# Edexcel GCSE Comb Sci Phys

## Topic 1 – Key concepts of physics

1.1 Recall and use the SI unit for physical quantities, as listed in Appendix 5

1. Metre (m).
2. Kilogram (kg).
3. Second (s).
4. Kelvin (K).
5. Ampere (A).
6. Force: newton (N); energy: joule (J); power: watt (W); pressure: pascal (Pa); charge: coulomb (C).

1.2 Recall and use multiples and sub-multiples of units, including giga (G), mega (M), kilo (k), centi (c), milli (m), micro (μ) and nano (n)

1. $10^9$.
2. $10^6$.
3. $10^3$.
4. $10^{-2}$.
5. Milli = $10^{-3}$; micro = $10^{-6}$; nano = $10^{-9}$.
6. 4.5 km = $4.5 \times 10^3$ m = 4500 m; 320 mm = $320 \times 10^{-3}$ m = 0.320 m; 7.2 μm = $7.2 \times 10^{-6}$ m; 8.0 ns = $8.0 \times 10^{-9}$ s.

1.3 Be able to convert between different units, including hours to seconds

1. 60 s.
2. 3600 s.
3. 2.5 × 3600 = 9000 s.
4. 7200 ÷ 3600 = 2 h.
5. 3.6 × 1000 = 3600 m.
6. 1500 m = 1.5 km; 2.0 min = 2.0 × 60 = 120 s.

1.4 Use significant figures and standard form where appropriate

1. 3 significant figures.
2. 2 significant figures.
3. $7.2 \times 10^{-5}$.
4. 630,000.
5. $(3.2 \times 10^4)(2.0 \times 10^{-3}) = 6.4 \times 10^1$.
6. 0.006784 m → 0.00678 m = $6.78 \times 10^{-3}$ m.

# Topic 2 – Motion and forces

2.1 Explain that a scalar quantity has magnitude (size) but no specific direction

1. A quantity with magnitude but no specific direction.
2. The size or numerical value of the quantity.
3. No.
4. Distance has magnitude only and no direction.
5. Speed has magnitude only and no direction.
6. Distance and speed; both have magnitude but no specific direction.

2.2 Explain that a vector quantity has both magnitude (size) and a specific direction

1. A quantity with both magnitude and a specific direction.
2. Magnitude and direction.
3. Displacement includes both the distance from the starting point and a direction.
4. Velocity includes speed and a stated direction.
5. Force has a size and acts in a particular direction.
6. Displacement and force; both have magnitude and direction.

2.3 Explain the difference between vector and scalar quantities

1. A scalar has magnitude only; a vector has magnitude and direction.
2. Scalar.
3. Vector.
4. Speed is scalar, whereas velocity includes a direction and is therefore a vector.
5. Distance is scalar, whereas displacement includes direction and is therefore a vector.
6. Velocity; 20 m/s north includes both magnitude and direction.

2.4 Recall vector and scalar quantities, including: a displacement/distance b velocity/speed c acceleration d force e weight/mass f momentum g energy

1. Displacement.
2. Velocity.
3. Acceleration, force, weight and momentum.
4. Energy.
5. Mass = scalar; weight = vector.
6. Displacement = vector; distance = scalar; velocity = vector; speed = scalar; acceleration = vector; force = vector; weight = vector; mass = scalar; momentum = vector; energy = scalar.

2.5 Recall that velocity is speed in a stated direction

1. Speed in a stated direction.
2. Direction.
3. 15 m/s east.
4. 8 m/s.
5. Its direction can change while its speed remains constant.
6. Yes. Its direction changes from north to south, so its velocity changes.

2.6 Recall and use the equations: a (average) speed (metre per second, m/s) = distance (metre, m) ÷ time (s) b distance travelled (metre, m) = average speed (metre per second, m/s) × time (s)

1. Speed = distance ÷ time.
2. Speed = 240 ÷ 12 = 20 m/s.
3. Distance = 8.0 × 25 = 200 m.
4. Time = 1500 ÷ 5.0 = 300 s.
5. 18 km = 18,000 m; 15 min = 900 s; speed = 18,000 ÷ 900 = 20 m/s.
6. 3.5 min = 210 s; distance = 22 × 210 = 4620 m = 4.62 km.

2.7 Analyse distance/time graphs including determination of speed from the gradient

1. Speed.
2. Calculate change in distance ÷ change in time.
3. The object is stationary.
4. The object is moving at constant speed.
5. 12 m/s.
6. Speed = (80 − 20) ÷ (9 − 4) = 60 ÷ 5 = 12 m/s.

2.8 Recall and use the equation: acceleration (metre per second squared, m/s2) = change in velocity (metre per second, m/s) ÷ time taken (second, s) ( ) t v u a − =

1. a = (v − u) ÷ t.
2. a = (25 − 5) ÷ 4 = 5.0 $m/s^2$.
3. a = (14 − 2) ÷ 6 = 2.0 $m/s^2$.
4. v = u + at = 4.0 + (3.0 × 8.0) = 28 m/s.
5. a = (10 − 30) ÷ 5.0 = −4.0 $m/s^2$.
6. t = change in velocity ÷ acceleration = 20 ÷ 2.5 = 8.0 s.

2.9 Use the equation: (final velocity)2 ((metre/second)2, (m/s)2) – (initial velocity)2 ((metre/second)2, (m/s)2) = 2 × acceleration (metre per second squared, m/s2) × distance (metre, m) v − u = 2× a× x

1. $v^2 - u^2 = 2ax$.
2. $v^2 = 0^2 + 2(4.0)(50) = 400$; v = 20 m/s.

3. $v^2 = 5.0^2 + 2(2.0)(20) = 105$; $v = 10.2$ m/s.
4. $0^2 - 25^2 = 2(-5.0)x$; $-625 = -10x$; $x = 62.5$ m.
5. $30^2 - 10^2 = 2a(100)$; $800 = 200a$; $a = 4.0$ m/s².
6. $20^2 - 8.0^2 = 2(1.5)x$; $336 = 3x$; $x = 112$ m.

2.10 Analyse velocity/time graphs to: a compare acceleration from gradients qualitatively b calculate the acceleration from the gradient (for uniform acceleration only) c determine the distance travelled using the area between the graph line and the time axis (for uniform acceleration only)

1. Acceleration.
2. The object with the steeper gradient has the greater acceleration.
3. Distance travelled.
4. $a = (20 - 0) \div 5 = 4.0$ m/s².
5. Distance = average velocity × time = $((10 + 30) \div 2) \times 4 = 80$ m.
6. Distance = $12 \times 8 = 96$ m.

2.11 Describe a range of laboratory methods for determining the speeds of objects such as the use of light gates

1. A light gate measures how long an object blocks a beam; speed = distance travelled ÷ time.
2. Distance travelled and time taken.
3. Measure the distance between the gates and the time taken to travel between them; average speed = distance ÷ time.
4. The known length allows the time for the card to block the beam to be converted into speed.
5. It gives accurate automatic timing and reduces human reaction-time error.
6. Attach a card of known length to a trolley and pass it through a light gate. Measure the time for the card to interrupt the beam. Speed = card length ÷ interruption time.

2.12 Recall some typical speeds encountered in everyday experience for wind and sound, and for walking, running, cycling and other transportation systems

1. About 1.5 m/s.
2. About 3 m/s.
3. About 6 m/s.
4. About 330 m/s.
5. About 10 m/s.
6. Walking ≈ 1.5 m/s; running ≈ 3 m/s; cycling ≈ 6 m/s; car ≈ 13 m/s; sound ≈ 330 m/s.

2.13 Recall that the acceleration, g, in free fall is 10 m/s2 and be able to estimate the magnitudes of everyday accelerations

1. 10 $m/s^2$.
2. Its velocity increases by about 10 m/s each second.
3. 10 $m/s^2$ downward.
4. By approximately 10 m/s each second.
5. $a = (20 - 0) \div 10 = 2.0\ m/s^2$.
6. $g = 10\ m/s^2$; this is greater than the typical car acceleration of about 2 $m/s^2$.

2.14 Recall Newton's first law and use it in the following situations: a where the resultant force on a body is zero, i.e. the body is moving at a constant velocity or is at rest b where the resultant force is not zero, i.e. the speed and/or direction of the body change(s)

1. An object remains at rest or continues at constant velocity unless acted on by a resultant force.
2. It remains at rest or moves at constant velocity.
3. Its velocity changes; its speed and/or direction changes.
4. Zero.
5. The resultant force is zero.
6. Its velocity changes because its direction changes, so it has acceleration and therefore a resultant centripetal force.

2.15 Recall and use Newton's second law as: force (newton, N) = mass (kilogram, kg) × acceleration (metre per second squared, m/s2) $F = m \times a$

1. $F = m \times a$.
2. $F = 5.0 \times 4.0 = 20$ N.
3. $F = 1200 \times 2.5 = 3000$ N.
4. $m = F \div a = 600 \div 3.0 = 200$ kg.
5. $a = F \div m = 80 \div 20 = 4.0\ m/s^2$.
6. $a = 4500 \div 1500 = 3.0\ m/s^2$; its velocity increases in the direction of the resultant force.

2.16 Define weight, recall and use the equation: weight (newton, N) = mass (kilogram, kg) × gravitational field strength (newton per kilogram, N/kg) $W = m \times g$

1. The force acting on an object due to gravity.
2. $W = m \times g$.
3. $W = 60 \times 10 = 600$ N.
4. $m = W \div g = 250 \div 10 = 25$ kg.
5. $W = 5.0 \times 4.0 = 20$ N.
6. Earth: $W = 70 \times 10 = 700$ N; planet: $W = 70 \times 3.0 = 210$ N.

2.17 Describe how weight is measured

1. A newton meter/force meter.

2. Force.
3. It measures the force exerted by gravity on the object.
4. To ensure the force is within the meter's measuring range and obtain an accurate reading.
5. Attach the object to a newton meter, allow it to hang freely and read the force in newtons.
6. Newtons (N).

2.18 Describe the relationship between the weight of a body and the gravitational field strength

1. Weight is directly proportional to gravitational field strength for constant mass.
2. Its weight increases.
3. The Moon has a weaker gravitational field strength.
4. No. Mass remains constant; weight changes because gravitational field strength changes.
5. Earth: $60 \times 10 = 600$ N; other planet: $60 \times 5 = 300$ N.
6. $W = mg$, so for the same g a greater mass gives a greater weight.

2.19 Core Practical: Investigate the relationship between force, mass and acceleration by varying the masses added to trolleys

1. $F = ma$; acceleration increases with resultant force and decreases as mass increases.
2. Resultant force.
3. Mass of trolley/system, track conditions and other relevant conditions such as starting position.
4. Use light gates/data logger or measure distance and time and calculate acceleration.
5. Keep the total force constant and transfer masses between the trolley and the hanging mass, increasing trolley mass while maintaining the same driving force; measure acceleration for each mass.
6. $a = F \div m = 2.0 \div 0.50 = 4.0$ m/s$^2$. Apply a known resultant force to a 0.50 kg trolley, measure its acceleration using light gates and compare with 4.0 m/s$^2$.

2.20 Explain that an object moving in a circular orbit at constant speed has a changing velocity (qualitative only)

1. Its direction continuously changes.
2. Its direction.
3. No. Velocity changes if either speed or direction changes.
4. Continuously, at every point on the circular path.

5. Its direction changes continuously, so its velocity changes and it has acceleration.
6. The direction of motion changes continuously even though the magnitude of velocity/speed remains constant.

2.21 Explain that for motion in a circle there must be a resultant force known as a centripetal force that acts towards the centre of the circle

1. The resultant force directed towards the centre of a circular path.
2. Towards the centre of the circle.
3. A resultant force is needed to continually change the direction of velocity.
4. It would move off in a straight line tangentially to the circle.
5. Gravity acting on a satellite orbiting Earth.
6. A force towards the centre continually changes the direction of the velocity vector.

2.22 Explain that inertial mass is a measure of how difficult it is to change the velocity of an object (including from rest) and know that it is defined as the ratio of force over acceleration

1. A measure of how difficult it is to change an object's velocity.
2. It is more difficult to change its velocity.
3. Inertial mass = force ÷ acceleration, m = F/a.
4. m = 50 ÷ 2.0 = 25 kg.
5. The first object; $m_1$ = F/4 and $m_2$ = F/2, so the second has twice the inertial mass. Therefore the second has the greater inertial mass.
6. Measure the force applied and resulting acceleration, then calculate m = F/a.

