Edexcel GCSE Triple Physics

Topic 1 – Key concepts of physics

1.1 Recall and use the SI unit for physical quantities, as listed in Appendix 3

1. The SI unit for length is the metre (m).
2. The SI unit for mass is the kilogram (kg).
3. The SI unit for time is the second (s).
4. The SI unit for electric current is the ampere (A).
5. The SI unit for temperature is the kelvin (K).
6. The SI unit for energy is the joule (J).

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. Giga (G) represents a multiplier of 10^9.
2. Mega (M) represents a multiplier of 10^6.
3. Kilo (k) represents a multiplier of 10^3.
4. Centi (c) represents a multiplier of 10^{-2}.
5. Milli (m) represents a multiplier of 10^{-3}.
6. Micro (μ) represents 10^{-6}, and nano (n) represents 10^{-9}.

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

1. There are 60 seconds in one minute.
2. There are 3600 seconds in one hour.
3. To convert hours into seconds, multiply the number of hours by 3600.
4. Time = 2.5 × 3600
   Time = 9000 s
5. Time = 3600 ÷ 3600
   Time = 1 hour
6. Length = 5 × 1000
   Length = 5000 m

1.4 Use significant figures and standard form where appropriate

1. Significant figures are the digits in a number that contribute to its precision, including all certain digits and the first uncertain digit.
2. 0.00450 has 3 significant figures: 4, 5 and 0.
3. 7.846 → 7.85 to three significant figures.
4. Standard form expresses a number as $a \times 10^n$, where $1 \le a < 10$ and n is an integer.
5. $450{,}000 = 4.5 \times 10^5$
6. $0.000032 = 3.2 \times 10^{-5}$

Topic 2 – Motion and forces

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

1. A scalar quantity is a physical quantity that has magnitude only, with no specific direction.
2. Magnitude describes the size or numerical value of a physical quantity.
3. No. A scalar quantity does not have a specific direction.
4. Yes. Distance is a scalar quantity because it has magnitude but no direction.
5. Yes. Speed is a scalar quantity because it has magnitude but no direction.
6. The defining feature of a scalar quantity is that it has magnitude but no direction.

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

1. A vector quantity is a physical quantity that has both magnitude and a specific direction.
2. A vector quantity has magnitude and direction.
3. Yes. A vector quantity has a specific direction as well as magnitude.
4. Yes. Velocity is a vector quantity.
5. Yes. Force is a vector quantity.
6. The defining feature of a vector quantity is that it has both magnitude and direction.

2.3 Explain the difference between vector and scalar quantities

1. A scalar has magnitude only, whereas a vector has magnitude and direction.
2. A scalar quantity has magnitude but no specific direction.
3. A vector quantity has both magnitude and direction.

4. Speed is scalar because it describes how fast an object moves without specifying a direction.
5. Velocity is vector because it describes speed in a stated direction.
6. A vector quantity requires directional information in addition to its magnitude.

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 is a vector quantity; distance is a scalar quantity.
2. Velocity is a vector quantity; speed is a scalar quantity.
3. Acceleration is a vector quantity.
4. Force, weight and momentum are vector quantities.
5. Mass is a scalar quantity.
6. Energy is a scalar quantity.

2.5 Recall that velocity is speed in a stated direction

1. Velocity is speed in a stated direction.
2. Velocity provides the direction of motion as well as the speed.
3. Velocity is a vector quantity because it has both magnitude and direction.
4. Speed gives magnitude only, whereas velocity gives magnitude and direction.
5. Yes. Two objects can have the same speed but different velocities if they are moving in different directions.
6. The object's velocity changes because its direction has changed, even though its speed remains constant.

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. Average speed = distance ÷ time
   speed = distance / time
2. The SI unit for speed is the metre per second (m/s).
3. Distance = average speed × time
   $d = v \times t$
4. speed = distance ÷ time
   speed = 150 m ÷ 10 s
   speed = 15 m/s

5. distance = speed × time
   distance = 20 m/s × 5 s
   distance = 100 m
6. The speed equation can be rearranged to:
   time = distance ÷ speed

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

1. The gradient of a distance/time graph represents the speed.
2. speed = change in distance ÷ change in time.
3. A horizontal line represents an object that is stationary, because its distance is not changing with time.
4. A straight line with a constant positive gradient represents constant speed.
5. A steeper gradient indicates a greater speed.
6. A changing gradient indicates that the object's speed is changing.

2.8 Recall and use the equation: acceleration (metre per second squared, m/s^2) = change in velocity (metre per second, m/s) ÷ time taken (second, s) $(v - u) \div t = a$

1. $a = (v - u) \div t$
2. The SI unit for acceleration is metres per second squared (m/s^2).
3. u represents the initial velocity.
4. v represents the final velocity.
5. a = change in velocity ÷ time
   a = 20 m/s ÷ 5 s
   $a = 4\ m/s^2$
6. Negative acceleration indicates that the object's velocity is decreasing in the chosen positive direction.

2.9 Use the equation: $(\text{final velocity})^2 - (\text{initial velocity})^2 = 2 \times$ acceleration × distance, $v^2 - u^2 = 2 \times a \times x$

1. $v^2 - u^2 = 2ax$
2. v represents the final velocity.
3. u represents the initial velocity.
4. a represents the acceleration.
5. x represents the distance travelled.
6. The equation can be used to calculate any one of the four quantities when the other three are known: final velocity, initial velocity, acceleration or distance.

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. The gradient of a velocity/time graph represents acceleration.
2. The object with the steeper gradient has the greater magnitude of acceleration.
3. acceleration = change in velocity ÷ change in time.
4. The area between the graph line and the time axis represents the distance travelled when velocity is positive.
5. The distance travelled can be determined by calculating the area under the velocity/time graph.
6. A horizontal line represents constant velocity, so the acceleration is zero.

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 is used to measure the time taken for an object to pass through a fixed point or for a card of known length to interrupt the light beam.
2. The speed can be determined by measuring the time taken for a known length of an object to pass through the light gate and using speed = distance ÷ time.
3. The measurements needed are the length of the object or card passing through the gate and the time taken.
4. A light gate measures time electronically, reducing human reaction-time errors associated with starting and stopping a stopwatch.
5. Another method is to use a stopwatch, measuring the distance travelled and the time taken.
6. speed = length of object ÷ time taken.
   For example, if a 0.20 m card takes 0.10 s to pass through the gate:
   speed = 0.20 m ÷ 0.10 s
   speed = 2.0 m/s

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

1. A typical walking speed is about 1.5 m/s.
2. A typical running speed is about 3 m/s.
3. A typical cycling speed is about 6 m/s.

4. The approximate speed of sound in air is 340 m/s.
5. A typical wind speed is about 10 m/s, although wind speeds vary considerably.
6. Typical transportation systems generally travel faster than walking and running, with cars commonly travelling at around 13–30 m/s depending on the road and speed limit.

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. The acceleration due to gravity near Earth's surface is $g = 10\ m/s^2$.
2. The SI unit for gravitational acceleration is m/s^2.
3. An acceleration of $10\ m/s^2$ means that the velocity of a freely falling object increases by 10 m/s every second, neglecting air resistance.
4. Gravitational acceleration acts downwards, towards the centre of the Earth.
5. An everyday acceleration can be estimated by measuring the change in velocity and dividing it by the time taken:
   a = change in velocity ÷ time
6. Gravitational acceleration of $10\ m/s^2$ is much larger than many ordinary accelerations, such as the acceleration of a person walking or cycling.

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. Newton's first law states that an object remains at rest or moves with constant velocity unless acted upon by a resultant external force.
2. When the resultant force is zero, an object remains at rest or continues moving at constant velocity.
3. Its velocity remains constant, including both its speed and direction.
4. When the resultant force is not zero, the object's velocity changes.
5. Yes. An object can be moving at constant velocity when the resultant force is zero.
6. A non-zero resultant force can cause a change in speed, direction, or both.

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 × a

1. $F = m \times a$
2. The SI unit of force is the newton (N).

3. If force increases while mass remains constant, acceleration increases in direct proportion to the force.
4. If mass increases while force remains constant, acceleration decreases.
5. $F = m \times a$
   $F = 5\ kg \times 4\ m/s^2$
   $F = 20\ N$
6. $a = F \div m$
   $a = 20\ N \div 4\ kg$
   $a = 5\ m/s^2$

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. Weight is the force acting on an object due to gravity.
2. $W = m \times g$
3. The SI unit for weight is the newton (N).
4. The SI unit for gravitational field strength is newtons per kilogram (N/kg).
5. $W = m \times g$
   $W = 10\ kg \times 10\ N/kg$
   $W = 100\ N$
6. If mass doubles in the same gravitational field, weight also doubles.

2.17 Describe how weight is measured

1. Weight can be measured using a spring balance (newton meter).
2. A spring balance measures force, including the force due to gravity acting on an object.
3. Weight is normally measured in newtons (N).
4. The object's weight stretches the spring, and the scale reading gives the force in newtons.
5. A spring balance is suitable because the extension of its spring is related to the force applied.
6. Attach the object to a spring balance, allow it to hang at rest, and read the force shown on the scale in newtons.

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

1. For a fixed mass, weight is directly proportional to gravitational field strength.
2. If gravitational field strength increases, weight increases.
3. If gravitational field strength decreases, weight decreases.

4. An object weighs more on a planet with greater gravitational field strength and less on one with weaker gravitational field strength.
5. Mass remains constant because mass is the amount of matter in an object, whereas weight depends on the gravitational field.
6. $W = m \times g$

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

1. The practical investigates the relationship $F = m \times a$, showing how acceleration depends on force and mass.
2. Suitable apparatus includes a trolley, masses, pulley, string, light gates or motion sensor, and a force-producing mass or force sensor.
3. Adding masses to the trolley changes the mass of the trolley system.
4. Measurements of velocity and time, or equivalent motion data from light gates or a motion sensor, are needed to determine acceleration.
5. When investigating the effect of force on acceleration, the total mass of the system should be kept constant.
6. When mass is kept constant, force and acceleration are directly proportional: increasing the force increases the acceleration by the same factor.

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

1. An object has changing velocity because its direction of motion continuously changes.
2. The direction component of velocity changes.
3. No. Velocity is not constant because its direction changes.
4. Velocity includes direction, whereas speed only describes magnitude.
5. The direction of velocity changes continuously as the object moves around the circle.
6. Circular motion is accelerated motion because acceleration is a change in velocity, and the velocity changes even when speed is 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. Centripetal force is the resultant force directed towards the centre of a circular path.
2. Centripetal force acts towards the centre of the circle.

3. A resultant force is required because the object's velocity is continually changing direction.
4. Centripetal force continually changes the direction of the object's velocity.
5. The object would move off in a straight line tangential to the circle at the point where the force disappeared.
6. It is directed towards the centre because this force provides the inward acceleration needed to continuously change the direction of motion.

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. Inertial mass is a measure of how difficult it is to change an object's velocity.
2. It measures an object's resistance to acceleration.
3. Greater inertial mass makes it more difficult to change the object's velocity.
4. Inertial mass is defined as the ratio of force to acceleration.
5. $m = F \div a$
6. Apply a known force to the object, measure its acceleration, and calculate: $m = F \div a$

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. Newton's third law states that when two objects interact, they exert equal and opposite forces on each other.
2. The forces in a third-law pair are equal in magnitude, opposite in direction, act on different objects, and are the same type of force.
3. In equilibrium, forces acting on an object can balance to give a zero resultant force, while the object's interaction forces on other objects are still equal and opposite.
4. During a collision, each object exerts an equal and opposite force on the other.
5. In an isolated collision, the total momentum before the collision equals the total momentum after the collision.
6. The equal and opposite interaction forces produce equal and opposite changes in momentum, so the total momentum of an isolated system is conserved.

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) $p = m \times v$

1. Momentum is the product of an object's mass and velocity.
2. $p = m \times v$
3. The SI unit for momentum is kilogram metre per second (kg m/s).
4. If mass doubles while velocity remains constant, momentum doubles.
5. If velocity doubles while mass remains constant, momentum doubles.
6. $p = m \times v$
   $p = 5$ kg × 4 m/s
   $p = 20$ kg m/s

2.25 Describe examples of momentum in collisions

1. During a collision, objects can transfer momentum between each other, while total momentum is conserved in an isolated system.
2. Conservation of momentum means that the total momentum before a collision equals the total momentum after the collision, provided no external resultant force acts.
3. Momentum can be transferred through the forces the objects exert on each other during the collision.
4. In an isolated collision, total momentum remains constant before and after the collision.
5. For example, when a moving trolley collides with a stationary trolley, the first trolley transfers momentum to the second, so the combined total momentum remains the same.
6. Momentum is important in vehicle collisions because it helps determine how vehicles' velocities change and the forces involved during the collision.

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

1. Newton's second law can be expressed as force = rate of change of momentum.
2. $F = (mv - mu) \div t$
3. $mv - mu$ represents the change in momentum.
4. For a fixed change in momentum, increasing the time taken causes the force to decrease.
5. F = change in momentum ÷ time
   F = 60 kg m/s ÷ 3 s
   F = 20 N
6. The SI unit of force is the newton (N).

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

1. Human reaction time is the time taken between a stimulus being received and the resulting response being made.
2. In a ruler-drop experiment, one person drops a ruler without warning and the other catches it; the distance the ruler falls is measured and converted to a reaction time.
3. The distance fallen by the ruler before it is caught is measured.
4. A computer-based test presents a stimulus and measures the time between the stimulus and the person's response, such as pressing a key.
5. Reaction time can be affected by tiredness, concentration, distractions, drugs, alcohol and individual differences.
6. A typical human reaction time is of the order of 0.1–0.3 s.

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. Stopping distance is the total distance travelled by a vehicle from the moment a hazard is identified until the vehicle stops.
2. Stopping distance consists of thinking distance and braking distance.
3. Thinking distance is the distance travelled during the driver's reaction time.
4. Braking distance is the distance travelled after the brakes are applied until the vehicle stops.
5. Stopping distance = thinking distance + braking distance
6. A vehicle continues travelling during reaction time because the driver has not yet responded by applying the brakes.

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. A greater vehicle mass generally increases the braking force required and the braking distance, if other conditions remain the same.
2. Increasing speed increases stopping distance; in particular, braking distance increases approximately with the square of speed when other conditions are constant.
3. A longer reaction time increases thinking distance and therefore increases stopping distance.
4. Worn or poorly functioning brakes can reduce braking effectiveness and increase braking distance.
5. Wet, icy or otherwise poor road conditions can reduce grip and increase braking distance.

6. Greater friction between the tyres and road generally increases the available braking force and reduces braking distance.

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

1. A driver's reaction time is the time between recognising a hazard and beginning the appropriate response.
2. Tiredness generally increases reaction time, making the driver slower to respond.
3. Distractions can increase reaction time by reducing the driver's attention to the road.
4. Drugs can alter alertness, concentration and coordination, potentially increasing reaction time.
5. An increased reaction time means the vehicle travels for longer before braking begins, increasing thinking distance.
6. Distractions can delay recognition of hazards and the driver's response, increasing the likelihood of a collision.

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

1. A large deceleration is a large decrease in velocity in a short period of time.
2. Large decelerations can cause serious injury because they produce large forces on vehicle occupants.
3. For a given mass, greater deceleration produces a greater force.
4. Newton's second law can be used:
   $F = m \times a$
   For example, for a 60 kg person decelerating at 10 m/s^2:
   $F = 60\ kg \times 10\ m/s^2$
   $F = 600\ N$
5. Safety features such as airbags and crumple zones increase the time over which passengers are brought to rest, reducing the force for a given change in momentum.
6. The quantities needed are the mass and acceleration (or deceleration). Alternatively, force can be calculated from change in momentum and time.

2.32P Estimate how the distance required for a road vehicle to stop in an emergency varies over a range of typical speeds

1. Total stopping distance consists of thinking distance + braking distance.
2. If reaction time is constant, thinking distance increases directly with speed.

