PE Studies Biomechanics Notes

Linear Kinetics:

Newton's 1st Law: A body at rest or in motion will remain at rest or in motion unless acted upon by an unbalanced force.
- The size of the force required to change the state of motion of the object depends on the mass of the object. The greater the mass of the object, the greater force needed to move it.

Inertia: The amount of a body's resistance to a change in its state of motion.
- The greater an objects inertia, the greater the force required to initiate movement or change its state of motion
- Is directly proportional to the objects mass.

Newton's 2nd Law: The rate of change acceleration of a body is proportional to the force applied to it and inversely proportional to the mass of the object.
- Force = Mass x Acceleration (F=MA)
- Small force = Slow acceleration

Momentum: Mass x Velocity
- The greater an objects momentum, the more force that needs to be applied in order to stop or slow the object down
- When two bodies collide, the one with the most momentum will be less affected.

Conservation of Linear Momentum: In a perfectly elastic collision, the total momentum of two objects before and after impact are equal.
- A perfectly elastic collision takes place when no energy is lost to sound or heat.
- The momentum of one object is transferred on contact to the other object, resulting in no change in total momentum, rather a transfer of momentum.

<u>Perfectly Elastic:</u> Momentum fully conserved (Pool balls hitting each other)
<u>Imperfectly Elastic:</u> Normal occurrence. Some momentum lost to the system (Tee-Ball)
<u>Perfectly Inelastic:</u> All momentum lost to the system. (Pool ball dropped into sand pit)

Newtons 3rd Law: For every action, there is an equal and opposite reaction.
- When two objects exert a forced upon each other, the forces are opposite in direction and equal in magnitude.

- This law directly applies to the concept of conservation of momentum.
- Newton's third law explains that when collisions occur, an equal and opposite force occurs resulting in the transfer of momentum from one object to the other.

Impulse: The change in momentum of an object.
- Impulse = Force x Time (I=FT)
- Therefore the longer the forced can be applied to an object and the greater the size of the force applied, the greater the objects impulse or change in momentum.

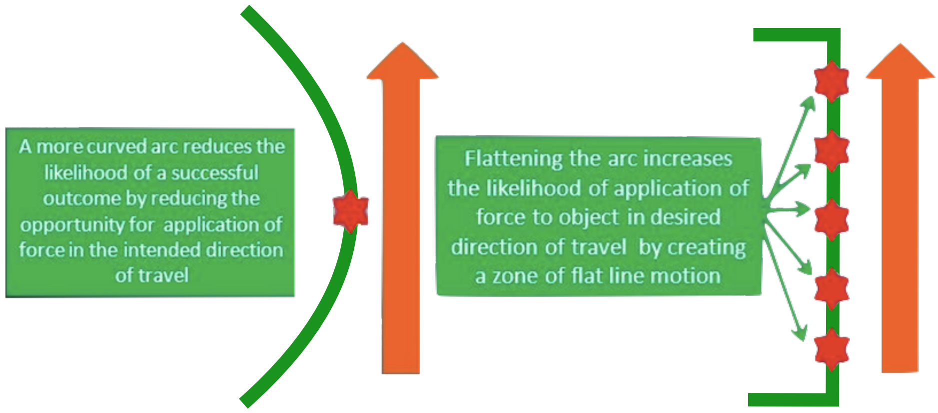
- Impulse is important in impact/collision situations
- As impulse is force x time, we can manipulate either one to suit domains of the situation:
    - <u>Increase Momentum:</u> In hockey, a hit will place a large force but over a small time. Whereas a drag flick places a small force over a longer period of time. Either way the ball is increasing its momentum. Ideally we look to maximise both force and time, however the human body really allows for this to happen.
    - <u>Decreasing momentum:</u> A cricket ball is hit towards a fielder. The fielder stops the ball by letting the ball hit his hands then giving with the ball. The fielder is increasing the time component of impulse to reduce the amount of force acting on his hands therefore reducing injury and decreasing the probability of the ball bouncing out of his hands.

