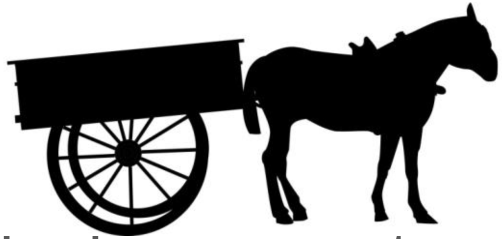
An Open-ended Question



“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.

Forces and Newton's laws: common misconceptions and how to deal with them

What are the main misconceptions pupils have with forces

Provide a few strategies to counter these misconceptions

IOP Scotland Teacher Network

Can you use the things in the bowl to demonstrate the following Forces

Contact

Grip
Slip
Drag
Buoyancy Force/upthrust
Support /compression/ normal contact
Tension

Non-Contact

Gravitational force
Magnetic Force
Electric Force

JH https://spark.iop.org/forces-cpd-videos#everydayforces Check your answers here!

IOP Institute of Physics
Scotland

Starting out

One of the first issues pupils can encounter when studying forces is identifying “on a object”.

Starting out

WHAT IS A FORCE?

A force is something that can change an object's shape or how it is moving (or not moving). A force can have any size and acts in a particular direction. Forces are something to think about when analyzing things such as, pressure, turning effect, momentum, & acceleration

Force Walk / Forces in context or action

What	Force	Effect	Comment
Flushing the loo	Push on handle		

Forces Specs

Forces cannot be seen but their effects can

- View forces through the special Force Specs!

by the legendary Bob Kibble

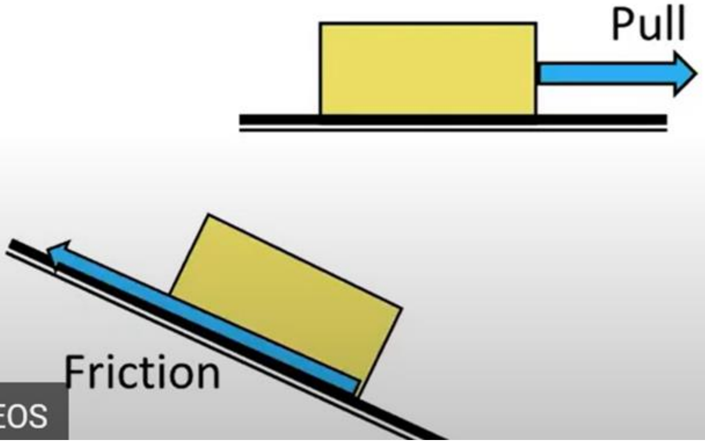
Force Arrows

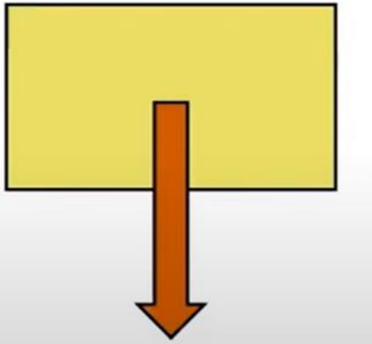
Contact forces

- Generally these act at the point of application or where surfaces meet.

Non-contact forces

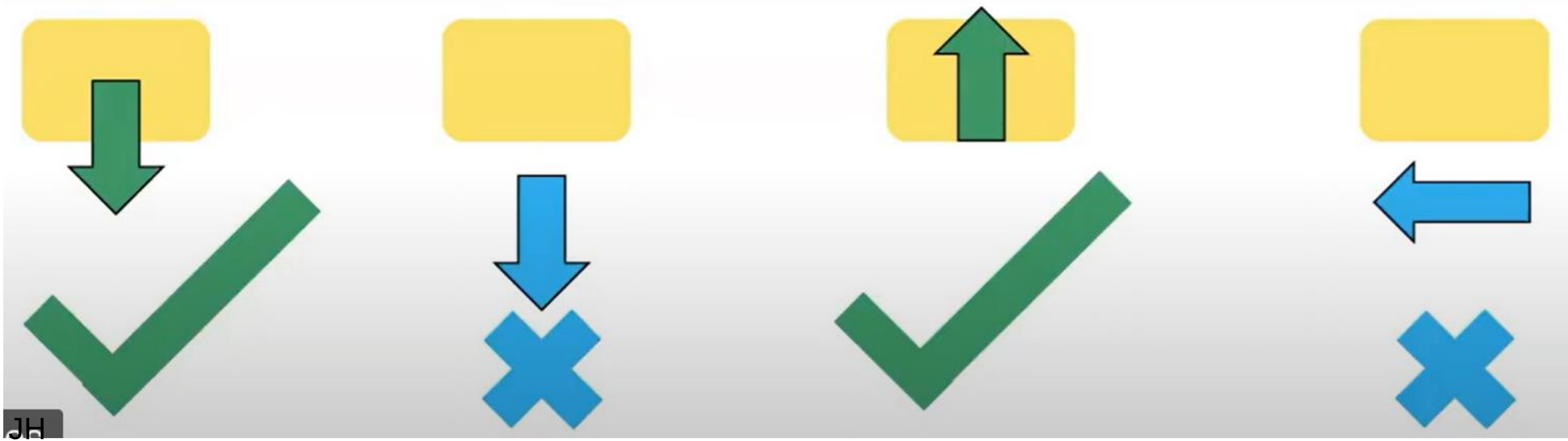
- Generally these act through the centre of mass.