3. Braking distance generally increases approximately with the square of speed.
4. Stopping distance increases significantly at higher speeds because braking distance increases approximately with speed squared.
5. Stopping-distance data can be used by comparing the measured or given distances at known speeds and estimating values between them or using the observed trend.
6. Factors include vehicle speed, driver reaction time, vehicle mass, brake condition, road condition and tyre-road friction.

2.33P Carry out calculations on work done to show the dependence of braking distance for a vehicle on initial velocity squared (work done to bring a vehicle to rest equals its initial kinetic energy)

1. A moving vehicle has kinetic energy because of its motion.
2. Kinetic energy depends on the square of initial velocity:
   $E_k = \frac{1}{2}mv^2$
3. If initial velocity is doubled:
   $E_k = \frac{1}{2}m(2v)^2$
   $E_k = \frac{1}{2}m \times 4v^2$
   $E_k = 4(\frac{1}{2}mv^2)$
   Therefore, kinetic energy quadruples.
4. The work done to bring a vehicle to rest is equal to its initial kinetic energy.
5. If the braking force is constant, work done is $W = F \times d$. Since the initial kinetic energy is proportional to v^2, the braking distance is also proportional to v^2.
6. A vehicle travelling at a higher initial velocity has more kinetic energy, so more work must be done by the brakes to bring it to rest, requiring a greater braking distance.

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) ΔGPE = m × g × Δh

1. $\Delta GPE = m \times g \times \Delta h$

2. Gravitational potential energy is measured in joules (J), mass in kilograms (kg), gravitational field strength in newtons per kilogram (N/kg), and height in metres (m).
3. $\Delta GPE = m \times g \times \Delta h$
   $\Delta GPE = 5\ kg \times 10\ N/kg \times 4\ m$
   $\Delta GPE = 200\ J$
4. $\Delta GPE = m \times g \times \Delta h$
   $600\ J = 20\ kg \times g \times 3\ m$
   $600 = 60g$
   $g = 600 \div 60$
   $g = 10\ N/kg$
5. $\Delta GPE = m \times g \times \Delta h$
   $1500\ J = m \times 10\ N/kg \times 5\ m$
   $1500 = 50m$
   $m = 1500 \div 50$
   $m = 30\ kg$
6. $\Delta GPE = m \times g \times \Delta h$
   $\Delta GPE = 2\ kg \times 10\ N/kg \times 8\ m$
   $\Delta GPE = 160\ J$

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 × m × v²

1. $KE = \frac{1}{2} \times m \times v^2$
2. The mass and speed of the object are needed.
3. $KE = \frac{1}{2} \times m \times v^2$
   $KE = \frac{1}{2} \times 4\ kg \times (5\ m/s)^2$
   $KE = 2 \times 25$
   $KE = 50\ J$
4. $KE = \frac{1}{2} \times m \times v^2$
   $KE = \frac{1}{2} \times 1000\ kg \times (10\ m/s)^2$
   $KE = 500 \times 100$
   $KE = 50{,}000\ J$
5. $KE = \frac{1}{2} \times m \times v^2$
   $100\ J = \frac{1}{2} \times 2\ kg \times v^2$
   $100 = v^2$
   $v = \sqrt{100}$
   $v = 10\ m/s$
6. Since $KE \propto v^2$, doubling the speed makes the kinetic energy four times greater.

3.3 Draw and interpret diagrams to represent energy transfers

1. An energy transfer diagram represents how energy moves between different stores or pathways in a system.
2. Arrows represent the direction of energy transfer.
3. A useful energy transfer is a transfer that provides the intended output of the device or system.
4. A wasted or dissipated energy transfer is an energy transfer that does not contribute usefully to the intended output and is transferred to the surroundings, often by heating or sound.
5. An electric kettle diagram could show electrical energy → thermal energy in the water, with some energy transferred by heating the kettle and surroundings.
6. Energy dissipation can be shown by arrows leaving the useful pathway and transferring energy to the surroundings, such as by heating or sound.

3.4 Explain what is meant by conservation of energy

1. Conservation of energy means that energy cannot be created or destroyed; it can only be transferred between stores or transformed from one form to another.
2. No. Energy cannot be created or destroyed.
3. The total amount of energy remains constant during an energy transfer.
4. When energy is described as wasted, it has been transferred to less useful energy stores, usually in the surroundings.
5. Calling energy "wasted" does not mean it has been destroyed because the energy has been transferred to another store rather than disappearing.
6. As a moving object comes to rest, its kinetic energy is transferred to other energy stores, such as thermal energy in the object and surroundings, so the total energy is conserved.

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. The object's gravitational potential energy store increases as it is raised.
2. When a moving object hits an obstacle, its kinetic energy decreases and is transferred to other stores, including thermal energy, elastic energy, sound and deformation of the objects.
3. The object's kinetic energy store increases as its speed increases.
4. The vehicle's kinetic energy store decreases as it slows down.
5. Electrical energy is transferred to the thermal energy store of the water, increasing its temperature until it reaches boiling point.

6. The vehicle's decreasing kinetic energy is transferred to other energy stores, mainly thermal energy in the brakes, tyres, road and surroundings, so total energy is conserved.

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 closed system is a system in which energy does not enter or leave the system.
2. The total energy in a closed system remains constant during energy transfers.
3. There is no net change because energy is transferred between stores within the system rather than entering or leaving it.
4. Energy can be transferred between different stores within the system while the total energy remains unchanged.
5. The total energy remains constant, although some energy may be transferred to less useful stores.
6. Energy dissipation does not violate conservation because the energy is transferred to other stores, rather than being destroyed.

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

1. Mechanical processes become wasteful when energy is dissipated to the surroundings, usually through friction, rather than being transferred usefully.
2. Friction transfers energy from useful mechanical energy stores to thermal energy stores in the objects and surroundings.
3. The temperature of the surfaces generally increases.
4. The thermal energy stores of the surfaces and surroundings increase.
5. A rise in temperature shows that energy has been transferred to thermal energy stores, making it less useful for the intended purpose.
6. Friction reduces efficiency because some of the input energy is dissipated as thermal energy instead of being transferred usefully.

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

1. Energy is dissipated when it is transferred to less useful energy stores, usually in the surroundings.
2. Energy is commonly dissipated as thermal energy, often with some energy transferred by sound.

3. When a moving object slows due to friction, its kinetic energy is transferred mainly to thermal energy stores in the object, surface and surroundings.
4. An electrical device can dissipate energy by heating its surroundings and producing unwanted sound.
5. Dissipated energy is less useful because it is spread into the surroundings and is difficult to transfer back into useful forms.
6. For example, when a bicycle brakes, kinetic energy is dissipated mainly as thermal energy in the brake pads, wheels and surroundings.

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

1. Lubrication reduces unwanted energy transfer by reducing friction between moving surfaces.
2. Lubrication reduces friction, so less mechanical energy is dissipated as thermal energy.
3. Thermal insulation reduces unwanted energy transfer by reducing the rate at which thermal energy is transferred between an object and its surroundings.
4. Building walls are fitted with insulating materials to reduce thermal energy transfer and slow the loss of thermal energy from the building.
5. Double glazing reduces thermal energy transfer by trapping an insulating layer of air or gas between the panes.
6. Reducing unwanted energy transfers means more of the supplied energy is transferred usefully, increasing efficiency.

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 generally reduces the rate of cooling.
2. Increasing thermal conductivity generally increases the rate of cooling.
3. Materials with low thermal conductivity are good insulators because they transfer thermal energy slowly.
4. A thicker wall provides more material through which thermal energy must be transferred, reducing the rate of transfer.
5. A building with thick, low-conductivity walls would cool more slowly.
6. Materials with low thermal conductivity are more suitable for insulation because they reduce the rate of thermal energy 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. Useful energy is the energy transferred in the intended or desired form by the device.
3. Total energy supplied is the total energy transferred to the device as input.
4. Efficiency = useful energy ÷ total energy supplied
   Efficiency = 400 J ÷ 500 J
   Efficiency = 0.80
5. Useful energy = efficiency × total energy supplied
   Useful energy = 0.75 × 800 J
   Useful energy = 600 J
6. Efficiency = useful energy ÷ total energy supplied
   Efficiency = 300 J ÷ 600 J
   Efficiency = 0.5
   Efficiency = 50%

3.12 Explain how efficiency can be increased

1. A high-efficiency device transfers a large proportion of its input energy usefully.
2. Reducing unwanted energy transfers means less input energy is wasted, so the proportion transferred usefully increases.
3. Lubrication reduces friction and therefore reduces energy dissipated as thermal energy, increasing efficiency.
4. Thermal insulation reduces unwanted thermal energy transfer, so more energy remains available for the intended purpose.
5. Reducing dissipated energy means a greater proportion of the input energy is transferred usefully.
6. If the total energy supplied stays the same, the useful energy transferred must increase.

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. The main non-renewable energy sources are fossil fuels (coal, oil and natural gas) and nuclear fuel.
2. The main renewable energy sources include bio-fuels, wind, hydroelectricity, tidal energy and solar energy from the Sun.
3. Fossil fuels are non-renewable because they take millions of years to form and are consumed much faster than they are replaced.
4. Wind, hydroelectric, tidal and solar energy are renewable because their energy sources are naturally replenished.

5. One advantage of fossil fuels is that they can provide reliable, controllable electricity. One disadvantage is that burning them releases carbon dioxide and other pollutants.
6. Nuclear fuel is non-renewable because its available fuel reserves are finite, whereas renewable energy sources are naturally replenished on a human timescale.

3.14 Explain patterns and trends in the use of energy resources

1. Factors include availability, cost, demand, reliability, environmental impact, technology and government policy.
2. Renewable energy use can increase as technology improves, costs fall and the need to reduce environmental impacts increases.
3. Fossil fuel use may decrease because of concerns about climate change, pollution, finite supplies and the development of renewable alternatives.
4. Technological developments can make energy sources more efficient, cheaper, more reliable or easier to use, changing their level of use.
5. Government policies can influence energy use through taxes, subsidies, regulations, targets and investment in particular energy sources.
6. Different countries have different patterns because they have different natural resources, energy demands, economies, technologies, geographical conditions and government policies.

Topic 4 – Waves

4.1 Recall that waves transfer energy and information without transferring matter

1. Waves transfer energy and information from one place to another.
2. No. Waves do not transfer matter overall from one place to another.
3. A wave transfers energy by causing particles or fields to oscillate and pass the disturbance to neighbouring particles or regions, without transporting the particles overall.
4. Waves can carry information by modulating properties of the wave, such as amplitude or frequency.
5. The matter through which a wave travels oscillates about its equilibrium position rather than travelling with the wave overall.
6. A water wave can transfer energy to a floating object without transporting the floating object with the wave over the whole distance.

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 generally moves up and down and may move back and forth, rather than travelling forward with the water wave.
2. Its motion shows that the water oscillates about its equilibrium position while the wave transfers energy forwards, rather than transporting the water itself.
3. A sound can travel from a source to a listener through air, but the air itself does not travel from the source to the listener; instead, air particles vibrate about their equilibrium positions.
4. Air particles vibrate back and forth about their equilibrium positions, producing compressions and rarefactions.
5. Water particles mainly oscillate about their equilibrium positions, showing that energy is transferred by the wave rather than the water being transported with it.
6. Air particles oscillate locally as the disturbance passes from particle to particle, showing that the sound wave travels through the air rather than the air itself travelling to the listener.

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

1. Frequency is the number of complete waves or oscillations passing a point each second.
2. The SI unit for frequency is the hertz (Hz).
3. Wavelength is the distance between corresponding points on two consecutive waves, such as crest to crest or compression to compression.
4. The symbol λ (lambda) is commonly used for wavelength.
5. A higher frequency means that more waves pass a point each second.
6. On a transverse wave, wavelength is measured as the horizontal distance between corresponding points on consecutive waves, such as crest to crest.

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

1. Amplitude is the maximum displacement of a point on a wave from its equilibrium position.
2. Period is the time taken for one complete wave or oscillation to pass a point.
3. Wave velocity is the speed and direction in which a wave travels.
4. A wavefront is a line or surface joining points on a wave that are in the same phase.
5. Frequency and period are related by:
   $f = 1 \div T$
   $T = 1 \div f$

6. Amplitude is the maximum displacement from the equilibrium position, so a greater amplitude means a greater maximum displacement.

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

1. In a longitudinal wave, oscillations are parallel to the direction of wave travel; in a transverse wave, oscillations are perpendicular to the direction of wave travel.
2. In a longitudinal wave, particles vibrate parallel to the direction of wave travel.
3. In a transverse wave, particles vibrate perpendicular to the direction of wave travel.
4. Sound in air is a longitudinal wave.
5. Electromagnetic waves are transverse waves.
6. Seismic waves can be longitudinal or transverse, while water surface waves involve a combination of transverse and longitudinal motion.

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) $v = x \div t$

1. $v = f \times \lambda$
2. $v = x \div t$
3. $v = f \times \lambda$
   $v = 5\ \text{Hz} \times 2\ \text{m}$
   $v = 10\ \text{m/s}$
4. $v = f \times \lambda$
   $\lambda = v \div f$
   $\lambda = 300\ \text{m/s} \div 150\ \text{Hz}$
   $\lambda = 2\ \text{m}$
5. $v = x \div t$
   $v = 120\ \text{m} \div 4\ \text{s}$
   $v = 30\ \text{m/s}$
6. $v = f \times \lambda$
   $f = v \div \lambda$
   $f = 20\ \text{m/s} \div 4\ \text{m}$
   $f = 5\ \text{Hz}$

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

1. The velocity of sound in air can be measured by placing two microphones a known distance apart, measuring the time delay between the sound reaching them, and calculating the speed.
2. The required measurements are the distance between the microphones and the time taken for the sound to travel between them.
3. The velocity of water ripples can be measured by measuring the distance travelled by a ripple over a known time, or by measuring frequency and wavelength.
4. v = x ÷ t. Measure the distance travelled and the time taken, then divide the distance by the time.
5. A larger distance gives a larger time delay, making the timing difference easier to measure accurately and reducing the effect of timing uncertainty.
6. A ruler or metre rule and a stroboscope or camera can be used to measure the wavelength of water ripples.

4.8P Calculate depth or distance from time and wave velocity

1. distance = wave velocity × time
   x = v × t
2. x = v × t
   x = 1500 m/s × 2 s
   x = 3000 m
3. x = v × t
   x = 340 m/s × 0.5 s
   x = 170 m
4. v = x ÷ t
   t = x ÷ v
   t = 600 m ÷ 300 m/s
   t = 2 s
5. x = v × t
   x = 340 m/s × 0.4 s
   x = 136 m
   Total distance = 136 m
6. The sound travels down to the seabed and back, so the total distance is twice the depth.
   Total distance = v × t
   Total distance = 1500 m/s × 0.6 s
   Total distance = 900 m
   Depth = 900 m ÷ 2
   Depth = 450 m

4.9P Describe the effects of a reflection b refraction c transmission d absorption of waves at material interfaces

1. During reflection, a wave changes direction and remains in the original medium.
2. During refraction, a wave changes speed and usually changes direction as it enters a different medium.
3. During transmission, a wave passes through a material or boundary into another region.
4. During absorption, the wave's energy is transferred to the material, often increasing its thermal energy.
5. During reflection, the wave changes direction according to the law of reflection.
6. When a wave is absorbed, its energy is transferred to the material and is no longer carried by the wave.

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

1. When a wave enters a different medium, its wave speed may change.
2. Refraction occurs because the wave changes speed at the boundary, causing its direction to change unless it enters along the normal.
3. If the wave enters a medium where its speed decreases, it generally bends towards the normal.
4. If the wave enters a medium where its speed increases, it generally bends away from the normal.
5. The frequency does not change when a wave crosses a boundary.
6. Since $v = f \times \lambda$ and frequency remains constant, a change in speed causes a corresponding change in wavelength; the change in speed causes the change in direction known as refraction.

