MINISTRY OF EDUCATION

SECONDARY ENGAGEMENT PROGRAMME

GRADE 10

PHYSICS

WEEK 11 **LESSON 2**

TOPIC: Motion

SUB-TOPIC: Momentum

OBJECTIVE: At the end of this lesson, students will be able to:

a) Define linear momentum and give its units
b) Describe events in which momentum is conserved
c) State the law of conservation of linear momentum
d) Solve problems involving conservation of momentum

CONTENT

Momentum is a word used mainly in Physics. It is a quantity that moving objects have. We could call it 'mass in motion'. The more mass something has or the faster it is moving, the more momentum it has. When objects move in a straight line, they have linear momentum (often just called momentum). When an object moves in a circle it has angular momentum.

The linear momentum (p) of a body is therefore defined as the product of its mass and its velocity.

Momentum = mass x velocity

$$p = m \times v$$

The units of momentum are those of mass times velocity: $kgms^{-1}$. There is no special name for the units. However, the units of momentum and impulse are equivalent. Let us prove how.

Impulse in everyday language implies doing things suddenly. Impulse in Physics is a measure of how the momentum of an object is changing.

Impulse = change of momentum = mv – mu = m (v – u)

Both impulse and momentum are vector quantities due to velocity and therefore its direction is significant.

The impulse is greater when:

a) The change of momentum happens very quickly, such as when a ball stops by bouncing on the end of your finger instead of sweeping your hands backwards as you catch it.
b) The change of momentum is large, such as when you catch a cricket ball instead of a beach ball, or catch a ball thrown very quickly instead of one tossed slowly.

Using Newton's second law (F = ma) and the definition of acceleration ($a = \frac{v-u}{t}$) gives:

$$F = \frac{m(v-u)}{t}$$

Multiplying both sides by t, gives

$$Ft = m(v-u) = impulse$$

Thus, the unit for momentum can also be the unit for impulse, Ns

Momentum is an extremely useful concept in Physics because it helps us to understand and calculate what happens in collisions and explosions. For example, we can calculate the motion of a rocket from the mass and velocity of the exhaust gases ejected from its engines.

N.B For motion along a straight line, positive values are assigned to one direction and negative values to the opposite direction.

Conservation of linear momentum

The law of conservation of linear momentum states that, in the absence of external forces, the total momentum of a system of bodies is constant.

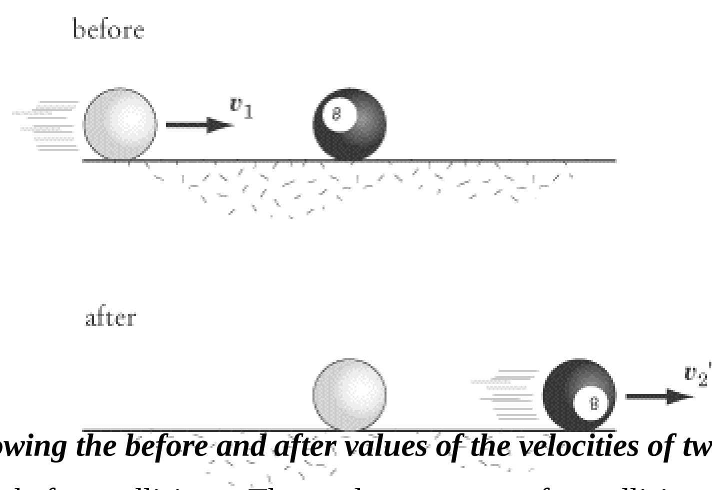


Figure 1 showing the before and after values of the velocities of two colliding objects

The total momentum before collision = The total momentum after collision

Question 1

A boy catches a cricket ball of mass 0.14 kg, which has a velocity of $20ms^{-1}$.

Calculate:

a) The momentum of the ball

b) The average force used by the boy's hands to stop the ball in

  i) 0.5 seconds

  ii) 0.01 seconds

Explain why stopping the ball in 0.01 seconds hurts the boy but stopping it in 0.05 seconds does not.

a) p = mv

  = 0.14kg x 20ms^{-1}

  = 2.8kgms^{-1}

b) $\Delta mv = -2.8kgms^{-1}$

  The value is taken to be negative as its momentum is reduced to zero.

  i) $F = \frac{\Delta mv}{\Delta t} = -\frac{2.8}{0.5} = -5.6N$

  ii) $F = \frac{\Delta mv}{\Delta t} = -\frac{2.8}{0.01} = -280N$

When the boy applies a force of 280N to the ball, the ball applies an equal and opposite force to his hands. A force of 280N acting on the boy's hands hurts him. When he stops the ball more slowly, by allowing his hands to move with the ball, a much smaller force is needed, which hurts less.

Tips for tackling problems involving the conservation of linear momentum

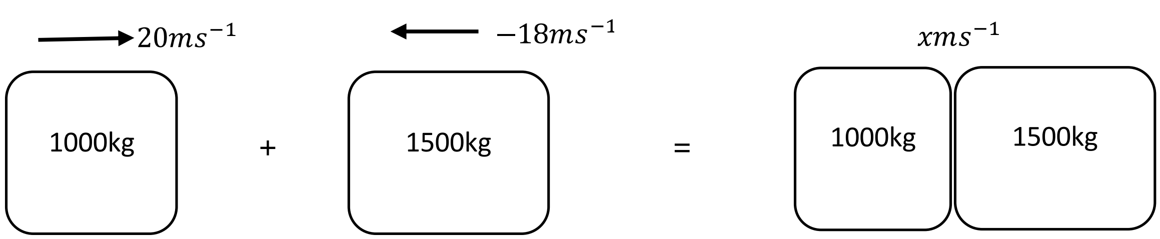
1. Select one direction as positive and the opposite direction as negative
2. Sketch a block diagram in equation form, including all objects immediately before and after the collision or explosion, indicating the mass and velocity of each. Do not put an arrow or sign for any unknown velocity.
3. Use the conservation law and the diagram to formulate a numerical equation.

4. If the solution to the equation is a velocity or momentum, you should state its magnitude and its direction. The sign will help you decide the latter.
5. Since mass x velocity is the only quantity on each side of the conservation equation, any unit of mass or velocity can be used so long as it is applied consistently within the calculations.

Question 2

A car of mass 1000kg travels north at $20ms^{-1}$ and collides head on with another car of mass 1500kg, which is moving south at $18ms^{-1}$. Determine the common velocity of the vehicles after the collision if they stick together.

Assign North as positive and South as negative



Total momentum before collision = Total momentum after collision

$$(1000 \times 20) + (1500 \times -18) = 1000x + 1500x$$

$$20000 - 27000 = 2500x$$

$$-7000 = 2500x$$

$$x = -\frac{7000}{2500}$$

$$\boldsymbol{x = -2.8ms^{-1}}$$

The negative sign is only to indicate direction (south).

Therefore, the common velocity after collision, $x = 2.8ms^{-1}$ towards south.

REFERENCES:

- DeFreitas, P. (2015). *Concise Revision Course CSEC Physics.* London: Collins.
- Duncan, T. (2013). *Physics for CSEC examination* (5th ed.). London: Hodder Education.
- Farley, A., & Trotz, C. (2014). *Physics for CSEC Examinations* (3rd ed.). (M. Taylor, Ed.) London: Macmillan.