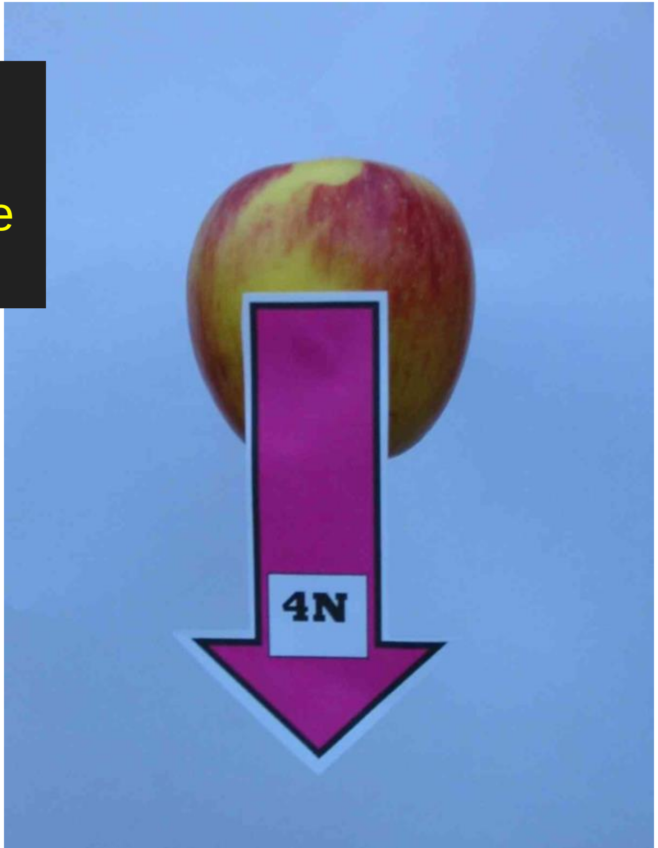
Force Arrows

- Forces always act on something so the tail of the arrow must always be anchored on something



Forces Specs

If forces came ready-labelled science might be easier.



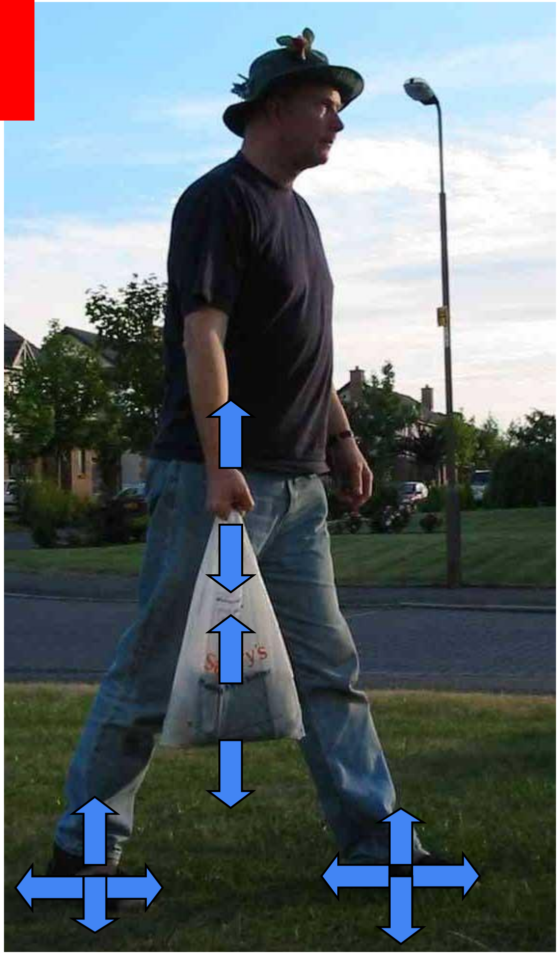
1.1

Forces specs

A shopper carries his shopping home.

How does this situation appear through forces spectacles?

Forces Specs



There are forces acting everywhere. Here are just a few of them.

1.3

Forces Specs

Let’s consider the forces acting on the hand.

