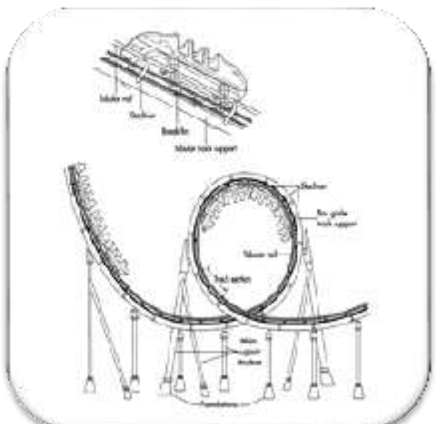
A2 Physics Unit 4
1 Forces & Momentum



KS5 AS PHYSICS 2450

Mr D Powell

Chapter Map

1.1 Momentum and impulse

Specification link-up 3.4.1: Momentum concepts

How do we calculate momentum?

What is the connection between Newton's first and second laws of motion and momentum?

What is an impulse, and how is it calculated from a force v. time graph?

1.2 Impact forces

Specification link-up 3.4.1: Momentum concepts

What happens to the impact force (and why?) if the duration of impact is reduced?

How do we calculate $\Delta(mv)$ for a moving object which stops or reverses?

What happens to the momentum of a ball when it bounces off a wall?

1.3 Conservation of momentum

Specification link-up 3.4.1: Momentum concepts

Is momentum ever lost in a collision?

What do we mean by *conservation of momentum*?

What condition must be satisfied if the momentum of a system is conserved?

1.4 Elastic and inelastic collisions

Specification link-up 3.4.1: Momentum concepts

What is the difference between an elastic collision and an inelastic collision?

What is conserved in a perfectly elastic collision?

Are any real collisions ever perfectly elastic?

1.5 Explosions

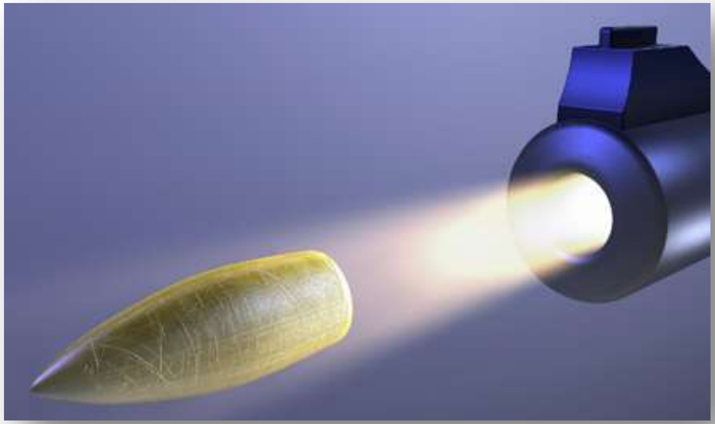
Specification link-up 3.4.1: Momentum concepts

What energy changes takes place in an explosion?

What can we always say about the total momentum of a system that has exploded?

What are the consequences when, after the explosion, only two bodies move apart?

Can you see the links... (there are two)



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1.3 Conservation of Momentum

Is momentum ever lost in a collision? (AO3)

What do we mean by conservation of momentum? (A02a)

What condition must be satisfied if the momentum of a system is conserved? (AO1a)

Starter activity.....

Can you derive a construction for the momentum changes before and after a collision and an explosion. Label each term in your construction....

Now.....

a) Calculate the momentum of a 40 kg person running at 6 m/s.
b) Calculate the momentum of a 80 kg person running at 3 m/s.
c) Calculate the velocity of a 80 kg bike with momentum of 2kg m/s.
d) Calculate the mass of a person with momentum of 2kg m/s and velocity of 0.02 m/s

Understanding ***Momentum*** *helps Physicists do* ***Calculations*** *on* ***Collisions***

The **momentum** of an object depends on two values — **mass** and **velocity**. The **product** of these two values is the momentum of the object.

Remember velocity is a vector quantity, which means it has size and direction.

momentum = mass × velocity or in symbols: $\boldsymbol{p}$ (in kg ms^{-1}) = $\boldsymbol{m}$ (in kg) × $\boldsymbol{v}$ (in ms^{-1})

Momentum is always **Conserved**

1) Assuming **no external forces** act, momentum is always **conserved**.
2) This means the **total momentum** of two objects **before** they collide will **equal** the total momentum **after** the collision.
3) This is very handy for working out the **velocity** of objects after a collision (as you do...):

Example A skater of mass 75 kg and velocity 4 ms^{-1} collides with a stationary skater of mass 50 kg. The two skaters join together and move off in the same direction. Calculate their velocity after impact.

