**Energy Conservation and Dissipation**

### Energy stores and changes

**System**
- An object or group of objects that interact together
  - EG: Kettle boiling water.

**Energy stores**
- Kinetic, chemical, internal (thermal), gravitational potential, magnetic, electrostatic, nuclear

**Ways to transfer energy**
- Light, sound, electricity, thermal, kinetic

**Unit**
- Joules (J)

**Work**
- Doing work transfers energy from one store to another
  - By applying a force to move an object the energy store is changed.

**Power**
- The rate of energy transfer
  - 1 Joule of energy per second = 1 watt of power

### Energy Pathways

<table>
<thead>
<tr>
<th>Mechanical</th>
<th>Electrical</th>
<th>Heat</th>
<th>Radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force acts upon an object</td>
<td>Electric current flow</td>
<td>Temperature difference between objects</td>
<td>Electromagnetic waves or sound</td>
</tr>
</tbody>
</table>

**Energy stores**

- **Kinetic energy**
  - Energy stored by a moving object
  - \( \frac{1}{2} \times \text{mass} \times (\text{speed})^2 \)

- **Elastic Potential energy**
  - Energy stored in a stretched spring, elastic band
  - \( \frac{1}{2} \times \text{spring constant} \times (\text{extension})^2 \)

- **Gravitational Potential energy**
  - Energy gained by an object raised above the ground
  - \( \text{Mass} \times \text{gravitational field strength} \times \text{height} \)

**Energy needed to raise 1kg of substance by 1°C**

- Depends on: mass of substance, what the substance is and energy put into the system.

### Efficiency

- **Higher:** Efficiency can be increased using machines.
- Efficiency = \( \frac{\text{useful output energy transfer}}{\text{total input energy transfer}} \)
- How much energy is usefully transferred

### Ways to reduce ‘wasted’ energy
- Insulation, streamline design, lubrication of moving parts.

### Energy transferred usefully
- Insulation, streamline design, lubrication of moving parts.

### Principle of conservation of energy
- The amount of energy always stays the same.
- Energy cannot be created or destroyed, only changed from one store to another.

### Units

- **Energy (KE, EPE, GPE, thermal)**
  - Joules (J)
- **Velocity**
  - Metres per second (m/s)
- **Spring constant**
  - Newton per metre (N/m)
- **Extension**
  - Metres (m)
- **Mass**
  - Kilogram (Kg)
- **Gravitational field strength**
  - Newton per kilogram (N/Kg)
- **Height**
  - Metres (m)

### Reducing friction
- - using wheels, applying lubrication. Reducing air resistance – travelling slowly, streamlining.

### Change in thermal energy

- \( \Delta E = m \times c \times \Delta \theta \)

### Specific Heat Capacity

- **Units**
  - Joules per Kilogram degree Celsius (J/Kg°C)

### Temperature change

- Degrees Celsius (°C)

### Work done

- Joules (J)

### Force

- Newton (N)

### Distance moved

- Metre (m)

### Power

- Watts (W)

### Time

- Seconds (s)

### Useful energy

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Multiple</th>
<th>Standard form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kilo</td>
<td>1000</td>
<td>10^3</td>
</tr>
<tr>
<td>Mega</td>
<td>1000000</td>
<td>10^6</td>
</tr>
<tr>
<td>Giga</td>
<td>10000000</td>
<td>10^9</td>
</tr>
</tbody>
</table>

### Energy transferred and used

- Dissipated energy, stored less usefully
- Wasted energy
- Work done = Force \times distance moved

**Frictional forces cause energy to be transferred as thermal energy. This is wasted.**

**HIGHER:** When an object is moved, energy is transferred by doing work.

**Reducing friction - using wheels, applying lubrication. Reducing air resistance – travelling slowly, streamlining.**
### Energy Resources