Can you identify the forces which act on the hand?

13

1.4

Forces Specs

A support force from the arm muscles acts on the hand

A force (the weight of the bag) acts on the hand

1.5

Forces Specs

Now consider the forces acting on the shopping.

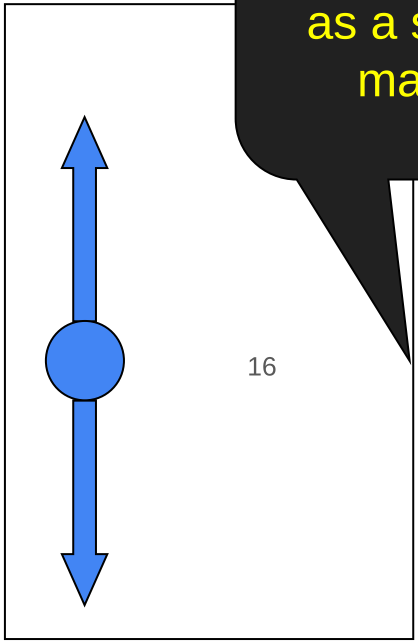
15

1.6

Forces Specs

The stretched plastic bag supports the shopping with an upward force.

The Force of Gravity acts on the shopping with a downward force.



The simplest model shows the shopping as a single mass.

Forces representations- don’t try reading it, watch the videos!

- draw on learners conception of their own actions and relate these to force
- explore and expose children's ideas of forces
- draw out children's everyday ideas about motion and the forces required
- introduce children to a new way of seeing – with forces
- convince children that inanimate things can push, just like they can
- developed the idea that a mechanism underpins the interaction that is replaced by force
- convince children that air can exert forces
- draw on children's own experience of action at the distance, probably through experiences with magnets
- draw on children's experiences, some of which will be vicarious, to establish the reality of gravity in space
- explore something of the mystery of action at a distance

Avoid these

- drawing arrows next two objects, or near objects, when you intend the force be acting on the object
- don't act as if the placing of arrows is obvious and open to a simple inspection
- don't refer to forces cancelling out
- avoid using complex objects on which forces might be acting (with internally moving parts – bicycles, cars, people.)
- using friction as a blanket term, without reference to its physical origins
- treating contact forces exerted by inanimate objects as obvious
- stating, without sharing the appropriate experiences that give the statements meaning
- treating action at a distance as obviously acceptable
- acting as if the similarities between the three non-contact forces always have been obvious
- over-emphasising the similarities
- conflating the terminology and representations for the three different forces

JH

The 3, 2, 1 of Newton's Laws

FCI is a tool for highlighting misconceptions pupils have students struggle with.

There are a number of version on Physport. But it must be kept secure and not referring to as FCI with students.

PhysPort

Supporting physics teaching with research-based resources

The 3, 2, 1 of Newton's Laws

Other sources of diagnostic questions:

University of York has produced their EPSE and BEST resources.

SparkIOP has a selection of these available too.

BEST™
Best Evidence Science Teaching

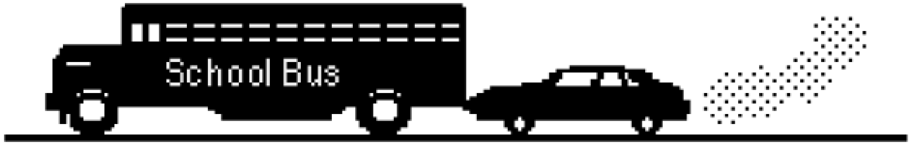
UNIVERSITY OF YORK
SCIENCE EDUCATION GROUP

Salters' Institute

IOP Institute of Physics

The 3, 2, 1 of Newton's Laws

A school bus breaks down, and a car pushes it back to the garage.



15. When the car begins to push the school bus, which applies the **larger** force on the other?

(A) Both apply forces of the same strength on each other.
(B) The **bus**, because it's heavier.
(C) The **car**. The bus applies a force, too.
(D) The **car**. The bus can't apply *any* force to the car, because its engine isn't running.
(E) Neither applies *any* force on the other. The bus is pushed forward because it's in the car's way.

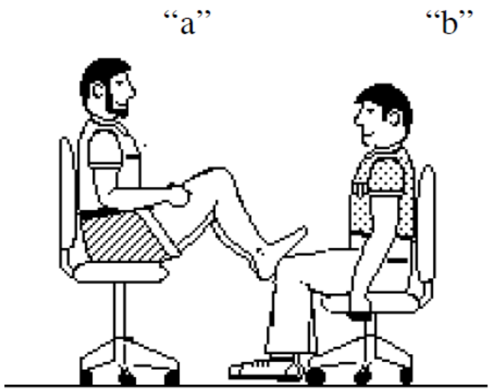
- What is it assessing?
- What are likely to be the common misconceptions?

