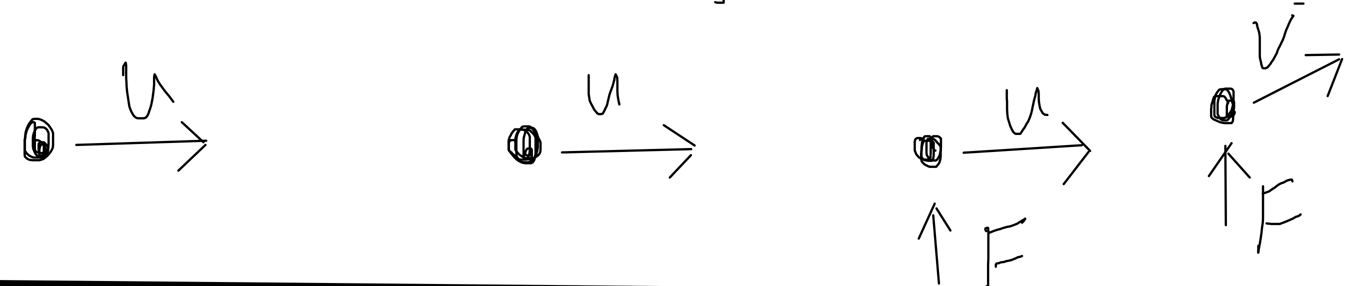
state each of Newton's laws of motion

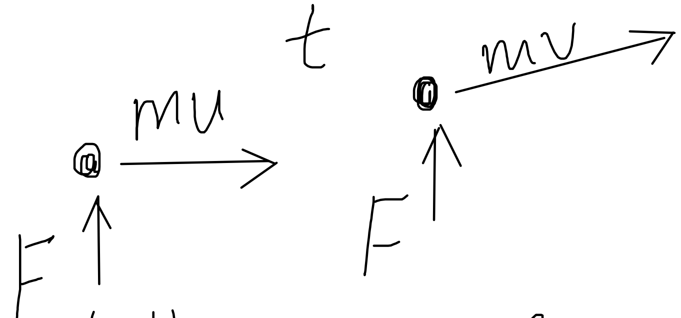
Newton's Laws

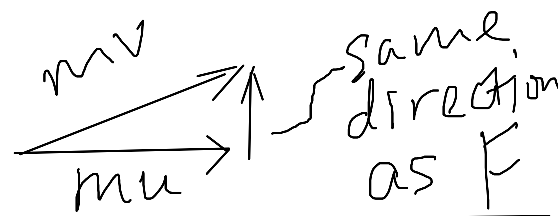
Dr K M Hock

1. A body <u>either</u> stays at rest <u>or</u> move in a straight line at the same speed
   – unless a force acts on it.



2. The rate of change of momentum of a body is <u>proportional</u> to the <u>resultant</u> force that acts on it.





3. When a force pushes on a body, the body pushes back with the same force
   – but in the opposite direction.

show an understanding that mass is the property of a body which resists change in motion

Inertia

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1st law :-

either stay at rest

or Stay at same velocity

unless forced to change.

$\Downarrow$

Suggests resistance to change.

Inertia – name for this tendency.

Measured by mass :

bigger mass $\longleftrightarrow$ bigger inertia

Weight

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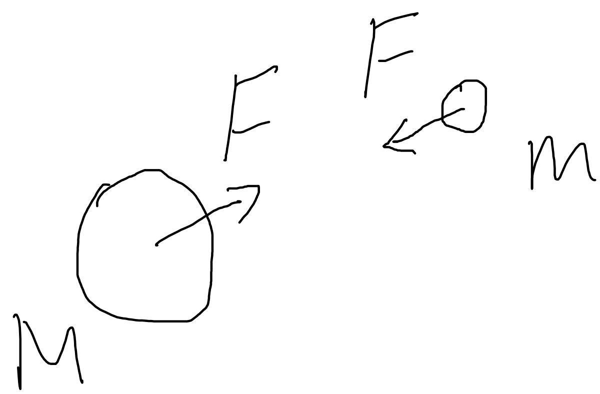
A body that can resist change to its motion (= has MASS) can also attract another mass.



This force is called gravity.

