CHAPTER 3 : DYNAMICS OF LINEAR MOTION

3.1 Momentum and Impulse

LO 3.1 a) Define momentum and impulse

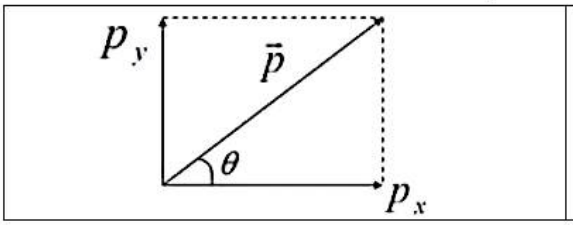
a) Linear momentum, $\vec{p}$

- Defined as the **product of mass** of an object and its **velocity.**
- A vector quantity (since velocity is a vector, so momentum too is a vector). The direction of momentum is the same as velocity.
- Equation and SI unit :

$$\vec{p} = m\vec{v}$$
SI unit : kg ms^{-1} @ N s

- Everyday usage of momentum is in accord with the definition and equation above :
  i) A fast-moving car has more momentum than a slow-moving car of the same mass.
  ii) A heavy truck has more momentum than a small car moving with the same speed.
- The **more momentum the object has, the harder it is to stop it**, and **the greater effect it will have on another object** if it is brought to rest by striking the object.
  E.g. A heavy and fast-moving truck can do more damage than a slow-moving motorcycle.

b) Note that momentum is a vector so the problems may involve both x- and y- component.



x- component :
$$p_x = p\cos\theta$$
y- component :
$$p_y = p\sin\theta$$

c) Impulse, $\vec{J}$

- Defined as the **product of average impulsive force,** $\vec{F}$ and the **time interval,** Δt **.**
- Equation and SI unit :

$$\vec{J} = \vec{F}_{ave}\Delta t$$
SI unit : N s @ kg ms^{-1}

- Also defined as the **change of momentum** of an object.
- Equation and SI unit :

$$\vec{J} = \Delta p = p_f - p_i = mv - mu$$
SI unit : N s @ kg ms^{-1}

Impulse-Momentum Theorem

- Impulse is a vector quantity and its direction follows the direction of $\vec{F}$ or $\vec{v}$.

LO 3.1 b) Solve problem related to impulse and impulse-momentum theorem

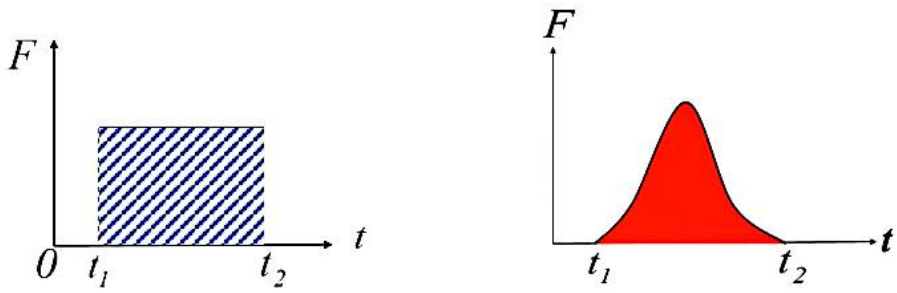
Example 1

A 500 g squash ball is travelling towards a wall on its right with a speed of 100 m s^{-1}. It then hits the wall and bounce back with a speed of 70 m s^{-1} in 10 ms. Calculate

a) the initial and final momentum of the squash ball. **[Answer : 20 kg m s^{-1} ; -14 kg m s^{-1}]**
b) the impulse delivered to the ball by the wall. **[Answer : -34 N s]**
c) the impulsive force exerted on the wall by the ball. **[Answer : 3400 N]**

LO 3.1 c) Use *F-t* graph to determine impulse

a) If a graph of **impulsive force against time** is plotted for a collision **the area under that graph is equal to the impulse (and change in momentum)** during the collision. This has the following shape :



Example 2

An estimated force-time curve for a tennis ball of mass 60.0 g struck by a racket is shown in the figure below. Determine

a) the impulse delivered to the ball. **[Answer : 14.1 N s]**

b) the velocity of the ball after being struck, assuming the ball is being served so it is nearly at rest initially. **[Answer : 240 m s^{-1}]**

c)