<table>
<thead>
<tr>
<th>Energy Resource</th>
<th>How it works</th>
<th>Uses</th>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil Fuels (coal, oil and gas)</td>
<td><strong>Burnt to release thermal energy used to turn water into steam to turn turbines</strong></td>
<td>Generating electricity, heating and transport</td>
<td>Provides most of the UK energy. Large reserves. Cheap to extract. Used in transport, heating and making electricity. Easy to transport.</td>
<td>Non-renewable. Burning coal and oil releases sulfur dioxide. When mixed with rain makes acid rain. Acid rain damages building and kills plants. Burning fossil fuels releases carbon dioxide which contributes to global warming. Serious environmental damage if oil spilt.</td>
</tr>
<tr>
<td>Nuclear</td>
<td><strong>Nuclear fission process</strong></td>
<td>Generating electricity</td>
<td>Lots of energy produced from small amounts of fuel.</td>
<td>Non-renewable. Dangers of radioactive materials being released into air or water. Nuclear sites need high levels of security. Start up costs and decommission costs very expensive. Toxic waste needs careful storing.</td>
</tr>
<tr>
<td>Biofuel</td>
<td><strong>Plant matter burnt to release thermal energy</strong></td>
<td>Transport and generating electricity</td>
<td>Renewable. As plants grow, they remove carbon dioxide. They are ‘carbon neutral’</td>
<td>Large areas of land needed to grow fuel crops. Habitats destroyed and food not grown. Emits carbon dioxide when burnt thus adding to greenhouse gases and global warming.</td>
</tr>
<tr>
<td>Tides</td>
<td><strong>Every day tides rise and fall, so generation of electricity can be predicted</strong></td>
<td>Generating electricity</td>
<td>Renewable. Predictable due to consistency of tides. No greenhouse gases produced.</td>
<td>Expensive to set up. A dam like structure is built across an estuary, altering habitats and causing problems for ships and boats.</td>
</tr>
<tr>
<td>Waves</td>
<td><strong>Up and down motion turns turbines</strong></td>
<td>Generating electricity</td>
<td>Renewable. No waste products.</td>
<td>Can be unreliable depends on wave output as large waves can stop the pistons working.</td>
</tr>
<tr>
<td>Hydroelectric</td>
<td><strong>Falling water spins a turbine</strong></td>
<td>Generating electricity</td>
<td>Renewable. No waste products.</td>
<td>Habitats destroyed when dam is built.</td>
</tr>
<tr>
<td>Solar</td>
<td><strong>Directly heats objects in solar panels or sunlight captured in photovoltaic cells</strong></td>
<td>Generating electricity and some heating</td>
<td>Renewable. No waste products.</td>
<td>Making and installing solar panels expensive. Unreliable due to light intensity.</td>
</tr>
<tr>
<td>Geothermal</td>
<td><strong>Hot rocks under the ground heats water to produce steam to turn turbine</strong></td>
<td>Generating electricity and heating</td>
<td>Renewable. Clean. No greenhouse gases produced.</td>
<td>Limited to a small number of countries. Geothermal power stations can cause earthquake tremors.</td>
</tr>
</tbody>
</table>
**Electricity**

- **Potential difference (p.d.)**: How much electrical work is done by a cell.
- **Amount of electricity travelling in a circuit**: Coulombs (C)
- **Flow of electrical charge**: Amperes (A)

**Domestic uses and safety**

- **Thermistor**: Resistance varies with temperature
- **LDR**: Resistance varies with light intensity

**Energy transfers**

- **AQA**: Energy transferred = Power \( P \times t \)
- **Work done when charge flowing**: Power = (current)\(^2\) \( R \)

**Series and parallel circuits**

- **Series circuit**: Total current is the same across all components.
- **Parallel circuit**: Total current is the sum of each component's current.

**Electrical fields**

- Charged objects create electric fields around them. Strongest closest to the object. The field direction is the direction of force on a positive charge. Add more charge increases field strength.

**Static electricity**

- **PHYSICS only**: When two insulating material are rubbed together, electrons move from one material to the other.
- **Electrical charge is stationary**: Shocks

- **Walking on carpet causes friction**: Electrons move to the person and charge builds up.