PE Studies Biomechanics Notes

Flattening the swing arc: Good technique can increase the contact time with a ball during collision sports

- This may provide the opportunity for increased force application in desired direction. (Hockey drag flick)
- May also provide increased accuracy, however usually occurs with a decrease in force application.

- Key is to create an area of flat line motion which allows an increased opportunity to make contact with the ball in the desired directional travel.
- Eg. When a batsmen plays a drive in cricket he or she creates a flattened arc of the cricket bat by;
  - The shift of body weight forward
  - The rotation of the body prior to the moment of contact
  - Bat moving in a straight line towards the intended target



Coefficient of Restitution (COR): Measures the elasticity of the collision between an object and a given surface. It measures how much energy remains in the object after a collision takes place.

- Elasticity if how much rebound exists following a collision (bounce).
- An objects COR is measured of a scale of 0 to 1
  - A COR of 1 represents a perfectly elastic collision (i.e. When a ball is dropped from a given height and the ball rebounds to that same height after colliding with the ground.)
  - A COR of 0 represents a perfectly inelastic collision , effectively stopping at the surface at which it collides. (i.e. When the ball is dropped and it doesn't bounce at all.

$$CoR = \sqrt{\frac{bounce\_height}{drop\_height}}$$

- **Factors affecting the COR:**
  1. Temperature of the ball:
     An increase in the temperature of the ball results in an increase in the COR.
     In sports such as squash we see a dramatic increase in the 'bounciness' of the warm squash ball compared with a cold one.
  2. Equipment and Materials:
     Condition of the balls – think about when a player calls for new balls in tennis how much faster they are able to serve.
     Type of equipment being used – in the American baseball wooden bats are compulsory as aluminium bats have a higher COR – this places the pitcher at increased risk of injury due to the ball leaving the bat face faster thus reducing action time
  3. Velocity of colliding bodies:
     The greater the velocity, the greater the compression of the object and and the slower its return to its original shape – the increased velocity reduces the coefficient of restitution.

PE Studies Biomechanics Notes

Angular Kinetics:

Types of Forces:
- Concentric Force: Force applied to produce linear motion. E.g. Hitting a flat serve in volleyball
- Eccentric Force: Off centre force applied to produce angular motion. E.g. Hitting a top spin serve in volleyball

Forces that create Angular Motion (Torque):
- Angular rotation is caused by the application of an eccentric(Off-centre) force
- When one eccentric force is applied to the object, both linear and angular motion occur (Volleyball top spin serve)
  - If one end of the object is fixed and an eccentric force is applied, then only angular rotation occurs (i.e. A gymnast rotating on a high bar)

- To increase the objects angular rotation, one can either;
  1. Increase the amount of force applied
  2. Increase the distance from the axis by which the force is applied (moment arm)

Forces that create Angular Motion (Torque):
- **Moment Arm:** The distance from the application of force to the axis of rotation:
- An increased moment arm means more angular rotation(torque) is achieved when the same amount of force is applied.

Torque: A force being applied <u>around</u> a pivot
- Torque = Force x Distance (moment arm) (T=FD)
- The longer the moment arm, the greater the rotational forced produced
- Maximum force can be generated when the moment arm is perpendicular to the axis of rotation