2.23 Recall and apply Newton's third law both to equilibrium situations and to collision interactions and relate it to the conservation of momentum in collisions

1. When two objects interact, they exert equal and opposite forces on each other.
2. Equal-magnitude, opposite-direction forces acting on different objects.
3. Earth's gravitational force on the book and the book's gravitational force on Earth.
4. Each car exerts an equal and opposite force on the other.
5. Equal and opposite forces produce equal and opposite changes in momentum, so total momentum is conserved if no external resultant force acts.
6. The forces are equal and opposite and act for the same time, giving equal and opposite momentum changes; therefore total momentum remains constant.

2.24 Define momentum, recall and use the equation: momentum (kilogram metre per second, kg m/s) = mass (kilogram, kg) × velocity (metre per second, m/s) $\rho = m \times v$

1. The product of mass and velocity.
2. $\rho = m \times v$.
3. $\rho = 4.0 \times 6.0 = 24$ kg m/s.
4. $\rho = 1200 \times 20 = 24{,}000$ kg m/s.
5. $v = \rho \div m = 150 \div 30 = 5.0$ m/s.
6. $\rho = 2.0 \times 8.0 = 16$ kg m/s east.

2.25 Describe examples of momentum in collisions

1. It remains constant if no external resultant force acts.
2. A moving trolley colliding with a stationary trolley.
3. Momentum is transferred from the moving car to the stationary car; total momentum is conserved.
4. Momentum depends on both mass and velocity: $\rho = mv$.
5. The moving trolley loses some momentum and the stationary trolley gains momentum; total momentum remains constant.
6. Calculate total momentum before and after the collision and set them equal for an isolated system.

2.26 Use Newton's second law as: force (newton, N) = change in momentum (kilogram metre per second, kg m/s) ÷ time (second, s) ( ) t mv mu F − =

1. $F = (mv - mu) \div t$.
2. Change in momentum = $Ft = 20 \times 0.50 = 10$ kg m/s.
3. $F = (40 - 10) \div 2.0 = 15$ N.
4. Change in momentum = $5.0(8.0 - 2.0) = 30$ kg m/s; $F = 30 \div 3.0 = 10$ N.
5. $F = 1200(10 - 25) \div 5.0 = -3600$ N; braking force = 3600 N opposite to motion.
6. Change in momentum = $Ft = 500 \times 0.20 = 100$ kg m/s. $100 = m(15 - 5)$; $m = 10$ kg.

2.27 Explain methods of measuring human reaction times and recall typical results

1. The time between a stimulus being presented and the response occurring.
2. Hold a ruler vertically, release it without warning and have the person catch it; record the distance fallen and convert it to reaction time.
3. Distance fallen by the ruler; the corresponding reaction time.
4. About 0.2–0.3 s.
5. Tiredness and distractions.
6. Repeats reduce the effect of random variation and allow a mean to be calculated, improving reliability.

2.28 Recall that the stopping distance of a vehicle is made up of the sum of the thinking distance and the braking distance

1. The distance travelled while the driver reacts before braking begins.
2. The distance travelled after braking begins until the vehicle stops.
3. Stopping distance = thinking distance + braking distance.
4. 15 + 25 = 40 m.
5. 60 − 20 = 40 m.
6. The driver needs time to detect the hazard, process the information and react before the brakes are applied.

2.29 Explain that the stopping distance of a vehicle is affected by a range of factors including: a the mass of the vehicle b the speed of the vehicle c the driver's reaction time d the state of the vehicle's brakes e the state of the road f the amount of friction between the tyre and the road surface

1. It generally increases stopping distance because greater mass gives greater momentum and kinetic energy.
2. It increases stopping distance, particularly braking distance.
3. It increases thinking distance.
4. Worn/faulty brakes reduce braking force and increase braking distance.
5. Wet/icy or otherwise low-friction roads reduce friction and increase braking distance.
6. Greater speed and mass increase momentum and kinetic energy, requiring greater force/work to bring the vehicle to rest.

2.30 Describe the factors affecting a driver's reaction time including drugs and distractions

1. The time between detecting a hazard and beginning a response.
2. Drugs can slow reactions or impair judgement and coordination.
3. Distractions reduce attention and delay the response.
4. The vehicle travels further before braking begins.
5. Tiredness and drugs.
6. Mobile-phone use distracts the driver, increasing reaction time and therefore thinking distance and stopping distance.

2.31 Explain the dangers caused by large decelerations and estimate the forces involved in typical situations on a public road

1. They produce large forces on occupants, which can cause injury.
2. The force increases because F = ma.
3. They increase the time over which the occupant is brought to rest, reducing deceleration and force.
4. F = ma = 70 × 10 = 700 N.

5. $F = ma = 1000 \times 8.0 = 8000$ N.
6. $F = ma = 60 \times 20 = 1200$ N; a large force can cause serious injury.

# Topic 3 – Conservation of energy

3.1 Recall and use the equation to calculate the change in gravitational PE when an object is raised above the ground: change in gravitational potential energy (joule, J) = mass (kilogram, kg) × gravitational field strength (newton per kilogram, N/kg) × change in vertical height (metre, m) $\Delta GPE = m \times g \times \Delta h$

1. $\Delta GPE = m \times g \times \Delta h$.
2. $\Delta GPE = 5.0 \times 10 \times 8.0 = 400$ J.
3. $\Delta h = 120 \div (2.0 \times 10) = 6.0$ m.
4. $\Delta GPE = 60 \times 10 \times 4.0 = 2400$ J.
5. $\Delta h = 7 - 2 = 5$ m; $\Delta GPE = 10 \times 10 \times 5 = 500$ J.
6. $\Delta h = 200 \div (4.0 \times 10) = 5.0$ m.

3.2 Recall and use the equation to calculate the amounts of energy associated with a moving object: kinetic energy (joule, J) = 1/2 × mass (kilogram, kg) × (speed)$^2$ ((metre/second)$^2$, (m/s)$^2$) $KE = 1/2 \times m \times v^2$

1. $KE = \frac{1}{2}mv^2$.
2. $KE = \frac{1}{2} \times 4.0 \times 5.0^2 = 50$ J.
3. $KE = \frac{1}{2} \times 1200 \times 20^2 = 240{,}000$ J.
4. $v = \sqrt{(2KE/m)} = \sqrt{(500/2.0)} = 15.8$ m/s.
5. $KE = \frac{1}{2} \times 80 \times 6.0^2 = 1440$ J.
6. It increases by a factor of 4.

3.3 Draw and interpret diagrams to represent energy transfers

1. The movement of energy from one store to another.
2. The initial and final energy stores and the direction of energy transfer.
3. Electrical energy → thermal energy of water.
4. Gravitational potential energy → kinetic energy, with some energy transferred to thermal energy due to air resistance.
5. Show an additional transfer to the thermal energy store of the surroundings.
6. Electrical energy → kinetic energy + thermal energy.

3.4 Explain what is meant by conservation of energy

1. Energy cannot be created or destroyed; it can only be transferred between stores.
2. No.

3. It remains constant in a closed system.
4. Gravitational potential energy decreases and is transferred mainly to kinetic energy, with some to thermal energy.
5. 500 – 350 = 150 J.
6. The energy remains present but is transferred to less useful stores, such as thermal energy in the surroundings.

3.5 Analyse the changes involved in the way energy is stored when a system changes, including: a an object projected upwards or up a slope b a moving object hitting an obstacle c an object being accelerated by a constant force d a vehicle slowing down e bringing water to a boil in an electric kettle

1. Kinetic energy decreases while gravitational potential energy increases.
2. Kinetic energy decreases and is transferred to thermal, sound and deformation stores.
3. Its kinetic energy store increases.
4. Kinetic energy decreases and is mainly transferred to thermal energy stores of the brakes, tyres and surroundings.
5. The thermal energy store of the water increases until boiling point is reached.
6. Kinetic energy is transferred to gravitational potential energy as it rises; at the highest point kinetic energy is zero; as it rolls back down, gravitational potential energy is transferred to kinetic energy, with some energy dissipated as thermal energy and sound.

3.6 Explain that where there are energy transfers in a closed system there is no net change to the total energy in that system

1. A system in which energy cannot enter or leave.
2. The total energy remains constant.
3. Energy is transferred between stores rather than created or destroyed.
4. 800 J.
5. Energy moves between stores, but the sum of all energy stores remains unchanged.
6. The gravitational potential energy lost equals the total increase in kinetic and thermal energy stores.

3.7 Explain that mechanical processes become wasteful when they cause a rise in temperature so dissipating energy in heating the surroundings

1. Useful energy is transferred to unwanted thermal energy stores.
2. Friction transfers kinetic/mechanical energy to thermal energy.
3. Their thermal energy stores increase and their temperature rises.
4. Less of the supplied energy is transferred usefully.

5. Kinetic energy is transferred to thermal energy in the bicycle, tyres and surroundings.
6. Some input energy is being transferred to thermal energy rather than the intended useful store.

3.8 Explain, using examples, how in all system changes energy is dissipated so that it is stored in less useful ways

1. Energy transferred to less useful stores, usually the thermal energy store of the surroundings.
2. It is difficult to recover and use for the original purpose.
3. Kinetic energy is transferred to thermal energy in the brakes, tyres and surroundings.
4. Some energy is transferred to thermal energy of the surroundings and other unwanted stores.
5. Friction converts kinetic energy into thermal energy in the surfaces and surroundings.
6. Energy is transferred to thermal energy and sound as the ball deforms and collides with the ground, so less energy remains in the ball's kinetic/gravitational stores.

3.9 Explain ways of reducing unwanted energy transfer including through lubrication, thermal insulation

1. It reduces friction between surfaces.
2. Less energy is transferred to unwanted thermal stores.
3. It reduces the rate of thermal energy transfer.
4. It traps air or uses materials with low thermal conductivity, reducing heat transfer from the house.
5. Lubrication reduces friction and therefore reduces unwanted thermal energy transfer.
6. Lubrication reduces mechanical friction; thermal insulation reduces thermal energy transfer.

3.10 Describe the effects of the thickness and thermal conductivity of the walls of a building on its rate of cooling qualitatively

1. Increasing wall thickness decreases the rate of cooling.
2. Increasing thermal conductivity increases the rate of cooling.
3. Low thermal conductivity reduces the rate of thermal energy transfer.
4. The building with thick walls.
5. The building with low thermal conductivity.
6. Thick walls provide a longer path for conduction, while low thermal conductivity reduces the rate of thermal transfer.

3.11 Recall and use the equation: efficiency = useful energy transferred by the device ÷ total energy supplied to the device

1. Efficiency = useful energy transferred ÷ total energy supplied.
2. Efficiency = 350 ÷ 500 = 0.70.
3. Useful energy = 0.75 × 800 = 600 J.
4. Total energy = 240 ÷ 0.60 = 400 J.
5. Useful energy = 2000 − 500 = 1500 J; efficiency = 1500 ÷ 2000 = 0.75.
6. 0.82 × 100 = 82%.

3.12 Explain how efficiency can be increased

1. A greater proportion of the input energy is transferred usefully.
2. It reduces friction and therefore reduces unwanted thermal energy transfer.
3. Less input energy is dissipated as thermal energy.
4. It reduces unwanted thermal energy transfer to the surroundings.
5. Lubricate moving parts/reduce friction so less energy is dissipated as thermal energy.
6. More of the supplied energy is transferred to the useful output rather than unwanted stores.

3.13 Describe the main energy sources available for use on Earth (including fossil fuels, nuclear fuel, bio-fuel, wind, hydroelectricity, the tides and the Sun), and compare the ways in which both renewable and non-renewable sources are used

1. Coal, oil, natural gas and nuclear fuel.
2. Biofuel, wind, hydroelectricity, tides and solar energy.
3. They are finite and cannot be replaced at the rate at which they are used.
4. Falling/moving water turns turbines connected to electrical generators.
5. Wind is renewable and produces no fuel combustion emissions but is intermittent; fossil fuels are reliable but finite and release greenhouse gases/pollutants.
6. Renewable resources are replenished and generally produce fewer greenhouse-gas emissions but can be intermittent or geographically limited; non-renewable resources are finite but can provide reliable, controllable energy.

