FLUID MECHANICS

The Effects of Water and Air.

Fluid

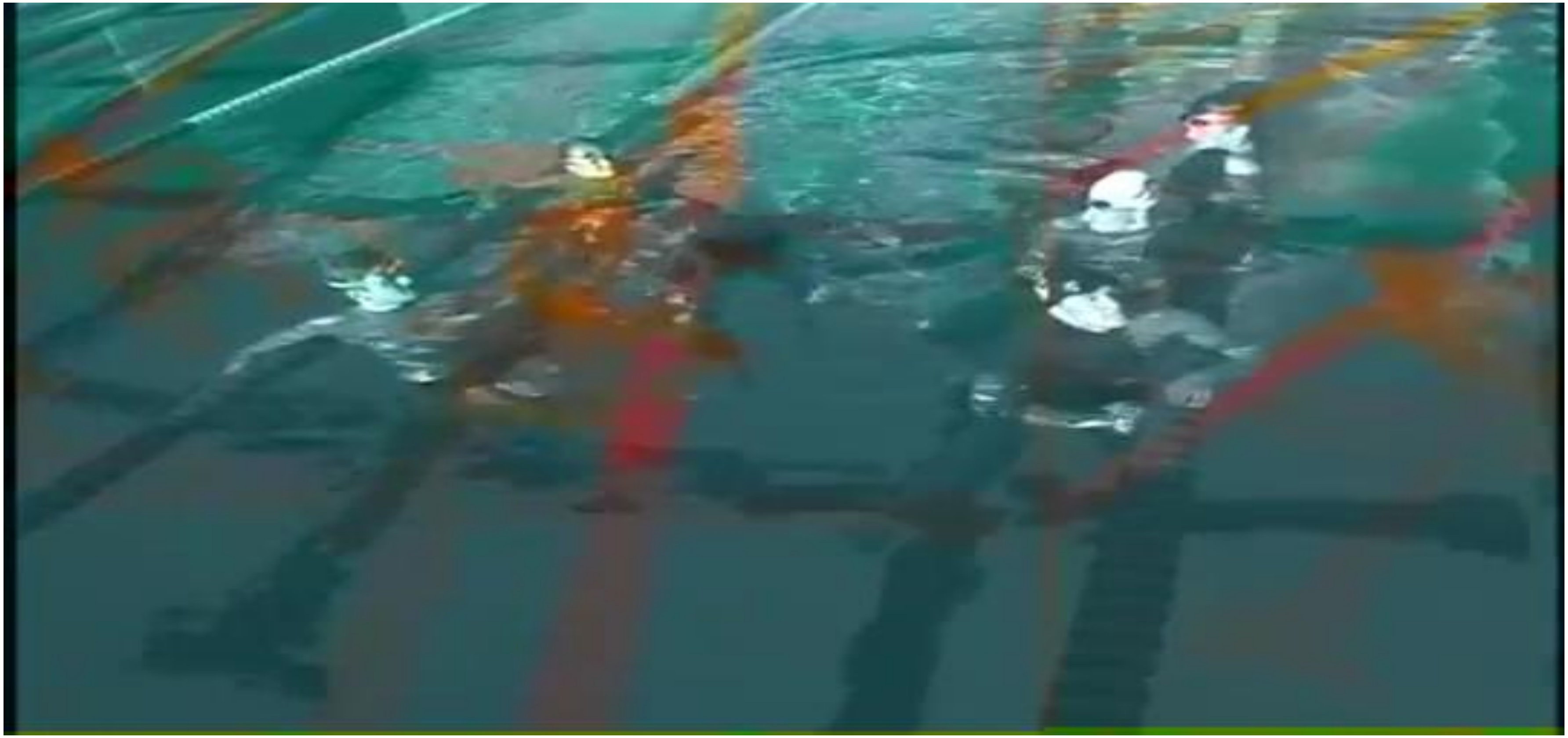
- Substance that flows when subjected to a shear stress.
- Both air and water are fluid mediums that exert forces on bodies moving through them.
- Both gases and liquids are fluids with similar mechanical properties.

Fluid properties

- Others factors that influence the magnitude of the forces a fluid generates are the fluid’s **density, specific weight, and viscosity.**
  - **Density** is mass/volume.
  - **Specific weight** is the ratio of weight to volume.
  - The denser and heavier the fluid medium surrounding a body, the greater the magnitude of the forces the fluid exerts on the body.
  - The property of **fluid viscosity** involves the internal resistance of a fluid to flow.
  - The greater the extent to which a fluid resists flow under an applied force, the more viscous the fluid is.
  - A thick molasses, for example, is more viscous that a liquid honey, which is more viscous than water.
  - Increased fluid viscosity results in increased forces exerted on bodies exposed to the fluid.
  - Atmospheric pressure and temperature influence a fluid’s density, specific weight, and viscosity.

The Nature of Fluids

- The ability to control the action of fluid forces differentiates elite from average swimmers.

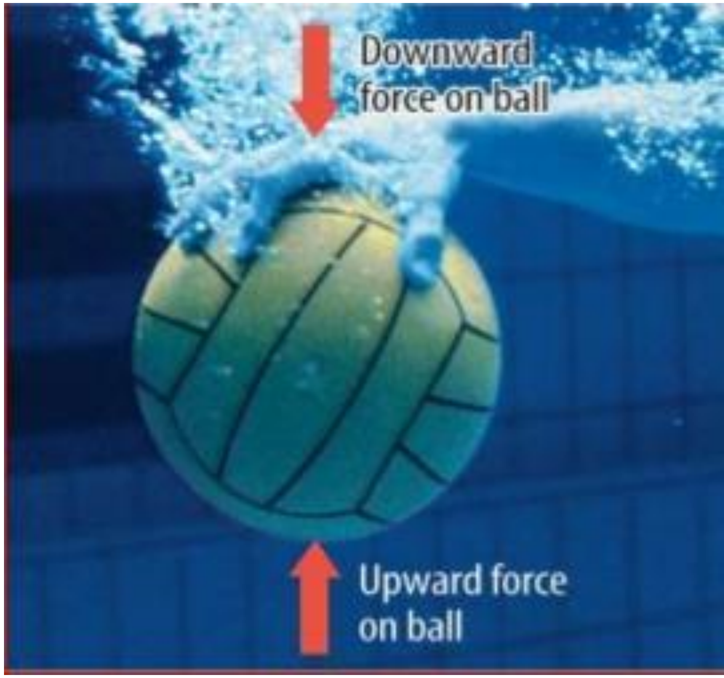


Forces in a Fluid Environment

- Two types of forces are exerted on an object by a fluid environment”

i) a buoyant force due to its immersion in the fluid and,

ii) a dynamic force due to its relative motion in the fluid.



Buoyancy

- A fluid force that always acts vertically upward.

What is buoyancy?

A fluid force with:

- magnitude based on Archimedes' principle,
- direction always vertically upward, and
- point of application being a body's center of volume.

Archimedes' Principle

- Physical law stating that the buoyant force acting on a body is equal to the weight of the fluid displaced by the body.

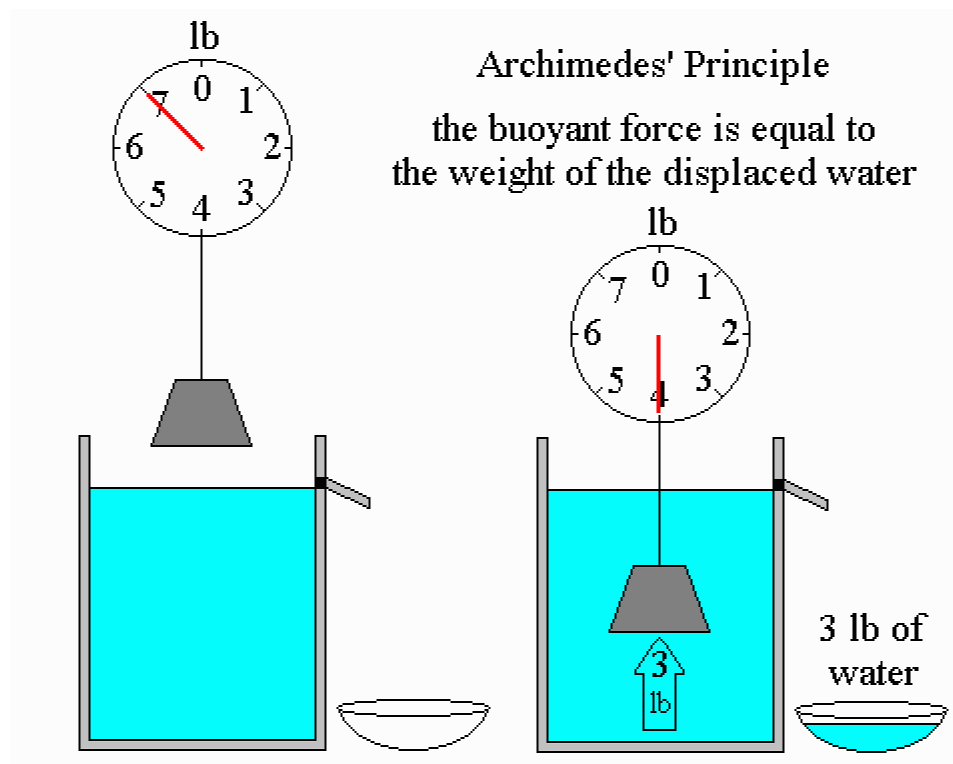
What is Archimedes' principle?

