HOW TO SPAGHETTIFY YOUR DOG

... and other science secrets of the universe



XXXXXXXX – H.N.K
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BLOOMSBURY CHILDREN'S BOOKS
Bloomsbury Publishing Plc
50 Bedford Square, London, WC1B 3DP, UK
29 Earlsfort Terrace, Dublin 2, Ireland

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First published in Great Britain 2023 by Bloomsbury Publishing Plc

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A catalogue record for this book is available from the British Library

ISBN: PB: 978-1-5266-2781-0; eBook: 978-1-5266-6442-6
2 4 6 8 10 9 7 5 3 1

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Paper from responsible sources
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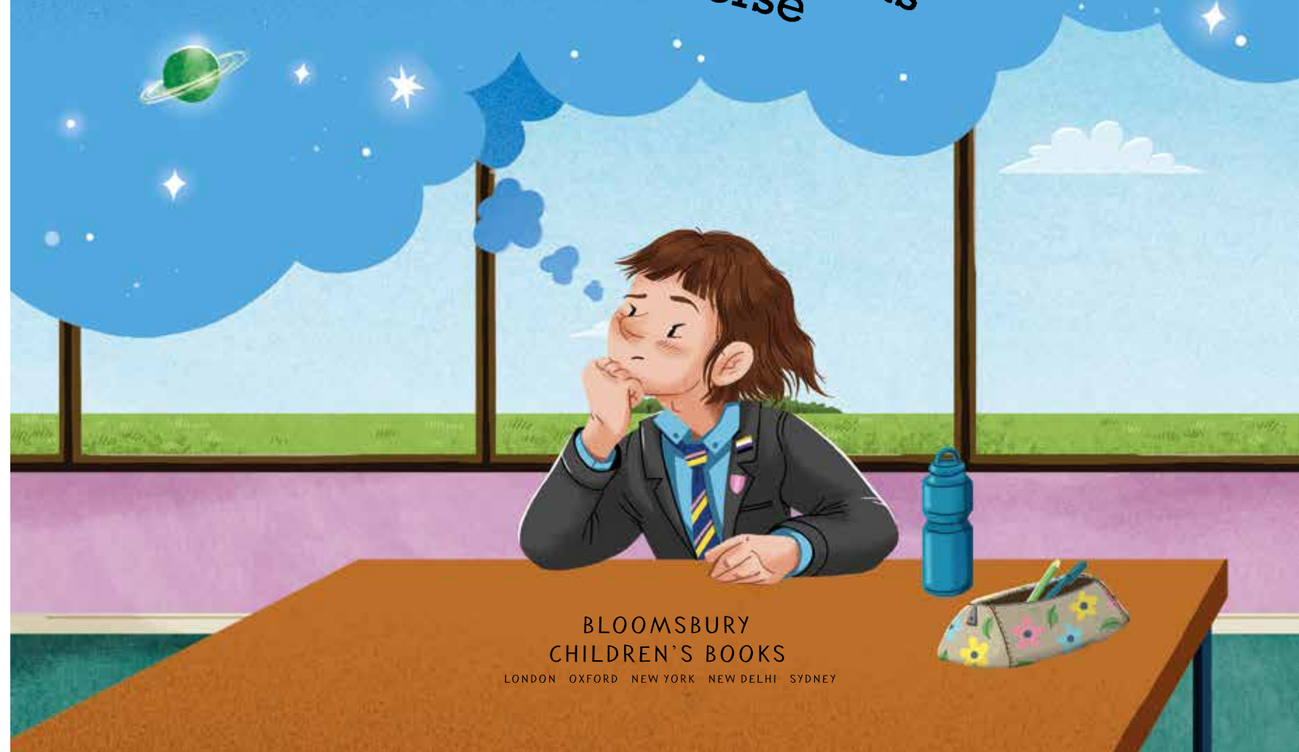
Printed and bound in China by Leo Paper Products, Heshan, Guangdong

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BLOOMSBURY
CHILDREN'S BOOKS
LONDON OXFORD NEW YORK NEW DELHI SYDNEY

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INTRODUCTION

Physics is the science of absolutely everything – the gigantic and the miniscule, visible and invisible. It is both beautifully simple and unimaginably complex, and through it we can make sense of the wonderful world around us.

From clouds to cars, eyeballs to stars and everything in between, physics is the key that unlocks our understanding of the universe. It can be marvellously mysterious, surprisingly simple and downright dazzling.

