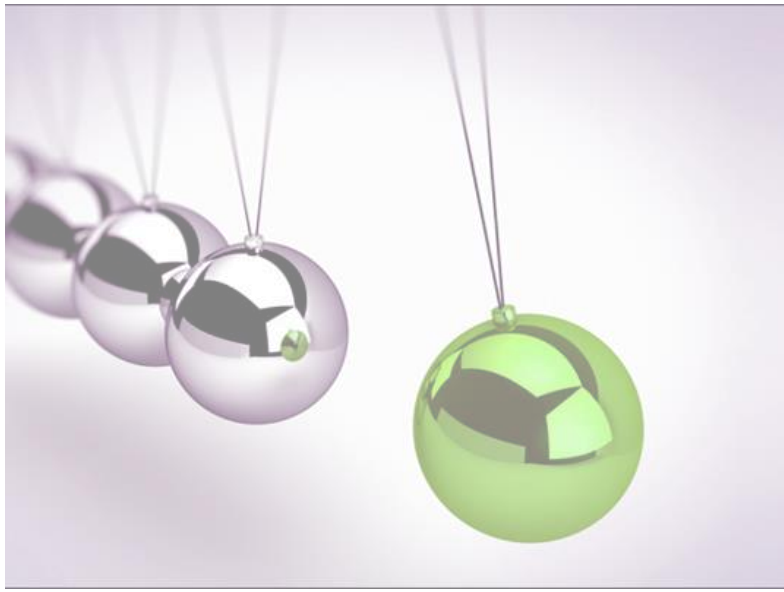
Mechanics & Materials

2015 AQA A Level Physics

Momentum and collisions



Physics Tutor Online

Momentum

An object having mass and velocity has MOMENTUM. Momentum (symbol "p") is simply given by the formula:

Momentum =	Mass	x	Velocity
(in $kgms^{-1}$)	*(in kg)*		*(in ms^{-1})*

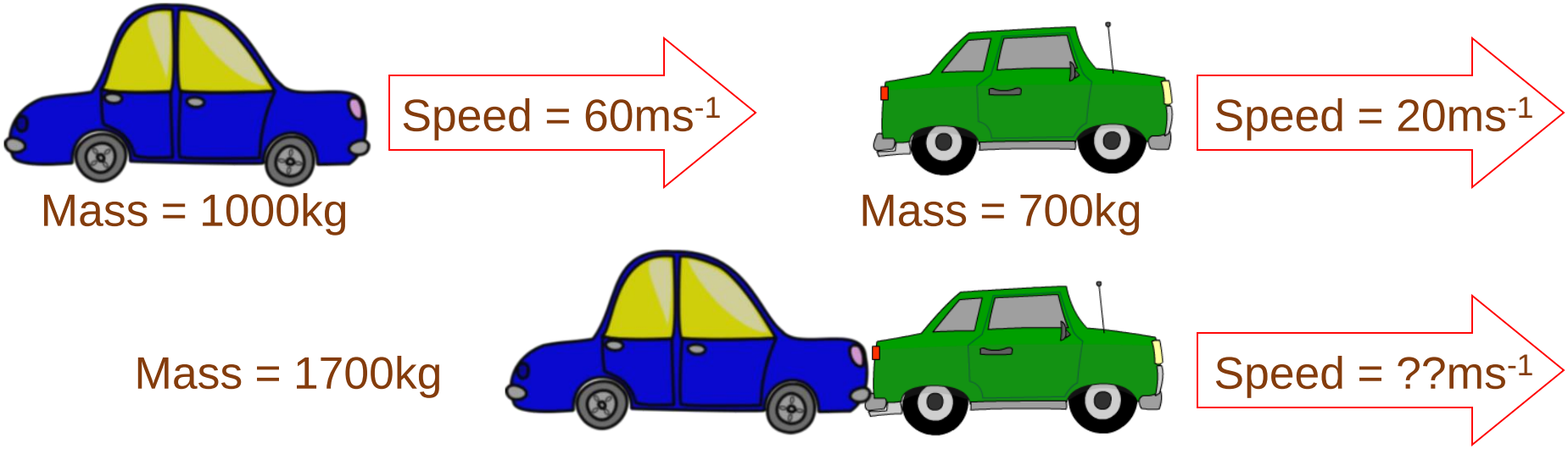
What is the momentum of the following?

