Impulse and Momentum in 1D

Read MHR: 195 - 201 (just the text)

DEFINITION OF MOMENTUM

Momentum is the product of an object's mass and its velocity.

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

Quantity	Symbol	SI unit
momentum	$\vec{p}$	$\frac{\text{kg}\cdot\text{m}}{\text{s}}$ (kilogram metres per second)
mass	m	kg (kilograms)
velocity	$\vec{v}$	$\frac{\text{m}}{\text{s}}$ (metres per second)

Unit Analysis

$(\text{mass})(\text{velocity}) = \text{kg}\cdot\frac{\text{m}}{\text{s}} = \frac{\text{kg}\cdot\text{m}}{\text{s}}$

Note: Momentum does not have a unique unit of its own.

DEFINITION OF IMPULSE

Impulse is the product of force and the time interval.

$$\vec{J} = \vec{F}\Delta t$$

Quantity	Symbol	SI unit
impulse	$\vec{J}$	N·s (newton seconds)
force	$\vec{F}$	N (newtons)
time interval	Δt	s (seconds)

Unit Analysis

(impulse) = (force)(time interval) = N·s

Note: Impulse is equal to the change in momentum, which has units of $\frac{\text{kg}\cdot\text{m}}{\text{s}}$. To show that these units are equivalent to the N·s, express N in terms of the base units.

$$\text{N}\cdot\text{s} = \frac{\text{kg}\cdot\text{m}}{\text{s}^2}\cdot\text{s} = \frac{\text{kg}\cdot\text{m}}{\text{s}}$$

IMPULSE-MOMENTUM THEOREM

Impulse is the difference of the final momentum and initial momentum of an object involved in an interaction.

$$\vec{F}\Delta t = m\vec{v}_2 - m\vec{v}_1$$

Quantity	Symbol	SI unit
force	$\vec{F}$	N (newtons)
time interval	Δt	s (seconds)
mass	m	kg (kilograms)
initial velocity	$\vec{v}_1$	$\frac{m}{s}$ (metres per second)
final velocity	$\vec{v}_2$	$\frac{m}{s}$ (metres per second)

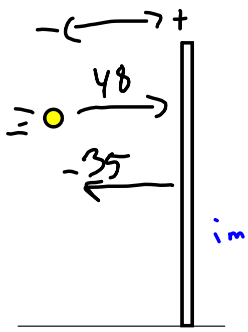
Unit Analysis

(force)(time interval) = (mass)(velocity)

$\mathrm{N \cdot s = kg\frac{m}{s}}$ $\quad \mathrm{\frac{kg \cdot m}{s^2}\, s = \frac{kg \cdot m}{s}}$

Note: Impulse is a vector quantity. The direction of the impulse is the same as the direction of the *change* in the momentum.

A student practices her tennis volleys by hitting a tennis ball against a wall.
a) If the 0.060 kg ball travels 48 m/s before hitting the wall and then bounces directly backward with a speed of 35 m/s, what is the impulse of the interaction? (-5.0 kg-m/s)
b) If the duration of the interaction is 0.025 s, what is the average force exerted on the ball by the wall? (-200 N)



$v_o = 48\,m/s$ $\quad m = 0.060\,kg$

$v_f = -35\,m/s$

$\vec{J} = \Delta\vec{P} = m(\vec{v}_f - \vec{v}_o)$ impulse

$= (0.060)(-35-48)$

$= -5.0\ kg \cdot m/s$

b) $\vec{F}_{avg} = ?$ $\quad t = 0.025\,s$

$Ft = m(v_f - v_o)$

$Ft = -5.0$

$F(0.025) = -5.0$

$F = \frac{-5.0}{0.025} = -200\,N$

Conservation of Momentum

For any collision between objects in a closed and isolated system, the total momentum before the collision is equal to the total momentum after the collision.

LAW OF CONSERVATION OF MOMENTUM

The sum of the momenta of two objects before a collision is equal to the sum of their momenta after they collide.

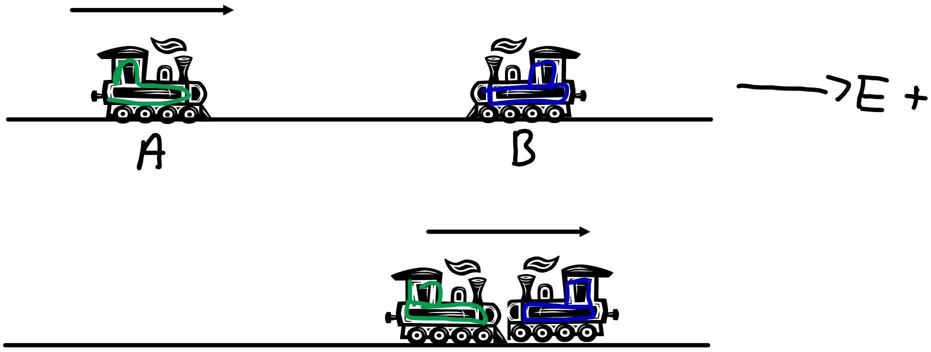
$$m_A\vec{v}_A + m_B\vec{v}_B = m_A\vec{v}'_A + m_B\vec{v}'_B$$

$$\vec{p}_{oT} = \vec{p}_{fT}$$

Quantity	Symbol	SI unit
mass of object A	m_A	kg (kilograms)
mass of object B	m_B	kg (kilograms)
velocity of object A before the collision	$\vec{v}_A$	$\frac{m}{s}$ (metres per second)
velocity of object B before the collision	$\vec{v}_B$	$\frac{m}{s}$ (metres per second)
velocity of object A after the collision	$\vec{v}'_A$	$\frac{m}{s}$ (metres per second)
velocity of object B after the collision	$\vec{v}'_B$	$\frac{m}{s}$ (metres per second)

Read MHR: Pg 310 - 315 (just text)

Example: A 6500 kg train travelling at 2.5 m/s collides with a stationary 8000 kg train. If they interlock upon collision, find their velocity after the collision.



Before

$m_A = 6500\,kg$

$v_A = 2.5\,m/s\,[E]$

$m_B = 8000\,kg$

$v_B = 0\,m/s$

After

$m_A = 6500\,kg$

$v_A' = ?$

$m_B = 8000\,kg$

$v_B' = ?$

* $v_A' = v_B'$ as they stick together

Say, v'

$$m_A v_A + m_B v_B = m_A v_A' + m_B v_B'$$

$$(6500)(2.5) + (8000)(0) = 6500v' + 8000v'$$

$$16250 = 14500v'$$

$$1.1\,m/s\,[E] = v'$$

Attachments

collision-lab_en.jar