UNIVERSITY OF KWAZULU-NATAL

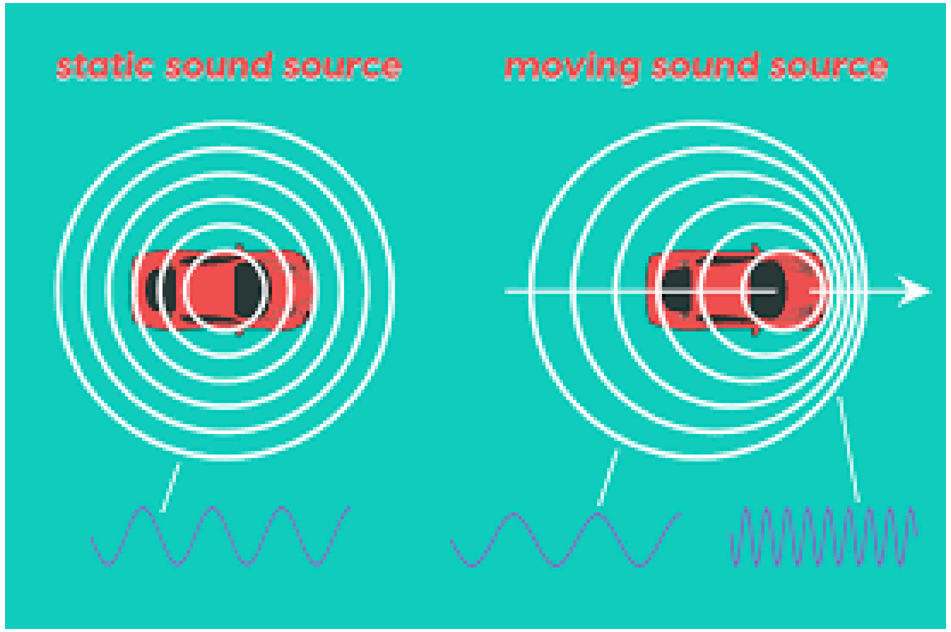
INYUVESI YAKWAZULU-NATALI

Grade 11 & 12 Revision

Topics:

Momentum

Doppler Effect



MOMENTUM

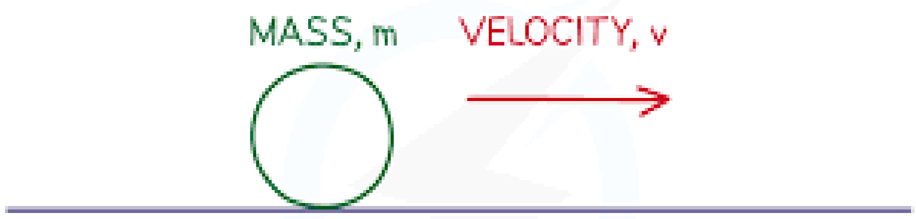
We only study objects moving in straight lines, for example, backwards and forwards, left and right or up and down.

Definition:

- The momentum, $\vec{p}$ of an object is defined as the product of its mass, m and velocity, $\vec{v}$

$$\vec{p} = m\,\vec{v}$$

- The unit of momentum is: $kg{\cdot}m{\cdot}s^{-1}$ because mass is measured in kilograms (kg) and velocity is measured in $m{\cdot}s^{-1}$
- Momentum is a **vector quantity** with the **same direction** as the **object's velocity**.



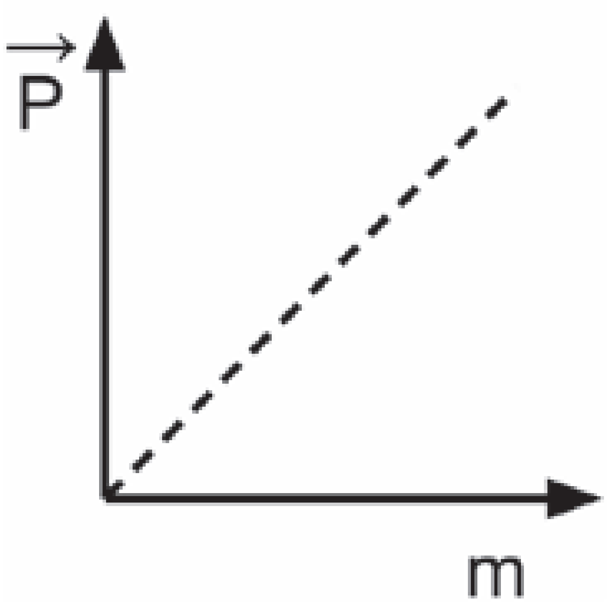
A vector quantity is a quantity with magnitude and direction