3.14 Explain patterns and trends in the use of energy resources

1. Population, energy demand, cost, availability, technology, government policy and environmental concerns.
2. Concerns about climate change, technological improvements and falling costs.
3. They are widely available, established and can provide reliable energy.

4. A larger population generally increases energy demand.
5. Improvements can make renewable technologies more efficient, cheaper and more widely used.
6. Energy use changes as demand, costs, resource availability, technology and environmental priorities change.

# Topic 4 – Waves

4.1 Recall that waves transfer energy and information without transferring matter

1. Energy and information.
2. Energy and information.
3. Particles oscillate around fixed/equilibrium positions while the disturbance transfers energy.
4. It oscillates/vibrates around an equilibrium position.
5. No. The water mainly oscillates while the wave transfers energy across the tank.
6. A wave transfers energy/information without a net transfer of matter.

4.2 Describe evidence that with water and sound waves it is the wave and not the water or air itself that travels

1. A floating object oscillates about its original position rather than travelling with the wave.
2. Observe a floating object as waves pass and see that it moves up/down rather than across the tank.
3. It oscillates, mainly up and down, around its original position.
4. Sound can travel through air while the air particles oscillate about fixed positions rather than travelling from source to listener.
5. Vibrating air particles transfer energy to neighbouring particles, producing a travelling disturbance.
6. The floating object returns approximately to its original position while the wave continues across the water.

4.3 Define and use the terms frequency and wavelength as applied to waves

1. The number of complete waves/oscillations passing a point per second.
2. Hertz (Hz).
3. The distance between corresponding points on consecutive waves, such as crest to crest.
4. $\lambda$ (lambda).
5. 50 complete waves pass a point each second.
6. Measure the distance between two consecutive corresponding points, such as adjacent crests or troughs.

4.4 Use the terms amplitude, period, wave velocity and wavefront as applied to waves

1. The maximum displacement from the equilibrium position.
2. The time taken for one complete oscillation/wave.
3. The speed and direction in which the wave travels.
4. A line joining points on a wave that are in the same phase.
5. Measure the maximum displacement from the equilibrium/midline to a crest or trough.
6. As equally spaced lines joining points in the same phase, such as successive wave crests.

4.5 Describe the difference between longitudinal and transverse waves by referring to sound, electromagnetic, seismic and water waves

1. In a transverse wave, oscillations are perpendicular to the direction of energy transfer.
2. In a longitudinal wave, oscillations are parallel to the direction of energy transfer.
3. Longitudinal.
4. Transverse.
5. Transverse waves oscillate perpendicular to the direction of travel; longitudinal waves oscillate parallel to it. Water waves can show transverse motion and seismic waves include both types.
6. Compressions are regions where particles are close together; rarefactions are regions where particles are spread further apart.

4.6 Recall and use both the equations below for all waves: wave speed (metre/second, m/s) = frequency (hertz, Hz) × wavelength (metre, m) $v = f \times \lambda$ wave speed (metre/second, m/s) = distance (metre, m) ÷ time (second, s) t x v =

1. $v = f \times \lambda$.
2. $v = 25 \times 0.40 = 10$ m/s.
3. $\lambda = v \div f = 12 \div 6 = 2.0$ m.
4. v = distance ÷ time.
5. $v = 680 \div 2.0 = 340$ m/s.
6. Distance = speed × time = 15 × 4.0 = 60 m.

4.7 Describe how to measure the velocity of sound in air and ripples on water surfaces

1. Place two microphones a known distance apart, connect them to an oscilloscope and measure the time difference between the signals.
2. To calculate velocity using velocity = distance ÷ time.

3. Measure the time difference between the corresponding signals from the two microphones.
4. Velocity = distance between microphones ÷ time difference.
5. Use a stroboscope to make the ripples appear stationary and measure the wavelength/frequency.
6. Measure wavelength from the ripple pattern and frequency from the stroboscope or wave generator; calculate $v = f\lambda$.

4.10 Explain how waves will be refracted at a boundary in terms of the change of direction and speed

1. The change in direction and speed of a wave as it enters a different medium.
2. Its speed changes.
3. One side of the wavefront changes speed before the other, causing the wavefront to change direction.
4. It bends towards the normal.
5. Wavelength changes in proportion to wave speed because frequency remains constant.
6. The wave changes speed and bends at the boundary; if it slows down it bends towards the normal, and if it speeds up it bends away from the normal.

4.11 Recall that different substances may absorb, transmit, refract or reflect waves in ways that vary with wavelength

1. Transfer of wave energy into a material.
2. Passage of a wave through a material.
3. A wave changing direction at a boundary and travelling back into the original medium.
4. A change in wave direction as it enters a different medium.
5. Different materials interact differently with different wavelengths.
6. A material may absorb, transmit, reflect or refract one wavelength more strongly than another.

4.17 Core Practical: Investigate the suitability of equipment to measure the speed, frequency and wavelength of a wave in a solid and a fluid

1. A ripple tank, wave generator, light source/stroboscope and ruler.
2. A frequency generator or oscilloscope/data logger.
3. Measure the distance between successive corresponding wavefronts/crests using a ruler.
4. $v = f \times \lambda$.

5. Test different equipment under controlled conditions, compare measurements with expected values and assess resolution, precision, range and ease of use for waves in solids and fluids.
6. Consider frequency, wavelength, speed, distance/time measurements, resolution, uncertainty, repeatability, calibration and whether the equipment is appropriate for the medium.

# Topic 5 – Light and the electromagnetic spectrum

5.7 Recall that all electromagnetic waves are transverse, that they travel at the same speed in a vacuum

1. Transverse waves.
2. A wave in which the oscillations are perpendicular to the direction of energy transfer.
3. $3.0 \times 10^8$ m/s.
4. No. They all travel at $3.0 \times 10^8$ m/s in a vacuum.
5. All electromagnetic waves travel at the same speed in a vacuum; their frequencies and wavelengths differ.
6. Their speed decreases and depends on the substance they are travelling through.

5.8 Explain, with examples, that all electromagnetic waves transfer energy from source to observer

1. Energy.
2. Visible light carries energy from the Sun to Earth through space.
3. Microwaves transfer energy to the food, increasing its internal/thermal energy.
4. Infrared radiation transfers energy from the heater to the person, increasing their thermal energy.
5. X-rays transfer energy to body tissues as they pass through the body.
6. Infrared radiation from a heater transfers energy to a person.

5.9 Core Practical: Investigate refraction in rectangular glass blocks in terms of the interaction of electromagnetic waves with matter

1. Rectangular glass block, ray box/laser, paper, ruler, protractor and pencil.
2. Draw the normal at the point of incidence and measure the angles between the normal and the incident/refracted rays using a protractor.
3. It changes direction and bends towards the normal.

4. Its speed changes when it enters the glass.
5. Draw the incident ray, normal, refracted ray and emergent ray, then measure the relevant angles.
6. Measure several angles of incidence and the corresponding angles of refraction.

5.10 Recall the main groupings of the continuous electromagnetic spectrum including (in order) radio waves, microwaves, infrared, visible (including the colours of the visible spectrum), ultraviolet, x-rays and gamma rays

1. Radio waves, microwaves, infrared, visible light, ultraviolet, x-rays, gamma rays.
2. Radio waves.
3. Gamma rays.
4. Red, orange, yellow, green, blue, indigo, violet.
5. Visible light.
6. Ultraviolet, x-rays and gamma rays.

5.11 Describe the electromagnetic spectrum as continuous from radio waves to gamma rays and that the radiations within it can be grouped in order of decreasing wavelength and increasing frequency

1. The regions merge continuously with no gaps between different frequencies and wavelengths.
2. In order of decreasing wavelength and increasing frequency.
3. Wavelength decreases.
4. Frequency increases.
5. Ultraviolet radiation.
6. Microwaves.

5.12 Recall that our eyes can only detect a limited range of frequencies of electromagnetic radiation

1. Visible light.
2. Their frequencies are outside the range detected by the human eye.
3. The range of electromagnetic radiation that can be detected by the human eye.
4. Infrared and ultraviolet.
5. The eye can detect only a small range of electromagnetic frequencies.
6. It detects only a very small range compared with the full electromagnetic spectrum.

5.13 Recall that different substances may absorb, transmit, refract or reflect electromagnetic waves in ways that vary with wavelength

1. Its energy is transferred to the substance.
2. The radiation passes through the substance.
3. The radiation changes direction and travels back from the surface.
4. Its direction changes because its speed changes as it passes between substances.
5. Different substances interact differently with different wavelengths.
6. Glass transmits visible light but can absorb some ultraviolet radiation.

5.14 Explain the effects of differences in the velocities of electromagnetic waves in different substances

1. Their interaction with matter causes their speeds to depend on the substance.
2. It decreases.
3. A change in speed at a boundary causes the wave to change direction.
4. Its direction changes, causing refraction.
5. Its frequency remains constant.
6. Since $v = f \times \lambda$ and frequency remains constant, a change in velocity causes a change in wavelength.

5.20 Recall that the potential danger associated with an electromagnetic wave increases with increasing frequency

1. It increases.
2. Ultraviolet radiation.
3. X-rays.
4. X-rays and gamma rays.
5. Gamma rays have a much higher frequency and therefore greater potential danger.
6. Higher frequency electromagnetic radiation has greater potential danger.

5.21 Describe the harmful effects on people of excessive exposure to electromagnetic radiation, including: a microwaves: internal heating of body cells b infrared: skin burns c ultraviolet: damage to surface cells and eyes, leading to skin cancer and eye conditions d x-rays and gamma rays: mutation or damage to cells in the body

1. Internal heating of body cells.
2. Skin burns.
3. It can damage surface cells and the eyes.
4. Damage to cells can lead to mutations and increase the risk of skin cancer.
5. They can damage cells and cause mutations.
6. They can damage cells and DNA, potentially causing mutations.

5.22 Describe some uses of electromagnetic radiation a radio waves: including broadcasting, communications and satellite transmissions b microwaves: including cooking, communications and satellite transmissions c infrared: including cooking, thermal imaging, short range communications, optical fibres, television remote controls and security systems d visible light: including vision, photography and illumination e ultraviolet: including security marking, fluorescent lamps, detecting forged bank notes and disinfecting water f x-rays: including observing the internal structure of objects, airport security scanners and medical x-rays g gamma rays: including sterilising food and medical equipment, and the detection of cancer and its treatment

1. Broadcasting, communications and satellite transmissions.
2. Cooking, communications and satellite transmissions.
3. Cooking, thermal imaging and television remote controls.
4. Vision, photography and illumination.
5. Security marking, fluorescent lamps and detecting forged bank notes.
6. X-rays: observing internal structures, airport security scanners and medical x-rays. Gamma rays: sterilising food and medical equipment, detecting cancer and treating cancer.

5.23 Recall that radio waves can be produced by, or can themselves induce, oscillations in electrical circuits

1. An oscillating electrical current produces radio waves.
2. A repeated variation in current or voltage in the circuit.
3. A radio wave induces an alternating electrical current/oscillation in a conductor such as an aerial.
4. An alternating electrical current is induced in the aerial.
5. Oscillating electrical currents produce electromagnetic radiation in the form of radio waves.
6. Radio waves can be transmitted from an aerial and induce electrical oscillations in a receiving aerial, allowing information to be transmitted.

5.24 Recall that changes in atoms and nuclei can a generate radiations over a wide frequency range b be caused by absorption of a range of radiations

1. Changes in electron energy levels can cause atoms to emit electromagnetic radiation.
2. Changes in the nucleus can cause electromagnetic radiation, including gamma radiation.
3. They can produce electromagnetic radiation with many different frequencies.
4. Electrons can absorb energy and move to higher energy levels.
5. A nucleus can absorb electromagnetic radiation and change its energy state.

6. Atoms and nuclei can absorb electromagnetic radiation and move to higher energy states; they can later emit radiation when returning to lower energy states.

