§ 5-4 Momentum + Newton's Laws

momentum - directly related to both an object's mass and its velocity. It is defined as the <u>product</u> of mass and velocity.

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

where $\vec{p}$ is the momentum $\left(kg \cdot \frac{m}{s}\right)$

m is the mass (kg)

$\vec{v}$ is the velocity $\left(\frac{m}{s}\right)$

mp|197

$m = 0.300\,kg$

$\vec{v} = 5.55\,\frac{m}{s}\,[N]$

$\vec{p} = ?$

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

$\vec{p} = (0.300\,kg)(5.55\,\frac{m}{s}\,[N])$

$\vec{p} \doteq 1.66\,kg \cdot \frac{m}{s}\,[N]$

Impulse – directly related to the force acting on an object and the length of time that the force acts. It is the product of force and duration (Δt).

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

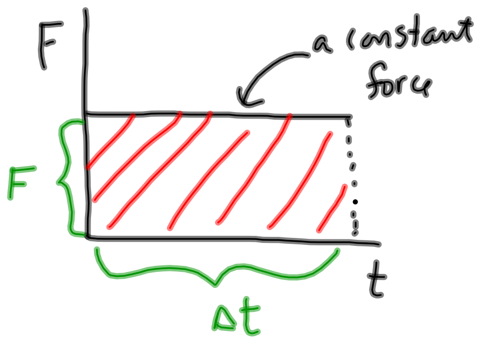
where $\vec{J}$ is the impulse (N·s)
$\vec{F}$ is the force (N)
Δt is the duration (s)

MP|199

$\vec{F} = 5.25\times10^{3}\,N\,[W]$
$\Delta t = 5.45\times10^{-4}\,s$
$\vec{J} = ?$

$\vec{J} = \vec{F}\Delta t$
$\vec{J} = (5.25\times10^{3}\,N\,[W])(5.45\times10^{-4}\,s)$
$\vec{J} \doteq 2.86\,N\cdot s\,[W]$

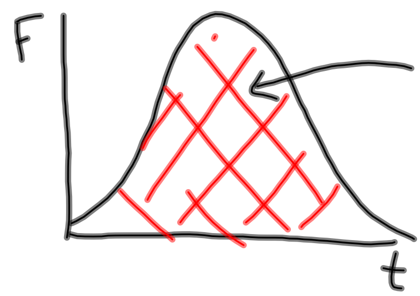
Consider a F-t graph:



Area of rectangle $= l \times w$

Area $= F\Delta t$ ← $\vec{J}$

∴ Area = Impulse
F-t graph



count squares!

or use calculus

or use technology (Logger Pro)

Impulse & Momentum Theorem

Recall Newton's Second Law:

$$\vec{F} = m\vec{a}$$

$$\vec{F} = m\frac{\Delta\vec{v}}{\Delta t}$$

$$\vec{F}\Delta t = m\Delta\vec{v}$$

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

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

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

$$\vec{F}\Delta t = \Delta\vec{p}$$ ← Impulse-Momentum Theorem

The impulse on an object is equal to the object's change in momentum.

$$\vec{J} = \Delta\vec{p}$$

$$\vec{F}\Delta t = m\Delta\vec{v}$$

MP|201

$m = 0.060\text{ kg}$

$\vec{v}_1 = 48\text{ m/s}$ [toward] (+)

$\vec{v}_2 = 35\text{ m/s}$ [away] (−)

a) $\vec{J} = ?$

b) if $\Delta t = 25\text{ ms}$, $\vec{F} = ?$

a) $\vec{J} = \Delta\vec{p}$ ← $\Delta\vec{p} = m\Delta\vec{v}$

$$\vec{J} = \vec{p}_2 - \vec{p}_1$$

$$\vec{J} = m\vec{v}_2 - m\vec{v}_1$$

$$\vec{J} = m(\vec{v}_2 - \vec{v}_1)$$

$$\vec{J} = 0.060\text{ kg}(-35\text{ m/s} - 48\text{ m/s})$$

$$\vec{J} = 0.060\text{ kg}(-83\text{ m/s})$$

$$\vec{J} \doteq -5.0\text{ kg}\cdot\text{m/s}$$

$$\vec{J} \doteq 5.0\ \text{kg}\cdot\frac{\text{m}}{\text{s}}\text{ [away]}$$

$\text{N}\cdot\text{s}$

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

$\text{kg}\cdot\frac{\text{m}}{\text{s}}$

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

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

$$\vec{F} = \frac{5.0\text{ kg}\cdot\text{m/s [away]}}{25\times10^{-3}\text{ s}}$$ — $\text{kg}\cdot\frac{\text{m}}{\text{s}^2} = \text{N}$

$$\vec{F} \doteq 2.0\times10^{2}\text{ N [away]}$$

TO DO:

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- PP|200
- PP|203