MOMENTUM

Momentum is directly proportional to the mass of an object

$$\vec{p} = m\,\vec{v}$$

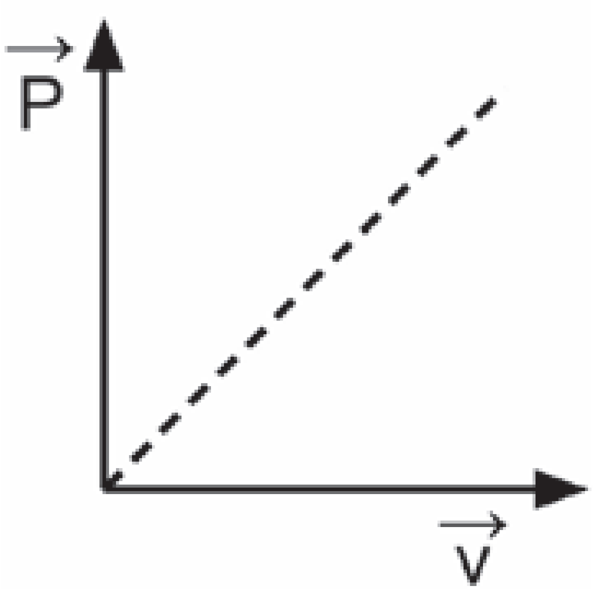
Let the velocity remain constant and m change:



Momentum is directly proportional to the velocity of an object

$$\vec{p} = m\,\vec{v}$$

Let the mass remain constant and v change:



Example 1

<u>Question:</u>

A car has a momentum of 20 000 kg·m·s^{-1}. What will the car's new momentum be if its mass is doubled (by adding more passengers and a greater load) and it travels at the same velocity?

<u>Solution:</u>

The formula for momentum is $\vec{p}$ = m $\vec{v}$, so the momentum will double and will be equal to 40 000 kg·m·s^{-1} in the same direction as before.

Change in momentum

- When an object's velocity changes in magnitude (size) or direction, its momentum will also change.
- Since an object's mass remains constant during a collision (assuming it does not break up or approach light speed), it follows that the change in its velocity is what causes a change in its momentum.

$$\Delta\vec{p} = \vec{p}_f - \vec{p}_i$$

$$\Delta\vec{p} = m\vec{v}_f - m\vec{v}_i$$

$$\Delta\vec{p} = m(\vec{v}_f - \vec{v}_i)$$

Examples of Momentum

- A truck full of logs has a large mass and must slow down long

before a stop light because even with a small velocity, it has a large momentum and is difficult to stop.

- A bullet, although small in mass, has a large momentum because of an extremely large velocity.

- Rugby players colliding with each other.

Impulse

Definition:

- Impulse is the product of the **net force** acting on an object and the **time** that the force is applied to an object. Impulse is a measure of the amount of force applied to an object, for a certain period of time.

$$\text{Impulse} = \Delta\vec{p} = \vec{F}_{net}\,\Delta t \qquad \text{(Units: N·s)}$$

- $\Delta\vec{p}$ is directly proportional to the net force acting on the object F_{net} .
- $\Delta\vec{p}$ is directly proportional to the time that the net force acts on the object Δt in the direction of the net force acting on the object.