A physical law stating that the buoyant force acting on a body is equal to the weight of the fluid displaced by the body: $F_b = V_d \gamma$

Where F_b = buoyant force

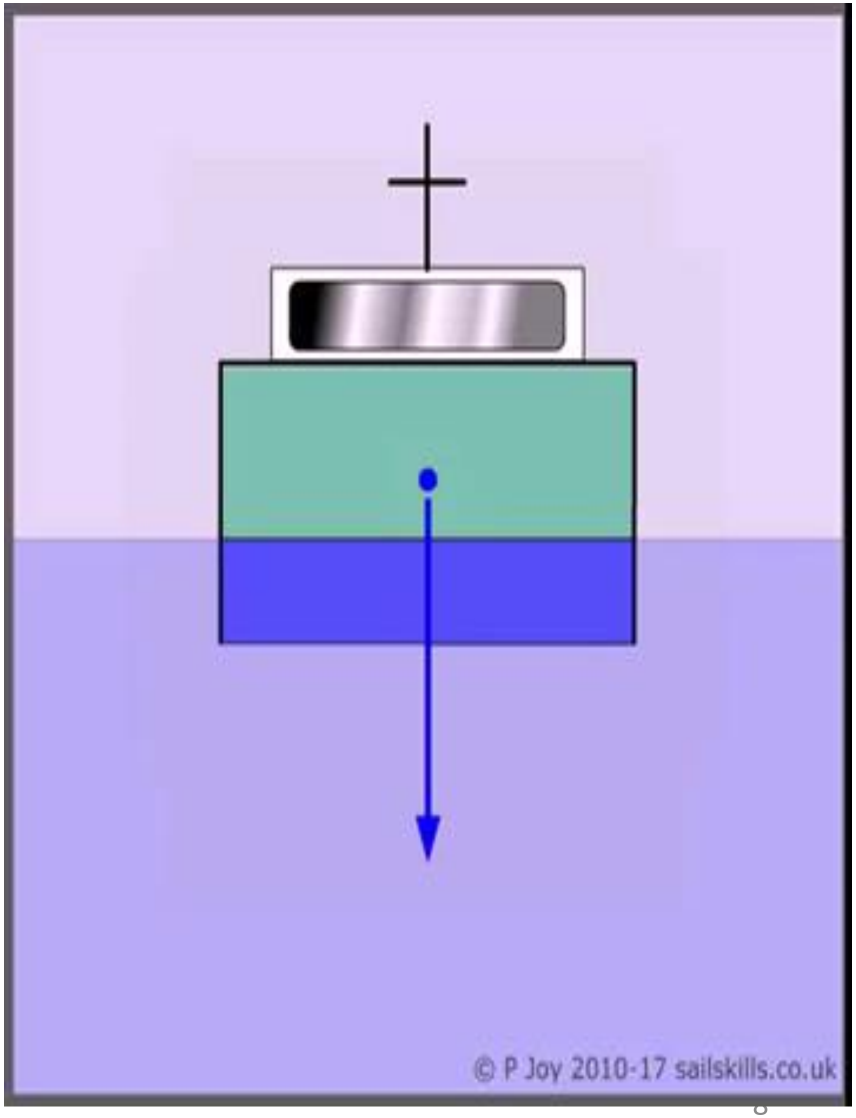
V_d = displaced fluid volume

γ = fluid specific weight

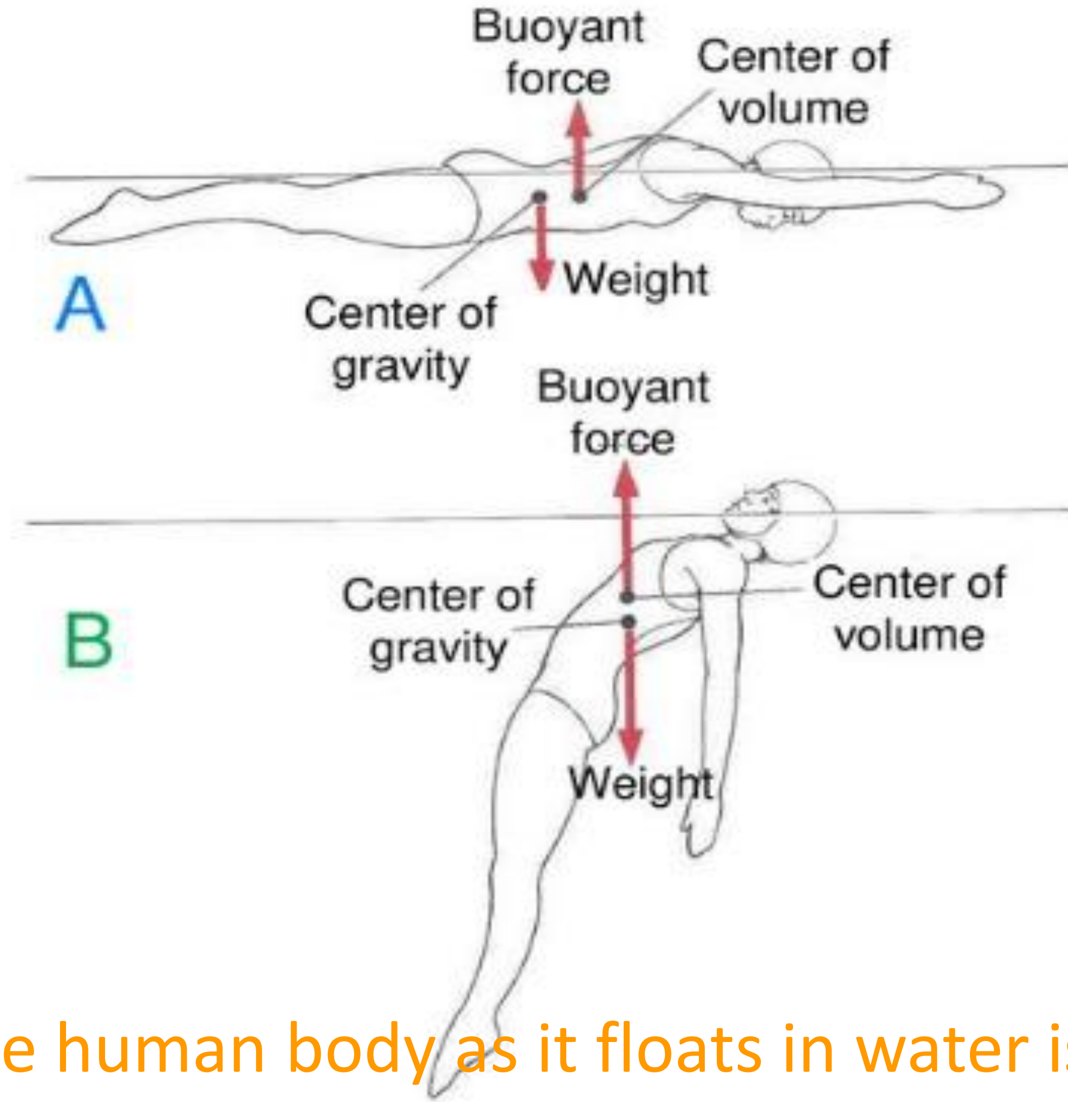


Buoyancy

- Because the magnitude of the buoyant force is directly related to the volume of the submerged object, the point at which the buoyant force acts is the object's center of volume, which is also known as the center of buoyancy.



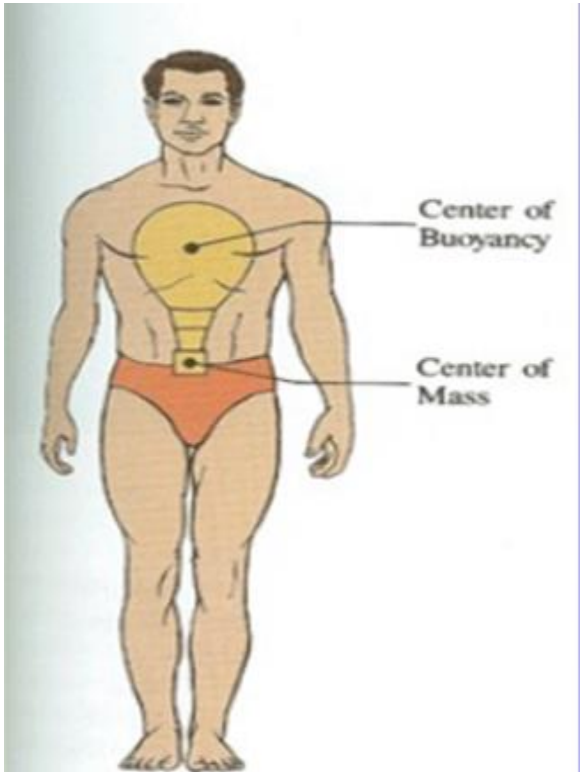
A floating body at rest (position A) will rotate until the buoyant force and weight force are vertically aligned (position B) so that zero torque is present.



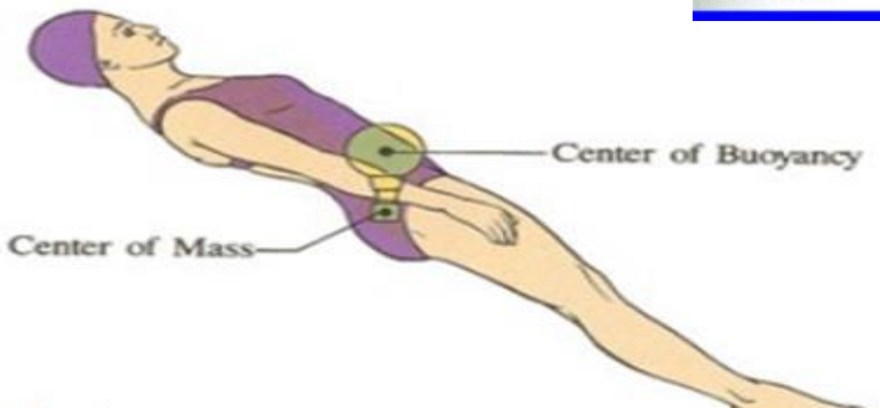
The orientation of the human body as it floats in water is determined by the relative position of the total body center of gravity(CG) relative to the total body center of volume(CV).