This book is for everyone who has ever looked around them and wondered *how*, or asked *why*?

Through these pages you will be transported across our universe, whizzing through time and space to discover the astounding and confounding curiosities of our cosmos.

I'll see you on the other side!



FIDGETY ATOMS

The world's tiny building blocks

Have you ever wondered what you're made of? Of course, you've got bones, muscle, skin, snot and much more in your body, but what are all ***those*** things made from? If you **zoom** in on your fingernail, or a blob of saliva, you'd find something quite fascinating. Billions of the teeniest, tiniest things: **ATOMS**.

Atoms are the tiny building blocks of our universe, forming almost everything around us. They make up paint splatters, planets, zebras and chocolate pudding. In case you didn't realise how important atoms are when I mentioned chocolate pudding, atoms are absolutely **everywhere**.





FACT
The average human has around 7 billion, billion, billion atoms in them!

If **everything** is made up of atoms, then why doesn't everything look and feel the same? Well, there are actually more than 100 different types of atom. Atoms **bond** together into groups called **molecules**. Atoms are like little bricks – they can join up in different orders to create molecules, which are like bigger bricks. By stacking them together you create new structures. If you keeeeep stacking molecules, you could end up with a bicycle, or a rabbit!

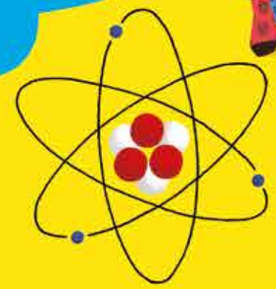


Atoms are so itsy that it's entirely impossible to see them with the eyes. Even eagles, whose eyesight is eight times better than humans, are unable to see atoms!



Using microscopes, scientists reckon they look like this:

- Proton
- Neutron
- Electron



Atoms themselves contain EVEN teenier tinier particles inside them. Different numbers of **protons** and **neutrons** make up a tiny central nucleus, while **electrons** whizz through the vast space around the nucleus ridiculously fast.

FACT
Dazzling diamonds, lumpy coal and 20 per cent of your body is made from the same atom – carbon! It's found in every living thing, and depending on how the atoms are joined, the finished product can be many things, including soft, hard, shiny and flaky.





Another thing you should know about atoms is that they just can't help but **fidget**! Whether it's atoms in an ice cube, a dog's tail or a lamppost, they're **always** moving, a bit like when you really desperately need the toilet!



STATES OF MATTER

MATTER

Solids, liquids and gases

Atoms and molecules, also called particles, make up the stuff all around you, and anything made from particles is called ***matter***. From the invisible air you breathe to the pencils you draw with, from the food you munched for breakfast to the bubbles in your bath, **EVERYTHING** is made from matter.

First, we have **solids** like ice, sand, cake, bones, bricks, books and doorknobs. The atoms and molecules in solids are **closely packed together** in a pattern so they can't move about. They stay in one shape and place unless heated up or cooled down, and keep their **volume (the amount of space they take up)** – which is why you can't walk through a wall!



Next come **liquids** like water, custard, lava, milk, wee, and strawberry milkshake. Particles in liquids stay **close** to each other but are **free to move around**. They aren't stuck in a pattern and so can slide and shapeshift! If you pour cake mix from a jug into a dog-shaped cake tin, it will happily flow into dog-shape. The volume has to stay the same though, so if the glass had a bigger capacity than the tin, the mix would flow over the edges.





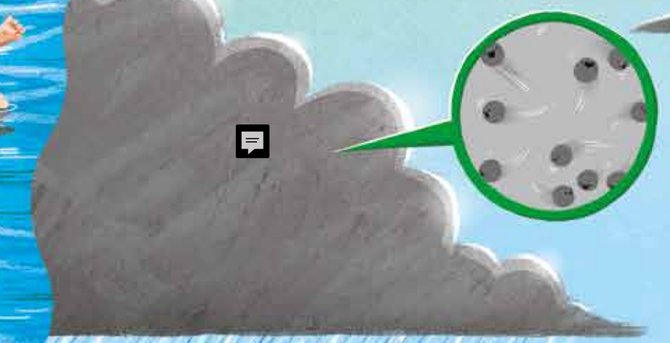
Then **gases** like helium, steam, oxygen and carbon dioxide.