1) A 1kg football travelling at $10ms^{-1}$
2) A 1000kg Ford Capri travelling at $30ms^{-1}$
3) A 20g pen being thrown across the room at $5ms^{-1}$
4) A 70kg bungi-jumper falling at $40ms^{-1}$

Conservation of Momentum

The Principle of the Conservation of Momentum: In any collision or explosion momentum is conserved, provided that no external forces have an effect.

Two cars are racing on the motorway. Car A collides with the back of car B and the cars stick together. What speed do they move at after the collision?



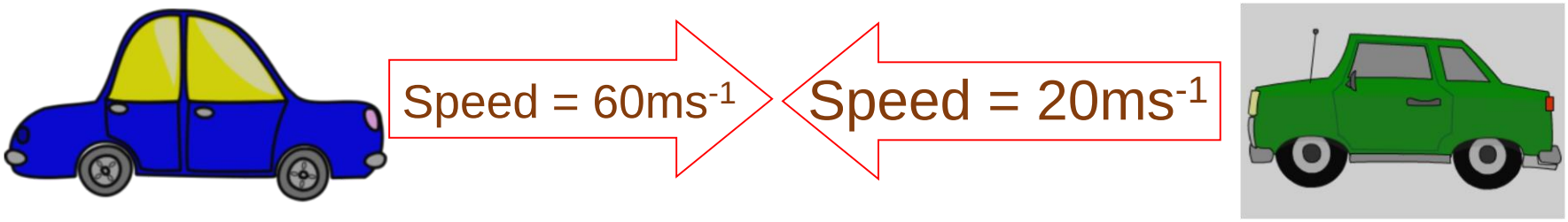
Momentum before = momentum after…

…so (1000 x 60) + (700 x 20) = 1700 x V…

V = 43.5 ms^{-1}

Momentum in different directions

What happens if the bodies are moving in opposite directions?



Momentum is a VECTOR quantity, so the momentum of the second car is negative…

Total momentum = (1000 x 60)– (700 x 20) = 46000 $kgms^{-1}$

Speed after collision = 46000 $kgms^{-1}$ / 1700 = **27.1ms^{-1}**

More questions…

1) A white snooker ball moving at $6ms^{-1}$ strikes a red ball and pots it. Both balls have a mass of 1.5kg. If the white ball continued in the same direction at $2ms^{-1}$ what was the velocity of the red ball?

2) A car of mass 900kg heading up the M1 at $70ms^{-1}$ collides with a stationary truck of mass 8500kg and sticks to it. What velocity does the wreckage move forward at?

3) A defender running away from a goalkeeper at $5ms^{-1}$ is hit in the back of his head by the goal kick. The ball stops dead and the player's speed increases to $6.6ms^{-1}$. If the ball had a mass of 700g and the player had a mass of 60kg how fast was the ball moving?

4) A gun has a recoil speed of $3ms^{-1}$ when firing. If the gun has a mass of 2kg and the bullet has a mass of 12g what speed does the bullet come out at?

Newton's 2nd Law and Impulse

Instead of F=ma Newton actually said that the force acting on an object is that object's rate of change of momentum. In other words…

$$\text{Force} = \frac{\text{Change in momentum}}{\text{Time}}$$

(in N) (in $kgms^{-1}$) (in s)

Also called "impulse"

For example, Dimitri Payet takes a free kick by kicking a stationary football with a force of 50N. If the ball has a mass of 0.5kg and his foot is in contact with the ball for 0.1s calculate:

1) The change in momentum of the ball (its impulse),

2) The speed the ball moves away with

Example questions

1) Alice likes playing golf. She strikes a golf ball with a force of 85N. If the ball has a mass of 300g and the club is in contact with it for 0.3s calculate a) the change in momentum of the golf ball, b) its speed.

