Name:

Junior Science

Motion

Downloadable Resource

Tina Youngman

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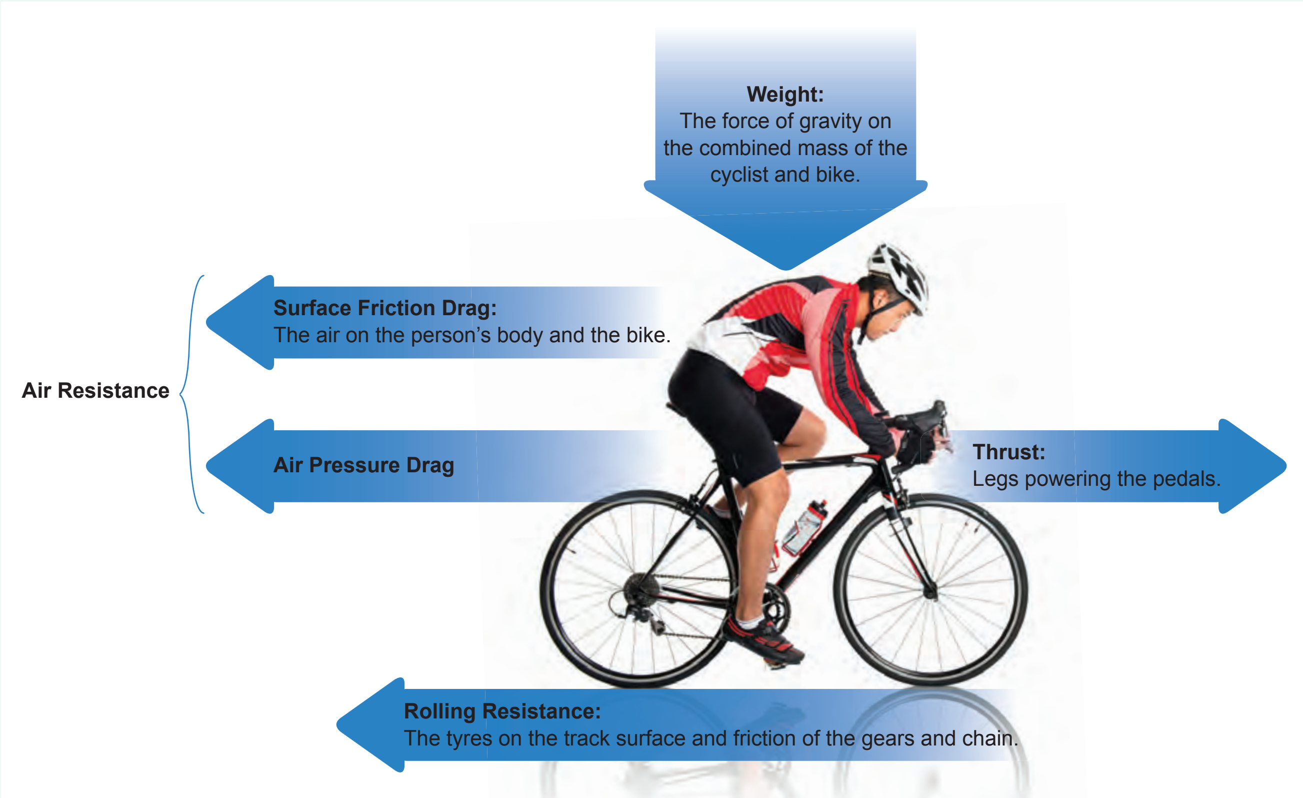
Why do Cyclists Shave Their Legs?

The main forces acting on a cyclist as they travel along a surface are shown in the diagram below.

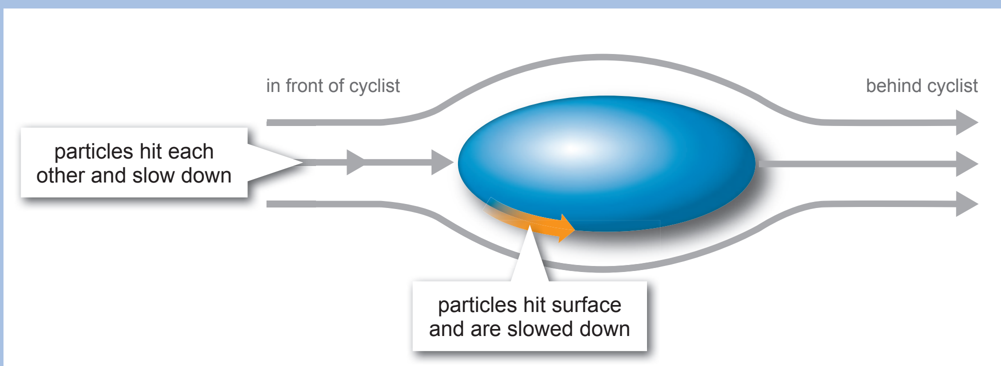


The amount of **rolling resistance** and the **friction** of the gears and chain don't really change much with the speed of the cyclist, they are fairly constant. However, the air resistance and surface friction drag do change, so it is important these forces that are opposing the movement of the cyclist, don't exceed the thrust force that the cyclist has to apply to the pedals to make the bike go forward. Competitive cyclists look to reduce resistance so that they can minimise the energy expended in struggling against the opposing forces. They look to science to help them reduce air resistance by modifying their bikes and altering their body surface.