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

1. Absorption occurs when a material takes in energy carried by a wave.
2. Transmission occurs when a wave passes through a material.
3. Reflection occurs when a wave bounces back from a boundary.
4. Refraction occurs when a wave changes speed and usually direction as it enters a different medium.
5. Different wavelengths interact differently with materials because the material's properties and structure affect how strongly it interacts with each wavelength.
6. A material may absorb some wavelengths while allowing others to be transmitted, depending on the wavelength and the material's properties.

4.12P Describe the processes which convert wave disturbances between sound waves and vibrations in solids, and a explain why such processes only work over a limited frequency range b use this to explain the way the human ear works

1. A sound wave can cause a solid to vibrate when the sound's pressure variations exert forces on the solid.
2. Vibrations in a solid can produce sound waves when the vibrating solid causes pressure variations in the surrounding medium.
3. These processes work over a limited frequency range because the response of the material or system depends on frequency, and it does not respond equally effectively to all frequencies.
4. The eardrum vibrates in response to sound waves.
5. Vibrations from the eardrum are transferred through the middle ear by the three small bones—the ossicles—to the cochlea.
6. The cochlea converts mechanical vibrations into electrical nerve signals, which are sent to the brain for processing.

4.13P Recall that sound with frequencies greater than 20 000 hertz, Hz, is known as ultrasound

1. Ultrasound is sound with a frequency greater than 20,000 Hz.
2. Ultrasound has frequencies above 20,000 Hz.
3. Yes. 25,000 Hz is ultrasound because it is greater than 20,000 Hz.
4. No. 15,000 Hz is not ultrasound because it is below 20,000 Hz.
5. The minimum frequency required is greater than 20,000 Hz.
6. Humans cannot normally hear ultrasound because the human hearing range does not extend above about 20,000 Hz.

4.14P Recall that sound with frequencies less than 20 hertz, Hz, is known as infrasound

1. Infrasound is sound with a frequency less than 20 Hz.
2. Infrasound has frequencies below 20 Hz.
3. Yes. 10 Hz is infrasound because it is below 20 Hz.
4. No. 25 Hz is not infrasound because it is above 20 Hz.
5. The maximum frequency for infrasound is less than 20 Hz.
6. Humans cannot normally hear infrasound because the human hearing range does not extend below about 20 Hz.

4.15P Explain uses of ultrasound and infrasound, including a sonar b foetal scanning c exploration of the Earth's core

1. In sonar, ultrasound pulses are sent into water and reflected from objects or the seabed; the time taken for the echo to return can be used to determine distance or depth.
2. During foetal scanning, ultrasound is transmitted into the body and reflected at boundaries between different tissues, producing information that can be used to form an image.
3. Ultrasound is suitable for foetal scanning because it is non-ionising and can produce images from echoes at tissue boundaries.
4. Infrasound can provide information about the Earth's interior through low-frequency seismic waves and their behaviour as they travel through the Earth.
5. Seismic waves are useful because their speeds, paths, reflections and refractions change when they encounter different materials, providing evidence about the Earth's internal structure.
6. Reflection and refraction reveal information about internal boundaries because changes in the wave's path or return time indicate changes in the materials through which the wave travels.

4.16P Describe how changes, if any, in velocity, frequency and wavelength, in the transmission of sound waves from one medium to another are inter-related

1. The speed of a sound wave usually changes when it enters a different medium.
2. The frequency of a sound wave does not change when it enters a different medium.
3. If speed changes while frequency remains constant, the wavelength changes in the same proportion as the speed.
4. $v = f \times \lambda$
5. $v = f \times \lambda$
   Since frequency remains constant and speed increases, wavelength increases.
6. $v = f \times \lambda$
   $\lambda = v \div f$
   $\lambda = 340 \text{ m/s} \div 500 \text{ Hz}$
   $\lambda = 0.68 \text{ m}$

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. To calculate wave speed, measurements of frequency and wavelength are needed, using $v = f \times \lambda$, or distance and time using $v = x \div t$.

2. Frequency can be measured by counting the number of complete waves passing a point in a known time or using an electronic frequency measuring device.
3. Wavelength can be measured by measuring the distance between corresponding points on consecutive waves, such as crest-to-crest.
4. Use $v = f \times \lambda$: measure the frequency and wavelength, then multiply them to calculate the wave speed.
5. Equipment for waves in a solid could include a signal generator, vibration source, solid rod or string, microphone/sensor and oscilloscope.
6. Equipment for waves in a fluid could include a ripple tank, lamp, ruler, signal generator and vibration source, with a camera or stroboscope used to observe the waves.

Topic 5 – Light and the electromagnetic spectrum

5.1P Explain, with the aid of ray diagrams, reflection, refraction and total internal reflection (TIR), including the law of reflection and critical angle

1. Reflection is the change in direction of light when it bounces off a surface and remains in the original medium.
2. Refraction is the change in direction of light caused by a change in its speed when it passes from one medium to another.
3. The law of reflection states that the angle of incidence equals the angle of reflection, measured from the normal.
4. The critical angle is the angle of incidence in the higher refractive index medium for which the angle of refraction is 90°.
5. TIR requires:
    - Light to travel from a higher refractive index medium to a lower refractive index medium.
    - The angle of incidence to be greater than the critical angle.
6. The ray undergoes total internal reflection and is reflected completely back into the higher refractive index medium.

5.2P Explain the difference between specular and diffuse reflection

1. Specular reflection is reflection from a smooth surface in which parallel incident rays remain parallel after reflection.
2. Diffuse reflection is reflection from a rough surface in which parallel incident rays are reflected in different directions.

3. Specular reflection occurs at smooth surfaces, whereas diffuse reflection occurs at rough or uneven surfaces.
4. A smooth surface has a normal that is effectively the same across the reflecting area, so the reflected rays remain orderly and parallel.
5. A rough surface has normals at different angles, so reflected rays travel in different directions.
6. In specular reflection, reflected rays are parallel or regularly arranged; in diffuse reflection, they are scattered in many directions.

5.3P Explain how colour of light is related to a differential absorption at surfaces b transmission of light through filters

1. An object appears a particular colour because it reflects or transmits some wavelengths of visible light more than others.
2. Differential absorption means that a surface absorbs some wavelengths more strongly than others, so the remaining reflected light determines the colour seen.
3. A coloured filter transmits some wavelengths and absorbs others.
4. A red filter transmits mainly red wavelengths and absorbs most other visible wavelengths.
5. Wavelengths absorbed by a coloured filter are not transmitted through the filter; their energy is absorbed by the material.
6. The colour seen through a filter depends on the wavelengths transmitted by the filter, because these are the wavelengths that reach the observer.

5.4P Relate the power of a lens to its focal length and shape

1. The power of a lens is a measure of how strongly the lens converges or diverges light.
2. Power is inversely proportional to focal length.
3. $P = 1 \div f$
   where P is power in dioptres (D) and f is focal length in metres (m).
4. $P = 1 \div f$
   $P = 1 \div 0.5$ m
   $P = 2$ D
5. $P = 1 \div f$
   $f = 1 \div P$
   $f = 1 \div 4$ D
   $f = 0.25$ m
6. A lens with greater curvature generally has greater power and a shorter focal length.

5.5P Use ray diagrams to show the similarities and differences in the refraction of light by converging and diverging lenses

1. A converging lens refracts parallel rays so that they meet at the principal focus.
2. A diverging lens refracts parallel rays so that they spread out.
3. Parallel rays converge at the principal focus on the opposite side of a converging lens.
4. After passing through a diverging lens, rays spread out as though they came from a principal focus on the same side as the object.
5. A converging-lens ray diagram shows rays meeting, whereas a diverging-lens diagram shows rays spreading apart.
6. A ray travelling through the optical centre of a thin lens passes through without significant deviation.

5.6P Explain the effects of different types of lens in producing real and virtual images

1. A real image is formed when light rays actually converge at a point and can therefore be formed on a screen.
2. A virtual image is formed when light rays only appear to come from a point and cannot be formed on a screen.
3. A converging lens can produce both real and virtual images, depending on the object's position.
4. A diverging lens normally produces a virtual, upright and diminished image.
5. Yes. A real image can be formed on a screen.
6. For a converging lens, an object outside the focal length produces a real image, while an object inside the focal length produces a virtual image.

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

1. All electromagnetic waves are transverse waves.
2. The speed of electromagnetic waves in a vacuum is approximately 3.0×10^8 m/s.
3. Yes. All electromagnetic waves travel at approximately 3.0×10^8 m/s in a vacuum.
4. In a transverse wave, vibrations are perpendicular to the direction of wave travel.
5. No. Electromagnetic waves do not require a medium and can travel through a vacuum.
6. Electromagnetic waves can travel through empty space because they consist of oscillating electric and magnetic fields that sustain each other.

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

1. Electromagnetic waves transfer energy from a source to an observer or receiver.
2. Visible light from the Sun transfers radiant energy to Earth, where it can be absorbed and converted into other forms of energy.
3. Infrared radiation transfers energy from a warm object to objects and surfaces that absorb the radiation.
4. Microwaves transfer energy to food by causing molecules in the food to absorb electromagnetic radiation and increase their thermal energy.
5. Gamma rays transfer energy to cells when they are absorbed by matter in the body.
6. Electromagnetic waves can transfer energy through a vacuum because they do not require particles of a medium to carry the disturbance.

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

1. When light enters a rectangular glass block at an angle, it changes speed and refracts towards the normal.
2. When the ray leaves the glass into air, it changes speed again and refracts away from the normal.
3. Equipment includes a rectangular glass block, ray box or laser, paper, ruler, protractor and pencil.
4. Draw the normal at the boundary and use a protractor to measure the angles between the rays and the normal.
5. Light changes direction because its speed changes when it enters glass from air.
6. Trace the incident, refracted and emergent rays, draw the normals and measure the relevant angles with a protractor.

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. From lowest to highest frequency: radio waves → microwaves → infrared → visible light → ultraviolet → x-rays → gamma rays.
2. Radio waves have the longest wavelength.
3. Gamma rays have the highest frequency.
4. From longest to shortest wavelength: red → orange → yellow → green → blue → indigo → violet.

5. Infrared lies between microwaves and visible light.
6. X-rays lie between ultraviolet 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. A continuous electromagnetic spectrum means that electromagnetic radiation covers a continuous range of frequencies and wavelengths, rather than consisting of isolated values.
2. Wavelength decreases in the order: radio waves → microwaves → infrared → visible → ultraviolet → x-rays → gamma rays.
3. Frequency increases in the order: radio waves → microwaves → infrared → visible → ultraviolet → x-rays → gamma rays.
4. Ultraviolet has a greater frequency than infrared.
5. Microwaves have a longer wavelength than visible light.
6. As wavelength decreases, frequency increases.

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

1. Human eyes detect visible light.
2. Humans cannot normally see infrared because its frequency is below the range detectable by the human eye.
3. Humans cannot normally see ultraviolet because its frequency is above the range detectable by the human eye.
4. The visible region is the limited range of electromagnetic frequencies that can be detected by the human eye.
5. The visible range is only a very small part of the full electromagnetic spectrum.
6. Visible light is only a small part because the electromagnetic spectrum contains a much wider range of frequencies than those detectable by human eyes.

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

1. Absorption occurs when a substance takes in energy from electromagnetic radiation.
2. Transmission occurs when electromagnetic radiation passes through a substance.

3. Reflection occurs when electromagnetic radiation bounces back from a surface or boundary.
4. Refraction occurs when electromagnetic radiation changes speed and usually direction as it enters a different substance.
5. A substance can interact differently with different wavelengths because its electrical and structural properties affect how it interacts with electromagnetic radiation.
6. A material may transmit visible light while absorbing infrared because its absorption and transmission properties depend on wavelength.

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

1. The speed of an electromagnetic wave usually changes when it enters a different substance.
2. An electromagnetic wave can be refracted because its speed changes at the boundary between substances.
3. When its speed changes at a boundary, its direction may change, producing refraction.
4. The frequency does not change when an electromagnetic wave enters a different medium.
5. If speed decreases while frequency remains constant, wavelength decreases because $v = f \times \lambda$.
6. Different substances allow electromagnetic waves to travel at different speeds, so the change in speed at a boundary can cause the wave to change direction.

5.15P Explain that all bodies emit radiation, that the intensity and wavelength distribution of any emission depends on their temperature

1. All bodies emit electromagnetic radiation, including infrared radiation.
2. As an object's temperature increases, the intensity of its emitted radiation increases.
3. As temperature increases, the distribution shifts towards shorter wavelengths.
4. A hot object emits more thermal radiation than a cooler object.
5. As temperature increases, the wavelength distribution shifts so that a greater proportion of the radiation is at shorter wavelengths.
6. Thermal imaging detects temperature differences because objects at different temperatures emit different amounts of infrared radiation.

5.16P Explain that for a body to be at a constant temperature it needs to radiate the same average power that it absorbs

1. For an object to remain at constant temperature, its average power emitted must equal its average power absorbed.
2. When emitted and absorbed powers are equal, the object's temperature remains constant.
3. If an object absorbs more power than it radiates, its temperature increases.
4. If an object radiates more power than it absorbs, its temperature decreases.
5. There is no net change in the object's energy because energy absorbed equals energy emitted.
6. Temperature determines the balance between emission and absorption; an object changes temperature until the average powers absorbed and emitted become equal.

5.17P Explain what happens to a body if the average power it radiates is less or more than the average power that it absorbs

1. If a body absorbs more power than it radiates, its temperature increases.
2. If a body radiates more power than it absorbs, its temperature decreases.
3. When absorbed and radiated powers are equal, the body's temperature remains constant.
4. The body warms because more energy enters it than leaves it, increasing its thermal energy.
5. The body cools because more energy leaves it than enters it, decreasing its thermal energy.
6. If the difference between absorbed and emitted power is zero, the body's temperature remains constant.

5.18P Explain how the temperature of the Earth is affected by factors controlling the balance between incoming radiation and radiation emitted

1. The main incoming radiation is solar electromagnetic radiation from the Sun.
2. If incoming radiation increases while emitted radiation remains constant, Earth's temperature increases.
3. If emitted radiation increases while incoming radiation remains constant, Earth's temperature decreases.
4. Changes in the atmosphere can alter the balance by affecting the absorption, transmission and emission of infrared radiation.

5. Earth reaches a stable average temperature when the average incoming power equals the average outgoing power.
6. An increase in absorbed radiation causes Earth's average temperature to increase until the outgoing radiation increases sufficiently to restore balance.

5.19P Core Practical: Investigate how the nature of a surface affects the amount of thermal energy radiated or absorbed

1. The nature of a surface affects how effectively it emits and absorbs infrared radiation.
2. A dull, dark surface is generally a better emitter of infrared radiation than a shiny surface.
3. A dull, dark surface is generally a better absorber of infrared radiation than a shiny surface.
4. Equipment could include identical containers with different surface finishes, a heat source, thermometers or temperature sensors, and a stopwatch.
5. The initial temperature, mass of material, container size, heating time, heat source and surrounding conditions should be controlled.
6. Compare the rate of temperature change or radiation measurements for each surface; a greater rate of energy emission or absorption indicates a better emitter or absorber.

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

1. The potential danger generally increases as electromagnetic-wave frequency increases.
2. Ultraviolet is potentially more dangerous than infrared.
3. X-rays are potentially more dangerous than visible light.
4. Gamma rays have the highest frequencies.
5. High-frequency electromagnetic radiation has higher energy per photon, so it can cause greater damage to living cells.
6. Gamma rays are potentially more dangerous than microwaves.

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. Excessive microwave exposure can cause internal heating of body tissues and cells.
2. Excessive infrared exposure can cause skin burns.
3. Excessive ultraviolet exposure can damage skin cells and eyes, causing conditions including skin damage and eye disorders.
4. Excessive ultraviolet exposure can damage DNA in skin cells, increasing the risk of skin cancer.
5. X-rays can damage or mutate cells, potentially causing cancer if exposure is excessive.
6. Gamma rays can cause cell damage and mutations, potentially causing cancer and other health problems.