FACT

Farts are a combination of different gases. Hydrogen sulfide makes them stinky, while methane and hydrogen make them flammable.

The particles in gases **roam around freely** with no fixed pattern or fixed shape. They can spread out or squish down to fit whatever container they find themselves in as their volume can change. Not only are gases **super-shapeshifters** but they are also usually invisible.



TRY THIS

1. Take a few **solid** ice cubes and put them into a pan.

2. With the help of an adult, heat the pan. The cube will melt into **liquid**. Next, the liquid will start to boil. Watch as it turns into **gas**. Eventually, there will be nothing left in the pan because the gas molecules will be invisibly drifting around the room!



WHAT HAPPENED?

Heat is an energy that gives solids a new lease of life – they vibrate until they break free of their fixed pattern – or in other words, **melt**! If you keep heating the sloshy liquid atoms, they'll start to shake and jump wildly until they whizz off into the air – or **evaporate** – as gas! You've just witnessed the three **states of matter** of water – see how different each one is?

WHAT'S COLDER THAN ICE?

Super-cool supercooling

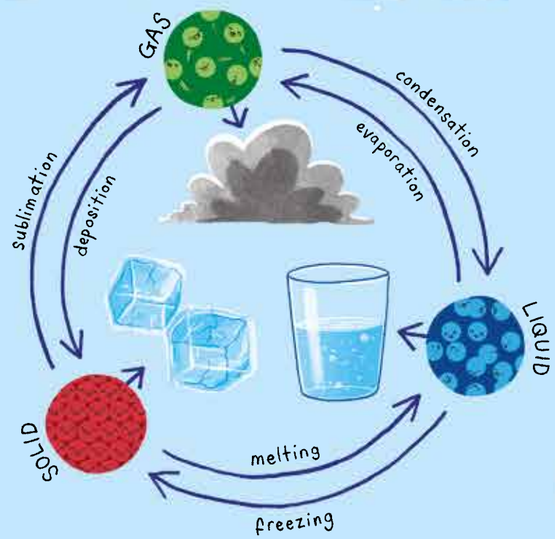
Remember how atoms **fidget**? No matter how many treats you bribe atoms with or how loudly you shout at them, they simply will not stop moving about. What you can do, though, is change how **much** they fidget.

Atoms in solids have the **least** amount of energy and space to move in, so they're pretty slow and lazy. Atoms in gases are the most lively and energetic, zipping about in all directions. Atoms in liquids are in between the two.

I'll let you in on a secret: if you need to calm an atom down, just make it **chill**! Cooling an atom's temperature slows it down.

Sublimation is when a solid turns into a gas.

Deposition is when a gas turns into a solid.



Condensation is when a gas turns into a liquid.

Evaporation is when liquid turns into a gas.

Normally, liquids freeze into solids (and vice versa) at fixed temperatures. Water becomes ice at 0°C. Melted chocolate becomes solid at 35°C. But there are exceptions ... super-cool ones. When liquids behave like rebels and **don't** turn into solids at temperatures even **below** their freezing point, it's called **supercooling**.

FACT

Absolute zero is the coldest possible temperature anything can reach at MINUS 273°C (ice is around 0°C!). At absolute zero, atoms have the absolute LEAST energy possible. You can bet they're not much fun to be around!

TRY THIS

1 Put two plastic bottles of filtered (not tap) water in a freezer. Leave them for around two and a half hours and go chill. When you take them out, the water should be supercooled and NOT frozen.

2 Hit the first bottle on a hard surface and watch the water turn to ice instantly!

3 Put an ice cube onto a plate and pour the water from the second bottle onto it. It will pour out as a liquid and magically freeze on contact with the ice cube!

Heat for atoms is like sugar for kids! The more sugar or heat, the livelier the kid or atom!



WHAT HAPPENED?

In order for ice crystals to form from water, the water needs to:

1) Be cold enough.
2) Have a special pattern of molecules that act as a base.

When the water was supercool, even though point 1 was fulfilled, it wasn't able to arrange molecules into the right pattern to build crystals. When you bumped the bottle, you allowed the molecules to move and find that pattern to build ice from. When you poured supercool water onto the ice cube, it was able to use the existing ice as a starting block.

Agh! Someone froze the milk! Not cool!

Some atoms are actually supercool.

Icy what you did there!