Before you start a momentum calculation, always draw a quick sketch.

Momentum of skaters before = momentum of skaters after

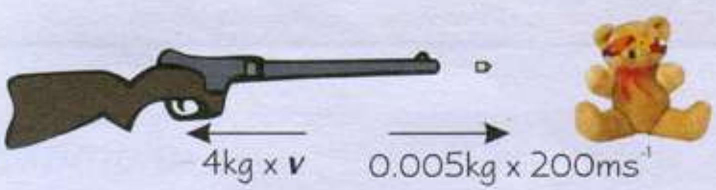
$$(75 \times 4) + (50 \times 0) = 125\,\boldsymbol{v}$$

$$300 = 125\,\boldsymbol{v}$$

$$\text{So } \boldsymbol{v} = 2.4 \text{ ms}^{-1}$$

The same principle can be applied in **explosions**. E.g. when you fire an **air rifle**, the **forward momentum** gained by the pellet **equals** the **backward momentum** of the rifle, and you feel the rifle recoiling into your shoulder.

Example A bullet of mass 0.005 kg is shot from a rifle at a speed of 200 ms^{-1}. The rifle has a mass of 4 kg. Calculate the velocity at which the rifle recoils.



Momentum before explosion = Momentum after explosion

$$0 = (0.005 \times 200) + (4 \times \boldsymbol{v})$$

$$0 = 1 + 4\boldsymbol{v}$$

$$\boldsymbol{v} = -0.25 \text{ ms}^{-1}$$

Rocket Propulsion can be Explained by *Momentum*

For a **rocket** to be **propelled forward** it must expel **exhaust gases**. The momentum of the rocket in the forward direction is **equal** to the momentum of the exhaust gases in a backward direction.

Example A rocket of mass 500 kg is completely stationary in an area of space a long way from any gravitational fields. It starts its engines. The rocket ejects 2.0 kg of gas per second at a speed of 1000 ms^{-1}. Calculate the velocity of the rocket after 1 second.

(For the purpose of this calculation ignore the loss of mass due to fuel use.)

The total momentum before launch = 0 kg ms^{-1} as initially the rocket is stationary, the total momentum after the launch must also = 0 kg ms^{-1}.

Total momentum after launch = $(500 \times \boldsymbol{v}) + (2 \times 1000) = 0$

$500\,\boldsymbol{v} = -2000$

$\boldsymbol{v} = -4\ ms^{-1}$

The minus sign shows that the rocket moves in the opposite direction to the exhaust gases.

Conservation of momentum

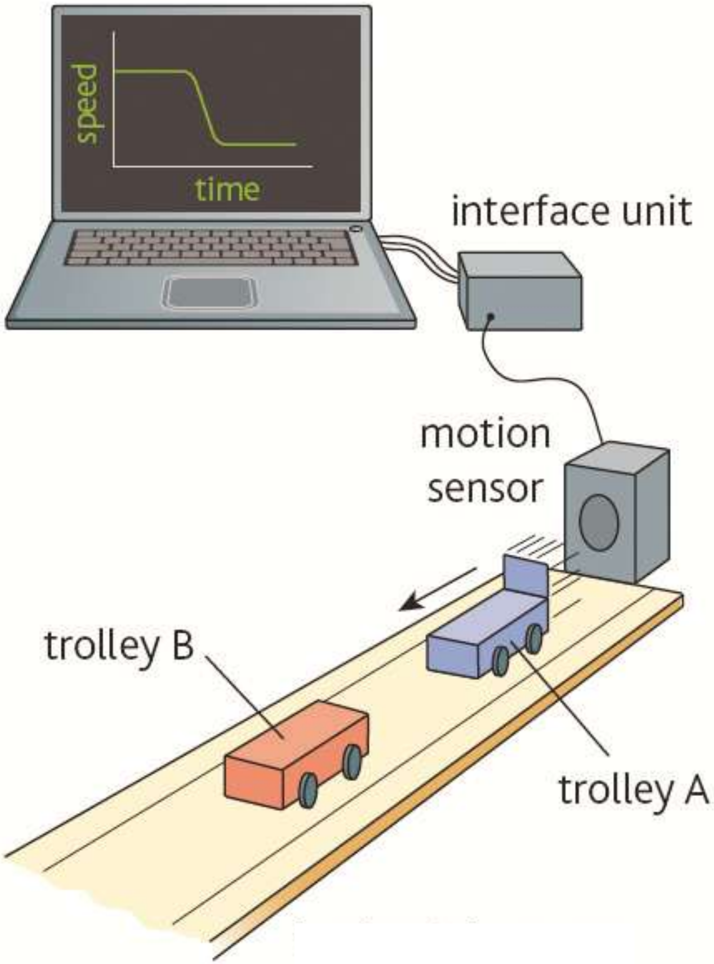
1. Explore this idea and prove and formula..

