The New Way Things Work Study Guide

The New Way Things Work by David Macaulay

Contents

Plot Summary

The New Way Things Work by David Macaulay is an illustrated book covering various topics in the categories of technology and mechanics. The book consists of four parts each of which which summarize a different aspect of mechanical science: simple machines, natural forces, light and sound waves, and electricity. The fifth section introduces computer technology and digital communication. It differs in that it has no introduction but includes the epilogue. Humor and the detailed hand drawn illustrations are accompanied by blurbs of text that break the large concepts into digestible amounts of information. A glossary of technical terms appears at the end of the book for the reader's further clarification.

Throughout the book the information is presented from different perspectives ranging from first person fictional accounts, to third person technical explanations, to diagrams which walk the reader through a process step by step. All the approaches compliment the central subject of that section to offer the reader various and diverse paths to understanding the information.

The first person accounts, narrated by a fictional inventor, appear throughout the book with a consistent font and illustrated earth tone cartoon background. The stories feature the inventor, his primitive but innovative and industrious people, and their domesticated woolly mammoths. These sections are the most narrative and sit above text that explains the technology or system being illustrated by the narrative. The technological text will include one or more clearly labeled diagrams illustrating the simple mechanics being demonstrated in the humorous mammoth story above.

Once a concept has been introduced, the author will spend several pages exploring instances where the mechanical concept is used.

Part One, Mechanics of Movement, covers different laws and properties of motion as they work in the simple machines that are the basis of all mechanical devices. Part Two, Harnessing the Elements, explores how the way in which molecules behave will effect the way a machine works. Part Three, Working With Waves, looks into the way in which waves of energy power everyday objects and extend the reach of our senses. Part Four, Electricity and Automation, introduces electrons, discusses machines which either produce or use electricity, and covers what happens when electricity is combined with movement.

Part Five is the final section on concepts and is an introduction to digital machines and systems. Entitled The Digital Domain & The Last Mammoth, it has a different structure from the previous sections. Instead of an introduction, it opens with a full cover mammoth story which introduces the concept of bits and binary code with a pumpkin metaphor. This is the only section which divides into designated chapters as opposed to subheadings. It includes a one page epilogue which gives conclusion to the mammoth story which has been used as a running illustration through the book.

The section following Part 5 is simply entitled "Eureka" and is an illustrated list of inventions categorized under the concepts they employ, and listed in the same order as they are introduced in the first five sections. A glossary of Technical Terms and an index make up the remainder of the book.

Part 1, The Mechanics of Movement

Part 1, The Mechanics of Movement Summary and Analysis

The Way Things Work by David Macaulay is an accessible guide to the workings of machines. The conservation of energy is the scientific principle which underlies or is involved in every machine. Mechanical, chemical, and nuclear energy make up the foundation of this book's text; however, the vast amounts of scientific explanation are supported with humor, diagrams, illustrations, and the observation of simple everyday tools.

Part One, The Mechanics of Movement, states that to understand the way things work, one needs to understand the underlying principles. The principle behind the action of any machine is the conservation of energy which is not, as the author points out, about saving energy. The principle of the conservation of energy states that energy is neither created nor destroyed. The Mechanics of Movement explores this principle as it plays into movement, force, and effort. A driving force will initiate movement which a machine can then convert into a force appropriate for the task at hand. The force, neither created nor destroyed, may be concentrated or dispersed by the movement to result in a greater or lesser force. Three forces hold things together and these are gravity, electricity, and nuclear power.

The simple machines introduced in Part One are governed by a law of physics which states that work is composed of the effort you put in and the distance over which the effort is done. Effort multiplied by distance equals the work done, so no matter how you approach the task, the same amount of work is accomplished. If you want to accomplish the work with half the effort, you must use twice the distance. The inclined plane extends the distance to a rise. By exerting your strength across a longer distance, your effort is reduced and your lesser strength becomes sufficient.

The wedge is the most common form of inclined plane found in machines. Rather than moving an object up the inclined plane, however, the wedge moves the plane itself to raise an object. The plane's greater distance means the object is lifted with greater force. The author uses the example of a door wedge which, as it slightly raises the door, creates a greater force which exerts friction and that, in turn, grips the floor to hold the door in place. Cutting machines almost always involve the wedge. The sharp tapered edge of axes, scissor blades, knives and razors are all wedges. A plow is a wedge which cuts through the soil. A zipper uses a triangular wedge to force the teeth apart, while using two lower curved wedges to push the teeth back together.

Levers are made up of a straight edge, such as a rod or bar, placed over a pivot point called a fulcrum. At one point on the lever a force called effort is applied. The lever moves to raise or overcome a weight or a resisting force called load. Again, there is a relationship between force and distance. The longer the distance, the less force required. In First-Class levers the effort and the load are equal distances from the fulcrum. In a Second-Class Lever the fulcrum sits at one end of the bar, the effort is applied to the opposite end, and the load sits somewhere between the two. The closer the load is to the fulcrum, the easier it is to lift the load, however the less distance the load will move. Increasing the distance between the fulcrum and the effort will also decrease the amount of effort needed. Second-Class levers can be used to increase lifting or pressing force. An example of a Second-Class lever for pressing would be a nutcracker. Third-Class Levers also have the fulcrum at one end; the position of the load and the effort are reversed from their positions in the Second-Class lever. The result is that the load travels a further distance with less force. Simple levers contain one fulcrum, a single point of effort and a single point of load. Compound levers still have a single fulcrum, but have two points of force and two points of load. Multiple levers are at work in machines that range from an excavator to a nail clipper.

The wheel and axle discussed here are not the wheels on a car or bike, which is how we usually think of wheels. The wheel and axle discussed here transmit force, and they are found wherever there is rotary motion. Common hand tools such as the screwdriver, hand drill and wrench all turn around a central point, creating an amplified force at that axle point.

Gears and belts are best understood with the help of the author's illustrations. The impact which a big wheel places on a smaller one, as well as variations in effect which belts can achieve are all drawn out on page 36 in terms of mammoth pulled Merry-Go-Rounds. If the edges of the two wheels touch, the rotation of one will cause the other to rotate. The axle of both of the wheels or gears will turn at an equal speed, but since the distance around the outside edge of the larger wheel is longer, the edge of the larger wheel will move faster. The greater the size difference, the greater the difference in the speed, and the greater the force produced. Two interlocking gears will rotate in opposite directions of each other, rotation in the same direction can be accomplished with a belt which wraps around two wheels or gears and pulls them in the same rotational direction.