# Topic 6 – Radioactivity

6.1 Describe an atom as a positively charged nucleus, consisting of protons and neutrons, surrounded by negatively charged electrons, with the nuclear radius much smaller than that of the atom and with almost all of the mass in the nucleus

1. Protons and neutrons.
2. Positive.
3. Electrons.
4. The nuclear radius is much smaller than the atomic radius.
5. In the nucleus.
6. An atom has a small, positively charged nucleus containing protons and neutrons, surrounded by negatively charged electrons. Almost all its mass is in the nucleus.

6.2 Recall the typical size (order of magnitude) of atoms and small molecules

1. About $10^{-10}$ m.
2. Approximately $1 \times 10^{-10}$ m.
3. They are of a similar order of magnitude.
4. The approximate power of ten representing the size.
5. $1 \times 10^{-9}$ m.
6. 0.1 nm.

6.3 Describe the structure of nuclei of isotopes using the terms atomic (proton) number and mass (nucleon) number and using symbols in the format $^{13}_{6}C$

1. The number of protons in the nucleus.
2. The total number of protons and neutrons in the nucleus.
3. Number of neutrons = mass number − atomic number.
4. It represents carbon-13, with 6 protons and 13 nucleons.
5. 6 protons, 7 neutrons and 6 electrons.
6. $^{18}_{8}O$.

6.4 Recall that the nucleus of each element has a characteristic positive charge, but that isotopes of an element differ in mass by having different numbers of neutrons

1. The number of protons in the nucleus.

2. They have the same number of protons.
3. Atoms of the same element with the same number of protons but different numbers of neutrons.
4. The number of neutrons.
5. They contain different numbers of neutrons.
6. $^{35}_{17}Cl$ has 18 neutrons; $^{37}_{17}Cl$ has 20 neutrons.

6.5 Recall the relative masses and relative electric charges of protons, neutrons, electrons and positrons

1. Relative mass = 1; relative charge = +1.
2. Relative mass = 1; relative charge = 0.
3. Relative mass = 1/1840; relative charge = −1.
4. Relative mass = 1/1840; relative charge = +1.
5. Electron and positron.
6. Protons and positrons have +1; electrons have −1.

6.6 Recall that in an atom the number of protons equals the number of electrons and is therefore neutral

1. The positive charge of the protons equals the negative charge of the electrons.
2. They are equal.
3. 12 electrons.
4. 17 protons.
5. It becomes a negative ion with a −1 charge.
6. It becomes a positive ion with a +1 charge.

6.7 Recall that in each atom its electrons orbit the nucleus at different set distances from the nucleus

1. A region/set distance around the nucleus in which an electron orbits.
2. At different set distances from the nucleus.
3. Electrons occupy different energy levels around the nucleus.
4. Its energy increases.
5. Electrons in the outermost orbit.
6. It increases.

6.8 Explain that electrons change orbit when there is absorption or emission of electromagnetic radiation

1. It moves to a higher-energy orbit.
2. Its energy increases.
3. It loses energy.
4. Electromagnetic radiation is emitted.

5. The radiation must have the correct energy corresponding to the difference between the energy levels.
6. Absorption causes electrons to move to higher energy levels; emission occurs when electrons move to lower energy levels.

6.9 Explain how atoms may form positive ions by losing outer electrons

1. By losing one or more outer electrons.
2. There are then more positive protons than negative electrons.
3. Outer electrons.
4. +1.
5. +1.
6. +2.

6.10 Recall that alpha, β– (beta minus), β+ (positron), gamma rays and neutron radiation are emitted from unstable nuclei in a random process

1. Alpha, beta minus, beta plus, gamma rays and neutron radiation.
2. The exact time at which an individual nucleus decays cannot be predicted.
3. Alpha radiation.
4. Beta plus radiation.
5. Gamma radiation.
6. No.

6.11 Recall that alpha, β– (beta minus), β+ (positron) and gamma rays are ionising radiations

1. Radiation that can remove electrons from atoms, forming ions.
2. Alpha, beta minus, beta plus and gamma rays.
3. Yes.
4. Yes.
5. Yes.
6. Yes.

6.12 Explain what is meant by background radiation

1. Radiation that is present naturally in the environment.
2. It comes from natural sources in the environment and space.
3. Yes.
4. It contributes to the detector reading even without the source being measured.
5. Measure the background count and subtract it from the source count.
6. Because background radiation is always present in the environment.

6.13 Describe the origins of background radiation from Earth and space

1. Earth and space.
2. Rocks and soil can contain naturally radioactive materials that emit radiation.
3. Radon is a radioactive gas released from rocks and soil.
4. Cosmic radiation from space reaches Earth.
5. The concentration of radioactive materials and exposure to cosmic radiation vary with location.
6. Earth: radioactive rocks, soil and radon gas. Space: cosmic radiation.

6.14 Describe methods for measuring and detecting radioactivity limited to photographic film and a Geiger–Müller tube

1. Expose photographic film to radiation and observe the resulting darkening.
2. It becomes darker.
3. Detecting ionising radiation/radioactive decay.
4. It produces electrical pulses/clicks or a count when radiation enters the tube.
5. The number of counts per unit time/activity.
6. Background radiation causes some counts.

6.15 Recall that an alpha particle is equivalent to a helium nucleus, a beta particle is an electron emitted from the nucleus and a gamma ray is electromagnetic radiation

1. A helium nucleus.
2. Two protons and two neutrons.
3. An electron emitted from the nucleus.
4. It is produced during a change involving a neutron in the nucleus.
5. Electromagnetic radiation.
6. Alpha = helium nucleus; beta minus = electron; gamma = electromagnetic radiation.

6.16 Compare alpha, beta and gamma radiations in terms of their abilities to penetrate and ionise

1. Alpha.
2. Gamma.
3. Alpha.
4. Beta.
5. Thick lead or concrete.
6. Alpha is the most ionising and least penetrating; beta has intermediate ionising and penetrating ability; gamma is the least ionising and most penetrating.

6.17 Describe how and why the atomic model has changed over time including reference to the plum pudding model and Rutherford alpha particle scattering leading to the Bohr model

1. The atom was thought to be a sphere of positive charge with electrons embedded in it.
2. Evidence for a small, dense, positively charged nucleus.
3. Most alpha particles passed straight through, showing that most of the atom is empty space.
4. A small number of alpha particles were deflected through large angles, showing a small, dense, positively charged nucleus.
5. Electrons occupy specific orbits/energy levels around the nucleus.
6. New experimental evidence did not agree with previous models, so the models were revised.

6.18 Describe the process of β– decay (a neutron becomes a proton plus an electron)

1. A neutron changes into a proton and emits an electron.
2. An electron.
3. It increases by 1.
4. It remains unchanged.
5. Electron.
6. One neutron becomes a proton and an electron is emitted, increasing the proton number by 1 while leaving the mass number unchanged.

6.19 Describe the process of β+ decay (a proton becomes a neutron plus a positron)

1. A proton changes into a neutron and emits a positron.
2. A positron.
3. It decreases by 1.
4. It remains unchanged.
5. Positron.
6. One proton becomes a neutron and a positron is emitted, decreasing the proton number by 1 while leaving the mass number unchanged.

6.20 Explain the effects on the atomic (proton) number and mass (nucleon) number of radioactive decays (α, β, γ and neutron emission)

1. Proton number decreases by 2; mass number decreases by 4.
2. Proton number increases by 1; mass number is unchanged.
3. Proton number decreases by 1; mass number is unchanged.
4. Neither proton number nor mass number changes.
5. Proton number is unchanged; mass number decreases by 1.

6. Alpha decay gives −2 proton number and −4 mass number; beta minus gives +1 proton number and no mass-number change. Overall: proton number decreases by 1 and mass number decreases by 4.

6.21 Recall that nuclei that have undergone radioactive decay often undergo nuclear rearrangement with a loss of energy as gamma radiation

1. It can undergo nuclear rearrangement.
2. A change in the arrangement/energy state of the nucleons within the nucleus.
3. It decreases.
4. Gamma radiation.
5. No.
6. The daughter nucleus may be left in an excited energy state and emit gamma radiation as it loses excess energy.

6.22 Use given data to balance nuclear equations in terms of mass and charge

1. Mass number and proton number/charge.
2. The total mass number must be the same on both sides.
3. The total proton number must be the same on both sides.
4. ${}^{4}_{2}He$.
5. ${}^{0}_{-1}e$.
6. ${}^{210}_{84}Po \rightarrow {}^{206}_{82}Pb + {}^{4}_{2}He$.

6.23 Describe how the activity of a radioactive source decreases over a period of time

1. It decreases.
2. Unstable nuclei decay, so fewer undecayed nuclei remain.
3. It decreases.
4. A decreasing exponential curve.
5. There are more undecayed nuclei available to decay initially; as their number decreases, the rate of decay decreases.
6. Activity is proportional to the number of undecayed nuclei.

6.24 Recall that the unit of activity of a radioactive isotope is the Becquerel, Bq

1. Becquerel.
2. Bq.
3. One radioactive decay per second.
4. 500 decays per second.
5. 800 Bq.
6. A higher rate of radioactive decay.

6.25 Explain that the half-life of a radioactive isotope is the time taken for half the undecayed nuclei to decay or the activity of a source to decay by half

1. The time taken for half the undecayed nuclei to decay or for the activity to halve.
2. Determine the time taken for the number of undecayed nuclei to fall to half its initial value.
3. Determine the time taken for the activity to fall to half its initial value.
4. 400 Bq.
5. 10,000 nuclei.
6. After 3 hours: 640 → 320 → 160 → 80 Bq. Activity = 80 Bq.

6.26 Explain that it cannot be predicted when a particular nucleus will decay but half-life enables the activity of a very large number of nuclei to be predicted during the decay process

1. No.
2. The decay of an individual nucleus is random.
3. The expected activity/number of undecayed nuclei over time.
4. Large numbers of nuclei follow a predictable statistical pattern.
5. One half of the original activity.
6. Individual decays are unpredictable, but the overall behaviour of a large sample follows a predictable half-life pattern.

6.27 Use the concept of half-life to carry out simple calculations on the decay of a radioactive isotope, including graphical representations

1. 1/8 of the original nuclei.
2. 640 → 320 → 160 → 80 Bq.
3. 80 → 40 → 20 → 10 g.
4. $1000 \div 2^3 = 125$ Bq.
5. 960 → 480 → 240 → 120 Bq, so 3 half-lives = $3 \times 4 = 12$ days.
6. Find the time interval for the activity to fall from one value to half that value.

6.29 Describe the dangers of ionising radiation in terms of tissue damage and possible mutations and relate this to the precautions needed

1. It can ionise atoms and molecules in living tissue.
2. It can damage cells and DNA.
3. Ionisation can alter DNA and cause changes in genetic material.
4. They can lead to uncontrolled cell growth or inherited changes.
5. To reduce the risk of tissue damage and mutations.
6. Minimise exposure time, maximise distance from the source, use suitable shielding and limit the radiation dose.

6.31 Explain the precautions taken to ensure the safety of people exposed to radiation, including limiting the dose for patients and the risks to medical personnel

1. To reduce the risk of tissue damage and mutations.
2. They may receive repeated exposure to ionising radiation.
3. Keep exposure time as short as practical.
4. Radiation intensity decreases with distance from the source.
5. Absorbing materials such as lead can reduce the radiation reaching personnel.
6. To minimise unnecessary exposure and reduce the risks of tissue damage and mutations.

6.32 Describe the differences between contamination and irradiation effects and compare the hazards associated with these two.

1. Radioactive material gets onto or into a person or object.
2. Exposure to radiation from a source without radioactive material necessarily being transferred to the person.
3. Contamination involves radioactive material being deposited or taken into the body; irradiation is exposure to radiation from a source.
4. The radioactive material remains on or inside the person and can continue to emit radiation.
5. Removing the external radiation source stops the irradiation.
6. Contamination can be more difficult to control because the radioactive material can remain on or inside the person and continue to emit radiation.

# Topic 8 – Energy – forces doing work

8.1 Describe the changes involved in the way energy is stored when systems change

1. Energy is transferred between different energy stores.
2. Gravitational potential energy.
3. Kinetic energy.
4. Kinetic energy decreases while thermal energy stores increase.
5. Elastic potential energy decreases and is transferred mainly to kinetic energy, with some dissipated as thermal energy and sound.
6. Kinetic energy decreases and is transferred mainly to thermal energy stores of the object, surfaces and surroundings.

