AS Level Physics

Chapter 3 – Forces and Motions

3.4.1 Motion with Non-Uniform Acceleration

Notes

DRAG

There are two types of friction:

1) **Contact friction -** A resistive force which acts between two solid surfaces that slide, across each other as shown on Fig 1.

2) **Fluid friction/Drag** – A resistive force which acts on any object which is moving through a FLUID (i.e. liquid, gas or anything that flows). This resistive force is known as Drag Force and acts in the opposite direction to the velocity. As shown on Fig 2.

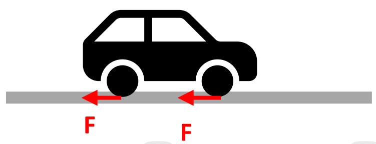

Fig 1: Contact friction acting between the wheels of a car and the road

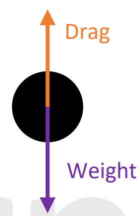

Fig 2: Drag force acting on a ball falling through air.

Things to note about friction:

- Always acts in the opposite direction to the motion.
- They convert kinetic energy to heat.
- They don't exist in a vacuum.

FACTORS THAT AFFECT DRAG

The size (magnitude) of the Drag Force depends on:

1) **Viscosity of the fluid** – Viscosity is a measure of a fluid's resistance to flow. E.g. honey is more viscous compared to water. The greater the viscosity of the fluid the greater the drag force.

2) **Shape of the object** – The more aerodynamic the object the smaller the drag force. E.g., an arrow will experience less drag force compared to a parachute.

3) **Surface area of the object** – The greater the surface area the greater the drag force.

4) **Speed of the object** – The faster the object is moving the greater the drag force.

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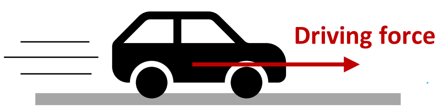
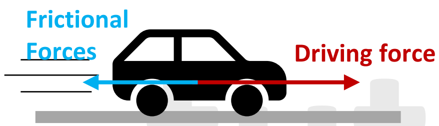
TERMINAL VELOCITY

Terminal velocity of an object is the **steady speed** achieved by an object when the driving force is equal to the frictional force. This can be achieved when the resultant force and acceleration is zero.

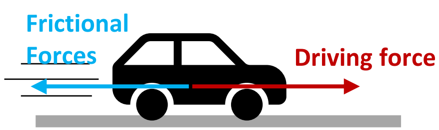
There are three main stages to achieving **terminal velocity**:



1) A car starts to accelerate from rest whilst using a constant driving force. Resultant force acts to the right.



2) As the car gains speed and the velocity increases, the resistance frictional forces (such as drag) also increase. This will reduce the resultant force and as a result reduce the acceleration of the car. The resultant force still acts to the right.



3) Finally, the car reaches a velocity where the resistive frictional forces are equal to the driving force. This means the resultant force and the acceleration are both zero. At this stage, the car has reached a constant velocity known as the Terminal Velocity.

This is why vehicles have a max speed. The forward driving force of the engine is matched by the backward frictional forces. In order to go faster the vehicle would need an engine that can provide a greater driving force. The vehicle can also reach higher speeds by designing it to be more aerodynamic and thereby reduce the frictional forces.

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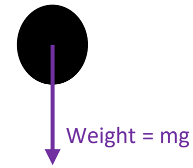
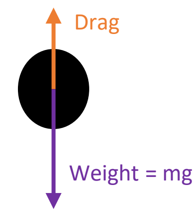
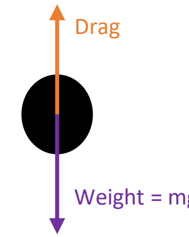
A BALL BEARING FALLING THROUGH A FLUID

Consider a ball bearing released from rest into a fluid.

		
• At the beginning the ball has just been released. • The only force acting on the ball is its own weight. • Weight is a constant force acting downwards. • The weight force causes the ball to accelerate. • The resultant force is equal to the weight (W). $Weight > Drag$	• As the ball continues to fall, its velocity increases and so does the resistive drag force. • This reduces the resultant force acting on the ball and therefore reduces the acceleration. • The resultant force decreases because now the total resultant force is equal to Weight minus Drag force. • But remember the weight force is still greater than the Drag. $Weight > Drag$	Eventually the ball reaches a velocity where the weight force is equal to the drag force. Here the resultant force is zero and the acceleration is also zero. This means the ball bearing is travelling at a constant velocity. When the ball bearing is moving at a constant velocity it is known as the Terminal Velocity. $Weight = Drag$

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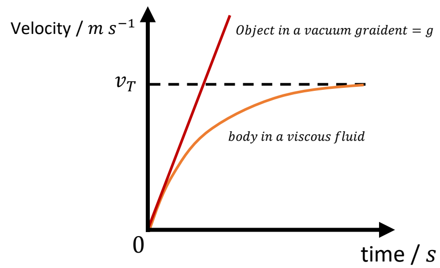
TERMINAL VELOCITY GRAPHS

You need to be able to draw and understand the velocity time and acceleration time graphs for an object undergoing terminal velocity.

