Thermal Physics

States of matter **Solids** - Solids have a definite shape and a definite volume - Solids cannot flow and are not compressible **Liquids** - Liquids have no definite shape but do have a definite volume - Liquids are able to flow to take the shape of a container but they are not compressible **Gases** - Gases have no definite shape and no fixed volume - Gases can flow to take the shape of their container and are highly compressible

Thermal Equilibrium - As an object **absorbs** thermal radiation it will become **hotter** - As it gets hotter it will also **emit** more thermal radiation - The temperature of a body increases when the body absorbs radiation faster than it emits radiation - Eventually, an object will reach a point of **constant temperature** where it is **absorbing** radiation at the **same rate** as it is **emitting** radiation - At this point, the object will be in **thermal equilibrium** ***An object will remain at a constant temperature if it absorbs heat at the same rate as it loses heat***

Changes of State When a substance changes state, the number of molecules in that substance doesn't change and so neither does its mass - The only thing that changes is its **energy** - Changes of state are physical changes and so they are **reversible** **Melting & Freezing** - Melting occurs when a solid turns into a liquid (e.g. ice to water) - Freezing occurs when a liquid turns into a solid **Boiling & Condensing** - Boiling occurs when a liquid turns into a gas - This is also called evaporating - Condensing occurs when a gas turns into a liquid

The greenhouse effect. - If the Earth had no atmosphere, the temperature on the surface would drop to about −180 °C at night, the same as the Moon's surface at night - This would happen because the surface would be emitting **all** the radiation from the Sun into space - The temperature of the Earth is affected by factors controlling the balance between **incoming** radiation and radiation **emitted** - The Earth receives the majority of its heat in the form of thermal radiation from the Sun - At the same time, the Earth **emits** its own thermal radiation, with a slightly longer wavelength than the thermal radiation it receives (the surface temperature of the Earth is significantly smaller than the surface temperature of the Sun) - Some gases in the atmosphere, such as water vapour, methane, and carbon dioxide (greenhouse gases) absorb and reflect back longer-wavelength infrared radiation from the Earth and prevent it from escaping into space - These gases **absorb** the radiation and then **emit** it back to the **surface** - This process makes the Earth warmer than it would be if these gases were not in its atmosphere

Thermal Physics (cont)

Thermal Conduction in Solids - Conduction is the main method of thermal energy transfer in **solids** - Conduction occurs when: **Two solids of different temperatures come in contact with one another, thermal energy is transferred from the hotter object to the cooler object** - Metals are the best thermal **conductors** - This is because they have a high number of **free electrons**. ***Conduction: the atoms in a solid vibrate and bump into each other*** - Conduction can occur through two mechanisms: - Atomic vibrations - Free electron collisions - When a substance is heated, the atoms, or ions, **start to move around (vibrate) more** - The atoms at the hotter end of the solid will vibrate more than the atoms at the cooler end - As they do so they **bump into each other**, transferring energy from atom to atom - These collisions transfer internal energy until **thermal equilibrium** is achieved throughout the substance - This occurs in **all solids**, metals and non-metals alike

Thermal Expansion - When materials are heated, they expand - This expansion happens because the molecules start to move around (or vibrate) faster, which causes them to knock into each other and push each other apart - Thermal expansion occurs in solids, liquids and gases - When temperature is increased (at constant pressure); - Solids will tend to expand the least - Gases expand the most - Liquids fall in between the two - Molecules do not expand, but the space in between them does - When solids, liquids and gases are heated:

Thermal Conduction in Liquids & Gases - For thermal conduction to occur the particles need to be close together so that when they vibrate the vibrations are passed along - This does not happen easily in fluids - In liquids particles are close, but slide past each other - In gases particles are widely spread apart and will not 'nudge' each other - Both types of **fluid**, liquids and gases, are poor conductors of heat

Relative Thermal Conductivity - Conductors tend to be **metals** - Better thermal conductors are those with delocalised electrons which can easily transfer energy - This means that there is a **wide range** of thermal conductivity

Convection - Convection is the main way that heat travels through **liquids and gases** - Convection **only** occurs in fluids - Convection **cannot** happen in solids