Weight = force from earth (or maybe moon, or another planet) pulling on a body.

define linear momentum and impulse

Momentum and Impulse

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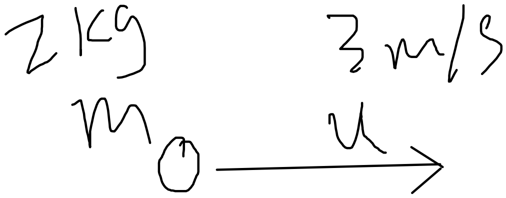
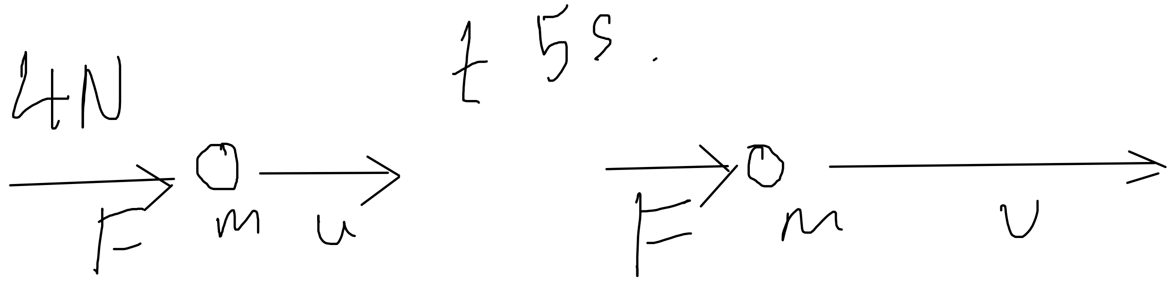


Define: momentum

= mass × velocity

e.g. $= 2 \times 3 = 6$ kg m/s



Define: impulse

= force × time

e.g. $= 4 \times 5 = 20$ Ns.

2nd law ⟹ impulse = change in momentum

e.g. (Ft) 20 Ns $= mv - mu$

Force

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2nd law: force $\propto$ rate of change of momentum

$$F = k\,\frac{mv - mu}{t}$$

SI unit sets $k = 1$.

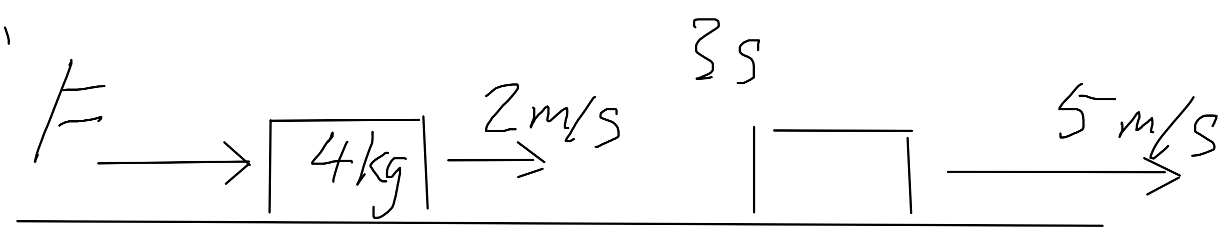
∴ defines force as rate of change of momentum.

$$F = \frac{mv - mu}{t}$$

$$= m\,\frac{v - u}{t}$$

$$\therefore F = ma.$$

e.g.



$$F = \frac{4\times 5 - 4\times 2}{3}$$

$$= 4\,\text{N}.$$

recall and solve problems using the relationship F = ma, appreciating that force and acceleration are always in the same direction

$F = ma$

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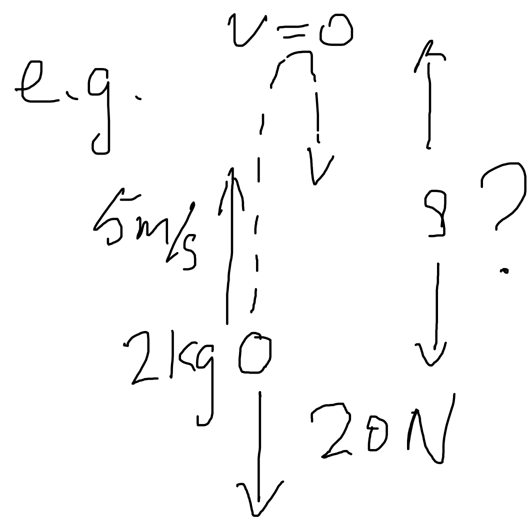
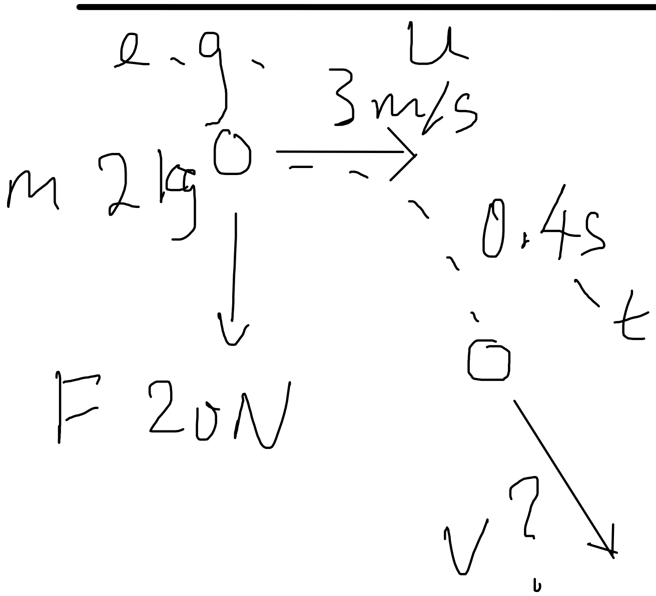