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. Radio waves are used for broadcasting, communications and satellite transmissions.
2. Microwaves are used for cooking, communications and satellite transmissions.
3. Infrared is used for cooking, thermal imaging, short-range communications, optical fibres, television remote controls and security systems.
4. Visible light is used for vision, photography and illumination.
5. Ultraviolet is used for security marking, fluorescent lamps, detecting forged bank notes and disinfecting water.
6. X-rays are used for medical imaging and airport security scanners, while gamma rays are used for sterilising food and medical equipment and for detecting and treating cancer.

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

1. Radio waves can be produced by oscillating electric charges or alternating currents in an aerial.
2. When radio waves induce oscillations in an electrical circuit, they cause alternating electrical currents or voltages to oscillate at the wave's frequency.
3. Oscillating electric current or charge in an aerial can produce radio waves.
4. An oscillating electrical current produces electromagnetic radiation because accelerating charges generate changing electric and magnetic fields that propagate outward.
5. Radio waves can cause alternating currents or voltages to be induced in a receiving aerial or circuit.
6. Oscillating electrical charges are important because their changing electric and magnetic fields produce electromagnetic waves, while incoming waves can induce oscillations for detection.

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 atoms can generate electromagnetic radiation when electrons move between different energy levels and release energy as photons.
2. Changes in atomic nuclei can generate electromagnetic radiation, particularly gamma radiation from changes in the nucleus.
3. The frequency depends on the energy difference associated with the atomic or nuclear change.
4. Atoms can absorb electromagnetic radiation when the energy of the radiation matches an allowed energy change within the atom.
5. Nuclei can be affected by absorbing electromagnetic radiation if the radiation has suitable energy to produce a nuclear transition or other nuclear change.
6. Atoms and nuclei have different possible energy changes, so they can produce or absorb electromagnetic radiation over a wide range of frequencies.

Absolutely. I'll follow all 11 rules, including no divider lines. Here is the redone Topic 6 with exactly six answers under every specification point, without repeating the questions.

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. The nucleus contains protons and neutrons.
2. The nucleus has an overall positive charge because protons are positively charged and neutrons have no charge.
3. Negatively charged electrons surround the nucleus.
4. The nuclear radius is much smaller than the radius of the atom.
5. Almost all of the atom's mass is concentrated in the nucleus, because protons and neutrons are much more massive than electrons.
6. An atom is neutral because it has equal numbers of positively charged protons and negatively charged electrons, so the charges cancel to zero.

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

1. The typical order of magnitude of an atomic radius is 10^{-10} m.
2. An atom is approximately 0.1 nm, or 1×10^{-10} m, in radius.
3. The order of magnitude is the power of ten that gives the approximate size of a measurement.
4. Atoms are enormously smaller than everyday objects; even a tiny grain of dust contains many billions of atoms.
5. The typical size of a small molecule is also approximately 10^{-10} m in order of magnitude.
6. Atoms and small molecules are described as extremely small because their dimensions are around one ten-billionth of a metre.

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 atomic number is the number of protons in the nucleus.
2. The mass number is the total number of protons and neutrons in the nucleus.
3. Number of neutrons = mass number − atomic number.
4. $^{13}_{6}C$ contains 6 protons and 7 neutrons, because 13 − 6 = 7.
5. $^{23}_{11}Na$ has 11 protons and 12 neutrons, because 23 − 11 = 12.
6. Isotopes are represented as ^{A}ZX, where A is the mass number, Z is the atomic number and X is the element symbol.

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 positive charge of a nucleus is determined by its number of protons.
2. All atoms of the same element have the same number of protons because the proton number defines the element.
3. Isotopes are atoms of the same element with the same number of protons but different numbers of neutrons.
4. Isotopes differ in their number of neutrons and therefore their mass numbers.
5. Isotopes have different masses because they contain different numbers of neutrons.
6. Carbon-12 has 6 neutrons, while carbon-14 has 8 neutrons.

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

1. A proton has relative mass 1 and relative charge +1.
2. A neutron has relative mass 1 and relative charge 0.
3. An electron has relative mass approximately 1/1840 and relative charge −1.
4. A positron has relative mass approximately 1/1840 and relative charge +1.
5. A positron has approximately the same mass as an electron but the opposite charge.
6. The neutron has zero electric charge.

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

1. An atom is electrically neutral because its positive proton charge balances its negative electron charge.
2. A neutral atom has equal numbers of protons and electrons.
3. A neutral atom with 8 protons has 8 electrons.
4. A neutral atom with 17 electrons has 17 protons.
5. If an atom loses an electron, it becomes a positive ion.
6. If an atom gains an electron, it becomes a negative ion.

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

1. Electrons occupy specific electron shells or energy levels around the nucleus.
2. The set distances correspond to the electron's allowed energy levels.

3. No; electrons can occupy different shells at different distances from the nucleus.
4. An electron shell is a set energy level or region around the nucleus occupied by electrons.
5. Electrons with the lowest energy are generally found in the shell closest to the nucleus.
6. Electrons farther from the nucleus generally occupy higher energy levels.

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

1. When an atom absorbs electromagnetic radiation of the correct energy, an electron moves to a higher energy level.
2. When an atom emits electromagnetic radiation, an electron moves to a lower energy level.
3. The electron moves to a higher energy level because it absorbs energy.
4. An electron moving to a lower energy level releases its excess energy as electromagnetic radiation.
5. The frequency depends on the energy difference between the two electron energy levels, according to $E = hf$.
6. Electromagnetic radiation is therefore absorbed or emitted when electrons change between allowed energy levels.

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

1. A positive ion is an atom or group of atoms with an overall positive charge.
2. An atom becomes a positive ion when it loses one or more electrons.
3. Losing an electron removes negative charge while leaving the number of positive protons unchanged, producing a net positive charge.
4. The outermost electrons are most likely to be lost because they are less strongly attracted to the nucleus.
5. The number of protons does not change when an atom loses an electron.
6. After losing two electrons, an atom has a charge of +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. Unstable nuclei emit radioactive radiation.
2. The five types are alpha, β−, β+, gamma and neutron radiation.
3. Beta minus decay emits a high-speed electron from the nucleus.
4. Beta plus decay emits a positron from the nucleus.

5. No; it is impossible to predict exactly when a particular unstable nucleus will decay.
6. Radioactive decay is random because the time at which an individual unstable nucleus decays cannot be predicted.

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

1. Ionising radiation has enough energy to remove electrons from atoms or molecules, forming ions.
2. The four ionising radiations are alpha, β−, β+ and gamma.
3. Yes, alpha radiation is strongly ionising.
4. Yes, gamma radiation is ionising, although it is less strongly ionising than alpha radiation.
5. Ionising radiation can remove electrons from atoms, producing positive ions and free electrons.
6. Ionisation can damage living tissue by breaking chemical bonds and damaging DNA.

6.12 Explain what is meant by background radiation

1. Background radiation is the low-level ionising radiation that is continually present in the environment.
2. It is found everywhere, including indoors and outdoors.
3. Yes, it is present even when no radioactive source has deliberately been introduced.
4. It must be considered because a detector records background radiation as well as radiation from the source being investigated.
5. It is present all around us because radiation comes from natural sources on Earth and from space.
6. A Geiger–Müller tube records background counts, which can make the measured activity higher than the activity due only to the radioactive source.

6.13 Describe the origins of background radiation from Earth and space

1. The two broad origins are natural sources on Earth and cosmic radiation from space.
2. Rocks and soil can contain naturally radioactive isotopes that emit ionising radiation.
3. Cosmic rays are high-energy radiation arriving from space.
4. Radioactive substances in building materials and radon gas can contribute to background radiation indoors.

5. Radiation from space enters Earth's atmosphere and reaches the Earth's surface as cosmic radiation and secondary radiation.
6. Background radiation varies because the concentration of radioactive materials, altitude and local environmental conditions vary between locations.

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

1. Photographic film detects ionising radiation because radiation darkens the film when it exposes the photographic material.
2. Exposure to ionising radiation causes the film to become darker after development.
3. A Geiger–Müller tube detects ionising radiation.
4. When radiation enters the tube, it produces an electrical pulse, which can be counted by a Geiger counter.
5. The count rate can be measured over a known time to determine the activity or rate of detected radioactive decays, after accounting for background radiation.
6. Background radiation should be measured so that the background count can be subtracted from the measured count rate.

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. An alpha particle is a helium nucleus containing two protons and two neutrons.
2. An alpha particle consists of 2 protons and 2 neutrons.
3. A beta minus particle is a high-speed electron emitted from the nucleus.
4. The electron is produced during the transformation of a neutron into a proton.
5. A gamma ray is high-frequency electromagnetic radiation.
6. An alpha particle is a massive particle containing 2 protons and 2 neutrons, whereas a beta particle is a single electron.

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

1. Alpha radiation is the most strongly ionising.
2. Gamma radiation is the most penetrating.
3. Alpha radiation can be stopped by paper or a few centimetres of air.
4. Beta radiation can be significantly reduced by a thin sheet of aluminium.

5. Gamma radiation penetrates further because it is uncharged electromagnetic radiation with much greater penetrating power.
6. In general, the more strongly ionising radiation is less penetrating, while less strongly ionising radiation is more 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 plum pudding model proposed that an atom was a sphere of positive charge with electrons embedded throughout it.
2. Rutherford's alpha particle scattering experiment provided evidence for a small, dense, positively charged nucleus.
3. Rutherford's model proposed that most of the atom is empty space surrounding a small positive nucleus.
4. The fact that a small fraction of alpha particles were deflected through very large angles showed that the positive charge and most of the mass were concentrated in a very small nucleus.
5. Bohr added that electrons occupy specific fixed energy levels around the nucleus.
6. Scientists changed the atomic model because experimental evidence contradicted earlier models and supported more accurate explanations.

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

1. In beta minus decay, a neutron changes into a proton.
2. An electron is emitted from the nucleus.
3. The number of protons increases by 1.
4. The number of neutrons decreases by 1.
5. The mass number does not change.
6. The atomic number increases by 1.

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

1. In beta plus decay, a proton changes into a neutron.
2. A positron is emitted from the nucleus.
3. The number of protons decreases by 1.
4. The number of neutrons increases by 1.
5. The mass number does not change.
6. The atomic number decreases by 1.

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

1. Alpha decay decreases the atomic number by 2 and the mass number by 4.
2. Beta minus decay increases the atomic number by 1 while the mass number stays unchanged.
3. Beta plus decay decreases the atomic number by 1 while the mass number stays unchanged.
4. Gamma emission causes no change to either atomic number or mass number.
5. Emission of a neutron decreases the mass number by 1.
6. Emission of a neutron causes no change to the atomic number, because a neutron has no proton.

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

1. After radioactive decay, a nucleus may be left in an excited state and can rearrange itself into a lower-energy state.
2. Nuclear rearrangement is a change in the arrangement or energy state of particles within the nucleus.
3. An excited nucleus can emit gamma radiation as it loses energy.
4. The energy of the nucleus decreases when gamma radiation is emitted.
5. Gamma emission does not change the number of protons.
6. Gamma emission does not change the mass number.

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

1. Mass number and atomic number (charge) must both be conserved.
2. During alpha decay, the mass number decreases by 4.
3. During beta minus decay, the atomic number increases by 1.
4. $^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$.
5. $^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$.
6. $^{22}_{11}Na \rightarrow {}^{22}_{10}Ne + {}^{0}_{+1}e$.

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

1. The activity of a radioactive source decreases over time.

2. Activity decreases because the number of undecayed unstable nuclei decreases.
3. The number of undecayed nuclei decreases continuously as nuclei decay.
4. An activity-time graph produces a decreasing exponential curve.
5. No; radioactive activity does not decrease at a constant rate.
6. Activity is proportional to the number of undecayed radioactive nuclei remaining, so fewer nuclei give a lower activity.

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

1. The SI unit of radioactive activity is the becquerel.
2. The symbol is Bq.
3. One becquerel represents one radioactive decay per second.
4. An activity of 500 Bq means that 500 nuclei decay per second on average.
5. 800 Bq is greater than 200 Bq, so the 800 Bq source has the greater activity.
6. A higher activity indicates a greater 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. Half-life is the time taken for half the undecayed nuclei in a radioactive sample to decay, or for its activity to fall to half its original value.
2. From an activity-time graph, find an activity value, calculate half of it, and read the time taken to reach that half-value.
3. After one half-life, the activity becomes half its original value.
4. After one half-life, one-half of the original undecayed nuclei remain.
5. Initial activity = 800 Bq.
   After one half-life:
   800 ÷ 2 = 400 Bq
   Final activity = 400 Bq.
6. Half-life remains constant for a particular isotope because the probability of decay for each nucleus is constant.

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, the exact time at which an individual unstable nucleus decays cannot be predicted.

2. Decay is random because each individual nucleus has a constant probability of decaying at any particular time, but its actual decay time is unpredictable.
3. Half-life allows the average behaviour of a large number of nuclei and the activity of a sample to be predicted.
4. With a large number of nuclei, random individual variations average out, producing predictable statistical behaviour.
5. Knowing the half-life allows the activity to be repeatedly halved over successive half-lives.
6. Larger samples contain more nuclei, so statistical fluctuations are relatively smaller and predictions are more reliable.

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

1. Initial activity = 640 Bq.
   After one half-life:
   640 ÷ 2 = 320 Bq
   Final activity = 320 Bq.
2. Number of half-lives:
   15 ÷ 5 = 3 half-lives
   Activity after 1 half-life:
   800 ÷ 2 = 400 Bq
   After 2 half-lives:
   400 ÷ 2 = 200 Bq
   After 3 half-lives:
   200 ÷ 2 = 100 Bq
   Final activity = 100 Bq.
3. Initial number = 1,600 nuclei.
   After 1 half-life:
   1,600 ÷ 2 = 800
   After 2 half-lives:
   800 ÷ 2 = 400
   After 3 half-lives:
   400 ÷ 2 = 200 nuclei
   Final number = 200 nuclei.
4. 1,200 Bq → 600 Bq → 300 Bq → 150 Bq.
   Therefore, the activity has halved 3 times.
   Number of half-lives = 3.
5. 400 Bq → 200 Bq → 100 Bq → 50 Bq.
   This is 3 half-lives.
   Time = 3 × 4 hours = 12 hours.

6. On an activity-time graph, choose an activity value, find half of it, and determine the time difference between the two values. This time difference is the half-life.

6.28P Describe uses of radioactivity, including: a household fire (smoke) alarms b irradiating food c sterilisation of equipment d tracing and gauging thicknesses e diagnosis and treatment of cancer

1. Smoke alarms use a small alpha source to ionise air; smoke reduces the ionisation and changes the electrical current, triggering the alarm.
2. Food can be irradiated with ionising radiation to kill microorganisms and insects and slow spoilage without significantly heating the food.
3. Medical equipment can be sterilised using gamma radiation, which kills microorganisms.
4. Radioactive sources can be used to gauge thickness because the amount of radiation reaching a detector changes when the thickness of the material changes.
5. Radioactive tracers can be introduced into the body and their radiation detected to follow the movement or function of substances in organs.
6. Radiation can be used to destroy cancer cells in radiotherapy, while radioactive tracers can help diagnose cancer and identify abnormal tissue.

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

1. Ionising radiation can damage or kill cells by ionising atoms and molecules and breaking chemical bonds.
2. It can cause mutations by damaging or altering DNA.
3. Mutations can be harmful because they may cause abnormal cell function or uncontrolled cell division, potentially leading to cancer.
4. Exposure should be kept as low as reasonably possible to reduce the risk of tissue damage and mutations.
5. Precautions include reducing exposure time, increasing distance, using appropriate shielding and handling sources remotely where possible.
6. Reducing exposure time reduces the number of radiation interactions with the body, so the absorbed dose and risk are reduced.