Buoyancy

- The exact locations of the CG and CV vary with anthropometric dimensions and body composition.
- Typically the CG is inferior to the CV due to the relatively large volume and relatively small weight of the lungs.



▲ FIG. 2-3



▲ FIG. 2-4

What determines whether a body floats or sinks?

- Floating occurs when the buoyant force is greater than or equal to body weight.
- Sinking occurs when body weight is greater than the buoyant force.

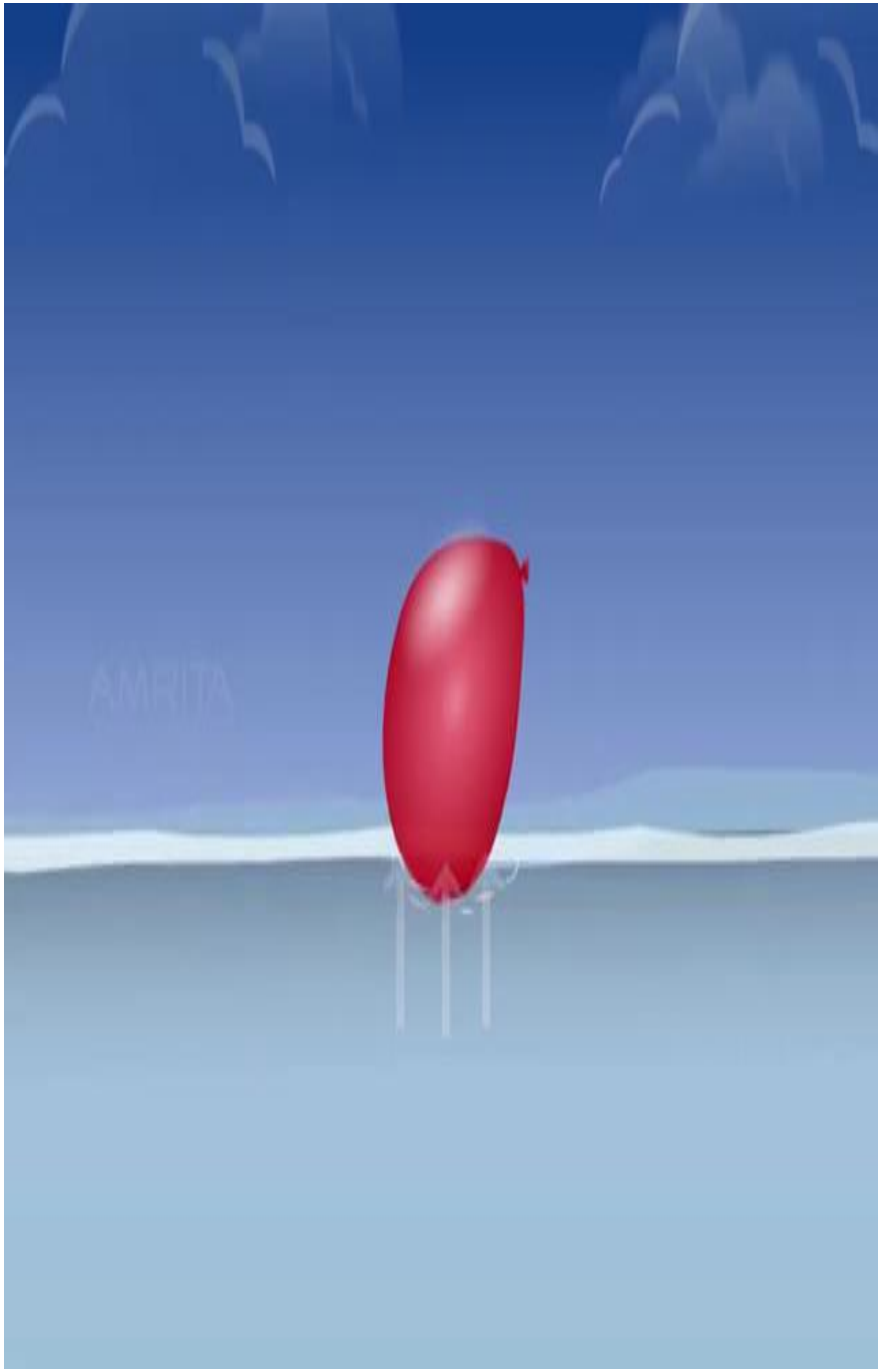
Volume

- Amount of space occupied by a body.

- In the metric system, common units of volume are cubic centimeters (cm^3), m^3, and liters.
- One (1) = 1000 cm^3

Mass, Volume, and Density

- **Volume** is not the same as weight or mass.
    - ➢ An 8 kg shot and softball occupy approximately the same volume of space, but the weight of the shot is much greater than that of the softball.
    - ➢ If a lean, muscular individual and an obese person have identical body weights, the obese person's body volume would be greater.



Density

- Density - mass per unit volume.
- Metric = kg/m^3.
- English does not usually use units of density.
- Specific wt (wt per unit volume) is used instead.

Dynamic Fluid Force

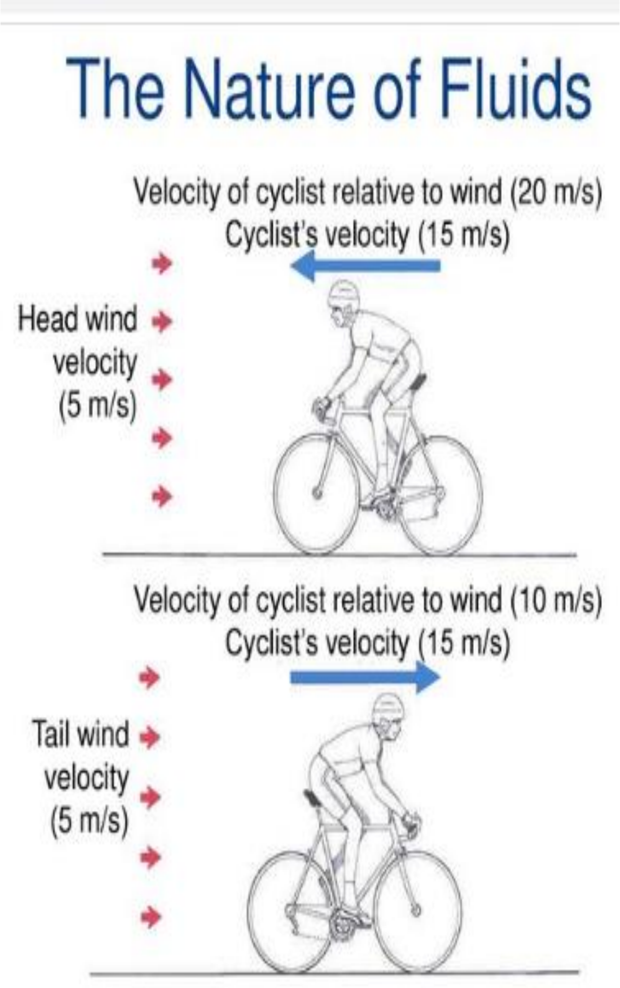
- Force due to relative motion.
- When an object moves within a fluid (or when a fluid moves past an object immersed in it), dynamic fluid forces are exerted on the object by the fluid.
    - Fire hose on rioters

Dynamic Fluid Force

- The dynamic fluid force is proportional to the
  - density of the fluid
  - the surface area of the object immersed in the fluid
  - the square of the relative velocity of the object to the fluid

Relative Motion

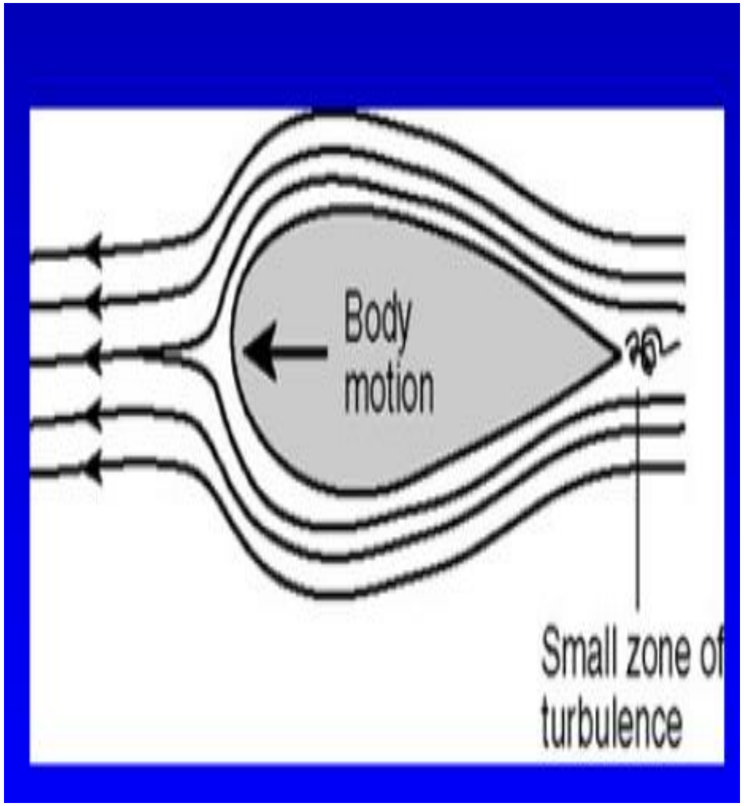
- Because a fluid is a medium capable of flow, the influence of the fluid on a body moving through it depends not only on the body's velocity but also on the velocity of the fluid.
    - Swimming upstream and downstream

