Topic 1 – Energy Retrieval Starters

4.1.1.1 Energy stores and systems

1. A system is an object or group of objects being studied where energy can be transferred.
2. Energy is transferred between different energy stores when a change occurs.
3. The kinetic energy store decreases and the gravitational potential energy store increases.
4. The kinetic energy store decreases and energy is transferred to thermal, sound and elastic potential energy stores.
5. Electrical energy is transferred to the thermal energy store of the water.
6. Energy changes can be calculated using equations that link energy transfers to quantities such as mass, velocity, height, power and temperature change.

4.1.1.2 Changes in energy

1. 202.5 J
2. 240,000 J
3. 0.25 J
4. 300 N/m
5. 15 kg
6. 147 J

4.1.1.3 Energy changes in systems

1. 300 J/kg°C
2. The energy needed to raise the temperature of 1 kg of a substance by 1°C.
3. 5000 J
4. Mass, temperature change and specific heat capacity.
5. Measure the mass of the material, heat it with a known energy input, measure the temperature change and calculate the specific heat capacity.
6. The energy store of the heater decreases and the thermal energy store of the object increases.

4.1.1.4 Power

1. Power is the rate of energy transfer.
2. 30 seconds
3. Power = Work done ÷ Time
4. 200 W

5. Watts (W)
6. It transfers the same amount of energy in a shorter time, so the energy transfer rate is higher.

4.1.2.1 Energy transfers in a system

1. Energy cannot be created or destroyed, only transferred between stores.
2. The total energy remains constant in a closed system.
3. Dissipated energy is energy transferred to unwanted stores, usually thermal energy in the surroundings.
4. It is described as wasted because it is transferred to stores that are not useful.
5. Lubrication reduces friction, lowering unwanted thermal energy transfers.
6. Increasing insulation thickness reduces the rate of cooling because less thermal energy is transferred to the surroundings.

4.1.2.2 Efficiency

1. 1500 J
2. 0.8 means 80% of the input energy is transferred usefully.
3. 2500 W
4. Multiply the decimal by 100.
5. 80%
6. Reduce unwanted energy transfers, such as friction and heat loss.

4.1.3 National and global energy resources

1. Coal, oil, natural gas and nuclear fuels.
2. Wind, solar, hydroelectric, tidal, wave, geothermal and biofuels.
3. Renewable resources are replaced naturally; non-renewable resources are finite and will eventually run out.
4. Advantage: reliable and high energy output. Disadvantage: fossil fuels release carbon dioxide and contribute to climate change.
5. Some resources depend on weather conditions, while others can produce energy continuously.
6. Different resources can cause pollution, greenhouse gas emissions, waste or damage to habitats.

Topic 1 Review

1. When an object is lifted, energy is transferred to the gravitational potential energy store. When released, this transfers to the kinetic energy store.
2. 112,500 J
3. Energy is conserved because it is transferred between stores, but some energy is dissipated to the surroundings as heat or sound.

4. 98 J
5. Efficiency calculations show the proportion of input energy transferred usefully.
6. Renewable resources are sustainable and usually have fewer environmental impacts, while non-renewable resources can cause pollution and climate change.

Topic 2 – Electricity Retrieval Starters

4.2.1.1 Standard circuit diagram symbols

1. Voltmeter – Circle with V inside.
2. Resistor – Rectangle.
3. Battery – Two or more cells shown by alternating long and short parallel lines.
4. LED (Light Emitting Diode) – Diode symbol with two arrows pointing away from it.
5. Thermistor – Resistor symbol with a diagonal line and temperature marker.
6. Series circuit: One cell connected in a single loop with a switch, lamp and resistor all in series.

4.2.1.2 Electrical charge and current

1. A complete closed circuit.
2. The rate of flow of electric charge.
3. $I = Q \div t = 120 \div 30 = 4$ A
4. $Q = I \times t = 5 \times 120 = 600$ C
5. 3 minutes = 180 seconds
   $I = Q \div t = 600 \div 180 = 3.3$ A
6. Because charge is not used up and cannot build up at any point in a series circuit.

4.2.1.3 Current, resistance and potential difference

1. $R = V \div I = 12 \div 3 = 4\ \Omega$
2. $V = I \times R = 0.5 \times 20 = 10$ V
3. $I = V \div R = 6 \div 12 = 0.5$ A
4. The current decreases.
5. Resistance increases as wire length increases.
6. The current increases.

4.2.2 Series and parallel circuits

1. The current is the same through every component.
2. The potential difference is shared between the components.
3. Total resistance = 5 + 10 = 15 Ω
4. Total resistance = 8 + 12 = 20 Ω
5. The potential difference is the same across each branch.
6. More branches provide more paths for charge to flow, reducing the total resistance.

4.2.3.1 Direct and alternating potential difference

1. Direct potential difference always acts in one direction. Alternating potential difference repeatedly changes direction.
2. Alternating current (AC).
3. 50 Hz
4. 230 V
5. Batteries provide a constant potential difference in one direction.
6. The direction of the current reverses many times each second.

4.2.3.2 Mains electricity

1. Carries the alternating potential difference into the appliance.
2. Completes the circuit by carrying current away from the appliance.
3. Provides a safe path to Earth if a fault occurs.
4. The live wire is still connected to the supply and remains at a dangerous potential.
5. It prevents the metal case becoming live if a fault occurs.
6. Live = Brown, Neutral = Blue, Earth = Green/Yellow.