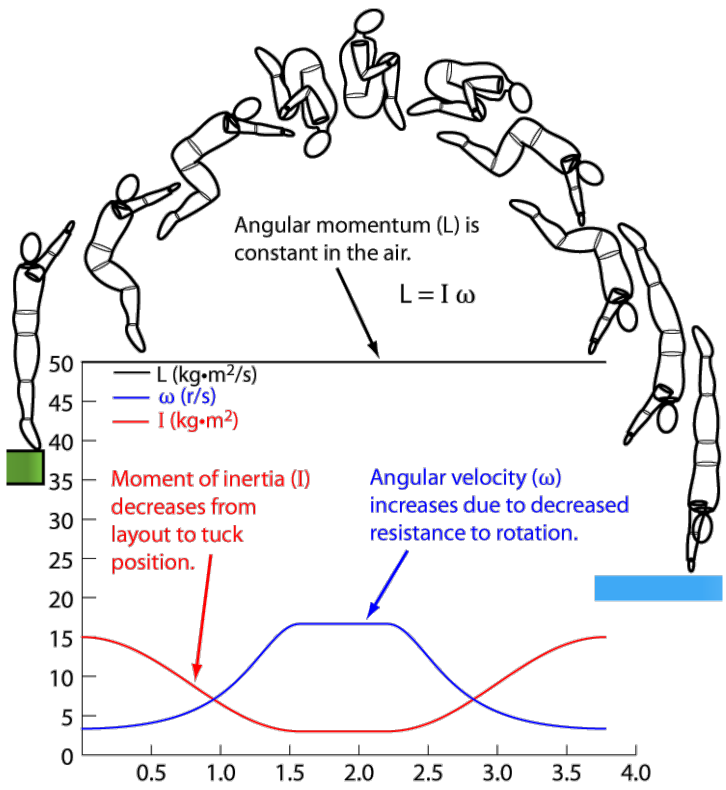
Angular Momentum: The quantity of angular motion possessed by a rotating body
- Angular momentum = Angular velocity x Moment of Inertia
- The same as linear momentum just in an angular sense

- **Moment of Inertia:** Mass of object x Radius of rotation
  - Radius of rotation: how the mass of the object is distributed about the axis of rotation

- If the body's mass is close to the axis of rotation, rotation is easier to manipulate. This makes the moment of inertia smaller and results in an increase in angular velocity
- Moving the mass further away from the axis of rotation slows down angular velocity

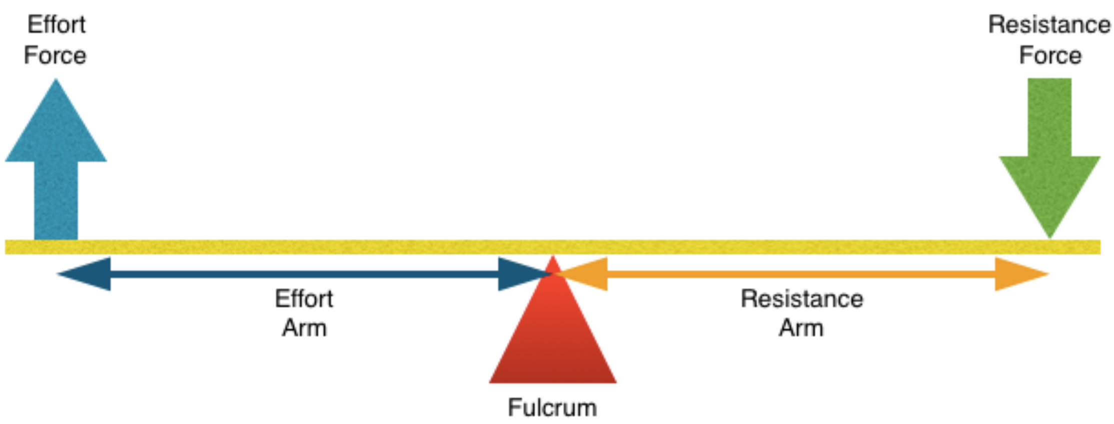
PE Studies Biomechanics Notes

Conservation of Angular Momentum: A spinning body will continue spinning indefinitely unless an external force acts on it.



Levers:

- **Main parts:**
  1. Axis/pivot point/fulcrum: Point around which the lever rotates
  2. Input Force (Effort/Force): Force exerted on the lever
  3. Output Force (Resistance/weight/load): Force exerted by the lever
  4. Effort/Force Arm: The distance between the fulcrum and the point at which the force is applied.
  5. Resistance Arm: The distance between the fulcrum and the centre of the resistance

