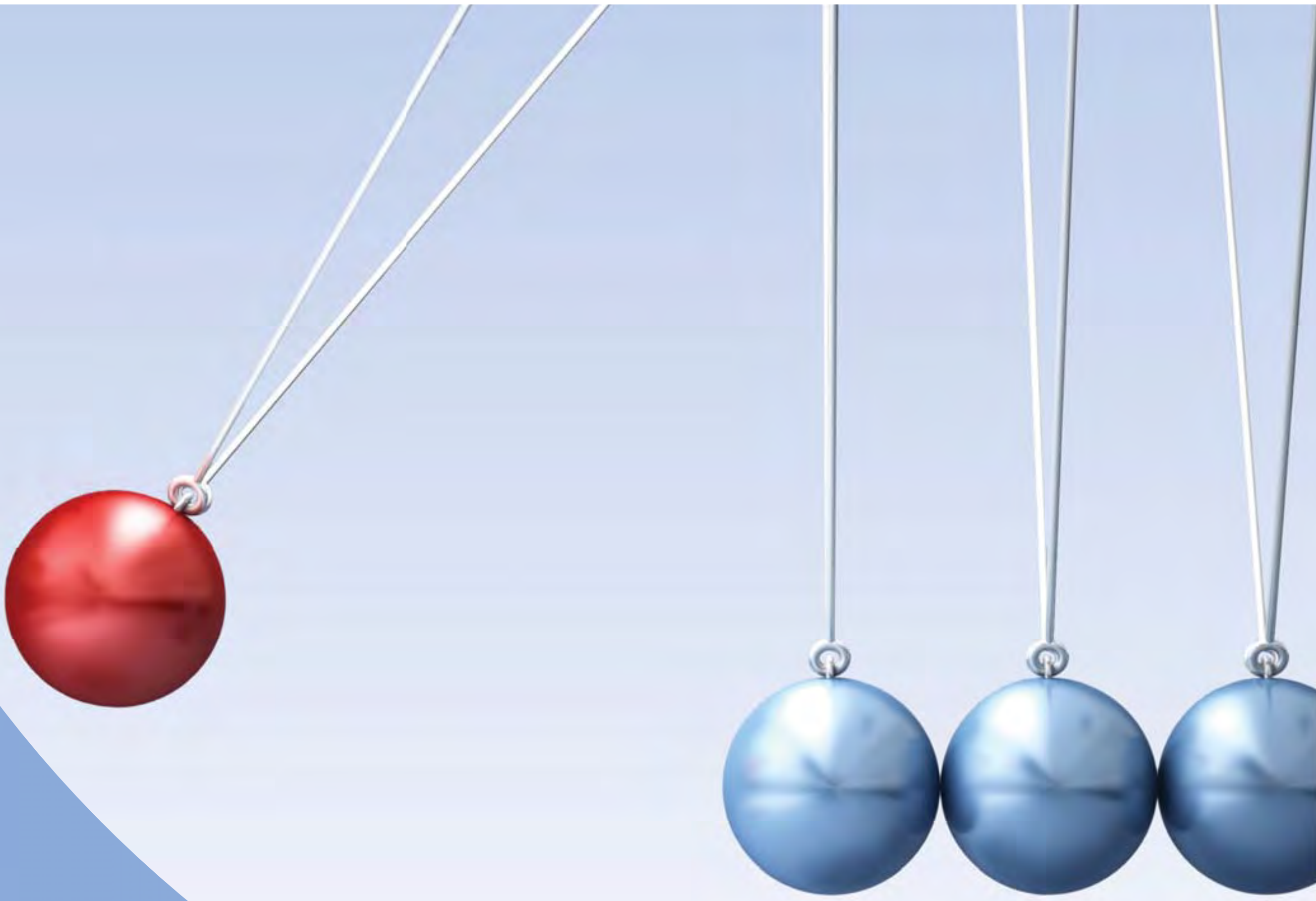
Name:

Junior Science

Forces and Energy

Downloadable Resource



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How an Apple Changed the World

