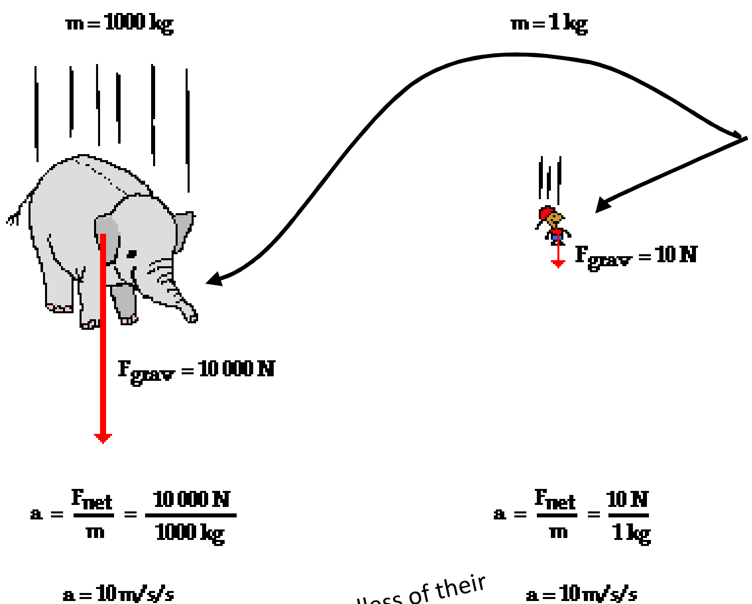
Free Fall

All objects (regardless of their mass) free fall with the same acceleration - 9.8 m/s/s. This particular acceleration value is so important in physics that it has its own peculiar name - the acceleration of gravity - and its own peculiar symbol - **g**. But why do all objects free fall at the same rate of acceleration regardless of their mass? Is it because they all weigh the same? ... because they all *have the same gravity*? ... because the air resistance is the same for each? Why?

Free Fall Motion

Free fall is a special type of motion in which the only force acting upon an object is gravity. Objects that are said to be undergoing *free fall*, are not encountering a significant force of air resistance; they are falling under the sole influence of gravity. Under such conditions, all objects will fall with the same rate of acceleration, regardless of their mass. But why?

Consider the free-falling motion of a 1000-kg baby elephant and a 1-kg overgrown mouse.



If Newton's second law were applied to their falling motion, and if a free-body diagram were constructed, then it would be seen that the 1000-kg baby elephant would experiences a greater force of gravity.

This greater force of gravity would have a direct affect upon the elephant's acceleration; thus, based on force alone, it *might be thought* that the 1000-kg baby elephant would accelerate faster. But acceleration depends upon two factors: **force and mass**.

The 1000-kg baby elephant obviously has more mass (or inertia). This increased mass has an inverse affect upon the elephant's acceleration. And thus, the direct affect of greater force on the 1000-kg elephant is *offset* by the inverse affect of the greater mass of the 1000-kg elephant; and so each object accelerates at the same rate - approximately 10 m/s^2.

The ratio of force to mass (F_{net}/m) is the same for the elephant and the mouse under situations involving free fall.

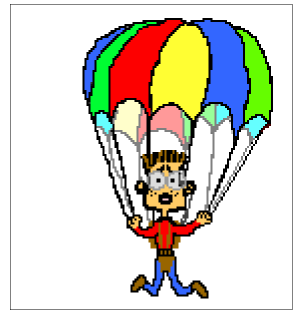
All objects, regardless of their mass, fall at this rate while here on Earth.

Remember!

Earth's g=-9.8m/s^2 or approximately -10m/s/s

Falling with Air Resistance

As an object falls through air, it usually encounters some degree of air resistance. Air resistance is the result of collisions of the object's leading surface with air molecules. The actual amount of air resistance encountered by the object is dependent upon a variety of factors.



