

<p>Topic 3 From Ideas to Implementation</p>	
<p>Focus 1 Increased understanding of cathode rays led to the development of the television.</p>	
<ul style="list-style-type: none"> • Explain why the apparent inconsistent behaviour of cathode rays caused debate as to whether they were charged particles or electromagnetic waves. 	<p>Cathode rays are now known to be streams of electrons emitted within an evacuated tube from a cathode (negative electrode) to an anode (positive electrode). They were first observed in discharge tubes.</p> <p>There were a number of observations recorded for cathode rays that placed cathode rays as both electromagnetic waves and charged particles.</p> <p>Observations that fitted the wave model:</p> <ul style="list-style-type: none"> • Travelled in straight lines • Shadow appeared when opaque objects were placed in its path. • Passed through thin metal foils without damaging them. <p>Observations that fitted the particle model:</p> <ul style="list-style-type: none"> • Left the cathode at right angles to the surface. • Deflected by magnetic fields • Small paddle wheels turned when placed in their path • Travelled considerably slower than light.
<ul style="list-style-type: none"> • Explain that cathode ray tubes allowed the manipulation of a stream of charged particles. 	<p>A cathode ray tube is a sealed glass tube from which most of the air is removed by vacuum pump. A beam of electrons travels from the cathode to the anode and can be deflected by electrical and/or magnetic fields.</p> <p>The cathode ray tube consisted of:</p> <ul style="list-style-type: none"> • Highly evacuated glass tube containing two electrodes • High voltage applied across the electrodes • Cathode rays, streams of electrons, flow from cathode to anode. <p>Manipulation of cathode rays:</p> <ul style="list-style-type: none"> • Structures built into or around cathode ray tube, manipulating the rays. • Further electrodes built into the cathode ray tube creating an electric field which changes the path of cathode rays. • Magnetic fields applied to cathode rays through the glass from outside the tube. • Solid objects placed inside the tube to block the path of the rays.
<ul style="list-style-type: none"> • Identify that moving charged 	<p>A charged particle moving through a magnetic field experiences a force due to the interaction of the two magnetic fields present.</p>

<p>particles in a magnetic field experience a force</p> <ul style="list-style-type: none"> Describe quantitatively the force acting on a charge moving through a magnetic field. 	<p>The magnitude of this force is given by: $F = qvB \sin \theta$ where: q – Charge on the particle in coulombs (C) v – Velocity of the particle in ms⁻¹. B – Magnetic Field Strength in Teslas (T) θ – Angle of the particle with reference to the magnetic field.</p> <p>Charged Particle Undergoing Circular Motion: When an electron enters a magnetic field, it begins undertaking circular motion. The electron is then undergoing continual acceleration towards the centre of the circular path. This acceleration means that the electric field and magnetic field produced by the electron are continually changing. These changing fields will give rise to electromagnetic radiation which will be released from the accelerating electron. This occurs so the principle of conservation of energy is not violated. This means that the electron loses kinetic energy.</p>
<ul style="list-style-type: none"> Identify that charged plates produce an electric field. 	<p>A uniform electric field can be produced by placing charges on two parallel plates that are separated by a small distance (comparative to their length).</p>
<ul style="list-style-type: none"> Discuss qualitatively the electric field strength due to a point charge, positive and negative charges and oppositely charged parallel plates. 	<p>Electric Field Strength:</p> <p>Point Charge: The strength of an electric field at any point is equal to the force that a positive, 1 Coulomb charge, would be subjected to if placed at that point.</p> <p>Positive or Negative Charges: Remember that a test charge is always positive.</p> <p>Positive Charges:</p> <ul style="list-style-type: none"> Strength is inversely proportional to distance. Direction points radially away from the particle. <p>Negative Charges:</p> <ul style="list-style-type: none"> Strength is inversely proportional to distance. Direction points radially towards the particle. <p>Oppositely Charged Parallel Plates: Charged plates exert a force on other charged objects, indicating that an electric field exists.</p> <p>The magnitude, E, of the electric field between two charged plates is:</p> <ul style="list-style-type: none"> Proportional to the potential difference between the plates. Inversely proportional to the distance separating the plates.
<ul style="list-style-type: none"> Describe quantitatively 	<p>Electric Field Strength in terms of a particle:</p>

