COSMOS
FOR SCHOOLS

Physics

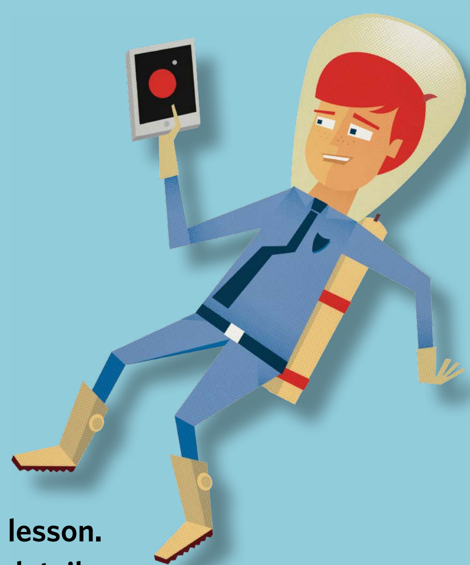
Forces II : Getting a grip

How would you like to be able to climb up walls like Spiderman? Geckos can do this – they even walk upside down on ceilings. By studying the forces involved, scientists have figured out how to get a human up a wall, gecko-style.

In this lesson you will investigate:

- What do forces do?
- When are forces balanced and unbalanced?
- What are net forces?
- How do we measure forces?

So, what are you waiting for...do we have to force you into the lesson?



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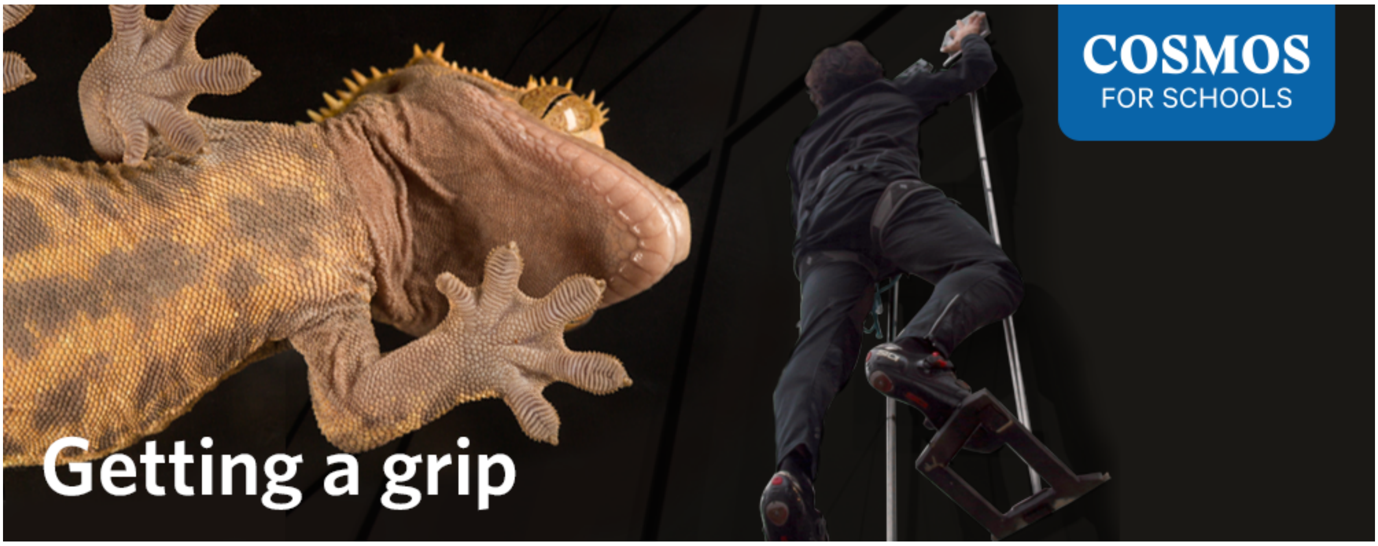
Introduction: Forces II



How do you climb up a sheer glass wall? If you're a gecko, just walk. But for humans, scaling walls this way only happens in fiction...until recently. Elliot Hawkes, an engineering student in the U.S, did it in real life.

What was the trick? Elliot and his team copied geckos. *They* use a type of electrostatic force that exists between all matter, but only when it's very close.

When you put your hand on glass the hand is so uneven it only touches the glass at a few points. Zoom in and you'll see that even there only a few small patches of skin actually touch. These areas are attracted to the glass, but there's not enough of them for you to notice the forces.

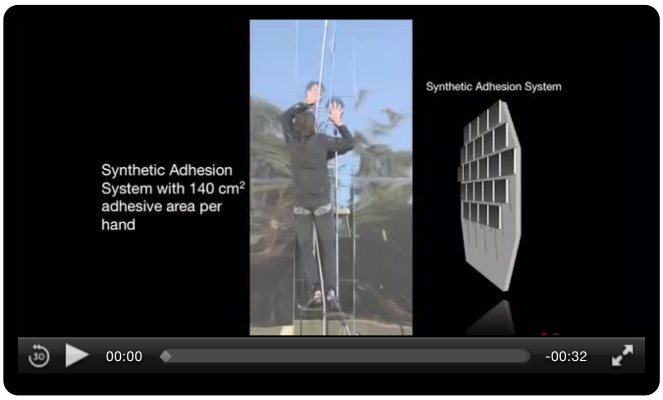
In contrast, gecko feet have hundreds of thousands of microscopic hairs. They all touch the surface and bend to lie along it. There's enough close contact that the forces can support a gecko's weight. And when it wants to move the gecko just tilts its foot to peel the hairs away.

Inspired by this, Elliot's team designed a tile covered with minute flexible ridges. The tiles are mounted onto a pad, each one with a spring to push it closely against a surface. So far it only works on smooth surfaces like glass, and Elliot is no Spiderman, but it's a great first step (pun intended).