There are four basic types of gears. Spur gears inter-mesh in the same plane and reverse the direction of rotation. Rack and pinion gears mesh the teeth of the pinion gear to a toothed rack. This changes rotary motion into a lateral back and forth motion. Worm gears have a threaded shaft which intersects with a toothed wheel. This changes the rotation by a right angle. Bevel gears meet at an angle resulting in a change of rotation opposite in both angle and direction from the first gear. Again, the author's illustrations on page 37 use labeled diagrams with arrows to best illustrate the movement of each of these gears. The size of the gear controls the movement. A larger wheel moves with greater force while a smaller wheel moves more quickly.

A cam is a fixed wheel with one or more projections on its edge. As the wheel turns, the projection pushes an object such as a rod, rocker or spring which opens or closes a latch or valve. The camshaft in a car engine is an example of cams turning to press a spring and open a valve, in this case to admit fuel or expel exhaust.

Cranks are a wheel and rod attached by a hinge. The hinge is attached, on one end, to a pivot point on the wheel and, on the other, to a pivot point on the rod. As the rod moves, the wheel turns.

Pulleys work because it is easier to pull something down than it is to pull it up. A load that needs to be lifted can be roped to a pulley. The force of a downward pull then reverses into an upward pull as the rope passes over a fixed wheel. The load can rise to the height of the wheel. A single pulley consists of one rope and one fixed wheel. The body weight of the person pulling counters the weight of the load rather than adding to it. Connecting pulleys can amplify the force of the person pulling. The amplification of force depends on how many pulleys are used. Many common lifting devices such as hoists, cranes, elevators and escalators operate on pulley systems.

A screw is actually an inclined plane wrapped around a cylinder. The spiral ramp creates the threads. Screws are usually used as wedges producing a strong force to hold objects together. Drills are one form of screw, and an auger is a screw which pulls out the dirt it cuts through on its wide threads. On page 68 the author gives the reader a diagram of a Combine Harvester which employs multiple screws and augers as well as many of the other mechanisms discussed earlier in Part One.

The book returns to wheels on page 70 and discusses three properties of rotating wheels: precession, inertia, and centrifugal force. Precession refers to the tendency of a rotating wheel to pull the axle to a right angle. This pull actually helps a rolling wheel stay upright, and the faster the wheel spins, the stronger the precession. Inertia is the resistance of an object to any change in its speed. The greater the weight of an object, the greater its inertia is. It is difficult to make a heavy object go from a dead stop into motion, and it is also difficult to stop that object once it is in motion. Inertia resists changing speed and direction, so when moving in a circular path, the object will place its force into moving straight, or away from the center. This is called centrifugal force and is usually used to throw objects outward, such as when water is expelled from the spinning clothes in a spin dryer.

Springs have two shapes and three main purposes, but in every case a spring's nature is to retain its shape. So the main purpose springs serve is to return things to their previous position, to measure force or weight by the amount they extend, and to store energy. When a spring is extended or contracted, it has a force driving it to return it to its original shape and/or position. If it is held back from returning, this energy will remain stored in the spring. In normal circumstances molecules have an attracting force and a repelling force which work together. The balance between these two forces keeps molecules a certain distance apart. When squeezed or stretched, the molecules will be driven to return to that distance.

Friction is a factor in all machines. It is the result of the same property found in springs. When two surfaces come together, the molecules in both surfaces want to pull together. Friction will divert energy away from work into heat and sound. In some cases the friction is necessary, such as tires or brakes. It is the friction of the air against the parachute which keeps the jumper from crashing from the sky. Engineers work to reduce the friction by using lubricants, streamlining or ball bearings. No measures can remove friction completely and so, without a constant source of fuel or electricity, all machines will eventually lose the energy needed to move. Only in outer space, where there is no air present, is a machine freed from friction and capable of perpetual motion.

Part 2, Harnassing the Elements, Introduction, Floating, Flying and Pressure Power, pp.91-141

Part 2, Harnassing the Elements, Introduction, Floating, Flying and Pressure Power, pp.91-141 Summary and Analysis

The introduction to Harnessing the Elements discusses the Greek's belief in four elements: earth, air, water, and fire. We know now that elements number many more than four, and that earth, air, water and fire are each built on a combination of two or more elements. An element is a substance which contains only one type of atom. Atoms combine to build molecules and Part 2, Harnessing the Elements, is actually about harnessing molecules, or rather the forces created by the molecules' strong urges to huddle together or spread apart. The reader will remember that in Part 1, while studying springs, it was explained that under normal circumstances molecules have an attracting force and a repelling force. When squeezed or stretched beyond the boundaries of their comfortable balance, the molecules are driven to return to that balance. Part 2 is about exploiting the bonds or attraction and the movement or repelling of molecules to and from each other.

Floating harnesses this power in the form of upthrust. When an object is placed in water, the water molecules push against it. The force of the water pushing back is called upthrust. The amount of upthrust depends on how much water the object displaces. When the force of upthrust is equal to the weight of the object, the object will float. Density, the object's weight divided by its volume, is the factor which determines an object's ability to float. Objects with lower density (large and light in weight) have greater upthrust.

The density of water also changes. Salt water is denser than fresh water. Cold water is denser that warm water whose molecules are moving around more loosely. A ship will vary in density according to its load, so a plimsoll line, made up of different level marks for different types of water, is on the side of each ship. In this way a ship can measure its load so that its density will not exceed the force of upthrust in whatever type of water it sails.

Powered crafts move in or on the water by imparting movement into the air or water around them with a device such as a propeller. To control direction, a water craft will use a rudder. For sideways movements, thrusters and stabilizers are used. Thrusters are small propellers mounted sideways in the base of the ship's hull. Stabilizers are large fins which adjust their tilt to compensate for waves.

The propellers and rudders work on two major principles. The Principle of Action and Reaction is happening as the propeller pushes the water back (action) and as that same water which has been pushed back rolls forward again and hits the propeller (reaction). The Principle of Suction occurs when the curve of the blade creates a water flow which moves around the blade, with the faster movement occurring across the front. The speed across the front of the blade lowers the water pressure in the space ahead of the propeller. Molecules rushing to balance the pressure create a suction force which draws the propeller forward. The rudder operates with these same two principles.

Crafts with sails can use the sail for both propulsion and direction using the sail to catch the wind from different angles. A boat with two triangular sails, such as a yacht, can achieve two additional suction forces. The slot between the two sails splits the suction force into thrust or forward movement and heel or sideways tilt which combine to propel the yacht and direct its path forward.