Aerodynamics is the study of how gases, such as air, interact with moving objects. It is concerned with drag, which is also called **air resistance**. This resistance works against the object's forward motion and can slow it down. This occurs in two main ways:

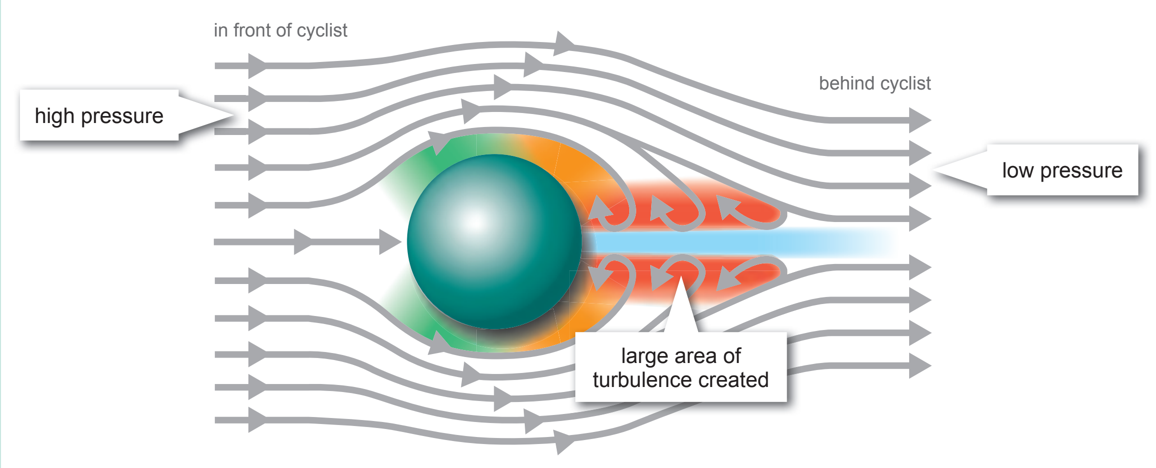
Surface Friction Drag

Surface friction drag is where particles of air hit the rough surface of the object (e.g. skin and hairs) and slow its motion. As a cyclist rides forwards, they hit a wall of air and the faster they go, the bigger and stronger the wall is. The air particles bump into the cyclists' skin and are slowed down. They also slow the particles behind them, thus creating resistance to the rider. This is shown in the diagram below.



Air Pressure Drag

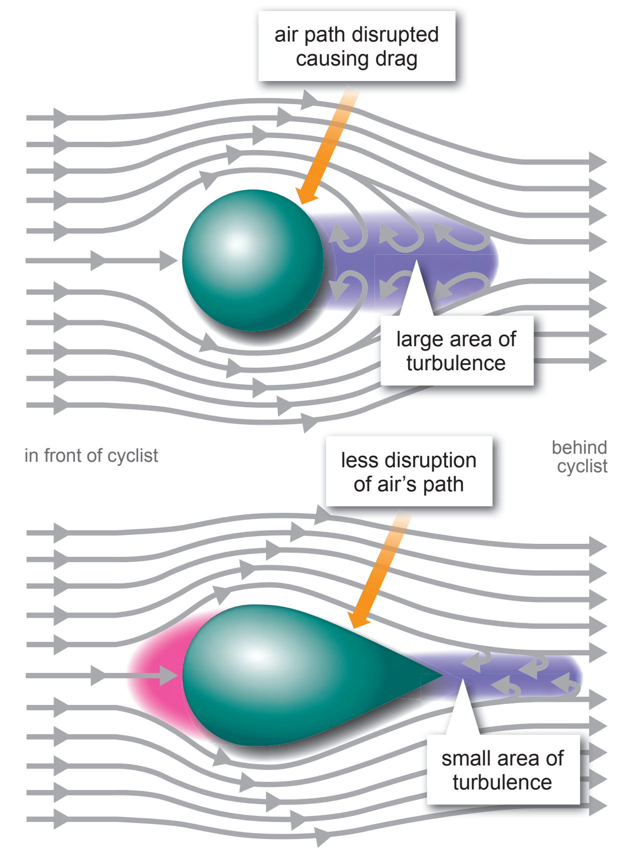
Air pressure drag has a much greater effect on the motion of the cyclist than surface friction drag. The air particles in front of the cyclist are under greater pressure than the particles behind the cyclist. This means that the particles are denser and closer together in front. This difference in pressure essentially pulls the cyclist backwards as it pushes more on the front than the back. The faster the cyclist rides, the greater this resistance becomes. At high speeds, the cyclist can use 90% of their energy just trying to fight the drag. This is shown in the diagram below.



