8 Newton's Laws of Motion

8.1 Force and Acceleration

An **air track** allows motion to be observed in the **absence of friction**.

- The glider floats on a cushion of air.
- And the track is **level**.

The glider moves at a **constant velocity** along the track because friction is absent.

Newton's First Law of Motion: Objects either stay at rest or moves with constant velocity unless acted on by a force.

- When an object is acted on by a **resultant force**, the result is to change the object's velocity.
- An object moving at **constant velocity** is either acted on by no force or the forces acting on it are balanced.

Newton's Second Law of Motion: F is proportional to ma.

By defining the unit of force, the **newton** as the amount of force that will give an object of mass 1kg an acceleration of 1ms^2, we can write.

$$F = ma$$

Weight

The force of gravity on the object is its **weight**.

$$W = mg$$

g is also referred to as the **gravitational field strength**.

- An object in equilibrium has a supporting force on it equal and opposite to its weight.
- The mass of an object is a measure of its **inertia** - resistance to change of moment.

8.2 Using $F = ma$

When an object is acted on by **two unequal forces acting in opposite directions**, the object accelerates in the direction of the larger force.

$$\text{resultant } F_1 - F_2 = ma$$

8.3 Terminal Speed

Any object moving through a fluid experiences a forces that **drags on it**.

The **drag force** depends on

- The **shape** of the object.
- Its **speed**.
- The **viscosity** of the fluid.

Motion of an Object Falling in a Fluid

1. The speed of an object released from rest in a fluid **increases as it falls**.
2. The **resultant force** on the object is the difference between its weight and the drag force.
3. As the **drag force increases**, the resultant force decreases, so **acceleration becomes less** as it falls.
4. If it continues falling, it attains **terminal speed**.
    - The drag force on it is equal and opposite to its weight.
    - Its acceleration is zero and it speed remains constant as it falls.

$$\text{The acceleration of the object} = g - \frac{D}{m}$$

- The **initial acceleration** is g.
- At terminal speed, the potential energy of the object is transferred into **internal energy of the fluid** by the drag force.

Motion of a Powered Vehicle

The resultant force on a powered vehicle is $F_E - F_R$

- F_E is the **motive force** provided by the engine.
- F_R is the **resistive force** opposing the motion of the vehicle.

Its acceleration is

$$a = \frac{F_E - F_R}{m}$$

8.4 On the Road

- **Thinking distance** is the distance travelled by a vehicle in the time it takes the driver to react.

$$s_1 = ut_0$$

- **Braking distance** is the distance travelled by a car in the time it takes to stop safely.

$$s_2 = \frac{u^2}{2a}$$

$$\begin{aligned} \textbf{stopping distance} &= \text{thinking distance} + \text{braking distance} \\ &= ut_0 + \frac{u^2}{2a} \end{aligned}$$

8.5 Vehicle Safety

The effect of a collision on a vehicle can be measured in terms of the **acceleration** of the vehicle - expressed in terms of g.

The **impact time** t is the duration of the impact force.

$$\begin{aligned} \text{impact time } t &= \frac{2s}{u+v} \\ \text{acceleration } a &= \frac{v-u}{t} \\ \text{impact force } F &= ma \end{aligned}$$