Crafts which need to be able to sink as well as rise and float, such as submersibles and submarines, achieve this with ballasts. Ballasts are tanks that take in water to increase the density of the craft. The ballast can then expel water and the decreased pressure within the ballast tank forces the craft to rise to equalize the pressure.

Flying, like floating, uses the two principles of Action and Reaction and Suction. In flying, however, suction is referred to as lift. Kites depend on wind for their power, whereas all other forms of aircraft use the airfoil. The airfoil is a shape that divides the air as it passes through. A curved air flow passes over the surface while a straight current flows under the airfoil's surface. The curved air path creates a faster air flow above, and the lower air pressure below creates the suction force called lift.

Two separate pairs of opposing forces are at work in all aircraft. The first pair is lift created by the airfoil, which has to overcome weight from gravity. As the air pressure under the airfoil wing increases, it forces the wing upward with suction.

The second pair is thrust from inertia working against drag from friction against the surrounding air molecules. Inertia, first discussed in Part One, is the resistance of an object to any change in its speed or direction. In other words, an object in motion stays in motion. Thrust can also be created by a propeller.

Rotor blades are used in aircraft such as helicopters. Rotor blades revolve on a shaft which runs through two swashplates separated by a layer of bearings sometimes called ball bearings because of their shape. The bearings allow the swashplates to turn. Control columns beneath the lower swashplate can be used to tilt both swashplates. This, along with pitch control rods on the upper plate, controls the angle or pitch of the rotor blades. Through pitch, the blades can move the craft forward, backward, or vertically. The rotor blades also allow the craft to remain in a hover.

Part 2, Harnassing the Elements, Exploiting Heat, Nuclear Power, pp. 142-173

Part 2, Harnassing the Elements, Exploiting Heat, Nuclear Power, pp. 142-173 Summary and Analysis

Increasing heat increases the movement of molecules. Decreasing heat will slow the molecules down. Heat travels in three ways: in the form of rays (radiation), through solids with conduction, or from one liquid or gas molecule to another by convection.

Thermal Radiation is the transfer of heat through infrared rays. When the ray contacts the surface molecules, they speed up and heat is created. Conduction occurs because molecules which begin vibrating in a solid will speed up their vibration when heated. This causes the surrounding molecules to vibrate. The spread of increased movement spreads the heat. Convection occurs as heated molecules in liquids and gasses, which are already in movement, move even further apart causing expansion.

The sun emits both infrared and light rays. How these rays react to an object depends on what substance makes up the object. Rays will pass through some substances, be reflected off of others, or be absorbed into the substance. When an object absorbs the rays, the energy is held in the object as heat. Microwaves also work in this way.

Since a vacuum is an absence of substance, heat can not travel through it. This is how a thermos can keep cold liquids cold and hot liquids hot. The double walls enclose a vacuum. Heat will, however, travel through the insulated stopper since that can only slow the conduction of heat.

Combustion is what happens as something burns. It is the result of a collision of molecules which break on impact forming new and different molecules. Combustion machines harness the heat created in a reaction between a fuel and oxygen in the air. Oxygen will react with hydrogen, acetylene and other gaseous fuel. Explosives must contain one element which is the detonator and another reactive element which acts as the propellant.

Electric heat is the final subject of Part 2. This is not to be confused with electricity as a whole, which is discussed in Part 4. Heat, light and magnetism are all effects of electricity. Heating elements, such as ones in electric kettles, hair dryers and toasters use heat created by electrons flowing through a wire in what is called a current. The wire is made up of metal atoms. As the released molecules flow into the wire, they pass from atom to atom, These small electrons bump and jostle the larger atoms. The result is an increasing vibration. Vibration is movement and the increase of movement creates heat. Heating elements are made up of these wires, but the heat they create travels through conduction and convection to heat surrounding liquids, solids and gasses. In the hair dryer, for example, the heat from the element travels into the air inside the dryer and that heated air is then pushed out by a fan creating the blast of heat. Electric heat is not only harnessed to warm things up. Machines which need to remain cold, such as refrigerators, will harness heat to remove it from a space. Heat will be taken in by molecules of water as in a car's system, or by a refrigerant as in refrigerators and air conditioners. As the refrigerant travels through an evaporator, it expands and takes in the heat. A compressor then pumps the refrigerant out where the vapor condenses into water which releases heat into the air. Heat causes expansion, so as a metal heats up it will expand. This movement due to heat is used in thermostats where a piece of metal will expand or contract enough to push on a contact point or open a valve.

An internal combustion engine is any engine which burns fuel inside the engine. This includes gasoline and diesel engines as well as jet and rocket engines. In a gas engine, gasoline and air burn in a chamber to operate a piston which turns a crankshaft connected to the wheels. In a jet engine, burning kerosene or paraffin creates power to turn a fan which sucks in air and then ejects it behind the plane at high speed. In a rocket engine, the combustion of two propellants creates a release of vapors strong enough to power the craft.

Before the arrival of the internal combustion engine, there were steam engines. The Industrial Revolution was spurred by the invention of the steam engine. This type of engine would boil water and then use the steam created to push a piston up and down inside a cylinder. Though the steam engine is no longer used, steam is used in thermal power stations where water is heated to a boil by burning coal or oil. This creates steam to power turbines which generate electricity that we use in our daily lives.

Nuclear Power is introduced as a concrete woolly mammoth anonymously left at the town gates. The story is a clear parallel to the Trojan Horse, and the author is challenging the reader, at some level, to remember the moral of that story of a people who too quickly embraced the unknown gift.

Nuclear power comes from a two-part process of nuclear fission and nuclear fusion. It is called nuclear because the entire process takes place in a the nucleus of the atom. Molecules are built up out of atoms, and so far in Part 2, the forces have created the bonds between molecules. But a molecule is made up of atoms and each atom has a central particle which is called the nucleus. Nuclear power produced in a nuclear reactor is called nuclear fission. This process is explained concisely on page 164 where the author writes, "Fission starts when a fast moving neuron strikes a nucleus. The nucleus cannot take in the extra neutron, and the whole nucleus breaks apart into two smaller nuclei." This collision also causes some of the neutrons to be ejected and these loose neutrons are the ones that are speeding around slamming into other nuclei. This self perpetuating process is called a chain reaction. As the nuclei collide, they emit gamma rays, the most deadly type of radiation.