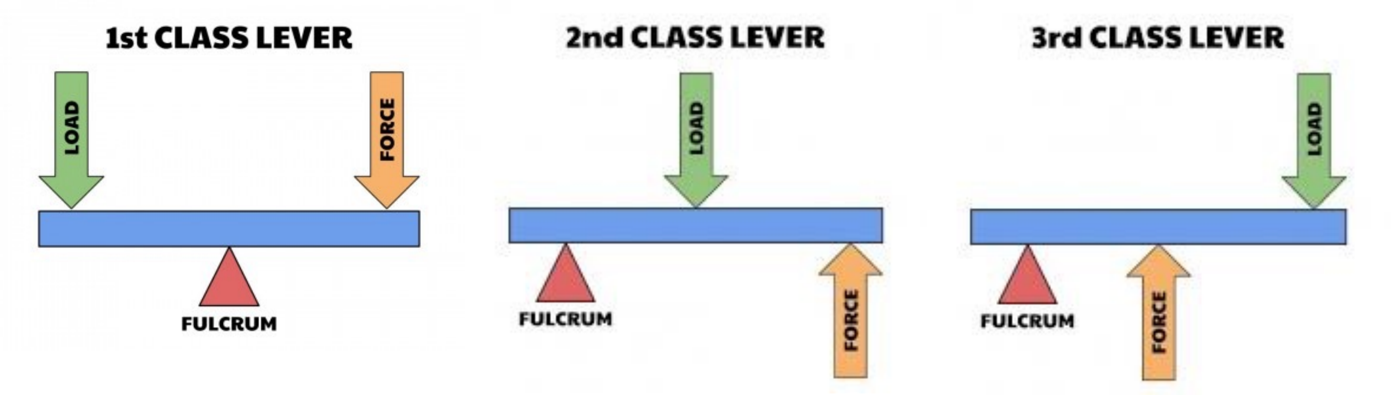


PE Studies Biomechanics Notes

Levers:

- **Functions:**
  1. Increase application of force by making the force arm longer than the resistance arm
  2. Increase speed of movement by making the force arm shorter than the resistance arm

- **Lever Types:** A = Axis, R = Resistance, F = Force
- 1st Class Lever: FAR/ RAF (Axis in Middle) e.g. See saw
  - The point of application of force in relation to the axis/fulcrum will determine the mechanical advantage provided by a 1st class lever.
  - The farther one applies force from the fulcrum, the easier it is to move objects and vice versa. This allows for individuals to move heavy objects as seen when using a crow bar
- 2nd Class Lever: ARF/FRA (Resistance in Middle) e.g. Wheelbarrow
  - The larger force arm present in a 2nd class lever ensures more strength can be applied to an object.
- 3rd Class Lever: AFR/RFA (Force in Middle) e.g. Bicep Curl
  - Most common type of lever in the human body as mechanically we are built for speed
    - The larger resistance arm present in a 3rd class lever ensures more speed can be obtained.
  - By increasing the length of the resistance arm, it is possible to generate greater velocity of the striking surface, resulting in greater force being transferred onto the ball. However in striking sports, an increase in the length of the lever may result in and increased weight, affecting control.



- **Factors affecting the use of levers:**
  1. Length of the lever:
     - Velocity is greatest at the distal end of a lever
     - Longer the lever, greater the velocity at impact
  2. The inertia of the lever:
     - The longer the lever, the heavier it usually is and therefore the more difficult to rotate.
     - By choking down the club in striking sports, athletes can reduce rotational inertia of the implement therefore making it easier to swing.
  3. The amount of force:
     - The amount of force an athlete is able to generate via their muscles determines the length of the lever the athlete should use
       - Longer levers are usually heavier therefore more force is required to move them.
       - Using longer and heavier equipment is crucial if athletes are not physically strong enough, as this will sacrifice control
     - A smaller force can balance a larger resistance when the force arm is longer than the resistance arm
     - A force can move a resistance through a greater range of motion when the force are is shorter than the resistance arm

PE Studies Biomechanics Notes

Fluid Mechanics

Drag: A force acting opposite to the relative motion of any object moving with respect to a surrounding fluid.

