Year 11 Physics Week 3

Newtons Laws

The 3 Laws of Motion

First Law — Balanced Forces Mean No Change in Velocity

So long as the forces on an object are all balanced, then it'll just stay still, or else if it's already moving it'll just carry on at the same velocity — so long as the forces are all balanced.

When a train or car or bus or anything else is moving at a constant velocity then the forces on it must all be balanced.

To keep going at a steady speed, there must be zero resultant force

Inertia

Newton's first law tells us that objects have in-built resistance to any change in their motion.

A stationary object only starts to move when you apply a resultant force.

This reluctance to change velocity is called **inertia**.

The inertia of an object depends on its mass.

A bigger mass needs a bigger force to overcome its inertia and change its motion.

Momentum

The mass and velocity of an object determine its **momentum**:

2000 kg moving at 5 m s^{-1}

0.02 kg moving at 400 m s^{-1}

Momentum

Momentum sometimes has the symbol p, and is measured in kg m s^{-1}.

Momentum is defined as mass multiplied by velocity

momentum, p	=	**mass, m**	×	**velocity, v**
(kg m s^{-1})		(kg)		(m s^{-1})

or

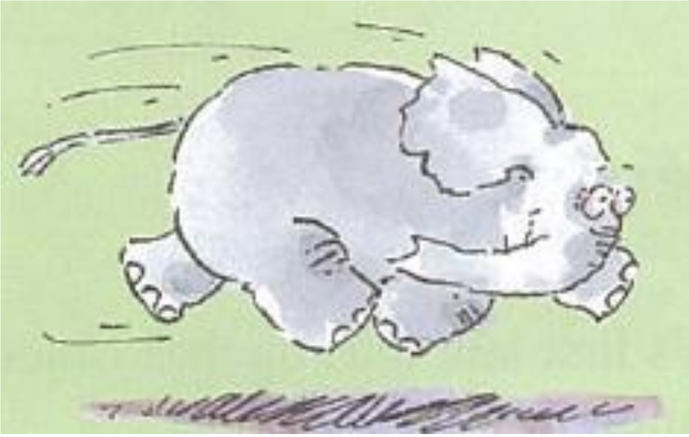
$$p = mv$$

The greater an object's momentum, the more force needed to stop it.

Momentum is a vector quantity

Momentum Worked Example

Calculate the momentum of an elephant of mass 2000 kg moving at 40 m s^{-1} !



momentum, $\boldsymbol{p} = \boldsymbol{m}\boldsymbol{v} = 2000 \text{ kg} \times 40 \text{ m s}^{-1} = \underline{80\,000 \text{ kg m s}^{-1}}$

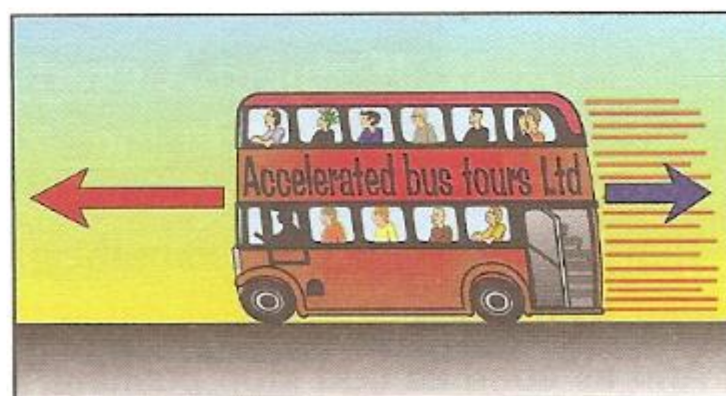
Second Law — A Resultant Force Means Acceleration

If there is an unbalanced force, then the object will accelerate in that direction.

An unbalanced force will always produce acceleration (or deceleration).

This "acceleration" can take five different forms: Starting, stopping, speeding up, slowing down and changing direction.

On a force diagram, the arrows will be unequal:



Obvious Points to Note!

The bigger the force, the greater the acceleration or deceleration.

The bigger the mass, the smaller the acceleration.

To get a big mass to accelerate as fast as a small mass it needs a bigger force.

The Overall Unbalanced Force is Often Called the Resultant Force

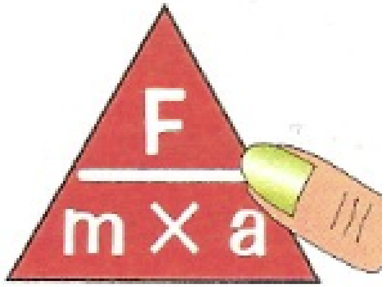
Any resultant force will produce acceleration, and this is the formula for it:

$$F = ma \quad \text{or} \quad a = F/m$$

m = mass, a = acceleration, F is always the resultant force.