Newton's second law of motion in terms of momentum:

The net (resultant) force acting on an object is equal to the object's rate of change of momentum.

$$F_{net} = \frac{\Delta\vec{p}}{\Delta t}$$

Example 2

A cricket ball of mass 175 g is thrown horizontally towards a player at 12 m·s^{-1}. It is hit back in the opposite direction with a velocity of 30 m·s^{-1}. The ball is in contact with the bat for a period of 0,05 s. Calculate:

1. The impulse of the ball.

2. The force exerted on the ball by the bat.

Solutions:

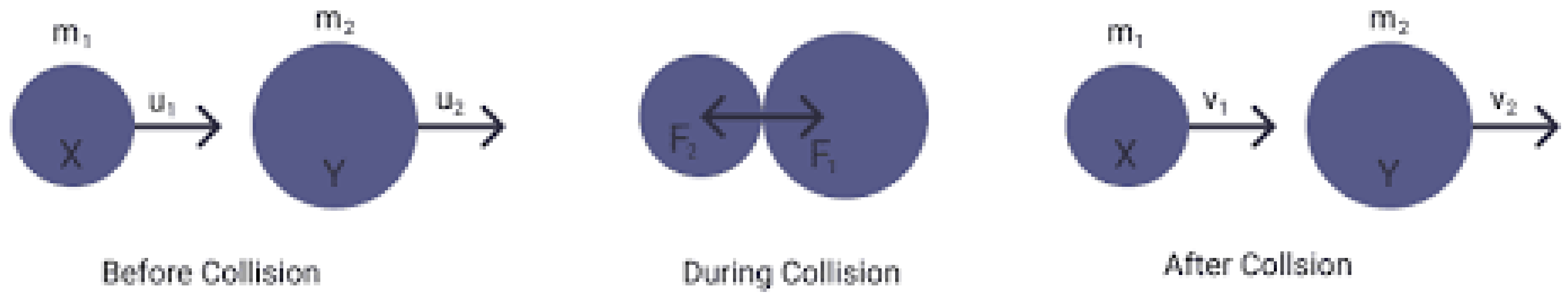
1. impulse = $\vec{F}\,\Delta t = m\,\Delta\vec{v}$ = (0,175)[(–30)–(12)] = –7,35 N·s therefore 7,35 N·s away from the bat.

2. $\vec{F}\,\Delta t$ = –7,35 = F(0,05) ∴ F = $\frac{-7,35}{0.05}$ = -147 N therefore 147 N away from the bat

The principle of conservation of linear momentum

- The principle of conservation of linear momentum states that: The total linear momentum in a closed system remains constant (is conserved).

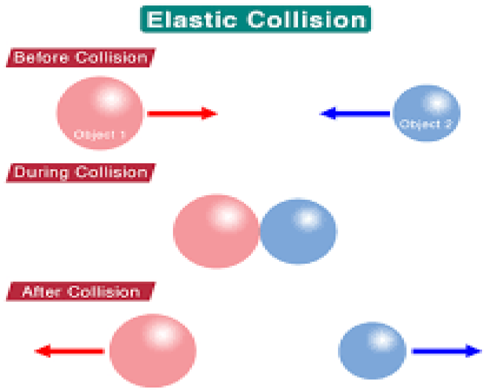
"momentum before = momentum after"



Elastic and Inelastic collisions

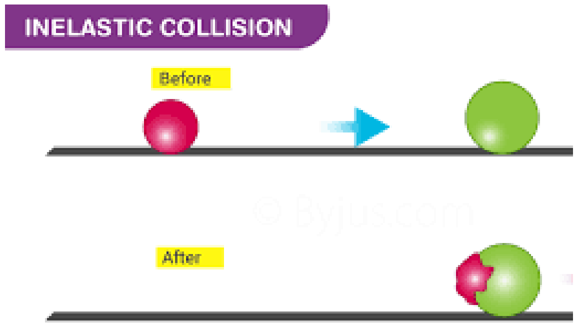
Elastic Collisions

- linear momentum is conserved
- colliding objects remain separate and are not changed in any way
- total kinetic energy is conserved the initial kinetic energy is not transformed into any other forms of energy.

