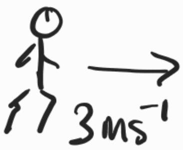
Physics 2.4 - Momentum

Definition of Momentum 動量 p (unit $kgms^{-1}$)

$p = mv$ (vector)

Example



40kg $3ms^{-1}$

Boy jogging

$p = 40 \times 3$

$= 120 kgms^{-1}$

$10 ms^{-1}$

100kg

Man Cycling

$p = 100 \times (-10)$

$= -1000 \, kgms^{-1}$

Momentum and Newton's 2^{nd} law

$$F_{net} = ma = m\frac{(v-u)}{t} = \frac{mv - mu}{t}$$

final momentum

initial momentum

$$\therefore \quad F_{net} = \frac{\text{change in momentum}}{\text{time}}$$

$\therefore$ The net force acting on an object = rate of change of momentum

Also: Impulse (衝量) = $F_{net} \times$ time = change of momentum

Example

once hit the boxes car comes to rest in 0.8s

$22ms^{-1}$

m = 1200kg

1m 1m

Question

a) Find the force exerted on the car, by the boxes

b) Find the number of boxes crushed

Solution

a) $F_{net} = \frac{mv - mu}{t} = \frac{0 - (1200)(22)}{0.8} = -33000N$

b) $s = \frac{1}{2}(v+u)t = \frac{1}{2}(0+22)(0.8) = 8.8m$ 9 boxes crushed

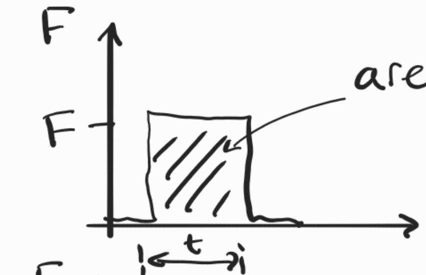
Alternative for b) $\frac{1}{2}mv^2 = Fs$ ($\frac{1}{2}mv^2$ = KE, Fs = Work)

$\frac{1}{2}(1200)(22)^2 = (33{,}000)s$

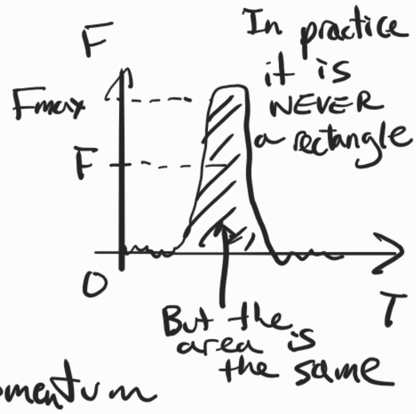
$s = 8.8\text{ m}$ //

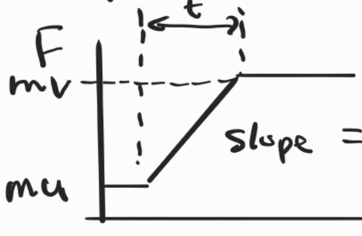
Force - Time Graph

Area under the F-T graph = change in momentum



area = $mv - mu$
$= Ft$ ← force profile

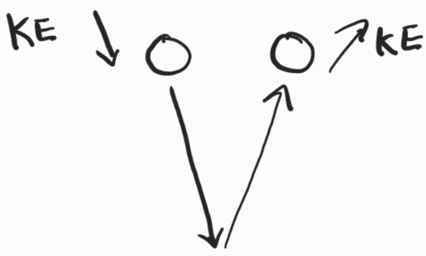




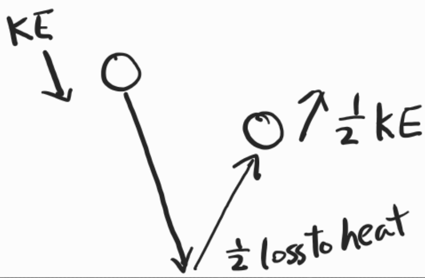
slope $= \frac{mv - mu}{T}$ ← rate of change of momentum