GRIPPING, SKIDDING AND SLIPPING

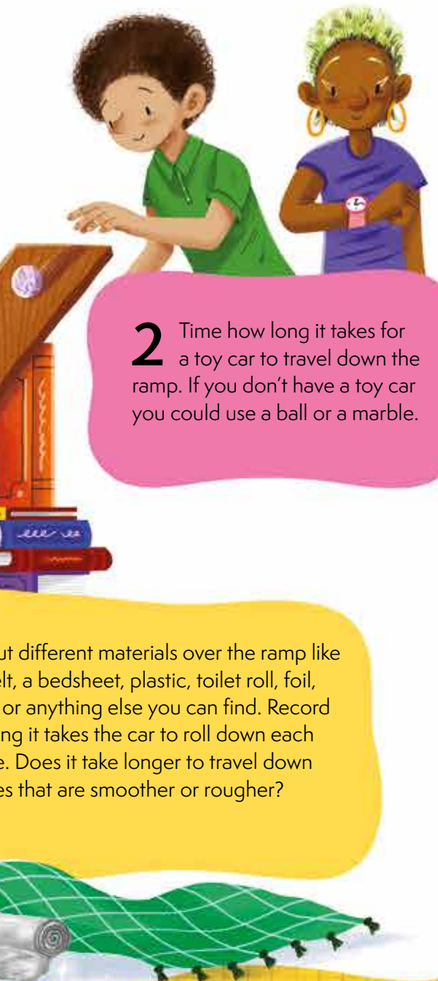
The force of friction

The universe is ruled by **forces**. Forces are invisible interactions between objects, and they either have a pushing or a pulling effect. Some are contact forces, occurring when two objects touch each other, like when you kick a ball. Non-contact forces occur when an object can mysteriously push or pull another without touching it ... like when magnets connect.



There is a particular contact force that helps you to climb hills, grip spoons, write on paper and **so** much more called **FRICTION**. It is a force that acts between two surfaces. Friction **always** acts against the direction of motion, so it has a slowing down effect, like when you press the brakes on your bike.

Sometimes friction gets a bad reputation for being a nuisance, like when it causes the soles of your shoes to wear out or gives you nasty rope burn on the climbing frame, but that's just one side of the story. If this force stopped working you wouldn't be able to take a single step! Your legs would run but you'd be stuck slipping about in one spot. Pretty frustrating when you've got somewhere to be!



TRY THIS

1 Set up a sloped ramp using a smooth surface like a piece of wood, cardboard or even a big book.

2 Time how long it takes for a toy car to travel down the ramp. If you don't have a toy car you could use a ball or a marble.

3 Put different materials over the ramp like felt, a bedsheet, plastic, toilet roll, foil, Velcro or anything else you can find. Record how long it takes the car to roll down each surface. Does it take longer to travel down surfaces that are smoother or rougher?

WHAT HAPPENED?

Friction makes surfaces slightly stick together. The amount of friction between the car's wheels and the ramp changes according to the material. Smooth surfaces, like plastic or wood, create less friction than rough ones, like Velcro or felt, allowing the car to move faster.