Track cyclists usually race indoors in a special stadium called a **velodrome** where there is no actual wind and the weather conditions are constant. However, there is still air resistance due to the shape of the athlete and the speeds that they go. The individual pursuit is an Olympic event that involves two riders battling each other to see who's fastest over a distance of 3 km around an oval shaped 250 m track. The cyclists reach speeds of up to 50 km/h, which is impressive on a short oval circuit. New Zealander Sarah Ulmer set the women's World Record for this event at the Olympics in Athens in 2004, with a time of 3 minutes 24.5 seconds. Cyclists like Sarah Ulmer use all sorts of adaptations to help them go faster.

The weight of a cyclist and their bicycle can create more resistance, especially the rolling resistance of the tyres on the ground. The greater the weight, the more resistance created. Bicycle design has played a large part in reducing this by altering the materials that the bikes are made from. They can be made from steel, aluminium or carbon fibre, and each material has its advantages as well as disadvantages. Carbon fibre is light weight and very strong, however, it is **irreparable** if damaged as it tends to splinter. Steel is heavy and can be twice the weight of a carbon fibre bike, however, in comparison it is cheap and able to be repaired easily. Aluminium is also light but not as light as carbon fibre. It is strong and while it can't be repaired easily, it is cheaper to replace than carbon fibre. Because the weight of the bike affects how safe and strong it is, the UCI (Union Cycliste Internationale) have made a rule stating that a bike must be at least 6.8 kg. This has prevented the materials being modified too much.

Cyclists are very poorly shaped as a human sitting atop a bicycle isn't very **streamlined**. Their bodies are like a wall that impedes air flow and creates drag, which means they have to cycle harder and **expend** more energy in order to maintain their speed. The area of their bodies facing the air coming at the bike, is referred to as the **frontal area size**. If you sit upright on a bicycle, there is more area for the air to hit, thus increasing drag. Cyclists take a hunched over position close to the handlebars, with their back flat. This shape reduces drag. Professional cyclists have additional or specially designed handle bars called **aerobars** that sit low and allow the rider to grip on in this low, bent over position. The shape of the bike frame can also increase the amount of drag. If the frame uses circular tubing, it creates more resistance than a teardrop shape, as shown in the diagram opposite. The area of **turbulence** is reduced greatly with



tear drop shape reduces resistance

the teardrop shaped frame. Brake and gear cables can create drag if they are hanging of loose so bike manufacturers tend to hide these behind the frame to reduce drag. The human head is a block shape that increases the frontal area of the cyclist. By wearing an **aerohat** (teardrop shaped helmet), drag is reduced as it cuts through the air and reduces the pressure differences which can occur.

Cyclist wearing an aerohat.

Bikes have wheels and friction is needed to get the cyclist moving. The rubber tyres on the wheels grip to the surface, giving the cyclist **traction** so that movement occurs. But the amount of friction created shouldn't be too much that it slows the cyclist. This is why they have smooth tyres instead of chunky tread. For example, mountain bikes need extra friction to ride through soft mud and dirt. The smooth rubber tyres reduce the surface friction drag because the air isn't hitting the tread and slowing the cyclist down. The type of wheel on a professional racing bike is very different to a normal bike. They do not have spokes but instead have solid discs. The spokes break the air passing and each one creates **eddies** (swirling air) which in turn slows the bike down. The flat solid disc is slightly heavier but the increase in rolling resistance is far less than the reduction in drag.

The surface of a human's skin isn't smooth and neither are many fibres such as wool or cotton. When air hits this rough surface, it slows down and creates surface friction which slows the bike. Cyclists wear tight fitting clothes and often shave their leg and arm hair to create smooth surfaces for the air to bounce off easily. The clothing is often made of Lycra as this is a very smooth and shiny material that reduces friction.

The percentage of aerodynamic drag reduction has been calculated for some of these methods:

Method	Percentage of Aerodynamic Drag Reduction
disk wheels	70%
drop down position	27.8%
tight clothing	11%
aerohat	7%
Lycra clothing	11%

As you can see, there is a whole lot of science behind cycling. Cyclists have a range of tricks up their sleeves to try and go that little bit faster than their rivals. In fact, some of these techniques are so effective they have been banned or restricted by the UCI, these include:

- No bikes lighter than 6.8 kg.
- Cyclists must wear a helmet that is protective.
- Lotus Monocoque frame is banned (shown in the photo above).
- Obree Position is banned (arms tucked in, knees together and hunched far forward over the handle bars).
- No modification of factory parts, e.g. by taping parts down or plugging holes.
- Bikes must have equal size front and back wheels.
- Only the equipment that is available to anyone who races bicycles, is allowed to be used.
- A rider has three points of support on the bicycle. These are feet on the pedals, hands on the handlebars and seat on the saddle.