The 3, 2, 1 of Newton's Laws

28. Student **a** weighs 160 pounds and student **b** weighs 120 pounds. They sit in identical office chairs facing each other. The chairs have wheels.

Student **a** puts his feet on the knees of student **b** and suddenly pushes outward with his feet, causing both chairs to move.

During the push and while the students are still touching each other, which student applies a **larger** force on the other?



(A) Neither student applies *any* force on the other; they move because they're in each other's way.

(B) **a** applies a force on **b**, but **b** doesn't apply *any* force on **a**.

(C) **b** applies the larger force.

(D) **a** applies the larger force. **b** applies a smaller force.

(E) Each student applies the same strength force on the other, but they react differently.

- What is it assessing?
- What are likely to be the common misconceptions?

MB

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The 3, 2, 1 of Newton’s Laws

Newton’s 3rd Law!

“Learners generally appear to think of a force as a property of a single object rather than as a feature of an interaction”

Driver R. et al. (1994) *Making Sense of Secondary Science: research into children’s ideas*. Routledge (pg149)

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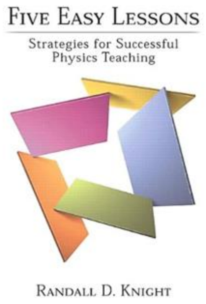
The 3, 2, 1 of Newton’s Laws

“Specific difficulties students have with Newton’s third law and with interacting situations are:

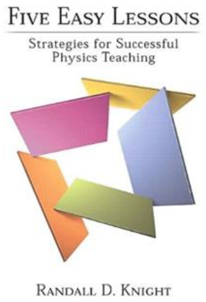
- Students don’t believe Newton’s third law. It’s too contradictory to common sense.
- Students have difficulty isolating systems from each other and from the environment.
- Students confuse equal force with equal acceleration.”



Knight R. (2004) *Five Easy Lesson: Strategies for Successful Physics Teaching*. Addison Wesley (pg98).

The 3, 2, 1 of Newton's Laws

- Students have difficulty identifying action/reaction force pairs:
  - They match two forces on the same object.
  - They attach forces to the wrong objects.
  - They don't believe that long range forces (e.g. gravity) have reaction forces.



Knight R. (2004) *Five Easy Lesson: Strategies for Successful Physics Teaching*. Addison Wesley (pg98).

The 3, 2, 1 of Newton's Laws

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.