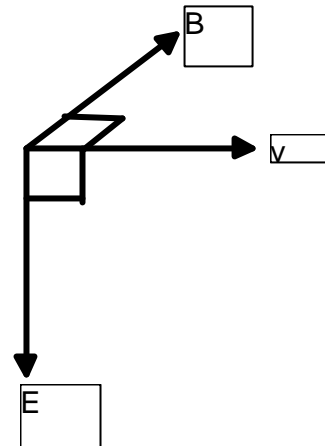
<p>the electric field due to oppositely charged parallel plates.</p>	$E = \frac{F}{q}$ <p>Where</p> <p>E – Electric Field Strength in NC⁻¹. F – Force on the particle in Newtons (N) q – Charge on the particle in coulombs (C)</p> <p>Electric Field Strength in terms of the plates:</p> $E = \frac{V}{d}$ <p>Where</p> <p>E – Electric Field Strength in NC⁻¹. V – Potential difference between the plates in Volts (V). d – Distance between the plates in metres (m).</p>
<ul style="list-style-type: none"> • Outline Thomson's experiment to measure the charge/mass ratio of an electron. 	<p><u>Experiment:</u></p> <p><u>Aim:</u> To show whether cathode rays were waves or particles.</p> <p><u>Results:</u></p> <ul style="list-style-type: none"> • Showed beyond doubt that the rays were streams of electrons. • Absence of deflection due to conductivity conferred on rarefied gas by rays. • Evacuated chamber and the rays were observed as being deflected towards the positive plate. <p><u>Experiment:</u></p> <p><u>Aim:</u> To determine the charge to mass ratio of an electron.</p> <p><u>Method:</u></p> <ol style="list-style-type: none"> 1. Thomson set up a magnetic field and an electric field until they opposed each other. 2. He then varied the strengths of the fields until their opposing forces cancelled, leaving cathode rays undeflected. 3. He then applied the same strength magnetic field but without the electric field and determined the radius of the circle made by the electron. 4. By combining the two results, he obtained the charge to mass ratio of an electron. <p>Determining Charge to Mass Ratio: When charged particles enter an electric field they follow a trajectory under the influence of an electric force. Similarly, when a charged particle enters a magnetic field, it experiences a magnetic force.</p> <p>We can combine these two effects by arranging the electric field, magnetic field and velocity at right angles to each other.</p> <p>By adjusting the strengths of the magnetic and electric fields, the effects on the motion of the particle can cancel each other out.</p>

$$Bqv = \frac{mv^2}{r}$$

Rearranging:

$$\frac{q}{m} = \frac{E}{B^2 r}$$

The charge to mass ratio is equal to the electric field strength divided by the product of the magnetic field strength squared and the radius of curvature.



- Outline the role of:
 - Electrodes in the electron gun
 - The deflection plates or coils
 - The fluorescent screen
 in the cathode ray tube of conventional TV displays and oscilloscopes.

TV Displays & Oscilloscopes:

Electrodes in the Electron Gun:

- Heated cathode releases electrons by thermionic emission.
- Positively charged anode develops strong electric field exerting a force.
- This accelerates the rays along the tube.

Deflection Plates or Coils:

- Cathode ray oscilloscopes use deflection plates.
- Television displays use deflection coils.
- The function is the same for both.
- **Deflection Plates:**
 - Charged, producing electric field
 - They deflect a beam of electrons up, down, left or right.
 - Moves beam to all points of fluorescent screen.
- **Deflection Coils:**
 - Electric current passing through produces a magnetic field.
 - These fields direct the beam up, down, left or right.
 - Moves beam to all points of the fluorescent screen.

Fluorescent Screen:

- Glass coated screen with layers of fluorescent material.
- Electrons strike the screen.
- These electrons are absorbed, where their kinetic energy is converted into light energy.
- Different colours are achieved by:
 - Three electron guns – **Red**, **green** and **blue**.
 - These light up at different intensities for different colours.

- Perform an investigation and gather first-hand information to observe the occurrence of different

Experiment:

Aim:

To observe the effect that different gas pressures have on an electric discharge passed through a discharge tube.

Method:

1. Set up apparatus.
2. Connect the terminals to each of the discharge tubes in turn.
3. Record observations about the pattern being observed.

<p>striation patterns for different pressures in discharge tubes.</p>	<p><u>Conclusion:</u> The greater the pressure of the gas in the tube, the greater the density of the gas. Since there are then more particles in a smaller space more collisions will occur and this results in different striations and patterns.</p>
<p>• Perform an investigation to demonstrate and identify properties of cathode rays using discharge tubes:</p> <ul style="list-style-type: none"> ○ Containing a maltese cross ○ Containing electric plates ○ With a fluorescent display screen ○ Containing a glass wheel ○ Analyse information gathered to determine the sign of the charge on cathode rays. 	<p><u>Experiment:</u> <u>Aim:</u> To determine some of the properties of the rays which come from the cathode of a discharge tube. <u>Method:</u></p> <ol style="list-style-type: none"> 1. Connect the power pack to the induction coil and set it at 6 volts. Adjust the points on the induction coil so that a strong steady spark is produced. 2. Connect terminals to discharge tube containing maltese cross. 3. Replace this with discharge tube containing electric plates and connect terminals of the plates to its high DC voltage supply. 4. Connect the tube with the fluorescent screen display to the induction coil and record the effect of magnets placed near. 5. Attach the tube to the discharge tube containing the glass wheel. <p><u>Conclusion:</u></p> <ul style="list-style-type: none"> • A shadow appeared behind the maltese cross as cathode rays cannot pass through or bend around solid objects. • The cathode rays were attracted towards the positively charged electric plate as cathode rays are streams of negatively charged electrons. • The cathode rays will bend in a magnetic field. • They will produce fluorescence. • The glass wheel will turn meaning that cathode rays are particles.
<p>• Solve problems and analyse information using:</p>	<p>Substitute appropriate values in and solve for unknown variables.</p> $F = qvB \sin \theta$ $F = qE$ $E = \frac{V}{d}$ $\text{Energy} = eV$
<p>Focus 2 The reconceptualisation of the model of light led to an understanding of the photoelectric</p>	