As well as this, the UCI has the right to check each cyclist before racing and permission must be sought before the race for any modifications or unique technologies. So while the bike's design and the human can be modified to provide more speed through decreased resistance, it is heavily controlled. This makes it a fairer and a more level playing field.

The World's Fastest...

Humans love speed. We all get a thrill from going fast or twisting and turning on a speeding roller coaster, or even running really fast down a hill. What makes us love speed, is actually fear. When our body experiences fear, it releases a huge amount of **endorphins** and **dopamine** which are **neurotransmitters** (chemicals that take messages to the brain). These act in a similar way to drugs like opium or morphine, by attaching to specific **receptors** in our brains. In turn, this makes us feel good. Because we love speed and the rush it provides so much, we are always trying to go faster and set or beat world records.

Running really fast gets us excited and runners and supporters alike, get a rush from watching the 100 m sprints at events like the Olympic Games. The first officially recognised recorded result for a 100 m sprint was by American Donald Lippincott in 1912, with a time of 10.6 seconds. Since this first record was set, men have dedicated their lives to shaving seconds or even milliseconds off the previous record holder's time and become the fastest man on Earth. It wasn't until 1968, fifty six years later, that the record set was under 10 seconds. The current 100 m sprint record holder is Usain Bolt of Jamaica with a time of 9.58 seconds. Usain himself has set and beaten his own record three times. He first set the record in May 2008 with a time of 9.72 seconds then beat this in August 2008 with 9.69 seconds and exactly a year later set the current record.

Usain Bolt wins the 100 metres again in 2012.

It isn't just on the running track where humans try to set speed records, numerous attempts are made each year to break land speed records too. In 1898, the first official wheel driven land speed record was set by Frenchman Gaston de Chasseloup-Laubat with a speed of 63 km/h. This might seem a bit ridiculous nowadays, given that the speed limit in most towns is 50 km/h, but with the prehistoric vehicles of the time usually only travelling at 3 km/h, this record was really very fast. In 1906, American Fred Marriott was the first man to reach speeds of over 200 km/h and he used a steam powered car. By the 1940's, records were being set at speeds over 600 km/h. Around the 1960's, cars with jet propulsion engines started being used and these were able to reach much faster speeds. The first record was set by Craig Breedlove at 893 km/h and is currently held by Andy Green with a speed of 1227 km/h that he set in 1997.

A 1900 steam automobile in the Brighton to London veterans race, 2012.

Table Showing the Way Top Speeds have Changed in Motorcycle Land Speed Records Over the Years

Year	Speed (km/h)	Year	Speed (km/h)	Year	Speed (km/h)
1903	103	1932	244	1966	395
1907	219	1934	246	1970	410
1920	165	1935	256	1975	487
1923	174	1936	272	1978	509
1924	191	1937	279	1990	518
1926	195	1951	290	2006	564
1928	200	1955	297	2008	580
1929	207	1956	345	2009	591
1930	242	1962	361	2010	605

Note: The value in blue is an unofficial record.

These land speed records are also attempted in other types of vehicles including motorcycles, with the first record of this type set in 1903 at 103 km/h. In 1958, New Zealander Russel Wright set the record, reaching 297 km/h in Christchurch. The movie 'The World's Fastest Indian', focuses on another kiwi motorcycle fanatic Burt Munro, who also set land speed records but for motorcycles with smaller engine sizes. In his garage, Burt Munro modified his bike which had a previous world record speed of 89 km/h. In 1967, he reached speeds of 296 km/h, a record which still stands today. The current record for larger engine motorcycles was set by Rocky Robinson in 2010 at 605 km/h.

There are many more records for the worlds' fastest vehicles, ranging from radio controlled cars at 325 km/h, a wind powered car at 203 km/h, a human powered car at 133 km/h and even a manned rocket sled which runs on train tracks reaching 1017 km/h. Aircraft also have records from the very slow, a human powered craft that reached 44 km/h, to the very fast, an unmanned rocket which reached 21245 km/h. Going this fast is really very dangerous and many people have been seriously hurt or have died attempting to set speed records. However, if you are looking for a safer way to fill your need for speed, you could always try the world's fastest roller coaster in the United Arab Emirates which reaches 240 km/h, or even the Tower of Terror II in Dreamworld Australia which gets up to 160 km/h. Humans will always try to be the fastest and hold records but remember, speed is deadly and roller coasters, eating chillies or doing exercise, can give the same enjoyable chemical rush to your brain.

Mini-Biographies of Three Famous New Zealanders

John Britten

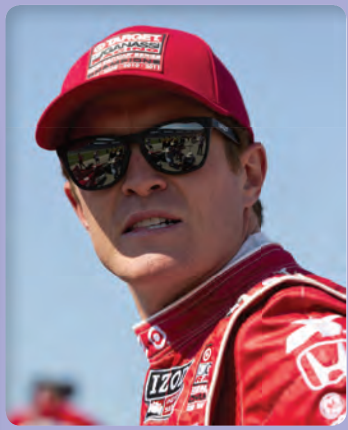
John Britten was born on the 1st of August, 1950 in Christchurch. He had a twin sister but they had different birthdates, this isn't what makes him a remarkable man but it is quite interesting. John was born just before midnight and his sister just after midnight and therefore on a different day, hence the different birthdates. He suffered from **dyslexia** and found school very hard. Despite these difficulties, he **persevered** and through the help of reader/writers, he graduated from university and became a successful engineer and architectural designer.