4.2.4.1 Power

1. $P = V \times I = 12 \times 5 = 60$ W
2. $P = I^2R = 4^2 \times 20 = 16 \times 20 = 320$ W
3. $I = P \div V = 600 \div 240 = 2.5$ A
4. The power increases.
5. The power increases.
6. Power is the rate at which energy is transferred.

4.2.4.2 Energy transfers in everyday appliances

1. $E = P \times t = 1000 \times 60 = 60{,}000$ J
2. $t = E \div P = 72{,}000 \div 1200 = 60$ s
3. $V = E \div Q = 5000 \div 20 = 250$ V

4. Electrical energy is transferred to thermal, kinetic, light or sound energy stores.
5. They transfer more energy every second.
6. Electrical energy is transferred mainly to the kinetic energy store, with some energy dissipated as thermal energy and sound.

4.2.4.3 The National Grid

1. A network of cables and transformers that transfers electricity from power stations to consumers.
2. To increase the potential difference and reduce the current.
3. To reduce the potential difference to a safe value before entering homes.
4. A higher potential difference means a lower current for the same power, reducing energy lost by heating.
5. By transmitting electricity at high potential difference and low current.
6. Electricity is generated at power stations, stepped up by transformers, transmitted through the National Grid, stepped down before reaching consumers.

4.2.5.1 Static charge (Physics only)

1. By friction transferring electrons between insulating materials.
2. Electrons.
3. A negative charge.
4. They repel.
5. They attract.
6. Because the force acts without the objects touching.

4.2.5.2 Electric fields (Physics only)

1. A region where a charged object experiences a force.
2. Closest to the charged object.
3. It decreases with distance.
4. Because the electric field exerts a force on any charged object placed within it.
5. Radial field lines pointing away from a positive charge or towards a negative charge.
6. Electric fields explain the attractive and repulsive forces between charged objects.

Topic 2 Review

1. $Q = I \times t = 3 \times (5 \times 60) = 3 \times 300 = 900$ C
2. $I = V \div R = 9 \div 3 = 3$ A
3. Total resistance = 15 + 25 = 40 Ω

4. $E = P \times t = 1200 \times 30 = 36{,}000$ J
5. High potential differences reduce the current, reducing energy lost as heat in the transmission cables.
6. Static electricity is produced by the transfer of electrons. Like charges repel and opposite charges attract.

Topic 3 – Particle Model of Matter Retrieval Starters

4.3.1.1 Density of materials

1. The mass per unit volume of a material.
2. Density = Mass ÷ Volume = 600 g ÷ 200 cm^3 = 3 g/cm^3
3. Mass = Density × Volume = 800 × 0.005 = 4 kg
4. Volume = Mass ÷ Density = 2 ÷ 400 = 0.005 m^3
5. Solid particles are packed closely together, whereas gas particles are far apart.
6. Measure the mass using a balance, measure the volume by water displacement in a measuring cylinder, then calculate Density = Mass ÷ Volume.

4.3.1.2 Changes of state

1. The mass stays the same.
2. No new substance is formed, so it is a physical change.
3. The particles gain energy and move more freely as they overcome some of the forces between them.
4. The particles lose energy, move more slowly and become fixed in position.
5. No particles are lost or gained, so the mass remains constant.
6. Evaporation happens at the surface and can occur below the boiling point. Boiling happens throughout the liquid at a fixed temperature.

4.3.2.1 Internal energy

1. The total kinetic energy and potential energy of all the particles in a system.
2. Kinetic energy and potential energy.
3. The particles gain energy.
4. The internal energy increases.
5. Energy can either increase the kinetic energy of the particles (raising temperature) or increase their potential energy (changing state).
6. Internal energy is the sum of the kinetic and potential energies of the particles.

4.3.2.2 Temperature changes in a system and specific heat capacity

1. Energy = Mass × SHC × Temperature change = 2 × 400 × 10 = 8000 J
2. SHC = Energy ÷ (Mass × Temperature change) = 6000 ÷ (3 × 5) = 6000 ÷ 15 = 400 J/kg°C
3. Temperature change = Energy ÷ (Mass × SHC) = 45,000 ÷ (5 × 900) = 45,000 ÷ 4500 = 10°C
4. The mass, specific heat capacity and temperature change.
5. The energy needed to raise the temperature of 1 kg of a substance by 1°C.
6. Different materials have different specific heat capacities, so they require different amounts of energy to raise their temperature.

4.3.2.3 Changes of state and specific latent heat

1. The energy needed to change the state of 1 kg of a substance without changing its temperature.
2. The temperature remains constant.
3. Energy = Mass × Specific latent heat = 2 × 300,000 = 600,000 J
4. Specific latent heat = Energy ÷ Mass = 900,000 ÷ 3 = 300,000 J/kg
5. Specific heat capacity changes temperature; specific latent heat changes state without changing temperature.
6. The internal energy increases because the potential energy of the particles increases while the kinetic energy remains constant.

4.3.3.1 Particle motion in gases

1. Gas particles are far apart and move rapidly in random directions.
2. The higher the temperature, the greater the average kinetic energy of the molecules.
3. The pressure increases.
4. The particles move faster and collide with the container walls more often and with greater force.
5. They collide with the walls of the container.
6. Pressure is caused by gas particles colliding with the walls of the container.