- **Types of Drag:** Total Drag = Surface Drag + Form Drag + Wave Drag
  - Surface Drag: Friction produced between fluid and surface of a moving object
    - Factors affecting surface drag:
      1. Relative velocity of moving object
      2. Relative roughness of surface of object
         - Speed skaters wear tight fitting clothing and swimmers shave their bodies to reduce surface drag
      3. Viscosity of the fluid
      4. Surface area of the object
- Form Drag (Profile Drag): Resistance created by a pressure differential between the front and back of an object moving through a fluid (increased pressure differential = increased drag)
    - Factors affecting form drag:
      1. Cross sectional area (CSA) of the object presented to the fluid
         - Cycling in upright vs crouched position
      2. Velocity of the object
         - At higher speeds athletes experience greater levels of form drag
      3. Surface roughness
         - Rough surfaces cause the air to cling to the surface for a longer period, causing a later separation point and hence less form drag (Laminar vs Turbulent Flow)
      4. Shape of the object
         - Round vs Oval ball
- Wave Drag: Resistance formed by the creation of waves at the point where are and water interact (major for of drag acting on swimmers)
    - Factors affecting wave drag:
      1. Relative velocity of the wave
         - Greater the velocity, greater the wave drag
      2. Technique
         - By being more streamlined in the water, swimmers can reduce the effects of race drag
         - Swimming underwater further reduces wave drag (rules of backstroke race)
         - Over reaching in backstroke will cause the body to move through its own waves causing resistance
      3. Open water (ocean) vs closed conditions (pool):
         - Lane ropes used to reduce wave drag by helping to dissipate moving surface of water

Fluid Resistance:

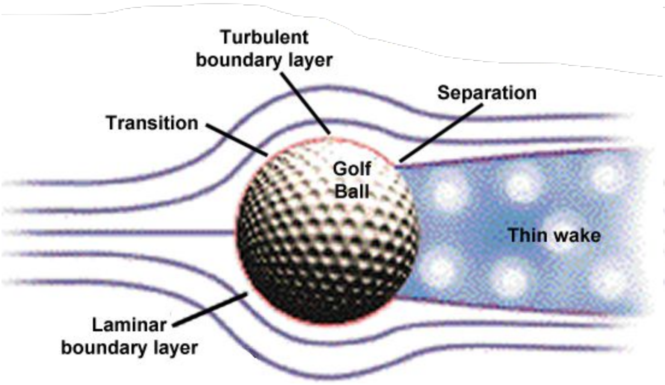
- 2 factors affecting fluid resistance:
  1. Density: The mass per unit of volume.
     - Generally the more dense the fluid, the greater the resistance. Fluid density is greatly affected by humidity, temperature and pressure (altitude).
  2. Viscosity: A measure of a fluid's resistance to flow.
     - E.g. Honey is more viscous than water, water is more viscous than air. Therefore a swimmer will obviously experience more viscosity than a runner.

PE Studies Biomechanics Notes

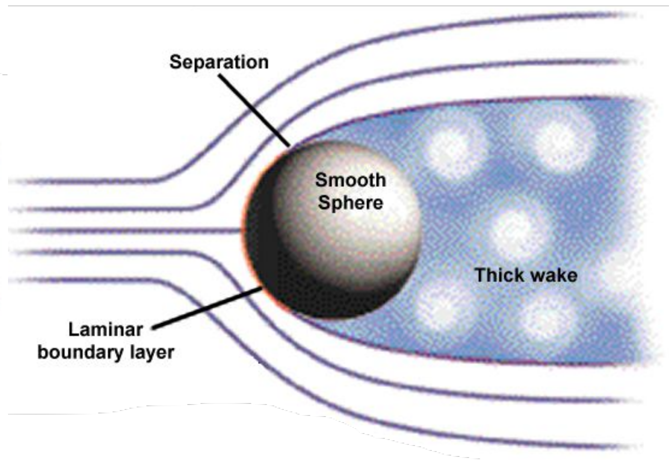
Fluid Resistance:

- **Laminar Flow:** A type of fluid flow in which fluid moves smoothly in individual layers or streams over an object.
    - This type of flow moves the point of separation towards the front of the object, thus increasing drag.
- **Turbulent Flow:** Flow in which the velocity at any point varies erratically.
    - The type of fluid flow in which the boundary layer becomes so turbulent that the point of separation moves further back on the object, thus reducing drag.