Nuclear fusion occurs when very small atoms smash together. They have only one or two protons and neutrons, and when smashed together at extremely high speeds their small nuclei fuse together. This causes one spare neutron to break off. As the newly fused nuclei and the spare neutron speed off they emit tremendous heat. Though the process creates no radiation, the loose neutrons are harmful. Because the process of fusion requires tiny atoms moving at incredibly high speeds, it is difficult for humans to create, much less harness. One exception is thermonuclear weapons. However, the sun produces its immense energy with fusion.

Combustion rearranges elements and creates waste which has released some of its energy as heat. With nuclear energy the elements are not rearranged but, rather, the element itself changes into a different element. In nuclear reactions, unlike the chemical reactions of combustion, the waste has less mass than the original fuel. In this way, atomic energy actually creates energy, giving it the potential to release immense amounts energy with just a small amount of mass.

The atom bomb uses nuclear fission by shooting a source of neutrons into a hollow uranium or plutonium sphere encased in explosives and an outer casing and then setting off the explosive to crush the sphere. This sets off the chain reaction of fission which "flashes through the uranium or plutonium in a fraction of a second." (page 168) The bomb explodes with intense power and radiation.

The hydrogen bomb is a thermonuclear weapon. However, to create the extreme heat and pressure needed for fusion, a fission bomb is used to compress deuterium and tritium (two forms of hydrogen). All the nuclear materials are crushed together with explosives to detonate the bomb. If the hydrogen bomb contains a jacket of uranium the blast itself is extremely powerful. The neutron bomb, on the other hand, gives off a much less powerful blast, but emits deadly penetrating neutrons. This kills the people, but will leave their buildings still standing intact.

The explosion of a nuclear bomb creates debris called fallout which travels through the atmosphere. A nuclear war would spread this fallout and send deadly radiation raining down. A fallout shelter would have to be buried deep down beneath the earth and stocked with enough supplies to allow the people to survive the many years it would take for the radiation to decrease. "Even then, climactic changes, shortage of food and the threat of disease would make life above ground a grim business." (page 169)

Part 3, Working with Waves

Part 3, Working with Waves Summary and Analysis

Whereas Part 2 described how machines move and alter molecules, Part 3 covers machines that use the energy of waves "to amplify and extend our eyes and ears." (p176) The two types of waves discussed are sound waves and electromagnetic waves. Waves differ from molecules in that molecules make up matter whereas waves pass through it. Electromagnetic waves are often referred to as rays. Whereas sound waves pass a vibration through molecules, electromagnetic waves vibrate electric and magnetic fields which can exist outside of matter. The distance between each peak of energy is the wavelength. How quickly the waves move past each peak is called their frequency. All waves and rays span a range of wavelengths and frequencies which effect how we perceive them. The frequency of sound waves creates a physical vibration which humans experience both as a vibration, and as sound. The faster the vibration, the shorter the wavelength, the faster the frequency, the higher pitched the sound will be. There are waves vibrating below and above our range of perception, such as the dog whistle which makes no sound to our ears, but is heard by dogs. Different frequencies of electromagnetic waves, which include light rays, appear to our eyes as colors and light. Our eyes cannot perceive longer infrared rays, microwaves and radio waves. Nor can we visually perceive shorter ultraviolet, gamma rays or x-rays.

Since all waves travel in a pattern, light and radio waves can also be used to communicate. Wave patterns can be interrupted to build signals and messages.

When orbiting electrons receive enough energy in the form of heat or electricity they jump away from their nucleus and then fall back emitting a ray of light on impact. We can create artificial light by either heating an object to the point that it burns or glows, or by passing an electric current through a vapor or gas. As the visible rays cross our lens, they are bent through the convex surface to form an image on the retina. That image then travels to our brain in the form of nerve impulses. A convex lens causes the rays to converge into a smaller image. A concave lens causes rays to diverge outward into a magnified image. Mirrors simply reflect light rays without distortion but reversed.

Primary colors of light are different than the primary colors in solids such as ink or paints. All light is made up from red, green and blue. White light is the combination of all three. Black light is the absence of any light at all. When red light is combined with green light the result is yellow. This is called additive mixing. In the case of solids, what the eye perceives is the reflection of light, or the colors of light which are not being absorbed by the surface. A yellow surface will absorb the blue, and a blue surface will absorb the red, so when a blue surface is combined with a yellow surface only the green is reflected. This is called subtractive mixing since it is the result of the red and blue rays being absorbed, or subtracted.

The energy of light rays travels by vibrating all the electric and magnetic fields that lie perpendicular to the ray. When light is polarized, filters block out all the rays except ones vibrating in a chosen field. The vertical waves which pass through the filter can be entirely blocked by a second horizontal filter. Polarized sunglasses block damaging UV rays but allow light rays in the visible range to pass through.

Liquid crystal displays, such as the numbers on digital clocks, are created by polarizing light and then sending the filtered ray through liquid crystals whose twisted molecules direct the single light ray at a right angle to travel through a second horizontal filter. When a weak electrical current causes the molecules to switch from their twisted arrangement into a straight path, the plane is flipped back to vertical. The segments which make up the number display are alternately lit and darkened in this way to form different numbers.

Laser stands for Light Amplification by Stimulated Emission of Radiation. Energy, such as an electric current, excites an atom causing it to release a light ray. The bumping of excited atoms, amplified by the reflected light rays that bounce off mirrors create multiple rays which all move in the same wavelength and vibrate together as one intense beam.

Photography is introduced as our inventor notices that mammoths blocking the sun for long periods cause the grass in their shade to die. The mammoths, who are able to stand in the exact same spot for days, cause the grass to die in the shape of their body's shadow. Light, such as the sunlight in the story, is thrown on a scene's surface. The rays reflect off the surface, such as the mammoth, and pass through a lens to land on the film. The film contains crystals of light sensitive silver compounds suspended in gelatin. As the reflected light hits the crystals, they break down into dark specks of silver, just as the grass blocked from light by the mammoth's body breaks down and turns brown. A fixer is used to dissolve the unaffected crystals creating a negative. The area touched by the reflected light is now black. The areas which reflected no light have dissolved into clear film. Light is then projected from behind the negative onto printing paper through a lens which enlarges the image. Printing paper is coated with light sensitive emulsion which picks up and holds the image. Color photographs are made with film made from three color sensitive layers, one sensitive to blue light, the middle to green and the bottom layer to red.

