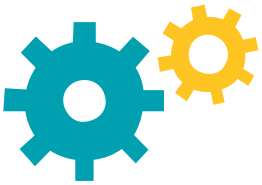
SCIENCE MUSEUM

WONDERLAB: THE EQUINOR GALLERY

The science and maths behind the exhibits

INFORMATION	Age	Topic	
	7–11 11–14	FORCES	30 MIN
	Location	LEVEL 3, SCIENCE MUSEUM, LONDON	

What's the science?



What more will you wonder?
The science and maths behind the exhibits

Wonderlab: The Equinor Gallery is packed with over 50 hands-on experiments and experiences. You need to look closer, ask questions and get creative to discover what they're all about.

If you're still curious you can find out more about the science and maths behind each of the exhibits using these handy resource packs. Check out each of the seven zones that you'll find in the gallery.

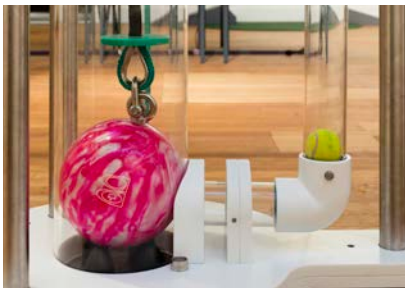
Forces

The forces we use every day let us slide, build, move and spin. Sometimes there are more forces at work than we realise.

Find out more about the science behind the Forces zone exhibits in this pack.

1 Air Cannon
2 Rotation Station
3 Pulley Up
4 Chaotic Rope
5 Flight Test
6 Gravity Run
7 Friction Slide
8 Arch Bridge
9 Balance Bridge
10 Overhang Challenge

The science behind the exhibit



Air Cannon is a great example of how a gas can be used to move something. Both gases and liquids are considered to be fluids because they can flow and move. This movement of air can be used to apply a force to an object. An object will only move if a force is applied to it.

If you look closely you'll see that one end of the tube is wide and contains a bowling ball. The tube then narrows and at the other end contains a tennis ball. When you drop the bowling ball you squash the air beneath it, causing the air pressure to increase. This change in pressure creates a net force and causes an acceleration of air through the tube.

When the air moves from the wide tube into the narrow tube it also has to speed up. This is because the air needs to move faster to get the same amount of air through the tube in the same time. This faster-flowing air hits the tennis ball with great force. The force of this air is enough to push the ball up the tube and out of the top into the air.

The tennis ball flies quite high into the air. This is because of the force of air pushing it, but also because this ball is lighter than the bowling ball. The same force will cause a lighter tennis ball to accelerate faster than the same force acting on a heavy bowling ball. So the tennis ball travels upwards much higher than the distance the bowling ball was dropped.

The science behind the exhibit

As you spin around on this exhibit lots of things are happening. The first thing you might notice is that you'll feel as though something is pulling you outwards as you spin – this is called centrifugal force.

What's weird is that this isn't actually a force at all. Centrifugal force is only a feeling of being pushed outwards when instead there is actually a force, called centripetal force, pulling you inwards to turn you in a circle. As you spin around your body wants to fly off in one direction (imagine swinging a weight on a string and letting it go). When you spin on this exhibit you keep turning in a circle because centripetal force acts through your arms to hold you on.

Another thing you might notice is that when you are spinning and you move your body closer to the centre you will speed up. This is due to angular momentum, which is the tendency of objects that spin in circles to keep spinning around. Angular momentum depends on both your mass and the distance you are spinning from the centre, as well as the speed you are spinning. When you aren't pushing yourself to spin faster the angular momentum will stay the same.

This means that when you pull yourself closer to the centre, one of the other variables has to change to keep the angular momentum the same. Your body mass can't change, which means the only other variable is your speed. This is why you speed up when you bring your body into the centre.

Whenever anything spins around these forces are at work. Just think about ice-skaters doing spins: they go much faster when they bring their arms into their bodies. You can try this yourself when you next spin around. Try it with your arms out and then bring them in – you go much faster.

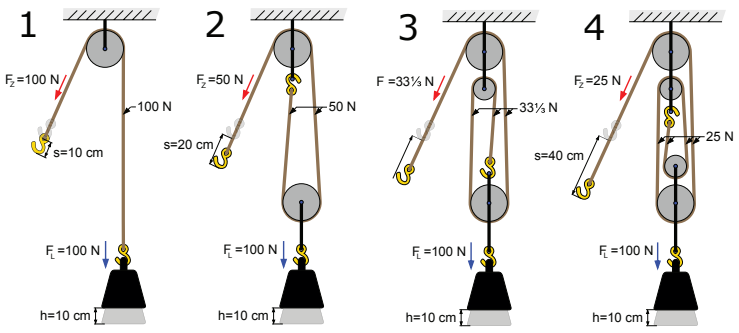
The science behind the exhibit

On the Pulley Up exhibit you can use pulleys to lift yourself up to the ceiling. Pulleys are simple machines that can be used to do lots of useful things. Pulleys all have a rope that slides around a disc, called a block. A pulley can be used to change the direction of a rope and reduce the amount of force needed to lift an object.

