Aerodynamic/Hydrodynamic Drag

Unit: Dynamics (Forces) & Gravitation

NGSS Standards: N/A

MA Curriculum Frameworks (2006): N/A

AP Physics 1 Learning Objectives: N/A

Knowledge/Understanding Goals:

- an intuitive sense of how aerodynamic drag works
- how aerodynamic drag is calculated

Language Objectives:

- Understand and correctly use the term “drag” when it refers to an object that is slowed down by a fluid.
- Accurately describe and apply the concepts described in this section, using appropriate academic language.
- Set up and solve word problems relating to aerodynamic drag.

Labs, Activities & Demonstrations:

- Crumpled piece of paper or tissue *vs.* golf ball (drag force doesn’t depend on mass).
- Projectiles with same mass but different shapes.

Notes:

Most of the AP Physics 1 problems that involve aerodynamic drag fall into two categories:

1. The drag force is small enough that we ignore it.
2. The drag force is equal to some other force that we can measure or calculate.
3. The question asks only for a qualitative comparison of forces with and without aerodynamic drag.

Calculations of aerodynamic or hydrodynamic drag are beyond the scope of the course and will not appear on the AP exam. However, it is interesting to estimate the drag force in simple situations, given the velocity, shape, and cross-sectional area of the object and the density of the fluid it is moving through.

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For simple situations involving aerodynamic drag, the drag force is given by the following equation:

$$\vec{F}_D = -\tfrac{1}{2}\rho\vec{v}^2 C_D A$$

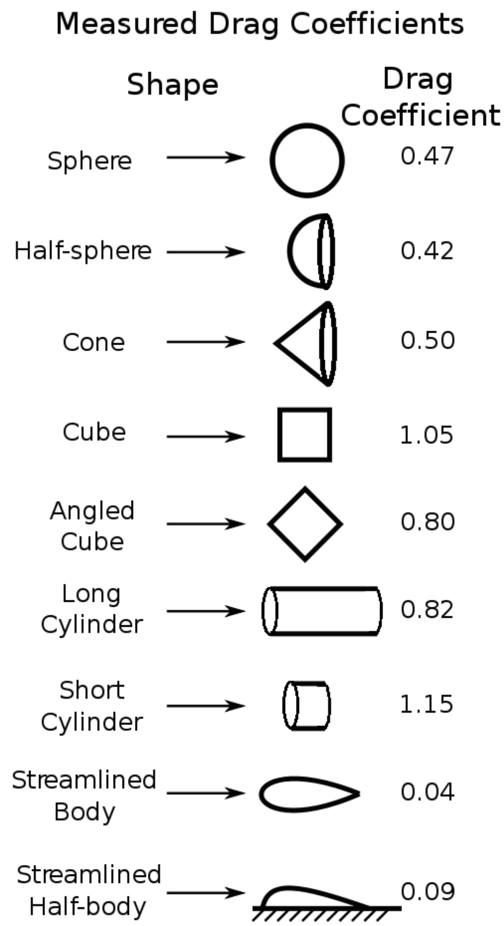
where:

$\vec{F}_D$ = drag force
ρ = density of the fluid that the object is moving through
$\vec{v}$ = velocity of the object (relative to the fluid)
C_D = drag coëfficient of the object (based on its shape)
A = cross-sectional area of the object in the direction of motion

This equation applies when the object has a blunt form factor, and the object's velocity relative to the properties of the fluid (such as viscosity) causes turbulence in the object's wake (*i.e.,* behind the object).

The drag coëfficient, C_D, is a dimensionless number (meaning that it has no units) that encompasses all of the types of friction associated with aerodynamic drag. It serves the same purpose in drag problems that the coëfficient of friction, μ, serves in problems involving friction between solid surfaces.

Approximate drag coëfficients for simple shapes are given in the table to the right, assuming that the fluid motion relative to the object is in the direction of the arrow.



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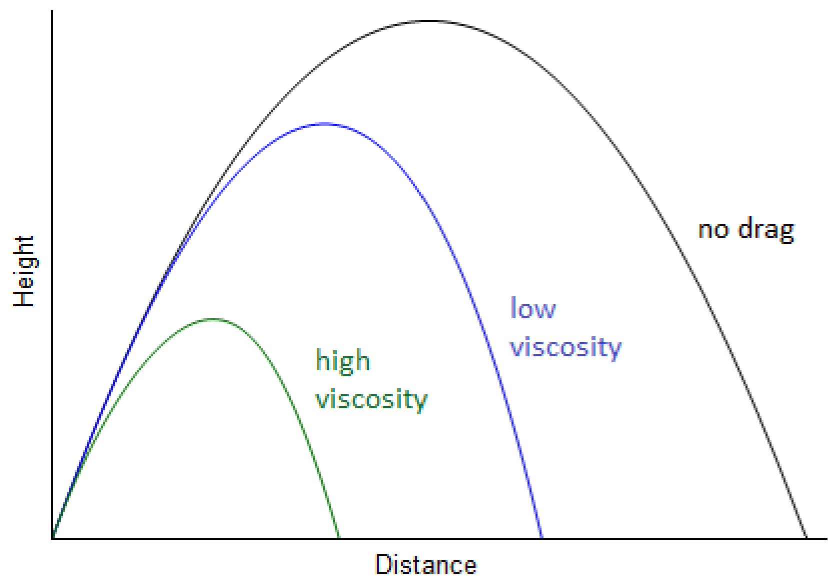
Note, that the equation and the drag coëfficients above assume that the fluid is in laminar (not turbulent) flow, and is not too viscous. (Viscosity measures how "gooey" a fluid is, meaning how much it resists flow and hinders the motion of objects through itself.)

The following graph shows how a projectile would move differently through fluids with different viscosities.



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