<p>effect and black body radiation.</p>	
<ul style="list-style-type: none"> Describe Hertz's observations of the effect of a radio wave on a receiver and the photoelectric effect he produced but failed to investigate. 	<p>Hertz, using an induction coil and a spark gap, succeeded in generating and detecting electromagnetic waves. He measured the speed of these waves, observed their interference, reflection, refraction and polarisation.</p> <p>Hertz was the first to discover radio waves.</p> <p>Hertz demonstrated that the radio waves had properties characteristic of light.</p> <p>The photoelectric effect is the name given to the release of electrons from a metal surface exposed to electromagnetic radiation.</p> <p>Later on, the following conclusions were drawn:</p> <ul style="list-style-type: none"> Electrons are emitted from an illuminated surface. These are known as photo-electrons. The emission of these photo electrons is practically instantaneous. There is a threshold frequency below which no photo-electrons are emitted. If the frequency of incident electromagnetic radiation exceeds the threshold frequency, then the excess energy appears as kinetic energy of the electron. The number of electrons is proportional to the intensity of the incident radiation.
<ul style="list-style-type: none"> Outline qualitatively Hertz's experiments in measuring the speed of radio waves and how they relate to light waves. 	<p>Hertz measured the speed of radio waves in 1888.</p> <p>He used a determined frequency from an oscillating circuit and a measured wavelength as determined by inference effects for the wave produced.</p> <p>Since he knew the wavelength and frequency, he could then calculate its velocity (since: $v = f\lambda$).</p> <p>He found that it corresponded to the speed predicted by Maxwell's equations.</p> <p>It was the speed of light.</p>
<ul style="list-style-type: none"> Identify Planck's hypothesis that radiation emitted and absorbed by the walls of a black body cavity is quantised. 	<p>To understand Planck's hypothesis, we must first understand black body radiation.</p> <p>Black body radiation is radiation from a hot body that does not reflect light.</p> <ul style="list-style-type: none"> All bodies at temperatures above absolute zero emit electromagnetic radiation. The hotter the body is, the higher the frequency of maximum emission.

	<p>Planck's Hypothesis:</p> <ul style="list-style-type: none"> • Emission and absorption of electromagnetic radiation for black bodies is quantised. • Energy is not continuous; it is in discrete amounts or packets called quanta.
<ul style="list-style-type: none"> • Identify Einstein's contribution to quantum theory and its relation to black body radiation. 	<p>Einstein helped to explain Planck's work:</p> <ul style="list-style-type: none"> • Energy associated with radiation from black bodies concentrated in packets of energy called photons. • A photon can only transfer all or none of its energy, not just a part of it. • Amount of energy carried by a photon is proportional to its frequency. • Intensity of light is proportional to the number of photons. <p>A photon is the smallest amount of radiation energy possible at a particular frequency.</p> <p>Relation to Black body Radiation:</p> <ul style="list-style-type: none"> • The higher the frequency, the greater the total energy radiated. This was shown by the black body radiation curves.
<ul style="list-style-type: none"> • Explain the particle model of light in terms of photons with particular energy and frequency. 	<p>Particle Model:</p> <ul style="list-style-type: none"> • Instead of being emitted as continuous waves, light and other electromagnetic waves travel in packets of energy called quanta. • Energy only occurred in packets. All energy is quantised. • All photons have zero rest mass regardless of frequency. <p>A photon is a unit or packet of energy relating to the quantum description of matter. It is also a particle of electromagnetic energy with a zero rest mass.</p>
<ul style="list-style-type: none"> • Identify the relationships between photon energy, frequency, speed of light and wavelength. 	<p>Photon Energy:</p> <ul style="list-style-type: none"> • The energy carried by a photon is proportional to its frequency. • All photons of the same frequency have the same amount of energy. • The higher the frequency, the greater the photon's energy. $E = hf$ <p>Speed of Light:</p> <ul style="list-style-type: none"> • Frequency is inversely proportional to wavelength and vice versa. • All photons travel at the same speed regardless of their frequency. $c = f\lambda$
<ul style="list-style-type: none"> • Perform an investigation to demonstrate the production and 	<p><u>Experiment:</u> <u>Aim:</u> To demonstrate the production and transmission of radio waves. <u>Method:</u></p>