Humans have been designing tools to make the most of forces since they first used a stick as a lever. It looks like there's still plenty to learn.

Read or listen to the full *Cosmos Magazine* article here.

Geckos climbing. Credit: Smart materials (1 of 5): Gecko Adhesive fit for Spiderman (YouTube).



Elliot Hawkes demonstrating the gecko pads. The video has been sped up to 4x actual speed. Credit: Stanford research, Human climbing with efficiently scaled gecko-inspired dry adhesives (YouTube).

Hi, I'm **Elliot** – the guy climbing the building. You can learn about me in the *Career* section, but in the meantime I'll be your guide for this lesson. First off, how would you like to climb that wall?

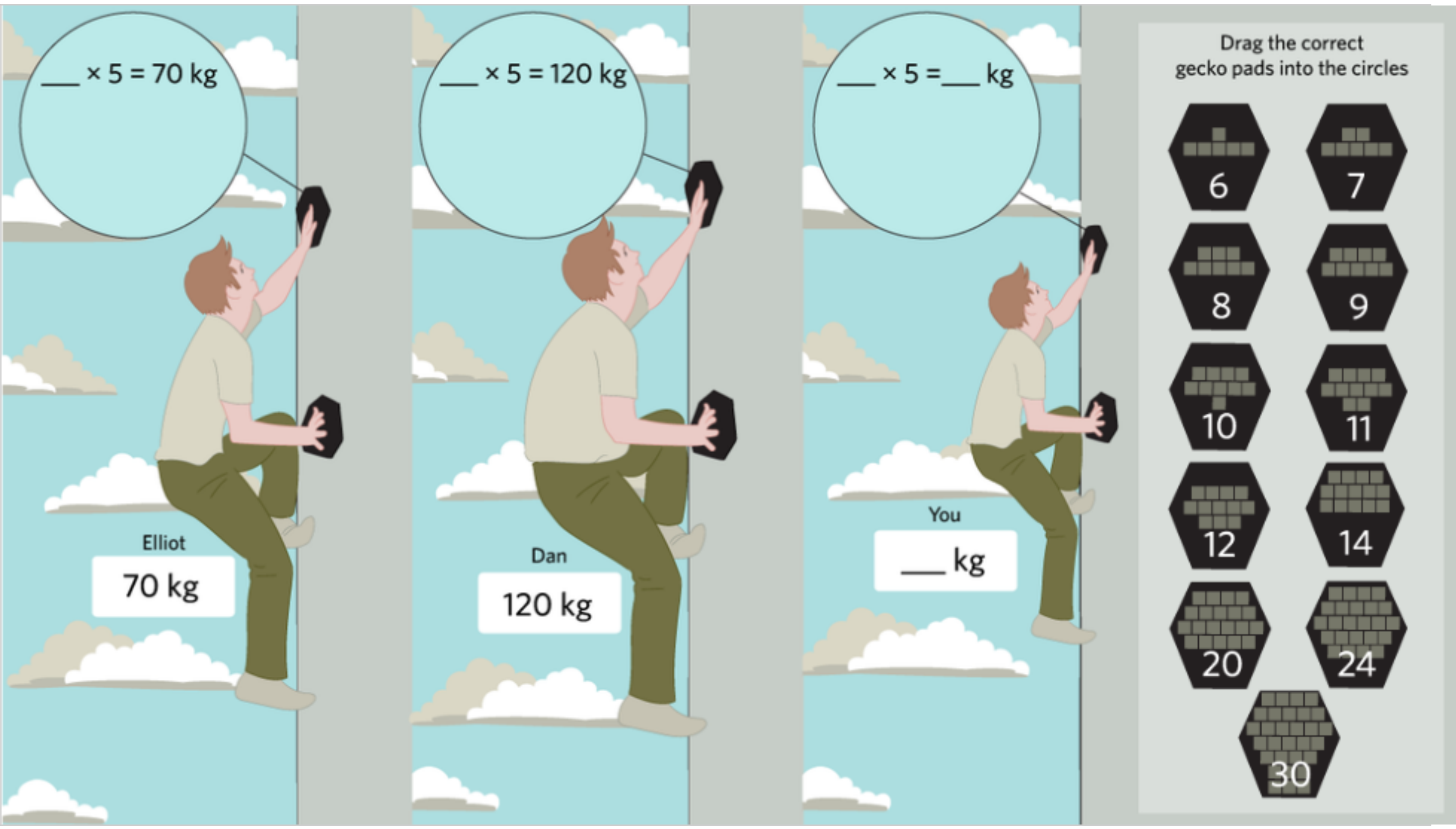
Question 1

Calculate: Each of the small tiles on Elliot's gecko pads can hold **5 kg**.

Work out the smallest number of tiles that would be enough to hold 1) Elliot, 70 kg, 2) Dan, 120 kg, and 3) you.

Note: Each pad has to carry the full weight of the climber.

Note 2: Elliot's actual pads had 24 tiles, so he had a few extras.