4.3.3.2 Pressure in gases

1. The pressure increases.
2. $\text{Pressure}_1 \times \text{Volume}_1 = \text{Pressure}_2 \times \text{Volume}_2$
   $100{,}000 \times 4 = \text{Pressure}_2 \times 2$
   $\text{Pressure}_2 = 400{,}000 \div 2 = 200{,}000$ Pa
3. $\text{Pressure}_1 \times \text{Volume}_1 = \text{Pressure}_2 \times \text{Volume}_2$
   $200{,}000 \times 3 = 600{,}000 \times \text{Volume}_2$
   $\text{Volume}_2 = 600{,}000 \div 600{,}000 = 1\ m^3$
4. Gas particles collide with the container walls more frequently.

5. The particles collide with the walls less often, so the pressure decreases.
6. Gas particles collide with the walls, exerting a force. Pressure is the force per unit area.

4.3.3.3 Increasing the pressure of a gas (HT only)

1. Its internal energy increases.
2. Work is done on the gas, increasing its internal energy and therefore its temperature.
3. The particles move faster.
4. Doing work transfers energy to the gas.
5. Mechanical energy is transferred to the internal energy store of the gas.
6. Increasing the pressure does work on the gas, increasing its internal energy and temperature.

Topic 3 Review

1. Density = Mass ÷ Volume = 3 ÷ 0.002 = 1500 kg/m^3
2. Particles gain energy, overcome some of the forces between them and move more freely.
3. Energy = Mass × SHC × Temperature change = 4 × 500 × 20 = 40,000 J
4. The energy supplied is used to change the state by increasing the particles' potential energy rather than increasing their kinetic energy.
5. Increasing the temperature increases the kinetic energy of the gas particles, causing more frequent and forceful collisions with the container walls, so the pressure increases.
6. Doing work on the gas transfers energy to its internal energy store, increasing the kinetic energy of the particles and therefore its temperature.

Topic 4 – Atomic Structure Retrieval Starters

4.4.1.1 The structure of an atom

1. Protons, neutrons and electrons.
2. In the nucleus.
3. Proton = +1, Neutron = 0, Electron = −1.
4. Electrons occupy shells (energy levels) around the nucleus.
5. Electrons move to a higher energy level (shell).
6. The nucleus is about 1/10,000 of the radius of the atom.

4.4.1.2 Mass number, atomic number and isotopes

1. Atomic number = 8, Mass number = 16.

2. Neutrons = Mass number − Atomic number = 24 − 12 = 12 neutrons.
3. The number of protons in the nucleus.
4. The total number of protons and neutrons in the nucleus.
5. Atoms of the same element with the same number of protons but different numbers of neutrons.
6. By losing one or more electrons.

4.4.1.3 The development of the model of the atom

1. It showed atoms contained smaller particles and were not solid spheres.
2. A sphere of positive charge with electrons embedded throughout.
3. Most of the atom is empty space with a small, dense, positively charged nucleus.
4. The nuclear model had a tiny central nucleus with electrons around it instead of positive charge spread throughout the atom.
5. Electrons orbit the nucleus in fixed energy levels (shells).
6. It explained the existence of isotopes and the extra mass of atoms.

4.4.2.1 Radioactive decay and nuclear radiation

1. The spontaneous emission of radiation from an unstable nucleus.
2. They have an unstable combination of protons and neutrons.
3. The number of nuclear decays per second.
4. Two protons and two neutrons.
5. A neutron changes into a proton and an electron is emitted.
6. Alpha: most ionising, least penetrating (stopped by paper). Beta: medium ionising and penetrating (stopped by aluminium. Gamma: least ionising, most penetrating (stopped by lead/ concrete).

4.4.2.2 Nuclear equations

1. Mass number decreases by 4 and atomic number decreases by 2.
2. Mass number stays the same and atomic number increases by 1.
3. ${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$. Mass number −4, atomic number −2.
4. ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$. Mass number unchanged, atomic number +1.
5. Gamma radiation has no mass and no charge.
6. ${}^{4}_{2}He$ (alpha particle).

4.4.2.3 Half-lives and the random nature of radioactive decay

1. The time taken for the activity (or number of undecayed nuclei) to halve.
2. 800 ÷ 2 = 400 counts/min after one half-life. 400 ÷ 2 = 200 counts/min after two half-lives.
3. 1200 ÷ 2 = 600 Bq after 5 years. 600 ÷ 2 = 300 Bq after 10 years.
4. It is impossible to predict exactly when an individual nucleus will decay.

5. Measure the time taken for the activity (or count rate) to halve.
6. There are fewer unstable nuclei remaining to decay.

4.4.2.4 Radioactive contamination

1. The unwanted presence of radioactive material on or inside an object.
2. The exposure of an object to radiation.
3. Contamination involves radioactive material being transferred; irradiation does not.
4. The radioactive material continues to emit radiation.
5. No radioactive material is transferred to the object.
6. It helps ensure scientific conclusions are checked for accuracy and reliability.

4.4.3.1 Background radiation

1. Radiation that is always present in the environment.
2. Radon gas and cosmic rays.
3. Medical X-rays and nuclear power stations.
4. Areas with more radon gas or higher altitude receive higher doses.
5. Jobs such as airline crew or nuclear industry workers may receive higher doses.
6. Sievert (Sv).

4.4.3.2 Different half-lives of radioactive isotopes

1. Different nuclei have different levels of stability.
2. It has a high activity because many nuclei decay each second.
3. It continues emitting radiation for a long time.
4. The half-life should suit the intended use.
5. After one half-life = ½. After two = ¼. After three = ⅛ remains.
6. It determines how long the source remains hazardous.

