3 Dynamics

3.1 Momentum and Newton's laws of motion

Candidates should be able to:

1 understand that mass is the property of an object that resists change in motion

2 recall $F = ma$ and solve problems using it, understanding that acceleration and resultant force are always in the same direction

3 define and use linear momentum as the product of mass and velocity

4 define and use force as rate of change of momentum

5 state and apply each of Newton's laws of motion

6 describe and use the concept of weight as the effect of a gravitational field on a mass and recall that the weight of an object is equal to the product of its mass and the acceleration of free fall

- **Mass** is a physical quantity that measures the amount of matter in an object
- The SI unit for mass is **kilograms** (kg)
- **Weight** is a force
- Since it is a force, the SI unit for weight is **Newtons** (N)
- You can calculate a body's **weight** (W) if you take the product of its **mass** (m) with the **acceleration** of free fall (g).

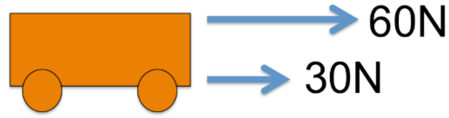
  W = mg

  g is the acceleration due to gravity or the gravitational field strength on Earth, this 9.81 ms^{-2}

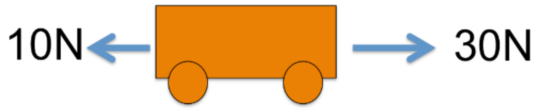
- **Free fall** is falling solely under the influence of gravity.
- On Earth an object in free fall **accelerates** towards the Earth at **9.81 ms^{-2}** if air resistance is absent.
- Generally, the heavier the planet, the higher its free fall acceleration would be and vice versa.
- This means while your **mass** will stay the same on Mars, your **weight** will much be much lower!
- **Newtons second law** states that an object will **accelerate** (a) **proportionally** to the **resultant force** (F) acting on the object and inversely proportional to its **mass** (m)

$$F = ma$$

- Acceleration will always be in the **same direction** as the resultant force.
- The resultant force is the vector sum of all forces acting on the body



= 90N to the right



= 20N to the right

- The resultant could also be at an angle which can be determined by using **triangle** or **parallelogram** method (Chapter 1.4).
- **Newton's First Law** states that a body will remain at rest or move with constant velocity unless acted on by an external force.
- **Newton's Third Law** states that if body A exerts a force on body B, body B will exert a force on body A of equal magnitude but in the opposite direction.
- **Linear momentum** (p) is defined as the product of mass (m) and velocity (v)
  p = mv
- The SI unit for momentum is $kgms^{-1}$
- Force is defined as the **rate of change of momentum** on a body.

$$F = \frac{\Delta p}{\Delta t}$$

Here the change in momentum (Δp) = p_{final} - $p_{initial}$

3.2 Non-uniform motion

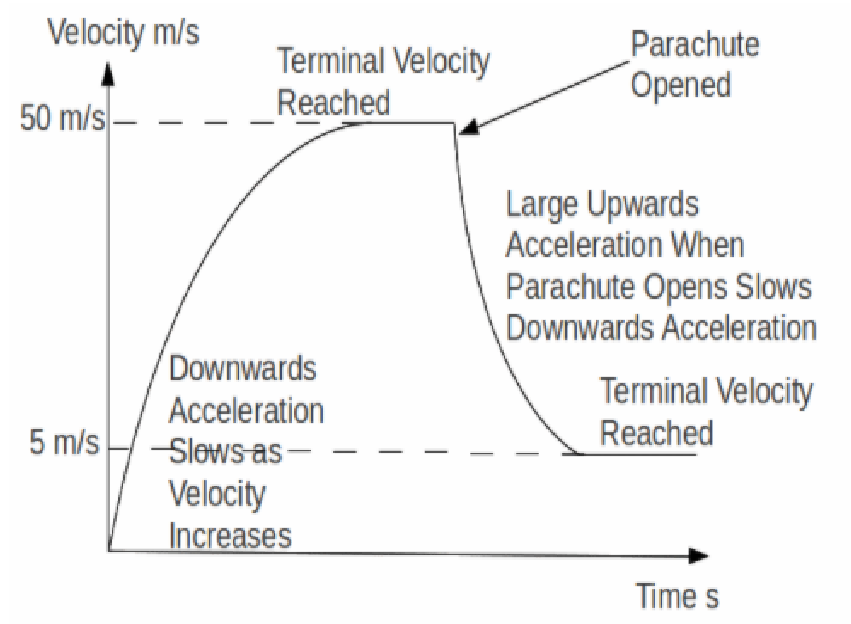
Candidates should be able to:

