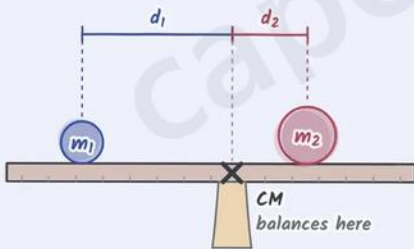


System of Particles and Rotational Motion

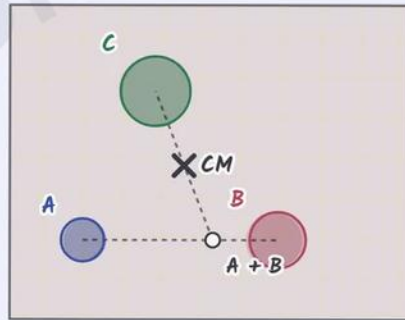
the whole body moves like its centre of mass, and spins about it too

Centre of mass

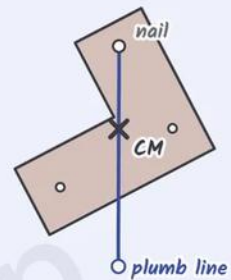
- the CM is the **one point** where the whole mass may be taken to sit
- two masses: it lies between them, **nearer the heavier one**
- a hung body settles with its CM **straight below** the nail
- the CM can lie **outside the body**: a ring's is at its empty centre



balanced on a finger at the CM



A and B first, then that point with C



hung from a nail: CM below it

Locating the CM

particles in space

$$\mathbf{R} = \frac{\sum m_i \mathbf{r}_i}{M}$$

two particles on a line

$$x_{cm} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$$

a continuous body

$$x_{cm} = \frac{1}{M} \int x \, dm$$

a **mass-weighted average** of position

Momentum of a system

total momentum

$$\mathbf{P} = \sum m_i \mathbf{v}_i = M \mathbf{V}_{cm}$$

Newton's second law

$$\mathbf{F}_{ext} = M \mathbf{A}_{cm} = \frac{d\mathbf{P}}{dt}$$

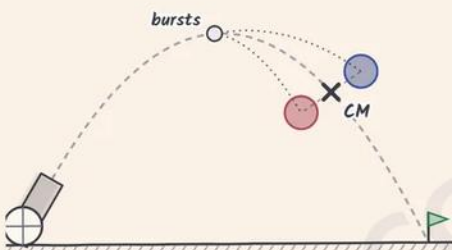
no external force

$$\mathbf{V}_{cm} = \text{constant}$$

one particle of mass M at the CM

Motion of the CM

- the CM moves as if all the mass sat there and all **external forces** acted there
- internal forces cancel in pairs: they **never move the CM**
- a bursting shell: the CM keeps the **same parabola**

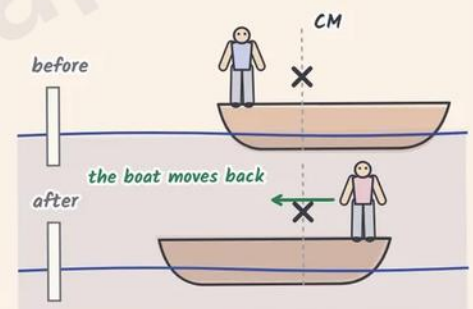


the CM stays on the parabola

CM: a smooth parabola
handle end: loops



the handle loops, the CM does not



the boat slides back; CM fixed