**Current and potential difference and resistance**

- **Charge = Current \times Time**: \( Q = I \times t \)

**Current**

- **Ampere (A)**
- **Volts (V)**

**Resistance**

- **Q = I \times t**
- **R = V \div I**

**Circuit symbols**

- **Series**
- **Parallel**

**Cells**

- Store of chemical energy
- Flow of electrical charge

**Amperes**

- Charge
- Change the p.d. of the cells

**Vocabulary**

- Current
- Charge
- Potential difference (p.d.)

**Questions**

- Change the p.d. of the cells
- Add more components

**Diagrams**

- Domestic uses and safety
- Thermistor
- LDR
- Alternating current
- Direct current

**Worked examples**

- Earthing
- Frequency
- Main supply
- Frequency

**Grids**

- National Grid
- Distributes electricity generated in power stations around UK

**Colours**

- Live - Brown
- Neutral - Blue
- Earth - Green and Yellow stripes

**Shocks**

- Charged objects create electric fields around them. Strongest closest to the object. The field direction is the direction of force on a positive charge. Add more charge increases field strength.
AQA PARTICLE MODEL OF MATTER

Pressure

- Change of state
- Internal energy and energy transfers

Pressure

Pressure of a fixed volume of gas increases as temperature increases (temperature increases, speed increases, collisions occur more frequently and with more force so pressure increases).

Temperature of gas is linked to the average kinetic energy of the particles.

If kinetic energy increases so does the temperature of gas.

No kinetic energy is lost when gas particles collide with each other or the container.

Gas particles are in a constant state of random motion.

Density

\[ \text{Density} = \frac{\text{mass}}{\text{volume}}. \]

\[ \text{Density} = \text{mass} ÷ \text{volume}. \]

\[ \text{PHYSICS ONLY:} \text{ when you do work the temperature increases e.g. pump air quickly into a ball, the air gets hot because as the piston in the pump moves the particles bounce off increasing kinetic energy, which causes a temperature rise.} \]

\[ \text{Reducing the volume of a fixed mass of gas increases the pressure.} \]

\[ \text{Halving the volume doubles the pressure.} \]

\[ PV = \text{constant.} \]

\[ P_1V_1 = P_2V_2 \]

Change in thermal energy

- Depends on:
  - Mass of substance
  - What the substance is
  - Energy put into the system.

\[ \Delta E = m \times c \times \Delta \theta \]

Internal energy

Internal energy is the total kinetic and potential energy of all the particles (atoms and molecules) in a system.

Heating changes the energy stored within a system

Heating causes a change in state. As particles separate, potential energy stored increases. Heating increases the temperature of a system. Particles move faster so kinetic energy of particles increases.

Energy stored inside a system by particles

Freezing

Liquid turns to a solid. Internal energy decreases.

Melting

Solid turns to a liquid. Internal energy increases.

Boiling / Evaporating

Liquid turns to a gas. Internal energy increases.

Condensation

Gas turns to a liquid. Internal energy decreases.

Sublimation

Solid turns directly into a gas. Internal energy increases.

Conservation of mass

When substances change state, mass is conserved.

Physical change

No new substance is made, process can be reversed.

Internal energy and energy transfers

Energy needed to change 1kg of a substance’s state

- Specific Latent Heat
  - Energy needed to change 1kg of solid into 1 kg of liquid at the same temperature

Energy needed to change 1kg of a substance by 1°C

- Specific Heat Capacity
  - Energy needed to raise 1kg of substance by 1°C

Energy needed = mass \times \text{specific latent heat}.

\[ \Delta E = m \times L \]

State

- Particle arrangement
  - Solid: Packed in a regular structure. Strong forces hold in place so cannot move.
  - Liquid: Close together, forces keep contact but can move about.
  - Gas: Separated by large distances. Weak forces so constantly randomly moving.

Properties

- Difficult to change shape.
- Can change shape but difficult to compress.
- Can expand to fill a space, easy to compress.