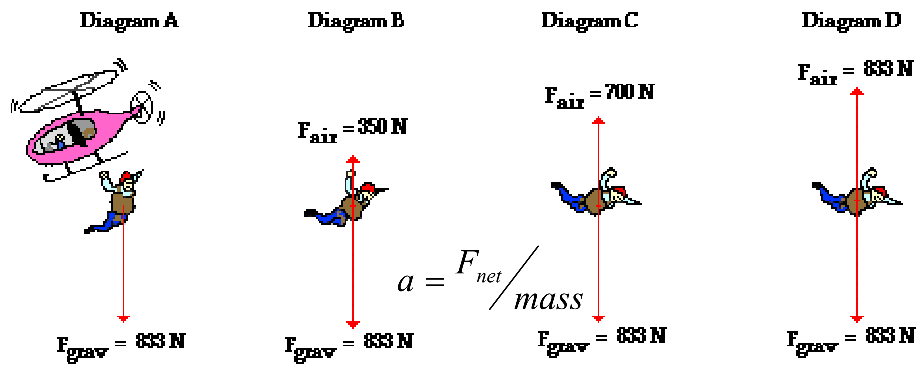
To keep the topic simple, it can be said that the two most common factors that have a direct affect upon the amount of air resistance are:

1. the speed of the object-Increased speeds result in an increased amount of air resistance.

2. cross-sectional area of the object-Increased cross-sectional areas result in an increased amount of air resistance.

Why does an object that encounters air resistance eventually reach a terminal velocity? To answer this questions, Newton's second law will be applied to the motion of a falling skydiver.

In the diagrams to the right, free-body diagrams showing the forces acting upon an 85-kg skydiver (equipment included) are shown. For each case, use the diagrams to determine the net force and acceleration of the skydiver at each instant in time.



$$a = F_{net} / mass$$

$$a = \frac{-833N}{85kg} = -9.8m/s^2$$

$$a = \frac{-833N + 350N}{85kg} = -5.7m/s^2$$

$$a = \frac{-833N + 700N}{85kg} = -1.6m/s^2$$

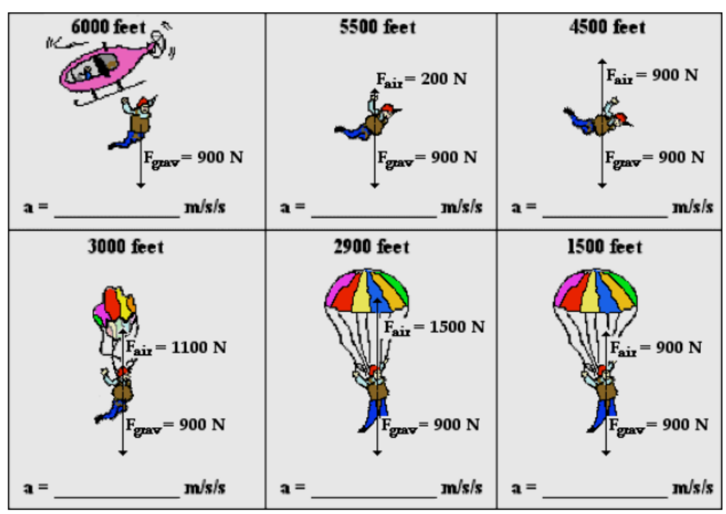
$$a = \frac{-833N + 833N}{85kg} = 0m/s^2$$

The diagrams illustrate a key principle. As an object falls, it picks up speed. The increase in speed leads to an increase in the amount of air resistance. Eventually, the force of air resistance becomes large enough to balances the force of gravity. At this instant in time, the net force is 0 Newton; the object will stop accelerating. The object is said to have reached a **terminal velocity**. The change in velocity terminates as a result of the balance of forces. The velocity at which this happens is called the terminal velocity.

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.

For each diagram, apply Newton's second law (Fnet = m•a) to determine the acceleration value.



1. At which two altitudes has the skydiver reached terminal velocity?

2. At which altitude(s) is the skydiver in the state of speeding up?

3. At which altitude(s) is the skydiver in the state of slowing down?

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.

6. Explain why air resistance decreases from 3000 feet to 1500 feet.