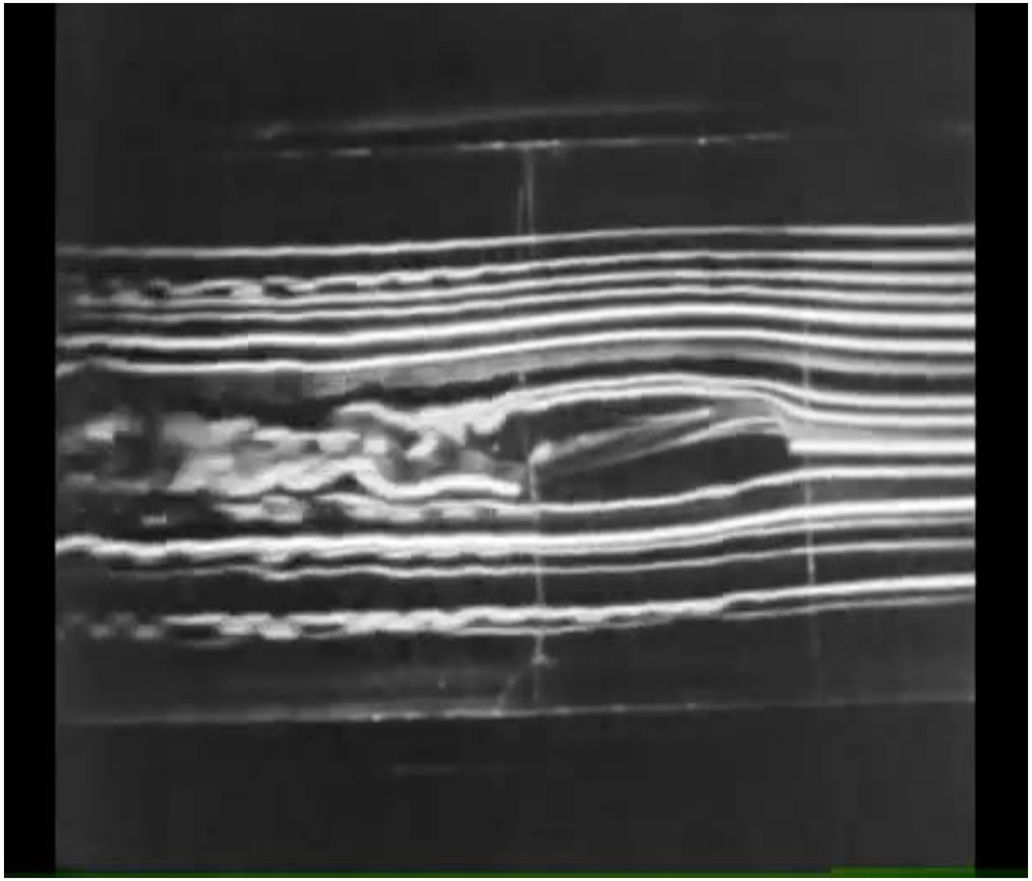


$$V_{c/w} = V_c - V_w$$

Flow properties

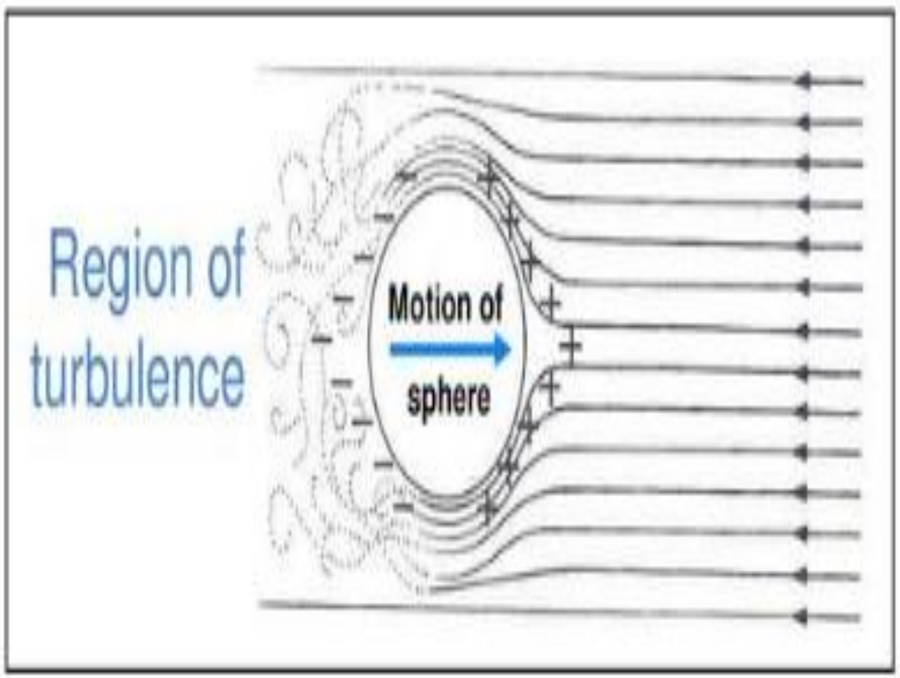
- Laminar flow - flow characterized by smooth, parallel layers of fluid.