6.30P Explain how the dangers of ionising radiation depend on half-life and relate this to the precautions needed

1. A longer half-life means the radioactive material remains radioactive for a longer period, potentially extending the duration of the hazard.
2. A long-half-life source decays slowly, so significant activity can remain for a long time.
3. A short-half-life source can have a high initial activity because many nuclei decay rapidly in a short period.
4. Half-life affects handling and storage because it determines how long precautions may be required.
5. A long-half-life source may require secure storage and monitoring for many years or longer.
6. Knowledge of half-life helps determine how long the source must be shielded, isolated, monitored and safely stored.

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. Exposure must be limited because ionising radiation can damage tissue and cause mutations.
2. Exposure time can be reduced by planning procedures efficiently and spending as little time as possible near the source.
3. Increasing distance reduces exposure because radiation intensity generally decreases as distance from the source increases.
4. Shielding such as lead, concrete or other suitable materials absorbs or reduces radiation before it reaches people.
5. Patients should receive only the necessary dose because radiation exposure carries a risk of tissue damage and mutations.
6. Medical personnel may receive repeated exposure, so they minimise dose using time, distance and shielding precautions.

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

1. Radioactive contamination occurs when radioactive material gets onto or inside a person or object.
2. Irradiation is exposure to radiation from a source without necessarily receiving radioactive material.
3. Contamination involves radioactive material being present on or in something, whereas irradiation is exposure to radiation without the material necessarily being transferred.
4. Contamination can continue exposing a person because the radioactive material remains on or inside the body until removed or decayed.

5. Irradiation does not necessarily leave radioactive material on a person because the person has simply been exposed to radiation.
6. Contamination can be particularly difficult to remove when radioactive material has entered the body, whereas irradiation stops when the source is removed or exposure ends.

6.33P Compare and contrast the treatment of tumours using radiation applied internally or externally

1. External radiotherapy directs high-energy radiation from a source outside the body towards the tumour.
2. Internal radiotherapy places a radioactive source inside or close to the tumour.
3. External treatment can target a tumour from outside while allowing the radiation beam to be carefully directed and adjusted.
4. Internal treatment places the source close to the tumour, allowing a high dose to the tumour while reducing exposure to some surrounding tissue.
5. Healthy tissue must be protected because ionising radiation can damage normal cells as well as cancer cells.
6. The main difference is that external radiotherapy delivers radiation from outside the body, whereas internal radiotherapy places the radioactive source within or close to the tumour.

6.34P Explain some of the uses of radioactive substances in diagnosis of medical conditions, including PET scanners and tracers

1. A radioactive tracer is a small amount of radioactive substance introduced into the body so its movement or distribution can be detected.
2. Tracers are useful because their radiation can be detected from outside the body, allowing doctors to observe biological processes or organ function.
3. A PET scanner detects gamma photons produced following positron annihilation.
4. Radioactive substances are used in PET scans because positron-emitting tracers produce detectable radiation that allows images of activity inside the body to be produced.
5. Tracers can show organ or tissue function because they accumulate in or move through particular biological processes.
6. The tracer must be carefully selected so it has a suitable half-life, appropriate biological behaviour and suitable radiation for detection, while minimising dose.

6.35P Explain why isotopes used in PET scanners have to be produced nearby

1. PET isotopes need to be produced nearby because many have very short half-lives.
2. A short half-life means the isotope's activity falls rapidly during transportation.
3. Its activity decreases as radioactive nuclei decay while the isotope is being transported.
4. A very long transport time could cause much of the isotope to decay, leaving insufficient activity for a useful scan.
5. PET isotopes must therefore be produced shortly before they are needed.
6. Radioactive decay limits their useful lifetime because the activity falls exponentially with time, making the isotope less effective as a tracer.

6.36P Evaluate the advantages and disadvantages of nuclear power for generating electricity, including the lack of carbon dioxide emissions, risks, public perception, waste disposal and safety issues

1. Nuclear power produces very little carbon dioxide during electricity generation, helping reduce greenhouse gas emissions compared with fossil-fuel generation.
2. Radioactive waste remains hazardous and requires careful storage and long-term management.
3. Safety risks include radiation exposure and the possibility of serious accidents if systems fail or are poorly managed.
4. Public perception can affect nuclear development because concerns about accidents, radiation and radioactive waste can influence planning and acceptance.
5. Nuclear waste requires long-term management because some radioactive materials have long half-lives and remain hazardous for extended periods.
6. Nuclear power provides reliable low-carbon electricity but must be weighed against construction costs, radioactive waste, accident risks and decommissioning, while renewables have low operational emissions and no radioactive waste but may be intermittent.

6.37P Recall that nuclear reactions, including fission, fusion and radioactive decay, can be a source of energy

1. Nuclear fission is the splitting of a large atomic nucleus into smaller nuclei, releasing energy.
2. Nuclear fusion is the joining of smaller nuclei to form a larger nucleus, releasing energy.

3. Radioactive decay can release energy because an unstable nucleus changes into a more stable, lower-energy configuration.
4. Nuclear fusion powers stars.
5. Nuclear fission is used in current nuclear power stations.
6. Nuclear reactions can release large amounts of energy because changes in nuclear binding involve very large energy changes associated with small differences in mass.

6.38P Explain how the fission of U-235 produces two daughter nuclei and the emission of two or more neutrons, accompanied by a release of energy

1. A U-235 nucleus absorbs a neutron and becomes unstable before splitting into two smaller daughter nuclei.
2. In a reactor, U-235 can undergo fission after absorbing a neutron.
3. Fission produces two daughter nuclei, two or more neutrons and energy.
4. Typically, two or three neutrons are emitted in U-235 fission.
5. Energy is released because the total mass of the products is slightly less than the mass of the original system, with the mass difference converted to energy.
6. The emitted neutrons can be absorbed by other U-235 nuclei, causing further fission reactions.

6.39P Explain the principle of a controlled nuclear chain reaction

1. A nuclear chain reaction is a process in which neutrons released by one fission cause further fissions.
2. One fission releases neutrons, and these neutrons can cause other U-235 nuclei to undergo fission.
3. Neutrons are therefore responsible for initiating and sustaining successive fission reactions.
4. A controlled chain reaction is one in which the number of fissions per unit time is regulated so that energy is released at a controlled rate.
5. The rate must be controlled to maintain a steady energy output and prevent the reaction from increasing too rapidly.
6. If uncontrolled, the chain reaction could increase rapidly, causing a very large and potentially dangerous release of energy.

6.40P Explain how the chain reaction is controlled in a nuclear reactor, including the action of moderators and control rods

1. A moderator is used to slow down neutrons released during fission.
2. The moderator reduces neutron speed through collisions with nuclei in the moderator material.

3. Control rods absorb neutrons.
4. By absorbing neutrons, control rods reduce the number available to cause further fission and therefore control the chain reaction rate.
5. Inserting the control rods further absorbs more neutrons, so the chain reaction slows down.
6. The moderator helps produce neutrons with an appropriate speed for further fission, while control rods regulate the number of neutrons available, allowing the reaction to be maintained at a controlled rate.

6.41P Describe how thermal (heat) energy from the chain reaction is used in the generation of electricity in a nuclear power station

1. The chain reaction releases thermal energy.
2. Thermal energy is transferred to water or another coolant through heating in the reactor.
3. The heated water produces steam, either directly or through a heat exchanger.
4. The steam causes a turbine to rotate.
5. The rotating turbine has mechanical energy.
6. The turbine drives a generator, which converts mechanical energy into electrical energy.

6.42P Recall that the products of nuclear fission are radioactive

1. The daughter nuclei produced by fission are often radioactive and undergo further radioactive decay.
2. Many fission products are radioactive because the daughter nuclei have unstable combinations of protons and neutrons.
3. They require careful handling because they can emit ionising radiation.
4. Radioactive fission products can emit alpha, beta and gamma radiation, depending on the isotope.
5. Fission waste must be stored safely to prevent radiation exposure and contamination.
6. Their radioactivity generally decreases over time as unstable nuclei decay.

6.43P Describe nuclear fusion as the creation of larger nuclei resulting in a loss of mass from smaller nuclei, accompanied by a release of energy, and recognise fusion as the energy source for stars

1. Nuclear fusion is the joining of smaller atomic nuclei to form a larger nucleus.
2. Smaller nuclei combine to form a larger nucleus, releasing energy.

3. Mass is lost because the mass of the products is slightly less than the combined mass of the original nuclei.
4. The lost mass is converted into energy according to $E = mc^2$.
5. Fusion powers stars because hydrogen nuclei combine through nuclear fusion, releasing enormous amounts of energy.
6. In a star's core, high temperature and pressure allow nuclei to fuse, producing larger nuclei and releasing energy.

6.44P Explain the difference between nuclear fusion and nuclear fission

1. Fission splits a large nucleus, whereas fusion joins smaller nuclei.
2. During fission, a large nucleus breaks into two or more smaller nuclei.
3. During fusion, smaller nuclei combine to form a larger nucleus.
4. Fission produces daughter nuclei from a larger parent nucleus.
5. Fusion combines smaller nuclei to form a larger nucleus.
6. Both can release energy because the products have greater nuclear stability and a lower total mass than the initial nuclei, with the mass difference converted into energy.

6.45P Explain why nuclear fusion does not happen at low temperatures and pressures, due to electrostatic repulsion of protons

1. Positively charged nuclei repel one another because like electric charges repel.
2. Electrostatic repulsion is the force that pushes positively charged nuclei apart.
3. Nuclei need very high kinetic energies to get close enough for the strong nuclear force to overcome their electrostatic repulsion.
4. Increasing temperature increases the particles' average kinetic energy, allowing more nuclei to overcome the repulsion.
5. High pressure forces nuclei closer together, increasing the likelihood of collisions and fusion.
6. At low temperatures and pressures, nuclei generally do not have enough energy or proximity to overcome electrostatic repulsion, so fusion is extremely unlikely.

6.46P Relate the conditions for fusion to the difficulty of making a practical and economic form of power station

1. Extremely high temperatures are required to give nuclei enough kinetic energy to overcome electrostatic repulsion.

2. Maintaining such extreme temperatures, pressures and plasma conditions is technically difficult and requires advanced equipment.
3. The hot plasma must be kept away from reactor walls because the extremely high temperature could damage or melt the materials.
4. A practical power station must produce more usable energy than is required to heat, confine and sustain the fusion reaction.
5. Difficulties in maintaining fusion conditions increase the complexity, cost and engineering demands, which affects economic viability.
6. Achieving fusion experimentally is not enough; a practical power station must sustain the reaction reliably, safely and economically while producing a useful net energy output.

Topic 7 – Astronomy

7.1P Explain how and why both the weight of any body and the value of g differ between the surface of the Earth and the surface of other bodies in space, including the Moon

1. Weight depends on an object's mass and the gravitational field strength of the celestial body: W = m × g.
2. The value of g depends mainly on the mass and radius of the celestial body.
3. An object's weight is different on the Moon because the Moon has a weaker gravitational field than Earth.
4. The object's mass does not change when it is moved from Earth to the Moon.
5. W = m × g
   W = 6 × 1.6
   W = 9.6 N
6. The value of g differs because celestial bodies have different masses and sizes, producing different gravitational fields.

7.2P Recall that our Solar System consists of the Sun (our star), eight planets and their natural satellites (such as our Moon); dwarf planets; asteroids and comets

1. The Sun is at the centre of our Solar System.
2. There are eight planets in our Solar System.
3. A natural satellite is a naturally occurring object that orbits a planet or other larger body, such as the Moon orbiting Earth.

4. A dwarf planet is a roughly spherical object that orbits the Sun but has not cleared its orbital region of other objects.
5. Asteroids are rocky objects that orbit the Sun.
6. Comets are bodies made mainly of ice and dust that orbit the Sun, often in elongated orbits.

7.3P Recall the names and order, in terms of distance from the Sun, of the eight planets

1. Mercury is the closest planet to the Sun.
2. Venus is the second planet from the Sun.
3. Earth is the third planet from the Sun.
4. Mars is the fourth planet from the Sun.
5. Jupiter is the fifth planet from the Sun.
6. The planets in order of increasing distance from the Sun are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune.

7.4P Describe how ideas about the structure of the Solar System have changed over time

1. The geocentric model proposed that Earth was at the centre of the Universe and that the Sun and planets moved around Earth.
2. The heliocentric model proposed that the Sun is at the centre of the Solar System and that the planets orbit the Sun.
3. Nicolaus Copernicus is strongly associated with the development of the heliocentric model.
4. The main difference is that the geocentric model places Earth at the centre, while the heliocentric model places the Sun at the centre of the Solar System.
5. Observations of planetary motion provided evidence that improved models of the Solar System.
6. Scientific models can change when new experimental or observational evidence shows that an existing model is incomplete or incorrect.

7.5P Describe the orbits of moons, planets, comets and artificial satellites

1. Gravity provides the force that keeps moons, planets, comets and artificial satellites in orbit.
2. A planet follows an approximately elliptical orbit around the Sun.
3. A moon is a natural satellite that orbits a planet or other larger body.
4. An artificial satellite can have an elliptical or approximately circular orbit around Earth.

5. A comet usually follows a highly elongated elliptical orbit compared with the nearly circular orbits of many planets.
6. An orbiting object continually changes direction because the gravitational force acts towards the central body.

7.6P Explain for circular orbits how the force of gravity can lead to changing velocity of a planet but unchanged speed

1. Gravity provides the centripetal force that keeps a planet in a circular orbit around the Sun.
2. The gravitational force acts towards the centre of the circular orbit, approximately towards the Sun.
3. The velocity changes because velocity includes both speed and direction, and the direction continually changes.
4. The speed can remain constant because the gravitational force acts perpendicular to the instantaneous direction of motion in a circular orbit.
5. The direction of velocity changes while its magnitude, the speed, remains constant.
6. An object moving at constant speed around a circle is accelerating because its velocity is continually changing direction.

7.7P Explain how, for a stable orbit, the radius must change if orbital speed changes (qualitative only)

1. For a stable circular orbit, increasing orbital speed requires a smaller orbital radius.
2. For a stable circular orbit, decreasing orbital speed requires a larger orbital radius.
3. The radius must change because the gravitational force available to provide the required centripetal force depends on distance from the central body.
4. Gravitational force decreases as the distance from the central body increases.
5. Orbital speed and radius are linked because both determine the centripetal force needed for a stable orbit.
6. Qualitatively, a higher orbital speed corresponds to a smaller stable circular orbital radius.

7.8P Compare the Steady State and Big Bang theories

1. The Big Bang theory proposes that the Universe began in an extremely hot, dense state and has expanded over time.

2. The Steady State theory proposes that the Universe has always existed and, although it expands, its overall appearance remains constant because new matter is continuously created.
3. The Big Bang theory proposes that the Universe was much hotter and denser in the past and has become less dense as it expanded.
4. The Steady State theory proposes an eternal Universe with no unique beginning.
5. The main difference is that the Big Bang describes an evolving Universe with a hot, dense beginning, whereas the Steady State theory describes an eternal Universe with a constant overall appearance.
6. The Big Bang theory proposes that the Universe has changed significantly from a much hotter, denser early state.

7.9P Describe evidence supporting the Big Bang theory, limited to red-shift and the cosmic microwave background (CMB) radiation

1. Red-shift is the increase in the observed wavelength of light from an object moving away from an observer.
2. The red-shift of distant galaxies shows that many galaxies are moving away from Earth, providing evidence that the Universe is expanding.
3. Cosmic microwave background radiation is weak microwave radiation detected throughout the Universe.
4. The CMB is evidence for the Big Bang because it is radiation left over from the hot, dense early Universe.
5. The CMB suggests that the early Universe was much hotter and denser than it is today.
6. Red-shift provides evidence that the Universe is expanding, while the CMB provides evidence of a hot, dense early Universe; together they strongly support the Big Bang theory.