1 show a qualitative understanding of frictional forces and viscous/drag forces including air resistance (no treatment of the coefficients of friction and viscosity is required, and a simple model of drag force increasing as speed increases is sufficient)

2 describe and explain qualitatively the motion of objects in a uniform gravitational field with air resistance

3 understand that objects moving against a resistive force may reach a terminal (constant) velocity

- **Drag forces** are forces acting on the opposite direction to an object moving through a fluid
- E.g. **friction** and **air resistance**
- Drag forces increases ad the speed of the object increases
- **Terminal velocity** is reached when the **force moving** the object **equals** to the **drag force**.
- The resultant force in this case is zero and acceleration is zero (constant velocity)
- E.g. for a body in free fall, the only force acting is its weight and the acceleration is g.
- The drag force increases as the velocity increases causing the acceleration of the body to decrease.
- At some point, the drag force will equal the weight of the body and the resultant force will be zero.
- The diagram below shows the velocity-time graph to describe the motion of a skydiver



3.3 Linear momentum and its conservation

Candidates should be able to:

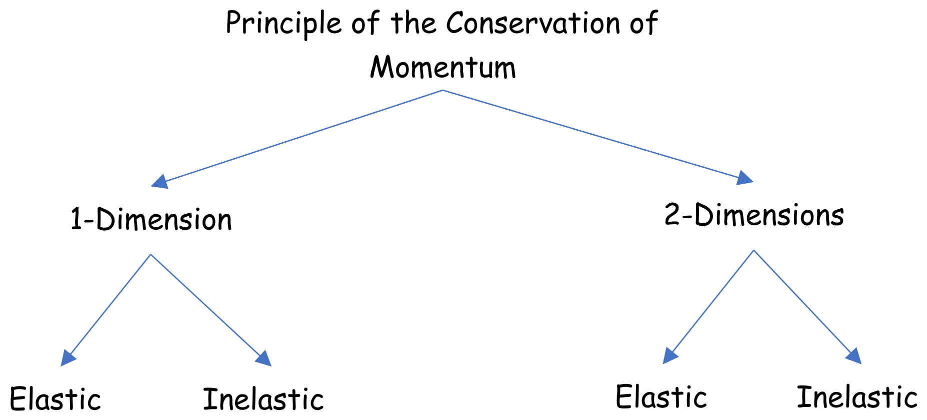
1 state the principle of conservation of momentum

2 apply the principle of conservation of momentum to solve simple problems, including elastic and inelastic interactions between objects in both one and two dimensions (knowledge of the concept of coefficient of restitution is not required)

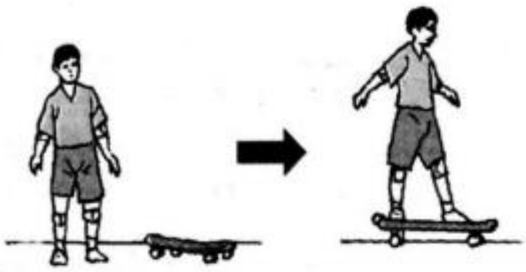
3 recall that, for an elastic collision, total kinetic energy is conserved and the relative speed of approach is equal to the relative speed of separation

4 understand that, while momentum of a system is always conserved in interactions between objects, some change in kinetic energy may take place

- The principal of **conservation of momentum** states that **the total momentum of a system remains constant provided no external force acts to it.**
- Or as I would like to say mom before = mom after
- You cannot change your mom
- **External forces** are forces that act on a body on the outside
- E.g. friction, weight, reaction, etc.
- **Internal forces** are forces exchanged by particles in the system.
- E.g. tension in a spring
- In A-levels the candidate must be able to solve collision problems in both **one** and **two dimensions** for both **elastic** and **inelastic** collisions.
- **Elastic collisions** are collisions when two objects collide and they spring apart **conserving** all of their **kinetic energy**.
- Since kinetic energy depends on the speed of an object, in a perfectly elastic collision (head-on approach) the **relative speed of approach = the relative speed of separation**
- **Inelastic collisions** is one where the **kinetic energy** is **not conserved**.
- An easier way to remember which collision is elastic or inelastic is to remember that **inelastic collisions** always result in both objects **sticking together** after collision.
- The reason behind this is because during an inelastic collision, some kinetic energy is used to deform both objects.



- An e.g. of an **elastic one-dimension** collision is shown below



- An e.g. of an **inelastic one-dimension** collisions is shown below

- An e.g. of an **elastic 2-D collision**.