8.2 Draw and interpret diagrams to represent energy transfers

1. Energy transfers between different energy stores.
2. Arrows show the direction of energy transfer.
3. Chemical energy store of the battery → kinetic energy store of the motor, with some energy transferred to thermal stores.
4. Gravitational potential energy store → kinetic energy store, with some energy dissipated to thermal energy.
5. An arrow can show energy transferred to the thermal energy store of the surroundings.
6. The width represents the amount of energy transferred.

8.3 Explain that where there are energy transfers in a closed system there is no net change to the total energy in that system

1. A system in which energy cannot be transferred into or out of the system.
2. The total energy remains constant.
3. Energy is transferred between stores but is not created or destroyed.
4. The total energy remains constant.
5. Energy is conserved while being transferred between stores.
6. 0 J.

8.4 Identify the different ways that the energy of a system can be changed a through work done by forces b in electrical equipment c in heating

1. Work done by forces, electrical transfer and heating.
2. A force does work when it moves an object, transferring energy mechanically.
3. Electrical current transfers energy to components.
4. Heating transfers energy due to a temperature difference.
5. Lifting an object against gravity.
6. Electrical: a motor transferring electrical energy to kinetic energy. Heating: a heater transferring energy to the thermal energy store of water.

8.5 Describe how to measure the work done by a force and understand that energy transferred (joule, J) is equal to work done (joule, J)

1. Measure the force and the distance moved in the direction of the force, then calculate work done.
2. Force and distance moved in the direction of the force.
3. Joule (J).
4. Energy transferred = work done.
5. The force and the distance moved in the direction of the force.
6. Work done is the energy transferred by the force.

8.6 Recall and use the equation: work done (joule, J) = force (newton, N) × distance moved in the direction of the force (metre, m) $E = F \times d$

1. $E = F \times d$.
2. Work done = joules (J); force = newtons (N); distance = metres (m).
3. $E = 50 \times 4 = 200$ J.
4. $d = 600 \div 120 = 5$ m.
5. $F = 240 \div 8 = 30$ N.
6. $E = 75 \times 12 = 900$ J.

8.7 Describe and calculate the changes in energy involved when a system is changed by work done by forces

1. Work done transfers energy into or out of the system.
2. It increases.
3. It increases.
4. $E = 40 \times 5 = 200$ J.
5. $E = 20 \times 3 = 60$ J.
6. Friction transfers kinetic/mechanical energy into thermal energy stores of the object, surfaces and surroundings.

8.8 Recall and use the equation to calculate the change in gravitational PE when an object is raised above the ground: change in gravitational potential energy (joule, J) = mass (kilogram, kg) × gravitational field strength (newton per kilogram, N/kg) × change in vertical height (metre, m) $\Delta GPE = m \times g \times \Delta h$

1. $\Delta GPE = m \times g \times \Delta h$.
2. Mass in kg, gravitational field strength in N/kg and height change in m.
3. $\Delta GPE = 5 \times 10 \times 4 = 200$ J.
4. $\Delta h = 60 \div (2 \times 10) = 3$ m.
5. $\Delta GPE = 10 \times 9.8 \times 3 = 294$ J.
6. $m = 980 \div (9.8 \times 5) = 20$ kg.

8.9 Recall and use the equation to calculate the amounts of energy associated with a moving object: kinetic energy (joule, J) = 1/2 × mass (kilogram, kg) × $(\text{speed})^2$ ($(\text{metre/second})^2$, $(m/s)^2$) $KE = 1/2 \times m \times v^2$

1. $KE = \frac{1}{2} \times m \times v^2$.
2. Mass in kg, speed in m/s and kinetic energy in J.
3. $KE = \frac{1}{2} \times 4 \times 5^2 = 50$ J.
4. $v = \sqrt{(2 \times 100 \div 2)} = 10$ m/s.
5. $KE = \frac{1}{2} \times 1000 \times 20^2 = 200{,}000$ J.
6. It increases by a factor of 4.

8.10 Explain, using examples, how in all system changes energy is dissipated so that it is stored in less useful ways

1. Energy is transferred to less useful energy stores, usually thermal stores of the surroundings.
2. It becomes spread out and is difficult to recover for useful purposes.
3. Kinetic energy is transferred to thermal energy stores in the brakes, tyres and surroundings.
4. Some gravitational potential energy is transferred to thermal energy and sound due to air resistance.
5. Energy can be transferred to thermal stores and sound.
6. Energy has not been destroyed; it has been transferred to other stores.

8.11 Explain that mechanical processes become wasteful when they cause a rise in temperature so dissipating energy in heating the surroundings

1. Friction causes mechanical energy to be transferred to thermal energy.
2. It transfers mechanical energy to thermal energy.
3. It is dissipated to thermal energy stores of the surfaces and surroundings.
4. Less energy remains available for useful purposes.
5. Braking a car causes friction that heats the brakes.
6. Less energy is dissipated as unwanted heat, so a greater proportion of the input energy is available for useful output.

8.12 Define power as the rate at which energy is transferred and use examples to explain this definition

1. The rate at which energy is transferred.
2. The amount of energy transferred per unit time.
3. Watt (W).
4. The 2000 W appliance.
5. The machine that transfers the energy in the shorter time.
6. It transfers 100 J of energy every second.

8.13 Recall and use the equation: power (watt, W) = work done (joule, J) ÷ time taken (second, s) $P = E \div t$

1. $P = E \div t$.
2. Power = watts (W); energy/work done = joules (J); time = seconds (s).
3. $P = 600 \div 20 = 30$ W.
4. $E = P \times t = 1500 \times 10 = 15{,}000$ J.
5. $t = E \div P = 12{,}000 \div 600 = 20$ s.
6. 2 minutes = 120 s; $P = 3600 \div 120 = 30$ W.

8.14 Recall that one watt is equal to one joule per second, J/s

1. 1 J/s.
2. It transfers 1 joule of energy every second.

3. 100 J/s.
4. 500 J.
5. 2000 J/s.
6. 3 kW = 3000 W = 3000 J/s.

8.15 Recall and use the equation: efficiency = useful energy transferred by the device ÷ total energy supplied to the device

1. Efficiency = useful energy transferred ÷ total energy supplied.
2. Energy transferred to the intended useful output.
3. The total energy supplied to the device.
4. Efficiency = 350 ÷ 500 = 0.70 = 70%.
5. Useful energy = 0.75 × 800 = 600 J.
6. Efficiency = 240 ÷ 600 = 0.40 = 40%.

# Topic 9 – Forces and their effects

9.1 Describe, with examples, how objects can interact a at a distance without contact, linking these to the gravitational, electrostatic and magnetic fields involved b by contact, including normal contact force and friction c producing pairs of forces which can be represented as vectors

1. Gravitational, electrostatic and magnetic forces.
2. A gravitational field produces a force on masses within the field.
3. Electrostatic and magnetic fields produce forces on suitable objects within the fields.
4. Normal contact force acts perpendicular to a surface; friction opposes relative motion between surfaces.
5. Two interacting objects exert forces on each other that are equal in magnitude and opposite in direction.
6. Draw arrows with lengths proportional to the force magnitudes and arrows pointing in the directions of the forces.

9.2 Explain the difference between vector and scalar quantities using examples

1. A quantity with magnitude only.
2. A quantity with magnitude and direction.
3. Scalars have magnitude only; vectors have magnitude and direction.
4. Distance and speed.
5. Force and velocity.
6. Force has both magnitude and direction.

9.3 Use vector diagrams to illustrate resolution of forces, a net force, and equilibrium situations (scale drawings only)

1. The overall force produced by combining all forces acting on an object.
2. Arrows show both the magnitude and direction of forces.
3. Splitting a force into components in different directions.
4. Draw each force to scale and use vector addition to find the resultant.
5. The vectors form a closed shape, showing that the resultant force is zero.
6. Draw the 6 N and 8 N vectors to scale at right angles and measure the diagonal/resultant; it would be approximately 10 N.

9.4 Draw and use free body force diagrams

1. A diagram showing all the forces acting on an object.
2. A force acting on the object, with the arrow direction showing the force direction.
3. The force name, direction and, where appropriate, magnitude.
4. Weight acts downward; normal contact force from the table acts upward.
5. Weight downward, normal contact force upward, driving force forwards and resistive forces backwards.
6. Compare the forces; equal and opposite forces give zero resultant force, while unequal forces give a non-zero resultant.

9.5 Explain examples of the forces acting on an isolated solid object or a system where several forces lead to a resultant force on an object and the special case of balanced forces when the resultant force is zero

1. The vector sum of all forces acting on an object.
2. Its velocity changes; it accelerates.
3. It remains at rest or moves at constant velocity.
4. A book resting on a table.
5. Resultant force = 2000 − 500 = 1500 N forwards.
6. Resultant force = 0 N; the forces are balanced.

9.10 Explain ways of reducing unwanted energy transfer through lubrication

1. By reducing friction between moving surfaces.
2. It reduces friction.
3. Less friction means less mechanical energy is transferred to thermal energy.
4. Lubricating the bearings/gears in a machine.
5. Oil forms a lubricating layer between moving surfaces, reducing direct contact and friction.
6. Less energy is dissipated as thermal energy, so a greater proportion of the input energy is transferred usefully.

# Topic 10 – Electricity and circuits

10.1 Describe the structure of the atom, limited to the position, mass and charge of protons, neutrons and electrons

1. Protons and neutrons are in the nucleus; electrons surround the nucleus.
2. Relative mass = 1; relative charge = +1.
3. Relative mass = 1; relative charge = 0.
4. Relative mass = 1/1840; relative charge = −1.
5. The positive charge of the protons balances the negative charge of the electrons.
6. Protons: relative mass 1, charge +1; neutrons: relative mass 1, charge 0; electrons: relative mass 1/1840, charge −1.

10.2 Draw and use electric circuit diagrams representing them with the conventions of positive and negative terminals, and the symbols that represent cells, including batteries, switches, voltmeters, ammeters, resistors, variable resistors, lamps, motors, diodes, thermistors, LDRs and LEDs

1. A cell is represented by one long line and one short line; the long line is positive and the short line is negative.
2. A battery is represented by two or more cells, shown as repeated long and short parallel lines.
3. An ammeter is shown by a circle containing A; a voltmeter is shown by a circle containing V.
4. A resistor is shown by a rectangle; a variable resistor is shown by a resistor symbol with a diagonal arrow.
5. Lamp: circle with a cross; motor: circle containing M; diode: triangle/arrow-like diode symbol with a bar; thermistor: resistor with a diagonal line; LDR: resistor symbol with arrows pointing towards it.
6. An LED is represented by a diode symbol with arrows pointing outwards; components should be connected using standard circuit symbols with correct positive and negative terminals.

10.3 Describe the differences between series and parallel circuits

1. A series circuit has components connected in a single loop.
2. A parallel circuit has components connected in separate branches.
3. In series, the current is the same throughout; in parallel, current splits between branches and recombines at junctions.
4. In series, the supply potential difference is shared between components; in parallel, each branch has the same potential difference as the supply.
5. All components stop working because the circuit is broken.

6. The other branches can continue to operate because they provide separate paths for current.

10.4 Recall that a voltmeter is connected in parallel with a component to measure the potential difference (voltage), in volt, across it

1. Connect it in parallel across the component.
2. It measures the potential difference between two points across the component.
3. Potential difference (voltage).
4. Volt (V).
5. Connect the voltmeter in parallel across the lamp.
6. A voltmeter has very high resistance and connecting it in series would greatly reduce the current in the circuit.

10.5 Explain that potential difference (voltage) is the energy transferred per unit charge passed and hence that the volt is a joule per coulomb

1. It tells you how much energy is transferred per unit charge passing through the component.
2. 5 J of energy is transferred for every coulomb of charge passing through the component.
3. Potential difference = energy transferred ÷ charge moved.
4. 1 V = 1 J/C.
5. $E = Q \times V = 2 \times 6 = 12$ J.
6. $V = E \div Q = 40 \div 8 = 5$ V.

10.6 Recall and use the equation: energy transferred (joule, J) = charge moved (coulomb, C) × potential difference (volt, V) $E = Q \times V$

1. $E = Q \times V$.
2. $E = 4 \times 12 = 48$ J.
3. $Q = 60 \div 15 = 4$ C.
4. $V = 100 \div 20 = 5$ V.
5. $E = 250 \times 9 = 2250$ J.
6. $V = 720 \div 120 = 6$ V.