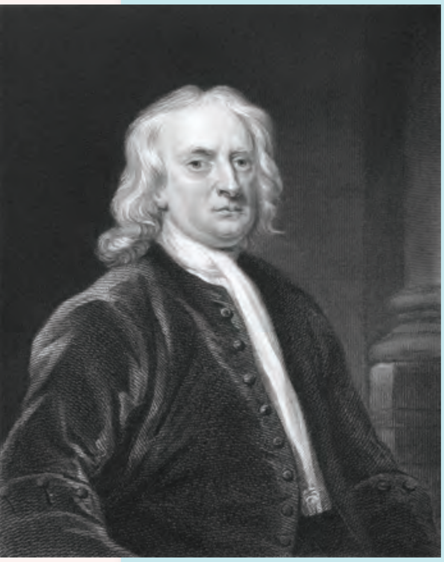
In the late 1600s a man was walking with a friend observing the world around him. He noticed an apple on a nearby tree fall to the ground and from this commonplace event he made two key observations that changed science for ever. Firstly, since it sped up before it hit the ground, there must be something constantly pulling on the apple to make it **accelerate** towards the Earth. He also thought that the apples at the very top of the tree must be experiencing the same force acting on them and perhaps even higher objects than that, maybe even as high up as the Moon.

At the time, the man was very interested in studying the planets and stars and had been **postulating** ideas about the subject for many years. He called this force '**gravitas**' which eventually became known as **gravity**. This man was Isaac Newton and he proposed numerous laws that now underpin modern physics. Many people had seen apples and other objects falling, so this definitely wasn't a new sight. However, Newton was the first person to ask *why* and then attempt to explain what was happening.

It isn't clear whether the apple account actually occurred or not. Over time it has become a story about Newton sitting under an apple tree when an apple fell on his head and in a '**eureka**' **moment** he had the idea of gravity. The version generally accepted is the original one and this is supported by the quotes below taken from the royal society paper written by William Stukeley.

*"Amid other **discourse**, he told me, he was just in the same situation, as when formerly the notion of gravitation came into his mind. Why sh[oul]d that apple always descend **perpendicularly** to the ground, thought he to himself; occasion'd by the fall of an apple, as he sat in **contemplative** mood."*

"Why sh[oul]d it not go sideways, or upwards? But constantly to the Earth's centre? Assuredly the reason is, that the Earth draws it. There must be a drawing power in matter. And the sum of the drawing power in the matter of the Earth must be in the Earth's centre, not in any side of the Earth."



One of Newton's laws is the Law of Universal Gravitation, which states that two objects will attract each other with a force that is relative to their size and their distance apart. This idea wasn't actually tested until over a hundred years later when the gravitational attraction between heavy balls of different size was measured. These measurements gave the force of gravity acting between the balls. There is even a gravitational attraction between you and other everyday objects but it is so small, it is difficult to measure. If at least one of the objects involved is very large then there will be a significant pull. For instance, the massive size of the sun holds several planets, moons and other **astronomical bodies** around it. Similarly, the Earth, because of its size, pulls all near objects towards it which is why things fall to the ground when dropped and not to one side or upwards. If falling objects were to move in other directions that would require additional forces to be applied momentarily or continuously in those directions as well.

Isaac Newton was born on Christmas day 1642 in England. He lived with his grandmother after his widowed mother was remarried to his step-father whom he disliked. He went to Kings School and studied Latin and finished there as one the school's top students. He tried farming when his mother became a widow for the second time. He had no interest in agriculture and did not enjoy this work. He later attended Cambridge University and studied for a Bachelor of Arts degree and while there developed a mathematics theory that later became **calculus** (a kind of mathematics that deals with the study of change using **infinitesimals**). While at college, he studied religion and philosophy but at home he focussed on mathematics, **optics** and gravitation.

During his studies, he was **prone** to arguments around the **authenticity** of his work and he had disagreements with other scientists such as Leibniz, Duillier and Hooke. Because Newton took the ideas of others and linked them, expanded on them, disproved them and built laws around them, he inevitably upset people and caused a lot of **controversy**.

In 1701 Newton became the Master of the Mint. The Mint was the organisation responsible for producing money and coins. He felt that there were too many fake coins being produced, so took it upon himself to personally find and punish the **counterfeiters** responsible for the fake coins. The punishment of the time for counterfeiting was to be hung, drawn and quartered. He went undercover in the many pubs of London and found evidence to prosecute 28 'coiners' as they were called.