<p>reception of radio waves.</p>	<ol style="list-style-type: none"> 1. Adjust the gap on the induction coil to about 5mm and adjust the transformer to 6V DC. 2. Adjust the tuner of the radio so it does not receive a station. 3. Move around the room and try to estimate where the radio can receive the static noise from the spark. 4. Adjust the gap to 10mm. 5. Change the tuner of the radio and scan through a range of wavelengths. <p><u>Conclusion:</u> The radio picked up the spark up to a distance of about 5m.</p>
<ul style="list-style-type: none"> • Identify data sources, gather, process and analyse information and use available evidence to assess Einstein's contribution to quantum theory and its relation to black body radiation. 	<p>Einstein helped to explain Planck's work:</p> <ul style="list-style-type: none"> • Energy associated with radiation from black bodies concentrated in packets of energy called photons. • A photon can only transfer all or none of its energy, not just a part of it. • Amount of energy carried by a photon is proportional to its frequency. • Intensity of light is proportional to the number of photons. <p>Relation to Black body Radiation: The higher the frequency, the greater the total energy radiated. This was shown by the black body radiation curves.</p>
<ul style="list-style-type: none"> • Identify data sources, gather, process and present information to summarise the use of the photoelectric effect in: <ul style="list-style-type: none"> ○ Solar cells ○ Photocells 	<p>Solar Cells: Sometimes called photovoltaic cells, solar cells use the photoelectric effect to convert the energy of sunlight into electrical energy. However, rather than relying on the sensitive and breakable vacuum tubes in earlier photocells, solar cells use semi-conductors.</p> <p>Photocells: Photocells, sometimes referred to as photo detectors, use the photo electric effect directly to produce an electric current in the circuit attached to them They are used to measure the intensity of light in camera exposure meters, in astronomical photometers and in automatic switching devices.</p>
<ul style="list-style-type: none"> • Solve problems and analyse information using: <ul style="list-style-type: none"> ○ $E = hf$ ○ $c = f\lambda$ 	<p>Substitute appropriate values in to find unknown values.</p>
<ul style="list-style-type: none"> • Process information to discuss Einstein and Planck's differing views about whether science 	<p>Both Max Planck and Albert Einstein lived in Germany during the early twentieth century. During World War One their friendship became strained. Einstein was a pacifist whilst Planck supported the German war effort, despite having lost a son in battle.</p> <p>When Hitler came to power Einstein left for the United States whilst</p>

<p>research is removed from social and political forces.</p>	<p>Planck continued to work in Germany. Planck, unlike Einstein, did not care to oppose Hitler but rather continued his work within the system.</p>
<p>Focus 3 Limitations of past technologies and increased research into the structure of the atom resulted in the invention of transistors.</p>	
<ul style="list-style-type: none"> Identify that some electrons in solids are shared between atoms and move freely. 	<p>Electron Orbits:</p> <ul style="list-style-type: none"> Individual atoms have specific orbits (stationary states) in which electrons exist. The lowest energy orbits generally are filled up first. In giving energy to the atom: <ul style="list-style-type: none"> Electrons can move into higher energy orbits Electrons can rapidly lose this energy and return to their normal level Energy can be lost through collisions or the emission of electromagnetic radiation. The most chemically stable substances have full outer orbits. <p>Bonding:</p> <ul style="list-style-type: none"> In molecular bonding, electrons are shared and can move freely between the two atoms. In ionic bonding, an outright transfer of electrons takes place. <p>Solid State Elements:</p> <ul style="list-style-type: none"> Conduct electricity when electrons in the outer orbit are free to move.
<ul style="list-style-type: none"> Describe the difference between conductors, insulators and semiconductors in terms of band structures and relative electrical resistance. 	<p>The conductivity of a substance depends on the ease with which electrons are able to move through the crystal lattice.</p> <p>A valence band is the energy band in a solid in which the outermost electrons are found.</p> <p>Conductors:</p> <ul style="list-style-type: none"> Conduction and valence bands overlap. Valence electrons easily move along the conduction band Have low electrical resistance <p>Insulators:</p> <ul style="list-style-type: none"> Large gap between conduction and valence bands Difficult for valence electrons to move into the conduction band Have high electrical resistance. <p>Semi-Conductors:</p>

