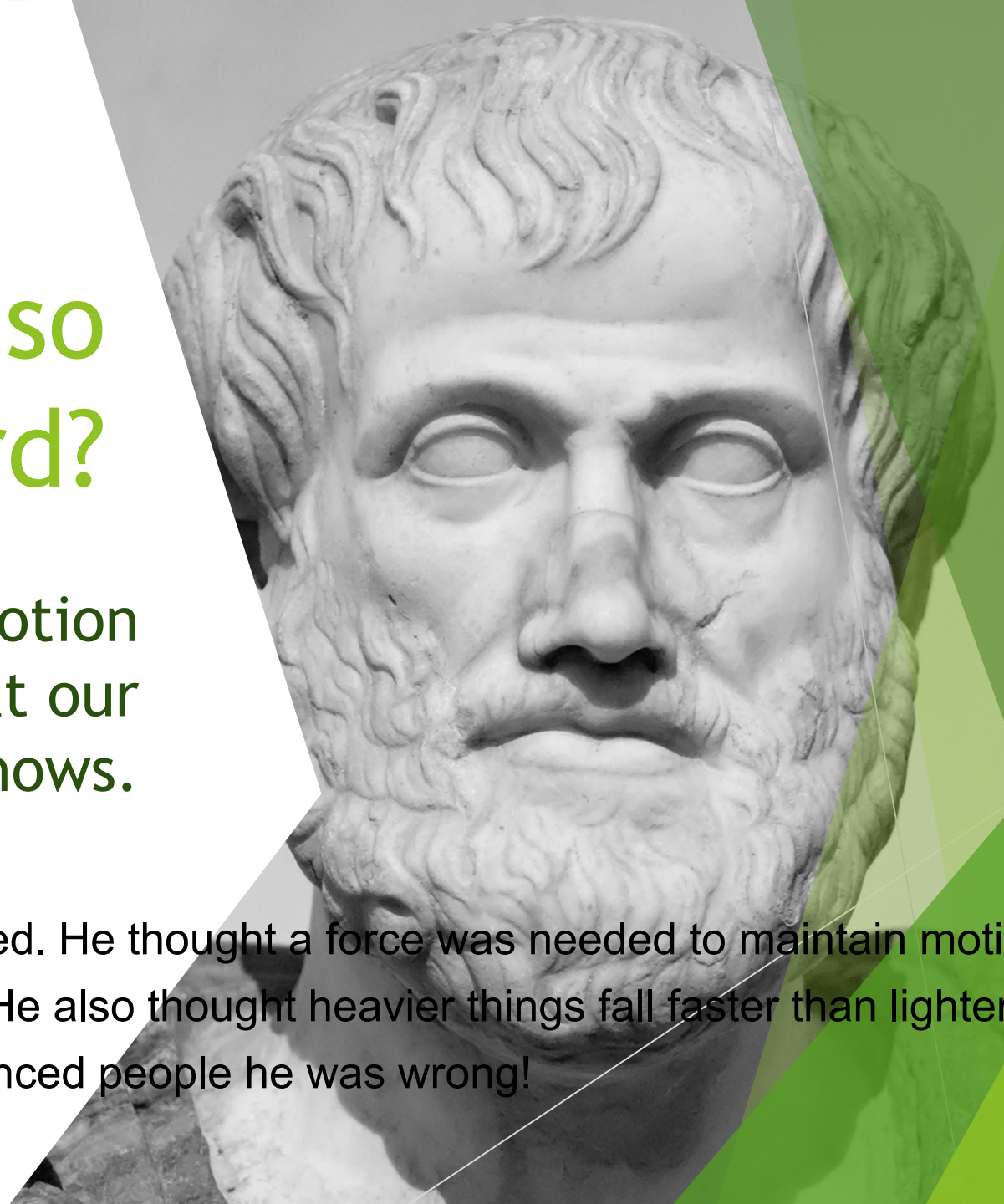
The 3, 2, 1 of Newton's Laws

N5 Physics- Dynamics

Why is this so hard?

Newton's 3 Laws of Motion aren't exactly what our experience shows.



Aristotle seemed to have motion cracked. He thought a force was needed to maintain motion-
I mean that is what we see in real life. He also thought heavier things fall faster than lighter objects
It took 2000 years before Galileo convinced people he was wrong!

Newton's 2nd and 1st Laws

Observations:

- Pedal (apply force) gently and your travel slowly.
- Pedal harder and you travel faster.
- Stop pedaling and you slow down and stop.

But this is wrong!

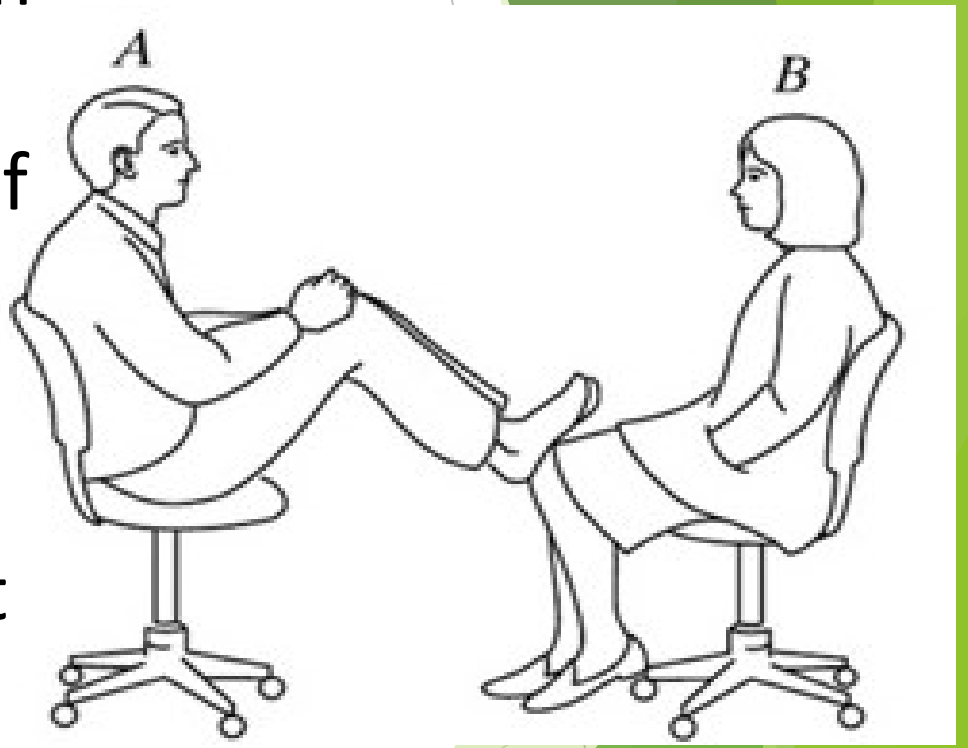
Conclusions:

- You need to apply a force to keep moving.
- Speed is proportional to the force applied.

Diagnostic assessment

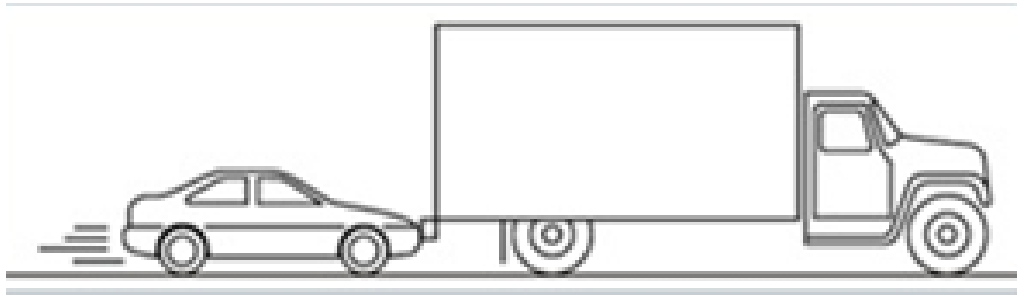
A large lorry collides head-on with a small car. Compare the force on the lorry from the car, with the force on the car from the lorry during the collision. Which force, if either, is larger?

- Student A has a mass of 95 kg and student B has a mass of 77 kg. They sit in identical office chairs facing each other. Student A places his feet on the knees of student B. Student A then suddenly pushes outwards with his feet, causing both chairs to move. What can you say about the amount of force each student exerts on the other during the push?



Diagnostic Questions

A large lorry breaks down and is pushed back into town by a small car, as shown.



Whilst the car, pushing the lorry, is speeding up, how does the force that the car exerts on the lorry compare with the force that the lorry exerts on the car?

After the car reaches the constant speed, at which the driver wished to push the lorry, how does the force that the car exerts on the lorry compare with the force that the lorry exerts on the car?

Let's do Newton's Third Law 1st!