10.7 Recall that an ammeter is connected in series with a component to measure the current, in amp, in the component

1. Connect it in series with the component.
2. The same current must flow through the ammeter and the component.
3. Electric current.
4. Ampere (A).
5. Place the ammeter in series with the resistor.

6. An ammeter has very low resistance, so connecting it in parallel could produce a very large current and damage the circuit.

10.8 Explain that an electric current as the rate of flow of charge and the current in metals is a flow of electrons

1. Electric current is the rate of flow of charge.
2. It means the amount of charge passing a point per unit time.
3. Electrons.
4. Electrons move from the negative terminal towards the positive terminal.
5. The current increases.
6. 3 C of charge flows through the wire every second.

10.9 Recall and use the equation: charge (coulomb, C) = current (ampere, A) × time (second, s) $Q = I \times t$

1. $Q = I \times t$.
2. $Q = 3 \times 20 = 60$ C.
3. $I = 120 \div 30 = 4$ A.
4. $t = 500 \div 5 = 100$ s.
5. 4 minutes = 240 s; $Q = 0.5 \times 240 = 120$ C.
6. 2 minutes = 120 s; $I = 1800 \div 120 = 15$ A.

10.10 Describe that when a closed circuit includes a source of potential difference there will be a current in the circuit

1. A closed conducting path and a source of potential difference.
2. A complete conducting path with no breaks.
3. It provides the potential difference that drives charge around the circuit.
4. There is no complete conducting path for charge to flow around.
5. The current stops.
6. The broken wire makes the circuit open, so there is no complete path for charge to flow.

10.11 Recall that current is conserved at a junction in a circuit

1. The total current entering a junction equals the total current leaving it.
2. Current entering = total current leaving.
3. $5 - 2 = 3$ A.
4. $1.5 + 2.5 = 4$ A.
5. $2 + 3 + 4 = 9$ A.
6. Charge cannot be created or destroyed at the junction, so the rate of charge flow is conserved.

10.12 Explain how changing the resistance in a circuit changes the current and how this can be achieved using a variable resistor

1. The current decreases.
2. The current increases.
3. Adjust its setting to increase or decrease the resistance.
4. Increasing resistance decreases current and makes the lamp dimmer; decreasing resistance increases current and makes the lamp brighter.
5. The current decreases.
6. It allows the resistance, and therefore the current, to be varied systematically during the investigation.

10.13 Recall and use the equation: potential difference (volt, V) = current (ampere, A) × resistance (ohm, Ω) V = I × R

1. $V = I \times R$.
2. $V = 2 \times 6 = 12$ V.
3. $I = 20 \div 10 = 2$ A.
4. $R = 12 \div 3 = 4\ \Omega$.
5. $R = 9 \div 0.5 = 18\ \Omega$.
6. $R = 240 \div 4 = 60\ \Omega$.

10.14 Explain why, if two resistors are in series, the net resistance is increased, whereas with two in parallel the net resistance is decreased

1. The total resistance increases.
2. The current has to pass through both resistors, so their resistances add.
3. The net resistance decreases.
4. Parallel branches provide additional paths for current, increasing the total current for a given potential difference.
5. $R = 10 + 10 = 20\ \Omega$.
6. Less than 10 Ω.

10.15 Calculate the currents, potential differences and resistances in series circuits

1. $R = 4 + 6 = 10\ \Omega$.
2. $R = 4 + 2 = 6\ \Omega$; $I = 12 \div 6 = 2$ A.
3. $R = 3 + 5 = 8\ \Omega$; $V = 2 \times 8 = 16$ V.
4. Total resistance = $24 \div 3 = 8\ \Omega$; second resistance = $8 - 4 = 4\ \Omega$.
5. Current = $9 \div (2 + 7) = 1$ A; 2 Ω resistor: $V = 1 \times 2 = 2$ V; 7 Ω resistor: $V = 1 \times 7 = 7$ V.
6. Total resistance = $5 + 10 + 15 = 30\ \Omega$; current = $60 \div 30 = 2$ A. Potential differences: 5 Ω = 10 V; 10 Ω = 20 V; 15 Ω = 30 V.

10.16 Explain the design and construction of series circuits for testing and measuring

1. A series circuit allows the same current to flow through components and makes current measurements straightforward.
2. In series with the component being tested.
3. In parallel across the component.
4. Connect the variable resistor in series so its resistance can be adjusted.
5. The resistance and other relevant conditions should be kept constant when appropriate.
6. To prevent incorrect readings, short circuits, excessive currents or damage to components.

10.17 Core Practical: Construct electrical circuits to: a investigate the relationship between potential difference, current and resistance for a resistor and a filament lamp b test series and parallel circuits using resistors and filament lamps

1. Connect the power supply, resistor, ammeter and variable resistor in series, with a voltmeter connected in parallel across the resistor.
2. The ammeter is in series; the voltmeter is in parallel across the resistor.
3. Adjust the variable resistor or change the power supply to vary the potential difference.
4. The filament lamp becomes hotter and its resistance increases, so the current increases less rapidly than for a fixed resistor.
5. Construct one circuit with the components in a single series loop and another with the components arranged in separate parallel branches.
6. Measure current and potential difference at appropriate points; repeat measurements and calculate means to improve reliability.

10.18 Explain how current varies with potential difference for the following devices and how this relates to resistance a filament lamps b diodes c fixed resistors

1. The current is directly proportional to potential difference, so the resistance remains constant.
2. The filament heats up, causing its resistance to increase.
3. The current increases, but at a decreasing rate as the resistance increases.
4. The current is very small initially, then increases rapidly after the diode's threshold potential difference is reached.
5. The diode has very high resistance in the reverse direction, so very little current flows.
6. A straight-line graph through the origin indicates constant resistance; a curved graph indicates changing resistance, while a diode has negligible reverse current and a sharp forward increase.

10.19 Describe how the resistance of a light-dependent resistor (LDR) varies with light intensity

1. Its resistance decreases.
2. Its resistance increases.
3. Its resistance changes predictably with light intensity, allowing changes in light level to be detected.
4. The current increases.
5. Vary the light intensity, measure the potential difference and current, calculate R = V ÷ I, and record the results.
6. Automatic street lighting; its resistance changes with light level, allowing a circuit to switch lights on when it becomes dark.

10.20 Describe how the resistance of a thermistor varies with change of temperature (negative temperature coefficient thermistors only)

1. Its resistance decreases.
2. Its resistance increases.
3. Its resistance decreases as temperature increases.
4. The current increases.
5. Vary the temperature, measure potential difference and current, calculate R = V ÷ I, and record resistance against temperature.
6. Temperature sensors/thermostats; the resistance changes with temperature, allowing a circuit to detect and respond to temperature changes.

10.21 Explain how the design and use of circuits can be used to explore the variation of resistance in the following devices a filament lamps b diodes c thermistors d LDRs

1. Vary the current using a variable resistor, measure current and potential difference, and calculate resistance at different operating conditions.
2. Measure the potential difference across and current through the diode at different values, then use R = V ÷ I.
3. Vary the temperature, measure current and potential difference, and calculate resistance using R = V ÷ I.
4. Vary the light intensity, measure current and potential difference, and calculate resistance using R = V ÷ I.
5. Measure the potential difference across and current through the device, together with the relevant changing variable such as temperature or light intensity.
6. It can vary the current and potential difference safely and systematically, allowing the resistance to be determined under different conditions.

10.22 Recall that, when there is an electric current in a resistor, there is an energy transfer which heats the resistor

1. It heats up.

2. Electrical energy is transferred to thermal energy.
3. Electrical energy is transferred to the resistor's thermal energy store.
4. The heating effect increases.
5. The heating effect increases.
6. Electric kettles and electric heaters.

10.23 Explain that electrical energy is dissipated as thermal energy in the surroundings when an electrical current does work against electrical resistance

1. Some electrical energy is transferred to thermal energy.
2. Energy is transferred to less useful energy stores, mainly thermal energy in the surroundings.
3. Electrons transfer energy to the lattice as they move through the resistance.
4. Thermal energy.
5. Energy is conserved; it is transferred from one energy store to another.
6. Resistance transfers electrical energy into thermal energy, which may be unwanted and reduces the energy available for useful output.

10.24 Explain the energy transfer (in 10.22 above) as the result of collisions between electrons and the ions in the lattice

1. Electrons.
2. Positive ions in the metal lattice.
3. Energy is transferred from the electrons to the ions, increasing the ions' vibrations.
4. The increased vibrations of the ions correspond to an increase in thermal energy and temperature.
5. Collisions impede the movement of electrons and cause energy transfer from electrons to the lattice.
6. Electrons collide with ions in the lattice, transferring energy to them and increasing their vibrational motion, which heats the metal.

10.25 Explain ways of reducing unwanted energy transfer through low resistance wires

1. Low resistance causes less electrical energy to be transferred to thermal energy.
2. Greater resistance generally causes greater energy dissipation for a given current and time.
3. Less energy is wasted as thermal energy during transmission.
4. Increase the cross-sectional area, reduce the length, or use a material with lower resistivity.
5. A thicker wire has a lower resistance, so less energy is dissipated as heat.

6. Low resistance reduces heating losses, so more of the electrical energy reaches the intended destination.

10.26 Describe the advantages and disadvantages of the heating effect of an electric current

1. Electric kettles and electric heaters.
2. Electrical energy is transferred to thermal energy, heating the water.
3. Electrical energy is transferred to thermal energy, producing useful heat.
4. Energy is dissipated as unwanted thermal energy.
5. More input energy is wasted as heat, so less is available for useful transfer.
6. Advantage: useful heating in devices such as kettles. Disadvantage: unwanted heating in cables wastes energy.

10.27 Use the equation: energy transferred (joule, J) = current (ampere, A) × potential difference (volt, V) × time (second, s) $E = I \times V \times t$

1. $E = I \times V \times t$.
2. $E = 2 \times 12 \times 30 = 720$ J.
3. $E = 5 \times 230 \times 60 = 69{,}000$ J.
4. $I = 36{,}000 \div (12 \times 300) = 10$ A.
5. $t = 24{,}000 \div (10 \times 12) = 200$ s.
6. 5 minutes = 300 s; $E = 230 \times 4 \times 300 = 276{,}000$ J.

10.28 Describe power as the energy transferred per second and recall that it is measured in watt

1. The rate at which an electrical device transfers energy.
2. Power is energy transferred per unit time.
3. Watt (W).
4. It transfers 60 J of energy per second.
5. The 500 W device.
6. $P = 1200 \div 10 = 120$ W.

10.29 Recall and use the equation: power (watt, W) = energy transferred (joule, J) ÷ time taken (second, s) $P = E \div t$

1. $P = E \div t$.
2. $P = 600 \div 20 = 30$ W.
3. $E = P \times t = 100 \times 30 = 3000$ J.
4. $t = E \div P = 6000 \div 200 = 30$ s.
5. 10 minutes = 600 s; $P = 360{,}000 \div 600 = 600$ W.
6. 5 minutes = 300 s; $E = 60 \times 300 = 18{,}000$ J.

10.30 Explain how the power transfer in any circuit device is related to the potential difference across it and the current in it

1. For a given current, increasing potential difference increases power transfer.
2. For a given potential difference, increasing current increases power transfer.
3. It increases.
4. It increases.
5. Power is proportional to current at constant potential difference, so increasing current increases the rate of energy transfer.
6. A high-power appliance transfers more energy per second.

10.31 Recall and use the equations: electrical power (watt, W) = current (ampere, A) × potential difference (volt, V) $P = I \times V$ electrical power (watt, W) = current squared (ampere2, A2) × resistance (ohm, Ω) $P = I^2 \times R$

1. $P = I \times V$.
2. $P = 4 \times 230 = 920$ W.
3. $P = I^2 \times R$.
4. $P = 3^2 \times 10 = 90$ W.
5. $I = \sqrt{(P \div R)} = \sqrt{(180 \div 20)} = 3$ A.
6. $I = P \div V = 920 \div 230 = 4$ A.