	<ul style="list-style-type: none"> • Small gap between conduction and valence bands. • When temperature is increased, electrons have enough energy to move into the conduction band. • Temperature is inversely proportional to electrical resistance.
<ul style="list-style-type: none"> • Identify absences of electrons in a nearly full band as holes, and recognise that both electrons and holes help to carry current. 	<p>Creating Holes: When an electron jumps from the valence band into the conduction band, a hole is left where the electron was.</p> <p>Carrying Current: This hole is then attempted to be filled by another electron moving in its place, but this just moves the hole. Electrons continually try to fill the hole, hence creating an electric current.</p> <p>In many materials, including metals, resistivity increases with temperature. However, in semi-conductors, resistivity decreases with temperature.</p> <p>At absolute zero, all of the electrons in a semi-conductor occupy the valence band and the material acts as an insulator.</p> <p>As temperature increases, thermal energy allows some electrons to cross the gap into the conduction band. This leaves the valence band unfilled.</p> <p>This means that holes have been created in the valence band, which then acts as a positive flow of current moving in the opposite direction to the electron current flow.</p> <p>Thus, conduction is possible both in the conduction band as a flow of electrons and in the valence band as a flow of positive holes.</p>
<ul style="list-style-type: none"> • Compare qualitatively the relative number of free electrons that can drift from atom to atom in conductors, semi-conductors and insulators. 	<p>Conductors contain large numbers of free electrons in the conduction band.</p> <p>Insulators and semi-conductors have far less free electrons.</p> <p>However, by the implementation of certain conditions, electrons can be moved into the conduction band:</p> <ul style="list-style-type: none"> • Increased Temperature • Certain lighting conditions • Applying a potential difference
<ul style="list-style-type: none"> • Identify that the use of germanium in early transistors is related to a lack of ability to produce other materials of suitable purity. 	<p>Early diodes and transistors were made from germanium.</p> <ul style="list-style-type: none"> • At the time there were suitable industrial techniques capable of purifying germanium. • An ultra pure level of a substance is required for semi-conductors. <p>However, there were a few problems:</p> <ul style="list-style-type: none"> • Too good a conductor when hot • Hot germanium allows too much current to flow, damaging circuits. • Resistance to a large current will generate heat.

	<p>Later on, silicon replaced germanium.</p> <ul style="list-style-type: none"> • It was more abundant and cheaper • Retains semi-conducting properties at higher temperatures than germanium. • Handles higher electric currents
<ul style="list-style-type: none"> • Describe how 'doping' a semiconductor can change its electrical properties. 	<p>A dopant is a tiny amount of an impurity that is placed in an otherwise pure crystal to alter its electrical properties.</p> <p>If that dopant atom has a different number of valence electrons from the atom of the semi-conductor it replaces, extra energy levels can be formed within the gap between the valence band and the conduction band.</p>
<ul style="list-style-type: none"> • Identify differences in p and n-type semiconductors in terms of the relative number of negative charge carriers and positive holes. 	<p>N-Type Semiconductors: N-Type semiconductors are formed when a semiconductor is doped with a group 5 element. In other words, a foreign substance put into the semiconductor that has one more electron in its valence band.</p> <p>This means that there is an extra negative charge carrier and it enters the conduction band. N-type semiconductors are faster and more efficient than P-type semiconductors as the conduction band is more efficient than positive holes.</p> <p>P-Type Semiconductors: P-Type semiconductors are formed when a semiconductor is doped with a group 3 element. This means that the semiconductor contains an impurity with one less electron in its valence band. This means there is an extra positive hole, creating a current from a flow of positive holes.</p>
<ul style="list-style-type: none"> • Describe differences between solid state and thermionic devices and discuss why solid state devices replaced thermionic devices. 	<p>Thermionic Devices: Thermionic devices use thermionic emission to operate. Thermionic emission is the release of electrons from materials by heating them. A cathode emits electrons when heated to high temperatures. However, they require a near vacuum environment to operate and so are packaged in an evacuated glass tube. A valve is a thermionic device in which two or more electrodes are enclosed in a glass vacuum tube. The name comes from the rectifying property of the device; that is, the current flows in only one direction.</p> <p>Solid State Devices: Solid state devices are electronic devices that use semiconductors instead of valves. Semiconductors are used to generate the electron flow with no heated circuit required. Transistors and integrated circuits are examples of solid state devices.</p>

	<p>Reasons for Replacement:</p> <ul style="list-style-type: none"> • Solid state devices were smaller in size • Solid state devices were cheaper and more simple to construct • They used less power • They operated faster • They were generally more reliable • Thermionic devices produced a lot of wasted heat energy • The thermionic coating on the cathode was evaporated by the heat produced, giving valves a limited life. • The valve components of thermionic devices were mounted on metal bases, insulated by bakerlite rings, which often cracked or degraded due to heat.
<ul style="list-style-type: none"> • Perform an investigation to model the behaviour of semiconductors , including the creation of a hole or positive charge on the atom that has lost the electron and the movement of electrons and holes in opposite directions when an electric field is applied across the semiconductor. 	<p>The best way to view this is through the website: http://oldsite.vislab.usyd.edu.au/photronics/devices/semic/creature0.html</p>
<ul style="list-style-type: none"> • Gather, process and present secondary information to discuss how shortcomings in available communication technology lead to an increased knowledge of the properties of materials with particular reference to the invention of the 	<p>Prior to Transistors:</p> <ul style="list-style-type: none"> • Radios and electronic devices require increased voltage to receive signals that drive the electronics. • This is achieved mainly through thermionic devices and vacuum tubes. • These tubes were very fragile, lost their vacuum over time and the electrodes corroded. <p>For this reason, other inventions were developed, in particular, the invention of the transistor.</p> <ul style="list-style-type: none"> • They were called the transistor amplifier. • They were small, long lasting and reliable. <p>Other Inventions:</p> <ul style="list-style-type: none"> • Light-emitting diodes (LEDs) • Semi-conductor lasers