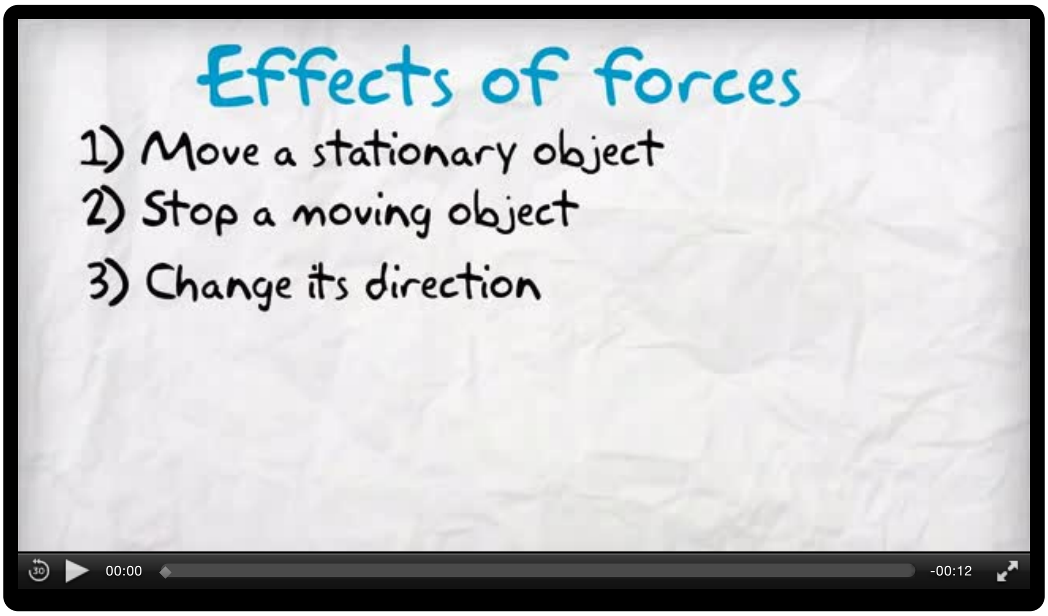
Gather: Forces II

Left: Arm wrestlers – a battle of forces. Right: Dancers – finely balanced forces.

What do forces do?

Forces are pushes, pulls, or twists. Mostly, they affect how objects **move**.

When Elliot climbs up the wall, the movement tells us that forces are at work. And if he slips and falls back down, *that* movement says that forces are at work too.



Credit: NovelLearningCentre, What Is A Force (YouTube).

Question 1

Describe: The table below describes some situations where forces act. In the last column write down which of the effects listed above might occur.

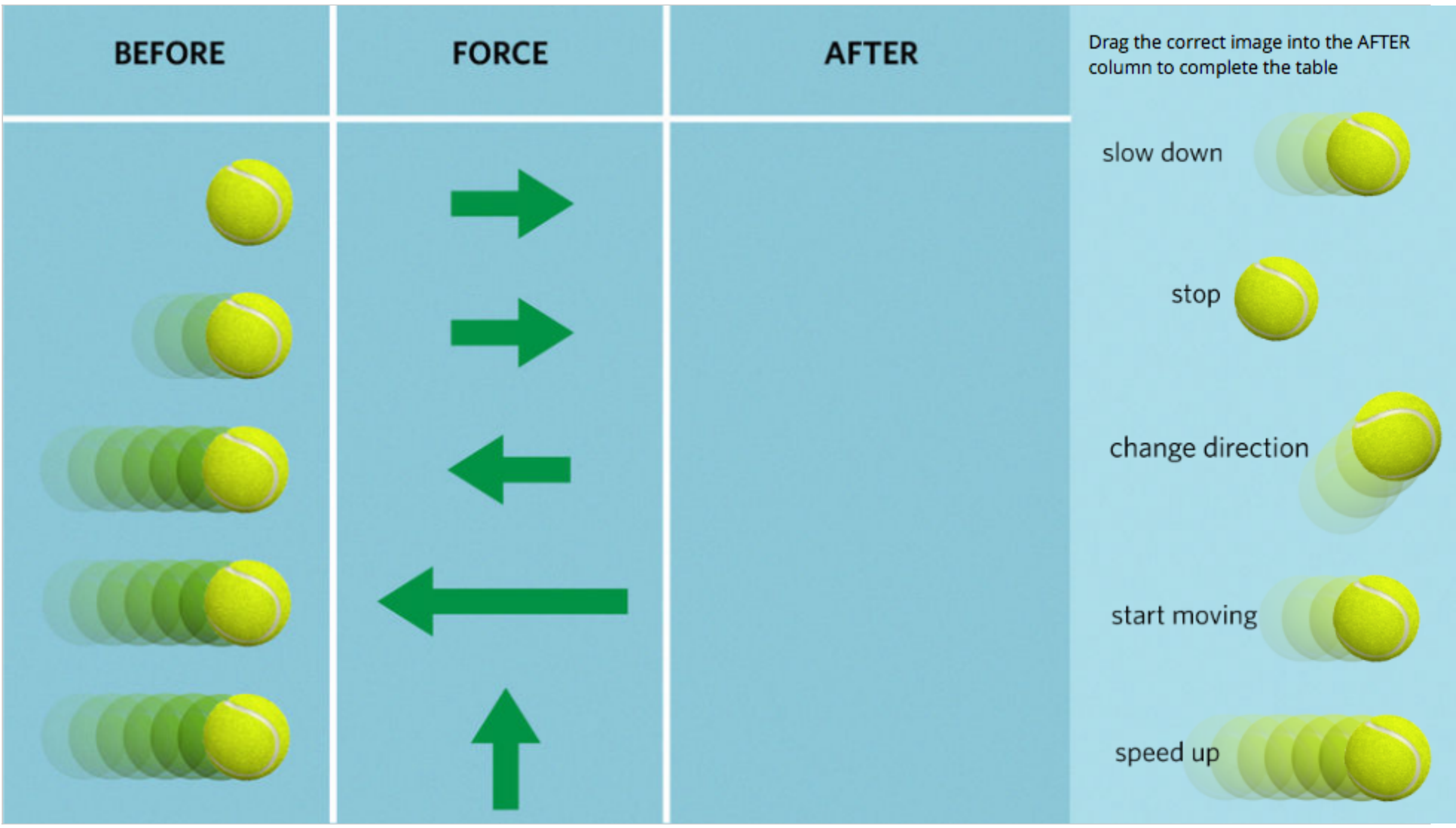
Note: List all of the effects of each force that you can think of.