Turbulent Flow



Laminar Flow



Fluid Resistance:

- **Boundary layer separation:** Where the thin layer of air surrounding or "attached" to the ball breaks away.
    - The earlier the boundary layer separation, the greater the pressure gradient between the front and back of the ball leading to an increase in drag.
- Factors affecting boundary separation point:
    1. Velocity:
        - Low velocity means boundary layer clings to surface casing separation well towards the rear thus minor drag.
        - High velocity means separation occurs further forward thus increased drag
    2. Surface roughness
        - Rough surfaces create turbulent boundary layer, reducing the effect of drag.
        - Dimpled golf ball vs Smooth golf ball

PE Studies Biomechanics Notes

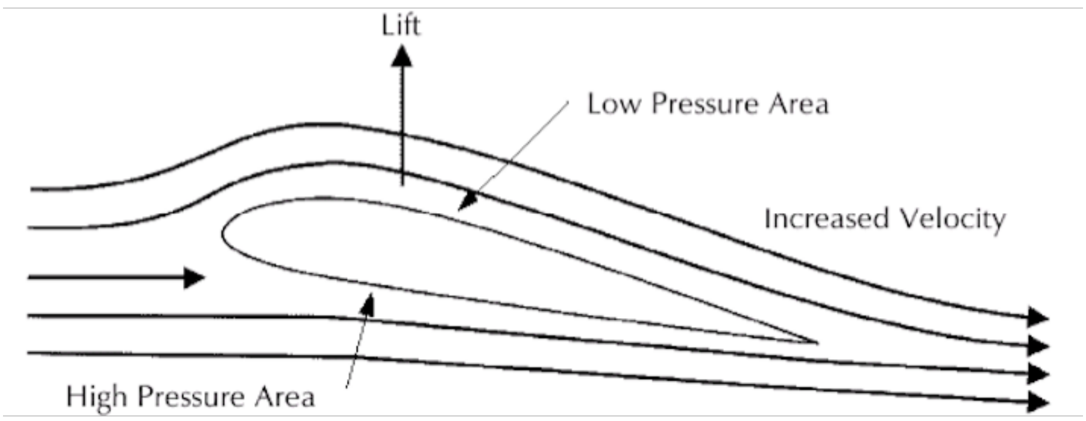
Fluid Resistance:

- **Factors affecting drag:**
  1. Drag coefficient:
     - Measure used to quantify the drag or resistance of an object in a fluid environment
     - Directly related to the cross sectional area
  2. Cross sectional area (SCA)
     - Linear relationship exists between SCA exposed to air and drag (Increased SCA = Increased Drag)
  3. Speed
     - The faster the ball moves through the air, the earlier the boundary layer separates from the ball creating a large pressure differential between the front and back and hence more drag
  4. Surface roughness:
     - Rougher surfaces allow for the air stream to cling to the ball for longer periods, resulting in a smaller pressure differential between the from and back of the ball and hence less drag
  5. Mass:
     - The greater the mass of the ball, the less the effect of drag
  6. Shape
     - Round ball vs oval ball
       - Gridiron ball cuts through the air more clean than a soccer ball
       - Oval shaped balls encourage the air stream to cling to the contours of the ball all the way to then end of the tail, resulting in a much smaller pressure differential between the from and back of the ball and therefore less drag

- **Environmental factors affecting drag:**
  1. Air density:
     - Higher altitude = decreased drag
     - Smaller the object, greater the effect
  2. Atmospheric pressure:
     - Increased pressure = Increased density = Increased drag
  3. Humidity
     - Increased humidity = Increased density = Increased drag
  4. Temperature:
     - Increased temperature = Decreased density = Decreased drag