transistor.	<ul style="list-style-type: none"> • Photo detectors and solar cells
<ul style="list-style-type: none"> • Identify data sources, gather, process, analyse information and use available evidence to assess the impact of the invention of transistors on society with particular reference to their use in microchips and microprocessors. 	<p>Impacts of Transistors on Society:</p> <ul style="list-style-type: none"> • Greater access to communication • Increase in leisure time • Increase in obesity • Change in the nature of work • Less danger of electrocution • “Cashless” society • Decrease in social interaction • Increased unemployment • Entertainment is cheaper and more freely available. • Change in the delivery of education programs <p>Impacts on Microchips & Microprocessors:</p> <ul style="list-style-type: none"> • Able to have multiple devices and circuit elements on a single crystal of silicon. • Able to put thousands of transistors on a tiny microchip • Miniaturised and allows for faster transfer, storage and processing of information. • Easily incorporated into appliances • Many task previously done manually are now done electronically.
<p>Focus 4 Investigations into the electrical properties of particular metals at different temperatures led to the identification of superconductivity and the exploration of possible applications.</p>	
<ul style="list-style-type: none"> • Outline the methods used by the Braggs to determine crystal structure. 	<p>The Braggs used X-ray diffraction to determine the internal structure of crystals.</p> <p>Method: They fired x-rays at a crystal. The wavelength of the x-rays was comparable to the distance between atoms. These x-rays passed through the crystal and were diffracted before hitting a photographic screen.</p> <p>The pattern observed on the photographic screen allowed them to determine the internal structure of the crystal. The internal structure could be determined by calculations of angles between spots on the screen.</p> <p>Results: From the calculations, direct evidence had now been produced for the periodic atomic structure of crystals.</p>

<ul style="list-style-type: none"> Identify that metals possess a crystal lattice structure. 	<ul style="list-style-type: none"> Atoms are arranged in the crystal in regular repeating patterns A crystal lattice is defined by repeated 3D units
<ul style="list-style-type: none"> Describe conduction in metals as a free movement of electrons unimpeded by the lattice. 	<p>The metal ions are surrounded by a sea of electrons which are able to move freely throughout the lattice.</p> <p>These electrons are shared by all the ions in the lattice.</p>
<ul style="list-style-type: none"> Identify that resistance in metals is increased by the presence of impurities and scattering of electrons by lattice vibrations. 	<p>Impurities:</p> <ul style="list-style-type: none"> Disrupt the lattice integrity by distorting its shape This distortion impedes the free movement of electrons, increasing resistance. <p>Lattice Vibrations:</p> <ul style="list-style-type: none"> As the temperature increases, more lattice vibrations occur. The more the lattice vibrates, the more collisions electrons have with the lattice, increasing resistance. Electrons are deflected from their normal linear progress through the crystal.
<ul style="list-style-type: none"> Describe the occurrence in superconductors below their critical temperature of a population of electron pairs unaffected by electrical resistance. 	<p>A superconductor is a substance that when cooled to a temperature below its critical temperature, it exhibits the property of zero electrical resistance.</p> <p>Types of Superconductors:</p> <ul style="list-style-type: none"> Type 1 – These are pure metals and only become superconductive at temperatures near absolute zero. Type 2 – These are alloys, ceramics and metal oxides and become superconductive at temperatures much higher than type 1. <p>Currently only type 1 superconductors can be explained, and this is through using the idea that electrons pair up in a superconductor and are able to overcome obstacles in the lattice.</p>
<ul style="list-style-type: none"> Discuss the BCS theory. 	<p>Remember that, as of yet, type 2 superconductors cannot be explained.</p> <p>The BCS Theory: Type 1 superconductors are explained using the Nobel Prize winning BCS theory proposed in 1957 by Leon Cooper, John Bardeen and Robert Schrieffer. The BCS theory states that electrons pair up in what is known as 'Cooper Pairs.' In a typical metal at room temperature, electrons are able to move throughout the lattice structure of metals, giving metals their conductive properties. However, due to the temperature, vibrations occur inside the lattice and this causes collisions</p>