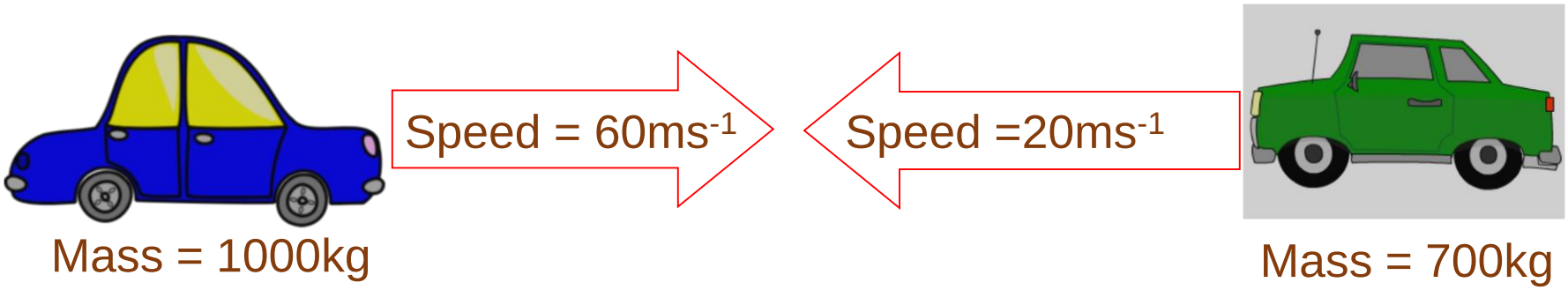
2) Sam thinks it's funny to hit tennis balls at Sean. He strikes a serve with a force of 35N. If the ball has a mass of 250g and the racket is in contact with it for 0.2s calculate the ball's change in momentum and its speed.

3) Dom takes a dropkick by kicking a 0.5kg rugby ball away at 13m/s. If his foot was in contact with the ball for 0.1 seconds calculate the force he applied to the ball.

4) Steve strikes a 200g golf ball away at $70ms^{-1}$. If he applied a force of 60N calculate how long his club was in contact with the ball for.

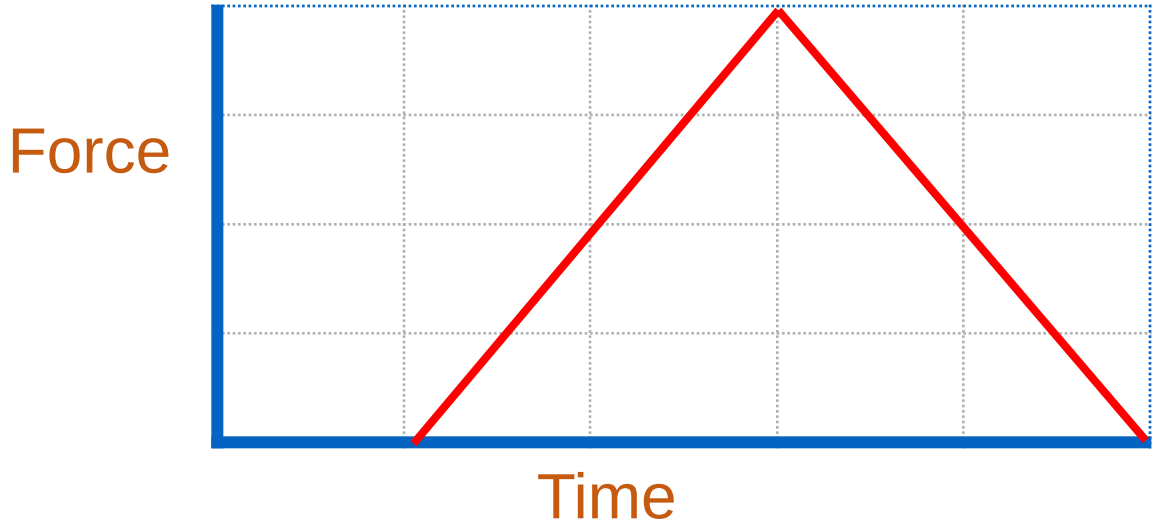
Another way to ask the same question…

Here's a situation we looked at earlier…



What's the impulse of the car on the left if the cars stick together?

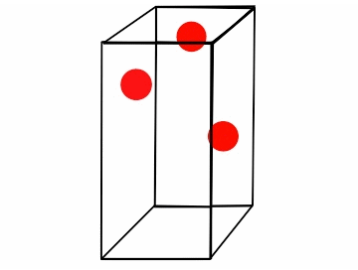
Calculate appropriate scales for the force-time graph shown.