7.10P Recall that as there is more evidence supporting the Big Bang theory than the Steady State theory, it is the currently accepted model for the origin of the Universe

1. The Big Bang theory is the currently accepted model for the origin and evolution of the Universe.
2. It is accepted because there is more supporting evidence for it than for the Steady State theory.
3. Important evidence includes the red-shift of galaxies and cosmic microwave background radiation.
4. The Steady State theory is no longer the accepted model because it does not explain the evidence as successfully as the Big Bang theory.
5. Scientific evidence can cause theories to become accepted, rejected or modified.

6. The Big Bang being the accepted model means that it currently provides the best-supported scientific explanation of the origin and evolution of the Universe.

7.11P Describe that if a wave source is moving relative to an observer there will be a change in the observed frequency and wavelength

1. When a wave source moves towards an observer, the observed frequency increases.
2. When a wave source moves away from an observer, the observed frequency decreases.
3. When a source moves towards an observer, the observed wavelength decreases.
4. When a source moves away from an observer, the observed wavelength increases.
5. The relative motion of the source and observer changes the frequency and wavelength measured by the observer.
6. This change in observed frequency caused by relative motion is called the Doppler effect.

7.12P Describe the red-shift in light received from galaxies at different distances away from the Earth

1. Red-shift is the increase in the observed wavelength of light from a source moving away from the observer.
2. The wavelength of light from a red-shifted galaxy is increased.
3. More distant galaxies generally show greater red-shifts.
4. A greater red-shift indicates that the galaxy is moving away from Earth at a greater speed.
5. Light from distant galaxies is often red-shifted because the galaxies are moving away as the Universe expands.
6. Measuring red-shift allows astronomers to investigate the relative motion of galaxies and estimate their recession speeds.

7.13P Explain why the red-shift of galaxies provides evidence for the Universe expanding

1. Red-shift indicates that galaxies are generally moving away from Earth.
2. Light from a galaxy moving away from Earth has an increased observed wavelength, producing red-shift.
3. The widespread red-shift of galaxies suggests that space is expanding and galaxies are generally moving apart.

4. The greater red-shift of more distant galaxies supports the relationship between distance and recession speed expected for an expanding Universe.
5. A completely static Universe would not naturally explain the widespread pattern of galaxy red-shifts.
6. The red-shift of many galaxies across different directions provides evidence for overall expansion rather than simply the motion of one individual galaxy.

7.14P Explain how both the Big Bang and Steady State theories of the origin of the Universe both account for red-shift of galaxies

1. The Big Bang theory explains galaxy red-shift as evidence that the Universe has expanded from an earlier, hotter and denser state.
2. The Steady State theory also allows an expanding Universe, so it can account for the observed red-shift of galaxies.
3. Both theories can therefore explain the observation that distant galaxies are generally red-shifted.
4. Red-shift alone cannot completely distinguish between the Big Bang and Steady State theories because both can account for an expanding Universe.
5. The cosmic microwave background provides additional evidence that strongly supports the Big Bang theory.
6. The Big Bang describes a Universe that evolved from a hot, dense beginning, whereas the Steady State theory proposes an eternal Universe with a constant overall appearance.

7.15P Explain how the discovery of the CMB radiation led to the Big Bang theory becoming the currently accepted model

1. The CMB is weak microwave radiation detected throughout the Universe.
2. Its discovery provided important evidence about the conditions of the early Universe.
3. The CMB is consistent with radiation left over from a very hot, dense early Universe.
4. The CMB strongly supports the Big Bang because the Steady State theory does not naturally predict this relic radiation from a hot, dense beginning.
5. The discovery caused scientists to favour the Big Bang model over the Steady State model.
6. The CMB, together with galaxy red-shift, provided strong evidence that contributed to the Big Bang becoming the accepted model.

7.16P Describe the evolution of stars of similar mass to the Sun through the following stages: a nebula b star (main sequence) c red giant d white dwarf

1. A nebula is a large cloud of gas and dust in space.
2. Gravity causes material in a nebula to come together and form a protostar, which can develop into a star.
3. A main-sequence star is a stable star in which nuclear fusion provides energy while gravity is balanced by outward pressure.
4. After the main sequence, a Sun-like star expands and becomes a red giant.
5. The outer layers are eventually lost, leaving behind a hot, dense white dwarf.
6. The sequence is nebula → main-sequence star → red giant → white dwarf.

7.17P Explain how the balance between thermal expansion and gravity affects the life cycle of stars

1. Gravity pulls the material of a star inward and tends to make the star contract.
2. Energy released by nuclear fusion heats the star, producing outward thermal pressure that tends to make it expand.
3. When gravity and outward thermal pressure are balanced, the star remains stable.
4. If gravity becomes greater than the outward pressure, the star contracts.
5. Changes in the balance between gravity and thermal pressure cause the star to change size and evolve.
6. The balance between inward gravity and outward thermal pressure controls the stability and changes that occur during a star's life cycle.

7.18P Describe the evolution of stars with a mass larger than the Sun

1. A massive star forms from a nebula and undergoes a main-sequence stage, but it uses its nuclear fuel more rapidly than a Sun-like star.
2. After the main sequence, a massive star becomes a red supergiant and undergoes further nuclear fusion reactions.
3. A supernova is a powerful explosion in which a massive star's outer layers are violently expelled.
4. A neutron star or black hole can remain after a massive star undergoes a supernova.
5. A neutron star can form when the core of a massive star collapses and becomes extremely dense.
6. If the remaining core is sufficiently massive, its gravity can cause it to collapse into a black hole.

7.19P Describe how methods of observing the Universe have changed over time including why some telescopes are located outside the Earth's atmosphere

1. Astronomical observations have developed from observations with the naked eye to increasingly powerful ground-based and space-based telescopes.
2. Modern telescopes can detect many regions of the electromagnetic spectrum, not just visible light.
3. Earth's atmosphere can absorb or scatter some electromagnetic radiation and can distort visible-light observations.
4. Some telescopes are placed above Earth's atmosphere to avoid atmospheric absorption, scattering and distortion.
5. Space telescopes can produce clearer observations and detect wavelengths that cannot pass effectively through the atmosphere.
6. Different telescopes are used because different wavelengths provide different information about astronomical objects.

Topic 8 – Energy – forces doing work

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

1. When a system changes, energy is transferred between different energy stores.
2. Raising an object increases its gravitational potential energy store.
3. Increasing an object's speed increases its kinetic energy store.
4. When a moving object slows down, its kinetic energy store decreases.
5. Energy can be transferred mechanically, electrically, by heating or by radiation between different energy stores.
6. The total energy of a closed system remains constant during a change.

8.2 Draw and interpret diagrams to represent energy transfers

1. An energy transfer diagram represents how energy moves between different energy stores in a system.
2. It can show the energy store at the start, the transfers taking place and the energy stores at the end.
3. The width of an arrow can represent the relative amount of energy being transferred.
4. Dissipated energy can be shown as energy transferred to the thermal energy store of the surroundings.

5. A battery powering an electric motor can be represented as: chemical energy store → electrical transfer → kinetic energy store + thermal energy store.
6. Chemical energy transferred into kinetic energy and thermal energy means that the chemical energy store decreases while kinetic and thermal energy stores increase.

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 closed system is a system in which energy cannot enter or leave the system.
2. The total energy of a closed system remains constant when energy is transferred between stores.
3. Energy is not destroyed during a transfer; it is transferred between stores or to the surroundings.
4. If 500 J is transferred between stores within a closed system, the total energy lost from the system is 0 J.
5. The system still contains 2,000 J of total energy because internal transfers do not change the total energy.
6. Conservation of energy means that the total energy before a change equals the total energy after the change in a closed system.

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 changes the energy stores of a system by mechanical transfer.
2. Electrical equipment transfers energy electrically into different energy stores.
3. Heating transfers energy from a hotter object or source to a cooler system.
4. When a force accelerates an object, energy is transferred to its kinetic energy store.
5. When an electric heater heats water, electrical energy is transferred to the thermal energy store of the water and surroundings.
6. When an object is heated by a flame, energy is transferred by heating from the flame to the object's thermal energy store.

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. Work done can be measured by multiplying the force by the distance moved in the direction of the force.
2. The force and the distance moved in the direction of the force are needed to calculate work done.
3. The unit of work done is the joule, J.
4. Energy transferred is equal to the work done, so both are measured in joules.
5. Energy transferred = work done = 250 J.
6. Work done is an energy transfer because a force transfers energy when it moves an object through a distance.

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 × d

1. The equation is $E = F \times d$.
2. Work done or energy transferred is measured in joules, J.
3. $E = F \times d$
   $E = 20 \times 5$
   $E = 100$ J
4. $E = F \times d$
   $600 = 150 \times d$
   $d = 600 \div 150$
   $d = 4$ m
5. $E = F \times d$
   $E = 40 \times 8$
   $E = 320$ J
6. $E = F \times d$
   $900 = F \times 3$
   $F = 900 \div 3$
   $F = 300$ N

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

1. Work done by a force transfers energy into or out of a system.
2. A resultant force that accelerates an object increases its kinetic energy store.
3. Work done to raise an object increases its gravitational potential energy store.
4. $E = F \times d$
   $E = 50 \times 6$
   $E = 300$ J

5. $\Delta GPE = m \times g \times \Delta h$
   $\Delta GPE = 4 \times 10 \times 5$
   $\Delta GPE = 200$ J
6. $KE = 1/2 \times m \times v^2$
   $KE = 1/2 \times 2 \times 10^2$
   $KE = 1 \times 100$
   $KE = 100$ J

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. The equation is $\Delta GPE = m \times g \times \Delta h$.
2. Gravitational potential energy increases when an object is raised.
3. $\Delta GPE = m \times g \times \Delta h$
   $\Delta GPE = 5 \times 10 \times 4$
   $\Delta GPE = 200$ J
4. $\Delta GPE = m \times g \times \Delta h$
   $120 = 2 \times g \times 6$
   $120 = 12g$
   $g = 120 \div 12$
   $g = 10$ N/kg
5. $\Delta GPE = m \times g \times \Delta h$
   $500 = m \times 10 \times 5$
   $500 = 50m$
   $m = 500 \div 50$
   $m = 10$ kg
6. $\Delta GPE = m \times g \times \Delta h$
   $\Delta GPE = 10 \times 8 \times 3$
   $\Delta GPE = 240$ J

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) × (speed)² ((metre/second)², (m/s)²) $KE = 1/2 \times m \times v^2$

1. The equation is $KE = 1/2 \times m \times v^2$.
2. Kinetic energy increases with the square of speed.
3. $KE = 1/2 \times m \times v^2$
   $KE = 1/2 \times 4 \times 5^2$
   $KE = 2 \times 25$
   $KE = 50$ J

4. $KE = 1/2 \times m \times v^2$
   $100 = 1/2 \times 2 \times v^2$
   $100 = v^2$
   $v = \sqrt{100}$
   $v = 10$ m/s
5. $KE = 1/2 \times m \times v^2$
   $KE = 1/2 \times 10 \times 8^2$
   $KE = 5 \times 64$
   $KE = 320$ J
6. If speed doubles, kinetic energy increases by a factor of 4 because KE is proportional to v^2.

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 dissipated when it is transferred to stores that are less useful for doing useful work, usually the thermal energy store of the surroundings.
2. Dissipated energy is less useful because it becomes spread out in the surroundings and is harder to transfer into useful forms.
3. When a car brakes, friction transfers kinetic energy to the thermal energy stores of the brakes, tyres, road and surroundings.
4. When an object slides across a rough surface, friction transfers kinetic energy to thermal energy stores.
5. Friction causes energy to be transferred from useful stores into thermal energy stores of the objects and surroundings.
6. A moving bicycle braking is an example where energy is transferred to the thermal energy store of the surroundings.

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

1. Friction transfers useful mechanical energy to thermal energy, making the process less efficient.
2. When friction causes surfaces to heat up, mechanical energy is transferred to their thermal energy stores.
3. Heating the surroundings is considered wasteful when the thermal energy is not useful for the intended purpose.
4. Friction reduces the efficiency of a mechanical system by dissipating some of the input energy.
5. The temperature of surfaces increases when mechanical energy is transferred to their thermal energy stores.
6. A rise in temperature shows that energy has been transferred into thermal energy stores, indicating energy dissipation.

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

1. Power is the rate at which energy is transferred.
2. The rate of energy transfer describes how much energy is transferred per unit time.
3. A 1,000 W device transfers energy more quickly than a 500 W device.
4. The machine that transfers the same amount of energy in less time has the greater power.
5. A high-power appliance transfers more energy each second than a low-power appliance.
6. An electrical appliance rated at 1 W transfers 1 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 ÷ t

1. The equation is P = E ÷ t.
2. Power is measured in watts, W; energy or work done is measured in joules, J; time is measured in seconds, s.
3. P = E ÷ t
   P = 6,000 ÷ 20
   P = 300 W
4. P = E ÷ t
   500 = E ÷ 30
   E = 500 × 30
   E = 15,000 J
5. P = E ÷ t
   600 = 12,000 ÷ t
   t = 12,000 ÷ 600
   t = 20 s
6. P = E ÷ t
   P = 9,000 ÷ 15
   P = 600 W

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

1. One watt is equal to one joule per second: 1 W = 1 J/s.
2. A power rating of 1 W means that 1 J of energy is transferred every second.
3. Energy transferred each second = 100 J.
4. Energy transferred = 2,000 J.
5. P = E ÷ t
   P = 500 ÷ 1
   P = 500 W

6. E = P × t
   E = 60 × 10
   E = 600 J

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

1. The equation is efficiency = useful energy transferred ÷ total energy supplied.
2. Efficiency is between 0 and 1 for a real device and can be expressed as a percentage by multiplying by 100.
3. Efficiency = useful energy ÷ total energy
   Efficiency = 400 ÷ 500
   Efficiency = 0.8
   Efficiency = 80%
4. Efficiency = useful energy ÷ total energy
   0.8 = useful energy ÷ 2,000
   Useful energy = 0.8 × 2,000
   Useful energy = 1,600 J
5. Efficiency = useful energy ÷ total energy
   Efficiency = 600 ÷ 1,000
   Efficiency = 0.6
   Efficiency = 60%
6. Efficiency = useful energy ÷ total energy
   0.75 = useful energy ÷ 4,000
   Useful energy = 0.75 × 4,000
   Useful energy = 3,000 J

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 can act between objects without physical contact.
2. A gravitational field allows masses to attract each other at a distance.
3. An electrostatic field allows charged objects to exert forces on each other at a distance; like charges repel and unlike charges attract.

4. Normal contact force and friction are contact forces because they act between objects that are touching.
5. When two objects interact, each object exerts a force on the other; the forces are equal in size and opposite in direction.
6. Forces can be represented as vectors using arrows, with the direction of the arrow showing the direction of the force and the length representing its magnitude to a chosen scale.

9.2 Explain the difference between vector and scalar quantities using examples

1. A scalar quantity has magnitude only.
2. A vector quantity has both magnitude and direction.
3. A scalar gives the size of a quantity, whereas a vector gives both the size and direction.
4. Speed is a scalar quantity.
5. Velocity is a vector quantity.
6. A force of 10 N acting to the right can be represented by an arrow pointing to the right, with its length representing 10 N on a chosen scale.

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

1. Resolution of a force is the process of representing one force as two or more component forces acting in different directions.
2. The net force is the resultant force obtained by combining all the forces acting on an object.
3. A vector diagram can show the resultant force by combining the force vectors according to their magnitudes and directions.
4. When forces are in equilibrium, the vectors balance so that the resultant force is zero.
5. Resultant = $\sqrt{(3^2 + 4^2)}$
   Resultant = $\sqrt{(9 + 16)}$
   Resultant = $\sqrt{25}$
   Resultant = 5 N
6. Draw the force vectors to a suitable scale and in their correct directions, complete the vector triangle or parallelogram, and measure the resultant using the same scale.

9.4 Draw and use free body force diagrams

1. A free body force diagram shows all the external forces acting on an object using labelled arrows.
2. Each arrow represents one force acting on the object.