2. Set your ramp height to about 27mm to avoid frictional changes in velocity

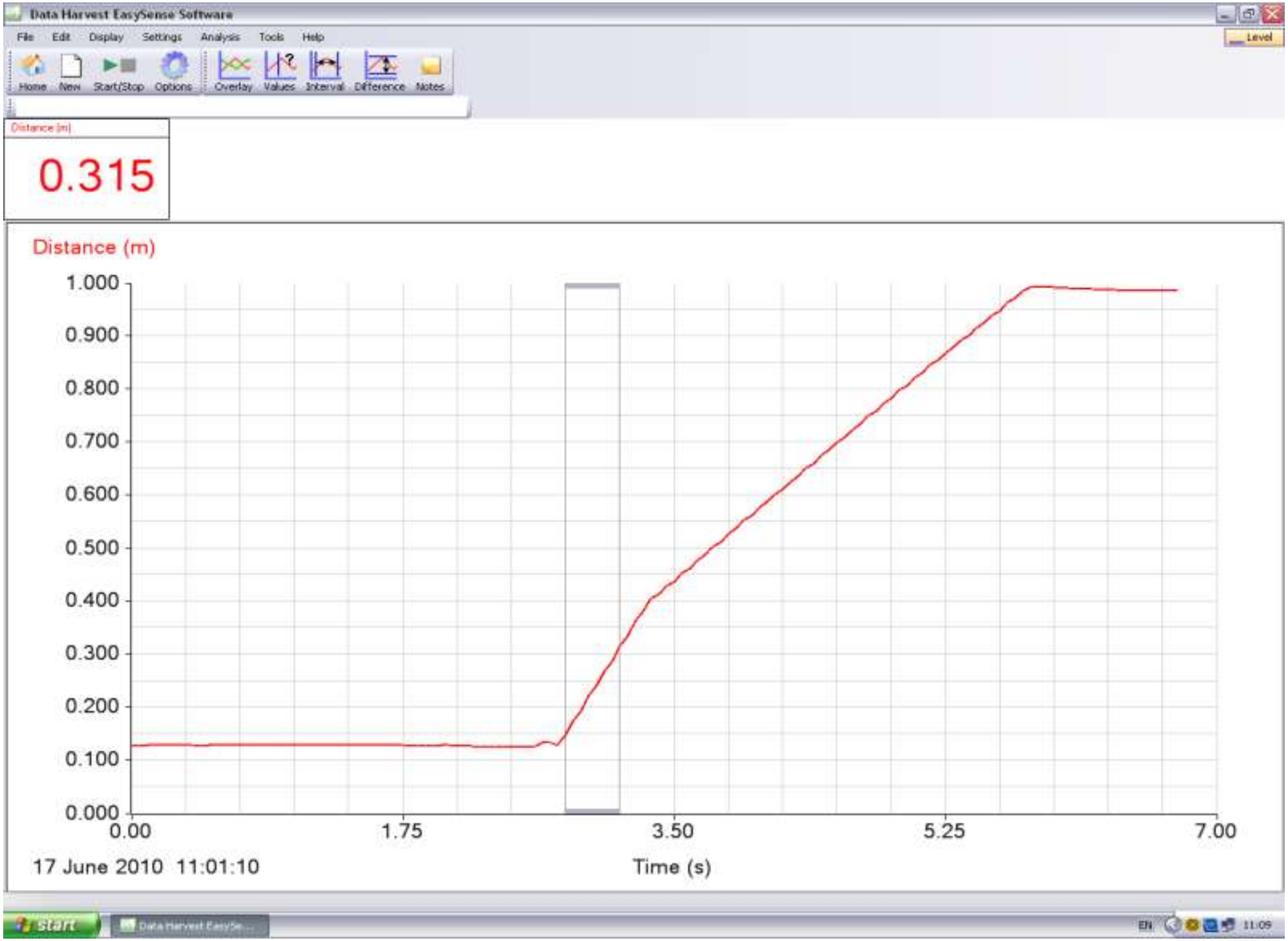
$$(m_B + m_A)V = m_A u_A$$

3. Work out the calculations using the gradient of the distance time graph (our logger cannot do speed time)

4. Now think about errors..



$$\frac{\Delta s}{\Delta t} = v$$



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Conservation of momentum.

Set of example results...