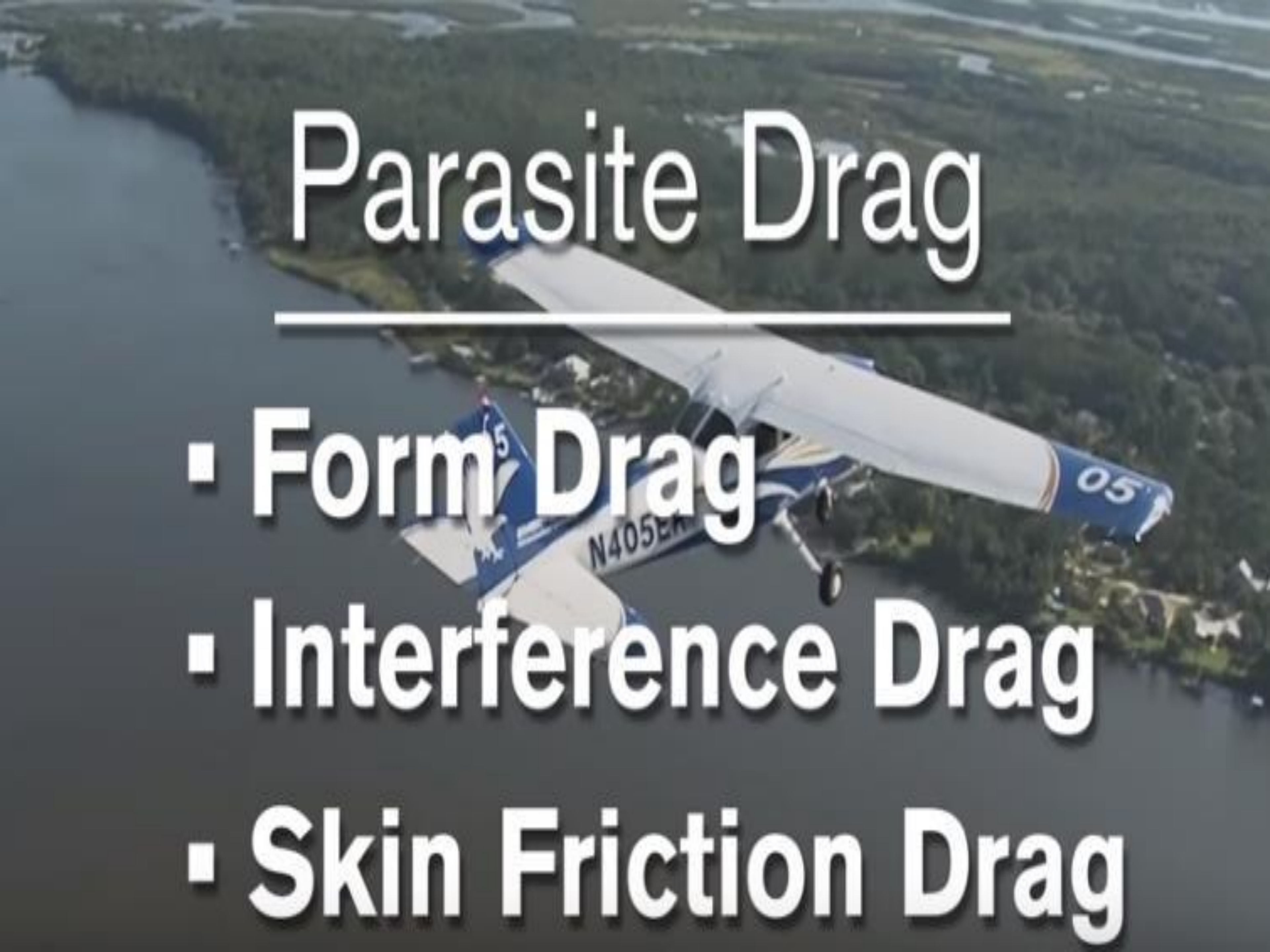




Flow properties

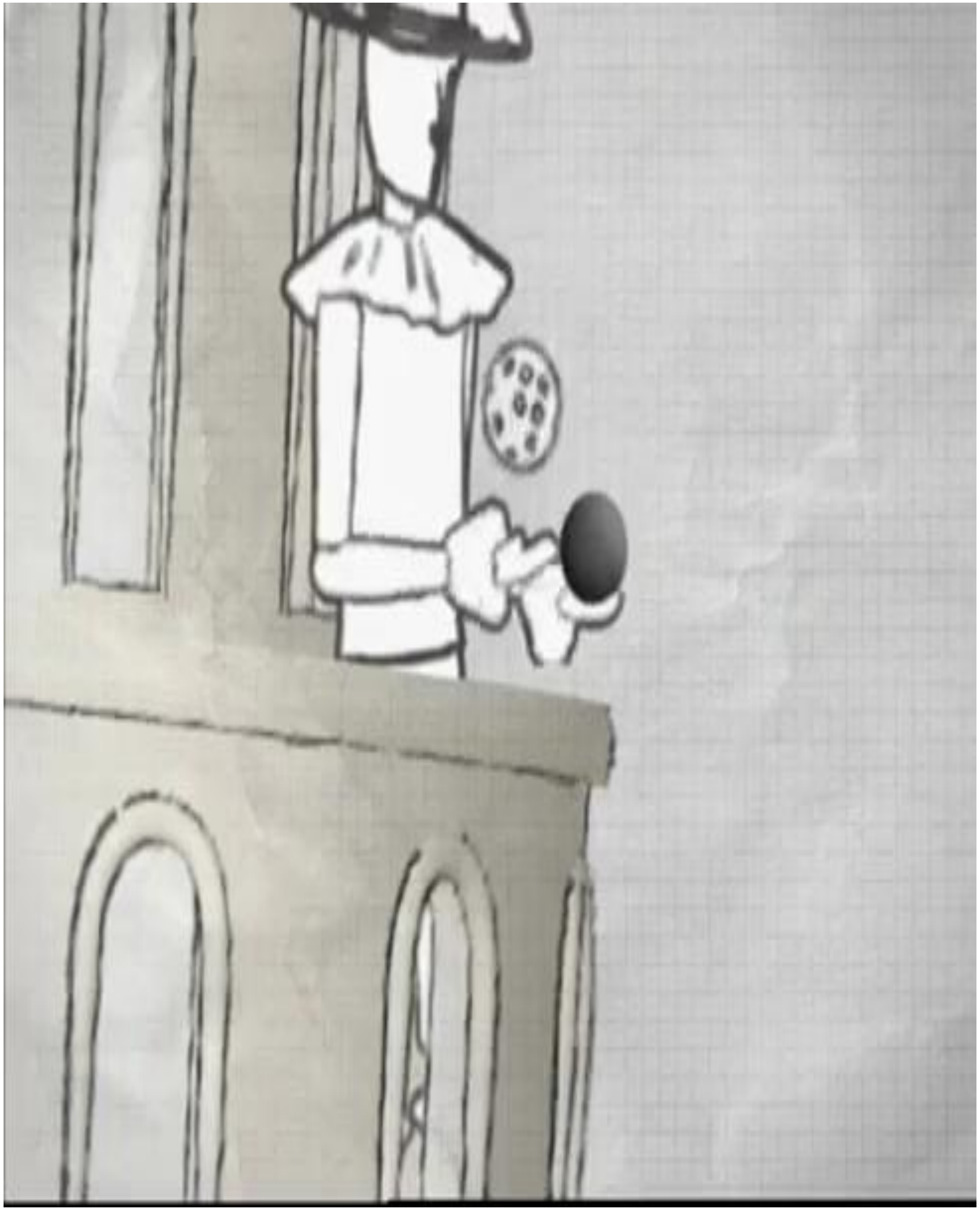
- Turbulent flow - flow characterized by mixing of adjacent fluid layers.




Parasite Drag
Form Drag
Interference Drag
Skin Friction Drag
05

Drag

- A resistance force.
- A force that slows the motion of a body moving through a fluid.

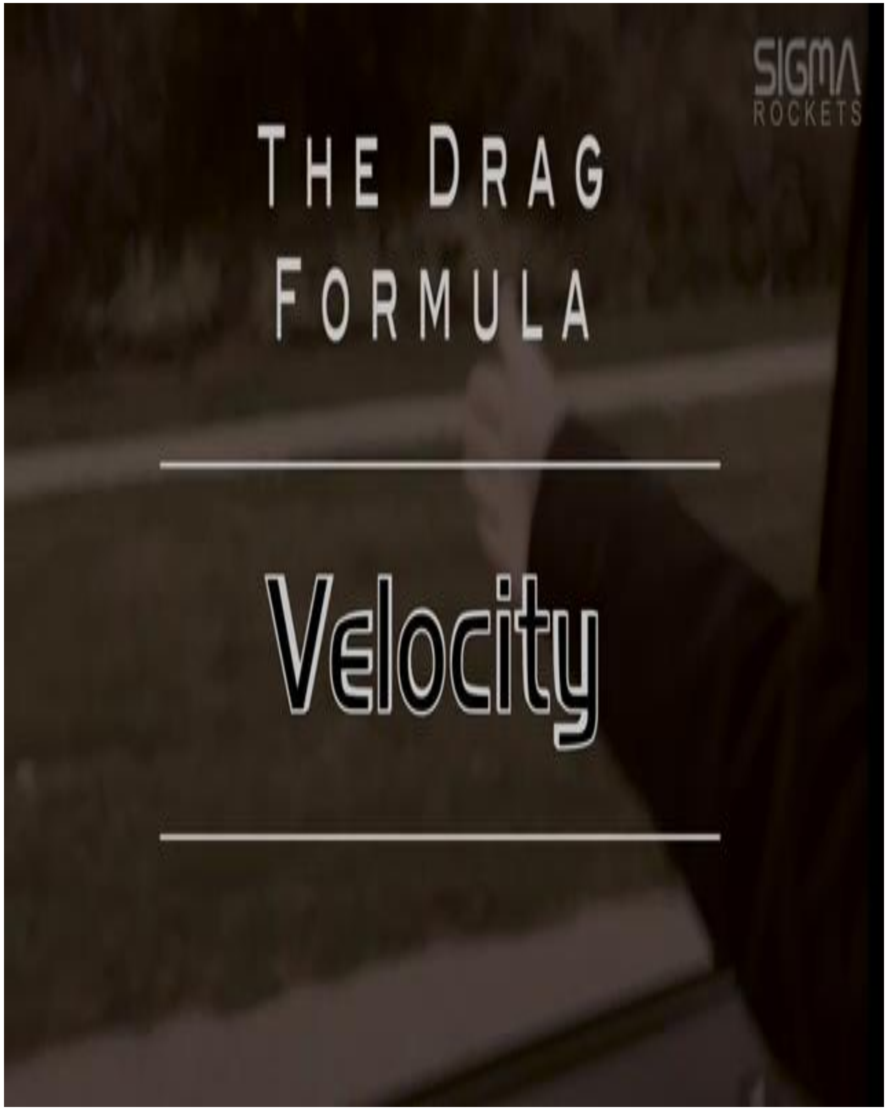


Coefficient of Drag

- Depends on the shape and orientation of a body relative to the fluid flow, with long, streamlined bodies generally having lower coefficients of drag than blunt or irregularly shaped objects.

Theoretical Square Law

- Drag increases approximately with the square of velocity when relative velocity is low.
- According to this law, if cyclists double their speed and other factors remain constant, the drag force opposing them increases fourfold.



Drag

- The effect of drag is more consequential when a body is moving with high velocity, which occurs in sports such as cycling, speed skating, downhill skiing, the bobsled and luge.

Skin friction

- Skin friction is derived from the sliding contacts between successive layers of fluid close to the surface of a moving body.
- It is also called surface drag and viscous drag.

Skin friction

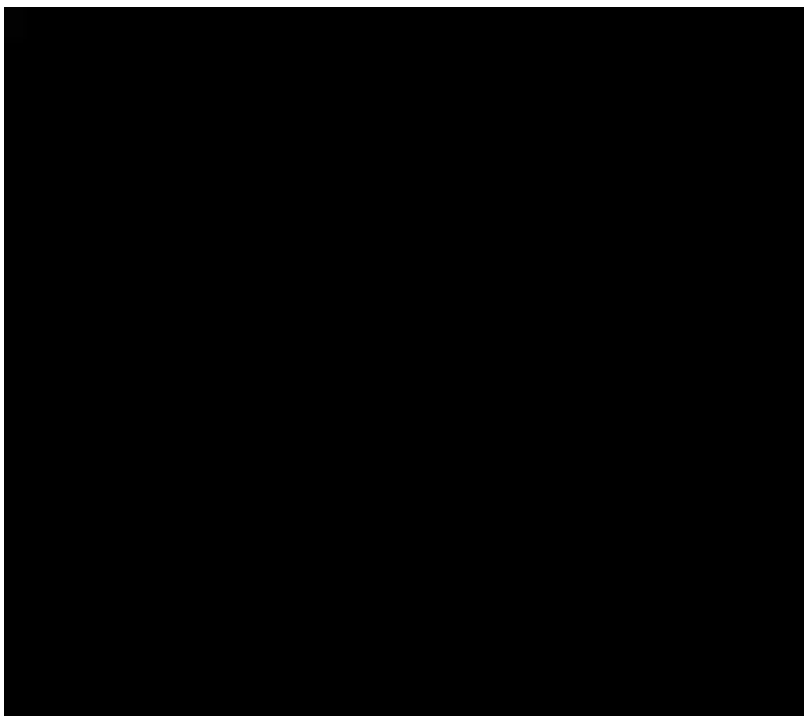
- Several factors affect the magnitude of skin friction drag:
  - It increases proportionally with increases in the relative velocity of the fluid flow,
  - the surface area of the body over which the flow occurs,
  - the roughness of the body surface,
  - and the viscosity of the fluid.

