform velocity unless acted upon by an external or unbalanced force'

- **Inertia –** The resistance an object has to a change in its state of motion

If an object is at rest it will remain still. If it is moving in one direction it will continue to do so at the same speed until another force is exerted upon
The bigger the mass, the larger the inertia. This means that more force will be needed to change its state of motion

E.G the player will be in a state of rest before they leave the ground. The player must exert a greater force into the ground than their own weight

Newtons Laws of Motion – Newtons 2nd Law (Acceleration)

- **Newtons 2nd Law –** Momentum is the amount of motion possessed by a body

This acceleration is proportional to the force placed on it

' the rate of change of momentum of a body is proportional to the size of the force applied and acts in the same direction as the force applied '

Force = Mass X Acceleration / F = Ma

E.G the basketball player will accelerate upwards. The greater the forces the greater the acceleration which means that the player will jump higher

Newtons Laws of Motion – Newtons 3rd Law

- **Newtons 3rd Law –** A force that is applied to an object will react with equal or opposite force

' for every action force applied to a body there is an equal opposite reaction force '

E.G the player pushes downwards on the ground and the ground applies an equal and opposite force upwards on the player

Net Force

- **Net Force –** The sum of all forces acting on a body, also termed resultant force

It is the overall force acting on a body when all individual forces have been considered

If net force force = 0, there is no change in motion as the forces are balanced

Balanced Forces

- **Balanced Forces –** These occur when 2 or more forces acting on a body are equal in size and opposite in direction

Net force = 0, the body will remain at rest or in motion with constant velocity

Unbalanced Forces

- **Unbalanced Forces –** These occur when 2 forces are unequal in size and opposite in direction

Weight

- **Weight –** The gravitational pull that the earth exerts on a body

Weight (N) = Mass X Acceleration due to Gravity

Weight force is always present and acts downwards from the body's centre of mass

Reaction

- **Reaction –** The equal and opposite force exerted by a body in response to the action force placed upon it

It is a result of Newtons 3rd law of motion and is always present when 2 bodies are in contact

Friction

- **Friction –** The force that opposes the motion of 2 surfaces in contact

Friction is Affected by …

- Roughness of the ground surface
- Roughness of the contact surface
- Temperature
- Size of normal reaction

Air Resistance

- **Air Resistance –** The force that opposes the motion through the air

It is a form of fluid friction and is measured in Newtons (N)

Air Resistance is Affected by …

- Velocity
- Shape
- Frontal cross – sectional area
- Smoothness of surface

Forces

Internal Force

- **Internal Force –** generated through the contraction of skeletal muscle

External Force

- **External Force –** Come from outside the body

Factors Affecting a Generated Force

- Size of force
- Direction of the force
- Position of application of force

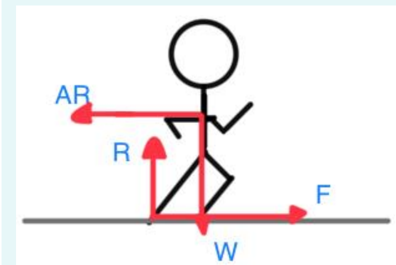
Free Body Diagram

Weight (W)
From centre of mass extending vertically down

Reaction (R)
From the point of contact extending vertically upwards

Friction (F)
From the point of contact, usually horizontally in the direction of motion

Air Resistance (AR)
From the centre of mass extending horizontally against the direction of motion



Friction

- **Friction –** The resistance to motion of 2 moving objects or surfaces that touch

Increased roughness = Increased friction (contact surface)
Increased reaction force = Increased friction
Increased temperature = Increased friction

Biomechanics

- Biomechanical Principles (Newton's Laws of Motion, Force , the use of Technology, Stability & Lever Systems)

Air Resistance

- **Air Resistance –** Opposes the motion of a body travelling through the air

Depends Upon …

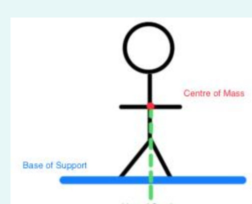
Velocity of Moving Body
Cross – Sectional Area of Moving Body
Shape / Surface Characteristics