Just before the force acts	A force acts when...	Possible effects of the force
You hold a sponge	You squeeze the sponge	
Driving along at steady speed on a straight road	You put your foot down on the accelerator	
You throw down a basketball	The ball hits the ground	
A sailing ship motionless on a windless day	The wind springs up	
A ball is heading for the goal in a football match	The goalie intercepts	

You've learnt how to represent forces with arrows that show the direction a force acts, and the size of the force. Now try combining that with what you've learnt about the effects of forces.

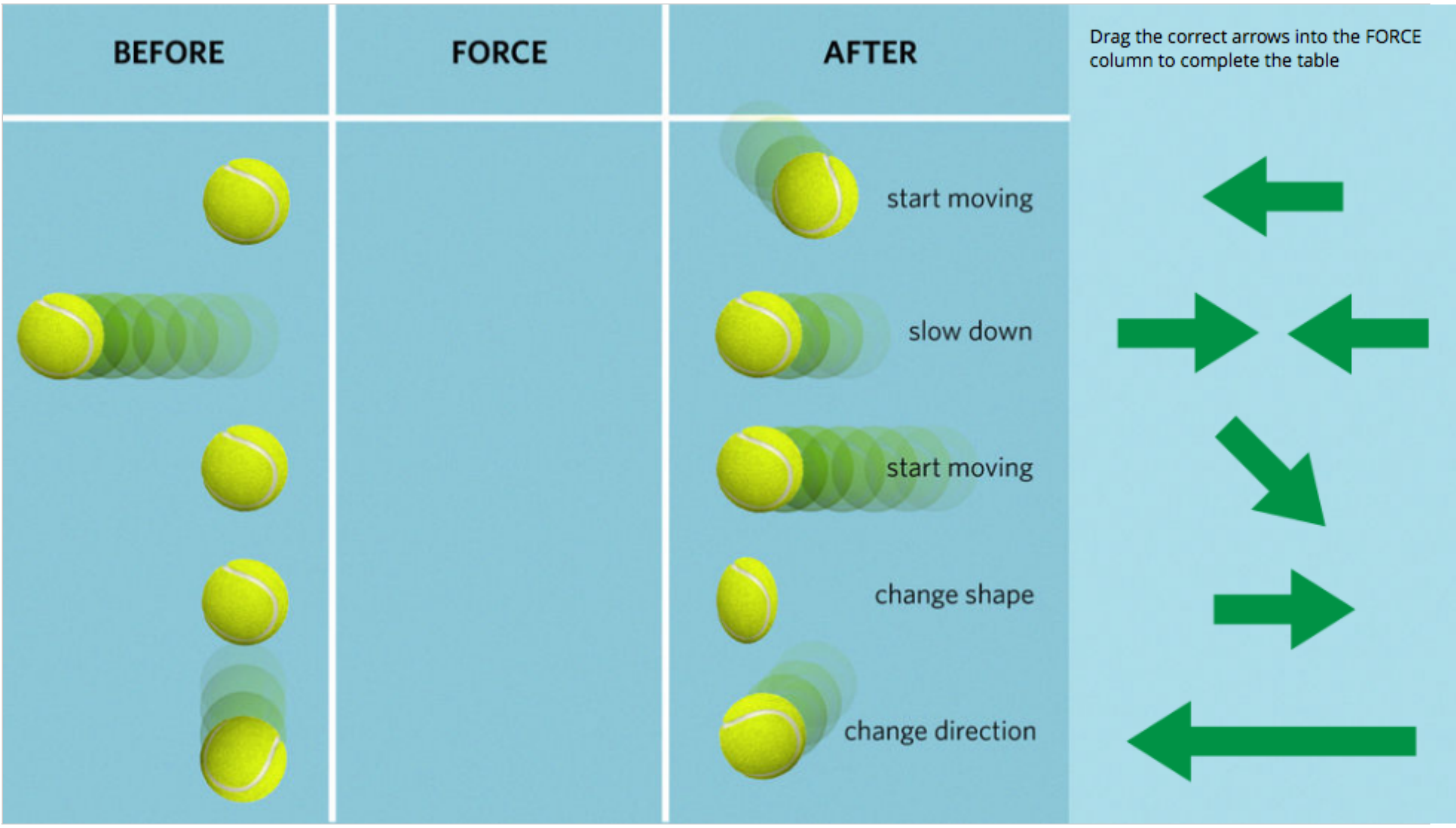
Question 2

Match: What will these forces do to the tennis balls?