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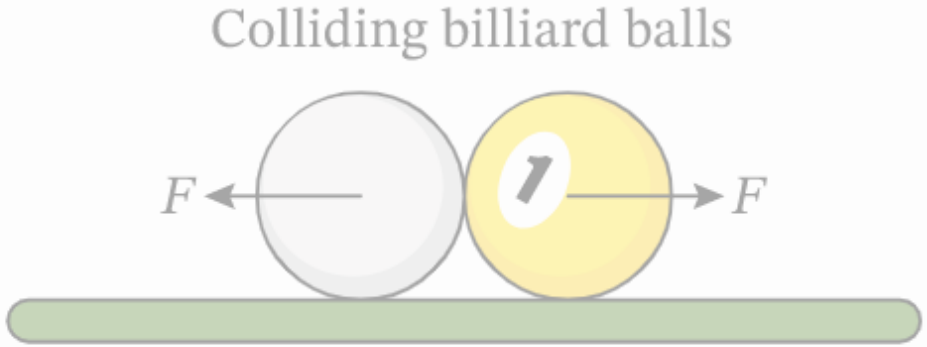
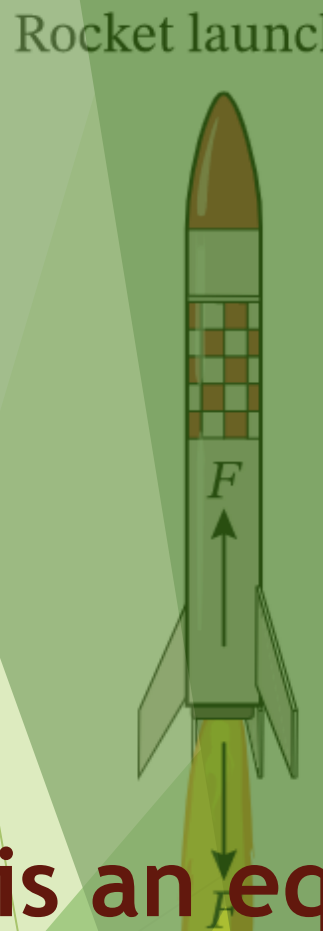
Newton's Third Law





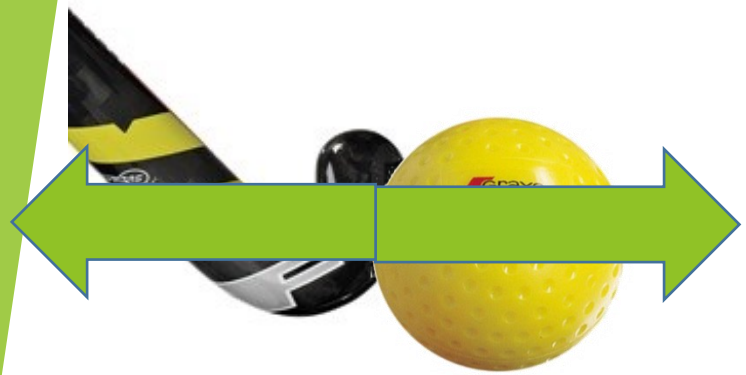
- For every action there is an equal but opposite reaction. or
- If A exerts a force on B, B exerts an equal but opposite force on A.

When identifying Newton Pairs

To identify a ‘reaction’ force to a specific ‘action’ force it is first necessary to identify clearly:

- the type of ‘action’ force
- the object causing the ‘action’ force
- the object on which the ‘action’ force acts, and
- the direction in which the ‘action’ force acts.

Newton Pair eg 1



Action:

The hockey stick pushes forward on the ball

type of force – push

object causing the 'action' force – hockey stick

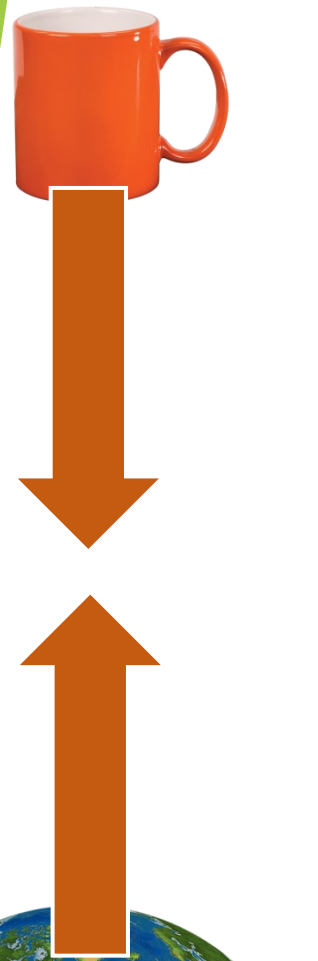
object on which the 'action' force acts – ball

direction of force - forwards

Reaction:

The ball pushes backwards on the hockey stick

Newton Pair eg 2



Action:

The gravitational pull of the Earth downwards on the mug

type of force – gravitational pull

object causing the 'action' force – the Earth

object on which the 'action' force acts – mug

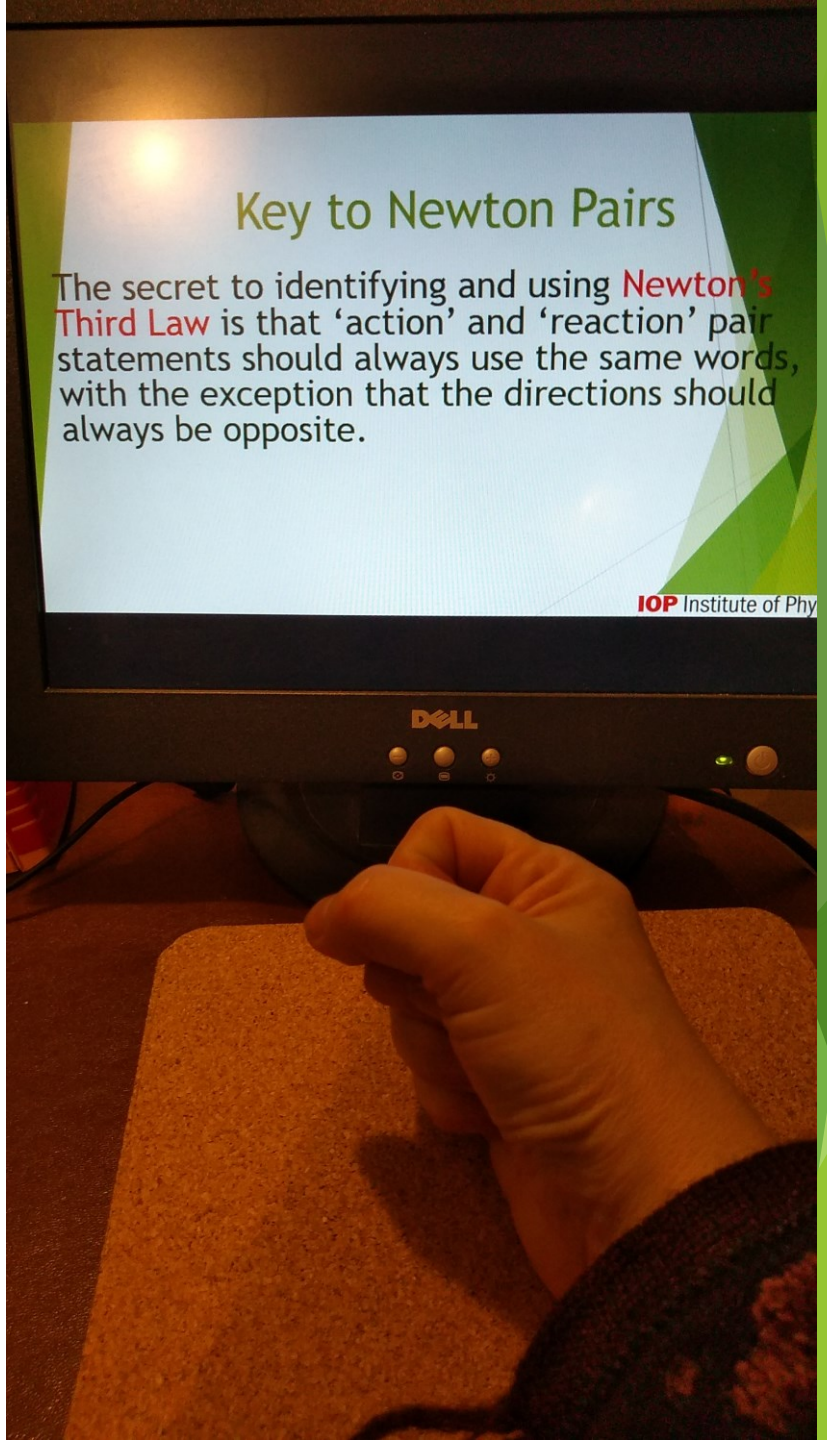
direction of force - downwards

Reaction:

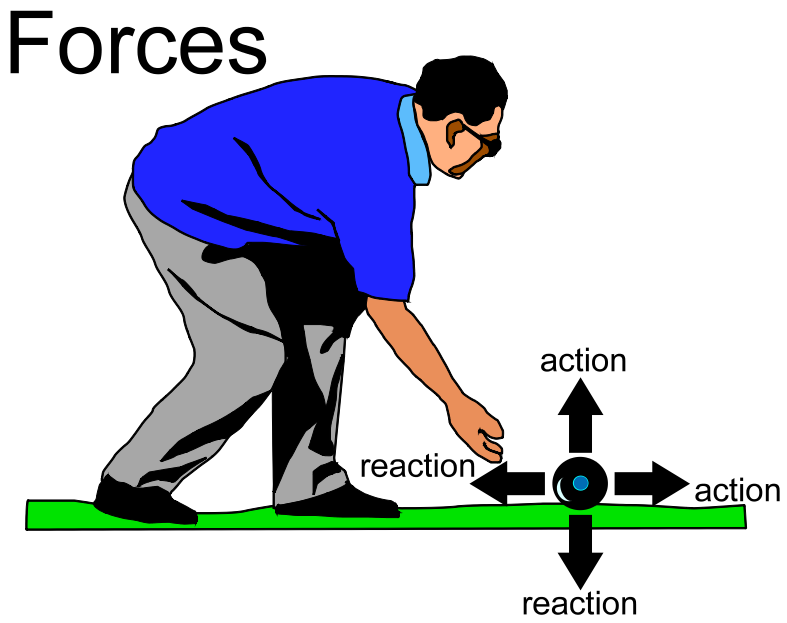
The gravitational pull of the mug upwards on the Earth

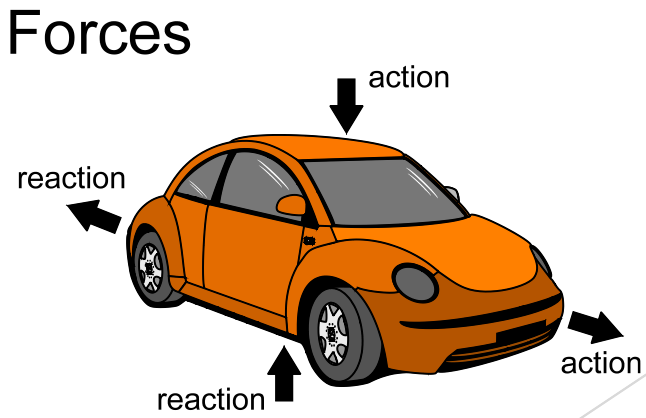
Key to Newton Pairs

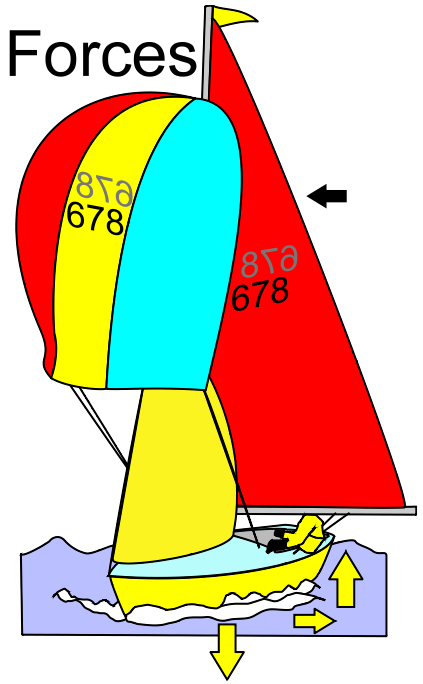
The fist applies a push on the desk, the desk applies an equal but opposite push on the fist.