John Britten had a passion for motorcycles and spent many years designing and building **custom** machines with unique modifications. In 1992, he began manufacturing racing motorbikes through his company the Britten Motorcycle Company. His homemade bikes broke and set new world records in many big races. He surprised professional riders when the bike he made came second and third in an important American race. The bike he designed and produced had some radical innovations for its time. Many of his designs and ideas are now common place in racing bikes. Special features that his design included were:

- Carbon fibre body and some structural components.
- The radiator was under the rider's seat instead of under the handle bars near the front of the engine.
- The **chassis** had no frame and used the engine as structural support.
- The engine had computers that recorded data from rides.

Motorcycle legend Bruce Anstey on a Britten V1000.

His company produced and sold only a few of these motorbikes and they are now located in private collections or museums all over the world. Te Papa in Wellington has one of the 10 Britten V1000 motorcycles on permanent display. Unfortunately this 'can-do kiwi' died in 1995 at the age of 45 due to illnesses related to skin cancer. He truly was a motorcycle engineering pioneer who revolutionised motorbike design.



Scott Dixon

The IndyCar Series is a season of car racing on a variety of track types and shapes mainly in USA. It is a set of races that use **single seat open cockpit** cars that have been recorded reaching speeds as high as 378 km/h. Racers gain points throughout the season and the top scorer at the end receives $1 million US dollars as a bonus prize (approximately $1.4 million NZ dollars). The most famous part of the IndyCar Series is the Indianapolis 500 which is a race around a 2.5 mile (4 km) oval circuit. Drivers cover 500 miles (804 km) which is 200 laps. In this race alone, the first place getter receives over $2.5 million US dollars ($3.4 million NZ dollars). Australia born New Zealander Scott Dixon has won the IndyCar Series three times and the Indianapolis 500 once.

Dixon started racing karts at the age of seven and saloon cars at 13, for which he had to be granted a special licence as he was too young to drive legally. He has raced many different types of cars and after winning many New Zealand competitions, he moved to Australia. This allowed him to build on his skills and he soon became one of the top drivers in the Australian Formula Holden series.

Motorsport is expensive and his career was initially funded by a private businessman but with the move to Australia, came huge costs and a shareholder company was set up to pay his way. Once he decided that IndyCar was the best category for him to race in, he had to shift to America. This happened in 1999 and at the age of 19, Dixon was signed to an Indy motorsport team. He has gone on to be a **formidable** racer and now lives in the United States with his wife and two daughters. Due to his sporting excellence, he has won the New Zealand Sportsman of The Year award twice and in 2012 was appointed a member of the New Zealand Order of Merit which recognises his amazing contribution to motor racing. He has also won two important motorsport trophies multiple times; the Jim Clark Trophy three times and the Bruce McLaren Trophy twice.

Bruce McLaren

Bruce McLaren was born in Auckland in 1937. He was interested in cars and racing from an early age. Bruce entered his first race at age 16 and showed a natural talent for driving. From there he entered many more races throughout New Zealand and modified his own cars to improve their performance. He competed in the New Zealand Grand Prix in 1958 and for his outstanding performance, he was given a scholarship to race overseas. This gave him exposure to world class racing all year round. From this, he moved onto racing in the Formula One competition. This sport involves a series of Grand Prix races held in some of the most **luxurious** locations in the world. It uses the best technology available and the Formula One cars are said to be the most advanced motor vehicles on the planet. The 'Formula' refers to a set of rules the cars must follow in their structure and materials . It is a very wealthy sport and the high-tech state of the art cars can cost over $2.6 million US dollars ($3.5 million NZ dollars) in materials. Formula One is often criticised for being unfair because the richest team always wins since they can afford the best cars. Some people see it more as a money race than a race of driving skill.

Bruce McLaren was a promising young driver who, in his first year racing, won the 1959 United States Grand Prix. Not only did McLaren drive the cars but during his career he also built cars, made modifications, analysed data and managed his own team (initially called Bruce McLaren Racing Ltd). An example of his engineering brilliance is when he was out driving, he saw that the door which covered the fuel hole was flapping and he realised this movement was affecting the **aerodynamics** of the car. He then used a pair of metal shears to cut two holes in the body of the car, creating air flow and instantly stopping the flapping. He then continued to drive and his lap times were faster. These holes are found on all McLaren team cars to this day and are called 'nostrils' . In 1970, at the young age of 32, he tragically died after a catastrophic crash while testing a newly modified car in England. His name lives on in the McLaren Racing Group which is based in Britain. This team is the second oldest team behind Ferrari and is the most successful in Formula One history, with the most series wins ever; a great tribute to the amazing innovative man it is named after.