3. The arrow points in the direction in which the force acts.
4. A falling object normally has weight acting downward and air resistance acting upward.
5. An object resting on a horizontal surface has weight acting downward and normal contact force acting upward.
6. The forces shown on a free body diagram can be combined to determine the resultant force acting on the object.

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 resultant force is the single force that has the same effect on an object's motion as all the forces acting together.
2. If the resultant force is zero, the object is in equilibrium and remains stationary or continues moving at constant velocity.
3. Balanced forces are forces that combine to give a resultant force of zero.
4. Resultant force = 15 N − 9 N
   Resultant force = 6 N to the right
5. Resultant force = 20 N − 20 N
   Resultant force = 0 N
6. A resultant force can change an object's velocity by causing it to accelerate, decelerate or change direction.

9.6P Describe situations where forces can cause rotation

1. A force can cause an object to rotate when it acts at a distance from a pivot or axis of rotation.
2. The effectiveness of a force at causing rotation depends on the size of the force and its perpendicular distance from the pivot.
3. Pushing a door near its handle produces more rotation because the force acts further from the hinges, giving a greater moment.
4. Pushing a spanner causes it to rotate around the bolt because the force acts at a distance from the pivot.
5. A force acting at a greater perpendicular distance from a pivot produces a greater turning effect.
6. The position of the pivot affects the rotational effect because it changes the perpendicular distance between the force and the pivot.

9.7P Recall and use the equation: moment of a force (newton metre, N m) = force (newton, N) × distance normal to the direction of the force (metre, m)

1. Moment = force × perpendicular distance from the pivot
2. The unit of moment is the newton metre (N m).
3. The perpendicular distance is the shortest distance from the pivot to the line of action of the force.
4. Moment = F × d
   Moment = 20 × 0.5
   Moment = 10 N m
5. Moment = F × d
   60 = F × 0.3
   F = 60 ÷ 0.3
   F = 200 N
6. Moment = F × d
   45 = 15 × d
   d = 45 ÷ 15
   d = 3 m

9.8P Recall and use the principle of moments in situations where rotational forces are in equilibrium: the sum of clockwise moments = the sum of anti-clockwise moments for rotational forces in equilibrium

1. For rotational equilibrium, the sum of clockwise moments equals the sum of anti-clockwise moments.
2. Total clockwise moment = total anti-clockwise moment.
3. Moment = F × d
   Moment = 10 × 2
   Moment = 20 N m
   Therefore, an anti-clockwise moment of 20 N m is needed.
4. Clockwise moment = anti-clockwise moment
   30 × 0.4 = F × 0.6
   12 = 0.6F
   F = 12 ÷ 0.6
   F = 20 N
5. Moment = F × d
   80 = 20 × d
   d = 80 ÷ 20
   d = 4 m
6. The object remains rotationally stationary because the equal clockwise and anti-clockwise moments cancel, giving a resultant moment of zero.

9.9P Explain how levers and gears transmit the rotational effects of forces

1. A lever is a rigid object that rotates about a pivot when a force is applied.
2. A lever transmits the turning effect of a force from one point to another around a pivot.
3. Gears transmit rotational motion and can change the speed, direction and turning effect of the rotation.
4. Changing the sizes of gears changes the rotational speed; a larger driven gear rotates more slowly than a smaller driven gear.
5. Gears can increase or decrease the torque transmitted by changing the gear sizes.
6. A longer lever gives a greater perpendicular distance from the pivot, producing a greater moment for the same force.

9.10 Explain ways of reducing unwanted energy transfer through lubrication

1. Friction causes unwanted energy transfer from useful mechanical energy to thermal energy.
2. Lubrication reduces friction by forming a layer between moving surfaces, reducing direct contact between them.
3. Much of the unwanted energy becomes thermal energy in the surfaces and surroundings.
4. Lubrication can increase efficiency because less energy is dissipated through friction.
5. Reducing friction decreases the amount of thermal energy transferred to the surroundings.
6. Lubricating the moving parts of an engine can reduce friction and unwanted energy transfer.

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 are outside the nucleus in electron shells.
2. The relative charge of a proton is +1.
3. The relative charge of a neutron is 0.
4. The relative charge of an electron is −1.
5. Protons and neutrons have approximately equal masses.
6. The electron has a much smaller mass than a proton or neutron.

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 two parallel lines, one longer than the other. The longer line is the positive terminal.
2. A battery is represented by two or more cells connected together.
3. An ammeter is represented by a circle containing A.
4. A voltmeter is represented by a circle containing V.
5. A variable resistor is represented by a resistor with a diagonal arrow through it. A thermistor is represented by a resistor with a diagonal line through it. An LDR is represented by a resistor with arrows pointing towards it.
6. A diode is represented by a triangle-like diode symbol with a line at one end. An LED is a diode symbol with arrows pointing outwards. A lamp is represented by a circle containing a cross. A motor is represented by a circle containing M.

10.3 Describe the differences between series and parallel circuits

1. A series circuit has components connected in a single loop, so there is only one path for current.
2. A parallel circuit has components connected in separate branches, providing more than one path for current.
3. In a series circuit, current has only one path. In a parallel circuit, current can split between different branches.
4. The total current entering a junction equals the total current leaving the junction.
5. If one component breaks, the circuit is broken and current stops everywhere in the series circuit.
6. Components in a parallel circuit can operate independently because each branch provides a separate path 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. A voltmeter is connected in parallel with the component.
2. A voltmeter measures potential difference.
3. The unit of potential difference is the volt (V).

4. It must be connected in parallel so that it measures the potential difference across the component.
5. It should be connected across the two terminals of the resistor.
6. If connected in series, the voltmeter would greatly reduce the current because it has a very high resistance, giving an incorrect measurement.

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. Potential difference measures the energy transferred per unit charge.
2. Potential difference is related to energy transferred and charge by:

V = E / Q

3. A potential difference of 1 V means that 1 J of energy is transferred for every 1 C of charge.
4. 1 V = 1 J/C.
5. V = E / Q

V = 20 J / 5 C

V = 4 V

Answer: 4 V

6. Q = E / V

Q = 60 J / 12 V

Q = 5 C

Answer: 5 C

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

1. E = Q × V
2. E = Q × V

E = 4 C × 12 V

E = 48 J

Answer: 48 J

3. V = E / Q

V = 240 J / 10 C

V = 24 V

Answer: 24 V

4. Q = E / V

Q = 180 J / 9 V

Q = 20 C

Answer: 20 C

5. E = Q × V

E = 2.5 C × 6 V

E = 15 J

Answer: 15 J

6. V = E / Q

V = 1,200 J / 100 C

V = 12 V

Answer: 12 V

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

1. An ammeter is connected in series with the component.
2. An ammeter measures current.
3. The unit of current is the ampere (A).
4. It must be connected in series so that the same current flowing through the component flows through the ammeter.
5. It should be placed anywhere in series with the lamp.
6. Connecting an ammeter in parallel would provide a very low-resistance path and could cause a very large current to flow, potentially damaging the ammeter or 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 electric charge.
2. The rate of flow of charge describes how much charge passes a point per unit time.
3. Electrons carry electric charge through metals.
4. Electrons move from the negative terminal towards the positive terminal.
5. The current increases because the same amount of charge passes the point in a shorter time.
6. Current is the rate at which charge flows, whereas charge is the amount of electric charge transferred.

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

1. Q = I × t
2. Q = I × t

Q = 3 A × 20 s

Q = 60 C

Answer: 60 C

3. Q = I × t

Q = 0.5 A × 60 s

Q = 30 C

Answer: 30 C

4. I = Q / t

I = 240 C / 30 s

I = 8 A

Answer: 8 A

5. t = Q / I

t = 500 C / 2 A

t = 250 s

Answer: 250 s

6. Q = I × t

Q = 12 A × 5 s

Q = 60 C

Answer: 60 C

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

1. A complete closed circuit and a source of potential difference are required for continuous current to flow.
2. A closed circuit provides a complete path for charge to flow around.
3. A cell or battery provides the potential difference that drives charge around the circuit.
4. When a switch is opened, the circuit is broken and the current stops.
5. A current flows through the circuit.
6. A broken wire creates a gap in the circuit, 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. The current entering a parallel circuit is equal to the sum of the currents in the branches.
3. Current leaving the other branch = 5 A − 2 A

Current = 3 A

Answer: 3 A

4. Other current = 6 A − 2 A

Other current = 4 A

Answer: 4 A

5. Charge cannot be created or destroyed at the junction, so the rate of charge flow entering must equal the rate leaving.
6. Add the known branch currents and set their total equal to the current entering the junction, then rearrange to find the unknown current.

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

1. Current decreases when resistance increases while potential difference remains constant.
2. Current increases when resistance decreases while potential difference remains constant.
3. A variable resistor changes the resistance by changing the length of resistive material through which the current flows.
4. Changing the resistance changes the current for a fixed potential difference.
5. From:

$V = I \times R$

$I = V / R$

If R is doubled while V remains constant, the current is halved.

6. Connect a variable resistor in series with the component, vary its resistance, and measure the current for a fixed potential difference. The results can then be used to investigate the relationship between resistance and current.

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. $V = I \times R$

$V = 2\text{ A} \times 6\ \Omega$

$V = 12\text{ V}$

Answer: 12 V

3. $R = V / I$

$R = 12\text{ V} / 3\text{ A}$

$R = 4\ \Omega$

Answer: 4 Ω

4. $I = V / R$

I = 100 V / 20 Ω

I = 5 A

Answer: 5 A

5. V = I × R

V = 0.5 A × 16 Ω

V = 8 V

Answer: 8 V

6. Current decreases because current is inversely proportional to resistance when potential difference is constant.

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. Adding a resistor in series increases the total resistance because the current has to pass through both resistors.
2. The total resistance decreases when resistors are connected in parallel.
3. A parallel arrangement provides additional paths for current, making it easier for charge to flow.
4. R_total = R_1 + R_2

R_total = 5 Ω + 5 Ω

R_total = 10 Ω

Answer: 10 Ω

5. Their total resistance is less than 10 Ω.
6. The current has more than one path through the circuit, so the overall opposition to current flow is reduced below the resistance of either individual resistor.

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

1. The current is the same at every point in a series circuit.

2. The total potential difference is shared between the components, with the potential differences across the components adding to the supply potential difference.
3. $R_{total} = R_1 + R_2$

$R_{total} = 4\ \Omega + 6\ \Omega$

$R_{total} = 10\ \Omega$

Answer: 10 Ω

4. $R_{total} = 2\ \Omega + 4\ \Omega$

$R_{total} = 6\ \Omega$

$V = I \times R$

$I = V / R$

$I = 12\ V / 6\ \Omega$

$I = 2\ A$

Answer: 2 A

5. $R_{total} = V / I$

$R_{total} = 10\ V / 2\ A$

$R_{total} = 5\ \Omega$

$R_{unknown} = R_{total} - 3\ \Omega$

$R_{unknown} = 5\ \Omega - 3\ \Omega$

$R_{unknown} = 2\ \Omega$

Answer: 2 Ω

6. $V = I \times R$

$V = 0.5\ A \times 20\ \Omega$

$V = 10\ V$

Answer: 10 V

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

1. Components are connected in series when measuring current because the same current flows through every component in a series circuit.
2. The ammeter should be placed in series with the component being tested.
3. The voltmeter should be connected in parallel across the component.
4. A switch allows the circuit to be disconnected when measurements are not being taken and helps prevent unnecessary heating or damage.
5. A variable resistor allows the current and potential difference to be varied safely during testing.
6. The potential difference across the component and the current through it are needed.

R = V / I

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 component to a power supply with an ammeter in series and a voltmeter in parallel across the component. Vary the potential difference and record the current.
2. The ammeter is connected in series and the voltmeter is connected in parallel across the component.
3. Measure the potential difference and current, then calculate:

R = V / I

4. Increase the potential difference and measure the current. A fixed resistor has an approximately constant resistance at constant temperature, whereas a filament lamp's resistance increases as its temperature rises.
5. Measure the current and potential difference in the series and parallel circuits and compare the behaviour of the components.
6. Repeated measurements improve reliability and allow anomalous results to be identified.

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. For a fixed resistor at constant temperature, current is directly proportional to potential difference.
2. The filament gets hotter as potential difference increases, causing its resistance to increase.
3. Heating increases the resistance of the filament.
4. When forward biased, a diode has very little current below its threshold potential difference, then the current increases rapidly once the threshold is reached.
5. When reverse biased, a diode has a very high resistance, so almost no current flows.
6. A straight line through the origin on a current-potential difference graph indicates constant resistance. A changing gradient indicates changing resistance.

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

1. The resistance of an LDR decreases when light intensity increases.
2. The resistance of an LDR increases when light intensity decreases.
3. An LDR can be used as a light sensor because its resistance changes with light intensity.
4. An LDR can be incorporated into a circuit so that its increased resistance in darkness changes the potential difference or current in a control circuit, allowing a switch to activate.
5. The current increases because:

$I = V / R$

A decrease in resistance causes an increase in current when potential difference is constant.

6. Increasing light intensity decreases the resistance of an LDR.

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

1. The resistance of an NTC thermistor decreases when temperature increases.
2. The resistance increases when temperature decreases.
3. NTC means negative temperature coefficient.
4. An NTC thermistor can be used as a temperature sensor because its resistance changes with temperature.
5. The current increases because the resistance decreases while potential difference remains constant.

6. An NTC thermistor can be incorporated into a circuit so that a change in temperature changes the current or potential difference, allowing a temperature-sensitive circuit to respond.

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. Measure the potential difference across the device and the current through it, then calculate:

R = V / I

Repeat for different conditions.

2. Use a variable resistor to vary the current through the filament lamp and measure the potential difference and current. Calculate resistance for each pair of readings.
3. Measure current for different potential differences with the diode connected in the forward and reverse directions.
4. Vary the temperature of the thermistor and measure the potential difference and current. Calculate its resistance for each temperature.
5. Vary the light intensity reaching the LDR and measure the potential difference and current. Calculate its resistance for each light intensity.
6. A graph of potential difference against current can show whether the resistance is constant. A changing gradient indicates that resistance varies.

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

1. Electrical energy is transferred to the thermal energy store of the resistor.
2. The thermal energy store increases.
3. Electrical energy is transferred to thermal energy as current flows through the resistance.
4. The temperature of the resistor increases.
5. Electrical energy is transferred to thermal energy.
6. An electric heater is one useful example of the heating effect of a resistor.

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

1. Electrical energy is transferred to thermal energy when current encounters resistance.
2. Dissipated means energy is transferred to the surroundings, usually as thermal energy, so it is no longer usefully available for the intended purpose.
3. The resistor transfers thermal energy to the surroundings because it becomes heated by the electrical current.
4. Resistance causes electrical energy to be transferred to thermal energy in wires and components.
5. Electrons collide with particles in the material, transferring electrical energy to thermal energy.
6. Unwanted resistance causes useful electrical energy to be transferred as heat, reducing the efficiency of the system.

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 move through the metal when an electric current flows.
2. Positive ions form the lattice in a metal.
3. Electrons collide with ions in the metal lattice and transfer energy to them.
4. The collisions transfer electrical energy to the ions, increasing their vibrations and therefore increasing the thermal energy of the material.
5. Electrical energy is transferred to the thermal energy store through collisions between electrons and ions.
6. Greater resistance causes more energy to be dissipated as thermal energy for a given current.

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

1. Electrical resistance causes electrical energy to be transferred to thermal energy.
2. Low-resistance wires reduce the amount of electrical energy dissipated as heat.
3. Thick wires generally have lower resistance because they have a larger cross-sectional area.
4. Low-resistance wires reduce energy losses when transmitting electrical energy over long distances.
5. Reducing resistance reduces the amount of electrical energy dissipated as thermal energy.
6. Low-resistance materials are used in electrical cables to minimise unwanted heating and energy loss.