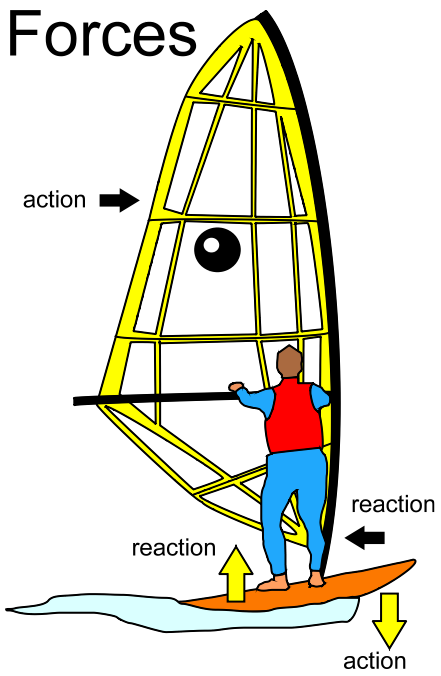


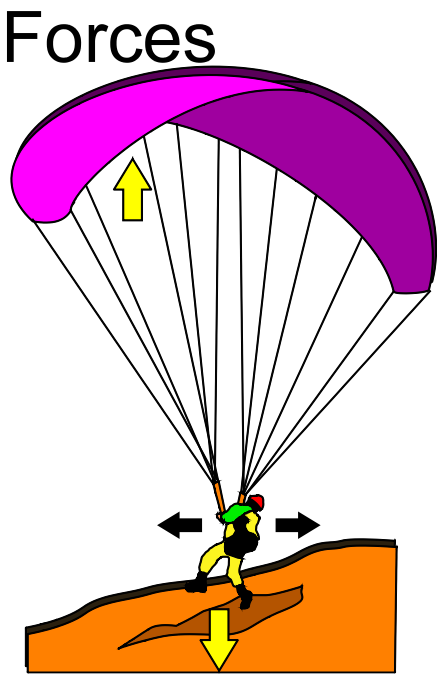
Identify the Newton Pairs









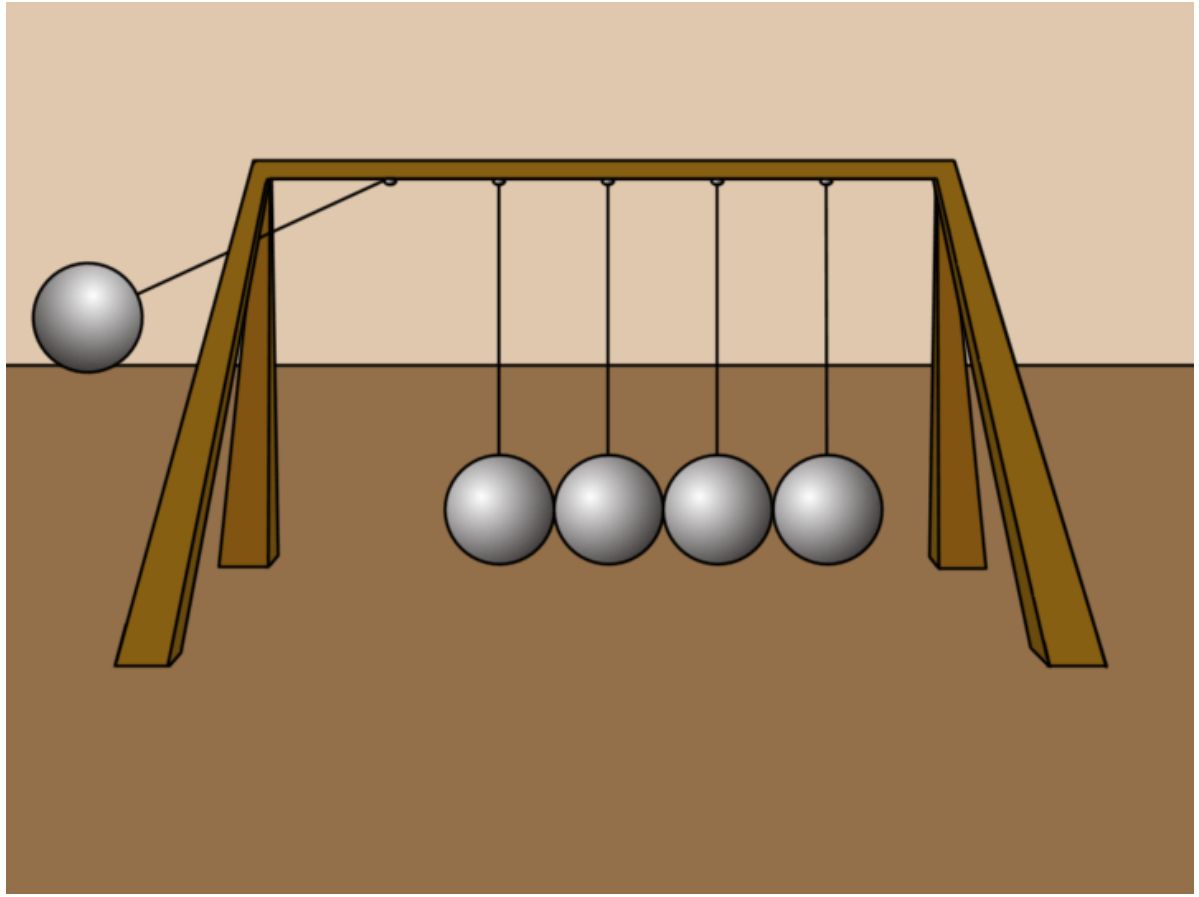


More Newton Pairs

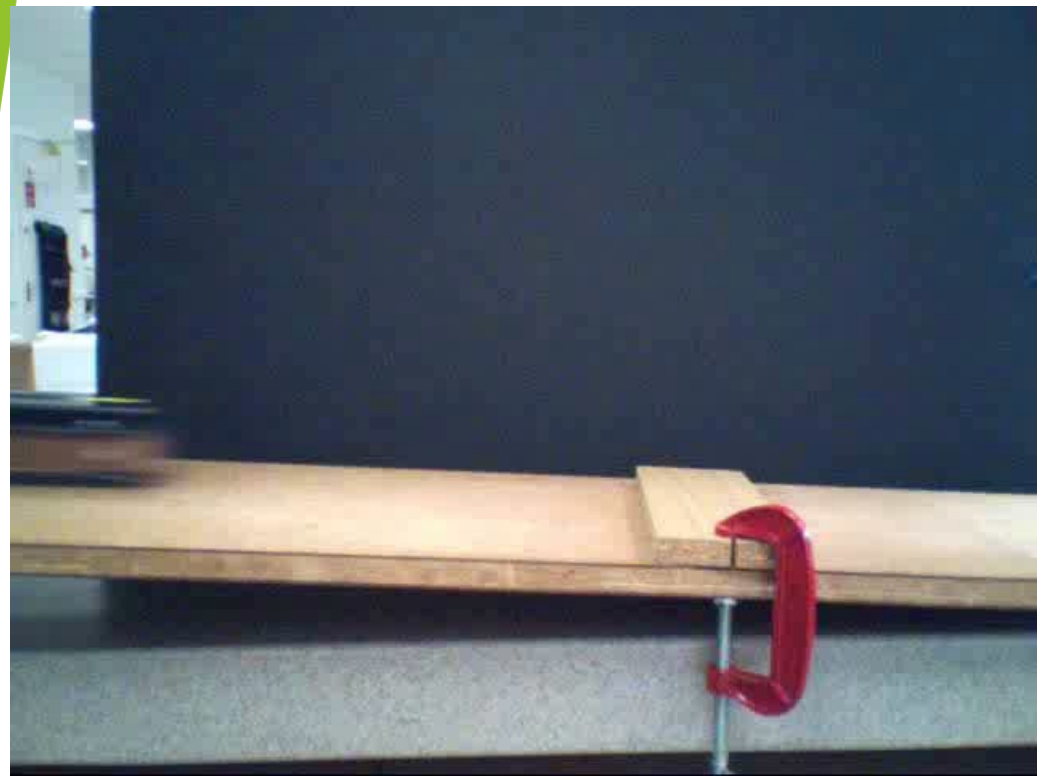
Newton's First Law

- A body will remain at rest or travel at a constant speed in a straight line, unless acted upon by an unbalanced force.

- A body will remain at rest or travel at constant velocity, unless acted upon by an unbalanced force.



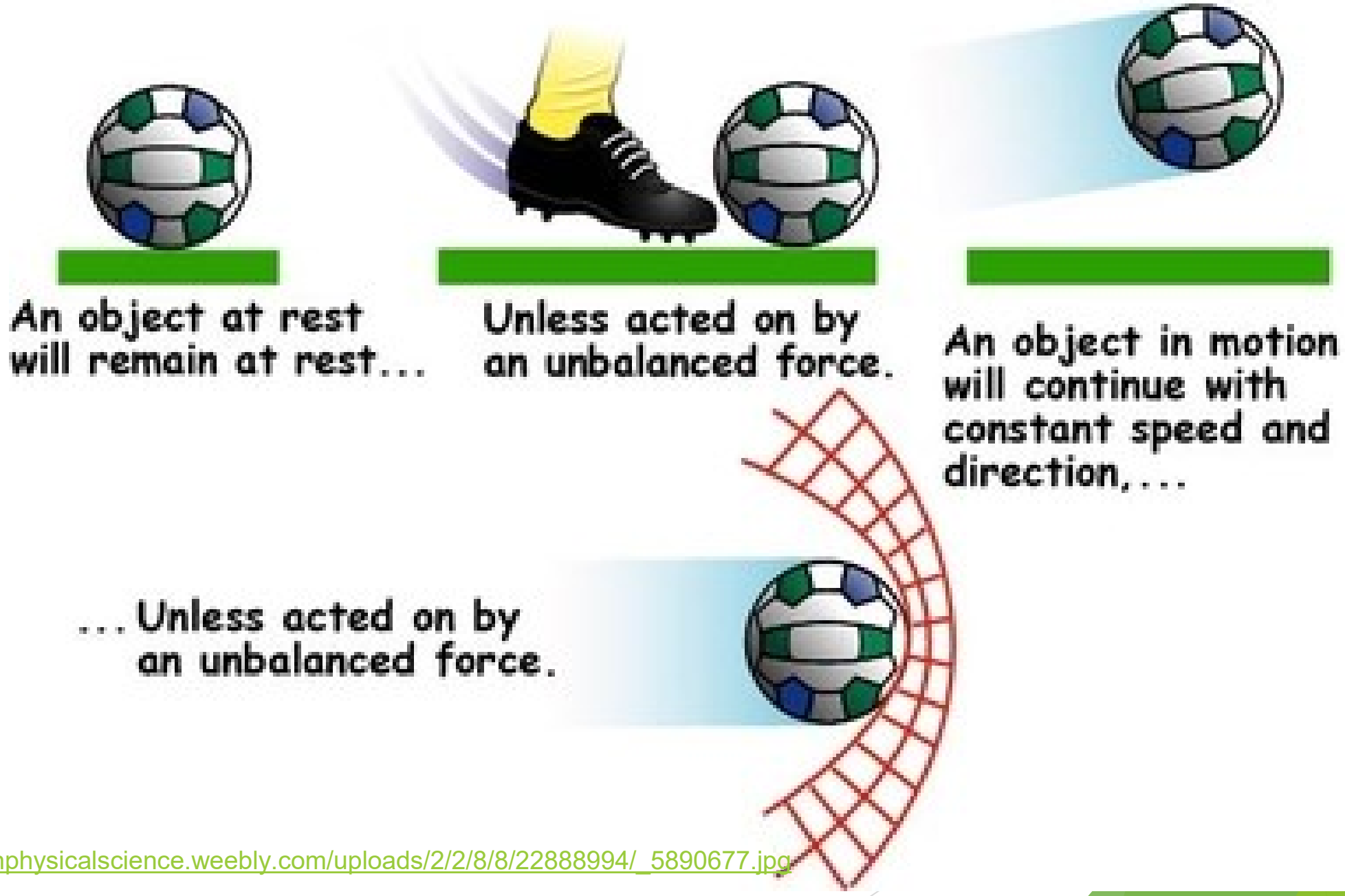
Newton's First Law



Zero unbalanced force does not cause an acceleration:

- **object continues with a constant speed in the same direction (constant velocity)**
- **remains at rest (special case of above)**

Newton's First Law of Motion



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N1L

An object will remain at rest or move at constant velocity unless acted on by an unbalanced force.

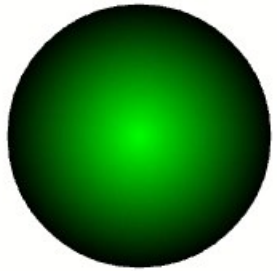
Newton's first law

The ball is initially stationary. No forces are being applied to it. A force of 1 N can be applied to the ball by clicking once on the up arrow on the left or right side of the screen. Try this and observe the motion of the ball.

Decrease Increase

Velocity = 0 m / s

Increase Decrease



Reset

When the forces on the ball are balanced, or there are no forces, the ball is either stationary or has a constant velocity.

Normally this is difficult to observe because of friction effects, which may not be obvious. In a frictionless situation, such as outer space, objects will behave like this ball.

Newton's 2nd Law

You need to understand the difference between speed/velocity and can explain acceleration before tackling Newton's Second Law. (so let's review!)