When you sit on the pulley chairs you pull the rope downwards. A pulley changes the direction of this downwards force into an upwards force to lift you. If you look closely you'll see that the chair is also hung from the pulley block itself. This means the force required to lift your weight is being shared between the metal frame the pulley is fixed to and you pulling the rope. This reduces the amount of force needed to lift yourself up. When more blocks are added to the pulley system there are more ropes supporting your weight, which means it requires even less force to lift yourself.

One of the chairs has more blocks in the pulley system than the other one. This makes this chair easier to use. However, while it may feel as though it is easy to lift yourself using the pulley chairs, the same amount of energy is still being put into the system. With a pulley system you are lifting the object by pulling with less force, but the trade-off is that you have to pull with this force over a bigger distance. This means you pull the rope further for longer.

You may notice that underneath each chair is another pulley system; this is used to wrap the length of rope that you pull down and keep it out of the way. On the chair with more pulleys this length of rope is much longer because of this trade-off. You'll see that this chair has more rope on it as a result.



The science behind the exhibit

This rope moves in unusual ways. However, the mechanics behind why it moves exactly the way it does haven't yet been fully explained. So far no-one has calculated its motion in detail.

We do know some of the forces that are involved, though. The rope is connected so that it makes a loop. When part of the rope goes through the motor it is accelerated. This part of the rope is pushed out of the motor at an angle. The rope will follow a curved flight path that will be steeper if the angle is higher. Gravity acts to pull it back towards the Earth. The motor sucks the other rope back in, making it go around in this circular motion.

If the rope wasn't connected in a loop, that would be all we would see. However, as the rope is connected in a circle it means there are other forces acting on each part of the rope. Each bit of the rope is also getting pulled and pushed by the rope ahead and behind it. This causes it to form the jumping circle that seems to stand up on the table.

It also means that an action applied to one part of the rope can ripple throughout the rest of it. So if you hit one part of the rope with the stick and make the rope bend out of its circle shape, it will transfer this bend through the whole rope.

The science behind the exhibit

Can you design, build, test and improve a flying machine? Flight Test is all about doing just this by using our air vent. The airflow from the vent provides an upwards force that acts on your flyer. An object will only move if a force is applied to it. So if your flyer is light enough this upwards force will make it fly into the air.

Your flying machine can be designed in many different ways to increase the time it flies in the air and how high it goes. One factor to think about is surface area. If your object has a large surface area this will increase the amount of space on your object that the airflow can push on, increasing the force being applied to it and helping it fly better.

This large surface area also means your object will have higher air resistance when it begins to fall. Air resistance is a type of friction that acts to slow down an object as it moves through the air. Air resistance increases with the surface area of an object. This means an object with a big surface area will also have a slow descent because of air resistance, so it will stay in the air for longer.

Another factor to consider in designing your flying machine is symmetry. To stop your flying machine moving left or right out of the air stream you need to make sure it's symmetrical. This will ensure that the same amount of force is being applied to all parts of the flyer.

Once you've made one successful flying machine, try to adapt the design and make something else. Perhaps you can make a flying machine that goes up quickly but falls down slowly, or one that spins in the air.

The science behind the exhibit

Gravity Run is all about using the force of gravity to make a ball roll downhill in different ways. Gravity is the force that attracts all objects towards each other. The greater the mass of the object, the greater its force of gravity.

The mass of the Earth is so great it makes this force of gravity very noticeable. Gravity causes objects to accelerate towards the Earth when they are dropped. This is a constant acceleration for all objects near the surface of the Earth, regardless of their mass. This means a heavier object doesn't fall faster than a lighter one (that's if air resistance isn't a factor, of course).

When you look closely at Gravity Run you may notice that the ball rolls faster when the slope is steeper. You've probably experienced this before when cycling, rolling or running downhill – the steeper the hill is, the more acceleration you have and the faster you go. This is because gravity acts straight downwards but our slope is at an angle. This means only a bit of gravity is acting along the slope to accelerate the object. If the angle is made steeper, it means more of the force of gravity can act along it and cause the object to accelerate more.

By placing the tubes at different angles and slopes you can control the speed of the marble as it rolls downhill. Make it roll slower by using shallower slopes and faster with steeper ones.

Work and energy are also involved on Gravity Run. If you look a bit closer at a steep slope, you'll notice that it's also taller than a shallower one. This means that when the ball is placed at the top of a steep slope it will have greater gravitational potential energy. When the ball is released this energy will be converted into kinetic energy (as well as sound, heat energy and so on). As the gravitational potential energy is greater for a steeper slope, the ball will have more kinetic energy and roll faster than a ball placed on a shallower slope.