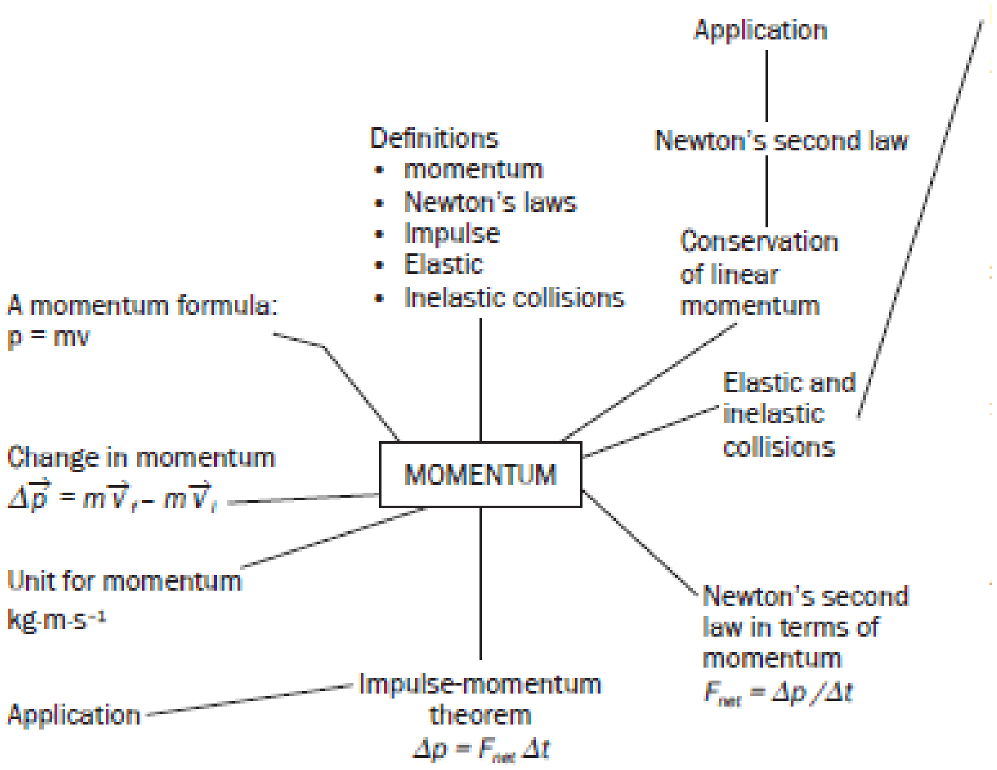


Inelastic Collisions

- linear momentum is conserved
- colliding objects are joined or change their shapes
- total kinetic energy is not conserved: some of the initial kinetic energy is transformed into other forms of energy e.g. heat, light, sound.



SUMMARY



Steps to follow when solving problems

1. Make a sketch (on your rough work page) of the situation.
2. Always choose and indicate direction and write it down clearly. It is recommended that you choose a positive direction (e.g. to the right is positive).
3. Write down the information in symbols. Remember to include the correct signs for the directions of the initial and final velocity.
4. Choose the correct formula from the information sheet.
5. Substitute the values into the formula.
6. Solve for the unknown variable.

Doppler Effect

- The Doppler Effect is the change in frequency or pitch of the sound or the colour of light that is detected when the wave source and the observer move relative to each other.
- The Doppler effect can be observed in all types of waves, including ultrasound, light and radiowaves

$$f_O = \left(\frac{v \pm v_S}{v \mp v_O} \right) f_S$$

- Where f_o is the frequency of the observer, f_s is the frequency of the source, v_s is the velocity of the source, v_o is the velocity of the observer and v is the speed of sound

Doppler Effect

Stationary source and moving observer

- If the observer moves **toward** the stationary source, the observed frequency is **higher** than the source frequency.
- If the observer is moving **away** from the stationary source, the observed frequency is **lower** than the source frequency.

$$f_o=\left(\frac{v}{v \pm vs}\right)f_s$$

Stationary observer and moving source

- If the observer is stationary but the source moves **toward** the observer at a speed $\mathbf{v_s}$, the observer still intercepts more waves per second and the frequency **goes up**.
- If the observer is stationary but the source moves **away** the observer at a speed $\mathbf{v_s}$, the observer intercepts less waves per second and the frequency **goes up**.

$$f_o=\left(\frac{v \pm v_o}{v}\right)f_s$$

Summary: Doppler Effect

- The Doppler effect is a change in observed frequency due to the relative motion of a source and an observer..
- The Doppler effect can be observed in all types of waves, including ultrasound, light and radiowaves

If the direction of the wave from the listener to the source is chosen as positive, the velocities have the following signs:

Source moves towards listener	v_S: *negative*
Source moves away from listener	v_S: *positive*
Listener moves towards source	v_L: *positive*
Listener moves away from source	v_L: *negative*