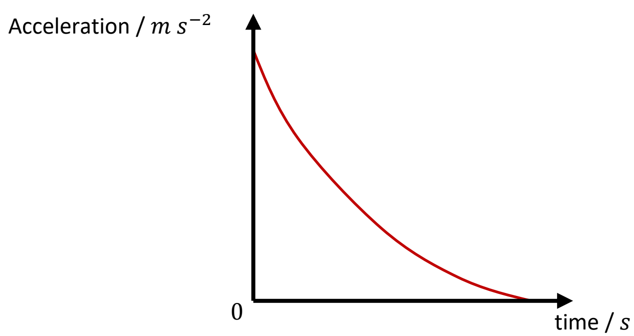
An object falling under gravity and where DRAG forces are negligible (a vacuum) you get a straight-line graph. This indicates a constant acceleration where the:
gradient = the acceleration of free fall = g ($9.81\ ms^{-2}$)



When an object is dropped in a fluid (i.e. through air), still under the influence of gravity, the object will gain a resistive Drag Force. At the beginning the acceleration is the same, as for an object falling in a vacuum, however the acceleration decreases gradually as the velocity increases. This can be seen by the decreasing gradient of the v/t graph above.

After a period of time, a velocity is reached at which the DRAG FORCE = the WEIGHT. Hence, there is zero resultant force and zero acceleration. This is shown by the flattening of the v/t curve and the zero gradient above. At this stage the object has reached its constant TERMINAL VELOCITY (v_T).

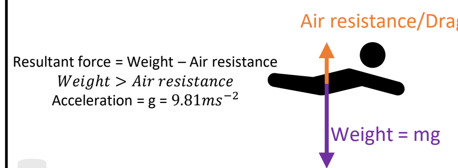
Remember that the gradient of the v/t graph gives us the acceleration therefore:



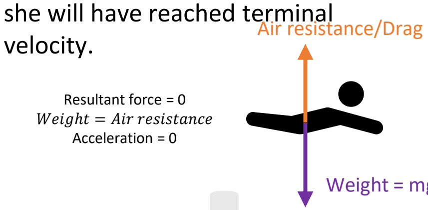
TERMINAL VELOCITY FOR A PARACHUTIST JUMPING FROM AN AEROPLANCE

When an object or person is falling through air, the weight of the object/person is a constant force causing it/them to accelerate downwards. Opposing this motion is air resistance, which increases with speed.

1) A skydiver jumps from a plane and she will accelerate until the air resistance equals to her weight.

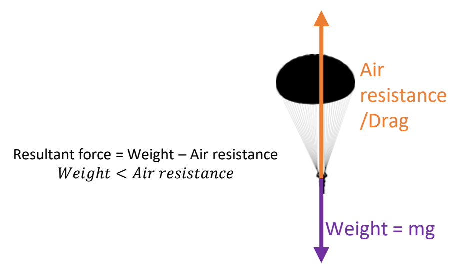


2) After a period of time, the air resistance will match her weight and she will have reached terminal velocity.

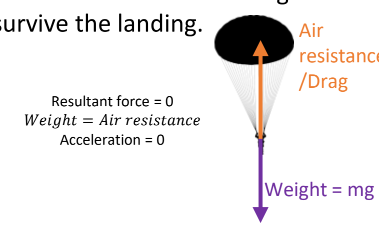


However, the terminal velocity she has reached in free fall is too high to land without being injured. So using a parachute increases the air resistance considerably, which slows her down to a lower terminal velocity for her to land safely.

3) Before reaching the ground she will open her parachute which instantly increases the air resistance so it is now greater than her weight.



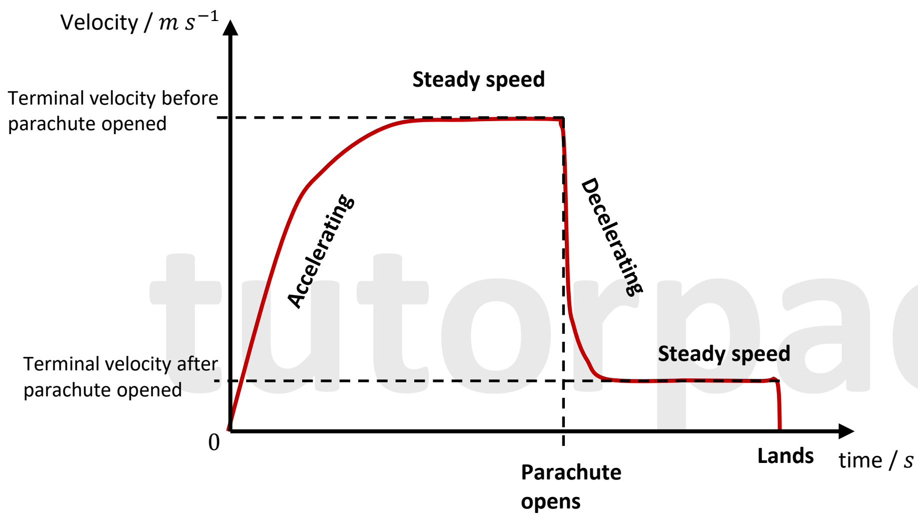
4) The increased air resistance will slow her down and she will reach a new terminal velocity where the air resistance and the weight are equal again. But this new terminal velocity she has reached is slow enough for her to survive the landing.



TERMINAL VELOCITY FOR A PARACHUTIST JUMPING FROM AN AEROPLANCE

The v/t graph

The v/t graph is slightly different for this scenario because we have achieved terminal velocity at two separate stages in time.



Please see the '3.4.2 Motion with Non-Uniform Acceleration Worked Examples' pack for worked examples.

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