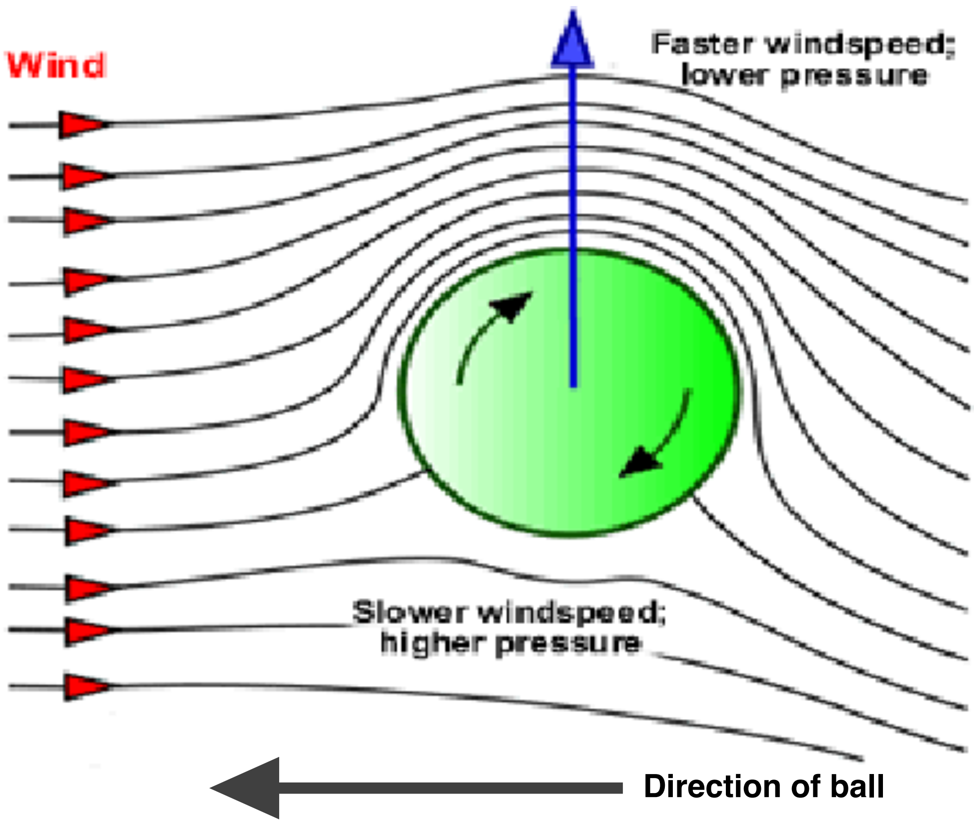
Lift: The component of force that acts perpendicular to the direction of flow
- Will act at a right angle to the direction of motion
- Only occurs in objects which are spinning or not perfectly symmetrical
- Created by different pressures on opposite sides of an object due to fluid flow past the object

- **Bernoulli's Principle:** Velocity is inversely proportional to pressure (High Velocity = Low Pressure)



PE Studies Biomechanics Notes

- **Magnus effect:** The effect the rotation of an object has on its path as it moves through a fluid
    - It applies Bernoulli's principle to explain the effect spin has on the trajectory or flight path of an object