Research Project: Friction in Cars

Many parts of the car are designed to use friction in some way and other parts are designed to reduce friction and air resistance.

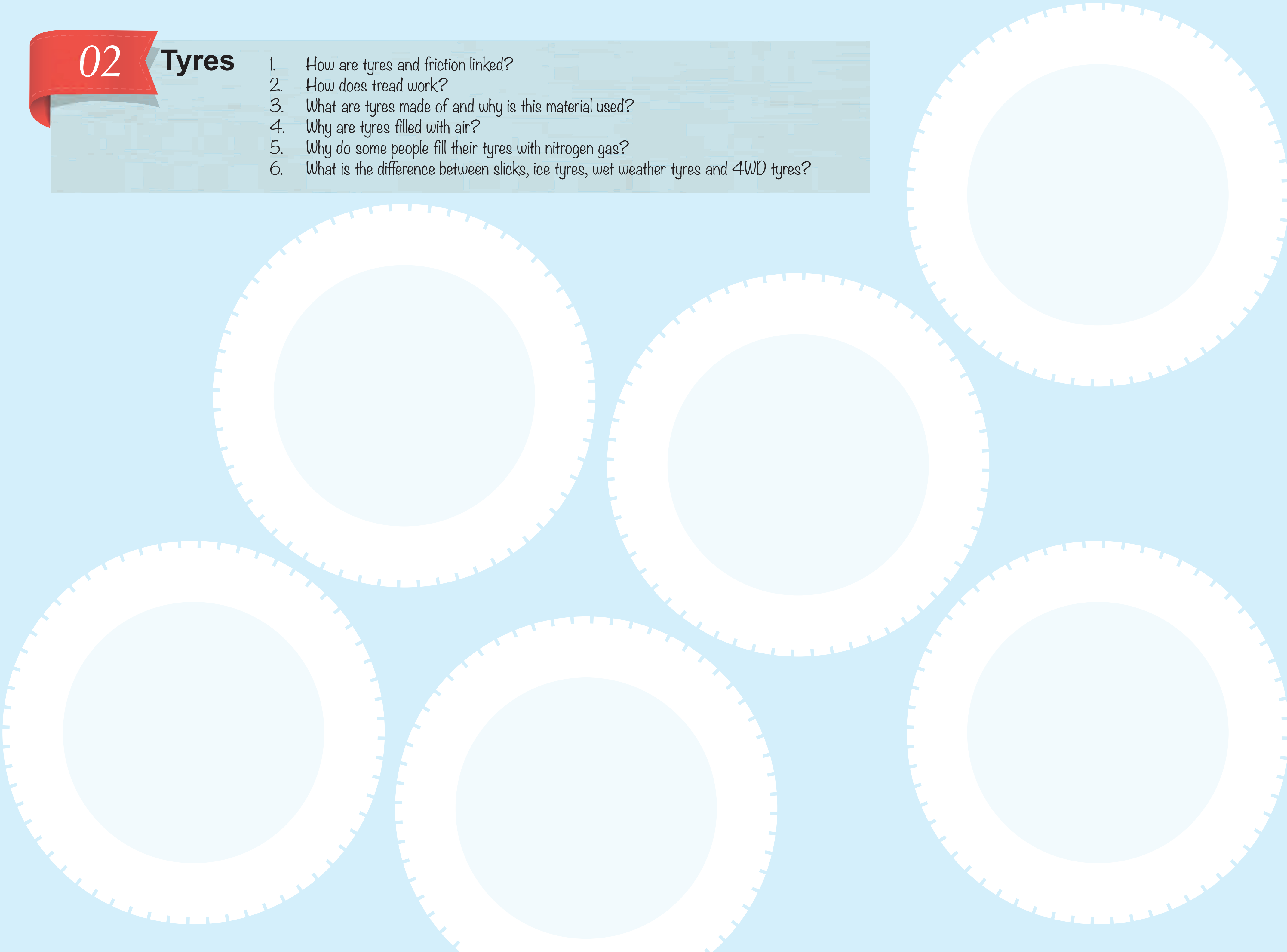
You need to investigate the following car components and find answers to the questions given as well as other interesting facts. Write the answers to the questions inside the car outlines and complete the references list.

01 Brakes

1. How are brakes and friction linked?
2. How do brakes work?
3. What are brake pads made of?
4. What different types of car brakes are there?

02 Tyres

1. How are tyres and friction linked?
2. How does tread work?
3. What are tyres made of and why is this material used?
4. Why are tyres filled with air?
5. Why do some people fill their tyres with nitrogen gas?
6. What is the difference between slicks, ice tyres, wet weather tyres and 4WD tyres?



03 The Clutch

1. How are the clutch and friction linked?
2. What does the clutch do?
3. How does a clutch work?

04 Wheels

1. Why are wheels round?
2. What role do bearings play in a wheel?
3. What link is there between wheel bearings and friction?