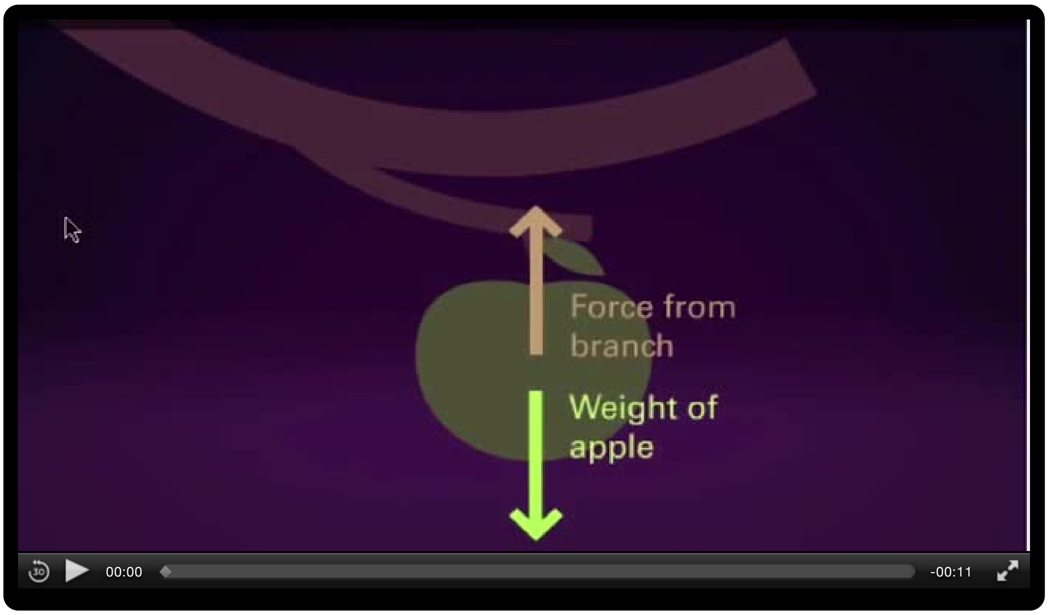
Question 3

Match: Which forces had the effects you see on the balls?



Balanced forces

If there is a change in the way that something moves, or it changes shape, then we know that a force has acted on it. But does that mean that there is a change in motion or shape every time a force is applied? Let's see...



Credit: BBC bitesize forces - KS3 (YouTube)

Question 4

Observe: What forces are acting on the apple?

Note: If you know alternative names for the forces in your answer, give those as well.

Question 5

Observe: Is the apple showing any of the effects of a force?

- ☐ Yes
- ☐ No
- ☐ I'm not sure

Question 6

Think: Why do you think the apple isn't moving or changing shape, even though there are forces acting on it?

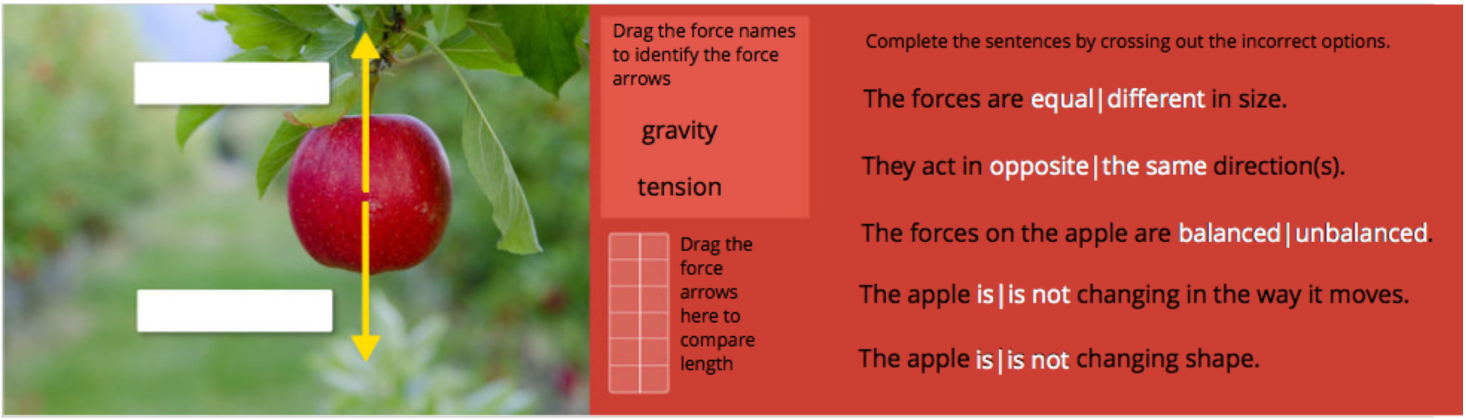
Hint: The video gives you a hint, but see if you can explain more. Then compare your answer to the explanation below.

Question 7

Reveal: Reveal the explanation in the canvas.

Question 8

Summarize: Complete the diagram below.



Unbalanced forces

Balanced forces cancel each other out. I bet you can guess what happens with unbalanced forces...

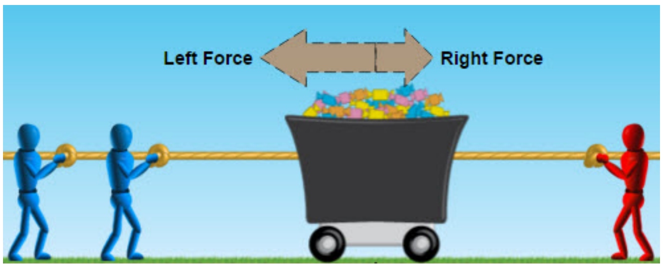
In the picture to the right two small figures are going to pull from the left and one from the right.

Each figure pulls with equal strength, so there will be **opposite** but **unequal** forces – **unbalanced** forces. You can see this from the size of the arrows.

What will happen when the figures start pulling?

Make your predictions below and then run the scenario in the animation below that to check.

Note: If you want, open the animation in another tab, here.



Question 9

Predict: What will happen when the figures start pulling:

1. Will there be any force effects?
2. If so, which one?
3. Can you predict anything about direction?

Question 10

Explain: Explain why you answered the previous question as you did.

Question 11

Reveal: Reveal the explanation in the canvas.

Question 12

Review: Was your explanation right? Either way, rewrite it here with any corrections it might need, but this time include the words **net force**.

Why did the trolley start moving to the left?

Process: Forces II

More forces: pushes in a game of air hockey, and pulling in a tug of war.

Newtons

Forces are measured in **newtons** – with a little "n". The symbol is a capital "N".

The newton is named after – can you guess? – Sir Isaac Newton. He discovered the laws that apply to forces in the 1680's.

So how much force is a newton? Not much...if you hold up an apple the gravitational force it puts down on your hand is a bit over one newton. A litre carton of milk presses down with around 10N.