Density & Convection Descriptions of convection currents always need to refer to changes in temperature causing changes in density - The temperature may fall or rise, both can create a convection current - **When a liquid (or gas) is heated (for example by a radiator near the floor)**: - The molecules push each other apart, **making the liquid/gas expand** - This makes the hot liquid/gas **less dense** than the surroundings - The **hot liquid/gas rises**, and the cooler (surrounding) liquid/gas moves in to take its place - Eventually the hot liquid/gas cools, contracts and sinks back down again - The resulting motion is called a **convection current**. ***When a liquid or gas is heated, it becomes less dense and rises*** - **When a liquid (or gas) is cooled (for example by an A.C. unit high up on a wall)**: - The molecules move together, **making the liquid/gas contract** - This makes the hot liquid/gas **more dense** than the surroundings - The **cold liquid/gas falls**, so that warmer liquid or gas can move into the space created - The warmer liquid or gas gets cooled and also contracts and falls down - The resulting motion is called a **convection current**

Thermal Physics (cont)

Thermal Radiation - All objects give off thermal radiation - The hotter an object is, the more thermal radiation it emits - Thermal radiation is the part of the electromagnetic spectrum called **infrared** - Thermal radiation is **the only way in which heat can travel through a vacuum** - It is the way in which heat reaches us from the Sun through the vacuum of space - The colour of an object affects how good it is at emitting and absorbing thermal radiation:

Electromagnetism

Electromotive force and potential difference - The Electromotive Force (e.m.f.) is the name given to the potential difference of the power source in a circuit - It is defined as **The electrical work done by a source in moving a unit charge around a complete circuit** - The Electromotive Force (EMF) is measured in volts (V)	**Alternating Current** - An alternating current (a.c.) is defined as **A current that continuously changes its direction, going back and forth around a circuit** - An a.c. power supply has two identical terminals that switches between positive and negative - The current is therefore defined as positive **or** negative, depending on which direction it is flowing at that time - The **frequency** of an alternating current is the number of times the current changes direction back and forth each second - In the UK, **mains electricity** is an **alternating** current with a frequency of 50 Hz and a potential difference of around 230 V
The EMF is the voltage supplied by a power supply: 12 V in the above case - The definition of e.m.f. can also be expressed using an equation - Where - E = electromotive force (e.m.f.) (V) - W = energy supplied **to the charges** from the power source (J) - Q = charge on each charge carrier (C)	Mains Electricity - Mains electricity is the electricity generated by power stations and transported around the country through the National Grid - Everyone connects to the mains when plugging in an appliance such as a phone charger or kettle - Mains electricity is an **alternating current** (a.c.) supply - In the UK, the domestic electricity supply has a **frequency** of **50 Hz** and a **potential difference** of about **230 V** - A frequency of 50 Hz means the direction of the current changes back and forth 50 times every second - Mains electricity, being an alternating current, does not have positive and negative sides to the power source - The equivalent to positive and negative are called **live** and **neutral** and these form either end of the electrical circuit

Electromagnetism (cont)

Electric Power - Power is defined as **The rate of energy transfer or the amount of energy transferred per second** - The power of a device depends on: - The **voltage** (potential difference) of the device - The **current** of the device - The power of an electrical component (or appliance) is given by the equation: P = IV	Induced EMF - An EMF will be induced in a conductor if there is **relative movement** between the conductor and the magnetic field - It will also be induced if the conductor is stationary in a changing magnetic field - For an electrical conductor moving in a fixed magnetic field - The conductor (e.g wire) **cuts** through the fields lines - This **induces an EMF** in the wire
- **Work** is done when charge flows through a circuit - Work done is equal to the **energy transferred** - The amount of energy transferred by electrical work in a component (or appliance) depends upon: - The **current**, I - The **potential difference**, V - The amount of **time** the component is used for, t - When charge flows through a resistor, for example, the energy transferred is what makes the resistor **hot** - The energy transferred can be calculated using the equation: $E = P \times t$ - Where: - E = energy transferred in joules (J) - P = power in watts (W) - t = time in seconds (s) - Since $P = IV$, this equation can also be written as: $E = I \times V \times t$	Lenz's Law **The direction of an induced potential difference always opposes the change that produces it.** - This means that any magnetic field created by the potential difference will act so that it tries to stop the wire or magnet from moving
Direct Current - A direct current (d.c.) is defined as **A current that is steady, constantly flowing in the same direction in a circuit, from positive to negative** - The potential difference across a cell in a d.c. circuit travels in **one direction only** - This means the current is only positive or only negative - A d.c. power supply has a fixed positive terminal and a fixed negative terminal - Electric **cells**, or **batteries**, produce direct current (d.c.)	**Demonstrating Lenz's Law** - If a magnet is pushed north end first into a coil of wire then the end of the coil closest to the magnet will become a **north pole** - Explanation - Due to the generator effect, a **potential difference** will be induced in the coil - The induced potential difference always **opposes** the change that produces it - The coil will apply a **force** to oppose the magnet being pushed into the coil - Therefore, the end of the coil closest to the magnet will become a **north pole** - This means it will **repel** the north pole of the magnet

Nuclear and Atomic Physics

- Atoms are the smallest particles in the world and they cannot be broken down into smaller parts since they are the smallest. - in Nuclear Physics there are 3 particles: - Alpha - Beta - Gamma	Gamma These are the most penetrating and are stopped only by many centimetres of lead. They ionise a gas even less than beta particles and are not deflected by electric and magnetic fields.