He was also a keen **alchemist** with a passion for studying metals, their properties and even finding ways of turning lead into gold. This is believed to have led to his death. In 1926 he died in his sleep of unknown causes but later tests conducted on his hair showed the presence of the metal mercury. Mercury poisoning damages the lungs, brain and kidneys and can cause a person to act in an odd manner, which is how Newton is believed to have behaved in his later life.

Sir Isaac Newton is one of the best known and most innovative scientists of all time. He is responsible for the advancement of both maths and science and his contribution to many of our modern scientific understandings is **unsurpassed**.

Joule in the Crown

Energy is measured in joules, in honour of the English physicist and brewer James Joule. He spent much of his life studying heat and famously made the link between mechanical work - the act of doing something and the production of heat as a by-product. Joule's father was a wealthy and famous brewer of beer. Due to his wealth he was able to pay for James to be tutored by a famous scientist called John Dalton. Dalton was famous due to his studies of the structure of atoms and his research into colour blindness. As an adult James managed his father's brewery, all the while carrying out experiments on electric motors and the amount of heat that they produced. His idea, that much of the energy produced in an electric motor was lost as heat, was not readily accepted. This was because he wasn't a scientist nor was he studying at University (he conducted his experiments at his home and in the brewery). Also, the theory of heat at the time (which Joule was disproving) had been proposed by a respected, established scientist. This meant that he had to work extra long and hard to prove to the scientific community that his ideas were correct. Even though atoms and molecules were not yet understood, Joule proposed that heat was due to the movement (kinetic energy) of particles, an idea that is now readily accepted.

Joule worked closely with Lord Kelvin (another famous mathematical physicist and engineer) and together they even attempted an experiment on Joule's honeymoon. They looked at whether the temperature at the bottom of a waterfall was greater than that at the top. The experiment was unsuccessful due to the water breaking up into fine spray. The two men worked together for many years with Joule conducting experiments and sending his results to Kelvin for analysis and interpretation. They developed the absolute scale of temperature which includes absolute zero a temperature determined to be -273.15°C. Based on the International System of Units (SI Units) the symbol for joule is a capital J, as it comes from a person's name. However the word joule (in reference to the name of the unit) is spelt with a lower case j.

1 joule of energy is equal to...
- The electricity needed to light a 1 Watt LED bulb for 1 second.
- The heat needed to raise the temperature of 1 g of water by 0.24°C.
- The amount of energy released as heat by a resting person every 60th of a second.

There are two scientific ideas known as Joule's Laws that he established. The first relates to the equation $Q = I^2.R.t$ which means that the amount of heat produced (Q) is related to the amount of electric current (I), the resistance in the object (R) and the time the current runs for (t). The more current, resistance and longer it is run, the more heat produced.

The second law of Joule's states that the internal energy of a gas does not change if volume and pressure change but it does change if temperature changes. This means that the amount of energy in a gas only changes if the gas is heated or cooled. If the gas is heated ,the amount of energy within the gas increases and if it is cooled it decreases.

Joule won many awards and was bestowed many honours for his great work on heat and the development of his theories around the relationship between work and heat. His work also lead to the development of the Law of Conservation of Energy and our modern understanding of how energy is transformed.

Joule died in his home on 11th October 1889 at the age of 70. He left behind a lasting scientific legacy and his family's brewery still exists today.

Roller Coasters

It is thought that the oldest roller coaster type rides have their origin in Russia and date back to the 1800s. They were sleds supported with wooden **struts** that ran down steep slopes made of ice. These 'Russian Mountains' weren't really able to be used in many other countries as they needed a very cold climate to make and keep the ice frozen. In France they attempted to make these ice slopes but it was too warm, so instead they developed wooden rails that a waxed bottomed sled slid down (similar to a bobsled). In 1885, LaMarcus Adna Thompson was granted a **patent** for the first wooden roller coaster. The basic design hasn't changed hugely since the first coaster opened in New York in 1884, where a specially designed car full of safety features such as harnesses and safety bars travels along a specialised rail track made of many twists, turns, loops and drops. Thompson based his design on a gravity powered railway that delivered coal down a hill. The railway was designed for coal but became a tourist attraction when the owners started charging people to have a ride. His roller coaster was a 180 m long one way track, where passengers boarded rolling benches at the top of a slope and travelled down then up the other side where they stopped got off and boarded a different car on a return set of tracks. This was not a very efficient model and so it was quickly changed to a full circuit oval track. Thompson also held the **patent** for tunnels with different scenes that the coasters ran through such as those found in the Goldrush ride at Rainbow's End.