Question 1

Select: Which sentences use the newton unit correctly to say how much force there is?

- [ ] Friction of 90 N was slowing the vehicle down.
- [ ] The piece of metal in the furnace is 1200 N hotter than the piece on the bench.
- [ ] The magnet exerted 12 N attraction on the piece of iron.
- [ ] When the gun fired it gave a 450 N push to the bullet, shooting it out the barrel.
- [ ] The adult deer has 500 N more mass than its calf.

Net forces

To get you prepared for the next questions, watch the video below. Who are you going for, Switzerland or South Africa?

Credit: Tug of War World Championships 2012 - Finale U23 M600, Somedia Production (YouTube).

Question 2

Find: Describe *two* arrangements where:

1. there are two figures on one side and one on the other, but
2. the forces are balanced.

Identify the figures as *small*, *medium* and *large*.

Hint: You can check if you turn on Values*, and double-check if you turn on* Sum of Forces*.*

Question 3

Explain: Set up one of the arrangements from the last question and tap the Go button.

What happens? Explain why. Make sure your answer refers to:

1. newtons, and
2. net force.

Question 4

Discover: Which of the following combinations give a net force of 50 N to the blue side?

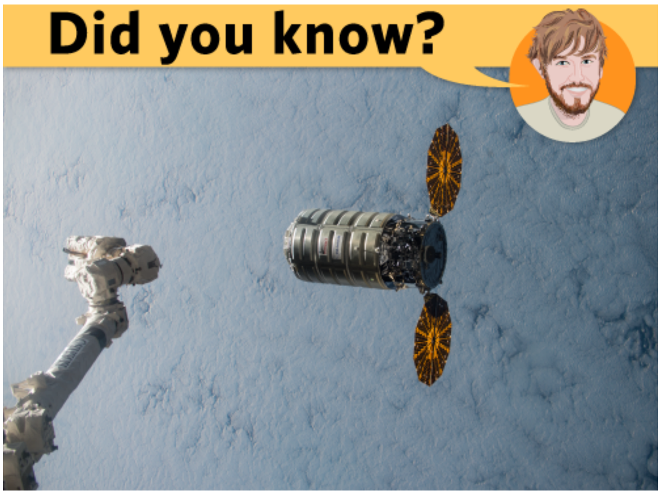
- ☐ Blue: 1 medium and 2 small, Red: 1 large
- ☐ Blue: 1 large and 1 medium, Red: 1 large and 1 small
- ☐ Blue: 2 small, Red: 1 large
- ☐ Blue: 1 small, Red: 1 small
- ☐ Blue: 1 small, Red: nothing

Question 5

Explain: Look at two arrangements:

1. One small red,
2. Two small blues and one large red.

What happens to the trolley in each case? Is there any difference, for the trolley, between the arrangements? Explain why or why not.



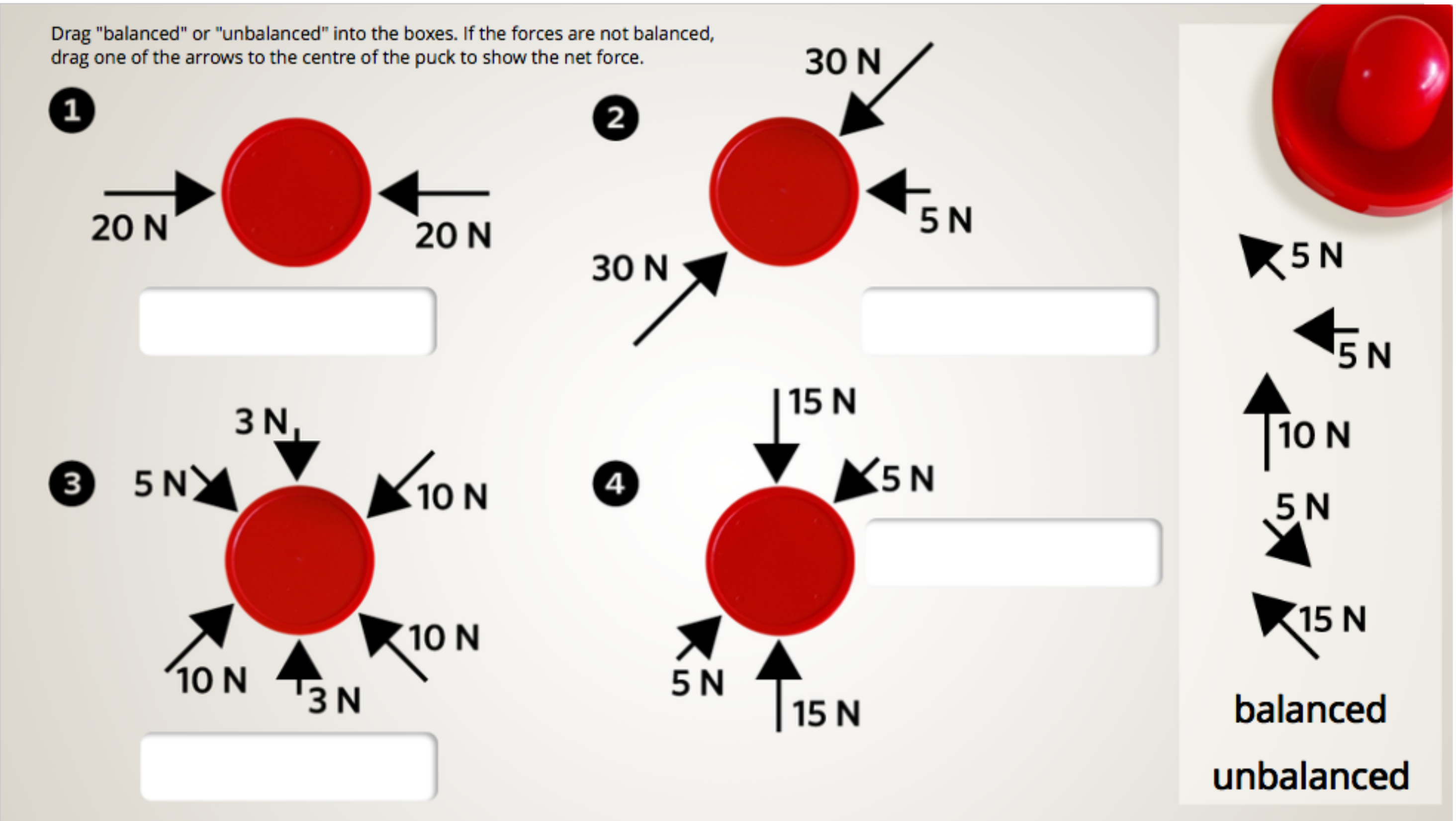
We have a project designing gecko pads for space. We want to be able to grab satellites with pads attached to the ends of mechanical arms – like the one in the picture. But it's difficult work when there's no air resistance.