4.4.3.3 Uses of nuclear radiation

1. Radioactive tracers detected outside the body.
2. Radiotherapy using gamma radiation.
3. They pass through the body and can be detected outside it.
4. Radiation can damage healthy cells and increase cancer risk.
5. They travel through the body and their movement can be detected.
6. Advantage: diagnose or treat disease. Disadvantage: exposure can damage healthy tissue.

4.4.4.1 Nuclear fission

1. The splitting of a large unstable nucleus into two smaller nuclei.
2. It makes the nucleus unstable enough to split.
3. It splits into two smaller nuclei, releases energy and emits two or three neutrons.
4. A self-sustaining series of fission reactions.
5. Control rods absorb excess neutrons.
6. Neutrons cause rapid uncontrolled fission, releasing huge amounts of energy.

4.4.4.2 Nuclear fusion

1. Two light nuclei join together to form a heavier nucleus.
2. They combine to form a larger nucleus.
3. Some mass is converted into energy.
4. Because the mass of the products is less than the mass of the reactants, so the missing mass is transferred as energy.
5. Fusion joins small nuclei; fission splits large nuclei.
6. Extremely high temperatures and pressures are needed to overcome electrostatic repulsion.

Topic 4 Review

1. Atomic number = 17, Mass number = 35.
2. It showed that atoms contain a small, dense, positively charged nucleus and are mostly empty space.
3. 1600 ÷ 2 = 800 Bq. 800 ÷ 2 = 400 Bq. 400 ÷ 2 = 200 Bq after three half-lives.
4. Alpha: highly ionising, least penetrating. Beta: medium ionising and penetrating. Gamma: weakly ionising, most penetrating.
5. Fission splits large nuclei; fusion joins small nuclei. Both release energy.
6. Radioactive isotopes are useful in medicine and industry but can damage living tissue through ionising radiation.

Topic 5 – Forces Retrieval Starters

4.5.1.1 Scalar and vector quantities

1. Scalar quantity.
2. Because it has both magnitude (20 N) and direction (to the right).
3. 0 m
4. The length represents the size (magnitude) of the force and the arrow shows its direction.
5. Speed – Scalar; Velocity – Vector; Distance – Scalar; Displacement – Vector.

6. Distance = 10 + 10 = 20 m. Displacement = 0 m.

4.5.1.2 Contact and non-contact forces

1. A contact force acts when objects are touching. A non-contact force acts without the objects touching.
2. Contact force (normal contact force).
3. Non-contact force because the magnet attracts the paper clip without touching it.
4. Contact forces: friction, air resistance. Non-contact forces: gravitational force, magnetic force.
5. The person pushes the trolley forwards and the trolley pushes back on the person with an equal and opposite force.
6. Contact force: air resistance. Non-contact force: gravitational force (weight).

4.5.1.3 Gravity

1. Weight = Mass × Gravitational field strength = 5 × 10 = 50 N
2. Mass = Weight ÷ Gravitational field strength = 98 ÷ 9.8 = 10 kg
3. Weight = Mass × Gravitational field strength = 60 × 9.8 = 588 N
4. Because gravitational field strength is different on different planets.
5. Weight = Mass × Gravitational field strength = 2 × 5 = 10 N
6. Mass is the amount of matter in an object and does not change. Weight depends on gravitational field strength.

4.5.1.4 Resultant forces

1. Resultant force = 10 + 15 = 25 N
2. Resultant force = 30 − 20 = 10 N to the right
3. It remains at rest or continues moving at constant velocity.
4. The car moves at a constant speed.
5. There is an unbalanced force causing the object's velocity to change.
6. Together, the two perpendicular components have the same overall effect as the single original force.

4.5.2 Work done and energy transfer

1. Work done = Force × Distance = 50 × 4 = 200 J
2. Force = Work done ÷ Distance = 3000 ÷ 10 = 300 N
3. Energy transferred = Work done = Force × Distance = 200 × 5 = 1000 J
4. No work is done because there is no movement in the direction of the force.
5. Energy is transferred from the kinetic energy store to the thermal energy stores of the box and the floor due to friction.

6. Work done = Force × Distance = 20 × 3 = 60 J

4.5.3 Forces and elasticity

1. Spring constant = Force ÷ Extension = 8 ÷ 0.04 = 200 N/m
2. Force = Spring constant × Extension = 250 × 0.02 = 5 N
3. Elastic deformation is reversible. Inelastic deformation is permanent.
4. Elastic potential energy = ½ × Spring constant × Extension^2
   $0.5 = \frac{1}{2} \times k \times (0.1)^2$
   $0.5 = \frac{1}{2} \times k \times 0.01$
   $0.5 = 0.005k$
   $k = 0.5 \div 0.005 = 100$ N/m
5. The elastic potential energy increases.
6. Suspend a spring from a clamp stand, add known masses one at a time, measure the extension after each mass is added, calculate the force (Weight = mass × gravitational field strength), and plot a graph of force against extension.

4.5.4 Moments, levers and gears

1. Moment = Force × Distance = 20 × 0.5 = 10 Nm
2. Force = Moment ÷ Distance = 100 ÷ 2 = 50 N
3. Because the moment equals force × distance from the pivot, so increasing the distance increases the turning effect.
4. 60 Nm
5. A lever increases the distance from the pivot, increasing the moment so less force is needed.
6. Gears can increase or decrease the turning effect and change the speed and direction of rotation.

4.5.5.1 Pressure in a fluid 1

1. A substance that can flow (a liquid or a gas).
2. Pressure = Force ÷ Area = 200 ÷ 4 = 50 Pa
3. Force = Pressure × Area = 500 × 2 = 1000 N
4. At right angles (perpendicular) to the surface.
5. Pascal (Pa).
6. Because fluid particles collide with surfaces equally in all directions.