	<p>between electrons and the lattice, causing resistance and a loss of energy.</p> <p>However, when a metal is supercooled, the lattice gets to a point (critical temperature), where the lattice effectively stops vibrating and the 'Cooper pairs' of electrons work together to overcome any remaining obstacles and avoid collisions. These two electrons work together to create a slipstream in much the same way that a car will be 'dragged' along a highway by a semi-trailer in front.</p>																																	
<ul style="list-style-type: none"> • Discuss the advantages of using superconductors and identify limitations to their use. 	<p>Advantages of Superconductors:</p> <p>The first and most obvious advantage is the negligible energy losses that occur in superconductors as opposed to regular conductors. It becomes exceedingly more cost and power efficient if electrical devices can be operated with no resistance to the flow of electrons. They are therefore able to carry large currents for a long time with negligible energy losses as heat. In all testing carried out so far, superconductors have carried currents for years with no recordable losses.</p> <p>They also have the potential to allow electronic devices to operate much faster and transport vehicles, such as trains, to reach speeds of up to 581 km h⁻¹.</p> <p>Limitations of superconductors:</p> <p>Type 1:</p> <ul style="list-style-type: none"> • Critical temperature too low to be practical. • Liquid nitrogen not cold enough to be used. • Can't be used with AC <p>Type 2:</p> <ul style="list-style-type: none"> • Critical temperature, whilst higher than in type 1 superconductors, still too low to be practical. • Brittle • Can't be used with AC 																																	
<ul style="list-style-type: none"> • Process information to identify some of the metals, metal alloys and compounds that have been identified as exhibiting the property of superconductivity and their critical temperatures. 	<p>Superconductive Substances:</p> <table border="1" data-bbox="475 1417 1297 1982"> <thead> <tr> <th>Substance</th> <th>Type</th> <th>T_c (K)</th> </tr> </thead> <tbody> <tr> <td>Rhodium</td> <td>1</td> <td>3.25 x 10⁻⁴</td> </tr> <tr> <td>Zinc</td> <td>1</td> <td>0.88</td> </tr> <tr> <td>Aluminium</td> <td>1</td> <td>1.20</td> </tr> <tr> <td>Tin</td> <td>1</td> <td>3.72</td> </tr> <tr> <td>Mercury</td> <td>1</td> <td>4.15</td> </tr> <tr> <td>Lead</td> <td>1</td> <td>7.20</td> </tr> <tr> <td>Niobium-germanium</td> <td>1</td> <td>23.2</td> </tr> <tr> <td>YBCO (YBa₂Cu₃O₇)</td> <td>2</td> <td>92</td> </tr> <tr> <td>Thallium-Barium-Calcium-Copper Oxide</td> <td>2</td> <td>125</td> </tr> <tr> <td>HgBa₂Ca₂Cu₃O₈</td> <td>2</td> <td>133</td> </tr> </tbody> </table>	Substance	Type	T _c (K)	Rhodium	1	3.25 x 10 ⁻⁴	Zinc	1	0.88	Aluminium	1	1.20	Tin	1	3.72	Mercury	1	4.15	Lead	1	7.20	Niobium-germanium	1	23.2	YBCO (YBa ₂ Cu ₃ O ₇)	2	92	Thallium-Barium-Calcium-Copper Oxide	2	125	HgBa ₂ Ca ₂ Cu ₃ O ₈	2	133
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<ul style="list-style-type: none"> Perform an investigation to demonstrate magnetic levitation. 	<p><u>Experiment:</u></p> <p><u>Aim:</u> To demonstrate magnetic levitation.</p> <p><u>Method:</u></p> <ol style="list-style-type: none"> Place a superconductive substance in a Styrofoam cup/dish. Put a perspex strip between the magnet and superconductor. Pour over liquid nitrogen. Remove the perspex and allow the magnet to levitate. Lift the magnet & observe what happens to the superconductor. Move a piece of paper between magnet and conductor to prove there is no physical link. Lower the magnet and allow to warm up. <p><u>Conclusion:</u> The magnet and superconductor repel but when the magnet is lifted, the superconductor lifts also and remains a set distance away.</p>			
<ul style="list-style-type: none"> Analyse information to explain why a magnet is able to hover above a superconducting material that has reached the temperature at which it is superconducting. 	<p>The Meissner Effect and Magnetic Levitation:</p> <p>The Meissner Effect is an effect whereby the magnetic field created in a superconductor will repel all other magnetic fields, regardless of whether they are changing or not. This means that if a magnet is placed over a superconductor it will levitate there inside the magnetic field.</p> <p>The amazing fact about the magnetic levitation observed in superconductors is that even though the two objects repel each other, they are not pushed away entirely, but remain 'stuck' a certain distance apart. If two normal magnets' North poles were placed facing each other, the magnets would be pushed apart by a force that exists (even though minutely) to a distance of infinity. However, a superconductor will repel a magnet a certain distance but then keep it at that distance.</p> <p>This is due to the way in which a superconductor sets up its magnetic field. When a magnetic field is created in a superconductor, poles are created to repel all fields.</p> <p>The Meissner Effect is different from regular diamagnetism in that it repels all magnetic fields, not just changing ones. Unlike a regular magnet, which has just a North Pole and a South Pole, a superconductor can create many poles to ensure that all poles are repelled depending on what it is trying to repel. This same effect, however, is responsible for holding the magnet at a certain distance away. This is because when a magnet is pulled away from it, the poles are reversed to hold the magnet in place.</p>			
<ul style="list-style-type: none"> Gather and process information to describe how superconductors and the 	<p>The MagLev train is a Magnetically Levitating train in which the train is kept 'on the tracks' by the magnetic field supplied by superconductors. The train effectively 'floats' over the magnets using the theory based on the Meissner Effect. Poles are set up on the track and also on the guidance rails so that the train is repelled from behind and attracted from in front.</p>			