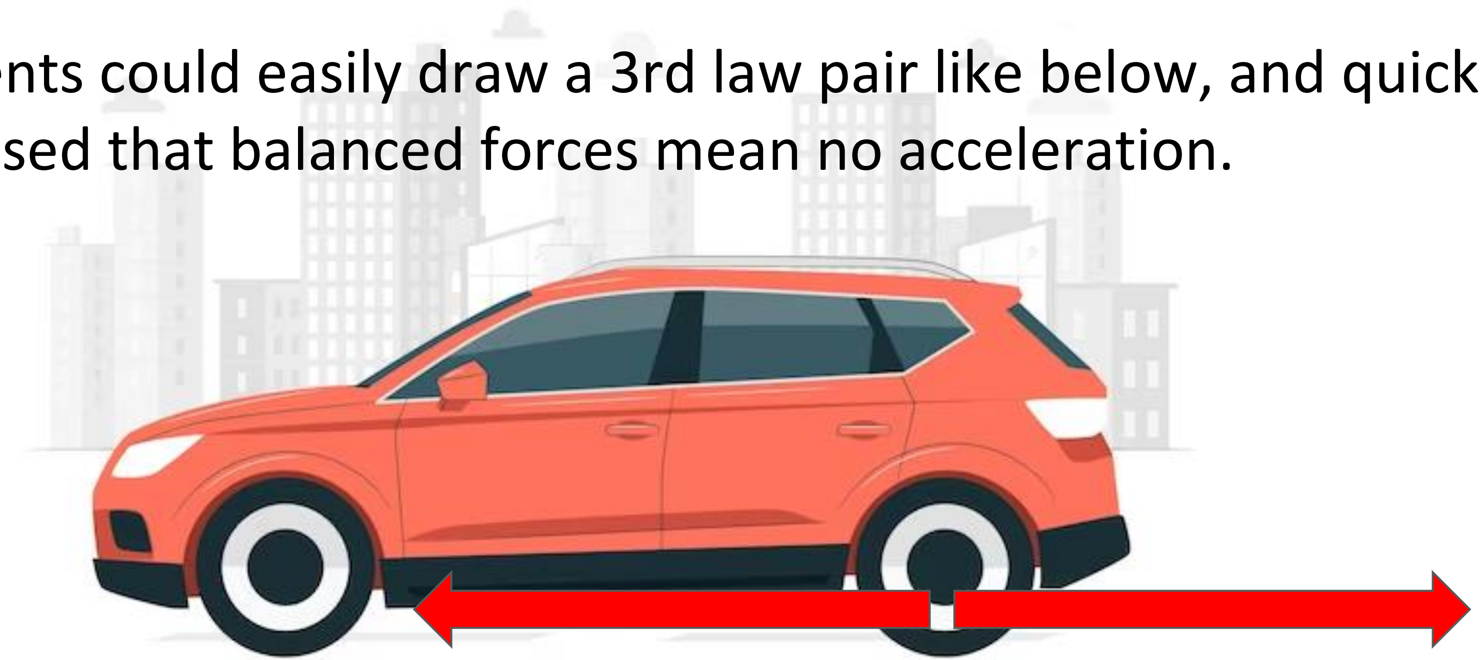
- action and reaction pair

The 3, 2, 1 of Newton's Laws

By teaching action-reaction pairs first we can guide pupils away from thinking of forces in terms of an object and as the interactions.

The 3, 2, 1 of Newton's Laws

Students could easily draw a 3rd law pair like below, and quickly be confused that balanced forces mean no acceleration.



The 3, 2, 1 of Newton's Laws

By colour coding our arrows we can help pupils see the forces are acting on different objects!

The 3, 2, 1 of Newton's Laws

To teach Newton's Third Law effectively it is important to use language carefully and consistently.

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.

The 3, 2, 1 of Newton's Laws

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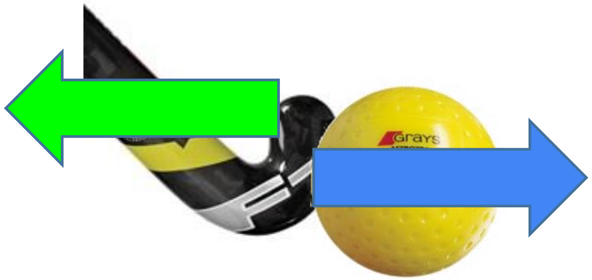
- the **direction** in which the 'action' force acts.

The 3, 2, 1 of Newton's Laws

Gender neutral sport



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

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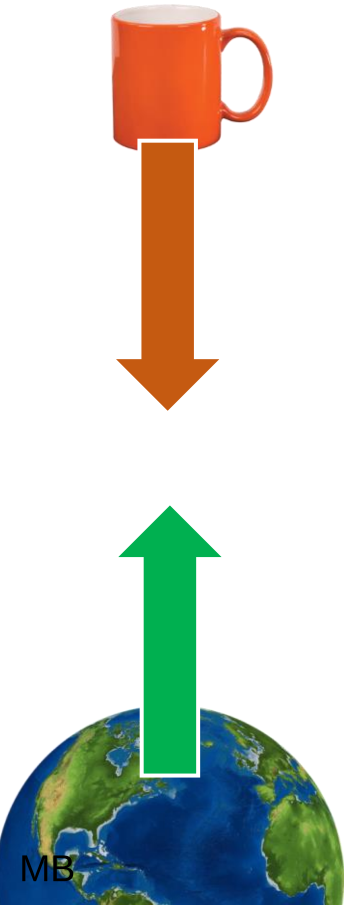
The 3, 2, 1 of Newton's Laws



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

The 3, 2, 1 of Newton’s Laws

The secret to identifying and using Newton’s Third Law is that ‘action’ and ‘reaction’ pair statements should always use the same words, with the exception that the directions should always be opposite.

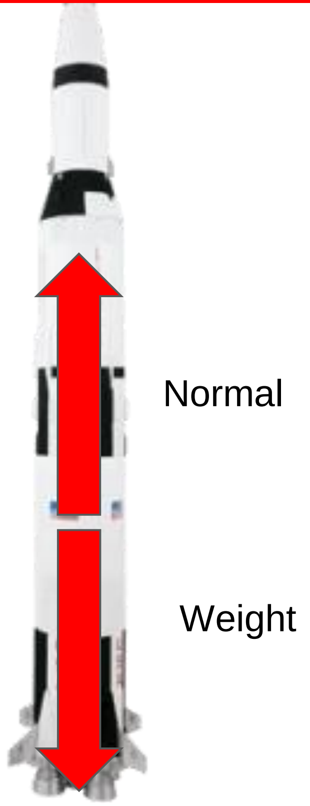
“Use the same words, just not necessarily in the same order”

The 3, 2, 1 of Newton’s Laws

A student says: **“This is an example of Newton’s third law”**.

Explain why they are wrong.

The situation does not show a third law pair, as the forces are acting on the same object and the forces are not the same type.