The three methods of modern printing are letterpress, gravure, and lithography. In letterpress, a raised letter or image is on the face of the plate; in gravure, the letter or image is recessed. Ink is rolled over the raised letter in letterpress, or poured into the recessed letter in gravure. A piece of paper is pressed against the plate and the ink transfers onto the paper in the shape of the letter. In lithography, an image of a letter is projected onto a plate. The image is treated with a waterproof lacquer, and the plate is then wet. The lacquer rejects the water. Ink is rolled across the plate. The wet area rejects the ink while the lacquer accepts it. Paper placed on the plate picks up the ink off the lacquered image.

Sound is vibrations which create waves of alternating high and low pressure. The wave bobs up as the vibrations move forward and compress the air ahead of it. Then the vibration drops back into a low pressure ring called rarefaction before moving forward again into a ompression. Alternating compression and rarefaction make up a sound wave measured by the pressure difference between the compression and the rarefaction. The larger the difference, the stronger the wave and the louder the sound will be. Waves must travel at a minimum of 20 compressions and 20 rarefactions per second to be audible to the human ear. The waves vibrate our ear drum which passes the vibration to the cochlea in the inner ear. From here they travel to the brain as electrical signals on our auditory nerve.

Instruments create waves in one of three ways. Percussion instruments are struck physically to set off vibrations. String instruments are vibrated by a bow or by being plucked. Woodwinds and brass instruments force wind through a hollow tube to produce vibrations. Different notes and pitches are created by altering the pressure or length of the waves.

Sound can be increased or amplified electronically. A weak signal's vibration is increased by an increased flow of electrons. Diaphragms, magnets and small semi-conductors called transistors are all factors which can increase the movement of electrons, and the consequent size of the sound wave.

Telecommunications, or the communications done outside the range of unaided sight or hearing, are portrayed by the author as stones being catapulted through the air in a particular sequence. The sequences which represent sounds, images and computer data travel by electricity, light or radio waves in the form of either analog or digital signals. Analog signals vary continuously in their levels. Digital signals are made with on-off pulses. These signals are added to the electric current, light beam or radio wave. Adding the signal to a carrier wave is called modulation. The modulated current, beam or wave, reaches a receiver which can distinguish signal from carrier and extract the signal. The signal can then be decoded and the sound, image or computer data reproduced.

Part Four: Electricity and Automation

Part Four: Electricity and Automation Summary and Analysis

Electricity comes from the movement of electrons, the tiny particles which circle the outer ring of an atom and carry a negative charge. The author tells us that there are three principles which govern the flow of electricity: "The electrons always need energy to make them move. They always travel in a set direction (from negative to positive) at a set speed. Furthermore, they will always produce particular effects while they are on the move." (Page 256) These particular effects are magnetism, heat, and/or light.

Static electricity happens when electrons are rubbed, shuffled or brushed off one surface onto another. The original object now has a positive charge while the object which has gotten all of its loose electrons has a negative charge. These opposites will always attract and draw together. Two negative charges, on the other hand, will repel each other.

In current electricity, electrons travel through a conductor such as metal, or any material that allows electrons to travel freely through it. This requires a source of energy. "This energy can be in the form of light, heat or pressure, or it can be the energy produced by a chemical reaction." (p. 259). The author illustrates a chemical reaction with a man harvesting giant lemons with a zinc lance while riding on the back of an elephant with a copper lance. As the two creatures both stab the same lemon with their spears, the lemon's citric acid causes a chemical reaction with the zinc and copper. The electrons are set in motion and man and beast are both horribly shocked.

Magnetism is caused by moving electrons. Electrons move toward the positive or north pole of a magnet, and away from the south pole. As with positive and negative particles, opposite poles attract while like poles repel. The magnetic field caused by an electric force is motive force, which is to say it can move objects. A magnetic field flows from a magnet into metal and, temporarily, makes the metal magnetic. This pulls the metal and magnet together. "An electromagnet," as the author explains on p. 276, "is a coil of wire wound around an iron core. When current flows through the coil, it creates a magnetic field." If the current is reversed, the poles of the magnet reverse and cause the magnet to repel what it has attracted. Because electrical current can be reversed or shut off, electromagnets use the forces of attraction and repulsion alternately to keep machines running.

Sensors and detectors are devices which, as their names imply, sense or detect a presence, measure and/or locate a force, and/or give feedback. Measurements of force are done for earthquakes and car crashes. Feedback is essential to running an autopilot program. Sensors and detectors measure electrical currents, rays and waves. Electrical currents can indicate particles such as smoke in the air or alcohol on the breath. X-Rays and gamma rays will be absorbed by heavy atoms, but pass through light ones, resulting in an image of something not visible to the naked eye. SONAR (Sound Navigation and Ranging) and ultrasound devices measure sound waves to gather information. RADAR employs radio waves (Radio Detection and Ranging). Radio waves used in combination with magnetic fields can be used for body scanners. The magnetic field lines up the atoms and causes them to spin which allows radio waves to bounce off the pattern of atoms to create an image.

Part 5: The Digital Domain and The Last Mammoth

Part 5: The Digital Domain and The Last Mammoth Summary and Analysis

The Digital Domain includes five chapters and an epilogue which cover the creation, storage, processing, and transfer of bits which are used in the most recent evolution of machines. The narrative is the story of the last remaining mammoth who meets "Bill" at the gates of "The Digital Domain." Bill sees the mammoth is lonely and invites him in. The creature is then measured and tested and his presence is reduced into numbers. Bill then records the numbers in a curious system of pumpkins and crates. The pumpkins represent bits. Bits are binary digits, which means, as opposed to decimals built on combinations of ten numerical symbols, binary digits create codes in a numerical sequence built entirely on two numbers: 0 and 1. When information is translated into binary code, it can be communicated through electrical pulses with "On" representing "1" and "Off" representing "0." In the case of Bill and the mammoth, "1" is a pumpkin in the crate and "0" is an empty crate. This is the input. Fingertip input requires we use our fingers to enter the code, such as when we press the buttons on our phones, type on a keyboard, use the mouse, or press buttons on a timer. Signal input happens without our touch using instead an analog-digital converter. Analog means levels rise and fall continuously. Heat, light and sound are analog quantities. The variations of an analog quality are turned into a sequence of numbers by an analog-digital converter. Once numbers, they can be changed into binary code, or bits, and sent out in electrical pulses to be stored and processed.

Chapter 2: Bill and the mammoth watch the pumpkins being stacked into rows and rows of tall shelves containing "pumpkins and non-pumpkins" (page 328) representing storage. Bits can be stored in memory chips, disks and tapes, bar codes, digital film sound, compact disks and recordable CD's, RAM (Random Access Memory), or "Flash Memory." RAM is for temporary storage only, so it puts bits in whatever random space is available on the chip. ROM (Read-Only Memory) is filled with permanent bits that cannot be changed. The on-off electric pulses of bits can be transformed into magnetic fields and stored on tapes and disks. Bar codes are an optical storage system where the number of bits is represented by the width of each black stripe.