An unbalanced force causes an acceleration:

- **a change in the speed (or magnitude of velocity)**
- **a change in direction (of velocity)**

Newton's Second Law

This is best learned as a formula

$$\text{Force} = \text{mass} \times \text{acceleration}$$

$$F=ma$$

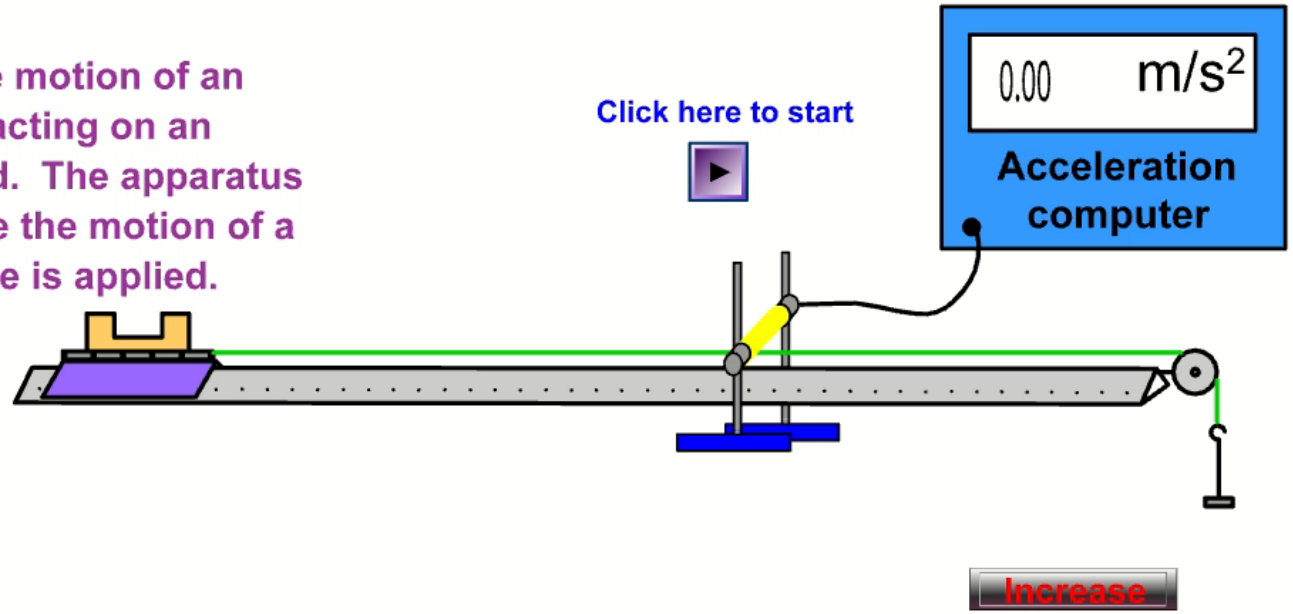
Where

Force in newtons, mass in kg and acceleration in ms^{-2}

Let’s Prove Newton’s Second Law

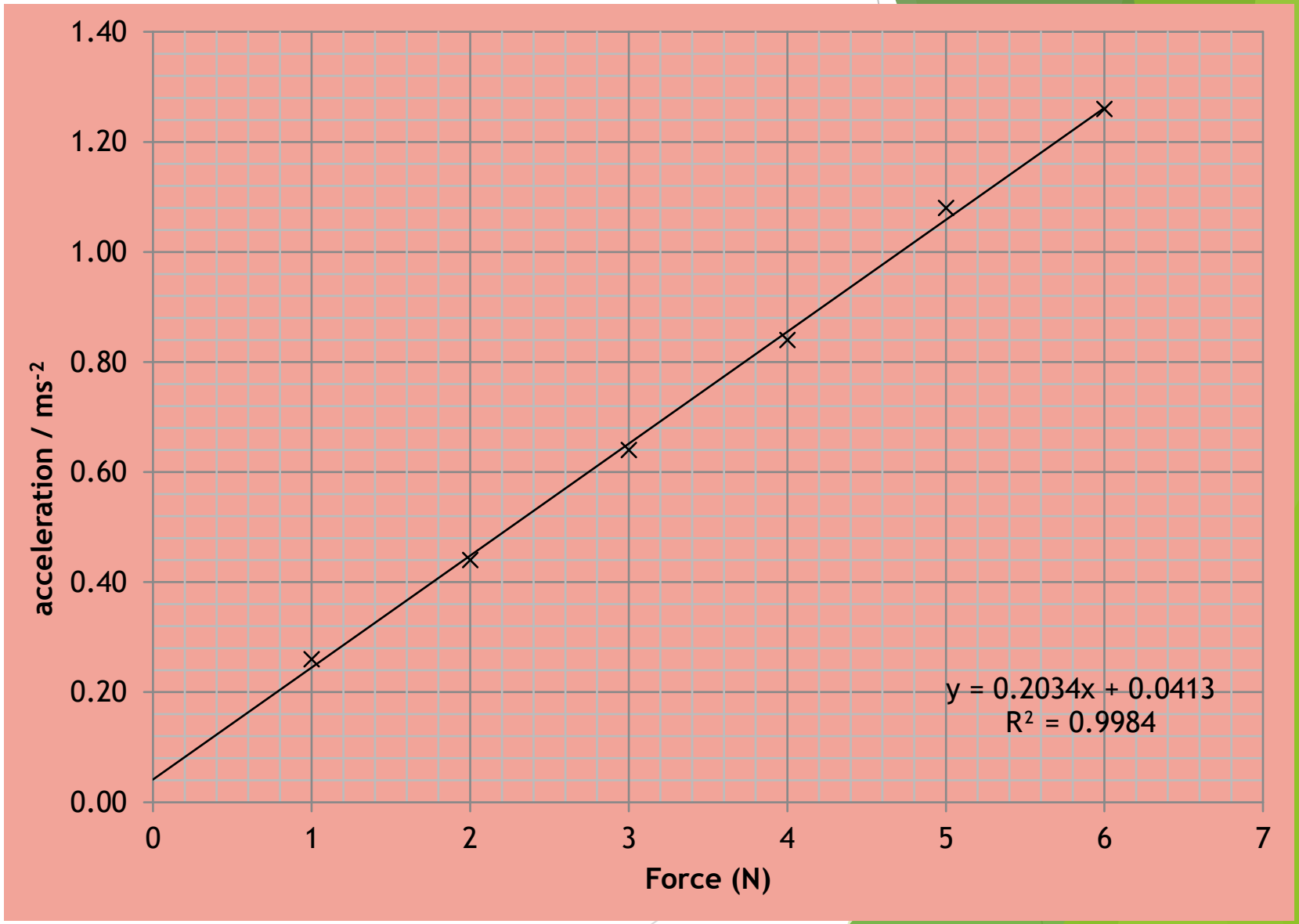
Acceleration and force

Newton's First Law describes the motion of an object when there are no forces acting on an object, or the forces are balanced. The apparatus shown can be used to investigate the motion of a vehicle when an unbalanced force is applied.



Summary of Results

	A	B	C
1	accelerating mass	Force	acceleration
2	(g)	(N)	(ms-2)
3	100	1	0.26
4	200	2	0.44
5	300	3	0.64
6	400	4	0.84
7	500	5	1.08
8	600	6	1.26

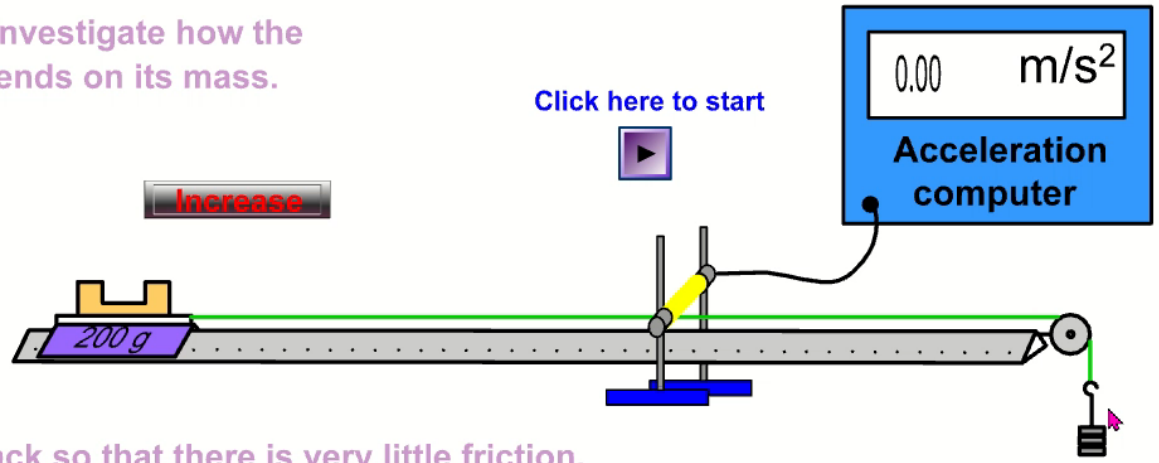


Can you suggest why it might not go through the origin?

Proving Newton's Second Law Part 2

Acceleration and mass

The apparatus can be used to investigate how the acceleration of the vehicle depends on its mass.

