§5-4 Momentum + Newton's Law

Momentum

Momentum is the product of mass and velocity

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

where $\vec{p}$ is the momentum (kg·m/s)

m is the mass (kg)

$\vec{v}$ is velocity (m/s)

MP|197

$m = 0.300\,kg$

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

$\vec{p} = ?$

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

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

$\vec{p} = 1.665\,kg\cdot m/s\,[N]$

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

Impulse

Impulse is the product of the force acting on an object and the duration it acts on the object.

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

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

MP/199

$\vec{F} = 5.25\times10^{3}\,N\,[W]$

$\Delta t = 5.45\times10^{-4}\,s$

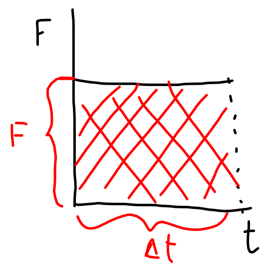
$\vec{J} = ?$

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

$\vec{J} = (5.25\times10^{3}\,N\,[W])(5.45\times10^{-4}\,s)$

$\vec{J} \doteq 2.86\,N\cdot s\,[W]$

Consider a F-t graph:

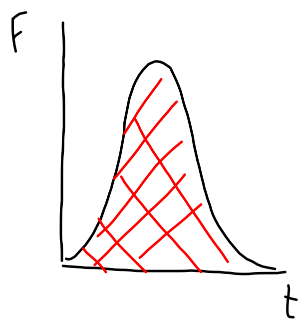


Area of rectangle $= l \times w$

Area $= F\Delta t$

but $J = F\Delta t$

So Area (F-t graph) = Impulse



How to find the area if the graph is curved?

✓ ① count squares
✓ ② use technology (integral)
later! ③ use Calculus.

What is the connection between the force, the time it acts and change in momentum?

Recall: $F = ma$ (Newton's Second Law)

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

$$F = \frac{m(v_2 - v_1)}{\Delta t}$$

$$F = \frac{mv_2 - mv_1}{\Delta t}$$

$$F = \frac{p_2 - p_1}{\Delta t}$$

$$F = \frac{\Delta p}{\Delta t}$$ ← The way Newton's Second Law was originally written

$$F\Delta t = \Delta p$$

impulse = change in momentum

The Impulse-Momentum Theorem:

$\vec{J} = \Delta\vec{p}$ ← concept

$\vec{F}\Delta t = m\Delta\vec{v}$ ← equation.

MP|201

$m = 0.060\,kg$

$\vec{v}_1 = 48\,m/s$ [towards wall] (+)

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

$\Delta t = 25\,ms$

a) $\vec{J} = ?$

b) $\vec{F} = ?$ (wall on ball)

a)

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

$$\vec{J} = m\Delta\vec{v}$$

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

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

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

$$\vec{J} = -7.84\,kg\cdot m/s$$

$\vec{J} = 7.84\,kg\cdot m/s$ [away from the wall]

b)

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

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

$$\vec{F} = \frac{7.84\,kg\cdot m/s\ [away]}{25\times10^{-3}\,s}$$

the force of the wall on the ball → $\vec{F} = 3.1\times10^{2}\,N$ [away]

The force of the ball on the wall will be $3.1\times10^{2}\,N$ [toward]

TO DO:

1. PP|197 (momentum)
2. PP|200 (impulse)
3. PP|203 (impulse - momentum)