4.5.5.1.2 Pressure in a fluid 2 (HT)

1. Pressure = Height × Density × Gravitational field strength = 5 × 1000 × 10 = 50,000 Pa
2. Because there is more liquid above, producing a greater weight.

3. A denser liquid has more mass per unit volume, so it exerts a greater pressure.
4. The deeper the diver goes, the greater the weight of water above them, so the pressure increases.
5. The upward force exerted by a fluid on an object.
6. Pressure is greater at the bottom of the object than at the top, producing a resultant upward force.

4.5.5.2 Atmospheric pressure

1. There are fewer air molecules above you at higher altitudes.
2. Air molecules collide with surfaces, producing a force per unit area.
3. The number of air molecules above them decreases.
4. There is a greater weight of air above sea level.
5. There are fewer air molecules above a hill than above a deep cave, so atmospheric pressure is lower.
6. Because the pressure inside the body balances the atmospheric pressure outside.

4.5.6.1.1 Distance and displacement

1. Distance is the total path travelled. Displacement is the shortest straight-line distance in a given direction.
2. 0 m
3. Distance = 200 m. Displacement = 200 m east.
4. Because it has both magnitude and direction.
5. Distance = 3 + 1 = 4 km
6. Because displacement includes both the distance and the direction from the starting point.

4.5.6.1.2 Speed

1. Speed = Distance ÷ Time = 120 ÷ 10 = 12 m/s
2. Distance = Speed × Time = 6 × 30 = 180 m
3. Average speed = Distance ÷ Time = 400 ÷ 80 = 5 m/s
4. Because it has magnitude only and no direction.
5. Distance = Speed × Time = 330 × 5 = 1650 m
6. Its speed stays the same, but its direction changes, so its velocity changes.

4.5.6.1.3 Velocity

1. Speed is a scalar quantity. Velocity is a vector quantity (speed in a given direction).
2. Because it has both a magnitude (20 m/s) and a direction (east).

3. Its direction is constantly changing, so its velocity changes even if its speed stays the same.
4. Speed = 250 m/s. Direction = north.
5. Because it has both magnitude and direction.
6. Its velocity changes because its direction changes.

4.5.6.1.4 Distance-time relationship

1. Speed = Distance ÷ Time = 200 ÷ 20 = 10 m/s
2. The object is stationary.
3. The object is travelling faster.
4. The object is moving at a constant speed.
5. Calculate the gradient (slope) of the graph.
6. The cyclist's speed increases.

4.5.6.1.5 Acceleration

1. Acceleration = (Final velocity − Initial velocity) ÷ Time = (30 − 10) ÷ 5 = 20 ÷ 5 = 4 m/s^2
2. Acceleration = (5 − 25) ÷ 4 = −20 ÷ 4 = −5 m/s^2
3. The object is slowing down (decelerating).
4. Final velocity = Initial velocity + (Acceleration × Time) = 0 + (3 × 10) = 30 m/s
5. Calculate the gradient (slope) of the velocity-time graph.
6. The distance travelled.

4.5.6.2.1 Newton's First Law

1. An object will remain at rest or continue moving at constant velocity unless acted on by a resultant force.
2. It remains at rest or continues moving at constant velocity.
3. The resultant force is zero (the forces are balanced).
4. The tendency of an object to continue in its current state of motion.
5. Because their body continues moving forwards due to inertia.
6. A resultant force.

4.5.6.2.2 Newton's Second Law

1. The acceleration of an object is proportional to the resultant force and inversely proportional to its mass (F = ma).
2. Acceleration = Force ÷ Mass = 20 ÷ 5 = 4 m/s^2
3. Mass = Force ÷ Acceleration = 12 ÷ 4 = 3 kg
4. Its acceleration decreases.
5. A measure of how difficult it is to change an object's velocity.
6. Because it has a greater mass (greater inertial mass), so more force is needed to produce the same acceleration.

4.5.6.2.3 Newton's Third Law

1. When two objects interact, they exert equal and opposite forces on each other.
2. The swimmer pushes the water backwards and the water pushes the swimmer forwards with an equal and opposite force.
3. The rocket pushes gases downwards and the gases push the rocket upwards with an equal and opposite force.
4. They are equal in size.
5. They act in opposite directions.
6. Because they act on different objects, not the same object.

4.5.6.3.1 Stopping distance

1. Thinking distance and braking distance.
2. The distance travelled during the driver's reaction time.
3. The distance travelled from when the brakes are applied until the vehicle stops.
4. The thinking distance and braking distance both increase.
5. The car travels further before the brakes are applied, increasing the thinking distance.
6. Because both the thinking distance and braking distance are greater.

4.5.6.3.2 Reaction time

1. 0.2–0.9 seconds
2. Tiredness and alcohol (or drugs).
3. Catching a falling ruler and measuring the distance it falls before being caught.
4. They increase the driver's reaction time, increasing the thinking distance.
5. It increases reaction time, increasing the thinking distance and stopping distance.
6. People have different ages, levels of tiredness, fitness and concentration.

4.5.6.3.3 Factors affecting braking distance 1

1. Wet roads and icy roads.
2. They reduce friction between the tyres and the road, increasing braking distance.
3. They provide less grip, increasing braking distance.
4. The vehicle has more kinetic energy, so more work must be done to stop it.
5. There is very little friction between the tyres and the road.