In the early 1900s John Miller **patented** a unique type of wheel that meant roller coasters could go faster and twist and turn more without the cars jumping off the tracks. These wheels are actually composed of three sets of wheels that clamp the cars to the tracks. This allows modern day coasters to do loops and hang passengers upside down in mid-air.

People love to ride roller coasters because the speeds and angles are always changing rapidly which gives us a unique experience and thrill. Roller coasters are designed to use **acceleration**, **inertia** and gravity to provide this body buzz. Inertia is an object's tendency to either stay still or keep moving at a constant speed in a straight line. These two scenarios can only be changed by a net force. Your body also has its own inertia inside a roller coaster car. When the coaster turns suddenly your body tries to carry on straight but is pushed or pulled so that you travel with the car. As a roller coaster travels along a curved track it is also forced to go round when it wants to go straight. In both cases the force which makes objects travel a curved path is an inwards force called centripetal force. The tendency to go in a straight line (inertia) is what makes us feel like we are being thrown outwards from the car. Centripetal forces can be easily shown with a bucket of water being spun around and around. The water stays in the bottom of the bucket and doesn't fall out because it is constantly trying to go in a straight line but is being pulled off the straight line direction by the base of the bucket which is already going around a curved path.

Formula Rossa

Most roller coasters use basic energy transformations to move them and produce a thrilling ride. As they don't contain engines to drive them along, they have to be given an initial amount of energy to get them going. One method, common to older roller coasters is to winch them up to the top of the first slope. This gives the coaster a large amount of **gravitational potential energy** and when released, this is transformed into enough **kinetic energy** to get the coaster up the next slope and so on. Another method is to use a **launch system** which involves **hydraulics** (pressurised liquids) or pressurised air or an electric motor. These all give the roller coaster a massive push and enough energy to take it up the first slope. From there, **gravitational potential energy** transforms into **kinetic energy**, allowing the ride to continue. Because the wheels of the roller coaster cars have axles and are touching the track as they travel along, there will be **friction**. This means some of the gravitational potential energy is converted to heat and this is why there is less kinetic to carry to the top of the next slope, which therefore has to be lower than the top of the first slope. If a roller coaster is well designed and friction and **wind resistance** are kept to a minimum, the cars will have enough **energy** to complete a long run without stopping.

There are hundreds of roller coasters throughout the world with a wide range of heights, speeds, lengths and number of loops. They provide thrills to millions of people each year. The top five fastest roller coasters are shown below to give a comparison with New Zealand's Rainbow's End roller coaster.

Rank	Name	Country	Top Speed	Height	Launch Type
1st	Formula Rossa	United Arab Emirates	240 km/h	52 m	hydraulic
2nd	Kingda Ka	USA	206 km/h	139 m	hydraulic
3rd	Top Thrill Dragster	USA	190 km/h	130 m	hydraulic
4th	Dodonpa	Japan	172 km/h	52 m	air pressure
5th =	Superman: Escape From Krypton	USA	160 km/h	126 m	motor
5th =	Tower of Terror II	Australia	160 km/h	115 m	motor
n/a	Corkscrew Coaster	Auckland	70 km/h	27 m	chain winch

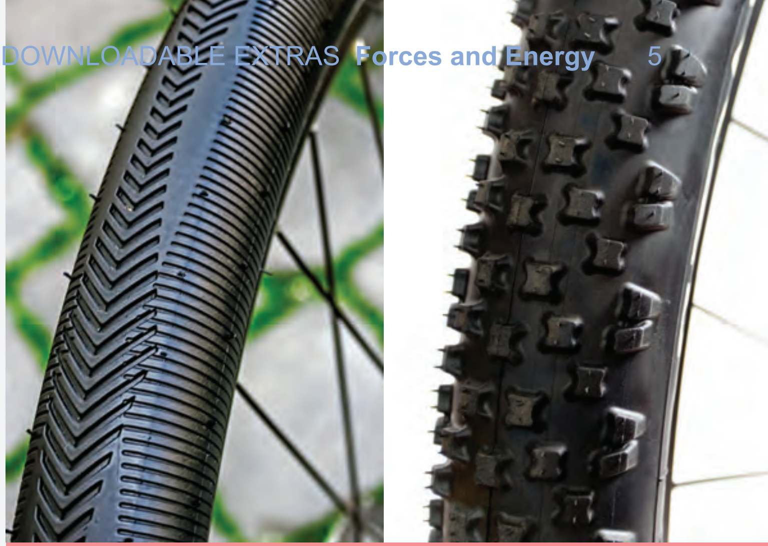
Data courtesy of Duane Marden, rcdb.com.