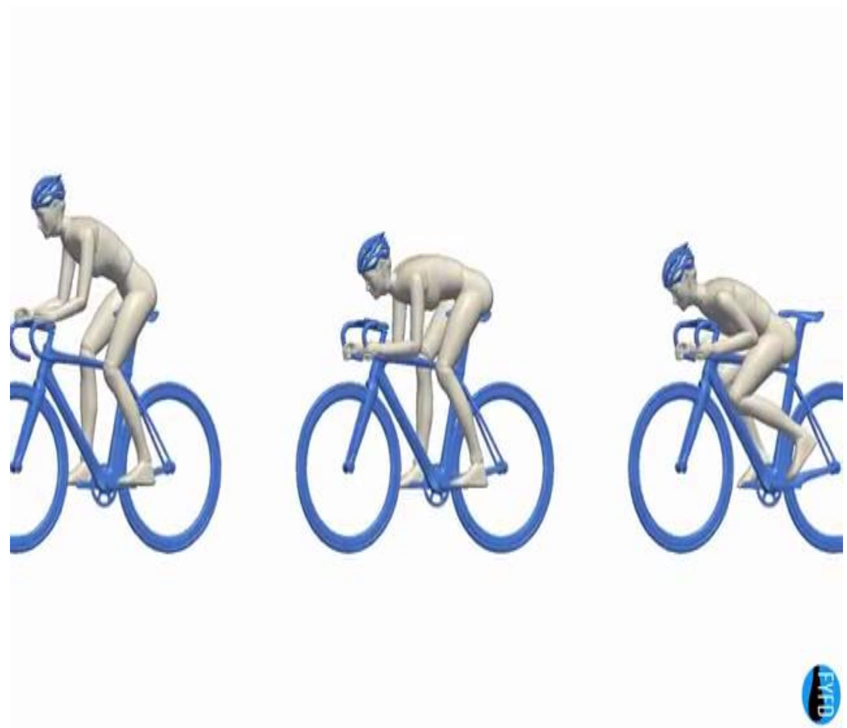
Skin friction

- Wearing smooth, snug clothing helps to minimize skin friction.

Form drag

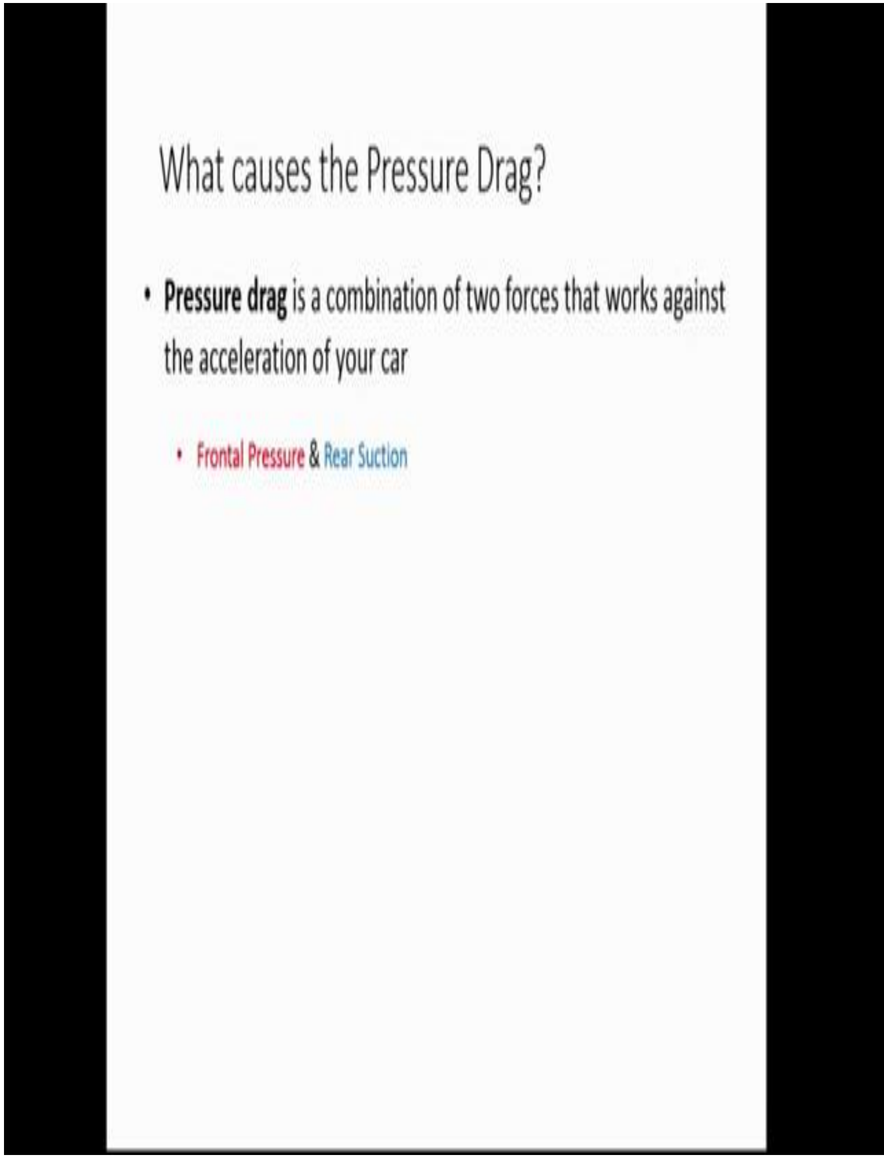
- Resistance created by a pressure differential between the **lead and rear sides** of a body moving through a fluid.
- Also called profile drag and pressure drag.





Form drag

- Form drag Several factors affect the magnitude of form drag including:
  - the relative velocity of the body with respect to the fluid,
  - the magnitude of the pressure gradient between the front and rear ends of the body,
  - and the size of the surface area that is aligned perpendicular to the flow.
  - Streamlining helps to minimize form drag.



Wave drag

- Resistance created by the generation of waves at the interface between two different fluids, such as air and water.

Small drag in streamlined position

Large drag in unstreamlined position

Wave drag

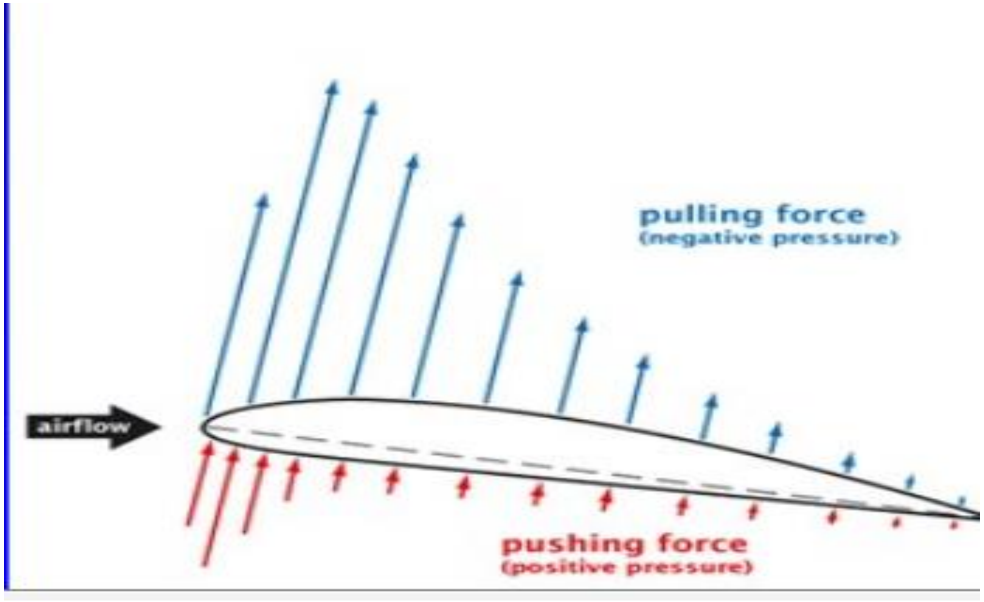
- Although bodies that are completely submerged in a fluid are not affected by wave drag, this form of drag can be a major contributor to the overall drag acting on a human swimmer, particularly when the swim is done in open water.

Wave drag

- When a swimmer moves a body segment along, near, or across the air and water interface, a wave is created in the more dense fluid (the water).
- The reaction force the water exerts on the swimmer constitutes wave drag.

Wave drag

- At fast swimming speeds, wave drag is generally the largest component of the total drag acting on the swimmer.



Lift Force

- According to this principle, regions of relative high velocity fluid flow are associated with regions of relative low pressure, and regions of relative low velocity are associated with regions of relative high pressure.

Lift Force

- When these regions of relative low and high pressure are created on opposite sides of the foil, the result is a lift force directed perpendicular to the foil from the high pressure zone toward the low pressure zone.