Elastic and Inelastic Collisions

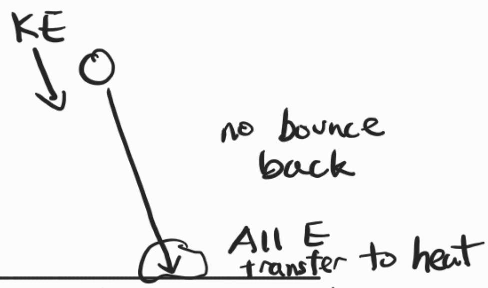
彈性 非彈性 碰撞



(total) Elastic collision



Inelastic collision



Perfectly inelastic collision

LAW OF CONSERVATION OF MOMENTUM

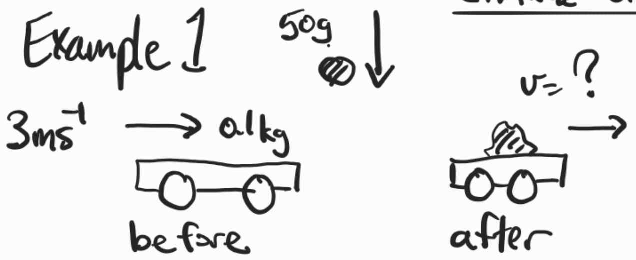
When no external force acting, the total momentum of a system is conserved.

$$\boxed{m_A u_A + m_B u_B = m_A v_A + m_B v_B}$$

	elastic collision	inelastic collision
Total momentum	conserved	conserved
Total KE	conserved	KE loss (energy transfer)

CHANGE OF MOMENTUM

Example 1



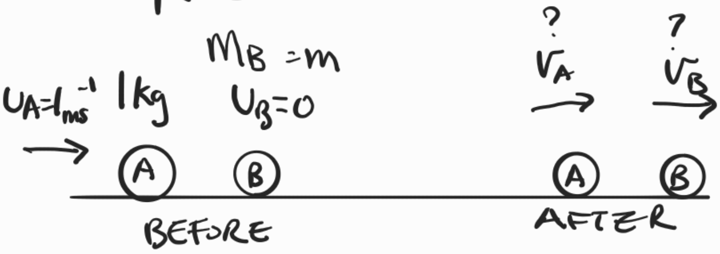
Since falling object is perfectly inelastic

$\therefore V_{水平} = 0\ ms^{-1}$

Momentum change: $3 \times 0.1 = V \times (0.1 + 0.05)$

$V = 2 ms^{-1}$ //

Example 2 ELASTIC COLLISION



For total elastic collision:

✓ conservation of momentum

✓ conservation of KE

There fore:

$$\left.\begin{aligned} M_A U_A + M_B U_B &= M_A V_A + M_B V_B \\ 1 \times 1 + m \times 0 &= M_A V_A + M_B V_B \end{aligned}\right\} \text{Conservation of momentum}$$

$$1 = 1 \times V_A + m V_B \text{ ----(1)}$$

$$\cancel{\tfrac{1}{2}} \cancelto{1}{m_A} U_A^2 + \cancel{\tfrac{1}{2}} \cancelto{0}{m_B U_B^2} = \cancel{\tfrac{1}{2}} \cancelto{1}{m_A} U_A^2 + \cancel{\tfrac{1}{2}} m_B U_B^2$$

$$1 = V_A^2 + m U_B^2 \text{ ----(2)}$$

Combine (1) and (2): and solve

$$V_A = \frac{1-m}{1+m} \qquad V_B = \frac{2}{1+m}$$

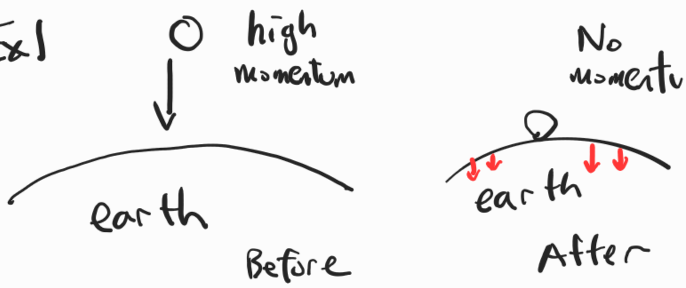
Case 1 if $m = 1kg$: $V_A = 0$ $\quad V_B = 1 ms^{-1}$ $\quad$ (m_B same mass)

Case 2 if $m = 1000 kg$: $V_A \approx -1 ms^{-1}$ $\quad V_B \approx 0 ms^{-1}$ $\quad$ (m_B much heavier)

case 3 if $m = 0.001 kg$: $V_A \approx 1 ms^{-1}$ $\quad V_B \approx 2 ms^{-1}$ $\quad$ (m_B much lighter)

Loss of Momentum? (not really)

Ex1



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Ex 2