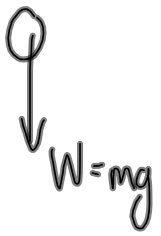
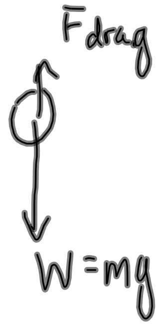
For a falling object with air resistance:

Body Released from Rest



Weight is the only force acting. The acceleration is g.

Body Accelerates



$(F_{drag} < W)$

Speed increases

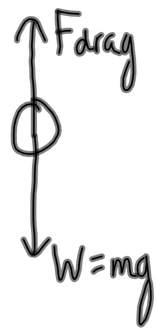
F_{drag} increases

F_{net} downward decreases

Acceleration decreases.

$(a < g)$

Body at Terminal Velocity



$(F_{drag} = W)$

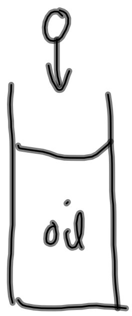
$F_{net} = 0$

acceleration is zero

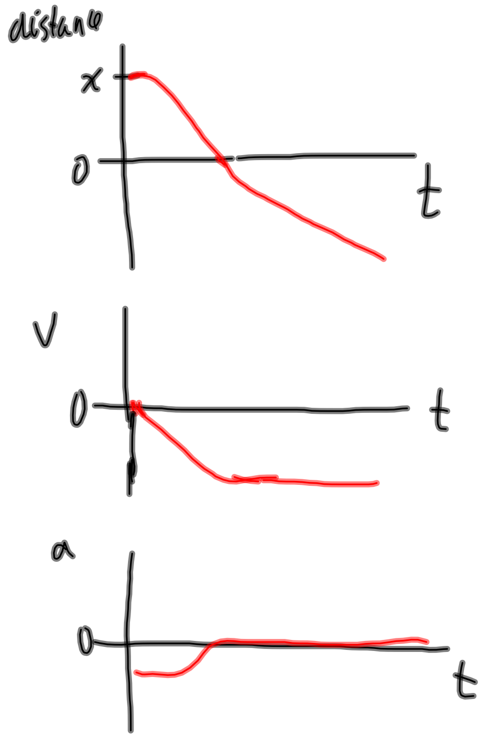
Terminal velocity

Example

A ball bearing is dropped from rest into oil from a small distance x above the oil. The ball bearing arrives at the surface of the oil above its terminal speed in the oil and subsequently slows to terminal speed as it falls through the oil.



Sketch distance-t, v-t, a-t from the time the ball was released in air to the time its speed reduces to its terminal speed in oil



* Surface of the oil is the reference level

Linear Momentum

Linear momentum is related to inertia (or inertial mass), but it is not the same.

If the inertia (inertial mass) of a truck is large, then it has a large resistance to the change in its motion. It would require a large force to accelerate it.

It is easier to stop the truck if it is travelling at a lower velocity.

Momentum is a quantity that depends on <u>both</u> the inertial mass of a body and its velocity.

Linear momentum $\vec{p}$

The linear momentum $\vec{p}$ of a body of mass m moving with a velocity $\vec{v}$ is the product of its mass and its velocity.

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

- a vector quantity
- units: $kg\ m\ s^{-1}$

Example

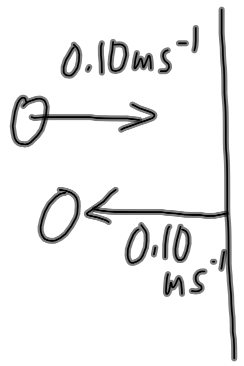
Determine the linear momentum of a truck of mass 10 000 kg moving east with a velocity of $20\ m s^{-1}$.

$m = 10\,000\ kg$
$\vec{v} = 20\ m s^{-1}\ [E]$
$\vec{p} = ?$

$\vec{p} = m\vec{v}$
$\vec{p} = (10\,000\ kg)(20\ m s^{-1}\ [E])$
$\vec{p} = 2 \times 10^{5}\ kg\ m s^{-1}\ [E]$

Example

A ball of mass 0.25kg moving east at 0.10ms^{-1} bounces off a wall rebounding with the same speed. Calculate the change in momentum of the ball.



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

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

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

$\Delta\vec{p} = 0.25\text{kg}\,(0.10\text{ms}^{-1}\,[W] - 0.10\text{ms}^{-1}\,[E]$

$\Delta\vec{p} = 0.25\text{kg}\,(-0.10\text{ms}^{-1}\,[E] - 0.10\text{ms}^{-1}\,[E$

$\Delta\vec{p} = 0.25\text{kg}\,(-0.20\text{ms}^{-1}\,[E])$

$\Delta\vec{p} = -0.050\ \text{kg}\cdot\text{m/s}\ [E]$

$\Delta\vec{p} = 0.050\,\text{kg}\cdot\text{m/s}\ [W]$

OR

$V_1 = +0.10\text{ms}^{-1}$

$V_2 = -0.10\text{ms}^{-1}$

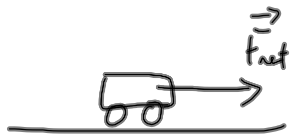
$\Delta V = -0.20\text{ms}^{-1}$

[W]

Relationship between force and change of momentum

If a net force $\vec{F}_{net}$ acts on a body of mass m, it accelerates, and according to Newton's second law:

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



Recall $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$

$$\vec{F}_{net} = m\left(\frac{\Delta \vec{v}}{\Delta t}\right)$$

$$\vec{F}_{net} = m\left(\frac{\vec{v}_2 - \vec{v}_1}{\Delta t}\right)$$

$$\vec{F}_{net} = \frac{m\vec{v}_2 - m\vec{v}_1}{\Delta t} \quad \text{OR} \quad \frac{mv - mu}{\Delta t}$$

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

$$\vec{F}_{net} = \frac{\Delta \vec{p}}{\Delta t}$$

← Really just another form of Newton's second law.

Newton's Second Law (Version 2!)

The net force acting on a body is equal to the rate of change of momentum that it produces in the body.

Two formats for Newton's Second Law:

① $\vec{F}_{net} = m\vec{a}$

② $\vec{F}_{net} = \frac{\Delta \vec{p}}{\Delta t}$