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The 3, 2, 1 of Newton's Laws

17. While you're slowly lifting a book straight upwards at a constant speed, the upward force of your hand on the book is:
    (A) greater than the downward force of gravity on the book.
    (B) equal to the downward force of gravity on the book.
    (C) smaller than the downward force of gravity on the book.
    (D) equal to the sum of the book's weight *and* the force of gravity on the book.
    (E) the *only* force on the book.

- What is it assessing?
- What are likely to be the common misconceptions?

The 3, 2, 1 of Newton's Laws

25. You push a large empty box slowly with a constant horizontal force, so that it moves down your school hallway at a constant speed. The force that you apply is:

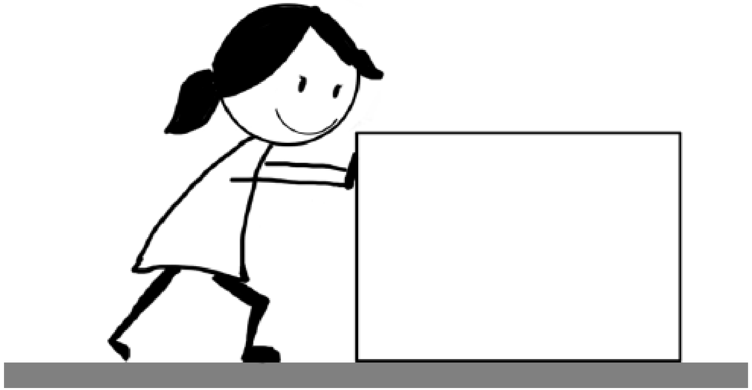
(A) the same as the weight of the box.

(B) greater than the weight of the box.

(C) the same as the total friction forces that resist the box's motion.

(D) greater than the total friction forces that resist the box's motion.

(E) the only horizontal force on the box. The friction forces aren't "real".



- What is it assessing?
- What are likely to be the common misconceptions?

MB

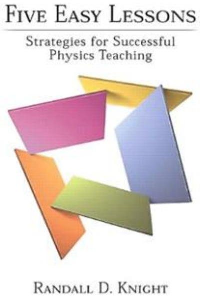
The 3, 2, 1 of Newton’s Laws

Newton’s 2nd!

The 3, 2, 1 of Newton's Laws

What the research says:

"The prevailing student belief is that motion requires a [resultant] force"



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The 3, 2, 1 of Newton's Laws

Why do pupil hold this misconceptions?

The 3, 2, 1 of Newton's Laws

Observations:

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

Conclusions:

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

The 3, 2, 1 of Newton's Laws

What the research says:

"The student version of the laws of motion is:

- If there is no force on an object, the object is at rest or will *immediately* come to rest.
- The converse is *not* true. An object at rest does *not* automatically imply no net force.
- Motion requires a force or, alternatively, force causes motion.
- In general, force is proportional to velocity"

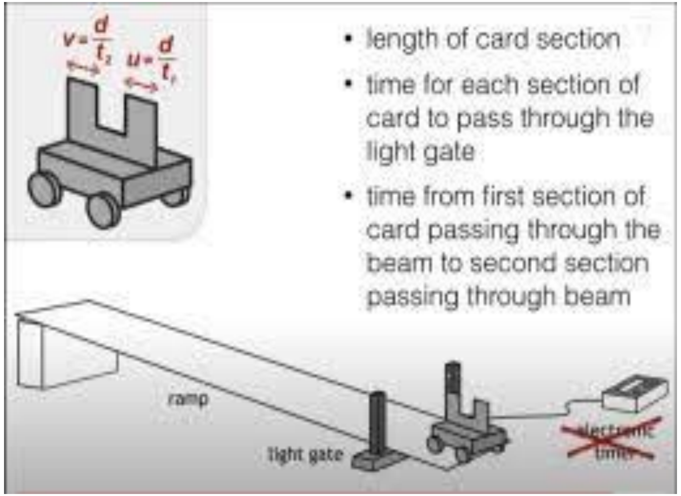
Knight R. (2004) *Five Easy Lesson: Strategies for Successful Physics Teaching*. Addison Wesley.

The 3, 2, 1 of Newton's Laws

Students need to have a **good understanding of the difference between speed/velocity and acceleration** before tackling Newton's Second Law.

Get pupils to investigation the acceleration from different heights, showing acceleration remains constant. Against many pupil predictions.

Giving pupil a firm understanding between the different of acceleration and velocity.