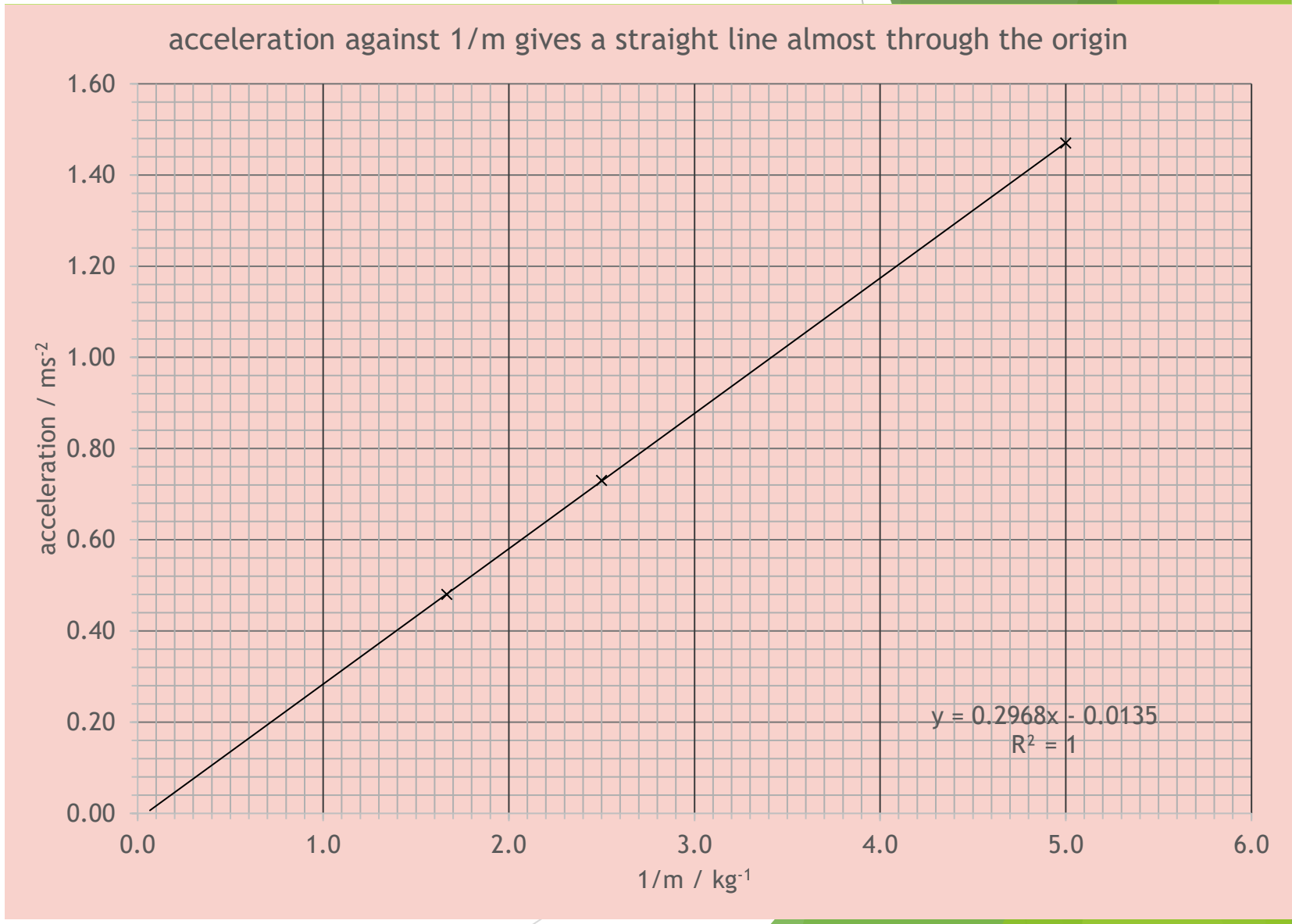


The vehicle is on a linear air track so that there is very little friction.
The unbalanced force acting on the vehicle is kept constant.
The mass of the vehicle can be varied by clicking on the Increase / Decrease buttons.

When the vehicle is released, an unbalanced force is applied and the acceleration is displayed. Use the apparatus to investigate how the acceleration depends on the mass of the vehicle when the unbalanced force remains constant.

Summary of Results

	A	B	C
1	mass	acceleration	1/m
2	(kg)	(ms^{-2})	(kg^{-1})
3	0.2	1.47	5.0
4	0.4	0.73	2.5
5	0.6	0.48	1.7



Newton's 2nd Law

Acceleration is proportional to force and not velocity.

$$a \propto F$$

and

$$a \propto {}^{1}/_{m}$$

and hence

$$a \propto {}^{F}/_{m}$$

giving

$$F_{un} = ma$$

Newton's 2nd and 1st Laws

Newton's 1st Law is just a special case of the 2nd Law.

When **F, the unbalanced force, is zero**. When that happens, the acceleration *a* must also be zero.

$$F_{un} = ma$$

An object of mass 20 kg

$$0\ N = 20\ kg \times acceleration$$

$$\frac{0}{20} = a = 0$$

0 acceleration is no change in velocity or constant velocity

Newton's Laws 3rd Law

Confusion between Newton's First and Third Laws:

Newton's First Law

Forces of equal magnitude and opposite direction acting on one object.

- balanced forces

Newton's Third Law

Forces of equal magnitude and opposite direction acting on two objects.

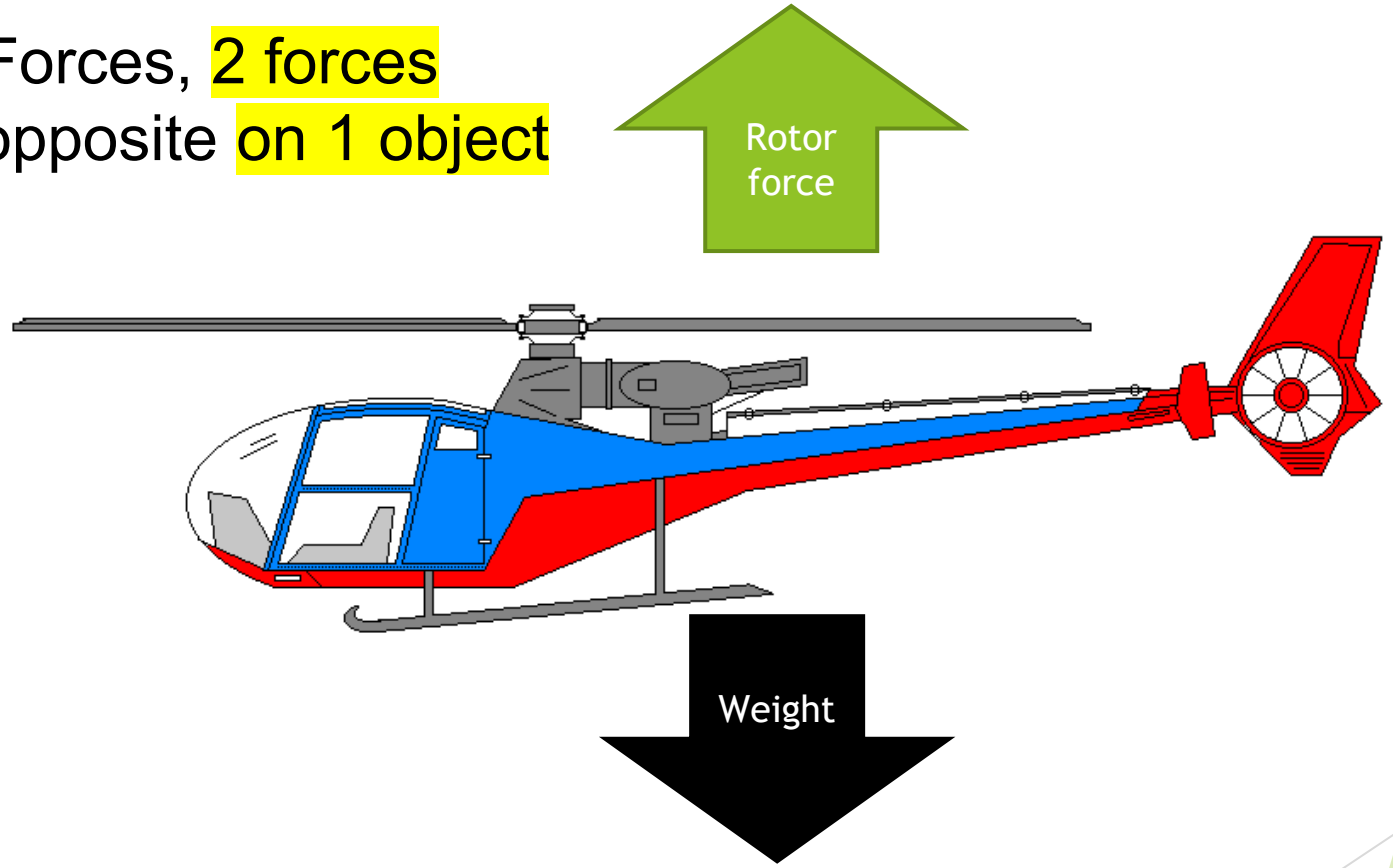
- action and reaction pair

Here's N1L and N3L

Rotor force

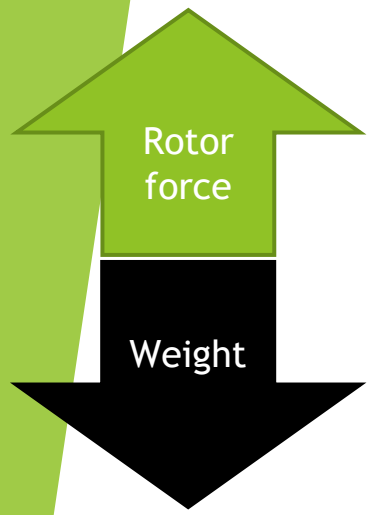
Weight

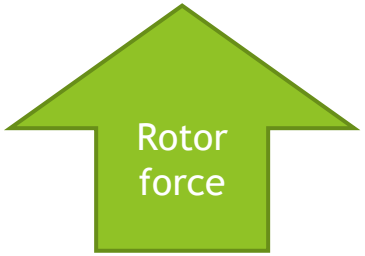
Balanced Forces, 2 forces equal but opposite on 1 object