05 Oil in the Engine

1. What is the link between engine oil and friction?
2. What is engine oil made of?
3. How is engine oil made?
4. What happens if you don't have oil in your engine?

06 Spoilers & Body Kits

1. What is the link between spoilers, body kits & air resistance?
2. What are spoilers and body kits?
3. What is the function of a spoiler on a car?
4. What is the function of a body kit on a car?

07 Other Parts

1. What other parts of the car are related to friction or air resistance?
2. How do these work to either increase or decrease friction or air resistance?

References

List all the websites and books that you used to get your information below. Write the name and author of any books and the name of any websites and their web address.

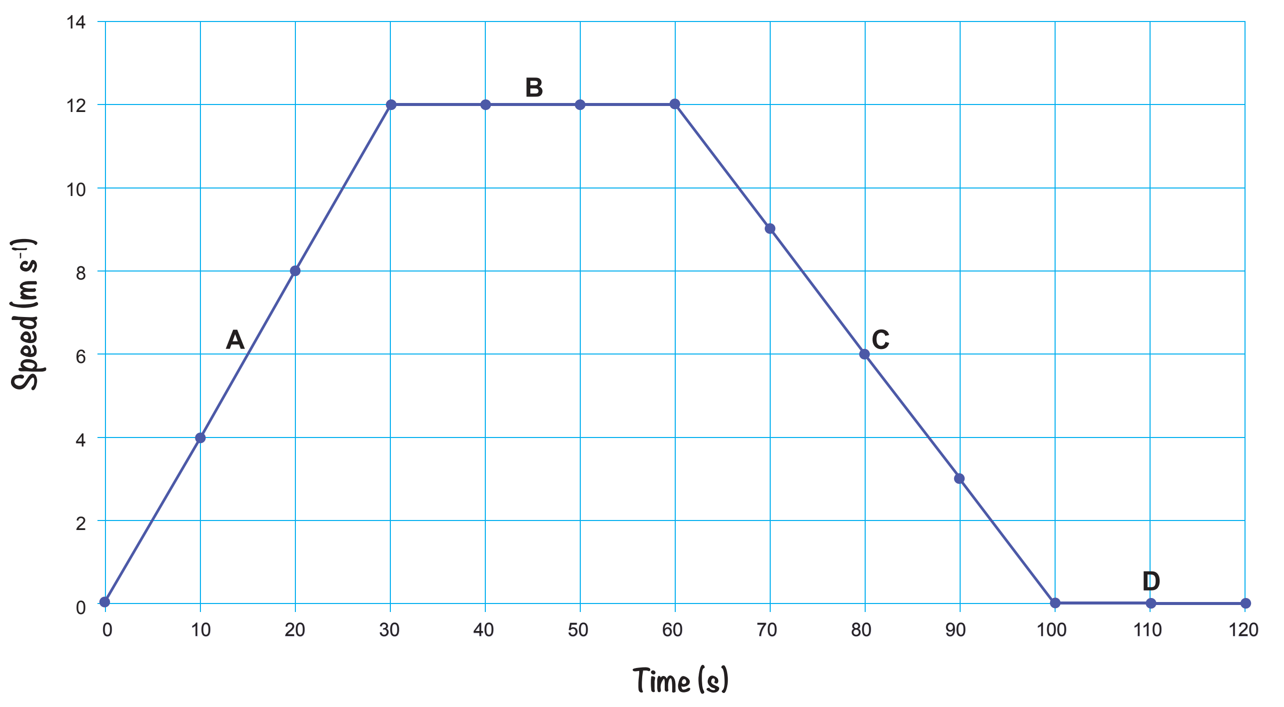
You may find the following websites useful but there are tonnes of others you can also use.

www.formula1-dictionary.net/
www.bbc.co.uk/education/clips/z462tfr
en.wikipedia.org/wiki/Tread
auto.howstuffworks.com/tire.htm
auto.howstuffworks.com/clutch.htm
www.theaa.com/motoring_advice/safety/filling-tyres-with-nitrogen.html

Thinking Questions

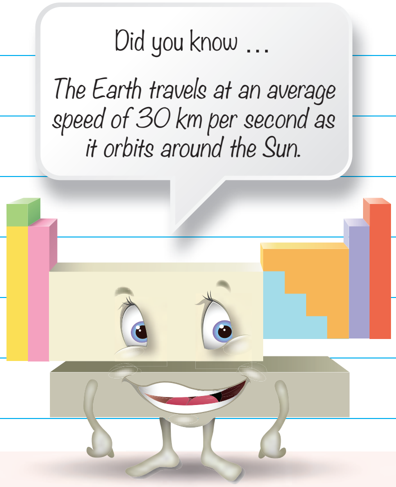
1. Sarah has a remote controlled toy car that she plays with in her parents' garden. The car has a top speed of 12 m s^{-1}. Sarah graphs her car's speed for her Science class and this graph is shown below.