Density

- Mass
- Volume
- Energy needed
- Specific latent heat
- Change in thermal energy
- Specific heat capacity
- Temperature change

Units

- Kilograms per metre cubed (kg/m³)
- Kilograms (kg)
- Metres cubed (m³)
- Joules (J)
- Joule per kilogram (J/kg)
- Joule per kilogram degrees Celsius (J/kg°C)
- Degrees Celsius (°C)
- Pascals (Pa)

Pressure

\[ P = \frac{m}{V} \]

Density

- Mass of a substance in a given volume

- Density

PHYSICS ONLY:

Pressure

\[ PV = \text{constant.} \]

\[ P_1V_1 = P_2V_2 \]

Energy stored inside a system by particles

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<table>
<thead>
<tr>
<th><strong>Unit</strong></th>
<th><strong>Newton (N)</strong></th>
<th><strong>Kilo</strong></th>
<th><strong>Newton per kilogram (N/kg)</strong></th>
<th><strong>Mega</strong></th>
<th><strong>Newton per meganewton (N/M)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gravitational field strength</strong></td>
<td>9.8N/kg</td>
<td>1000</td>
<td>9.8N/kg</td>
<td>1000000</td>
<td>9.8N/kg</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>1N</td>
<td>10 N</td>
<td>10 N</td>
<td>1000000 N</td>
<td>1000000 N</td>
</tr>
</tbody>
</table>

**Gravity**
- The weight of an object acts through a single point.
- The overall effect of all of the forces acting upon an object.

**Weight**
- Force acting upon an object due to gravity.
- A quantity that only has magnitude (size).
- A quantity that only has magnitude and direction.

**Scalar**
- A quantity that only has magnitude (size).
- E.g. mass, time, speed, temperature, energy.

**Vector**
- A quantity that only has magnitude and direction.
- E.g. force, velocity, momentum.

**An arrow can be used to show vectors**
- Length of arrow = magnitude of vector.
- Direction of arrow = direction of vector.

**Distance**
- How far.
- Distance + direction.

**Displacement**
- Distance + direction.

**Velocity**
- Speed + direction.
- The speed of a car is 30m/s. A car moves forward with a velocity of 30m/s.

**Distance**
- How far.
- The table is 1m long.

**Displacement**
- Distance + direction.
- The beach is 1km due east of the town.

**Pressure**
- Pressure = Force ÷ Area.

**Energy**
- Energy stored in a stretched spring.

<table>
<thead>
<tr>
<th><strong>Component</strong></th>
<th><strong>Value</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EPE</strong> (Elastic Potential energy)**</td>
<td>½ ke^2</td>
</tr>
<tr>
<td><strong>Spring constant</strong></td>
<td>Newton per metre (N/m)</td>
</tr>
<tr>
<td><strong>Extension</strong></td>
<td>Metres (m)</td>
</tr>
<tr>
<td><strong>EPE</strong></td>
<td>Joules (J)</td>
</tr>
</tbody>
</table>

**Combining forces**
- A single force can be split into two components acting at right angles to each other.

**Contact and Resultant forces**
- Resultant force.
- Resolving forces.
- Contact force.
- Non-contact force.
- The overall effect of all of the forces acting upon an object.

**Resultant force**
- Two forces acting in the same direction are added.
- Two forces acting in the opposite direction are taken away.

**Forces and their interactions**
- Gravity.

**AQA FORCES – part 1**
- Work done.
- When work is done, energy is transferred.

**Moments, levers and gears**
- A small force exerted with a long lever applies a large force.

**Principle of moments**
- In a balanced system, the sum of the clockwise moments = the sum of the anti-clockwise moments.