10.32 Describe how, in different domestic devices, energy is transferred from batteries and the a.c. mains to the energy of motors and heating devices

1. Electrical energy is transferred to kinetic energy.
2. Electrical energy is transferred to thermal energy.
3. The battery provides a potential difference that causes current to flow through the motor, transferring electrical energy to kinetic energy.
4. The a.c. mains supplies electrical energy, which is transferred to thermal energy in the kettle's heating element.
5. Electric fan.
6. Electric kettle.

10.33 Explain the difference between direct and alternating voltage

1. Direct voltage maintains the same polarity/direction.
2. Alternating voltage repeatedly changes polarity and direction.
3. Its polarity and direction repeatedly reverse.
4. Direct voltage has a constant polarity; alternating voltage repeatedly reverses polarity.
5. Direct voltage.
6. Alternating voltage.

10.34 Describe direct current (d.c.) as movement of charge in one direction only and recall that cells and batteries supply direct current (d.c.)

1. Current in which charge moves in one direction only.
2. In one direction only.
3. Direct current (d.c.).
4. Its terminals maintain a fixed polarity, causing charge to move in one direction.
5. It remains in the same direction.
6. Torch and battery-powered radio.

10.35 Describe that in alternating current (a.c.) the movement of charge changes direction

1. Current in which the direction of charge movement repeatedly changes.
2. It repeatedly reverses direction.
3. D.c. flows in one direction; a.c. repeatedly changes direction.
4. No. Its direction repeatedly changes.
5. The direction of charge movement changes repeatedly.
6. It repeatedly reverses direction.

10.36 Recall that in the UK the domestic supply is a.c., at a frequency of 50 Hz and a voltage of about 230 V

1. A.c.
2. 50 Hz.
3. About 230 V.
4. The direction of the current changes 50 times per second.
5. About 230 V a.c.
6. A.c., 50 Hz, approximately 230 V.

10.37 Explain the difference in function between the live and the neutral mains input wires

1. The live wire carries the alternating potential difference to the appliance.
2. The neutral wire provides the return path for current to the supply.
3. The live wire.
4. The potential difference between them drives current through the appliance.
5. The live wire can remain at a high potential relative to earth.
6. The live supplies the alternating potential difference/current path to the appliance; the neutral provides the return path to the supply.

10.38 Explain the function of an earth wire and of fuses or circuit breakers in ensuring safety

1. It provides a low-resistance path to earth if a fault makes the metal case live.

2. A large fault current flows through the earth wire, causing the fuse to melt or circuit breaker to trip.
3. It breaks the circuit if the current becomes too large.
4. It automatically switches off the circuit when the current exceeds a safe value.
5. The fuse melts and breaks the circuit.
6. A fault causes current to flow through the earth wire; the large current causes the fuse to melt or circuit breaker to trip, disconnecting the supply and reducing the risk of shock.

10.39 Explain why switches and fuses should be connected in the live wire of a domestic circuit

1. Opening the switch disconnects the appliance from the live supply.
2. If excessive current flows, the fuse disconnects the appliance from the live supply.
3. The appliance could remain connected to the live potential even when switched off.
4. Internal parts could still be at a dangerous potential relative to earth.
5. An excessive current melts the fuse and disconnects the live supply.
6. They ensure that switching off or a fuse operating disconnects the appliance from the dangerous live supply.

10.40 Recall the potential differences between the live, neutral and earth mains wires

1. About 230 V.
2. About 230 V.
3. Approximately 0 V.
4. The live wire.
5. Neutral and earth.
6. Live ≈ +230 V relative to earth; neutral ≈ 0 V relative to earth; earth ≈ 0 V relative to earth.

10.41 Explain the dangers of providing any connection between the live wire and earth

1. The live wire is at a high potential relative to earth, so a large current can flow through the connection.
2. A potentially dangerous current can flow through their body to earth.
3. The potential difference between live and earth can drive a large current.
4. The body can provide a conducting path between the live wire and earth.
5. The excessive current can cause the fuse to melt or circuit breaker to trip.

6. A person touching live while connected to earth provides a path for current through their body, which can cause a potentially fatal electric shock.

10.42 Describe, with examples, the relationship between the power ratings for domestic electrical appliances and the changes in stored energy when they are in use

1. The rate at which the appliance transfers energy.
2. A higher power rating means energy is transferred at a greater rate.
3. The 2 kW appliance.
4. Electrical energy is transferred from the supply into other energy stores, such as the thermal energy store of the heater.
5. Greater power means more energy is transferred in a given time.
6. 1000 W = 1000 J/s and 2000 W = 2000 J/s. In 5 minutes (300 s): 1000 W transfers 300,000 J; 2000 W transfers 600,000 J.

# Topic 12 – Magnetism and the motor effect

12.1 Recall that unlike magnetic poles attract and like magnetic poles repel

1. They attract.
2. They repel.
3. Unlike poles: north and south.
4. Like poles: north-north or south-south.
5. They attract.
6. They repel.

12.2 Describe the uses of permanent and temporary magnetic materials including cobalt, steel, iron and nickel

1. A material that remains magnetised after the magnetising field is removed.
2. A material that becomes magnetised when exposed to a magnetic field but loses most of its magnetism when the field is removed.
3. Steel is difficult to demagnetise, so it retains its magnetism.
4. Iron is easily magnetised and demagnetised.
5. A compass needle made from steel.
6. An electromagnet core made from iron.

12.3 Explain the difference between permanent and induced magnets

1. A magnet that retains its magnetism without an external magnetic field.

2. A magnet produced when a magnetic material is placed in a magnetic field.
3. An induced magnet only remains magnetised while near the magnetising field; a permanent magnet retains its magnetism.
4. It loses most or all of its magnetism.
5. Iron is easily magnetised and demagnetised.
6. An iron core in an electromagnet.

12.4 Describe the shape and direction of the magnetic field around bar magnets and for a uniform field, and relate the strength of the field to the concentration of lines

1. A region where a magnetic material or moving charge experiences a magnetic force.
2. From north to south.
3. Curved lines from the north pole to the south pole outside the magnet.
4. Parallel, equally spaced field lines.
5. Closer lines indicate a stronger magnetic field.
6. The field is strongest near the poles, where the field lines are most concentrated.

12.5 Describe the use of plotting compasses to show the shape and direction of the field of a magnet and the Earth's magnetic field

1. Place a plotting compass at different positions around the magnet and mark the direction indicated by the needle.
2. The north-seeking end points in the direction of the magnetic field.
3. Join the marked directions to form magnetic field lines.
4. Place compasses at different locations and record the direction in which their north-seeking ends point.
5. To map the field at different locations and determine its shape and direction.
6. Mark the compass directions at several points and join them to form field lines with arrows showing their direction.

12.6 Explain how the behaviour of a magnetic compass is related to evidence that the core of the Earth must be magnetic

1. It aligns with the Earth's magnetic field.
2. A compass needle consistently aligns in a particular direction, showing that a magnetic field exists around Earth.
3. A magnetic core can produce the magnetic field needed to explain the compass behaviour.
4. It aligns with the Earth's magnetic field.
5. The needle aligns with the local direction of the Earth's magnetic field.

6. The compass aligns with the Earth's magnetic field, providing evidence for a magnetic source within Earth, such as its magnetic core.

12.7 Describe how to show that a current can create a magnetic effect and relate the shape and direction of the magnetic field around a long straight conductor to the direction of the current

1. Pass a current through a straight wire and place plotting compasses around it; the compass needles deflect.
2. Concentric circles centred on the conductor.
3. The direction follows the right-hand grip rule; reversing the current reverses the field direction.
4. Place plotting compasses at different positions around the current-carrying wire and observe their directions.
5. The magnetic field direction reverses.
6. Pass current through the wire and use plotting compasses to map the circular field around it.

12.8 Recall that the strength of the field depends on the size of the current and the distance from the long straight conductor

1. It increases.
2. It decreases.
3. Closest to the conductor.
4. It increases.
5. The field becomes weaker.
6. The size of the current and the distance from the conductor.

12.9 Explain how inside a solenoid (an example of an electromagnet) the fields from individual coils a add together to form a very strong almost uniform field along the centre of the solenoid b cancel to give a weaker field outside the solenoid

1. A coil of wire consisting of many turns, usually carrying current.
2. They add together.
3. The magnetic fields from the individual coils reinforce each other along the centre.
4. They largely cancel.
5. The fields from different coils oppose each other outside the solenoid.
6. Inside, the fields reinforce to produce a strong, almost uniform field; outside, they largely cancel to produce a much weaker field.

12.10 Recall that a current carrying conductor placed near a magnet experiences a force and that an equal and opposite force acts on the magnet

1. It experiences a force.
2. The interaction between the magnetic field of the conductor and the magnetic field of the magnet.
3. An equal and opposite force.
4. They are equal in magnitude and opposite in direction.
5. The direction of the force reverses.
6. The direction of the force reverses.

12.11 Explain that magnetic forces are due to interactions between magnetic fields

1. The interaction between the magnetic field around the conductor and the external magnetic field.
2. The magnetic field of the current-carrying conductor and the magnetic field of the permanent magnet.
3. The two fields interact and produce a resultant force.
4. The interaction produces regions where the magnetic fields reinforce or oppose each other, resulting in a force.
5. The direction of the force reverses.
6. The conductor's magnetic field interacts with the magnet's field, producing a force on the conductor.

12.12 Recall and use Fleming's left-hand rule to represent the relative directions of the force, the current and the magnetic field for cases where they are mutually perpendicular

1. It shows the relative directions of force, conventional current and magnetic field.
2. The first finger represents the magnetic field.
3. The second finger represents conventional current.
4. The thumb represents the force/motion.
5. They must be mutually perpendicular.
6. Position the first finger in the magnetic field direction and the second finger in the conventional current direction; the thumb then gives the force direction.

12.13 Use the equation: force on a conductor at right angles to a magnetic field carrying a current (newton, N) = magnetic flux density (tesla, T or newton per ampere metre, N/A m) × current (ampere, A) × length (metre, m) $F = B \times I \times l$

1. $F = B \times I \times l$.
2. $F = 0.20 \times 4 \times 0.50 = 0.40$ N.
3. $B = 1.2 \div (3 \times 2) = 0.20$ T.
4. $I = 0.80 \div (0.50 \times 0.40) = 4$ A.
5. $l = 2.4 \div (0.60 \times 4) = 1.0$ m.
6. $F = 0.40 \times 6 \times 0.25 = 0.60$ N.

# Topic 13 – Electromagnetic induction

13.2 Recall the factors that affect the size and direction of an induced potential difference, and describe how the magnetic field produced opposes the original change

1. A potential difference produced by a change in magnetic flux through a conductor or coil.
2. It increases.
3. A stronger magnetic field increases the induced potential difference.
4. Increasing the number of turns increases the induced potential difference.
5. The direction of the change in magnetic field/flux and the direction of motion determine its direction.
6. This is Lenz's law: the induced effect opposes the change that produced it.

13.5 Explain how an alternating current in one circuit can induce a current in another circuit in a transformer

1. It produces a changing magnetic field around the primary coil.
2. The alternating current continually changes magnitude and direction, producing a changing magnetic field.
3. The changing magnetic field passes through the secondary coil and induces a potential difference across it.
4. A d.c. current produces a steady magnetic field after the initial change, so it does not continuously induce a potential difference.
5. An induced current flows through the secondary circuit.
6. A.c. in the primary creates a changing magnetic field in the core, which induces a potential difference and potentially a current in the secondary coil.

13.6 Recall that a transformer can change the size of an alternating voltage

1. To increase or decrease the size of an alternating voltage.
2. Alternating voltage.
3. It increases the voltage.
4. It decreases the voltage.
5. The relative number of turns on the primary and secondary coils.
6. A transformer requires a changing magnetic field to induce a voltage in the secondary coil, which d.c. does not continuously provide.

13.8 Explain why, in the national grid, electrical energy is transferred at high voltages from power stations, and then transferred at lower voltages in each locality for domestic uses as it improves the efficiency by reducing heat loss in transmission lines

1. To reduce the current for a given power.
2. The current decreases.
3. Less current causes less heating of the transmission lines.
4. Some electrical energy is transferred to thermal energy in the lines, reducing the energy delivered usefully.
5. Domestic appliances require a lower, safer voltage.
6. For a given power, increasing voltage reduces current; lower current causes less heating in the wires, reducing energy loss.