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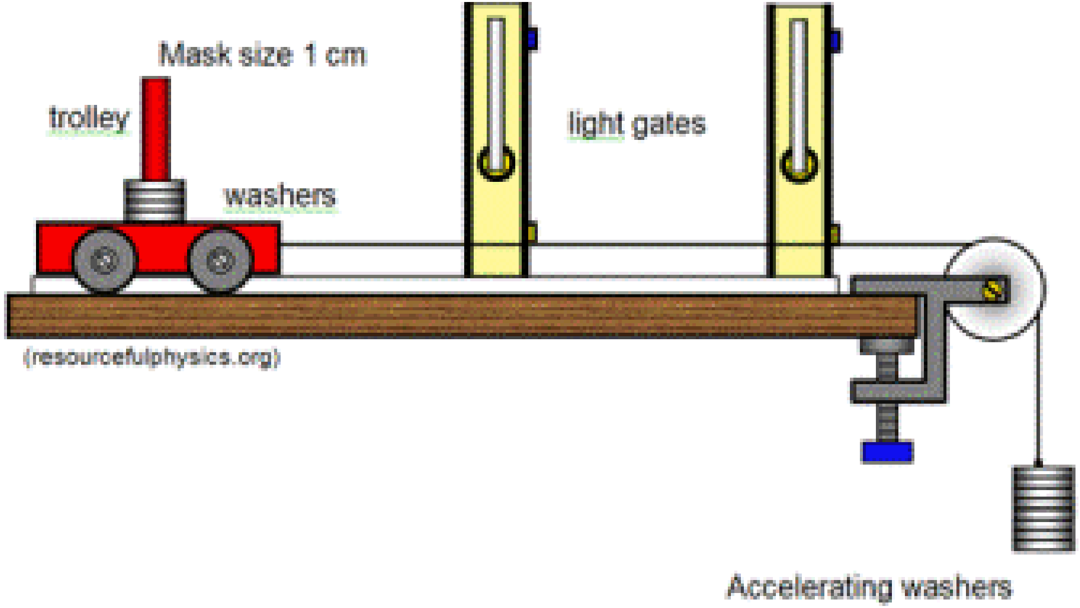
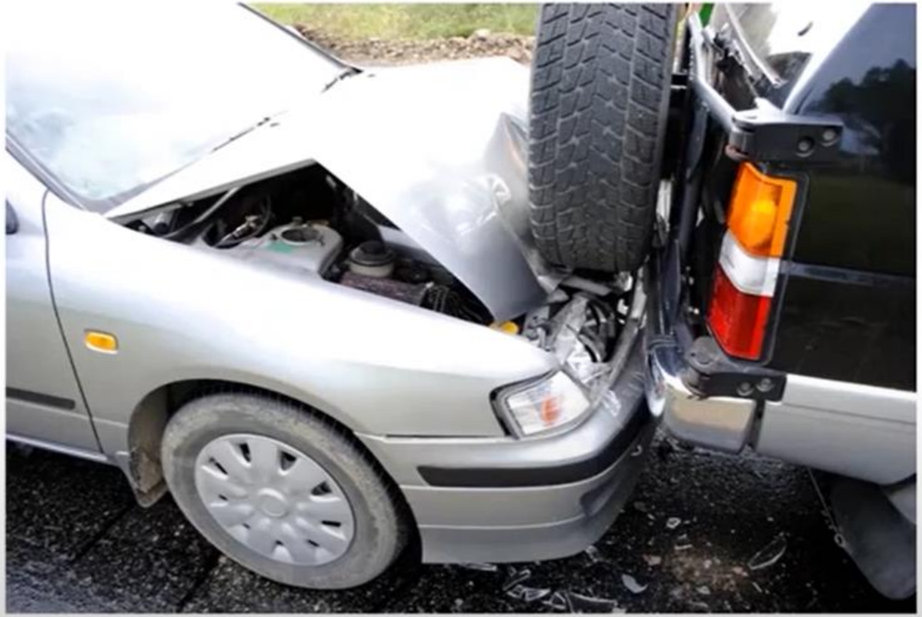
The 3, 2, 1 of Newton’s Laws

Prove experimentally that force is proportional to acceleration not velocity.



The 3, 2, 1 of Newton’s Laws



JH

The 3, 2, 1 of Newton's Laws

1. Two oranges accidentally fall out of an upstairs window of a house. One weighs twice as much as the other. The time it takes the **heavier** orange to hit the ground is:

   (A) about half as long as for the lighter orange.

   (B) about twice as long as for the lighter one.

   (C) about the same time for both oranges.

   (D) much less time, but not necessarily half as long.

   (E) much more time, but not necessarily twice as long

- What is it assessing?
- What are likely to be the common misconceptions?