**Lever**
- The moment of a force about a pivot.

**Turning effect of a force about a pivot**
- Moment = force X distance.

<table>
<thead>
<tr>
<th><strong>Moment</strong></th>
<th><strong>Force</strong></th>
<th><strong>Distance</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>kXe</td>
<td>5N</td>
<td>1m</td>
</tr>
</tbody>
</table>

**Elastic deflection**
- The object has been stretched but returns to its original length.

**Inelastic deflection**
- The object has been stretched but does not return to its original length.

**Extension**
- The difference between stretched and unstretched lengths.

**HYPER ONLY**
- Pressure.
- A liquid or gas.

<table>
<thead>
<tr>
<th><strong>Force</strong></th>
<th><strong>Pressure</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1N</td>
<td>1N/m</td>
</tr>
</tbody>
</table>

**Energy**
- Energy stored in a stretched spring.

**Elastic Potential energy (EPE)**
- Elastic Potential energy (EPE) = ½ ke^2.

**Energy stored in a stretched spring**
- Elastic Potential energy (EPE) = ½ ke^2.

**Contact and Resultant forces**
- Resultant force.
- Resolving forces.
- Contact force.
- Non-contact force.
- The overall effect of all of the forces acting upon an object.

**Resultant force**
- Two forces acting in the same direction are added.
- Two forces acting in the opposite direction are taken away.

**Forces and their interactions**
- Gravity.
Electromagnetic property of a wire: when current flows through a conductor, it creates a magnetic field around it. The strength of this field depends on several factors:

- **Current** (I): Larger current produces a stronger field.
- **Distance from the wire** (r): Closer to the wire, the field is stronger.
- **Number of turns** (N): More turns increase the field's intensity.
- **Material of the conductor**: Iron core, for example, can significantly enhance the field.

**Magnetic Field Rule**
- **Right-hand rule**: Point your thumb in the direction of the current, and your fingers curl to indicate the direction of the magnetic field.
- **Left-hand rule**: Use your fingers to indicate the direction of the force on a magnetic material.

**Magnetic Materials**
- **Permanent magnets**: Attracted to each other due to their internal magnetic field.
- **Induced magnets**: Become magnetic when placed in a magnetic field.

**Fleming's Left-hand Rule**
- **First finger** = direction of current.
- **Second finger** = direction of magnetic field.
- **Thumb** = direction of magnetic force on a conductor.

**Magnetic Force**
- **Force (F)** = magnetic flux density (B) × current (I) × length (L).
  \[ F = B \times I \times L \]

**Induced Potential**
- When a conducting wire moves through a magnetic field, an electric potential difference is induced.

**Transformer**
- **Step-up transformer** increases voltage and decreases current.
- **Step-down transformer** decreases voltage and increases current.

**Generator Effect**
- Turns mechanical energy into electrical energy.

**Relay**
- Used to control electrical circuits with low power by relaying higher power.

**Motor Effect**
- Current through a coil produces a magnetic field, interacting with another magnetic field.

**Generators**
- Produce electricity through the movement of a conductor through a magnetic field.

**Transformers**
- Increase or decrease voltage, maintaining constant current.

**Relaying**
- Control electrical circuits with low power using a relay.

**Inferential Properties of Electromagnetism**
- 
  - **Force (F)** = magnetic flux density (B) × current (I) × length (L).
  - **Magnetic field strength** (B) varies with the number of turns (N) and the current (I).
  - **Wire current** = \( \text{Amperes (A)} \).
  - **Electric current** = \( \text{Amperes (A)} \).
  - **Magnetic field** = \( \text{Newton (N)} \).
  - **Magnetic field** = \( \text{Tesla (T)} \).

**Electromagnetic Transformer**
- Converts voltage and current as current flows.

**Induced Potential**
- Voltage induced in a coil is proportional to the change in magnetic flux through it.

**EMF Formula**
- Voltage generated = \( V = n \times \frac{d\Phi}{dt} \)

**Transformer Efficiency**
- Efficient transformers have minimal energy loss.

**Motor Fundamentals**
- Electric current generates a magnetic field, which interacts with another field to create motion.

**Electromagnetic Properties**
- Magnets attract or repel due to their magnetic fields.

**Magnetic Materials**
- **Permanent magnets** have a magnetic dipole moment.
- **Induced magnets** become magnetic temporarily.