6. Effective brakes produce greater friction, reducing braking distance.

4.5.6.3.4 Factors affecting braking distance 2

1. The kinetic energy store.
2. Friction transfers kinetic energy to the thermal energy stores of the brakes and surroundings.
3. More kinetic energy must be removed, requiring a greater braking force.
4. They can cause loss of control or injury to passengers.
5. Friction provides the force needed to slow the vehicle.
6. Overheated brakes are less effective because friction is reduced (brake fade).

4.5.7.1 Momentum is a property of moving objects (HT)

1. Momentum is the product of an object's mass and velocity.
2. Momentum = Mass × Velocity = 5 × 4 = 20 kg m/s
3. Velocity = Momentum ÷ Mass = 6000 ÷ 1000 = 6 m/s
4. kg m/s
5. Its momentum increases.
6. Its momentum increases.

4.5.7.2 Conservation of momentum (HT)

1. In a closed system, the total momentum before an interaction equals the total momentum after the interaction.
2. A system where no external forces act.
3. The total momentum remains the same.
4. It allows the motion of objects before and after collisions to be analysed.
5. The other object gains equal momentum in the opposite direction.
6. Because no external forces act on the system.

4.5.7.3 Changes in momentum (HT)

1. Its momentum changes.
2. They increase the time taken for the change in momentum, reducing the force on the passenger.
3. The force decreases.
4. They increase the time taken to stop, reducing the force on the person.
5. The longer time taken to change momentum reduces the force acting on the car and passengers.
6. Seat belts increase the time taken for the passenger's momentum to change, reducing the force acting on them.

Topic 5 Review

1. A scalar has magnitude only (e.g. speed). A vector has magnitude and direction (e.g. velocity).
2. Momentum = Mass × Velocity = 1200 × 15 = 18,000 kg m/s
3. Newton's First Law: Objects remain at rest or move at constant velocity unless acted on by a resultant force. Newton's Second Law: F = ma. Newton's Third Law: Forces occur in equal and opposite pairs.
4. Work done = Force × Distance = 40 × 5 = 200 J
5. Higher speeds increase both thinking distance and braking distance because the vehicle has more kinetic energy, increasing the stopping distance and risk of collisions.
6. Contact forces act when objects touch (e.g. friction, air resistance). Non-contact forces act at a distance (e.g. gravity, magnetic force). Both can change an object's motion.

Topic 6 – Waves Retrieval Starters

4.6.1.1 Transverse and longitudinal waves

1. In a transverse wave, vibrations are perpendicular to the direction of energy transfer. In a longitudinal wave, vibrations are parallel to the direction of energy transfer.
2. Light (electromagnetic) waves.
3. Sound waves.
4. Compressions are regions where particles are close together. Rarefactions are regions where particles are spread apart.
5. Because the air particles vibrate parallel to the direction of energy transfer.
6. The particles vibrate about a fixed position, transferring energy to neighbouring particles without the medium moving overall.

4.6.1.2 Properties of waves

1. The maximum displacement of a point on a wave from its rest position.
2. The distance between two corresponding points on adjacent waves.
3. Wave speed = Frequency × Wavelength = 25 × 2 = 50 m/s
4. Wavelength = Wave speed ÷ Frequency = 300 ÷ 150 = 2 m
5. Period = 1 ÷ Frequency = 1 ÷ 50 = 0.02 s
6. Measure the distance travelled by the sound and the time taken, then calculate speed = distance ÷ time.

4.6.1.3 Reflection of waves (Physics only)

1. The wave bounces off the surface.
2. Reflection: the wave bounces back. Absorption: the wave's energy is taken in by the material. Transmission: the wave passes through the material.
3. Angle of incidence = angle of reflection.
4. Smooth, hard surfaces absorb less energy and reflect more.
5. Mirrors.
6. Because the surface is smooth, reflected rays remain parallel.

4.6.1.4 Sound waves (Physics only, HT)

1. Particles in the solid vibrate and pass the vibrations to neighbouring particles.
2. Sound waves make the eardrum vibrate, producing electrical impulses sent to the brain.
3. 20 Hz to 20,000 Hz (20 kHz)
4. Because its frequency is above 20,000 Hz.
5. Sound is produced by vibrating objects, which cause neighbouring particles to vibrate.
6. Seismic waves travelling through rock.

4.6.1.5 Waves for detection and exploration (Physics only, HT)

1. Sound waves with frequencies above 20,000 Hz.
2. Ultrasound pulses are reflected by different tissues and the echoes are used to produce an image.
3. Measure the time taken for an ultrasound pulse to return from the seabed and calculate the depth.
4. P-waves are longitudinal and travel through solids and liquids. S-waves are transverse and travel only through solids.
5. Liquids cannot transmit transverse waves.
6. The absence of S-waves and changes in P-waves show that the Earth's outer core is liquid.

4.6.2.1 Types of electromagnetic waves

1. Radio waves, Microwaves, Infrared, Visible light, Ultraviolet, X-rays, Gamma rays.
2. Their oscillations are perpendicular to the direction of energy transfer.
3. 3×10^8 m/s
4. By carrying energy from one place to another.
5. Visible light.
6. Sunlight transferring energy to the Earth.

4.6.2.2 Properties of electromagnetic waves 1

1. They change direction when entering a different medium.
2. Because their speed changes.
3. It usually decreases in denser media.
4. The ray bends towards or away from the normal depending on the change in speed.
5. They show one side of the wave slowing before the other, causing the wave to bend.
6. Heat identical cans with different surface finishes using infrared radiation and measure the temperature increase.