Choose ↑ as +ve.

a same direction as F, so a -ve.

$$a = \frac{F}{m} = -\frac{\cancel{20}\ 10}{\cancel{2}} \ m/s^2$$

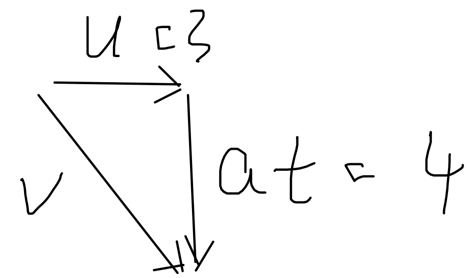
$$\underbrace{v^2}_{0} = \underbrace{u^2}_{5} + 2\underbrace{a}_{-10}\underbrace{s}_{?}$$



$$a = \frac{F}{m} = 10 \ m/s^2$$

change in velocity

$$= \underbrace{at}_{\text{same direction as } F} = 10 \times 0.4 = 4 \ m/s$$



$$\therefore v = \sqrt{3^2 + 4^2} = 5 \ m/s$$

state the principle of conservation of momentum

Conservation of Momentum

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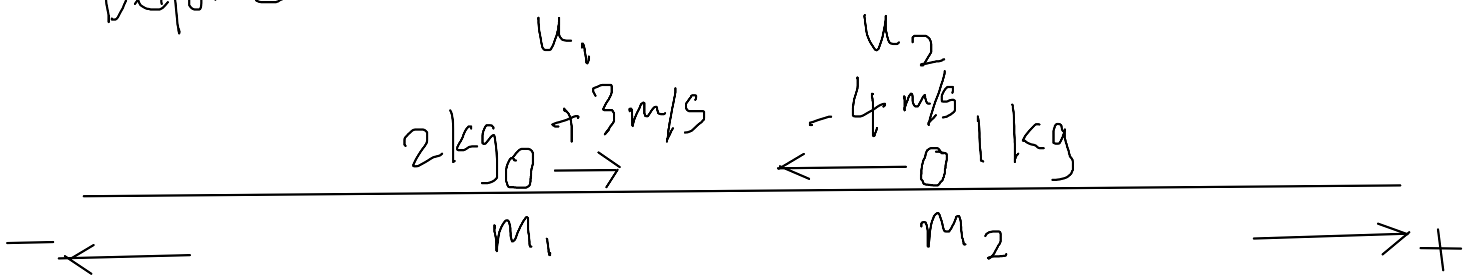
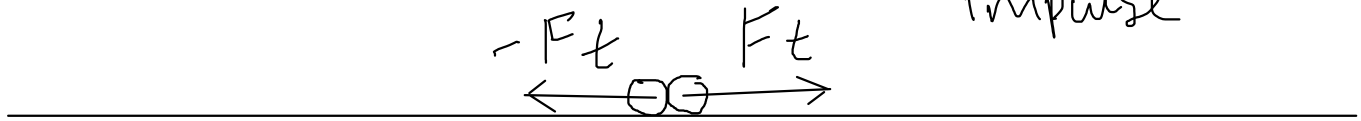
Before



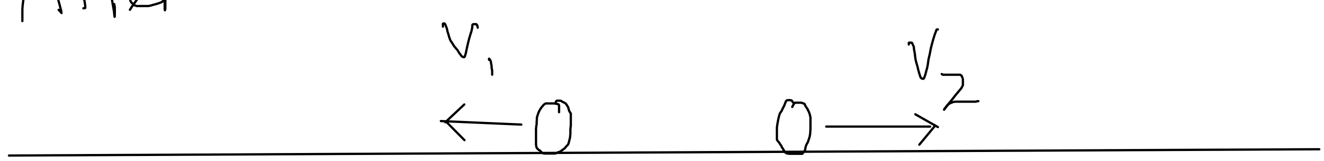
Collide

equal, opposite impulse



After

equal, opposite momentum change



e.g. m_1 momentum ↑
m_2 " ↓ by same amount

∴ total momentum same before and after:

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

apply the principle of conservation of momentum to solve simple problems including elastic and inelastic interactions between two bodies in one dimension.