There are many features deliberately built into roller coasters to create a thrilling and exciting ride. The twists, turns and sudden drops have been carefully placed and designed to give your body the different sensations you experience on a roller coaster. Fear and the unexpected movements cause a rush of **adrenaline** and make us feel pumped full of energy. Many of our organs and body parts are being pulled, pushed, tugged and squashed in different directions by various forces. Gravity and acceleration are used in a controlled way to produce excitement through the extreme stimulation of our senses.

Thinking Question

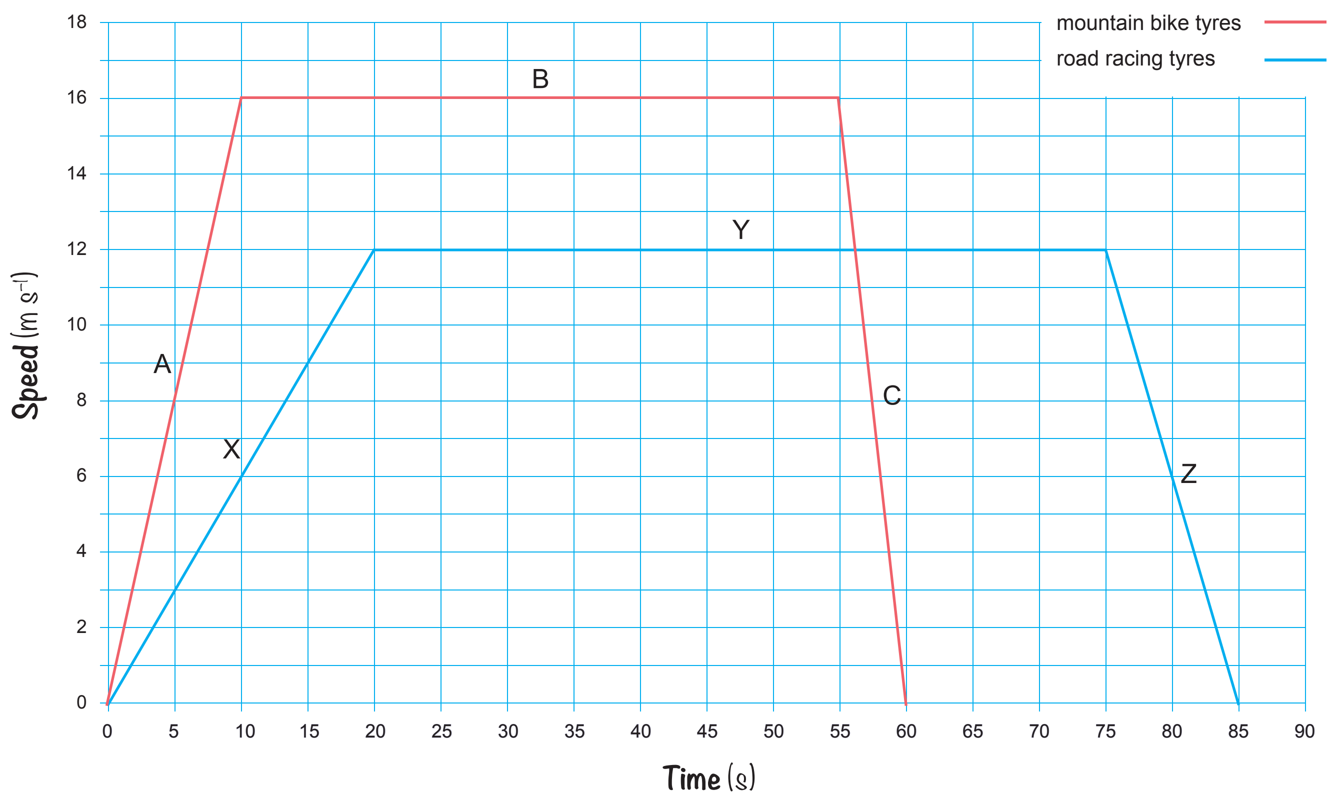
The pictures opposite show two different types of tyres. One is from a mountain bike and the other is from a road racing bike.