Chapter 3: Bill shows the mammoth a mass of tubes into which pumpkins are being dropped. In spite of how many pumpkins are put into the tubes, the pumpkins are deposited and rolled away in groups of eight "pumpkins and no pumpkins." The pumpkins are then pulled out systematically and placed into huge machines. The machines represent a CPU (central processing unit). The processor is the brain of the digital system and it is made up of logic gates which are rapidly switched on and off by transistors to pass or block bits. The logic gates are housed in a microchip which is "an electronic component containing many miniature circuits." (page 393).

Chapter 4: Bill and the Last Mammoth have arrived in a kitchen where the pumpkins and no pumpkins are rolling in on a conveyor belt. When the belt stops, the chefs who find a pumpkin in front of them put it into a pie and start to cook it producing puffs of smoke from their stoves. A barrage of apples/no apples responds to the smoke/no smoke pattern. This represents bits flying back and forth and being transformed into responses. The processor is able to send or receive bits through a modem which changes the bits into sound signals and then sends them through a telephone line. The internet is but one piece of this vast communications activity. Cash dispensers, digital phones, radio and television, fax machines and GPS units are also sending messages back and forth in the form of bits. Sounds, numbers, movements, words, images, colors and dimensions are turned into the binary digits of code. Code travels to be stored, processed and joined with other incoming bits of information. New code is formed and sent back through a digital-analog converter (ADC) and become, once again, sounds, numbers, movements, words, images, colors and dimensions. In our world, these reach us through output devices like printers, monitors, and speakers.

Chapter 5: The mammoth is traumatized when he is taken into a virtual reality which is the output of the numbers to which he was reduced at the start. At first he is overjoyed as he perceives himself to be among other mammoths. When he realizes it is an illusion, he is more depressed and angry than ever. We receive output as faxed and printed documents, images on a computer screen, or as the voices and music that come through our phones and computers.

Epilogue: The mammoth exits uncomfortable and lost, but Bill is convinced the mammoth will return, not for the technology and information, but for the apples and pumpkin pie.

Characters

The Inventor

There are no major characters in this book, unless you were to count Principles of Mechanics, Mechanical Parts, Driving Forces, Energy, Atoms, Sound Waves, Electromagnetic Rays or Bits. Though some individual inventors are mentioned in the Eureka section, it is only in single line references to their inventions. With this understanding, there can be only three characters found in the book, and they appear in the analogous narrative. The inventor is narrating the first four sections' fictional episodes which detail the problems and solutions made by a group of early humans with domesticated mammoths. It is an imagined time which is pre-technology, yet familiar with retail development and insurance coverage. It is a cartoon world and the inventor is the cartoon of the preoccupied scientist who can notice the pattern of dead grass but who needs a simple farmer to point out the more obvious facts. He seems hardly distressed as experiments go awry and helpless souls are flung off the pages, though it does leave him pondering what he can learn from the experiment. He embodies the superstitious theories of earlier people ("Perhaps it had something to do with the spirit of the air?") but invents the first wind turbine. The character's job is to explain some basic laws of physics in a humorous and accessible manner in an atmosphere where mistakes happen and much is left to still be discovered.

The Last Mammoth

Though we see many mammoths in the first four sections, by the fifth section there is only one Mammoth left. He is called only "The Last Mammoth." He is distressed with loneliness when he meets Bill, the man who runs The Digital Domain. Described as "tiny brained," the last mammoth, like all of the previously depicted mammoths in the book, appears gentle, sensitive, wary of anything new but ever willing to trust the humans who have perpetually exploited his fellow creatures. The Last Mammoth delights in things that are simple, like food, and finds the digital domain confusing and overwhelming. The experience of virtual company is not a comfort but a horrible deception to the lonely mammoth.

Bill

Head of the Digital Domain, Bill is an enthusiastic entrepreneur. His boyish look with casual dress, tousled hair and round glasses is no doubt meant to bring to mind Bill Gates of Microsoft, one of the clear leaders in the field of computer technology. The fact that Bill, in the story, considers apples, the actual fruit, "rather low-tech and behind the times" seems to back up the play on Microsoft and its top competitor, Apple Industries. Bill is certain that the mammoth will be as excited as he himself is with the tour of the digital domain. What seems fast and confusing to the mammoth only continues to feed

Bill's excitement and ingenuity. Bill sees the relevance and usefulness of his creations and seems to sincerely want to share their advances to create happiness for the Last Mammoth. Despite his best intentions, Bill fails to convince the mammoth of the glory of the Digital Domain. Bill is smart enough to see that, but the shrewd business man he is notes that the mammoth will return, not for the technology, but because the swamp grass is dying out the mammoth will need Bill's apples and pumpkins to survive.

Objects/Places

Gravity

Gravity is a natural force which pulls objects of mass toward each other. The greater the mass is, the stronger the pull is. We know gravity best as the force which holds us to the earth. Gravity gives an object weight, and creates the pressure in air and water. Weight is directly related to mass and density. An object's inertia depends on mass, and centrifugal force depends on inertia. Pressure in air and water drive suction, flotation, and other forces which create movement. Consequently, gravity is present in the workings of many machines.

Heat

Heat can increase pressure, decrease density, ignite chemical reactions. Heat is the driving force behind steam power and the combustion engine, two of the most significant advances which ushered in the industrial age.

Magnetism

Magnetism is a force which can attract or repulse objects within its field. Unlike gravity, its effect is only significant on objects which contain some amount of iron, magnetite, or a similar magnetic material.

Law of Inertia

The Law of Inertia states that an object in motion tends to remain in motion. More specifically, an object is resistant to changing speed or direction. That means to set an unmoving object into motion will require a force to overcome inertia, and to stop that same object once it is moving will require another force to counter inertia. Inertia also creates centrifugal force. Machines are built out of fixed and moving parts and their movement requires forces to overcome inertia.

Energy

Energy is neither created nor destroyed. This is what meant by the term "Conservation of Energy" in The New Way Things Work. Energy can be harnessed, change forms or transferred from one object to another, but energy itself is constant. All actions require energy, except for nuclear reactions. Movement, heat and electromagnetic waves, including light, are forms of energy.

Law of Action and Reaction

For every action, such as propeller blades moving to push water back, there is an equal and opposite reaction, such as the water pushing back on the propeller blades to move the propeller forward.