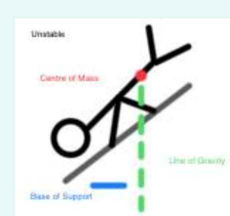
Decreased Frontal Cross – Sectional Area = Decreased AR
Aerodynamic = Decrease AR
Smooth Surface = Decrease AR
Increased Velocity = Increased AR
Air Density Decrease = Decrease AR

Centre of Mass

- **Centre of Mass –** The point at which the body is balanced in all directions

It's location is around the naval when standing in the anatomical position but will change during movement
The centre of mass can move outside the body and acts as a point of rotation
Stability is dependant on the Centre of Mass being directly above the base of support





Stability

- **Stability –** This is the ability to resist motion applied to it

It is also the ability to withstand a force and return back to the original position

Factors Affecting Stability
Mass of the Body & Height of Centre of Mass
Base of Support & Line of Gravity & Body Shape

Factors Affecting Stability

Body Shape
The distribution of body parts can affect centre of mass which can affect stability

Mass of the Body
The greater the mass the greater the inertia required to displace it

Height of Centre of Mass
The lower the centre of mass the greater the stability

Base of Support
The greater the size of the base the greater the stability

Line of Gravity
The more central the line the better the stability

Levers

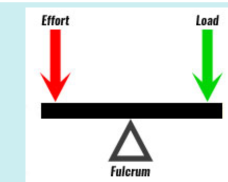
Levers consist of 3 components; Fulcrum (F), Effort (E), and Load (L)

- **Fulcrum –** The fixed point or pivot (joint)
- **Effort –** Point where the force/effort is applied (muscular force)
- **Load –** Point where the weight/resistance is coming from (resistance/weight of the limb)

Levers can be classified as; First Class, Second Class or Third Class

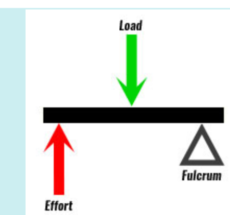
First Class Lever (EFL)

- **First Class –** This is a lever where the fulcrum (pivot) Occurs between the effort and the load



Second Class Lever (ELF)

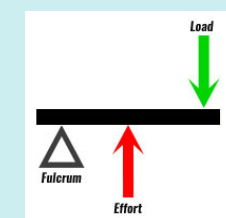
- **Second Class –** This lever occurs when the load is between the effort and the fulcrum



Third Class Lever (FEL)

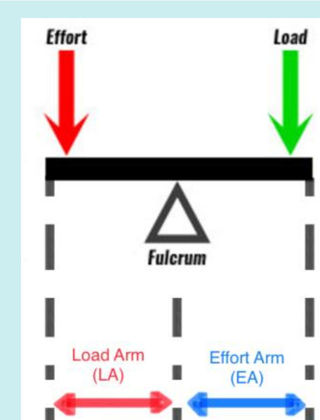
- **Third Class –** This lever occurs when the effort lies between the fulcrum and the load

This is very common in human movement



Type	Mid	Order
1	F	EFL
2	L	ELF
3	E	FEL

Effects of a Lever on the Human Body

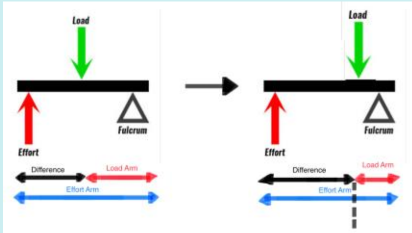


The extent to which a lever can increase speed depends upon the relative lengths of the load arm (LA) and effort arm (EA)

- **Load Arm –** Part of the lever between the fulcrum and the load
- **Effort Arm –** Part of the lever between the fulcrum and the effort

