Stopping of Vehicle by Retarding Force.

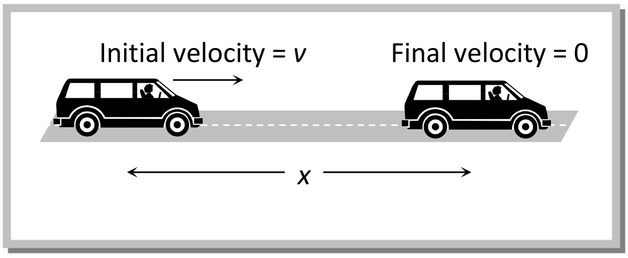
If a vehicle moves with some initial velocity and due to some retarding force it stops after covering some distance after some time.

(1) **Stopping distance:** Let m = Mass of vehicle, v = Velocity, P = Momentum, E = Kinetic energy

F = Stopping force, x = Stopping distance, t = Stopping time

Then, in this process stopping force does work on the vehicle and destroy the motion.

By the work- energy theorem



$$W = \Delta K = \frac{1}{2}mv^2$$

$\Rightarrow$ Stopping force (F) × Distance (x) = Kinetic energy (E)

$\Rightarrow$ Stopping distance (x) $= \dfrac{\text{Kinetic energy}(E)}{\text{Stopping force}(F)}$

$\Rightarrow$ $x = \dfrac{mv^2}{2F}$ .....(i)

(2) **Stopping time:** By the impulse-momentum theorem

$$F \times t = \Delta P \Rightarrow F \times t = P$$

$\therefore$ $t = \dfrac{P}{F}$

or $t = \dfrac{mv}{F}$ .....(ii)

(3) **Comparison of stopping distance and time for two vehicles:** Two vehicles of masses m_1 and m_2 are moving with velocities v_1 and v_2 respectively. When they are stopped by the same retarding force (F).

The ratio of their stopping distances $\dfrac{x_1}{x_2} = \dfrac{E_1}{E_2} = \dfrac{m_1 v_1^2}{m_2 v_2^2}$

and the ratio of their stopping time $\dfrac{t_1}{t_2} = \dfrac{P_1}{P_2} = \dfrac{m_1 v_1}{m_2 v_2}$

If vehicles possess same velocities		
$v_1 = v_2$	$\frac{x_1}{x_2} = \frac{m_1}{m_2}$	$\frac{t_1}{t_2} = \frac{m_1}{m_2}$
If vehicle possess same kinetic momentum		
$P_1 = P_2$	$\frac{x_1}{x_2} = \frac{E_1}{E_2} = \left(\frac{P_1^2}{2m_1}\right)\left(\frac{2m_2}{P_2^2}\right) = \frac{m_2}{m_1}$	$\frac{t_1}{t_2} = \frac{P_1}{P_2} = 1$
If vehicle possess same kinetic energy		
$E_1 = E_2$	$\frac{x_1}{x_2} = \frac{E_1}{E_2} = 1$	$\frac{t_1}{t_2} = \frac{P_1}{P_2} = \frac{\sqrt{2m_1E_1}}{\sqrt{2m_2E_2}} = \sqrt{\frac{m_1}{m_2}}$

Note: If vehicle is stopped by friction then

Stopping distance $x = \frac{\frac{1}{2}mv^2}{F} = \frac{\frac{1}{2}mv^2}{ma} = \frac{v^2}{2\mu g}$ [As $a = \mu g$]

Stopping time $t = \frac{mv}{F} = \frac{mv}{m\mu g} = \frac{v}{\mu g}$