Suction/Lift

A curved surface creates a differential in pressure between air or water flowing in a curved path over the surface, and the air or water moving in a straight path underneath. The curved flow moves faster than the straight flow which means the curved flow has lower pressure than the straight flow. The higher pressure of the slower moving air or water forces the surface up or forward toward the lower pressure flow. This creates a force called suction when it occurs in water, or lift when it occurs in air. This force is used for flotation and flight.

Electromagnetic Waves

Known in general as rays, these waves span vibrating electric fields. They are visible to us as light rays, but the visible rays occupy only the central part of the spectrum. Longer electromagnetic waves include radio, TV, microwave and infrared waves. Shorter rays include gamma and x-rays. Electrons must be accelerated to create any of the waves longer than the very short gamma rays.

Elements

All matter is made up of one or more of the elements. Each element contains only one kind of atom. Substances which contain more than one kind of atom are compounds of two or more elements. Compounds are substances in which atoms have grouped together to form molecules.

Molecules

"The way molecules behave governs the workings of many machines—," states the author on page 92. When tightly bound, molecules make a solid; as they loosen their bonds they become liquids and finally, in their loosest stage, they make gasses. Confining molecules to a small space, or heating molecules to increase their movement in a confined space, creates pressure. Differences in pressure create movement, such as suction and lift mentioned above.

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Atoms

The building blocks of molecules, atoms consist of a central nucleus, made up of protons and neutrons, being orbited by electrons. We use the energy of electrons in electricity. By breaking apart the nucleus we create nuclear energy.

Electrons

Electrons are the particles circling the nucleus of an atom. They hold a negative electric charge. This attracts them to the positive charge created by protons. The movement of electrons away from one atom to another is what creates electricity.

Bit and Byte

A bit is a binary number. Unlike decimal form numbers which use ten digits from 0 to 9, a binary number is made up of only two digits which stand for absence (0) or presence (1). Absence and presence can be represented by electrical charges turning off (absence) or on (presence). In this way, they can be sent electronically from one machine to another. Digital communication turns input into bits so it can be stored, processed or sent to other machines. Bits can then be converted back into a form we can use such as text or sound. Eight bits make up one byte.

Themes

Knowledge is Built on an Understanding of the Basics

A true understanding of the working of machines comes from first understanding the underlying principles. The way in which the book is structured groups machines and devices according to what makes them work to do the tasks they do. As the author states on page 8: "They may look different, be vastly different in scale and have different purposes but when seen in terms of principles they work in the same way." As technology advances, people have become more specialized. One shop takes care of your tires, another one your car's engine, and yet another place the vehicle's electronic systems. Whereas there once was "Your Doctor," one patient may see a dozen professionals to address their health— Ophthalmologists, Neurologists, Cardiologists, Pediatricians, Obstetricians, Oncologists, and Endocrinologists, to name a few. The New Way Things Work, marvels at how, especially in the Digital Domain, our machines are doing more and more specialized and detailed jobs, but the book is grounded in the bigger principles which are the foundation of this progress. Specialization should not begin and end in that focused place, but be built on the foundation of understanding the principles. For that reason the author divides the book as he does, and groups the nail clipper with the grand piano. The placing together of these vastly different objects emphasizes the connection that spans all mechanics and technology, none of which can be mastered without first grounding one's understanding in the principles.

Progress Must be Approached with Great Care

There is great power in this knowledge of the way things work, and, as Spiderman would say, "With great power comes great responsibility." Once the principles are understood, they can be seen working all around us. The mind awakened to these ideas can not only observe them, but can potentially visualize and create further uses for these machines and concepts. This knowledge holds the keys to progress and, in many ways, to our very survival. However, the author does not, despite the humor and accessible colorful diagrams, pass this knowledge along without a tone of warning. From the dangers of isolating some people or cultures, leaving them isolated, confused and overwhelmed like The Last Mammoth, to making people dependent on the ones who control the technology, like the man who holds all the apples and pumpkins, to the potential dangers of nuclear power implied in the introduction to Nuclear Power, where it first presents itself in the form of an enormous concrete mammoth which is a deliberate reference to the Trojan Horse, the point is made that progress must be approached with caution and foresight.

Progress Belongs to all of Humankind

The accessible style and diversity of ways in which the authors and illustrator relay the material show their conviction that technology, and the science behind it, is neither a mystical art nor a private club for an elite class of thinkers. It is our common heritage that has reached us through generations of human observation, thought and initiative. When the inventor dismisses a colleague's idea of hydropower (page 30), it shows that sometimes the most visionary thought is dismissed as ludicrous by others. In fact, as the inventor looks at a bandaged mammoth which bears a strong resemblance to a modern jet, he states that such an absurd design could never be airborne. There will always be discoveries and advances yet to make. The curiosity and vision to make them are a natural part of being human. The capability to do so may be found in anyone willing to open their mind to possibilities.

Style

Perspective

The New Way Things Work is written and illustrated by David Macaulay, with technical text written by Neil Ardley. It is a revision and update of Macaulay's 1988 book entitled simply: The Way Things Work. Though Ardley's text contributes much information, the book embodies the work and style of David Macaulay. Macaulay moved to America from the UK in his youth and found tremendous comfort and passion in drawing. He eventually studied architecture at the Rhode Island School of Design and graduated convinced that he never wanted to go into the field. Instead, he worked at various jobs including teaching and writing illustrated children's books. Macaulay put his background in art and architecture into his books on architectural structures before using his detailed drawings for explaining machines and molecules in The New Way Things Work. His style of illustration has the simple lines of a cartoon with the complex skill of an engineer. The teacher in Macaulay puts forward an engaging, visual, humorous and informational text. Much of what Macaulay covers is technical fact colored only by a desire to infect the reader with curiosity and creative thinking. Macaulay does not push forward opinions so much as provoke thought on subjects such as the use of nuclear power of the fast advancement of the digital age. It is the hand of a teacher who does not teach his students what to think, but rather, how to think. Macaulay has made the information interesting enough with his engaging drawings and humor that the reader may find they have an interest in a subject they had never been drawn to before reading the book.