Inelastic Collision

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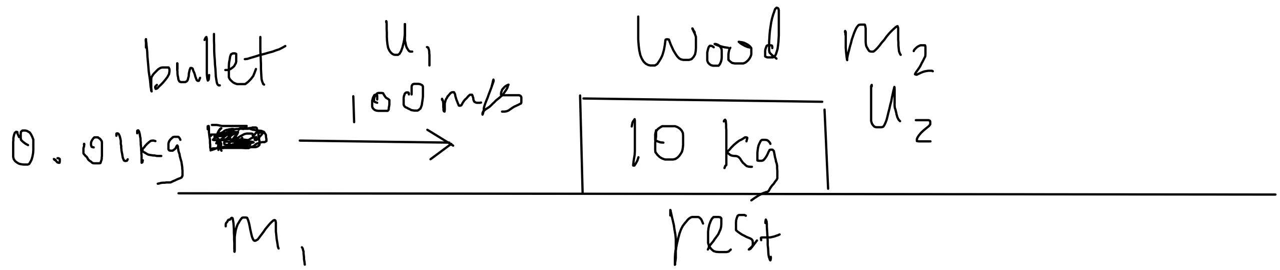
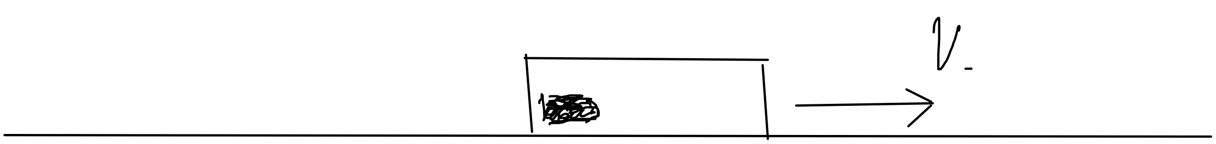
- When some kinetic energy is lost as during collision, e.g. to heat, sound.



If bullet is stuck in wood:



- what is velocity after impact?
- total kinetic energy ↑ or ↓ ?

Momentum conservation:

$$\underbrace{m_1}_{0.01\,kg}\underbrace{u_1}_{100\,m/s} + \underbrace{m_2}_{10\,kg}\underbrace{u_2}_{0} = m_1 \underbrace{v_1}_{v} + m_2 \underbrace{v_2}_{v}$$

Solve for v. Then find KE before, after...

recognise that, for a perfectly elastic collision between two bodies, the relative speed of approach is equal to the relative speed of separation

Elastic Collision

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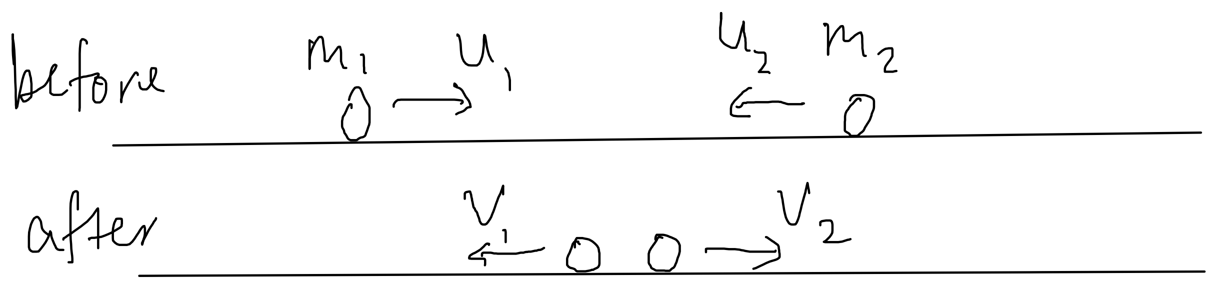
- when total KE same after collision.



momentum $\quad m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

KE $\quad \frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$

Algebra gives $\quad \underbrace{v_2 - v_1}_{\text{speed of separation}} = -\underbrace{(u_2 - u_1)}_{\text{speed of approach}}$

e.g. if $m_1 = m_2 = 1\,kg$

$u_1 = 2\,m/s$, $\quad u_2 = 0\,m/s$.

find v_1 , v_2.

Equations:

$$\overset{1kg}{m_1}\overset{2m/s}{u_1} + \overset{1kg}{m_2}\overset{0}{u_2} = \overset{1}{m_1}\overset{?}{v_1} + \overset{1}{m_2}\overset{?}{v_2}$$

$$\overset{?}{v_2} - \overset{?}{v_1} = -(\overset{0}{u_2} - \overset{2}{u_1})$$

$\boxed{\text{Solve for } v_1, v_2}$