4.6.2.3 Properties of electromagnetic waves 2

1. By oscillating electrons in an electrical circuit.
2. From changes within the nucleus of radioactive atoms.
3. They are ionising and can damage cells and DNA.
4. Radiation that removes electrons from atoms.
5. Sunburn.
6. Ionising radiation can damage DNA, increasing the chance of mutations and cancer.

4.6.2.4 Uses and applications of electromagnetic waves

1. Radio broadcasting.
2. They pass through the Earth's atmosphere and carry information over long distances.
3. Thermal imaging (or TV remote controls).
4. It undergoes total internal reflection with little energy loss.
5. X-rays for medical imaging (or gamma rays for cancer treatment).
6. Different electromagnetic waves have different properties, making them suitable for different uses.

4.6.2.5 Lenses (Physics only)

1. A convex lens refracts light rays so they meet at a focus to form an image.
2. A convex lens converges light. A concave lens diverges light.
3. The distance from the centre of the lens to the principal focus.
4. Magnification = Image height ÷ Object height = $12 \div 4 = 3$
5. A real image can be projected onto a screen. A virtual image cannot.
6. Measure the object and image heights for different object distances and calculate magnification.

4.6.2.6 Visible light (Physics only)

1. Specular reflection occurs from smooth surfaces. Diffuse reflection occurs from rough surfaces.
2. It transmits its own colour and absorbs the other colours.
3. It reflects red light and absorbs the other colours.
4. It reflects all colours of visible light.
5. Transparent materials allow light through clearly. Translucent materials allow some light through but scatter it.
6. It appears black because it absorbs nearly all visible light.

4.6.3.1 Emission and absorption of infrared radiation

1. Infrared radiation.
2. The hotter the object, the more infrared radiation it emits.
3. An object that absorbs all incident electromagnetic radiation.
4. Good absorbers are also good emitters.
5. It reflects most infrared radiation instead of absorbing it.
6. A matt black surface.

4.6.3.2 Perfect black bodies and radiation

1. Because all objects above absolute zero emit infrared radiation.
2. As temperature increases, the rate of emission increases.
3. Its temperature increases.
4. It emits energy at the same rate as it absorbs energy.
5. It depends on the balance between incoming solar radiation and outgoing infrared radiation.
6. More energy is reflected into space, so less is absorbed by the Earth, reducing its temperature.

Topic 6 Review

1. Transverse waves vibrate perpendicular to the direction of energy transfer (e.g. light). Longitudinal waves vibrate parallel to the direction of energy transfer (e.g. sound).
2. Wave speed = Frequency × Wavelength = 200 × 1.5 = 300 m/s
3. Ultrasound – medical imaging. Seismic waves – studying the Earth's structure. Electromagnetic waves – communication (e.g. radio waves).
4. Different parts of the electromagnetic spectrum have different properties such as penetration and wavelength, making them suitable for different applications.
5. Magnification = 3
6. If the Earth absorbs more radiation than it emits, its temperature increases. If it emits more than it absorbs, its temperature decreases.

Topic 7 – Magnetism and Electromagnetism Retrieval Starters

4.7.1.1 Poles of a magnet

1. Because the magnetic field is strongest at the poles.
2. They repel each other.
3. They attract each other.
4. A permanent magnet produces its own magnetic field. An induced magnet only becomes magnetic in an external magnetic field.
5. The induced pole nearest the permanent magnet is always the opposite pole.
6. It usually loses its magnetism.

4.7.1.2 Magnetic fields

1. The region around a magnet where another magnet or magnetic material experiences a force.
2. Because the magnetic field lines are closest together at the poles.
3. Place a plotting compass around the magnet and mark the direction of the needle at different positions to map the field lines.
4. Because this is the direction a north pole would move in the field.
5. The magnetic material becomes an induced magnet with the opposite pole nearest the permanent magnet.
6. The Earth acts like a giant magnet and the compass aligns with its magnetic field.

4.7.2.1 Electromagnetism

1. A magnetic field is produced around the wire.
2. The magnetic field becomes stronger.
3. The magnetic fields from each coil add together, producing a stronger overall field.
4. Similar to the field around a bar magnet.
5. Iron is easily magnetised, increasing the strength of the magnetic field.
6. An electromagnet can be switched on and off and its strength can be changed.

4.7.2.2 Fleming's left-hand rule (HT only)

1. A force acts on the conductor (the motor effect).
2. First finger = Magnetic field. Second finger = Current. Thumb = Force (motion).
3. Force = Magnetic flux density × Current × Length = $0.30 \times 4 \times 0.50 = 0.6$ N

4. The force increases.
5. The force increases.
6. Because both a magnetic field and an electric current are needed to produce the force.

4.7.2.3 Electric motors (HT only)

1. Opposite sides of the coil experience forces in opposite directions, causing it to rotate.
2. The split-ring commutator reverses the current every half turn so the coil continues rotating in the same direction.
3. Because the current flows in opposite directions on each side of the coil.
4. To reverse the current every half turn.
5. So the turning force continues to act in the same direction.
6. Electric fan.

4.7.2.4 Loudspeakers (Physics only, HT only)

1. A current-carrying coil in a magnetic field moves and causes the cone to vibrate, producing sound waves.
2. The changing current changes the direction and size of the force on the coil.
3. The current-carrying coil moves in the magnetic field, causing vibrations that produce sound.
4. A larger alternating current produces a larger force, so the cone moves further.
5. The vibrating cone compresses and rarefies the surrounding air.
6. The permanent magnet provides the magnetic field and the current-carrying coil experiences the motor effect.