$\Delta s_A = 0.15$
$\Delta t_A = 0.35$

$\Delta s_{AB} = 0.15$
$\Delta t_{AB} = 0.70$

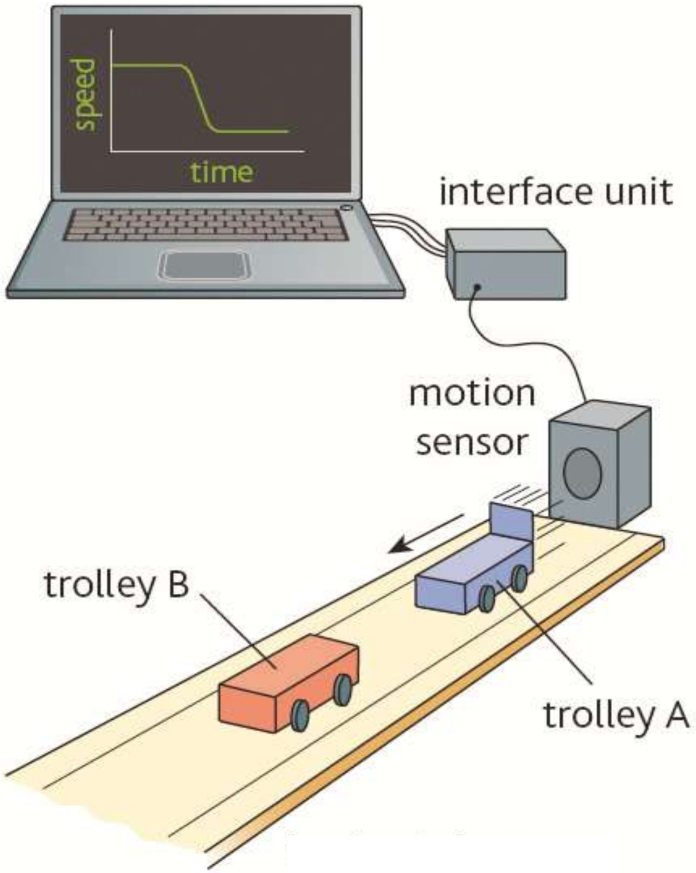
Calculated

$V_A = 0.43ms^{-1}$
$V_{AB} = 0.214ms^{-1}$

Mass

$M_A = 0.890kg$
$M_B = 0.889kg$

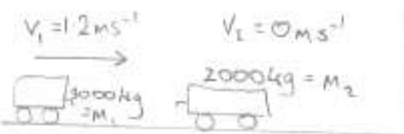
Velocity from formula = $0.215ms^{-1}$

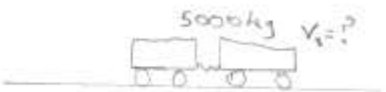


$$(m_B + m_A)V = m_A u_A$$

Cons of Momentum 1.3

Q1





$M_1V_1 + M_2V_2 = (M_1+M_2)V_3$

$\frac{M_1V_1}{M_1+M_2} = V_3$ as $V_2 = 0$

$\frac{3000 \times 1.2}{5000} = 0.72ms^{-1}$

Q2

Before	After
$M_1 = 5000kg$ $V_1 = 1.6ms^{-1}$	$V_3 = ?$
$M_2 = 3000kg$ $V_2 = 0ms^{-1}$	$V_4 = 1.5ms^{-1}$

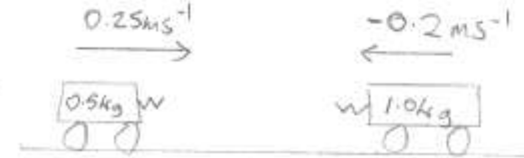
$M_1V_1 + M_2V_2 = M_1V_3 + M_2V_4$ ($M_2V_2 \to 0$)

$\frac{M_1V_1 - M_2V_4}{M_1} = V_3$

$\frac{8000 - 4500}{5000} = 0.7ms^{-1}$

(same direction)

Q3



$M_1V_1 + M_2V_2 = (M_1+M_2)V_3$

$\frac{M_1V_1 + M_2V_2}{M_1+M_2} = V_3$

$\frac{0.25 \times 0.5 - 0.2 \times 1}{1.5} = -0.05ms^{-1}$

So motion is from right to left or direction of 1.0kg cart

Q4

Before	After
$M_1 = 0.8$ $V_1 = 0.25ms^{-1}$	$V_4 = ?$
$M_2 = 2.5kg$ $V_2 = 0$	$V_3 = 1.0ms^{-1}$ →

$0.8 \times 2.5ms^{-1} = 2.5 \times 1 + 0.8M_1$

$\frac{0.8 \times 2.5 - 2.5}{0.8} = -0.625$

Ball moves in direction ←

(rebound)