Graph Showing Speed of a Remote Controlled Car Over Time



Explain the forces acting on the car at each stage (A-D) of its journey. Make sure you include the following in your answer:

- On the picture of the car add labelled arrows to show the 4 forces acting on it.
- Describe the motion of the toy car at each stage (A-D).
- Describe the forces as balanced or unbalanced at each stage (A-D).
- Describe the relative size of the forces at each stage (A-D), e.g. thrust is less than friction.
- Calculate how much the speed changes by at each stage (A-D).


Did you know …
The Earth travels at an average speed of 30 km per second as it orbits around the Sun.

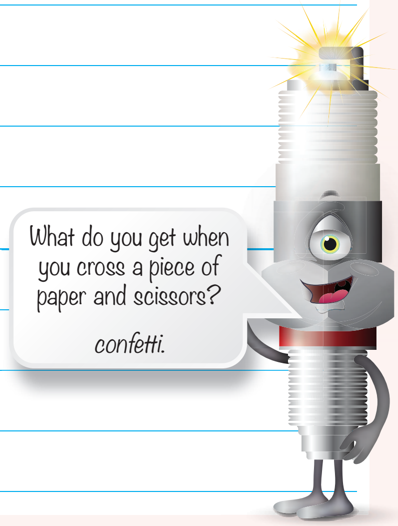
2. Humans use friction in many different ways. It can be very helpful or very harmful in sports.

   Below are 3 pictures of footwear worn in different sports. The sports that they are worn in are Skiing, Rugby and Basketball.

   These sports are played on different surfaces which include grass, wood and snow/ice.

Relate the bottom of the sporting footwear and the surface that they are used on to friction. Make sure you include the following in your answer:

- Match each shoe with the sport that it is worn in and the surface that it is played on.
- Describe whether the footwear is trying to reduce or increase friction.
- Explain how each piece of footwear uses friction.



Word Games

1. Terminology Tornado

Using the following science term, see how many words of 3 or more letters you can make in 10 minutes.

Points
3-4 letters = 1 point
5+ letters = 2 points

Scores
0-5 points = awful
6-10 = average
10+ = amazing

2. Six Word Scramble

Use the clues to work out what the 6 key science words are and then spell the word in the grid by colouring in the squares that make up the word. Use different colours for each answer.

GHT	LA	MET	LOC
IFT	WEI	ON	NC
CTI	VE	UPL	FRI
RES	ITY	BA	ED

Clues

a. The force between two surfaces that creates heat. (8) ____________
b. The force of gravity. (6) ____________
c. When the forces are equal, they are said to be … (8) ____________
d. Another word for speed. (8) ____________
e. The standard units for distance. (6) ____________
f. The force of air under a flying object. (6) ____________

3. Anagrams

Solve the anagrams below by unscrambling the words then draw a line between them and the correct definition. The answers are all only one word.

Anagram	Definition
RAIN TOASTY	When forces on an object are not equal they are …
BAD UNCLEAN	Opposes movement, e.g. air or water.
I FIT CORN	The force of water holding up a floating object.
AORTA LICENCE	When an object is not moving it is …
CRONE TV	Force between two touching moving objects.
CANE SISTER	Speeding up.
HUT SPURT	Changing from one type of units to another, e.g. cm ⟶ m.

4. Topic Word and Number Find

Colour Key	Clue	Answer
	Standard units for mass.	
	Standard units for width.	
	Standard units for time.	
	Standard units for temperature.	
	Standard units for volume.	
	Number of cm in a m.	
	Number of s in a minute.	
	d = 60 m t = 3 s v = ? m s^{-1}	
	d = 1 km t = 20 s v = ? m s^{-1}	
	d = ? m t = 1 minute v = 0.4 m s^{-1}	
	d = 88 m t = ? s v = 11 m s^{-1}	
	d = ? m t = 42 s v = 1.5 m s^{-1}	
	d = 6 m t = ? s v = 2 m s^{-1}	
	d = ? m t = 5 s v = 9 m s^{-1}	

S	L	S	E	T	H	R	O	U	H	E	M	I	U
T	F	E	E	C	G	X	I	Y	E	O	N	E	N
E	I	I	G	E	G	H	G	R	F	H	H	D	E
G	H	S	I	X	T	Y	T	H	R	E	E	G	H
T	E	G	H	D	K	I	L	O	G	R	A	M	U
O	H	E	U	H	L	D	E	D	D	G	R	E	N
T	U	R	U	O	F	Y	T	N	E	W	T	E	L
K	H	K	E	S	T	F	U	O	R	N	E	H	T
H	V	S	R	E	W	H	W	C	T	D	E	G	E
S	U	I	S	L	E	C	S	E	E	R	G	E	D
I	F	O	T	N	N	S	J	S	M	I	F	V	E
X	O	F	O	R	T	Y	F	I	V	E	F	G	T
T	U	S	F	H	Y	R	T	H	J	K	A	D	I
Y	T	F	I	F	G	I	F	Y	R	U	O	F	K