The 3, 2, 1 of Newton’s Laws

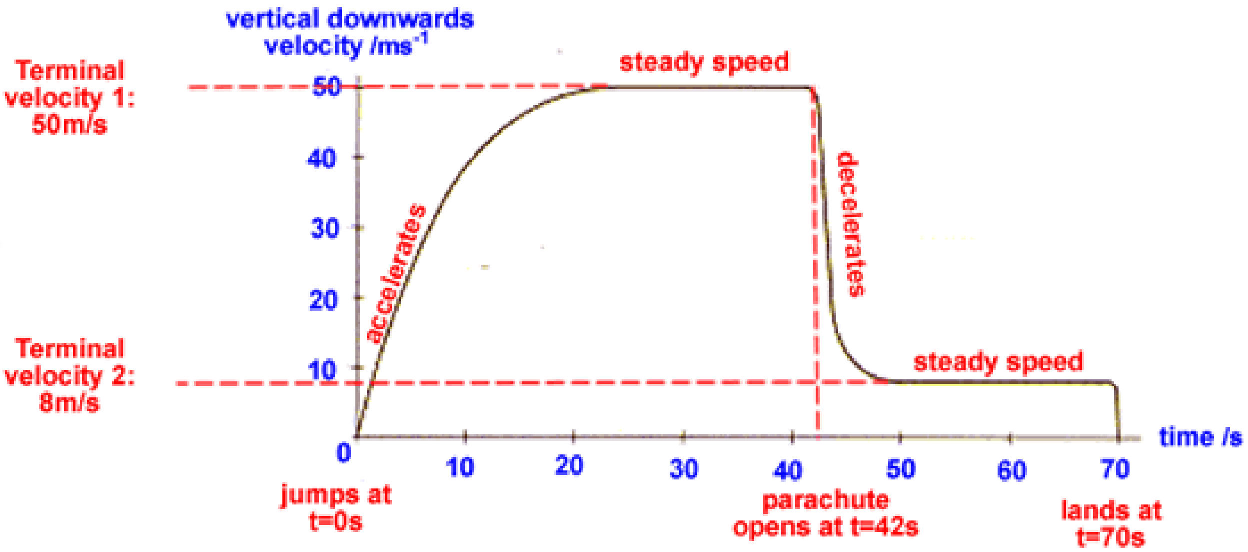
Which will hits the ground first?

The 3, 2, 1 of Newton's Laws

Which ball hits the ground first?

The 3, 2, 1 of Newton’s Laws

Studying the forces on a parachuter.



https://www.cyberphysics.co.uk/topics/forces/terminal_velocity.htm

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The 3, 2, 1 of Newton's Laws

'Newton's First Law is just a special case of the Second Law.

$$F_{un}=ma$$

Therefore no resultant force means no acceleration.

The 3, 2, 1 of Newton's Laws

No acceleration means an object at rest stays at rest, or a moving object stays moving.

The 3, 2, 1 of Newton's Laws

Balanced forces and still moving!

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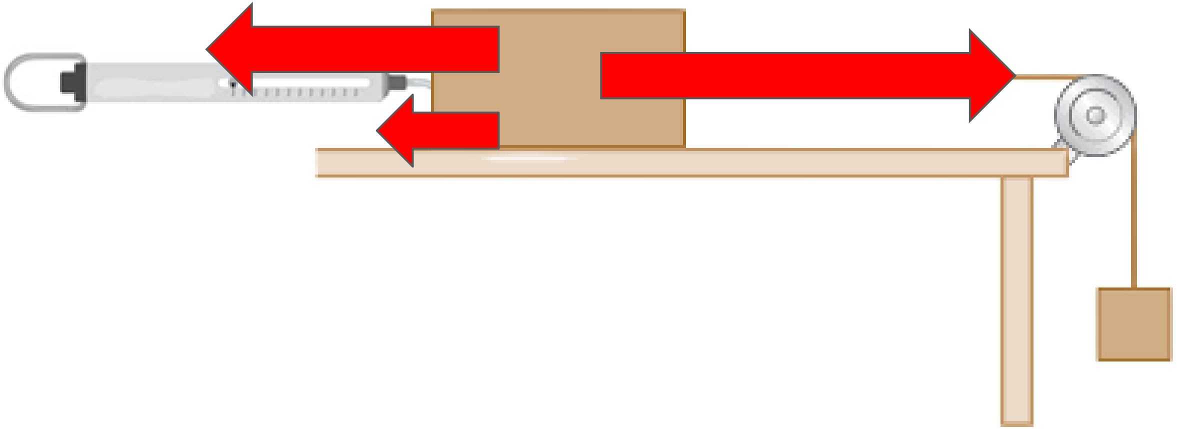
The 3, 2, 1 of Newton's Laws

An odd case of Newton's 1st law?



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The 3, 2, 1 of Newton's Laws

Domain Videos

The domain videos are less than 15 minutes and cover misconceptions and possible activities for forces and many other areas.

https://spark.iop.org/iop-domains-physics-cpd-programme

DOMAINS CPD videos
Forces
Energy and Thermal Physics
Electricity
Light, Sound and Waves
Matter and Nuclear Physics
Space