Nuclear and Atomic Physics (cont)

Ionizing effect of radiation - A charged electroscope discharges when a lighted match or a radium source (held in forceps) is brought near the cap and this causes radiation	Half Life The rate of Decay is unaffected by temperature but every radioactive element has its own definitive decay rate, expressed by it's half life. This is the average time for half the atoms in a given sample to decay.
Alpha These are stopped by a thick sheet of paper and have a range in air of only few centimetres since they cause ionisation in a gas due to frequent collisions with gas molecules.	Background Radiation A type of radiation that is being recieved from the surroundings like e.g. Underground, In the sky etc.

Beta These are stopped by a few millimetres of aluminium and some have a range in air of several metres and their ionizing power is much less than that of alpha particles. As well as being easily deflected by electric fields, they are more easily deflected by magnetic fields.

General Physics

Momentum - An object with that is in motion has momentum which is defined by the equation (Momentum = mass x velocity).	Kinetic energy - The kinetic energy, *E*, of an object (also known as its kinetic store) is defined as: K **The energy an object has as a result of its mass and speed** - This means that any object in **motion** has energy in its kinetic energy store - Kinetic energy can be calculated using the equation: ***E*K = ½ × *m* × *v2***
Collisions The total momentum before a collision = The total momentum after a collision - Before the collision: - The momentum is only of mass *m* which is moving - If the right is taken as the positive direction, the total momentum of the system is ***m* × *u*** - After the collision: - Mass *M* also now has momentum - The velocity of *m* is now -*v* (since it is now travelling to the left) and the velocity of *M* is *V* - The total momentum is now the momentum of *M* + momentum of *m* - This is (*M* × *V*) + (*m* × -*v*) or **(*M* × *V*) – (*m* × *v*)**	Gravitational potential energy - The gravitational potential energy, *E*, of an object (also known as its gravitational store) is defined as: P **The energy an object has due to its height in a gravitational field** - This means: - If an object is lifted up, energy will be transferred **to** its gravitational store - If an object falls, energy will be transferred **away from** its gravitational store - The GPE of an object can be calculated using the equation: **Δ*E*P = *mg*Δh**
Impulse - When a resultant (unbalanced) force acts on a mass, the momentum of that mass will change - The **impulse of a force** is equal to that force multiplied by the time for which it acts: **impulse = force × change in time impulse = *F*Δ*t*** - The change in momentum of a mass is equal to the impulse provided by the force: **impulse = change in momentum impulse = *F*Δ*t* = Δ*p*** - Change in momentum can also be described as: **Δ*p* =Δ*(mv)* Δ*p* = *mv* − *mu*** - Where: - *m* = mass in kg - *v* = final velocity in m/s - *u* = initial velocity in m/s - Therefore: **impulse = *F*Δ*t* = Δ*p* = *mv* − *mu***	Work done - Work is done when an object is moved over a **distance** by a **force** applied in the **direction** of its displacement - It is said that the **force does work** on the object - If a force is applied to an object but doesn't result in any movement, no work is done ***Work is done when a force is used to move an object*** - The formula for work done is: **Work done = force × distance *W* = *fd***

General Physics (cont)

Energy - Energy is a property that must be transferred to an object in order to perform **work on** or **heat up** that object - It is measured in units of **Joules (J)** - Energy will often be described as part of an energy **system** - In physics, a system is defined as: **An object or group of objects** - Therefore, when describing the changes within a system, only the objects or group of objects and the surroundings need to be considered - Energy can be stored in different ways, and there are changes in the way it is stored when a system **changes** - The principle of conservation of energy states that: **Energy cannot be created or destroyed, it can only be transferred from one store to another** - This means that for a closed system, the total amount of energy is **constant**

Efficiency of energy transfer - The efficiency of a system is a measure of how well energy is transferred in a system - Efficiency is defined as: **The ratio of the useful power or energy transfer output from a system to its total power or energy transfer input** - If a system has **high** efficiency, this means most of the energy transferred is **useful** - If a system has **low** efficiency, this means most of the energy transferred is **wasted**