If there is even a tiny unbalanced force on an object – for example we accidentally tap it – it will start moving and won't stop unless we can grab it. Without friction from air resistance there's no force acting to slow objects down.

Question 6

Analyze: Look at the air hockey pucks in the canvas below. Players are pushing on them with the forces shown.

1. Drag "balanced" or "unbalanced" as appropriate for each example.
2. If the forces are not balanced, drag one of the arrows to the centre of the puck to show the net force.

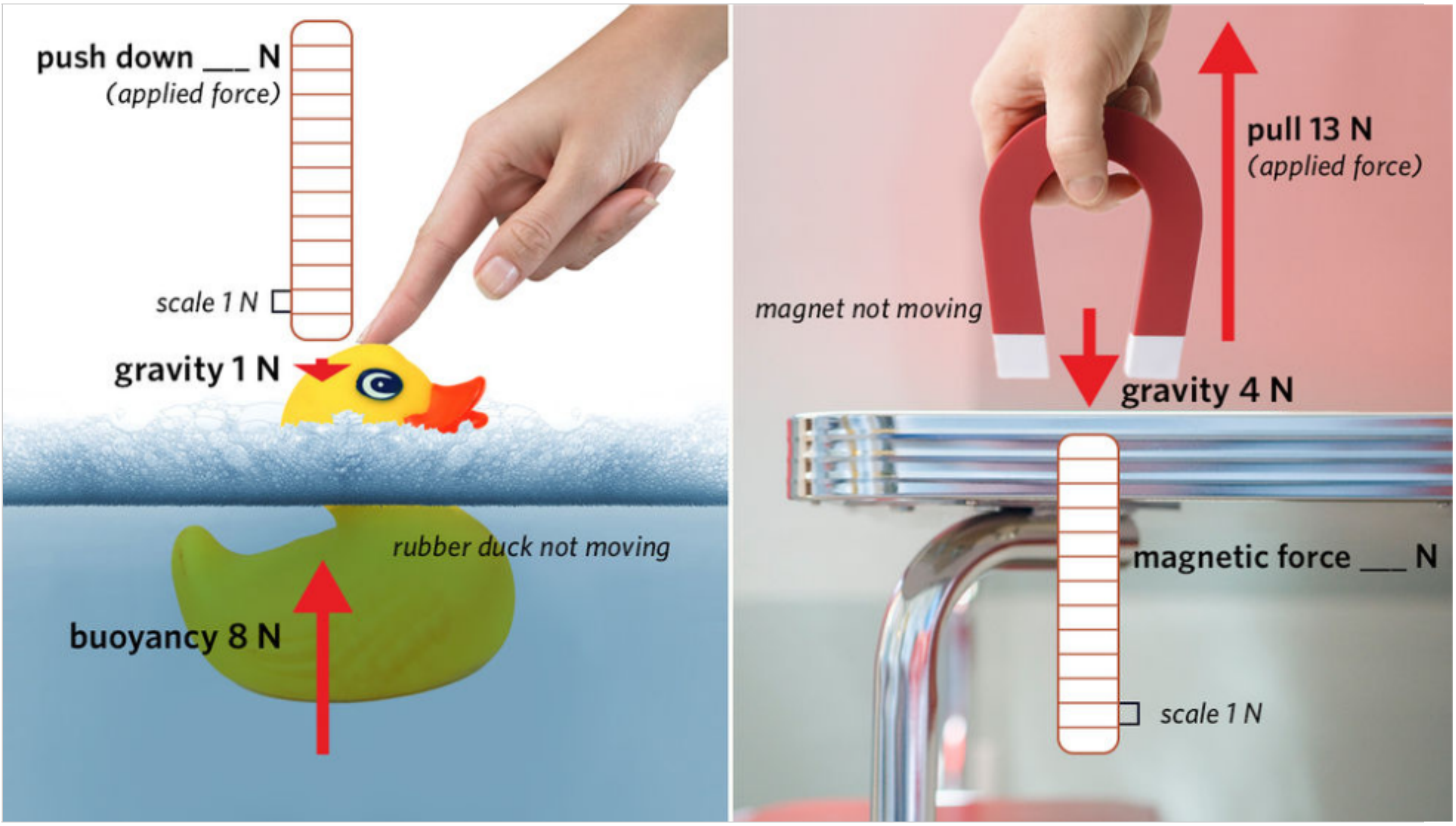


Question 7

Calculate: In the two scenarios below a person is pushing or pulling to keep an object stationary.

1. The person is holding a rubber duck down in the water.
2. The person is holding a magnet just above a metal table that the magnet is attracted to.

