8.4.2 ACCELERATION AND FORCES

An analysis of the external forces on vehicles helps to understand the effects of acceleration and deceleration

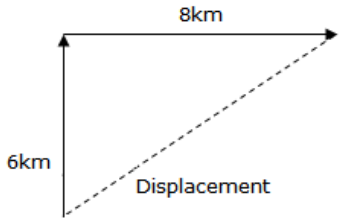
2.1 Describe the **motion of one body relative** to another

- Velocity of an object measured by a moving object is the **relative velocity** – e.g. frame of reference

$$\boldsymbol{V_{a\ relative\ to\ b} = V_{a/b} = V_a - V_b}$$

- Object B relative to object A is travelling at 20 km/h W, Object A relative to object B is travelling 20 km/h E

2.2 Identify the usefulness of **using vector diagrams** to assist **solving problems**



- Vector diagrams can solve problems where **objects are moving in different directions**
- E.g. finding the displacement when a cyclist moves 6 km north and 8 km east

2.3 Explain the need for a **net external force** to act in order to **change the velocity of an object**

- **Newton's First Law of Motion** (Law of Inertia) – an object will remain stationary or moving at a constant velocity unless acted upon by **an external unbalanced force**
- **Net force** – vector sum of all forces
- To change velocity, **force must be applied**, e.g. car changes velocity by increasing thrust from engine

2.4 Describe the **actions** that must be taken for a vehicle to **change direction, speed up and slow down**

- **Steering wheel** is turned to **change direction**
  - Direction of force changes – velocity changes direction
  - Is **acceleration** as there is a **change in velocity**
- Pushing down on the accelerator **speeds up** vehicle
  - **Force increases** against friction and air resistance
  - **Accelerates**
- Releasing accelerator **slows down** vehicle
  - **Force decreases** due to increased friction/air resistance
  - **Decelerates**

2.5 Describe the typical **effects** of **external forces on bodies** including: **friction between surfaces** and **air resistance**

- **Friction** – **resistance between two objects** – decelerates object
  - E.g. road friction – to maintain speed, larger size driving force applied
- **Air resistance** – resistance caused by **moving through air**
  - 'Drag', can be reduced by streamlining the object
- **Gravity** – pulls objects towards the ground

2.6 Define **average acceleration** as :$a_{av} = \frac{\Delta v}{\Delta t}$ therefore $a_{av} = \frac{v-u}{t}$

- Acceleration – **rate at which an object changes its velocity**
  - Δv is the **change in velocity** for a given time
  - Therefore $a_{av} = \frac{\Delta v}{\Delta t}$
- Δv is also the **final minus initial velocity**
  - Therefore $a_{av} = \frac{v-u}{t}$

2.7 Define the terms '**mass' and 'weight'** with reference to the **effects of gravity**

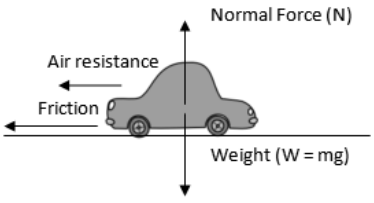
- Mass – scalar quantity, **amount of matter** in an obect
  - **Never changes** regardless of gravity
  - Units in **kg**
- Weight – **force on an object** due to gravity
  - Proportional to the **strength of the gravitational field** $g - W = mg$
    - W = weight, g = acceleration due to gravity (9.8 ms^{-2})
  - Dependent on gravity – will change at different locations
  - Units in **Newtons** (N)

2.8 Outline the **forces involved** in causing a **change in the velocity of a vehicle** when:

- **Normal reaction force** – **support** force, acts right angles to the surface

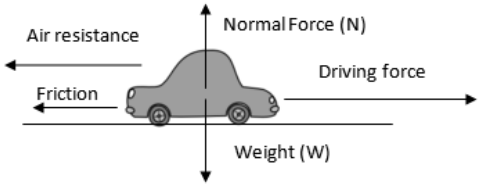
COASTING WITH NO PRESSURE ON THE ACCELERATOR

- Weight and normal force act perpendicularly upwards/downwards
- Friction and air resistance **slow down** the car
- Therefore car will **gradually slow down**