John and Tim have identical bikes except that John's bike has mountain bike tyres while Tim's bike has road racing tyres. They decide to test the performance of the two types of tyres by measuring the progress of the bikes around an 840 m muddy grass track they have marked out. John attaches his phone to each of the bikes in turn because it has an app which will record speed and time. To make it a fair test Tim does the riding of both bikes. From the phone app they obtain the speed time graph shown below.



road racing tyre | mountain bike tyre

Speed-Time Graph Showing an 840 m Bike Ride Using Two Different Types of Tyres



Section **A** = 0 to 10 Seconds
Section **X** = 0 to 20 Seconds

Section **B** = 10 to 55 Seconds
Section **Y** = 20 to 75 Seconds

Section **C** = 55 to 60 Seconds
Section **Z** = 75 to 85 Seconds

1. On the picture opposite of an **accelerating** cyclist, **sketch labelled arrows** to show the direction and relative size of the **four** forces acting on rider plus bike.

2. Explain the step that the boys took to make it a fair test.

3. Describe and compare the motion of each bike in the following sections of the graph:

Section A and X:

Section B and Y:

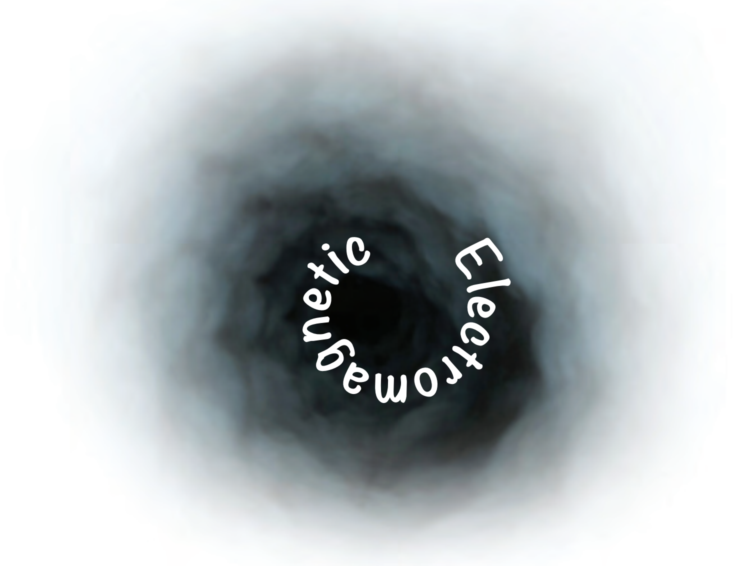
Section C and Z:

4. Discuss **why** the two graph lines are different in size and slope.

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.

RCE	CT	AVI	KI
ION	SO	POTE	GR
NET	NTI	UND	AL
FO	FRI	TY	IC

Clues

a. The force between two surfaces that creates heat. (8) ____________ ☐
b. The force pulling objects towards Earth. (7) ____________ ☐
c. Energy of particles being compressed in waves. (5) ____________ ☐
d. Movement energy. (7) ____________ ☐
e. Energy that is said to be stored, e.g. chemical. (8) ____________ ☐
f. Described as a push or pull. (5) ____________ ☐

3. Block Buster

Cross out each of the words that fit with one of the clues. You will be left with one word that doesn't fit; this is your answer.

cold is denser | sugar | poles | provides grip | petrol | iron
compound bonds | steel | lubricant | convection | car brakes | tyre tread
rock on a cliff | surfaces rubbing | conduction | field lines | nuclear | repel
speed | spring | temperature | heat made | radiation | attract

Clues

a. Associated with magnets.
b. Associated with friction.
c. Associated with heat.
d. Examples of potential energy.

Answer

____

4. Topic Word Find

The following word find contains…

- 8 energy types
- 6 forces
- 3 SI units

Find each of these in the word find below then write their names in the correct column in the table that follows.

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

Energy Types	Forces	SI Units