Terminal Velocity and Air Resistance

In general, whenever something moves through the air, the air exerts a force on the object to oppose its motion — we call this force **air resistance** or **drag force**. The size of the drag force depends on two factors:

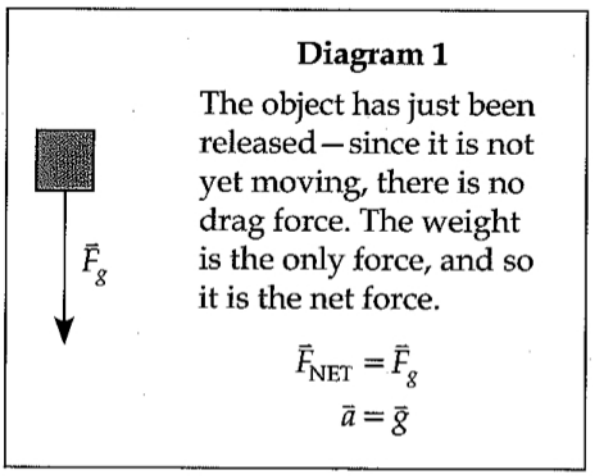
1. The speed of the object.
   - a faster moving object will experience a larger drag force

2. The surface area of the object.
   - objects with a larger surface area will experience a larger drag force

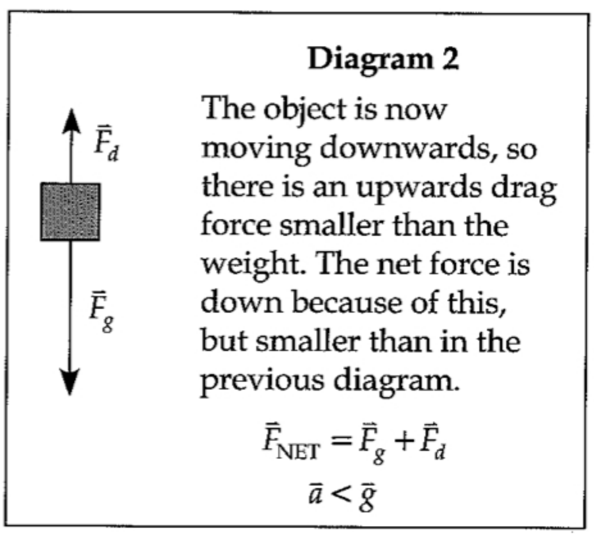
Terminal Velocity

Consider a falling object.

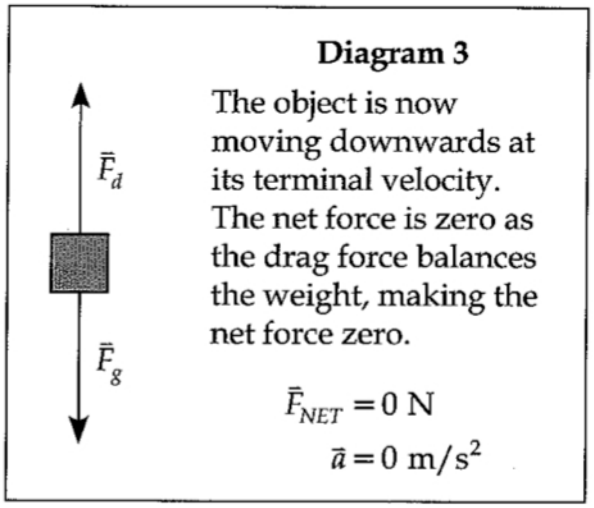
The net force causing the acceleration of the object is made up of two forces: the downward force of gravity (F_g), and the upward drag force (F_d).



As long as $F_g > F_d$, the net force will be downwards, and so downward acceleration will occur.



As the drag force increases (due to the object speeding up) the magnitude of the net force will decrease, thus decreasing the acceleration.



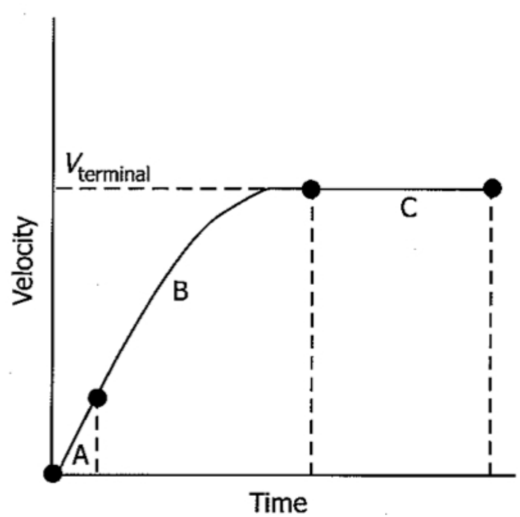
Eventually, the force of air resistance will equal the force of gravity. At this point, the net force on the object will be zero, and the object will no longer be accelerating (though it is certainly still moving!).

We say that the object has reached **terminal velocity**. The terminal velocity of an object is the velocity at which the drag force due to air resistance is equal in magnitude to the force of gravity. The net force on the object is zero, and its acceleration is zero.

The value for terminal velocity will vary, but in general it will be smaller for objects that are light compared to their size.

Terminal Velocity and a Parachutist

When a parachutist jumps from an airplane, a terminal velocity will be reached. The graph below shows possible velocities at various times (down is being used as the positive direction).



In section A, air resistance is negligible (small enough to be ignored), making gravity the only force worth considering. During this stage, the parachutist falls with an acceleration of $9.8\ m/s^2$ as we would expect. This results in a constant slope on the velocity-time graph.

In section B, the air resistance is no longer negligible, and is now increasing due to the increasing speed of the parachutist. This results in a decreasing net force and a decreasing acceleration. Thus, the graph is curved in this section, as the slope (acceleration) decreases. Note, however, that velocity continues to increase.

In section C, the air resistance has increased to the point where $F_g = F_d$ and the net force on the parachutist is zero. No acceleration occurs, so the slope of the velocity-time graph in this section is zero. The parachutist falls at a constant velocity — this is the terminal velocity.

A parachutist falling with a closed parachutist ha a pretty high terminal velocity — approximately $200\ km/h$. Once the parachute is opened, the falling person becomes a much larger object. Gravity does not change, but the air resistance becomes much larger. This means the upward drag force will be larger than gravity, producing an upwards acceleration, so the parachutist slows down. The reverse of the above then happens: as the parachutist slows down, the drag force decreases until it again matches the force of gravity. A new, much smaller, terminal velocity is reached — approximately $20\ km/h$ — that is slow enough for a safe landing.

Homework
Hand-in Assignment #4