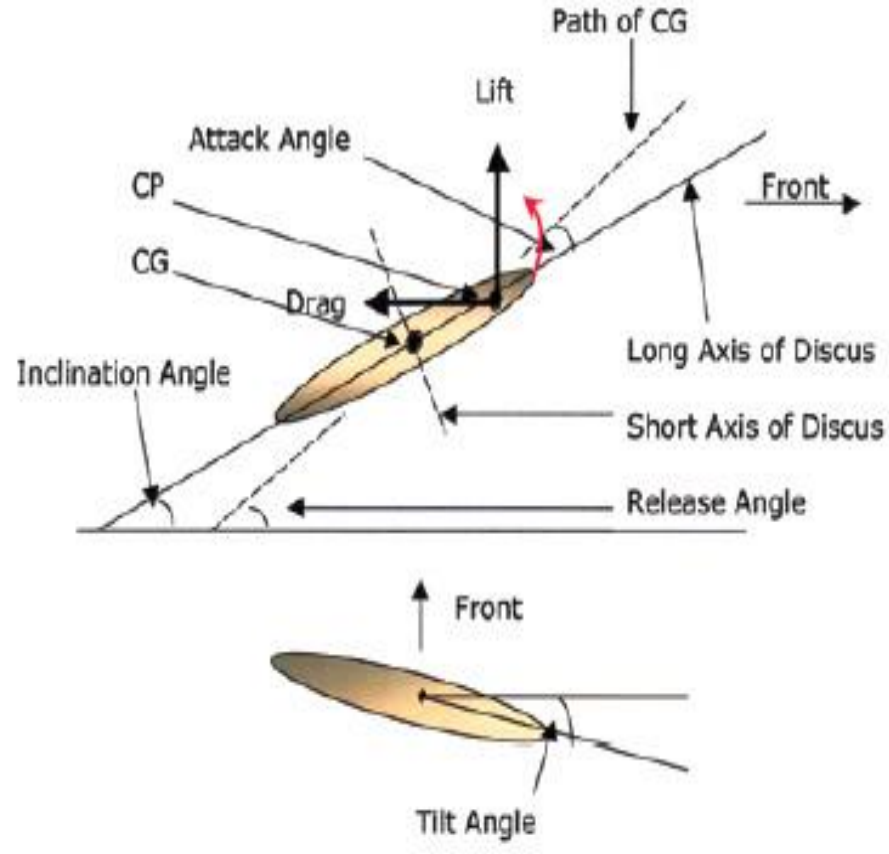


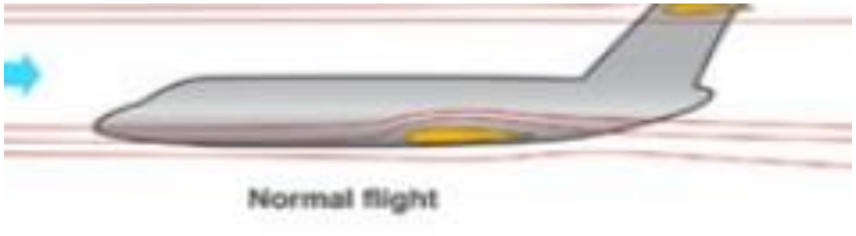
Figure 1. Aerodynamic forces and angles during the discus flight. Top: view from the side, bottom: view from the back. Red arrow depicts the pitching moment. CG=Center of Gravity, CP=Center of Pressure.

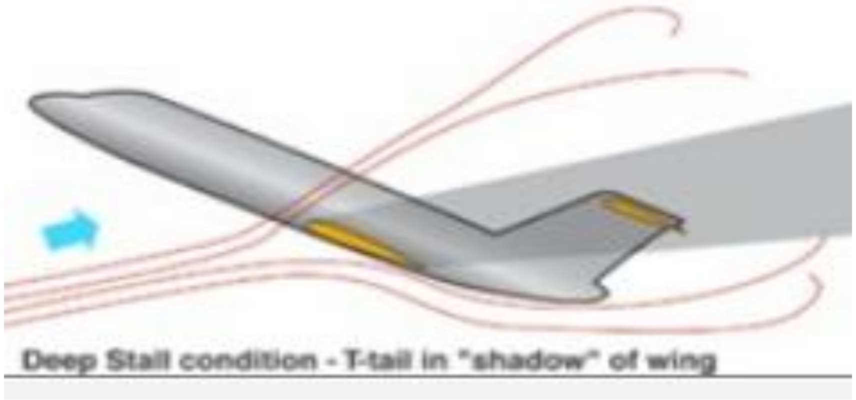
Lift Force

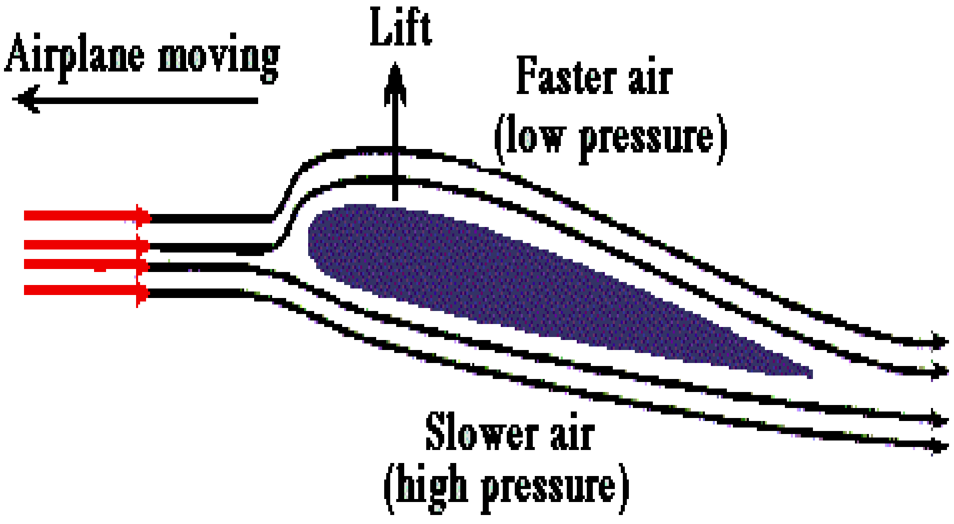
- As fluid density increases and/or surface area increases on the flat side of the foil, lift increases.
- The shape of the object also determine lift capabilities (coefficient of lift).

Lift Force

- With too steep of an angle of attack, the fluid cannot flow along the curved side of the foil or create.
- This can cause a stall and loss in altitude.