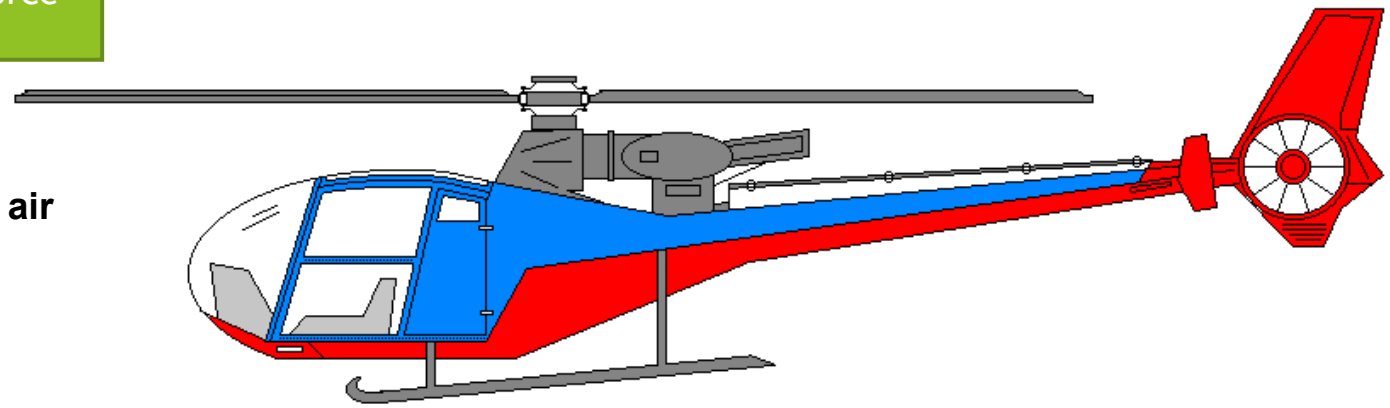
If the helicopter is hovering at constant height The helicopter main rotor generates a vertical force in opposition to the helicopter's weight .

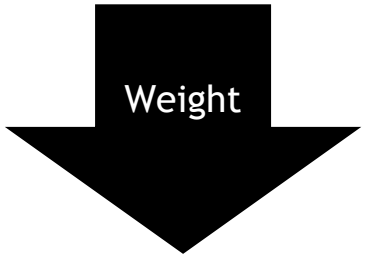
Here's N1L and N3L





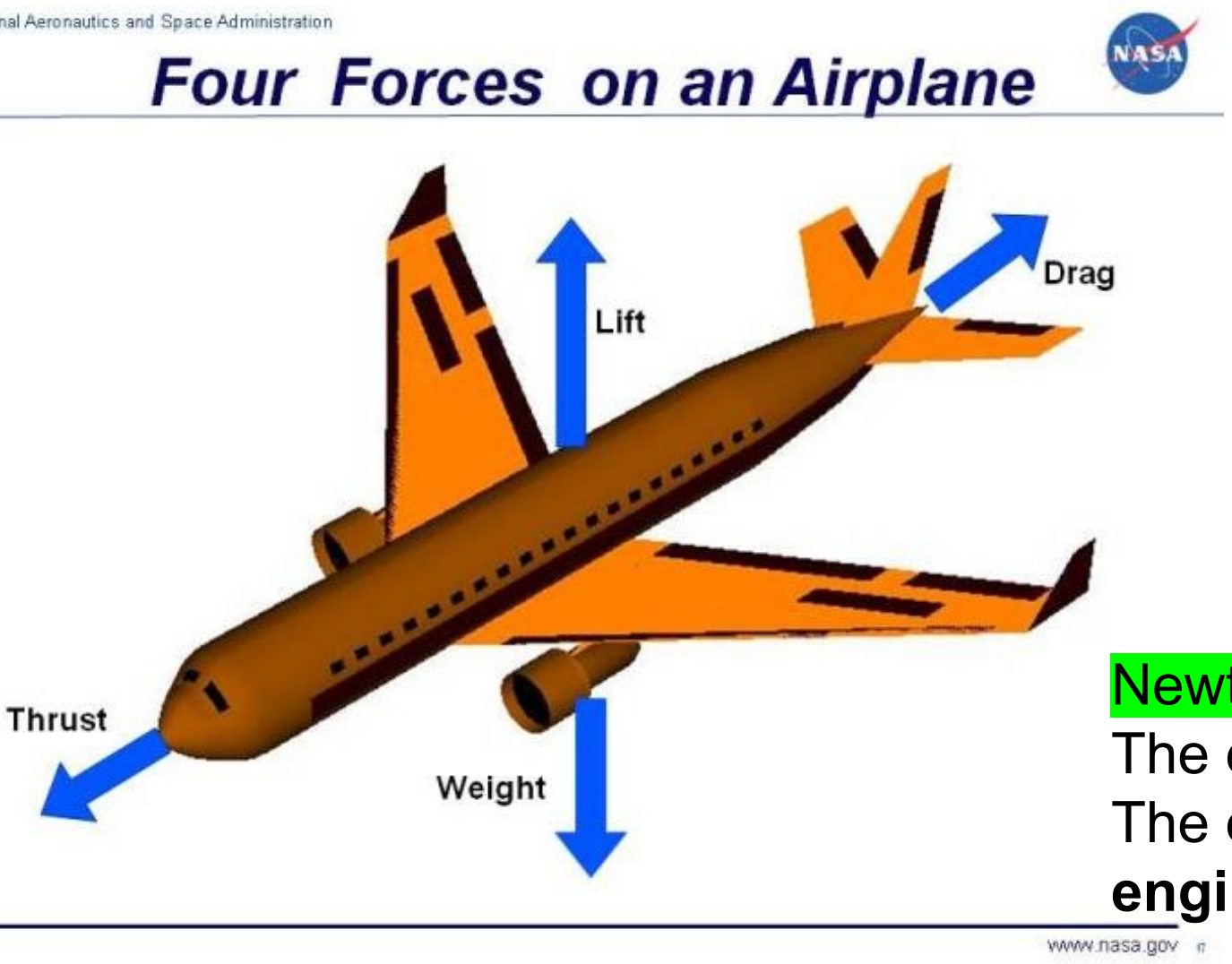
Newton Pair: (2 forces on 2 objects)
The **blade** pulls down the **air**
The **air** pulls up the **blade**





Newton Pair: (2 forces on 2 objects)
The **Earth** pulls down the **helicopter**
The **helicopter** pulls up the **Earth**

Now your turn: Remember balanced forces happens at constant height and constant velocity only! Newton Pairs all the time!