Mechanical Advantages and Disadvantages

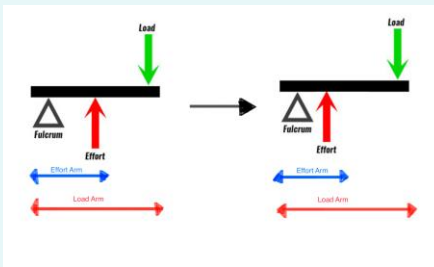
Class 2 Lever



By shortening the load arm less force is needed to move the same load, it becomes easier

Class 3 Lever

Most levers in the body are 3rd class levers where the load arm is always greater than the effort arm
The longer the load arm of the lever, the greater the speed of the effort arm



Force, Momentum, Acceleration and Weight

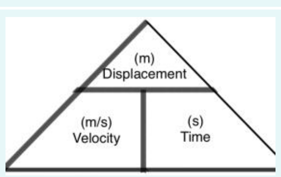
Balanced Force	Unbalanced Force
• **Balanced Force –** Two (or more) (opposing) forces are equal (in size) No change in motion Constant velocity/rest occurs	• **Unbalanced Force –** Two (or more) (opposing) forces are not equal (in size) Change in motion Acceleration/deceleration occurs

Mass	Weight
• **Mass –** Made up of bone, muscle fat, tissue and fluid It is a scalar quantity because it does not have direction	• **Weight –** Is the force on a given mass due to gravity Gravity is a constant value and means that an objects mass can be measured by its weight Weight is a vector quantity because it has both size and direction

Speed	Velocity
• **Speed –** The rate of change of position, it is a scalar quantity as it does not consider direction Speed = Distance Covered (M) / Time Taken (S)	• **Velocity –** The rate of change of position with reference to direction This means that it is a more precise description of motion and is a vector quantity Velocity = Displacement (M) / Time Taken (S)

Both of these terms can be defines as ‘ the rate of change of velocity’

Acceleration occurs when velocity increases and deceleration decreases



Momentum	Acceleration
• **Momentum –** The product of the mass and velocity of an object A large mass, coupled with the ability to run at a high velocity, results in a high momentum Momentum (kg/m/s) = Mass (kg) x Velocity (m/s)	• **Acceleration –** Rate of change of velocity Acceleration = Final Velocity – Initial Velocity / Time

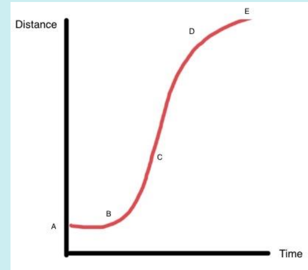
Ways to Increase Acceleration

- Increase force / velocity / speed
- Increase friction
- Reduce mass / weight
- Improve technique
- Reduce air resistance

Force = Mass x Acceleration

E.G 94kg x 2.41 m/s/s = 226.54 N

Distance / Time Graph

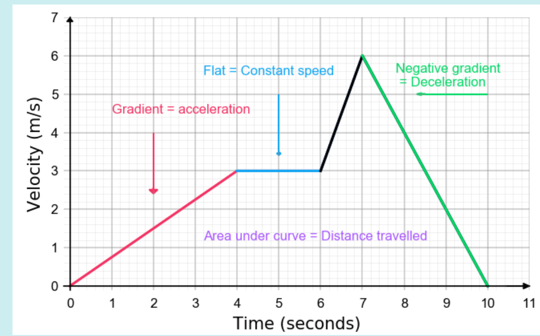


Distance time graph showing the motion of a 100m sprinter

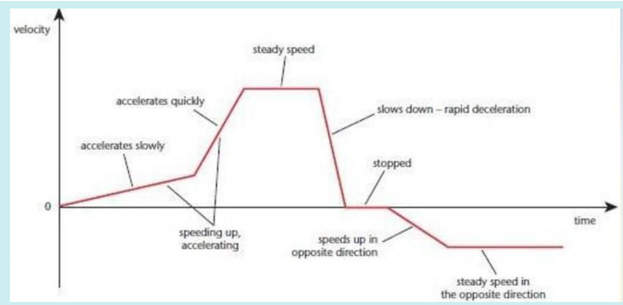
B = Rest
C = Acceleration
C —> D = Constant Speed
D –> E = Deceleration