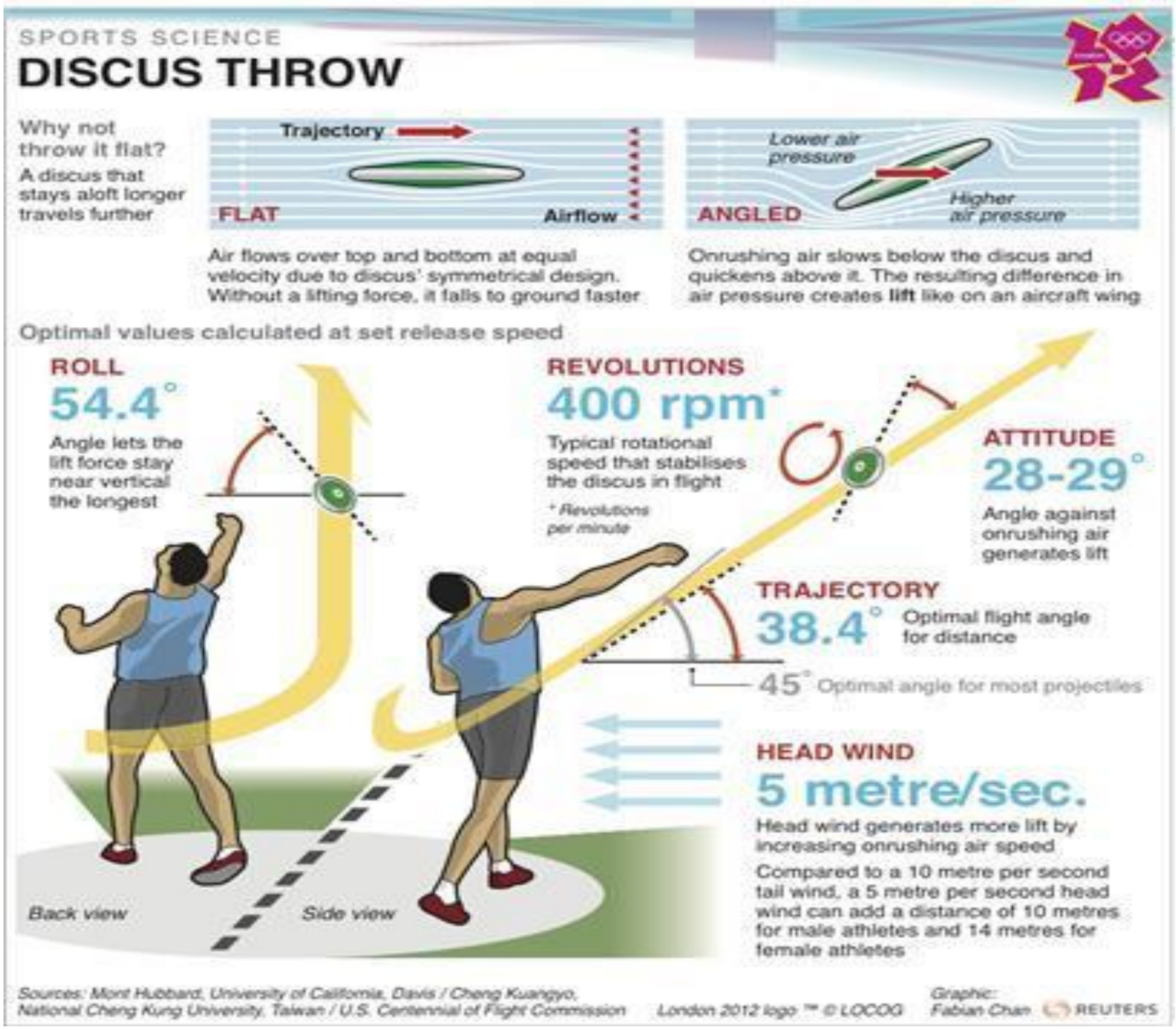






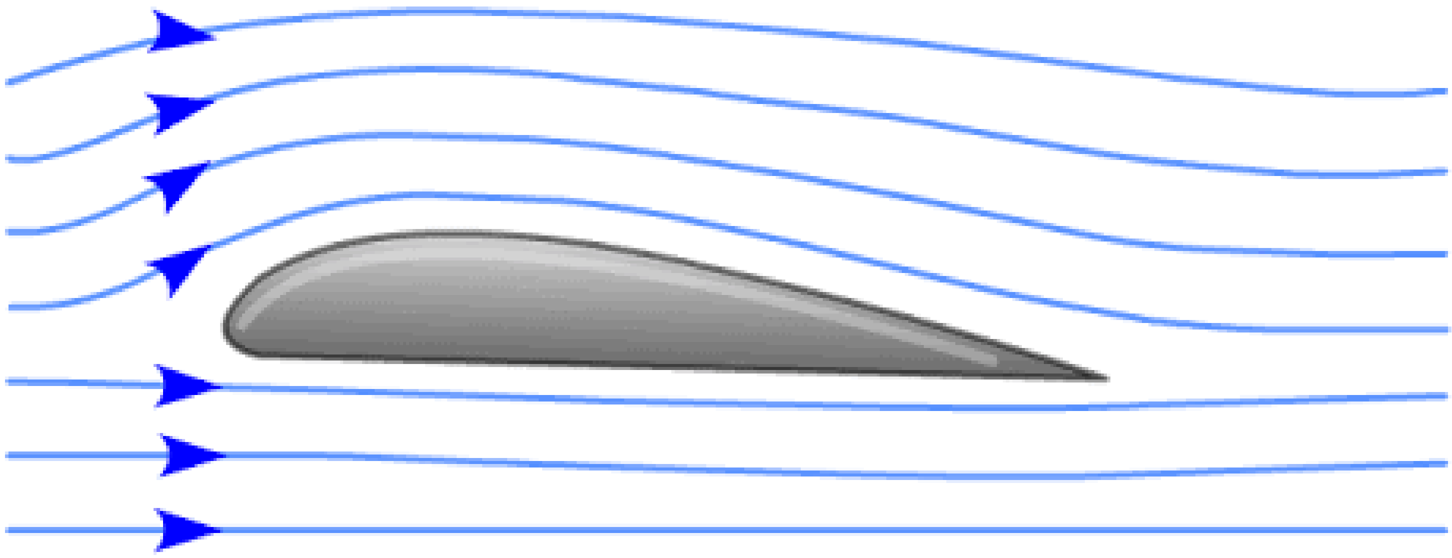
Factors affecting lift force

- The greater the velocity of the foil relative to the fluid, the greater the pressure differential and the lift force generated.



Foil

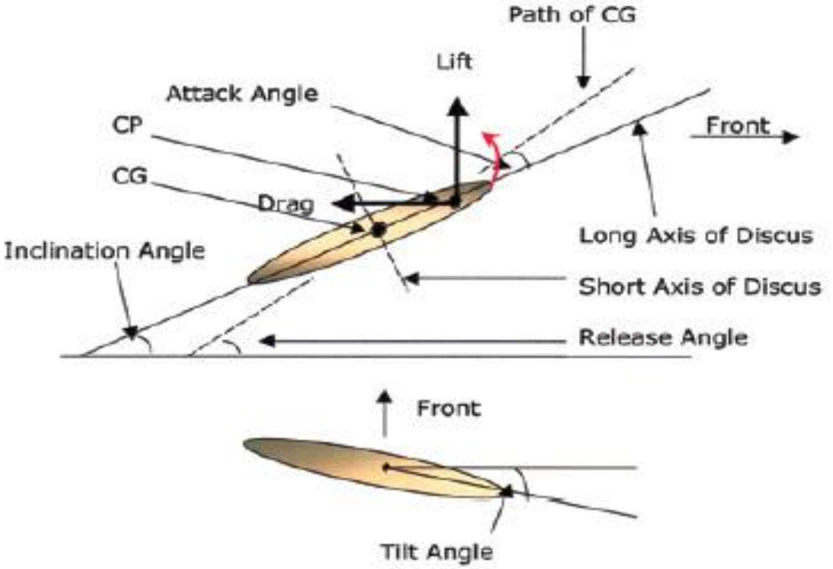
- Shape capable of generating lift in the presence of a fluid flow.



The shape of wing forces air to move faster over the top surface.

Angle of attack

- Angle between the longitudinal axis of a body and the direction of the fluid flow.
- A positive angle of attack is necessary to generate a lift force.



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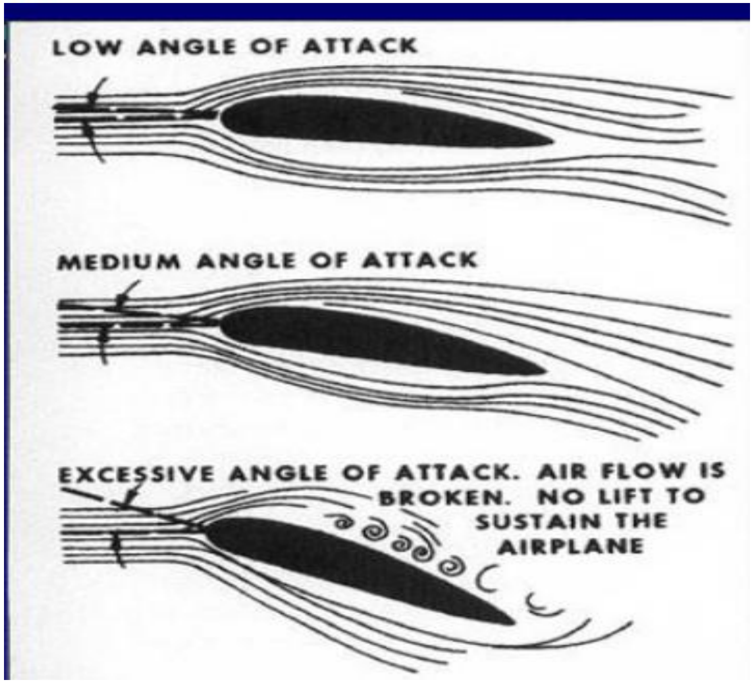
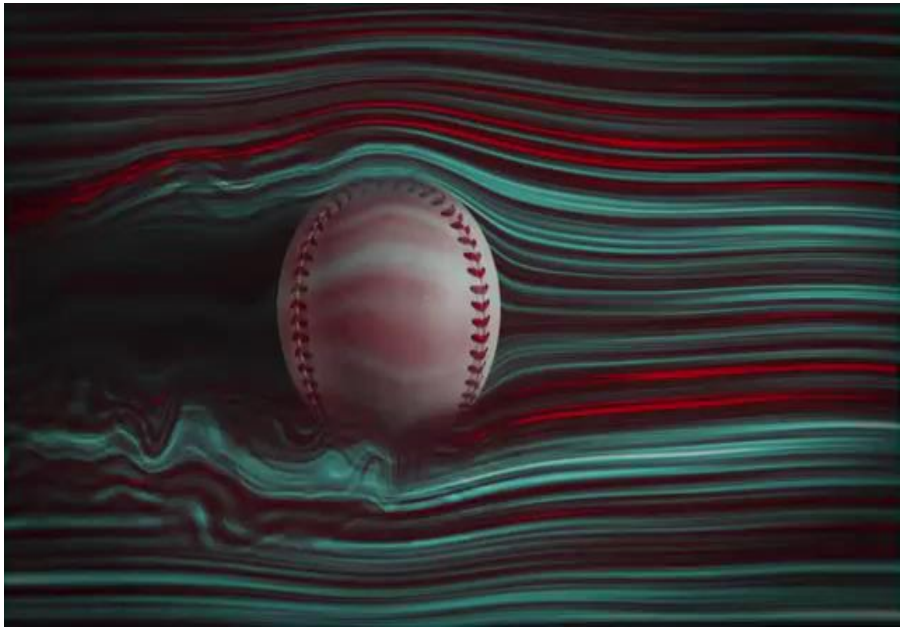


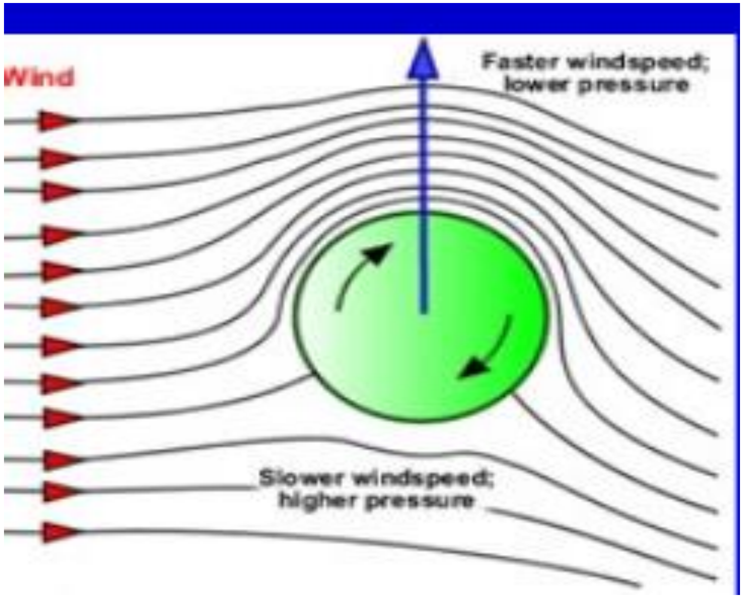
Lift/drag ratio

- The magnitude of the lift force divided by the magnitude of the total drag force acting on a body at a given time.
- Unitless number that is an index of a body’s ability to generate lift.

Magnus Effect/Bernoulli's Principle

- Spinning objects also generate lift.
- When an object in a fluid medium spins, the boundary layer of fluid molecules adjacent to the object spins with it.





Magnus Effect

- This creates a region of relative low velocity and high pressure.
- On the opposite side of the spinning object, the boundary layer moves in the same direction as the fluid flow, thereby creating a zone of relative high velocity and low pressure.
- This pressure differential creates a lift force directed from the high pressure region to the low pressure region (curve ball).


Thank You