Name: ____________________

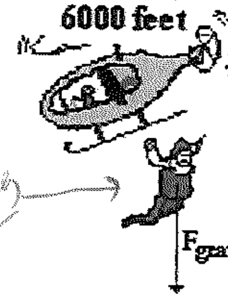
Skydiving

Read from **Lesson 3** of the **Newton's Laws** chapter at **The Physics Classroom:**

http://www.physicsclassroom.com/Class/newtlaws/u2l3e.html

MOP Connection: Newton's Laws: sublevel 11

A 90-kg (approx.) skydiver jumps out of a helicopter at 6000 feet above the ground. As he descends, the force of air resistance acting upon him continually changes. The free-body diagrams below represent the strength and direction of the two forces acting upon the skydiver at six positions during his fall. For each diagram, apply Newton's second law ($F_{net} = m \bullet a$) to determine the acceleration value.

6000 feet	5500 feet	4500 feet
	 $F_{air} = 200$ N	 $F_{air} = 900$ N
$F_{grav} = 900$ N	$F_{grav} = 900$ N	$F_{grav} = 900$ N
a = 10 m/s/s	a = 7.7 m/s/s	a = 0 m/s/s
3000 feet	**2900 feet**	**1500 feet**
 $F_{air} = 1100$ N	 $F_{air} = 1500$ N	 $F_{air} = 900$ N
$F_{grav} = 900$ N	$F_{grav} = 900$ N	$F_{grav} = 900$ N
a = +2.2 m/s/s	a = 6.6 m/s/s	a = 0 m/s/s

1. At which two altitudes has the skydiver reached terminal velocity? 4500 Ft / 1500 Ft
2. At which altitude(s) is the skydiver in the state of speeding up? 6000 Ft
3. At which altitude(s) is the skydiver in the state of slowing down? 3000 2900
4. At 2900 feet, the skydiver is __________. Choose two.
   a. moving upward (b.) moving downward c. speeding up (d.) slowing down
5. Explain why air resistance increases from 6000 feet to 4500 feet.
   More wind, resistance → Traveling faster
6. Explain why air resistance decreases from 3000 feet to 1500 feet.
   moving slower, larger area of chute

Aerodynamic/Hydrodynamic Drag

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:

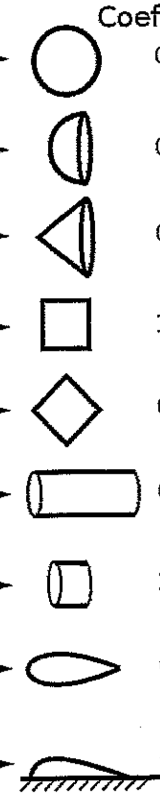
- $\vec{F}_D$ = drag force
- ρ = density of the fluid that the object is moving through
- $\vec{v}$ = velocity of the object (relative to the fluid)
- C_D = drag coëfficient of the object (based on its shape)
- A = cross-sectional area of the object in the direction of motion

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.

Measured Drag Coefficients

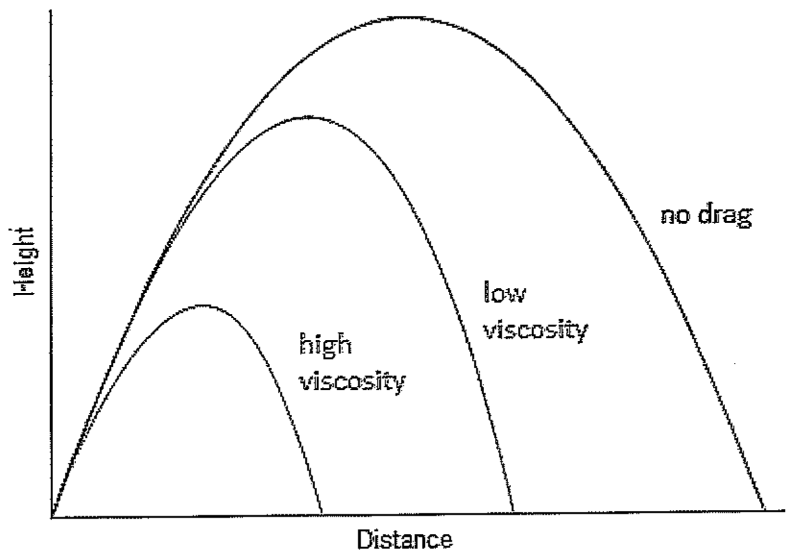


Shape	Drag Coefficient
Sphere →	0.47
Half-sphere →	0.42
Cone →	0.50
Cube →	1.05
Angled Cube →	0.80
Long Cylinder →	0.82
Short Cylinder →	1.15
Streamlined Body →	0.04
Streamlined Half-body →	0.09

Use this space for summary and/or additional notes.