Pressure - **Pressure** is defined as **The concentration of a force or the force per unit area** - For example, when a drawing pin is pushed downwards: - It is pushed into the surface, rather than up towards the finger - This is because the sharp point is more **concentrated** (a small area) creating a **larger** pressure

Liquid Pressure - A fluid is either a **liquid** or a **gas** When an object is immersed in a fluid, the fluid will exert pressure, squeezing the object - This pressure is exerted evenly across the whole surface of the fluid and in **all directions** - The pressure exerted on objects in fluids creates **forces** against surfaces - These forces act at **90 degrees** (at right angles) to the surface ***The pressure of a fluid on an object creates a force normal (at right angles) to the surface*** - The pressure of a fluid on an object will increase with: - Depth within the fluid - Increased density of the fluid ### **Calculating Pressure in Liquids** - The pressure is more accurately the **difference** in pressure at different depths *h* in a liquid, since the pressure changes with the depth - The pressure due to a column of liquid can be calculated using the equation $\Delta p = \rho g \Delta h$ or in simple words —> $Rho *Gravity* Height$

revision notes

Properties of Waves

- Waves transfer **energy** and **information** - Waves are described as **oscillations** or **vibrations** about a fixed point - For example, **ripples** cause particles of water to oscillate up and down - **Sound** waves cause particles of air to vibrate back and forth - In all cases, waves transfer **energy without** transferring **matter** - For water waves, this means it is the **wave** and not the **water** (the matter) itself that travels - For sound waves, this means it is the **wave** and not the **air molecules** (the matter) itself that travels - Objects floating on water provide evidence that waves only transfer energy and **not** matter	**Frequency** - Frequency is defined as: **The number of waves passing a point in a second** - Frequency is given the symbol ***f*** and is measured in **Hertz (Hz)**
Types of Waves - Transverse - e.g. vibrations of guitar string. - Longitudinal - e.g. Tsunami waves.	**Wave Speed** - Wave speed is the speed at which **energy** is transferred through a medium - Wave speed is defined as: **The distance travelled by a wave each second** - Wave speed is given the symbol, *v*, and is measured in **metres per second (m/s),** it can be calculated using: $wave speed = frequency × wavelength$
Features of a wave - When describing wave motion, there are several terms which are important to know, including: - Crest (Peak) - Trough - Amplitude - Wavelength - Frequency - Wave speed - Wavefront	**Wavefront** - Wavefronts are a useful way of picturing waves from above: each wavefront is used to represent a single wave - The image below illustrates how wavefronts are visualised: - The arrow shows the direction the wave is moving and is sometimes called a **ray** - The space between each wavefront represents the **wavelength** - When the wavefronts are **close together**, this represents a wave with a **short** wavelength - When the wavefronts are **far apart**, this represents a wave with a **long** wavelength - Wave speed is defined as: **The distance travelled by a wave each second** - Wave speed is given the symbol **v** and is measured in **metres per second (m/s)** - Wave speed is the speed at which energy is transferred through a medium - Transverse and longitudinal waves both obey the wave equation: V = f x lambda

Properties of Waves (cont)

Crests & Troughs - **A crest, or a peak, is defined as:** The highest point on a wave above the equilibrium, or rest, position - **A trough is defined as** The lowest point on a wave below the equilibrium, or rest, position**	- Where: - *v* = wave speed in metres per second (m/s) - *f* = frequency in Hertz (Hz) - λ = wavelength in metres (m)
Amplitude - Amplitude is defined as: The distance from the undisturbed position to the peak or trough of a wave - It is given the symbol **A** and is measured in **metres (m)** - Amplitude is the maximum or minimum **displacement** from the **undisturbed position**	**Transverse Waves** - Transverse waves are defined as: **Waves where the points along its length vibrate at 90 degrees to the direction of energy transfer**
Wavelength - Wavelength is defined as: The distance from one point on the wave to the same point on the next wave - In a transverse wave: - The wavelength can be measured from one peak to the next peak - In a longitudinal wave - The wavelength can be measured from the centre of one compression to the centre of the next - The wavelength is given the symbol **λ** (lambda) and is measured in **metres** (**m**) - The distance along a wave is typically put on the x-axis of a wave diagram	**Longitudinal Waves** - Longitudinal waves are defined as: **Waves where the points along its length vibrate parallel to the direction of energy transfer**