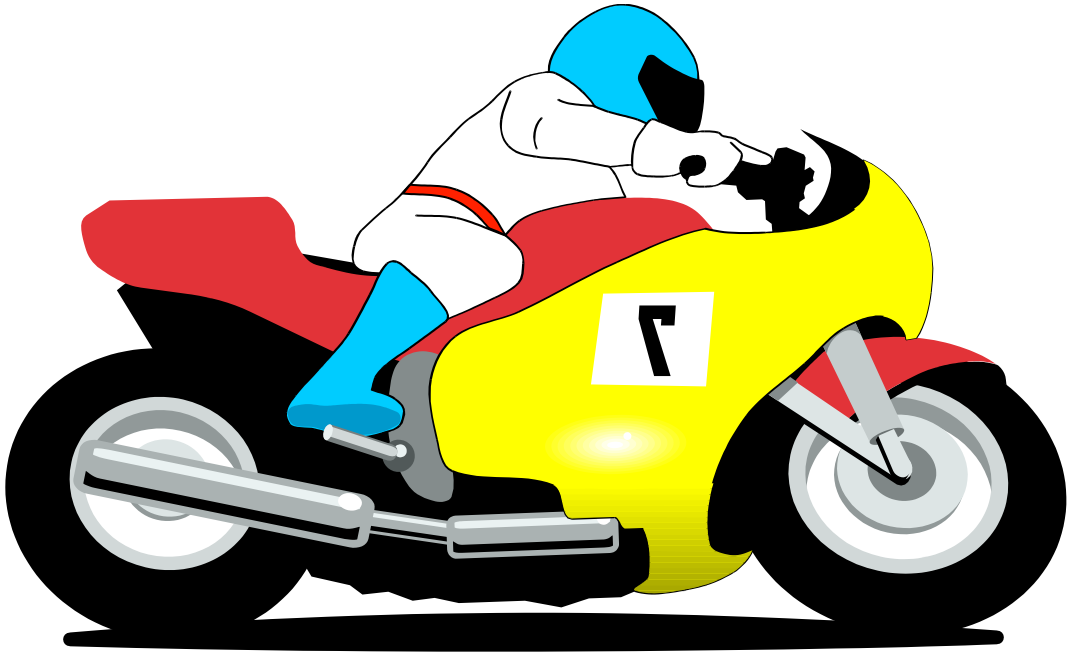
Newton Pair: (weight)
The **Earth** pulls down the **plane**
The **plane** pulls up the **Earth**

Newton Pair: (drag)
The **air** pushes back the **plane**
The **plane** pushes forward the **air**

Newton Pair: (Lift)
The **wing** pushes down on the **air**
The **air** pushes up on the **wing**

Newton Pair: (Thrust)
The **engine** pushes back the **exhaust gases**
The **exhaust gases** pushes forward the **engine**

Now you try all alone. A motorbike is travelling at constant velocity along a long straight road



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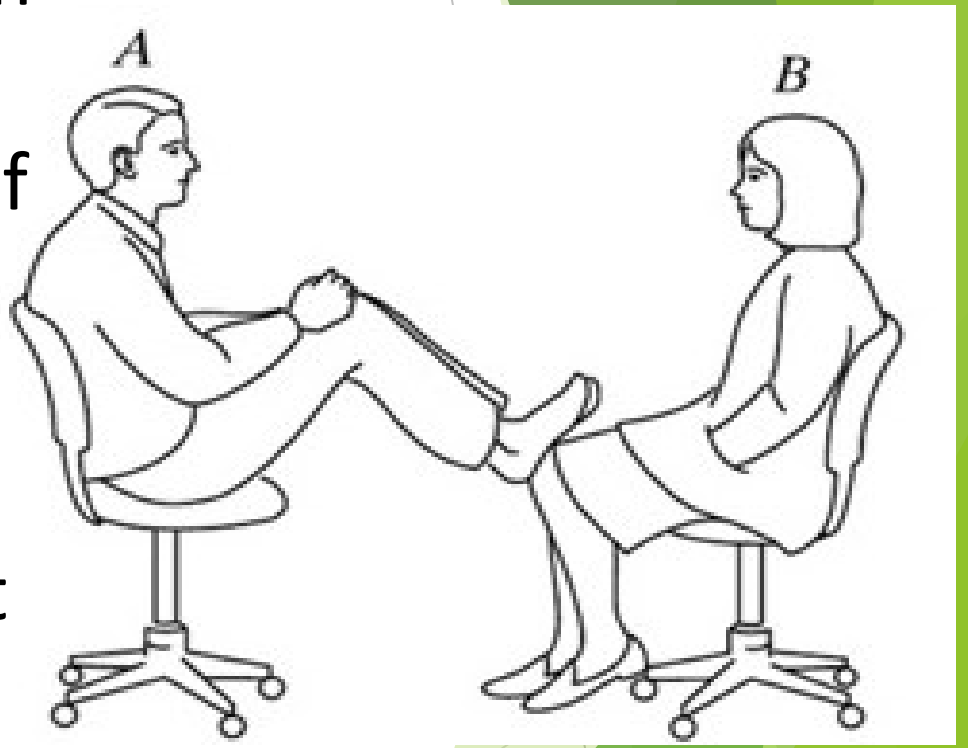
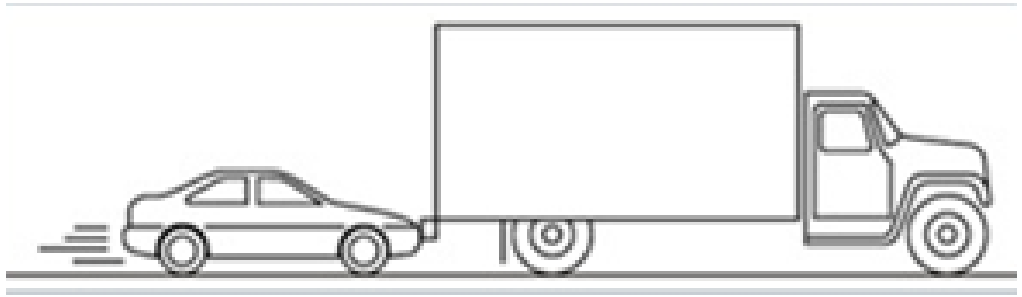


Diagnostic Questions

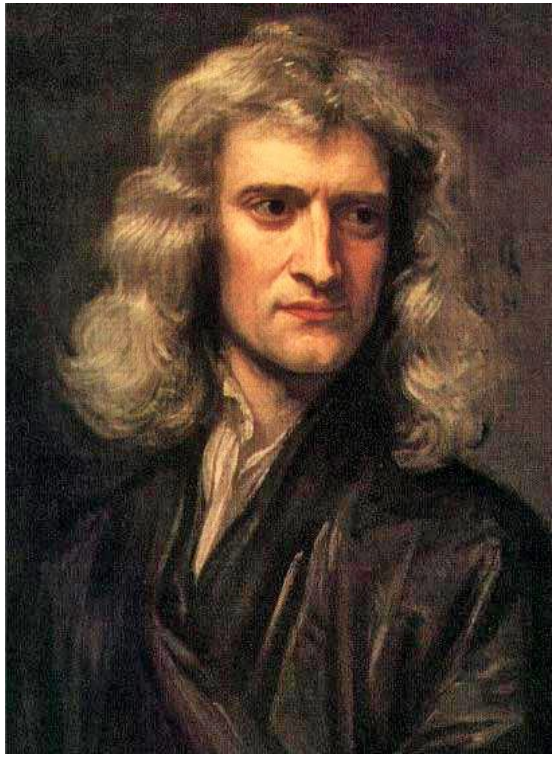
A large lorry breaks down and is pushed back into town by a small car, as shown.



Whilst the car, pushing the lorry, is speeding up, how does the force that the car exerts on the lorry compare with the force that the lorry exerts on the car?

After the car reaches the constant speed, at which the driver wished to push the lorry, how does the force that the car exerts on the lorry compare with the force that the lorry exerts on the car?

Reminder: Can you quote all 3 of Newton's 3 Laws of Motion



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Newton's First Law states:

A body will remain at rest or travel at a constant speed in a straight line, unless acted upon by an unbalanced force.

A body will remain at rest or travel at constant velocity, unless acted upon by an unbalanced force.

Newton's Second Law we normally write as a formula:

$$F_{un} = ma$$

$$\text{Unbalanced Force} = \text{mass} \times \text{gravitational field strength}$$

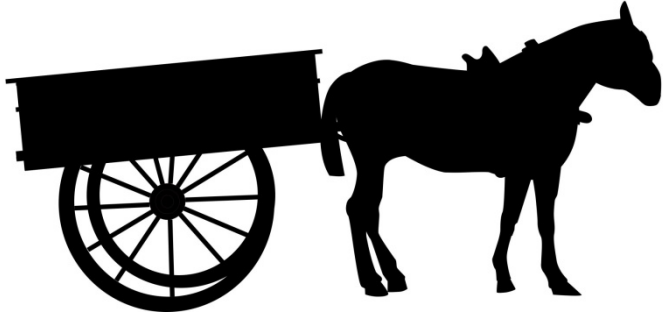
$$(\text{Newtons}) = (\text{Kilogram}) \times (\text{Newtons per kilogram})$$

Newton's Third Law states:

For every action there is an equal but opposite reaction.

or

If A exerts a force on B, B exerts an equal but opposite force on A.



Summary

“A horse is harnessed to a cart.

When the horse tries to pull the cart, the horse exerts a force on the cart. By Newton's third law the cart then exerts an equal and opposite force on the horse. Since the two forces are equal and opposite, they must add to zero, so Newton's second law tells us that the acceleration of the system must be zero. If the cart is at rest, and doesn't accelerate, it must remain at rest, and therefore no matter how hard the horse pulls, it can never move the cart.”

Use your knowledge of physics to comment on this statement.