Elastic and Inelastic collisions

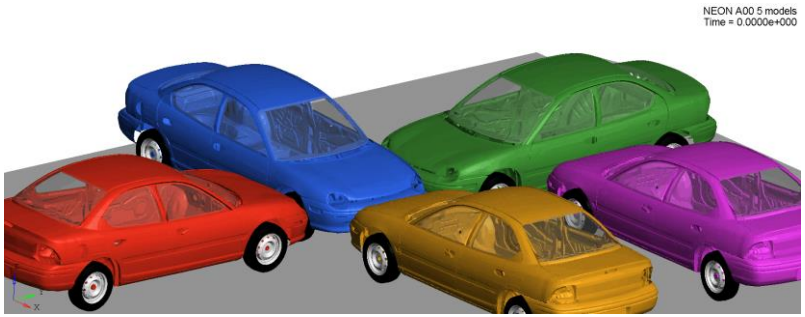
In an elastic collision, no kinetic energy is lost

Collisions between molecules in a gas can be treated as elastic



In an inelastic collision, kinetic energy is transferred to other energy stores

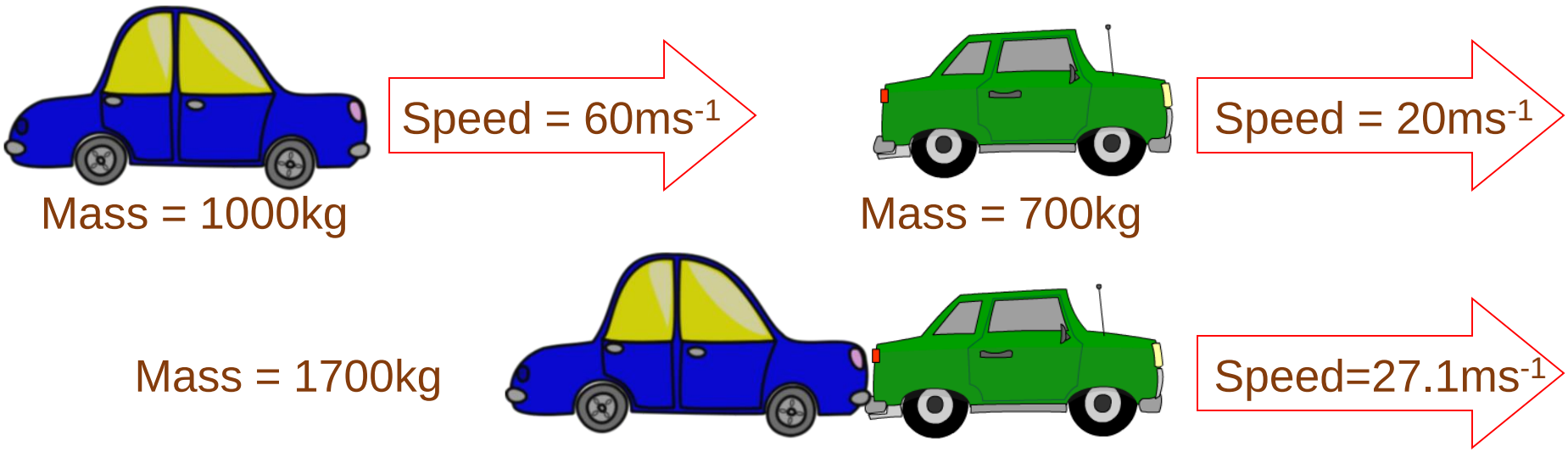
Collisions between everyday objects tend to generate sound and thermal energy and are therefore inelastic.



Elastic or inelastic?

Earlier we used conservation of momentum to calculate the velocity of the combined vehicles. Calculate the Kinetic energy before and after the collision

To determine whether the collision is elastic or inelastic



Kinetic Energy before = $(\frac{1}{2} \times 1000 \times 60^2) + (\frac{1}{2} \times 700 \times 20^2) = 1.96MJ$

Kinetic Energy after = $\frac{1}{2} \times 1700 \times 43.5^2 = 1.61MJ$

Collision is inelastic; 0.35MJ shifted to other stores (thermal, sound)