Speed / Time Graph

Base x Height / 2 = Triangle area
Length x Width = Rectangle area



Velocity/ Time Graph

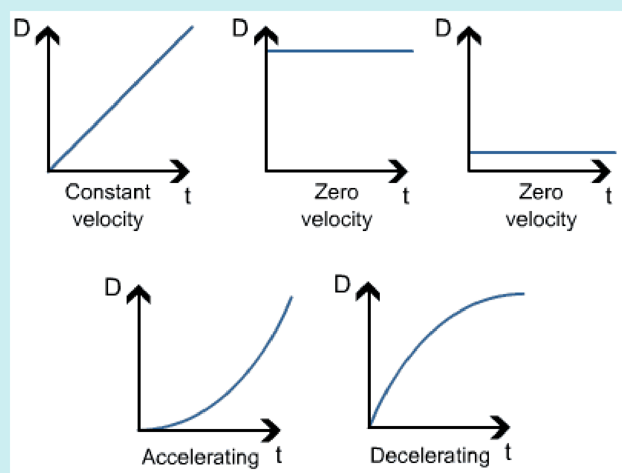


Velocity / time graphs show the velocity of an object over time

The curve indicates the acceleration of the body

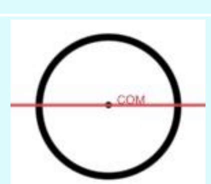
A negative curve below the x – axis shows a change in body’s direction

Linear Motion Graphs

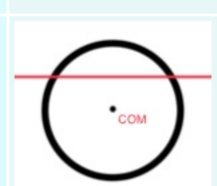


Velocity/time graphs show the velocity of an object over time

Linear Motion	Angular Motion
• **Linear Motion –** Motion in a straight or curved line, with all body parts moving the same distance at the same speed in the same direction	• **Angular Motion -** Movement of a body or part of a body in a circular path about an axis of rotation This occurs when a force is applied outside the centre of mass



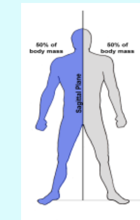
Direct force = Passes through centre of mass (COM)

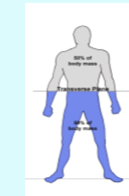


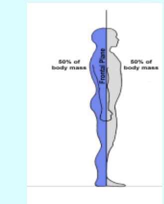
Eccentric force = External forces passes outside of the centre of mass

Planes of Movement

Sagittal	Transverse	Frontal
• Divides the body into anterior (front) and posterior (back) • Adduction and Abduction • Cartwheel	• Divides the body into superior (upper) and inferior (lower) • Horizontal flexion and extension • Twisting in a discus throw	• Divides the body into left (medial) and right (lateral) • Flexion and Extension • Kicking a football







Angular Velocity

A vector quantity as it makes reference to direction, angular velocity refers to the angular displacement that is covered in a certain time

Angular Velocity = Angular Displacement (rad) / Time Taken (s)

Angular Motion Quantities

- **Inertia –** Resistance to change in linear motion
- **Moment of Inertia (MOI) –** Therefore resistance of a body to angular motion

MOI Depends Upon 2 Factors ...

Mass of the body / object

➢ The greater the mass the greater the resistance to change and therefore the greater the moment of inertia

Distribution of mass from the axis of rotation

➢ The closer the mass is to the axis of rotation, the easier it is to turn – so the moment of inertia is low

Increasing the distance of the distribution of mass from the axis of rotation will increase the moment of inertia

Moment of Inertia = Mass (kg) / Distribution of Mass from the Axis (m2)

- **Angular Momentum –** It involves an object or body in motion around an axis

It depends upon the momentum of inertia and angular velocity. If momentum of inertia increases, angular velocity decreases and vice versa

Angular Momentum = MOI (kgm2) / Angular Velocity (rad/s)

Analysis Through Technology

- **Limb Kinematics –** Kinematics is the study of movement in relation to time and space

3D or optical motion analysis records an athlete performing a sporting action or a patient performing normal bodily movement