In most real situations there are at least two forces

The overall effect of these forces will decide the motion of the object



The Third Law — Reaction Forces

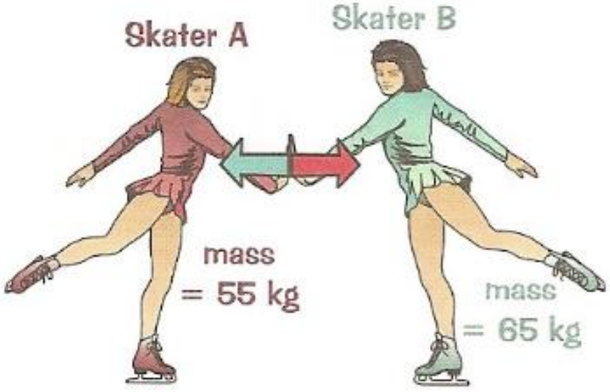
If object A exerts a force on object B then object B exerts the exact opposite force on object A.

That means if you push something, say a shopping trolley, the trolley will push back against you, just as hard.

And as soon as you stop pushing, so does the trolley.

If Forces are Equal How Do Things Ever Move?

- Acting on different objects



When skater A pushes on skater B (the 'action' force), she feels an equal and opposite force from skater B's hand (the 'reaction' force). Both skaters feel the same sized force, in opposite directions, and so accelerate away from each other.

Skater A will be accelerated more than skater B, though, because she has a smaller mass — remember F = ma.

Free Body Diagrams

Free-body force diagrams show a **single body** on its own.

The diagram should include all the **forces** that **act on** the body,

but **not** the **forces it exerts** on the rest of the world.

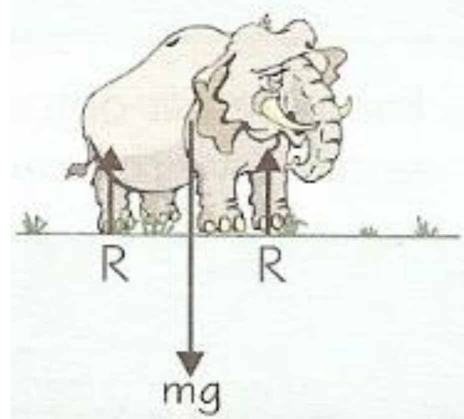
Remember **forces** are **vector quantities**

arrow labels should show the **size** and **direction** of the forces.

If a body is in **equilibrium** (i.e. not accelerating) the **forces** acting on it will be **balanced**.

Gravity pulls apple downwards (weight = m × g).

Gravity pulls man down. Air resistance pushes man up.



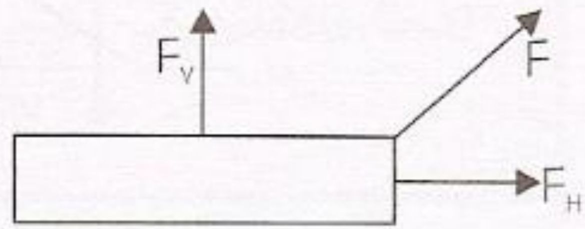
Gravity pulls elephant down. Earth pushes elephant up (reaction).

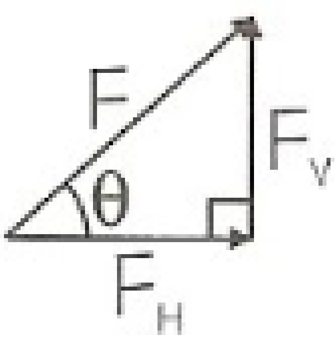
Resolving** a **Force** means **Splitting** it into **Components

Forces can be in **any direction**, so they're not always at right angles to each other.

To make an 'awkward' force easier to deal with, you can think of it as **two separate forces**, acting at **right angles** to **each other**.

The force F has exactly the same effect as the horizontal and vertical forces, F_H and F_V.
Replacing F with F_H and F_V is called **resolving the force F**.