13.9 Explain where and why step-up and step-down transformers are used in the transmission of electricity in the national grid

1. At power stations before electricity enters the transmission network.
2. To increase the transmission voltage and reduce the current, reducing heating losses.
3. Voltage increases and current decreases.
4. Near local substations before electricity is supplied to consumers.
5. To reduce the voltage to a suitable level for domestic use.
6. Power station → step-up transformer → high-voltage transmission → step-down transformer → lower-voltage local distribution → domestic consumer; transformers change voltage to improve transmission efficiency and provide a suitable domestic voltage.

13.10 Use the power equation (for transformers with 100% efficiency): potential difference across primary coil (volt, V) × current in primary coil (ampere, A) = potential difference across secondary coil (volt, V) × current in secondary coil (ampere, A) $V_p \times I_p = V_s \times I_s$

1. $V_p \times I_p = V_s \times I_s$.
2. $I_s = (12{,}000 \times 5) \div 240 = 250$ A.
3. $V_s = (230 \times 2) \div 0.5 = 920$ V.
4. $I_p = (230 \times 20) \div 11{,}000 \approx 0.42$ A.
5. $I_s = (400 \times 3) \div 120 = 10$ A.
6. $I_s = 9200 \div 230 = 40$ A.

# Topic 14 – Particle model

14.1 Use a simple kinetic theory model to explain the different states of matter (solids, liquids and gases) in terms of the movement and arrangement of particles

1. Particles are closely packed in a regular arrangement.
2. They vibrate about fixed positions.
3. Particles are close together but arranged irregularly.

4. They move around each other.
5. Gas particles are widely spaced and move rapidly in random directions.
6. Solids have closely packed particles with limited vibration; liquids have close particles that can move past one another; gases have widely spaced particles moving freely and rapidly.

14.2 Recall and use the equation: density (kilogram per cubic metre, kg/m3) = mass (kilogram, kg) ÷ volume (cubic metre, m3) $\rho = m \div V$

1. $\rho = m \div V$.
2. $\rho = 600 \div 3 = 200$ kg/m³.
3. $m = \rho V = 800 \times 0.5 = 400$ kg.
4. $V = m \div \rho = 120 \div 600 = 0.20$ m³.
5. $\rho = 2.4 \div 0.003 = 800$ kg/m³.
6. $V = 5 \div 1000 = 0.005$ m³.

14.3 Core Practical: Investigate the densities of solid and liquids

1. Measure its mass and calculate its volume from its dimensions, then use $\rho = m \div V$.
2. Measure the volume of water displaced when the irregular solid is fully submerged.
3. Use a balance to measure its mass.
4. Measure a known volume of liquid and its mass, then calculate $\rho = m \div V$.
5. Mass and volume.
6. Repeat measurements, use appropriate measuring equipment, read scales at eye level, avoid parallax, and ensure the object is fully submerged for displacement measurements.

14.4 Explain the differences in density between the different states of matter in terms of the arrangements of the atoms or molecules

1. The particles in a solid are much more closely packed than in a gas.
2. Smaller spacing means more mass is contained in a given volume, increasing density.
3. Solid particles are closely packed; gas particles are widely separated.
4. The particles become much further apart, increasing the volume for the same mass.
5. Density depends on how closely packed the particles are within a given volume.
6. Gas particles are widely separated, so a given mass occupies a much larger volume.

14.5 Describe that when substances melt, freeze, evaporate, boil, condense or sublimate mass is conserved and that these physical changes differ from some chemical changes because the material recovers its original properties if the change is reversed

1. The mass remains constant.
2. The mass remains constant, provided no material escapes from the system.
3. The mass remains constant in a closed system.
4. No new substance is formed and the change can be reversed.
5. A physical change can usually be reversed and the original properties recovered; a chemical change forms new substances.
6. The particles themselves are not created or destroyed; only their arrangement or energy changes.

14.6 Explain how heating a system will change the energy stored within the system and raise its temperature or produce changes of state

1. The energy stored in the system increases.
2. The particles gain energy, increasing their average kinetic energy and therefore temperature.
3. Energy is transferred into the system and used to change the arrangement/bonds between particles.
4. The supplied energy is used to change the arrangement or separation of particles rather than increasing their average kinetic energy.
5. Their energy increases.
6. Heating can increase particle kinetic energy and temperature; during a change of state, energy changes the particle arrangement/separation instead.

14.7 Define the terms specific heat capacity and specific latent heat and explain the differences between them

1. The energy required to raise the temperature of 1 kg of a substance by 1 °C.
2. The energy required to change the state of 1 kg of a substance without changing its temperature.
3. Specific heat capacity concerns temperature change; specific latent heat concerns change of state at constant temperature.
4. It requires a relatively large amount of energy.
5. It gives the energy required to change the state of 1 kg of the substance.
6. The energy is used to change the arrangement/separation of particles rather than increase their average kinetic energy.

14.8 Use the equation: change in thermal energy (joule, J) = mass (kilogram, kg) × specific heat capacity (joule per kilogram degree Celsius, J/kg °C) × change in temperature (degree Celsius, °C) $\Delta Q = m \times c \times \Delta\theta$

1. $\Delta Q = m \times c \times \Delta\theta$.
2. $\Delta Q = 2 \times 500 \times 20 = 20{,}000$ J.
3. $\Delta\theta = 10{,}000 \div (2 \times 500) = 10$ °C.
4. $m = 15{,}000 \div (750 \times 10) = 2$ kg.
5. $\Delta\theta = 70 - 20 = 50$ °C; $\Delta Q = 3 \times 400 \times 50 = 60{,}000$ J.
6. $c = 24{,}000 \div (2 \times 30) = 400$ J/kg °C.

14.9 Use the equation: thermal energy for a change of state (joule, J) = mass (kilogram, kg) × specific latent heat (joule per kilogram, J/kg) $Q = m \times L$

1. $Q = m \times L$.
2. $Q = 2 \times 200{,}000 = 400{,}000$ J.
3. $m = 600{,}000 \div 300{,}000 = 2$ kg.
4. $L = 900{,}000 \div 3 = 300{,}000$ J/kg.
5. $Q = 0.5 \times 2{,}000{,}000 = 1{,}000{,}000$ J.
6. 1.2 MJ = 1,200,000 J; $L = 1{,}200{,}000 \div 4 = 300{,}000$ J/kg.

14.10 Explain ways of reducing unwanted energy transfer through thermal insulation

1. Material or methods that reduce the rate of thermal energy transfer.
2. They reduce conduction, convection and/or radiation, decreasing the rate of thermal energy transfer.
3. Trapped air is a poor conductor and reduces convection when it is unable to circulate freely.
4. Use cavity wall insulation to trap air and reduce thermal conduction and convection.
5. Loft insulation traps air and reduces conduction and convection through the roof.
6. Cavity wall insulation reduces conduction/convection; loft insulation reduces thermal energy transfer through the roof.

14.11 Core Practical: Investigate the properties of water by determining the specific heat capacity of water and obtaining a temperature-time graph for melting ice

1. Measure the mass of water, supply a known electrical energy using a heater, measure the temperature change, and calculate $c = Q \div (m \times \Delta\theta)$.
2. Mass of water, electrical power, heating time and temperature change.
3. Specific heat capacity depends on mass, so an inaccurate mass gives an inaccurate result.
4. $Q = P \times t$.
5. It shows the temperature remaining approximately constant while the ice melts.

6. Energy is being used for the change of state rather than increasing the temperature.

14.12 Explain the pressure of a gas in terms of the motion of its particles

1. Gas particles collide with the container walls.
2. They exert forces on the walls and change their momentum.
3. Repeated collisions transfer momentum to the walls, producing a force.
4. More frequent collisions produce a greater force and therefore greater pressure.
5. Greater force on the walls produces greater pressure.
6. Gas particles move randomly and collide with the container walls; these collisions exert forces on the walls, producing pressure.

14.13 Explain the effect of changing the temperature of a gas on the velocity of its particles and hence on the pressure produced by a fixed mass of gas at constant volume (qualitative only)

1. Their average velocity increases.
2. Faster particles travel to the walls more quickly, increasing collision frequency.
3. Faster particles have greater momentum, producing greater changes in momentum during collisions.
4. The pressure increases.
5. The pressure decreases.
6. Increasing temperature increases particle velocity, causing more frequent and harder collisions with the walls, so the pressure increases at constant volume.

14.14 Describe the term absolute zero, −273 °C, in terms of the lack of movement of particles

1. The lowest possible temperature, at which particles have no thermal motion in the idealised model.
2. −273 °C.
3. It represents the point at which particle thermal motion is considered to cease.
4. Their movement decreases towards zero.
5. Temperatures below it would imply less than zero thermal energy/particle motion in the classical model.
6. −273 °C is absolute zero, where particles have no thermal motion in the idealised model.

14.15 Convert between the kelvin and Celsius scales

1. Temperature in kelvin = temperature in °C + 273; temperature in °C = temperature in kelvin − 273.
2. 27 + 273 = 300 K.
3. 100 + 273 = 373 K.
4. 300 − 273 = 27 °C.
5. 250 − 273 = −23 °C.
6. −73 + 273 = 200 K.

# Topic 15 – Forces and matter

15.1 Explain, using springs and other elastic objects, that stretching, bending or compressing an object requires more than one force

1. A single force would mainly move the spring rather than stretch it; opposing forces produce deformation.
2. Apply equal and opposite forces to its ends, pulling them apart.
3. Apply opposing forces directed towards each other at its ends.
4. Apply opposing forces at different positions/directions to produce a turning/deforming effect.
5. It returns towards its original shape if the distortion was elastic.
6. Pulling both ends of a spring in opposite directions stretches it; pushing both ends towards each other compresses it.

15.2 Describe the difference between elastic and inelastic distortion

1. Distortion where the object returns to its original shape when the force is removed.
2. Distortion where the object does not return fully to its original shape when the force is removed.
3. It returns to its original shape.
4. It remains permanently deformed to some extent.
5. Remove the applied force and observe whether the object returns to its original shape.
6. A spring can undergo elastic distortion: when the force is removed within its elastic limit, it returns to its original length.

15.3 Recall and use the equation for linear elastic distortion including calculating the spring constant: force exerted on a spring (newton, N) = spring constant (newton per metre, N/m) × extension (metre, m) $F = k \times x$

1. $F = k \times x$.
2. $F = 200 \times 0.05 = 10$ N.
3. $k = 12 \div 0.03 = 400$ N/m.
4. $x = 20 \div 400 = 0.05$ m.

5. $x = 6 \div 150 = 0.04$ m.
6. $k = 16 \div 0.08 = 200$ N/m.

15.4 Use the equation to calculate the work done in stretching a spring: energy transferred in stretching (joule, J) = 0.5 × spring constant (newton per metre, N/m) × (extension (metre, m))2 $E = 0.5 \times k \times x^2$

1. $E = 0.5 \times k \times x^2$.
2. $E = 0.5 \times 200 \times 0.10^2 = 1$ J.
3. $E = 0.5 \times 500 \times 0.20^2 = 10$ J.
4. $x = \sqrt{(2E \div k)} = \sqrt{(8 \div 800)} = 0.10$ m.
5. $k = 2E \div x^2 = 4 \div 0.01 = 400$ N/m.
6. $E = 0.5 \times 250 \times 0.12^2 = 1.8$ J.

15.5 Describe the difference between linear and non-linear relationships between force and extension

1. A relationship where force is directly proportional to extension.
2. A straight line through the origin.
3. A relationship where force is not directly proportional to extension.
4. It is curved rather than a straight line through the origin.
5. Plot force against extension; a straight line through the origin indicates a linear relationship.
6. It means that increasing the force by a given factor increases the extension by the same factor.

15.6 Core Practical: Investigate the extension and work done when applying forces to a spring

1. Hang the spring from a fixed support, measure its natural length, add known forces, and measure the new length after each addition.
2. The applied force and the spring's extension.
3. Add known masses gradually to the spring, allowing it to come to rest before measuring.
4. Extension = stretched length − natural length.
5. Plot force against extension; a straight line through the origin indicates linear behaviour.
6. Calculate the area under the force-extension graph; this represents the work done in stretching the spring.