<p>effects of magnetic fields have been applied to develop a maglev train.</p>	<p>The first MagLev train was developed in Japan in 1972 and Japan has been the leaders in levitated transport since. In 1990, the Yamanashi MagLev test line opened and has been operating ever since. The test line is an 18.4 km stretch of track that runs solely on the technology of superconductors. The MagLev trains are much safer, faster and environmentally friendly than their traditional counterparts. Japan is leading the way, continually investing more money into the further research of levitated vehicles.</p>
<p>• Process information to discuss possible applications of superconductivity and the effects of these applications on computers, generators & motors and the transmission of electricity through power grids.</p>	<p>Computers & Electric Devices:</p> <p>The integration of superconductors into computers could have a big improvement in the speed, capacity and performance of all computers and electric devices ranging from household devices to powerful supercomputers. Due to the negligible resistance of superconductors, computer processors could run at speeds in excess of 120GHz. This means that computers running on superconductor technology could run 30 times faster than current designs. Also as a result of no resistance, the processors are able to run not only at high speeds but also using less power. In fact, the power level of a superconductor microchip is 100,000 times more efficient than its silicon predecessor. SQUIDs, if implemented into computing, have the potential to allow computer manufacturers to begin mainstream release of quantum computers. Superconductors also have the ability to improve the amount of hard drive space available to the average consumer by implementing the technology into hard drives as well. All the advances in computer speeds are made possible by the theory of the Josephson Effect. The Josephson Effect is an effect observed in superconductors that are joined. When superconductors are joined by a thin, insulating layer, electrons are able to pass through much more easily. It is this theory that has made the potential for super fast electrical switches in computers a possibility.</p> <p>Motors and Generators:</p> <p>Currently, the production of electricity in generators is exceedingly inefficient when it comes to energy losses throughout the entire process. Because superconductors would have significantly lower energy losses during the generating phase, significantly less coal and other fossil fuels would be required. Generators that are wound with superconducting wires could generate the same amount of energy as conventional generators using significantly smaller equipment with less energy losses. In fact, superconducting generators have been theorised to be 99% efficient. These same properties can then be applied to electric motors, where there is little energy losses throughout the process. Currently, motors that have been made using superconducting technology have reached 5000 horsepower engines. Future motors could be produced without an iron core making them</p>

not only more space efficient but also lighter and more portable.

Electricity and the Power Grid:

Perhaps the field that will benefit most from superconductor technology is in the transmission, generation and storage of electricity.

Firstly, the superconducting technology would allow for the beginning of fusion power. Fusion requires large electromagnets in order to contain the immense power produced. Superconductors could be used as part of those electromagnets.

In regards to the storing of electrical energy, superconductors can be applied to Superconducting Magnetic Energy Storage Systems (D-SMES). These systems are capable of storing upwards of 3 million watts of power.

But when it comes to the transmission of electricity through the power grid, this is where superconductors can have arguably the biggest impact. If we were to implement superconducting technology into the power grid right now, the liquid nitrogen cooled cables could be placed underground in place of copper cables. These superconductor cables are 7000% more space efficient than their copper rivals. These new power lines effectively have negligible energy losses, reducing the need for boosting of voltage at substations. By using superconducting electrical cables as opposed to copper, the cost of the transmission is reduced and very large current densities are able to be transmitted with 3 to 5 times the current of regular wires. The only concern with this, as mentioned previously, is the practicality of cooling kilometres of underground cables.

Other Applications:

- MagLev Transport vehicles
- SQUIDs
- Quantum Computers
- Geophysical Surveying
- MRI Scans
- Magnetometers
- Powerful electromagnets
- Particle accelerators
- Microwave detectors & filters
- Motors & Generators
- Electricity production and transmission
- Fast Electronic devices