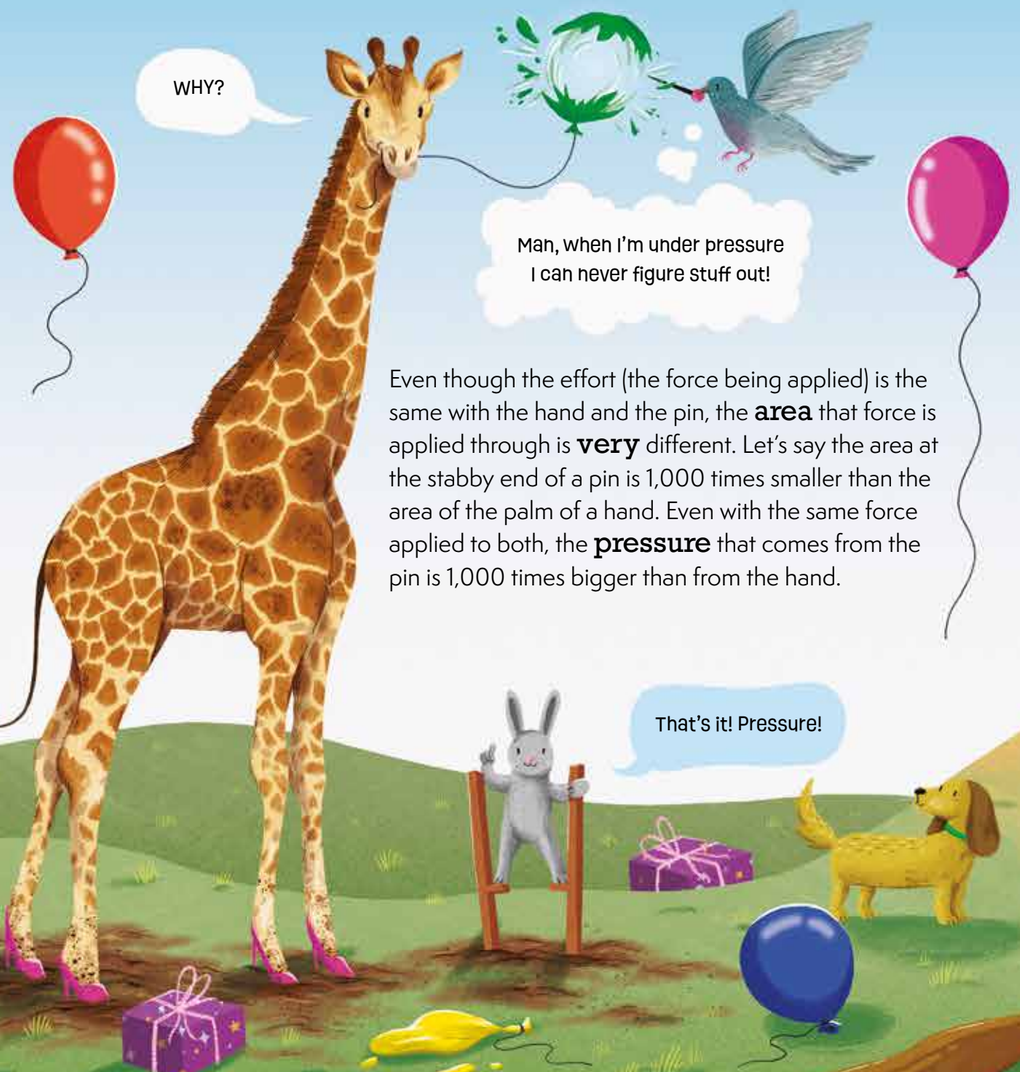


If you've ever played on a water slide, you'll know **all** about friction and **slipperiness**. To get that perfect **gliiiiiide**, you need a perfect combination of things. If you had water and no slide, you'd not get anywhere. And if you had the slide but no water there would be too much friction ... **BUT** when you have water AND a slide, the liquid reduces the friction between your body and the slide, allowing you to **whoooooosh** down it!

ELEPHANTS VS. HIGH HEELS

Under pressure

Imagine it's the end of a party and you need to pop the balloons. If someone pushed a balloon with the palm of their hand, not much would happen. If they used a pointy pin, and pushed it with the **same amount of force**, it would signal the end of that balloon's life. The exact same amount of force results in two completely **different outcomes …**



Even though the effort (the force being applied) is the same with the hand and the pin, the **area** that force is applied through is **very** different. Let's say the area at the stabby end of a pin is 1,000 times smaller than the area of the palm of a hand. Even with the same force applied to both, the **pressure** that comes from the pin is 1,000 times bigger than from the hand.

FACT

Camels have unusually wide hooves, which is super-handy when your days are spent walking across deserts. They put less pressure on the ground compared to narrow horse or deer hooves, which stops the camel from sinking into the sand. Snowshoes are designed in the same way.

Pressure tells us how intensely a force is being applied to an object. It's the amount of **force** applied per bit of **area**. This is why a mighty elephant exerts **less** pressure on the ground than a person wearing high heels! The elephant's force is **much** more than the person's because it is bigger but the **area** where that force is applied is **so** much more spread out – over four **ENORMOUS** elephant feet compared to the small points with high heels.

It's also why it's way smarter to wear wellies than stilts while walking through a muddy field – you'd be far less likely to sink deep into the mulch. Plus, wellies keep your feet nice and dry …

TRY THIS

Make some party sandwiches! With an adult nearby, press the flat edge of a butter knife against a block of butter. Not a very successful buttering method, right? Now increase the pressure by pressing the sharp edge of the knife against the butter. That's much butter!