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.



Use this space for summary and/or additional notes.

 Name: ____________________

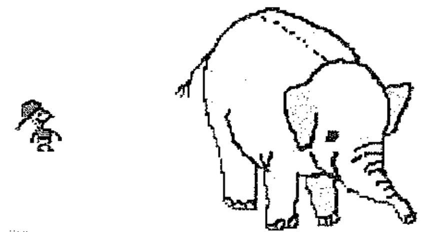
Air Resistance and Terminal Velocity

Read from **Lesson 3** of the **Newton's Laws** chapter at **The Physics Classroom:**

http://www.physicsclassroom.com/Class/newtlaws/u2l3e.html

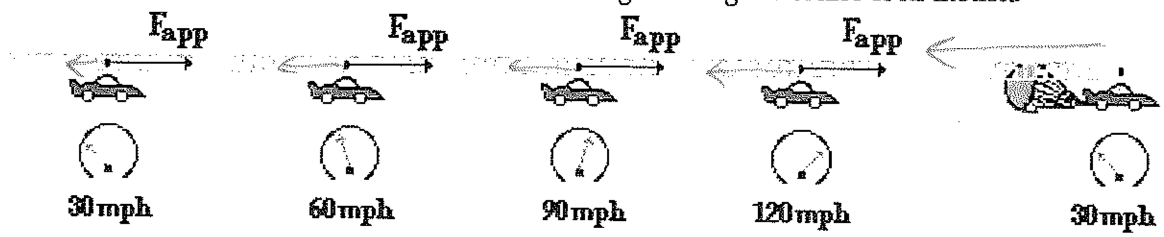
MOP Connection: Newton's Laws: sublevel 11

1. When falling under the influence of air resistance and dropped from the same height, which will fall to the ground at a faster rate?
   a. a mouse b. an elephant c. the same

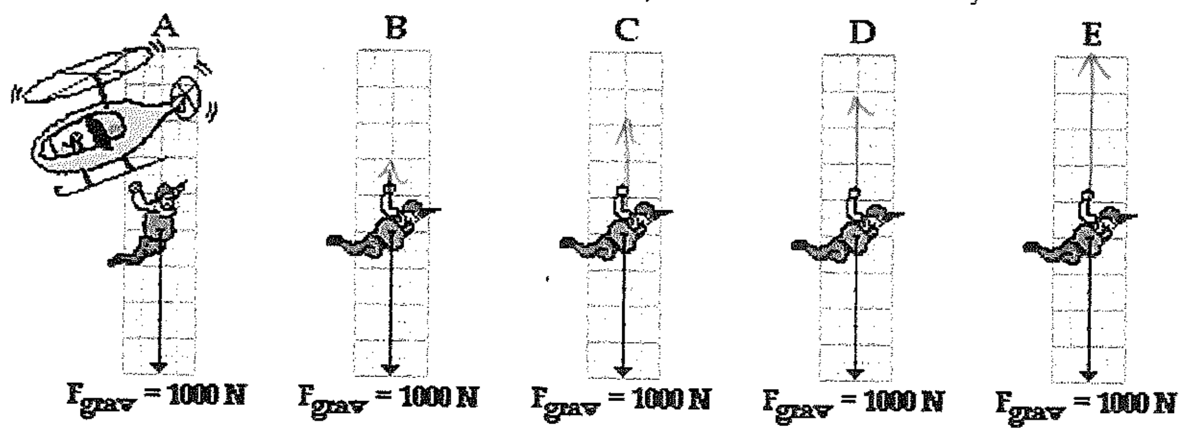


2. Which of the following variables will have a direct effect upon the amount of air resistance experienced by an object? (That is, for which of these quantities will an increase lead to a resulting increase in the air resistance force?)
   a. speed b. air density c. cross-sectional area

3. Consider the dragster's motion below. Speedometer readings and the forward propulsion force (F_{app}) are shown. The top (or terminal) speed is 120 mph. Draw F_{air} force arrows on each diagram to illustrate how the amount of air resistance changes during the course of its motion.



4. Draw F_{air} force arrows to show how the force of air resistance changes on the falling skydiver. At A, the diver has just jumped; and at E, the diver has just reached terminal velocity.



5. Fill in the blanks in the following paragraph.

   As an object moves faster and faster, the amount of air resistance ____________ (increases, decreases) until a state of terminal velocity is reached. Once terminal velocity is reached, the force of air resistance is ____________ (greater than, less than, equal to) the force of gravity. Hence, the object will ________________________ (continue to accelerate, stop its motion, stop its acceleration, move back up to its starting position).