**Electric Field**
- **Voltage (V)** = \( \text{Watts (W)} \).
- **Current (I)** = \( \text{Amperes (A)} \).

**Electric Power**
- Power = \( P = V \times I \).

**Magnetic Power**
- Power lost = Potential difference \( X \) Current (I).

**Sound Generation**
- Loudspeakers produce sound waves due to the interaction of magnetic fields.

**Microphones**
- Convert sound waves into electrical current.

**Electrical Energy Conversion**
- Generators convert mechanical energy to electrical energy.

**Electrical Power Station**
- **National Grid** distributes electrical energy generated from power stations around the UK.

**Magnetic Properties of Materials**
- **Materials** can be magnetic, conducting, or non-conducting.

**Metals and Non-metals**
- Metals are good conductors, while non-metals are poor conductors.

**Electromagnetic Induction**
- Induced current in a coil is proportional to the rate of change of the magnetic flux through it.

**External Magnetic Field**
- The direction of the field affects the force on a conductor.

**Generators and Transformers**
- Convert energy between electrical and mechanical forms.

**Electromagnetic Induction**
- Induced emf is generated in a conductor moving through a magnetic field.

**Magnetic Flux Density**
- Depends on the number of turns and the current.

**Magnetic Flux**
- Flux density is measured in Tesla (T).

**Magnetic Energy**
- Magnetic energy is stored in the field and is proportional to the square of the field strength.
**The life cycle of a star.**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nebula</td>
<td>A cloud of cold hydrogen gas and dust</td>
</tr>
<tr>
<td>Protostar</td>
<td>The large ball of gas contracts to form a star</td>
</tr>
<tr>
<td>Main sequence</td>
<td>Stable period of star</td>
</tr>
</tbody>
</table>

**Star formation:**
- Cloud collapses due to gravity, particles move very fast collapsing with each other, kinetic energy transfers into internal energy and the temperature increases.
- High temperature causes Hydrogen nuclei to collide and nuclear fusion begins. A star is 'born'.
- Gravity tries to collapse the star but enormous pressure of fusion energy expands and balances the inward force.

**Nebula**
- A large body orbiting the Sun
- A natural satellite orbiting a planet
- A body large enough to have its own gravity which caused a spherical shape
- Any object orbiting the Sun due to gravity
- Collection of billions of stars
- Collection of galaxies

**Galaxy**
- Collection of billions of stars

**Universe**
- Collection of galaxies

**SOLAR SYSTEM**
- Milky Way
- Our Galaxy

**SPEED OF ORBIT**
- Velocity = a vector.
- A planet’s velocity changes but speed remains constant.

**RED SHIFT**
- The observed increase in wavelength of light from most distance galaxies. Light moves towards the red end of the spectrum.

**REDSHIFT**
- Hubble (1929)
  - Studied light from distant galaxies; found as frequency decreases, wavelength increases.

**ORBITAL MOTIONS**
- Distance = 2πr, then average speed = distance ÷ time.
- Frequency of sound wave decreases, wavelength increases.

**AQA SPACE PHYSICS PHYSICS ONLY**
- Planets further away from the Sun, gravity pull is weaker. So speed of planet is slower.
- Galaxies are moving away from us in all directions.

**OR IF COLLAPSE IS INTO A REALLY TINY SPACE.**
- Black hole
  - No light escapes
  - Gravitational forces so strong everything is pulled in.

**REDSHIFT**
- Earth at the centre, other heavenly bodies move around the Earth.
- Sun at the centre, other heavenly bodies move around the Sun.
- Made a telescope, looked at Jupiter, found four moons rotating around planet.

**ARISTOTLE**
- Earth at the centre, other heavenly bodies move around the Earth.

**HIGHER:**
- Circular orbits.
- Planets close to the Sun, gravity pull is strong. Planets move quickly.

**HIGHER:**
- Planets further away from the Sun, gravity pull is weaker. So speed of planet is slower.