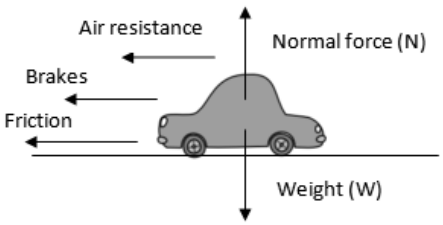
PRESSING ON THE ACCELERATOR

- Driving force provided by engine, overcomes friction force
- Car will increase in speed



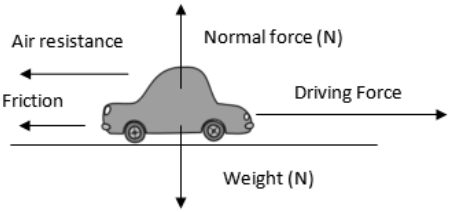
PRESSING ON THE BRAKES

- Deceleration force from brakes
- Friction/air resistance slows down car
- Car slows down at a greater rate



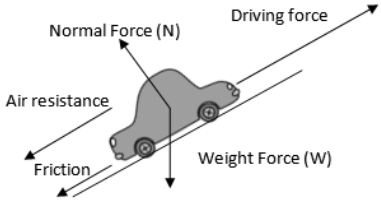
PASSING OVER AN ICY PATCH ON THE ROAD

- **Friction greatly reduced**
- Frictional force between tyres may **not be enough** to **speed up, slow down, change direction**
- May cause **car to skid**



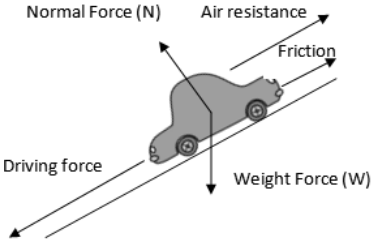
CLIMBING HILLS

- Weight force of car **acts perpendicular and parallel** to the plane
- Weight force **parallel** to plane and **friction/air resistance** slow down car
- Driving force needs to be large enough to overcome this force to move up



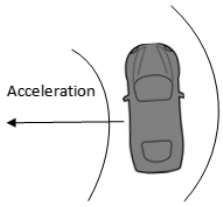
DESCENDING HILLS

- Weight force of car **acts perpendicular and parallel** to the plane
- Weight force **parallel** to plane and **driving force** move car faster
- **Friction/air resistance** slow down car
- Driving force needs to be large enough to overcome this force to move up



FOLLOWING A CURVE IN THE ROAD

- Weight, normal, friction and driving force all apply
- Car undergoes **circular motion** – centripetal force
  - Net force on an object travelling in a circular path at a constant speed
  - Force directed towards the center of the circle
  - Measured by $\boldsymbol{F = \frac{mv^2}{r}}$



2.9 Interpret **Newton's Second Law of Motion** and relate it to the **equation** $\sum \boldsymbol{F = ma}$

- Net force is equal to mass times acceleration
- Newton's Second Law of Motion: "The change in velocity (**acceleration**) with which an object moves is directly proportional to the **magnitude of the force** applied to the object and i**nversely proportional to the mass** of the object." **i.e.** $\boldsymbol{a = \frac{F}{m}}$

2.10 Identify the net force in a **wide variety of situations** involving **modes of transport** and explain the consequences of the application of that net force in terms of **Newton's Second Law of Motion**

- Allows **measurement of amount of force or maximum acceleration** needed
    - A plane that requires a specific acceleration take off will need a certain amount of force
    - Amount of force required to go against friction and air resistance

Practical Section In Construction

- analyse the effects of external forces operating on a vehicle
    -
- gather first-hand information about different situations where acceleration is positive or negative
    - Deceleration when acceleration is negative

Practicals

- plan, choose equipment or resources for and perform a first-hand investigation to demonstrate vector addition and subtraction
    - Spring balances on a ring with a sheet of paper
- plan, choose equipment or resources and perform first-hand investigations to gather data and use available evidence to show the relationship between force, mass and acceleration using suitable apparatus
    - Trolley and pulley used with ticker timer, load on the pulley is the **external force**
    - Trolley weight moved to the load on pulley and tested again
    - Graph with external force and acceleration, mass kept constant

Calculations and Problems

- solve problems and analyse information using $\sum F = ma$ for a range of situations involving modes of transport
- solve problems and analyse information involving $F = \frac{mv^2}{r}$ for vehicles travelling around curves
- solve problems using vector diagrams to determine resultant velocity, acceleration and force