Use your knowledge of the effects of forces and of balanced forces to calculate the size of the push and the magnetic attraction. Draw arrows of the right length and direction in the grids to represent the forces, then type in the number of newtons.

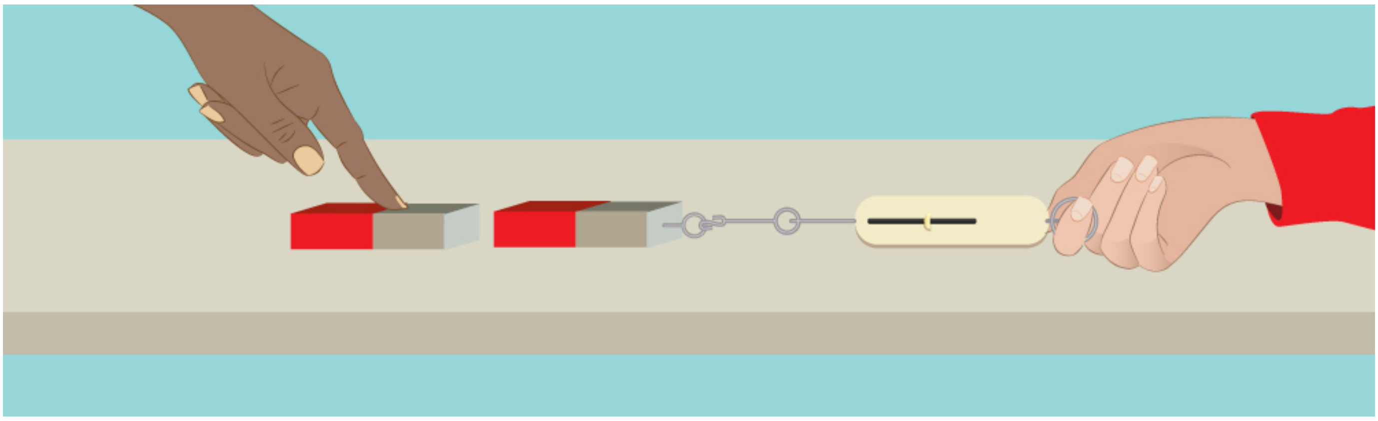


Question 8

Challenge Question: In your own words, explain what the problem is that Elliot describes in the *Did you know?* Why is it a particular problem in space? Be sure to say what forces are, or are not, involved.

Apply: Forces II

Demonstration: Measuring a magnetic force



Background

Many forces can be measured using a spring balance. The greater the pull on the balance the further the spring extends. The size of the force is shown by a pointer attached to the spring, on a scale.

You can measure a magnetic force using a spring balance, but you need to understand balanced forces to really see how it works.

Materials

- two magnets
- spring balance
- something to attach the spring balance to one of the magnets.

Procedure

1. Hold the spring balance in one hand and pull on the hook. Pull it out to 2 N and then to 5 N to feel the difference.
2. Position the magnets so that they snap together then lie them down on a table top.
3. Attach the balance to one of the magnets.
4. Holding one magnet (A) firm on the table top so that it doesn't move, pull the other one (B) with the spring balance. Pull hard enough to just hold the magnets a few millimetres apart.
5. Measure the force on the spring balance.

Question 1

Identify: In the first step of the procedure:

1. Could you feel the difference between 2 N and 5 N? Which did you have to pull harder?
2. Name the type of force that the spring balance was measuring.

Question 2

Explain: In step 4, when magnet B was close to magnet A but not moving, were the forces acting on it balanced? How do you know?

Question 3

State: What force was acting on magnet B *against* the magnetic attraction towards magnet A?

Question 4

Explain: Why can you say that the reading on the spring balance was a measure of the magnetic force between magnet A and magnet B? Ignore friction in your answer.

Hint: If you're not sure, go over the last two questions.

Question 5

Draw: Draw a diagram of your setup (use the *Canvas* tool or draw on paper then photograph and upload). Include arrows to represent the magnetic force acting on magnet B, and the force acting against it. Show the number of newtons you measured where appropriate.

Question 6

Conclude: Write a short conclusion saying how, using your understanding of balanced forces, you measured a magnetic force with a spring balance.

Career: Forces II

PROFILE ▶ Elliot Hawkes
Engineer
Stanford University, California

Using his understanding of forces to design gecko-style adhesive pads

You never get used to falling down! Each time Elliot Hawkes slipped while he was testing the gecko pads it was unexpected and frightening, even though he always had a safety line.

Elliot has graduated and is now an engineer at Stanford University, in California. Working in an engineering lab is like playing with the best toys, he says. Each day is all about coming up with fun new ideas or trying out the ones from the day before. He's built some cool robotic things: a "gripper" that can pick things up without having to squeeze at all, a remote-control fish, and a troop of tiny 2 cm robots that can carry his laptop up a glass wall!

Unlike most kids who grew up in Florida, USA, Elliot didn't spend much time at Disney World nearby. He liked sport and air-powered rockets.

He and his brother would usually shoot their rockets off in their backyard, but when they redesigned one to be bigger and better they took it to the local golf course instead. The rocket shot up so high they couldn't see it – until it came down again. It crashed into the fairway leaving a huge hole. They tried their best to cover it up, Elliot says, but needless to say they never launched rockets there again!

Nowadays any rocket experimentation happens at work. In his spare time Elliot's a keen cyclist who enjoys riding out to the Pacific Ocean or down to the redwood forests of northern California.

Question 1

Evaluate: Elliot and his team didn't just design the gecko pads and then climb up a wall – they had a lot of failures before success.

Are you good at sticking with tasks that you don't get right the first time? Describe a time when you had to have a lot of attempts before you got something right. Would you do better now? Why or why not?

COSMOS FOR SCHOOLS

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