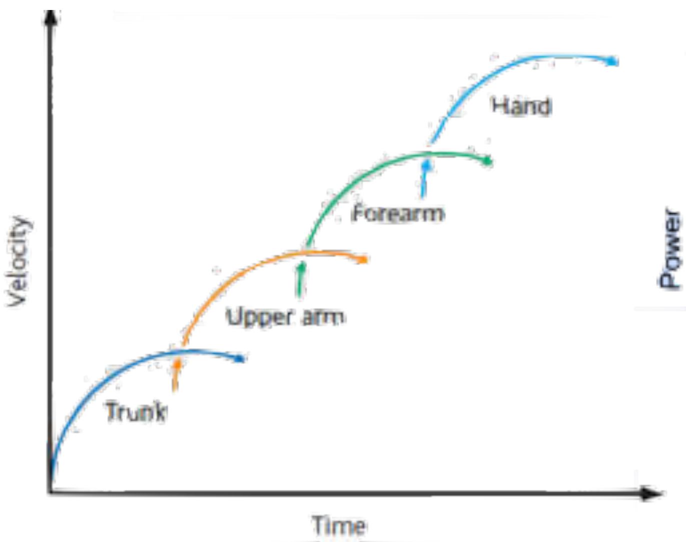
PE Studies Biomechanics Notes

Application of Biomechanical Principles

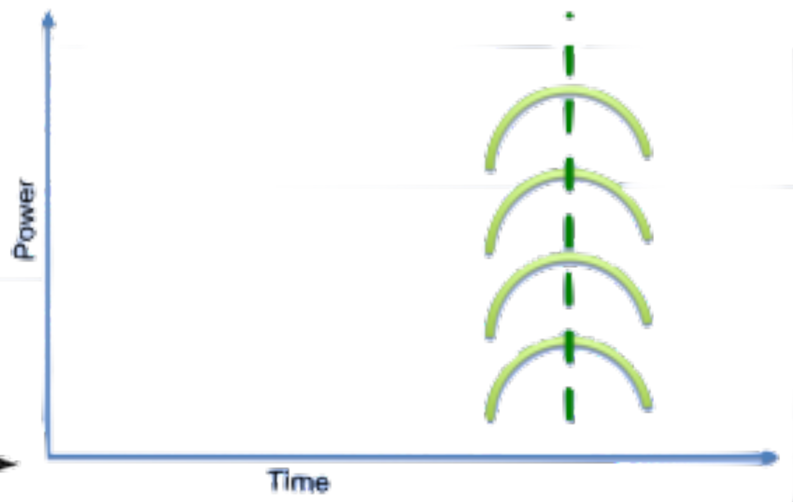
S - Segmental Interaction
C - Coordination Continuum
O - Optimal Projection
F - Force-Motion
F - Fore-Time
R - Range of Motion (levers)
I - Inertia
B - Balance
S - Spin

Coordination Continuum: Process that determines how to best use body segments depending on the task - Power or Accuracy ?
- Power: More segments used in sequential summation (Golf drive)
- Accuracy: Less segments needed in usually simultaneous summation (netball goal shot)

Sequential Force Summation



Simultaneous Force Summation



Segmental Interaction to achieve maximum velocity/force:
1. Ensure stronger/larger body parts of the legs and hips move first and small body parts of the wrist move last to ensure optimum momentum is pass onto the ball at the point of release/ impact.
2. Maximise the number of body segments by adopting a side on position to the large to ensure legs, hips, shoulders ect. are used in execution of the movement.
3. Sequentially accelerate each body segment. This is achieved by each segment beginning to move as the preceding segments reaches its maximal velocity (kinematic timing) to ensure optimum momentum is transferred onto the ball.
4. Each body part should be stable so that the next body part accelerates around a stable base to transfer momentum.
5. Follow through towards the target to ensure safe dissipation of force and ensure no deceleration of final segment at point of release/impact.
6. Ensure all forces are directed towards the target (more accuracy than force production).

PE Studies Biomechanics Notes

Optimal Projection:
- If the demands of the task are to maximise distance, the athlete must:
  - Maximise velocity through all biomechanics principles discussed
  - Maximise height of release without sacrificing velocity of release
  - Angle of release: With all other factors equal (i.e. Wind conditions) throw/strike at an angle of approximately 40-43 degrees to maximise distance due to height of release > landing height

Force-Motion:
- When referring to throwing and striking activities, greater contribution is made to the horizontal component compared with the vertical component as heigh of release is greater than landing height. This will ensure maximum distance is achieved.

Force-Time (Impulse):
- By adopting a side on throwing/batting position and extending the arm/bat back during the preparation phase, it allows for maximum distance and time for the summation of momentum, as force can be applied over the maximum possible time

Range of motion (ROM):
- A larger ROM at the shoulder joint ensures velocity of the bat and the ball can be developed over a larger distance resulting in a greater transfer of momentum onto the ball

Inertia/Moment of Inertia: The amount of resistance to a change in an objects state of motion.
- When referring to movements which involve rotation, we look at angular inertia/moment of inertia
- The goal is to reduce the arm/bats moment of inertia at the commencement of the throw/strike by bringing the ball/bat close to the axis of rotation (E.g. the shoulder) and therefore allowing the arm/bat to increase its angular velocity. This is achieved by bending at the elbow

Balance:
- Ensure you have a large stable base of support to ensure all segments rotate around a stable base

Spin:
- Through the application of backspin to the ball, it optimises the balls time in flight (as a result of the Magnus effect) and therefore maximises the distance achieved.s