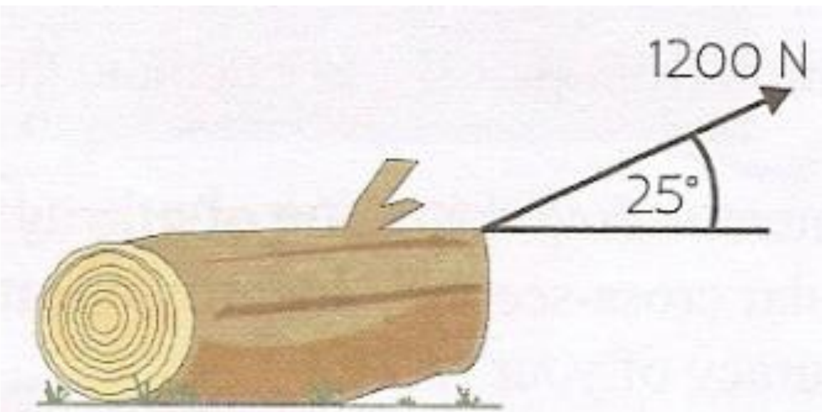


$$\frac{F_H}{F} = \cos\theta \quad \textit{or} \quad F_H = F\cos\theta$$

$$\frac{F_V}{F} = \sin\theta \quad \textit{or} \quad F_V = F\sin\theta$$

Another Worked Example

A tree trunk is pulled along the ground by an elephant exerting a force of 1200 N at an angle of 25° to the horizontal. Calculate the components of this force in the horizontal and vertical directions.



Horizontal force = $1200 \times \cos 25° =$ **1088 N**

Vertical force = $1200 \times \sin 25° =$ **507 N**

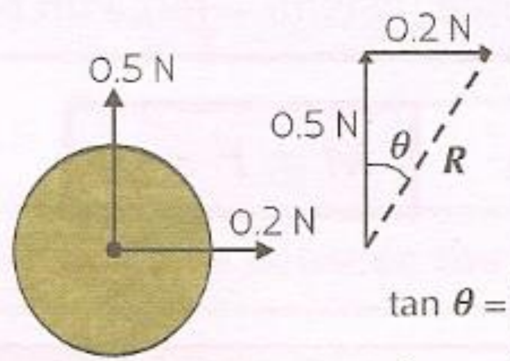
Add the ***Components Back Together*** *to get the* ***Resultant Force***

you find the **resultant** (total) **force** by adding the **vectors** together

=

closed triangle, with the resultant force represented by the **third side.**

Two dung beetles roll a dung ball along the ground at constant velocity. Beetle A applies a force of 0.5 N northwards while beetle B exerts a force of only 0.2 N eastwards.
What is the resultant force on the dung ball?



By Pythagoras

$R^2 = 0.5^2 + 0.2^2$
$R = \sqrt{0.29}$
$= 0.54$ N

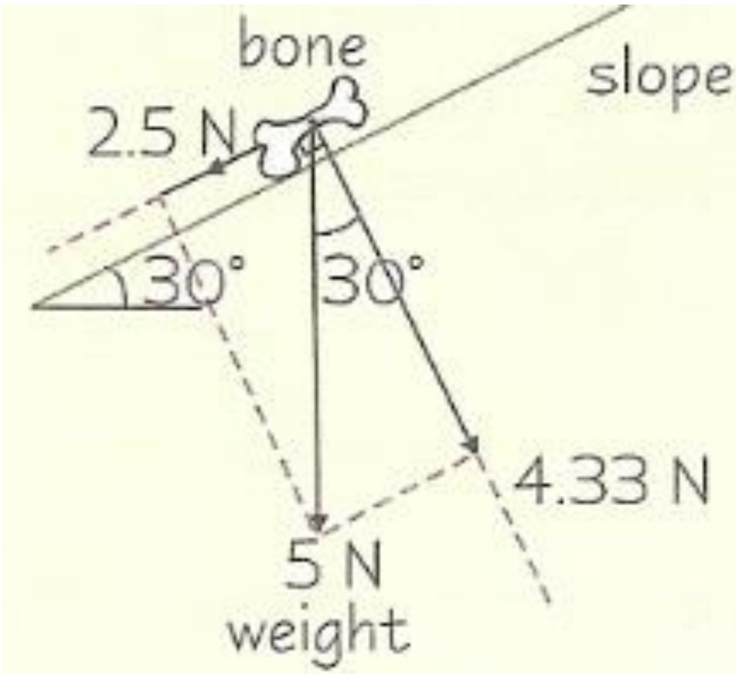
$\tan\theta = \frac{0.2}{0.5}$

$\theta = \tan^{-1} 0.4$

$\theta = 21.8°$

The resultant force is **0.54 N** at an angle of **21.8°** from North.

Worked Example



The component of the bone's weight down the slope is 2.5 N so you'd need 2.5 N of friction to stop it sliding away.

Points to Remember

Force is measured in newtons, N, where:
"1 N is the resultant (or unbalanced) force which causes a mass of 1 kg to accelerate at 1 m s^{-2}."