

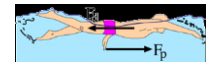
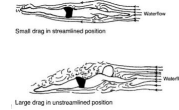
Swimming Kinetics



Swimming Kinetics

- Forces acting on the swimmer

- Gravity
- Buoyancy
- Resistive drag
- Propulsive drag



- Horizontal motion

$$\Sigma F = ma$$

$$F_{\text{propulsion}} - F_{\text{resistance}} = ma$$

$$F_{\text{propulsion}} = ma + F_{\text{resistance}}$$



Water

- Density

$$\rho = m/V$$

- ρ = 'rho' = density
- m = mass
- V = volume

$$\text{Units} = \text{kg/m}^3$$

– Water is about 784 times more dense than air.

- Dependent on temperature



Water

- Buoyancy Force

– The upward directed force keeping an object afloat.

– Equal in magnitude to the weight of water displaced.

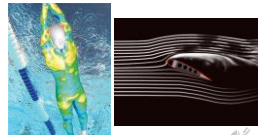


Buoyancy Force Wetsuits



Fluid Dynamics

- The science of flow of fluids.
 - Fluids we will focus on: air and water.
- Aerodynamics
 - The study of motion of air and other gases.
- Hydrodynamics
 - The study of motion of water.
- Two classes of forces:
 - Drag
 - Lift



Fluid Dynamics: Drag Force

- Types of drag forces:
 - Parasitic drag
 - Skin friction (aka surface drag)
 - C_{friction}
 - Profile drag (aka form drag)
 - C_{form}
 - Lift-induced drag
 - Wave drag
 - Function of length of object
 - Can be reduced by swimming underwater

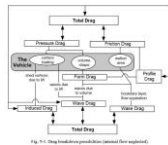


Fig. 10-1 Drag forces on a swimmer (adapted from Wikipedia)



- All are part of drag force.

Fluid Dynamics: Drag Force

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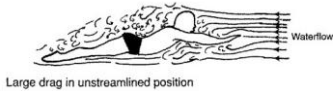
Resistance Drag

- All are part of drag force.



Drag Resistance Force

- Wetsuits:
 - Skin Friction (Surface Drag)
 - The drag caused by the fluid flowing along the surface of the body.
 - Some fluid on the surface of the body does not slide but sticks to the surface.



Drag Resistance Force

- Frontal Area
 - aka pressure drag or form drag
 - The area of an object that is exposed perpendicular to the flow partly determines the drag force.
 - Turbulent flow is a region of low pressure behind the object.
 - The cause of turbulent flow is the force of the object on the fluid (and the fluid pushes back with an equal and opposite force ... drag force).
 - Streamlining: causes a reduction of turbulent flow ... and a reduction in drag force.



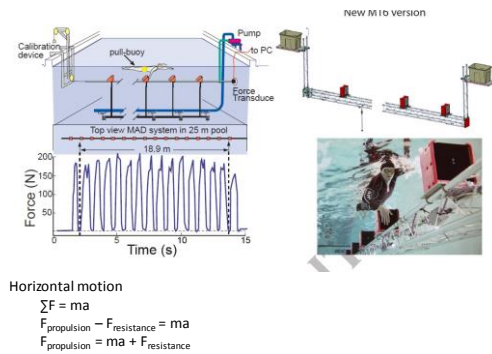
Drag Resistance Force

- aka Fluid Resistance
- Forces that oppose the relative motion of an object through a fluid.
 - Air: aerodynamic force
 - Water: hydrodynamic force
- $F_D = \frac{1}{2} \rho C_d A v^2$
 - F_D = drag force
 - ρ = density of fluid
 - C_d = drag coefficient (unitless parameter)
 - $C_d = C_{\text{friction}} + C_{\text{form}}$
 - A = frontal area
 - v^2 = velocity of object relative to fluid
 - It does not matter if the object is moving through the fluid or if the fluid is flowing over the object.
- Units: N

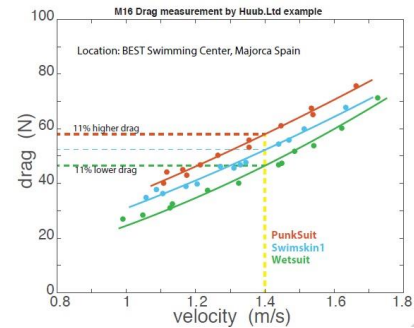
} $C_D A$



Drag Resistance Force – Skin Suit



Drag Resistance Force – Skin Suit

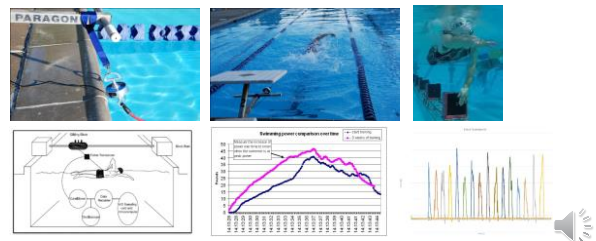


Drag Propulsive Force

- Drag force can be a propulsive force when the drag force acts in the same direction as the intended direction of the object.
 - Tail-wind
 - Blades of an oar pushing backward through the water.
 - Swimmer's hand pushing against the water to move the body forward.

Drag Propulsion Force

- The propulsive forces causing forward movement of the swimmer are not entirely clear.
 - Measurements in the water



Fluid Dynamics: Lift Forces

- Lift force acts perpendicular to the drag force.
 - The word lift suggests that all lift forces act upward (e.g., airplane wing). That is not the case for all objects moving through fluids.
 - Perpendicular to drag force
- Bernoulli's Principle
 - Where the flow velocity is fast, the pressure is low; where the flow velocity is slow, the pressure is high.



Fluid Dynamics: Lift Forces

- $F_L = \frac{1}{2} C_L \rho v^2 A$
 - F_L = lift force
 - C_L = coefficient of lift
 - A = area of body
 - ρ = density of fluid
 - v = relative flow velocity
- Coefficient of lift
 - An index of how much lift the object can create lift.
 - A wing has a higher C_L than a book when moving through air.
 - C_L is influenced by angle of attack.



Wet suits

- They Work
 - Warmth
 - Speed
 - Safety?
- Taking off wet suits



Summary

- Water
 - Density, buoyancy force
- Drag forces
 - Resistive Drag
 - Propulsive Drag
 - $F_D = \frac{1}{2} \rho v^2 C_d A$
 - Units: N