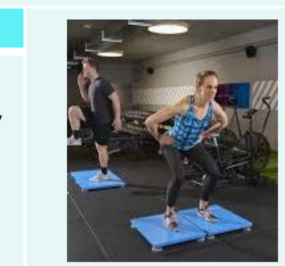
+	-
The data produced are immediate, objective and highly accurate and can be used by coaches to d just technique and improve performance The motion can focus on a specific limb and analyse technique	The accuracy and repeatability of results depends on the correct placement of the bodily markers and the mathematical principles the results are based upon do not cater for individual differences

Force Plates

- **Force Plates –** Ground reaction forces can be measured in laboratory conditions using force plates

Data from an athlete balancing, running or jumping on a force plate can be used to assess the size and direction of forces acting on the athlete, acceleration rates, work and power output

+	-
The site of the force and time the force is applied can be displayed in three planes of motion The use of force plates gives immediate, accurate and reliable results that biomechanists can use to analyse performance and health	They are specialist, expensive and usually housed in laboratory conditions, which can force some performers to adapt the way they run or jump in a real life sporting situation, limiting their potential use



Wind Tunnels

- **Wind Tunnels –** objects as small as a cycle helmet or as large as a F1 car may be tested for aerodynamic efficiency

The object is places inside the wind tunnel with instruments to measure the forces produced by the air against its surface

The aim is to improve the flow of air around an object, streamlining its path through the oncoming air and potentially increasing lift or decreasing drag

+	-
The use of wind tunnels allows engineers to have tight control on environmental variables such as wind speed or wind direction, and gives them the ability to control cross winds and measure air resistance and flow with precision accuracy in a very time efficient manner	These are very specialist facilities mainly housed in engineering bases. They are very expensive and require complex analysis of the results by research professionals

Factors That Affect Magnitude of Air Resistance

- Velocity
- Mass
- Frontal cross sectional area
- Streamlining and shape
- Surface characteristics

- **Fluid Mechanics –** The study of the forces acting on an object through the air or water
- **Air Resistance –** This is a force that opposes the motion of a body travelling through the air
- **Drag -** The force that opposes the direction of motion through the water

Air Resistance and Drag Depend Upon …

The velocity of the moving body —> a greater velocity results in a greater resistance

Frontal cross sectional area of the paving body —> the larger the cross sectional area, the greater the air resistance

Streamline and shape —> the more streamlined or aerodynamic the shape of the body in motion, the lower the air resistance or drag

Surface characteristics —> the smoother the surface the less resistance and drag

Mass —> the heavier you are the more air resistance and drag they have

Projectile Motion

- **Projectile Motion –** The movement of a body through the air following a curved flight path under the force of gravity
- **Projectile –** A body that is launched into the air losing contact with the ground surface

3 main factors

- Angle of Release – Speed of Release – Height of Release

Angle of Release

- **Angle of Release –** To achieve maximum horizontal distance, the angle of release of the projectile is important

The optimum angle of release is dependent upon release heigh and landing height

When both the release heigh ad the landing height are equal then the optimum angle of release is 45 degrees

A release height of 90 degrees will accelerate vertically and come straight back down = 0

Greater than 45 degrees the projectile will each its peak too quickly, lower than 45 degrees the object thrown will not achieve sufficient height

Speed of Release

- **Speed of Release –** The greater the release speed of a projectile, the greater the horizontal distance travelled

This is why athletes train to increase maximum power in arms e.g javelin

Height of Release

- **Height of Release –** If the release height is greater than the landing height, the optimum angle of release is less than 45 degrees e.g shot putter

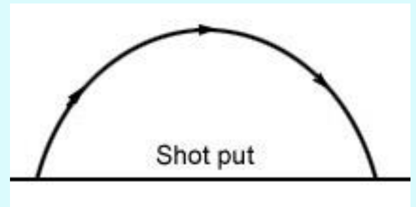
If the release height is below the landing height the optimum angle of release is greater than 45 degrees E.G basketball set/jump shot

Projectile in Flight

The flight paths are described as a parabolic shape. While in flight a projectile will be affected by weight and it resistance