The science behind the exhibit

Our giant Friction Slide has three lanes made from three different materials. There is wood, fibreglass and artificial grass. Each material will cause different amounts of friction.

Friction is a force that resists the motion of two objects sliding past one another. Friction always acts in the direction opposite to movement. The strength of friction depends on the type of surfaces in contact and how hard the surfaces are being pressed together. The material that causes more friction will slow you down more.

You might notice that it's quite difficult to race other people on these slides. Each slide causes different amounts of friction, which means people may have an advantage if they are in a particular lane.

The clothes you are wear also have an impact on your speed. Your clothes cause friction as they are in contact with the slide material. Some clothes will cause less friction with the slide than others and so will let you slide faster.

Finally, the way you position your body can also change how fast you slide. This is due to air resistance – another type of friction, which acts to slow down objects as they move through the air.

Air resistance increases with the surface area of an object. You can position your body on the slide to minimise your surface area by lying flat and pointy. This will reduce the air resistance acting on your body as you slide and mean that you go faster. If you sit up there will be more surface area against the airflow, which will cause more air resistance and slow you down more.

The science behind the exhibit

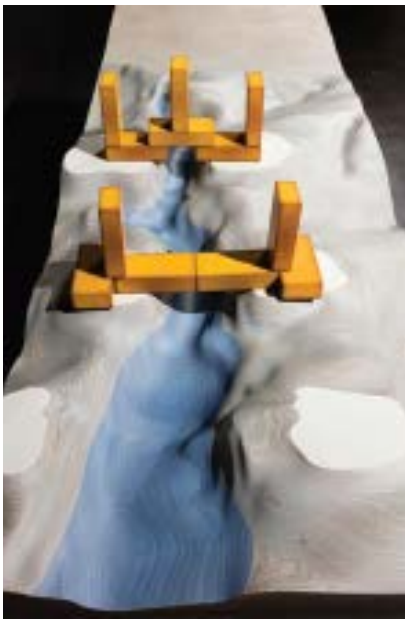
Arch bridges are very strong and stable structures. Once completed our Arch Bridge can even take the weight of a polar bear! To build such a stationary, stable structure all the forces acting on it must be balanced. This is because an object will only move if an unbalanced force is applied to it.

Arch bridges balance the forces acting on them by passing the forces from block to block. It is the curve of the arch that causes the downward force of the load to be carried outwards. Eventually this force is transferred to the supports at either end of the bridge. These supports, or abutments, are embedded in the ground and keep the ends of the bridge from spreading outwards. As these abutments are in contact with the ground, this offers a stable surface from which an equal and opposite force is exerted back onto the abutments.

This opposing force from the ground is again carried through the blocks of the bridge until it is acting on the keystone. This is the central block of the arch. The forces acting on the bridge are equal and balanced, so the arch is stable.

The friction between the blocks also prevents the blocks sliding past each other and keeps the bridge from moving. However, until the keystone is in place the bridge could easily fall down, as all the blocks need to be connected to pass the forces along. You need to work together to build the bridge successfully.

The science behind the exhibit



Building a bridge over the gorge involves placing the blocks on top of each other. You need to balance all the forces acting on the blocks to make a stationary, stable structure.

One important idea in balancing these blocks is the centre of mass. Generally most objects will have a centre of mass that lies at the centre point within the object. The centre of mass is the point that can be considered to be where all the mass of an object is located.

An object placed at the edge of a table will not fall off providing its centre of mass is still over the table. This is because the centre of mass is being supported. However, if force is applied to one end of the block and this is not balanced by an opposing force acting at the other end, then this will cause the block to turn around its centre of mass – meaning the block will turn at one end and fall off the table.

To prevent this happening other blocks can be used as counterbalances. These counterbalances are placed opposite the overhang and allow greater force to be applied. This means you can stack blocks to extend over the river, provided you use counterbalances at the other end.

A bridge can make use of supports on both sides. This means that counterbalances need to be placed on both sides of the bridge and the forces need to be balanced to keep the bridge stable. There are many ways to design a bridge so that it is stable, but it does need to meet in the middle and be high enough for the boat to pass under it.

The science behind the exhibit

On Overhang Challenge you need to balance blocks to make the longest overhang possible. To build a stationary, stable structure all the forces acting on it must be balanced.

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To prevent this happening other blocks can be used as counterbalances. These counterbalances are placed opposite the overhang and allow greater force to be applied. This means you can stack blocks to extend the overhang provided you use counterbalances at the other end. More counterbalances will be needed the longer the overhang gets. The centre of mass for the whole overhang also needs to be over the support or the whole thing will fall down.