4.7.3.1 Induced potential (HT only)

1. The production of a potential difference when a conductor moves through a magnetic field.
2. The conductor cuts across magnetic field lines, inducing a potential difference.
3. Because charge can only flow if there is a complete circuit.
4. Move the conductor faster; use a stronger magnetic field.
5. The direction of the induced current reverses.
6. Because of Lenz's Law.

4.7.3.2 Uses of the generator effect (HT only)

1. A coil rotates in a magnetic field, producing an alternating potential difference.

2. A split-ring commutator makes the current flow in one direction.
3. An alternator produces alternating current; a dynamo produces direct current.
4. A sine wave.
5. Because the direction of movement through the magnetic field reverses every half turn.
6. Bicycle dynamo.

4.7.3.3 Microphones (HT only)

1. Sound waves make a coil vibrate in a magnetic field, inducing a potential difference.
2. Pressure changes from the sound wave make the diaphragm and coil vibrate.
3. The moving coil cuts magnetic field lines, inducing a potential difference.
4. A louder sound causes larger vibrations, producing a larger induced potential difference and current.
5. The generator effect.
6. They transfer sound energy into electrical energy.

4.7.3.4 Transformers (HT only)

1. Because only an alternating current produces a changing magnetic field.
2. Secondary potential difference = Primary potential difference × (Secondary turns ÷ Primary turns) = 230 × (100 ÷ 500) = 230 × 0.2 = 46 V
3. A step-up transformer increases potential difference. A step-down transformer decreases potential difference.
4. Current = Power ÷ Potential difference = 240 ÷ 24 = 10 A
5. A higher potential difference produces a lower current for the same power, reducing energy losses due to heating.
6. Potential difference ratio = Number of turns ratio.

Topic 7 Review

1. A permanent magnet produces its own magnetic field. An induced magnet only becomes magnetic in an external magnetic field and usually loses its magnetism when the field is removed.
2. Move a plotting compass around the magnet and mark the direction of the needle to map the magnetic field lines.
3. Force = Magnetic flux density × Current × Length = 0.40 × 3 × 0.50 = 0.6 N
4. In both devices, the motor effect causes a current-carrying conductor in a magnetic field to experience a force. In a motor this produces rotation; in a loudspeaker it causes the cone to vibrate.

5. Both use the generator effect by moving a conductor through a magnetic field. An alternator produces alternating current, while a dynamo produces direct current.
6. Secondary potential difference = Primary potential difference × (Secondary turns ÷ Primary turns) = 12 × (1000 ÷ 200) = 12 × 5 = 60 V. It is a step-up transformer.

Topic 8 – Space Physics Retrieval Starters

4.8.1.1 The Solar System

1. The Solar System consists of the Sun, eight planets, dwarf planets, moons, asteroids and comets orbiting the Sun.
2. The Sun's gravitational force provides the centripetal force that keeps the planets in orbit.
3. Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune.
4. A planet orbits the Sun, a moon orbits a planet, and a dwarf planet orbits the Sun but has not cleared its orbit.
5. An elliptical orbit.
6. Gravity keeps the planets and other bodies in orbit around the Sun.

4.8.1.2 Life cycle of a star

1. Nebula → Protostar → Main sequence star.
2. Main sequence star → Red giant → White dwarf → Black dwarf.
3. Main sequence star → Red supergiant → Supernova → Neutron star or Black hole.
4. More massive stars burn their fuel faster and end in a supernova. Smaller stars become red giants and end as white dwarfs.
5. Fusion joins lighter nuclei to form heavier nuclei. Elements up to iron are formed during fusion inside stars. Elements heavier than iron are formed during a supernova.
6. The supernova ejects elements into space, providing the material needed to form new stars and planets.

4.8.1.3 Orbital motion, natural and artificial satellites

1. A natural satellite orbits naturally (e.g. the Moon). An artificial satellite is man-made (e.g. a communications satellite).
2. The Earth's gravity provides the centripetal force needed for its orbit.
3. They move forwards while gravity continually changes their direction, keeping them in orbit.

4. GPS navigation (or weather forecasting or satellite communications).
5. Gravity provides the centripetal force needed to keep the satellite moving in a circular (or nearly circular) orbit.
6. A circular or elliptical orbit around the Earth.

4.8.1.4 Red-shift

1. The increase in the wavelength of light from a galaxy moving away from the Earth.
2. It shows that galaxies are moving away from each other, so the Universe is expanding.
3. Because they are moving away faster.
4. The wavelength increases (it shifts towards the red end of the spectrum).
5. The Universe began from an extremely hot, dense state and has been expanding ever since.
6. Nearly all distant galaxies show red-shift, supporting the idea that the Universe is expanding from a common origin.

Topic 8 Review

1. The Sun's gravitational force provides the centripetal force that keeps the planets in orbit.
2. A Sun-sized star becomes a red giant, then a white dwarf, and finally a black dwarf. A much larger star becomes a red supergiant, explodes as a supernova, and ends as either a neutron star or a black hole.
3. Nuclear fusion joins lighter nuclei to form heavier nuclei. Elements heavier than iron are produced during the enormous energy release of a supernova.
4. A natural satellite orbits naturally (e.g. the Moon). An artificial satellite is man-made (e.g. a communications satellite).
5. Red-shift is the increase in the wavelength of light from distant galaxies. It shows that the Universe is expanding.
6. If it is about the same size as the Sun: Red giant → White dwarf → Black dwarf. If it is much larger than the Sun: Red supergiant → Supernova → Neutron star or Black hole.