Tone

The heavy emphasis on illustrations make the book accessible to a broad range of readers. Macaulay's writing is often fantastical and humorous which gives him a reputation for being "whimsical," which may seem at odds with a book on machinery. The mammoth as domesticated animals for a primitive culture is certainly fantastical, but it engages the reader to approach the material in a more free and creative way. Rather than risk losing a reader's interest, many of the machines are left under explained, but an interested reader would have enough information from the text and pictures to know how to research further, sometimes in other areas of the book, or sometimes by setting the book aside and turning to other references. He not only passes along information, but gives the reader tools to take the understanding further. Though Macaulay's machine drawings are often simplified versions of a machine or process, every illustration is accurate and extensively labeled. They often appear dotted by miniature humans or angels, reminding the reader to not get weighed down in the technicality. The result is an incredibly visual and informative piece done with enough attention to detail to make it a solid resource, but enough humor to make it an entertaining read.

Structure

The book is divided into five sections and two appendixes for reference. The first five sections each cover an aspect of mechanics and/or technology. The sixth section reviews the machines and concepts discussed throughout the book and looks at them through a historical perspective. The first appendix is a glossary of technical terms, and the book concludes with an index.

Parts 1-4 have a consistent style. They begin with a two page introduction. followed by a two page spread in which the inventor tells little vignettes about his solutions in an illustrated box above, while the concepts involved in the solutions are explained below. Once a concept is introduced, there are several pages of illustrations, with text, examining different tools and machines which employ the concept. Part 1 has ten such sections following the introduction; Part 2 has five such sections following the introduction; Part 3 again has five sections following the introduction; Part 4 merely has three parts following the introduction. The structure breaks down in Part 5 which was added in the revision. Instead of an introduction, followed by parts made up of story followed by mechanical diagrams of examples, Part 5 has five chapters and an epilogue. Though the chapters do have the pattern of story followed by diagrams, the story is one cohesive tale of the last mammoth and his tour of "Bill's" giant computer system.

Quotes

"They may look different, be vastly different in scale, and have different purposes, but when seen in terms of principles, they work in the same way." (page 8)

"Every object on Earth is held together and in place by three basic kinds of force; virtually all machines make use of only two of them." (page 9)

"Underlying the actions of all machines is one principle which encompasses all the others— the conservation of energy.. This is not about saving energy, but about what happens to energy when it is used. It holds that you can only get as much energy out of a machine as you put into it in the first place—no more, no less." (page 9)

"Work has two aspects to it: the effort that you put in, and the distance over which you maintain the effort. If the effort increases, the distance must decrease, and vice versa." (page 10)

"Elements are substances that contain only one kind of atom. All other substances are compounds of two or more elements in which the atoms group themselves together to form molecules." (page 92)

"Because molecules in liquids and in gases are always on the move, they have power. Each one of them may not have much, but together they become a force to be reckoned with." (page 93)

"If you squeeze more molecules into the same space, you get more pressure as more molecules strike the surface. The pressure produced by this restless movement is put to work in many ways." (page 93)

"When molecules are heated, they respond by moving faster. The pressure increases unless the molecules get farther apart, in which case the material expands. If the molecules are made to move fast enough, the bonds between them start to give way: a solid melts into a liquid and a liquid forms a gas." (page 93)

"There were those in the town who remained suspicious of the concrete mammoth. They wondered not only how it worked, but also where it had come from; could it really be as beneficial as it seemed?" (page 165)

"A future nuclear war would not only reduce cities and towns to ruins. Fallout from the nuclear explosions would spread through the atmosphere, bombarding the land with lethal amounts of radiation. The only means of escape would be to live in deep underground shelters away from the fallout." (page 169)

"At every moment of our lives, we are bombarded with waves of energy." (page 176)

"Through our senses we can detect a small but important part of this ceaseless barrage. We can feel heat energy through our skin, we can see light energy with our eyes, and we can detect sound energy with our ears." (page 176)

"The important feature of energy waves is that when they are conducted through matter, it is only the energy itself that moves." (page 176)

"Of the two, sound waves are easier to understand because they consist of vibrations in matter. They can only travel thorough matter—air, water, glass, steel, bricks, and mortar; if it can be made to vibrate, sound will travel through it." (page 177)

"Rather than vibrating molecules, electromagnetic waves—light, heat rays, and radio waves—consist of vibrating electric and magnetic fields. Because these fields can exist in empty space, electromagnetic waves can travel through nothingness itself." (page 177)

"The power behind electricity comes from the smallest things known to science. These are electrons, tiny particles within atoms, that each bear a minute electrical charge." (page 256)

"...all digital machines begin a task by converting things like these into numbers. Instead of the decimal form that uses ten digits, numbers in the digital domain are binary numbers which use only two digits and which are much more convenient for machines." (page 315)

"While it was true that the mammoth hadn't developed much of an appreciation for digital technology and all that it could complicate, he had developed a real taste for pumpkin pie and apples smeared in chocolate. These were a pleasant and entirely compatible replacement for swamp grass, which would soon become extinct. And Bill was the only supplier for miles and miles." (page 373)

Topics for Discussion

Does progress always require that mistakes be made along the way? If so, how can or should progress be approached when the mistakes could be potentially fatal or catastrophic?

This book is a revision of a book written ten years earlier. What advancements or achievements would you include if you were to revise the text today?

Some of the devices depicted in the book have since become obsolete (manual typewriters, the record player, the VCR). Some, such as the plow, were included, even though archaic, because they are still used in some form. Do you think there is still something to be learned from studying machines which are no longer in our everyday lives? How important will it be to understand the combustion engine, for example, if it ever becomes obsolete?

Sensors and detectors are discussed starting on page 290. Written before September 11th, 2001, when security took on a whole new life, these are viewed as marvelous devices for extending our senses. In the last decade of heightened security, the argument between privacy and security continues to rage. Do you think this is a real conflict? Is it a matter for technology to solve, or for communities to decide and limit?

The last mammoth is isolated, and feels betrayed by the empty offering of virtual reality. Do you think that technology is isolating us from one another, or is it building an alternative community which alleviates isolation? Do you think technology brings people together, or heightens divides?

Can progress be reversed, and in what situations might it be important to do so? If not reversed, are there situations where our progress needs to be reshaped?

The incredible growth of machines and technology reflects the incredible capabilities of the human mind. Given the accelerated progress since the industrial revolution, does it seem as if we have come too far too fast, or does it seem curious that we still seem so far from solutions that would replace older and less efficient technologies?

Often the greatest discoveries were dismissed, overlooked or outright scoffed at in the beginning. Are there ideas out there today which are being dismissed or overlooked? How do we determine which ideas may be solutions and which ones are gimmicks?

Describe what nuclear fission is and what nuclear fusion is. How do they differ? Name a place where you would find each.

Describe how an electric current can create a magnetic field. How can a magnet create an electric current?