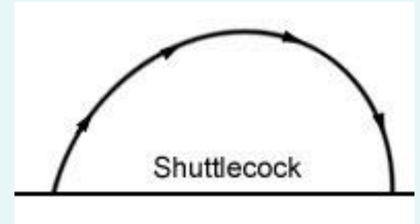
Shot Put

If weight is the dominant force the air resistance is less effective and a **parabolic** flight path occurs



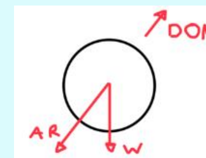
Shuttlecock

If air resistance is dominant over the weight a **non parabolic** flight path will occur



Projectile flick can be illustrated with a free body diagram

Projectiles with a large weight have a small air resistance and follow a perfect parabolic flight path



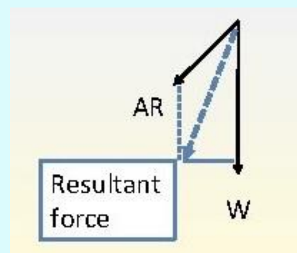
Football in flight

Parallelogram of Forces

Consider the resultant forces action on each of the projectiles (shot and shuttle) this is the net force of air resistance (AR) and weight (W) nd highlights which is the more dominant

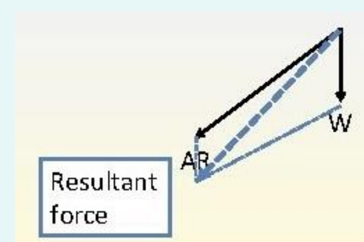
Shot Put

If weight is more dominant = more parabolic



Shuttlecock

If AR is more dominant – non parabolic



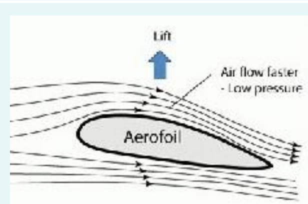
Lift and Bernoulli Principle

Longer Distance —> Faster —> Low Pressure
Shorter Distance —> Slower —> High Pressure

Air Velocity	Air Pressure
Faster / Higher	Low Pressure
Slower / Lower	High Pressure

- **Bernoulli's Principle –** The higher the velocity of air flow, the lower the surrounding pressure

This principle is the reason additional lift force can be applied to a projectile when thrown



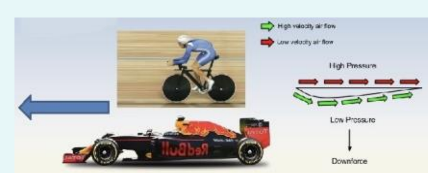
An aero foil shape has a curved upper and a flat underneath surface. The resultant effect is a low pressure above the object and a higher pressure below it

All fluids move from a high to low pressure and therefore creates additional 'lift'

This principle also works in reverse if the aerofoil is inverted

F1 and track cyclists spend large amounts of money and time tweaking and improving the downward force that holds the object to the track

During a track cycling race the key objective is to achieve a flat back position and draw air in below the bike to create a low pressure



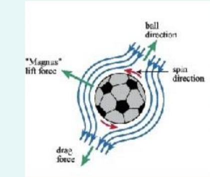
Spin and the Magnus Force

The Magnus effect at work in the curved flight path of balls that are thrown, hit, or kicked and at the same time are given a spin

Golfers, baseball pitchers, football and table tennis players all employ this effect to curve the flight path of the ball.

Spin and Magnus Force

Football diagram of the Magnus effect



Applying an external force outside of the centre of mass results in spin (angular momentum)

There are 4 types of spin that can be applied to an object :

Topspin
- Eccentric force applied above the centre of mass (spins downwards)

Backspin
- Eccentric force applied below the centre of mass (spins upwards)

Sidespin / Hook
- Eccentric force applied to the right of centre if mass (spins left)

Sidespin / Slice
- Eccentric force applied to the left of centre of mass (spins right)

The Magnus effect works the same as the Bernoulli principle. As force is applied off centre a pressure gradient is formed each side. The spin and additional magnus force creates a non – parabolic flight path