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

1. One useful application is an electric heater.
2. An electric kettle uses the heating effect to transfer electrical energy to thermal energy, heating the water.
3. An electric heater uses resistance to transfer electrical energy to thermal energy, heating the surroundings.
4. Heating can be unwanted because it transfers energy away from the intended useful output.
5. Unwanted heating can cause cables to become hot and can waste electrical energy.
6. The advantage is that electrical resistance can be used to produce useful heating. The disadvantage is that unwanted resistance causes energy loss and heating.

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. $E = I \times V \times t$

$E = 2\ A \times 12\ V \times 30\ s$

$E = 720\ J$

Answer: 720 J

3. $E = I \times V \times t$

$E = 5\ A \times 20\ V \times 10\ s$

$E = 1{,}000\ J$

Answer: 1,000 J

4. $t = E / (I \times V)$

$t = 6{,}000\ J / (5\ A \times 20\ V)$

$t = 6{,}000 / 100$

$t = 60\ s$

Answer: 60 s

5. $I = E / (V \times t)$

$I = 2{,}400\ J / (12\ V \times 60\ s)$

$I = 2{,}400 / 720$

$I = 3.33\ A$

Answer: 3.33 A

6. $E = I \times V \times t$

$E = 0.5\ A \times 10\ V \times 120\ s$

$E = 600\ J$

Answer: 600 J

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

1. Power is the rate of energy transfer.
2. A high power rating means that energy is transferred at a faster rate.
3. The unit of power is the watt (W).
4. A power rating of 1 W means that 1 J of energy is transferred every second.
5. A 500 W device transfers 500 J of energy each second.
6. A 1,000 W device transfers energy faster than a 100 W device.

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

1. $P = E / t$
2. $P = E / t$

$P = 4{,}000\ J / 20\ s$

$P = 200\ W$

Answer: 200 W

3. $E = P \times t$

$E = 600\ W \times 30\ s$

$E = 18{,}000\ J$

Answer: 18,000 J

4. t = E / P

t = 9,000 J / 300 W

t = 30 s

Answer: 30 s

5. P = E / t

P = 12,000 J / 60 s

P = 200 W

Answer: 200 W

6. t = 2 minutes × 60 = 120 s

E = P × t

E = 250 W × 120 s

E = 30,000 J

Answer: 30,000 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. Power increases when the potential difference increases, provided current remains constant.
2. Power increases when current increases, provided potential difference remains constant.
3. Power increases.
4. Power increases.
5. P = I × V

P = 2 A × 12 V

P = 24 W

Answer: 24 W

6. Power is the rate of energy transfer, and increasing both potential difference and current increases the rate at which energy is transferred.

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, A^2) × resistance (ohm, Ω) $P = I^2 \times R$

1. $P = I \times V$
2. $P = I^2 \times R$
3. $P = I \times V$

$P = 4\ A \times 12\ V$

$P = 48\ W$

Answer: 48 W

4. $P = I^2 \times R$

$P = (3\ A)^2 \times 5\ \Omega$

$P = 9\ A^2 \times 5\ \Omega$

$P = 45\ W$

Answer: 45 W

5. $P = I \times V$

$I = P / V$

$I = 1{,}000\ W / 250\ V$

$I = 4\ A$

Answer: 4 A

6. $P = I^2 \times R$

$R = P / I^2$

$R = 200\ W / (5\ A)^2$

$R = 200 / 25$

$R = 8\ \Omega$

Answer: 8 Ω

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. A battery transfers chemical energy to electrical energy in the circuit.
2. An electric motor transfers electrical energy to kinetic energy, causing movement.
3. An electric heater transfers electrical energy to thermal energy.
4. A washing machine uses a motor to transfer electrical energy into movement.
5. An electric kettle uses electrical heating.
6. Different devices contain different components that convert electrical energy into different useful forms, such as kinetic energy in a motor or thermal energy in a heater.

10.33 Explain the difference between direct and alternating voltage

1. Direct voltage has a constant polarity, so it drives charge in one direction.
2. Alternating voltage repeatedly changes polarity and direction with time.
3. Direct voltage has a constant direction of potential difference, whereas alternating voltage periodically reverses direction.
4. A cell supplies direct voltage.
5. The UK mains supply provides alternating voltage.
6. The direction of an alternating voltage repeatedly reverses with time.

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. Direct current is the movement of charge in one direction only.
2. Charge moves in one direction only in a d.c. circuit.
3. Cells and batteries supply direct current.
4. Cells produce d.c.
5. Batteries produce d.c.
6. In d.c., charge moves in one direction only. In a.c., the direction of charge movement changes repeatedly.

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

1. Alternating current is current in which the direction of charge movement changes repeatedly.
2. The direction of charge movement repeatedly reverses.

3. A.c. changes direction periodically, whereas d.c. flows in one direction only.
4. No. The direction of charge movement repeatedly changes.
5. Mains electricity is described as alternating current because the direction of charge movement changes repeatedly.
6. During one complete a.c. cycle, the current changes direction and then returns to its original 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. The UK domestic supply is alternating current (a.c.).
2. The frequency is 50 Hz.
3. The approximate voltage is 230 V.
4. A frequency of 50 Hz means that 50 complete cycles occur each second.
5. The UK domestic supply is approximately 230 V a.c.
6. 50 complete cycles occur each second.

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 from the mains supply to the appliance.
2. The neutral wire provides the return path for current to the supply.
3. The live wire carries the alternating potential difference to the appliance.
4. The neutral wire provides the return path for current.
5. The live wire is at a large potential difference relative to Earth, so touching it can cause a dangerous current to flow through a person to Earth.
6. The live wire supplies the potential difference and the neutral wire completes the circuit by providing the return path.

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

1. The earth wire provides a low-resistance path to Earth if a fault makes a metal case live.
2. If a metal case becomes live, the earth wire provides a path for a large current to flow, helping protective devices disconnect the supply.
3. A fuse melts when the current becomes too large, breaking the circuit.
4. A circuit breaker automatically switches off the circuit when the current becomes too large.
5. They stop excessive current from continuing to flow, reducing the risk of wires overheating.

6. The earth wire provides a safe low-resistance path during a fault, causing a large current that allows the fuse to melt or circuit breaker to trip and disconnect the supply.

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

1. A switch in the live wire disconnects the appliance from the dangerous potential difference when switched off.
2. A fuse in the live wire disconnects the appliance from the supply if the current becomes too large.
3. The appliance could remain connected to the live potential difference even when switched off, making it dangerous to touch.
4. Disconnecting the live wire removes the dangerous potential difference from the appliance.
5. If excessive current flows, the fuse melts and disconnects the appliance from the live supply.
6. A fuse only in the neutral wire could leave the appliance connected to the live wire at a dangerous potential difference even after the fuse has blown.

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

1. The potential difference between live and neutral is about 230 V.
2. The potential difference between live and earth is about 230 V.
3. The potential difference between neutral and earth is approximately 0 V under normal conditions.
4. The live wire is approximately 230 V relative to Earth.
5. Neutral and earth are approximately at the same potential under normal conditions.
6. The live wire is at a large potential difference relative to neutral and Earth, so touching it can cause a dangerous current to flow through the body.

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

1. A connection between live and earth can cause a large current to flow because there is a large potential difference between them.
2. A person can receive an electric shock, potentially causing serious injury or death.
3. Current can flow through a person because the body can provide a conducting path between live and Earth.
4. The large potential difference between live and Earth can drive a large current through a low-resistance path.

5. The large fault current can cause a fuse to melt or a circuit breaker to trip, disconnecting the supply.
6. Direct connections between live wires and earth are dangerous because they can cause large currents, electric shocks, overheating and fires.

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 power rating indicates the rate at which the appliance transfers energy.
2. A higher power rating means energy is transferred at a faster rate.
3. The 2,000 W kettle transfers energy faster.
4. E = P × t

E = 1,500 W × 60 s

E = 90,000 J

Answer: 90,000 J

5. t = 5 minutes × 60 = 300 s

E = P × t

E = 100 W × 300 s

E = 30,000 J

Answer: 30,000 J

6. Power is the rate of energy transfer, so a higher-power appliance transfers more energy in the same amount of time.

Yes — answers only, with the headings kept exactly as you gave them, and calculation questions include compact working. Based directly on your Topic 11 and 12 source.

Topic 11 – Static electricity

11.1P Explain how an insulator can be charged by friction, through the transfer of electrons

1. Rubbing an insulator against another material can transfer electrons between the two materials.
2. Electrons are transferred.
3. Electrons can move between different insulating materials when they are rubbed together.
4. Electrons are transferred from one material to the other, leaving the materials oppositely charged.
5. Protons are held tightly in the nuclei of atoms and cannot move between the materials.
6. Friction causes electrons to transfer from one insulator to the other, so one gains electrons and the other loses electrons.

11.2P Explain how the material gaining electrons becomes negatively charged and the material losing electrons is left with an equal positive charge

1. It becomes negatively charged.
2. It becomes positively charged.
3. Electrons have a negative charge, so gaining electrons gives the object a net negative charge.
4. Losing negatively charged electrons leaves an excess of positive charge.
5. Electrons are transferred between the materials, so one gains exactly the same amount of negative charge that the other loses.
6. The material gaining electrons becomes negative and the material losing electrons becomes positive, with equal magnitudes of charge.

11.3P Recall that like charges repel and unlike charges attract

1. They repel.
2. They repel.
3. They attract.
4. Charges of the same type, such as two positive charges or two negative charges.
5. Charges of different types, such as a positive and a negative charge.
6. Repulsion indicates like charges, while attraction indicates unlike charges.

11.4P Explain common electrostatic phenomena in terms of movement of electrons, including a shocks from everyday objects b lightning c attraction by induction such as a charged balloon attracted to a wall and a charged comb picking up small pieces of paper

1. Electrons suddenly transfer between the charged object and the person, producing a brief current that is felt as a shock.
2. Electrons move between regions of charge in clouds or between a cloud and the ground, producing a large electrical discharge.
3. The charged balloon causes electrons in the wall to redistribute, leaving an opposite charge closer to the balloon and producing attraction.
4. Electrostatic induction is the redistribution of electrons within a neutral object caused by a nearby charged object.
5. The charged comb induces a separation of charge in the paper, causing the opposite charge to be closer to the comb and producing attraction.
6. A charged object causes electrons in a nearby neutral object to redistribute, producing an attractive force between the opposite charges.

11.5P Explain how earthing removes excess charge by movement of electrons

1. Earthing provides a conducting path between a charged object and the Earth.
2. Excess electrons flow from the negatively charged object to the Earth.
3. Electrons flow from the Earth onto the positively charged object.
4. Electrons move from the object to the Earth.
5. The Earth is extremely large and can gain or lose electrons without becoming significantly charged.
6. Excess electrons move to or from Earth until the object becomes electrically neutral or closer to neutral.

11.6P Explain some of the uses of electrostatic charges in everyday situations, including insecticide sprayers

1. Insecticide droplets are given an electric charge as they are sprayed.
2. Droplets with the same charge repel each other.
3. The charged droplets are attracted to the plants and spread over their surfaces.
4. Charged droplets are attracted to opposite charges or induced charges on plant surfaces.
5. The droplets spread out and are attracted to the plants, giving more even coverage and reducing waste.
6. Repulsion causes similarly charged droplets to spread apart, producing a wider and more even spray.

11.7P Describe some of the dangers of sparking in everyday situations, including fuelling cars, and explain the use of earthing to prevent dangerous build-up of charge

1. A spark could ignite flammable fuel vapour.
2. A large potential difference can build up, causing electrons to suddenly move through the air as a spark.
3. The spark can ignite the fuel vapour and cause a fire or explosion.
4. Earthing provides a path for excess charge to flow safely to Earth.
5. It allows excess electrons to flow away, reducing the charge build-up and therefore reducing the risk of a spark.
6. Excess electrons flow to Earth instead of suddenly discharging as a spark near flammable substances.

11.8P Define an electric field as the region where an electric charge experiences a force

1. An electric field is a region where an electric charge experiences a force.
2. It experiences an electric force.
3. An electric field exists around charged objects.
4. A test charge can be used to detect an electric field because it experiences a force within the field.
5. It experiences an electric force.
6. An electric field is a region in which charges experience forces; it does not require the physical movement of charged particles.

11.9P Describe the shape and direction of the electric field around a point charge and between parallel plates and relate the strength of the field to the concentration of lines

1. The field lines radiate outwards from the positive point charge.
2. They point away from a positive point charge.
3. They point towards a negative point charge.
4. They are straight, parallel and evenly spaced, directed from the positive plate towards the negative plate.
5. A greater concentration of field lines indicates a stronger electric field.
6. The field lines are approximately parallel and evenly spaced between the plates, so the field strength is approximately constant away from the edges.

11.10P Explain how the concept of an electric field helps to explain the phenomena of static electricity

1. Charged objects produce electric fields, and charges within these fields experience forces.
2. The charged balloon's electric field causes electrons in the neutral wall to redistribute, producing attraction.

3. It exerts a force on nearby charged particles.
4. Like charges produce forces that push the charges apart.
5. Unlike charges produce forces that pull the charges together.
6. Electric fields provide an explanation for the forces acting between charged objects without the objects needing to touch.

Topic 12 – Magnetism and the motor effect

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

1. They repel.
2. They repel.
3. They attract.
4. Two north poles or two south poles.
5. A north pole and a south pole.
6. Attraction indicates unlike poles, while repulsion indicates like poles.

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

1. A permanent magnetic material remains magnetised after the external magnetic field is removed.
2. A temporary magnetic material becomes magnetised in a magnetic field but loses most or all of its magnetism when the field is removed.
3. Steel is difficult to magnetise but retains its magnetism, making it suitable for permanent magnets.
4. Iron is easily magnetised and loses its magnetism readily, making it suitable for temporary magnets.
5. Cobalt and nickel are magnetic materials that can be used in making permanent magnets and magnetic alloys.
6. Iron is suitable because it is easily magnetised and demagnetised, making it useful as an electromagnet core.

12.3 Explain the difference between permanent and induced magnets

1. A permanent magnet remains magnetised when the external magnetic field is removed.

2. An induced magnet becomes magnetised when placed in an external magnetic field.
3. A permanent magnet retains its magnetism, whereas an induced magnet only remains magnetised while influenced by an external magnetic field.
4. The external magnetic field causes the magnetic domains to become aligned, but they become less aligned when the field is removed.
5. Placing a magnetic material near a magnet can cause its magnetic domains to align temporarily.
6. Soft magnetic materials are easily magnetised and demagnetised.

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. The field lines form curved loops around the bar magnet.
2. Outside the magnet, field lines travel from north to south.
3. They point from north to south.
4. A uniform magnetic field has straight, parallel and evenly spaced field lines.
5. A greater concentration of field lines indicates a stronger magnetic field.
6. The field is strongest at the poles.

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 in which its needle points.
2. The compass needle indicates the direction of the magnetic field.
3. Mark the direction of the needle at several positions and join the points to produce magnetic field lines.
4. The compass needle aligns with the magnetic field, showing its direction at each position.
5. A plotting compass can be placed at different positions around Earth to determine the direction of Earth's magnetic field.
6. Moving the compass to several positions allows the shape and direction of the whole magnetic field to be mapped.

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

1. The compass needle aligns with Earth's magnetic field, approximately in a north-south direction.
2. It provides evidence that Earth has a magnetic field.

3. Earth's magnetic field exerts a force on the magnetic compass needle.
4. It suggests that Earth's interior contains magnetic material or produces a magnetic field.
5. The compass behaves as though it is interacting with a large magnet because it aligns with Earth's magnetic field.
6. The compass aligns with Earth's magnetic field, providing evidence that Earth has a magnetic field and that its core must therefore be magnetic.

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

1. Pass a current through a straight wire and place plotting compasses around it. The compass needles change direction, showing a magnetic field.
2. The field consists of concentric circles centred on the conductor.
3. The direction of the magnetic field depends on the direction of the current.
4. The magnetic field disappears when the current is switched off.
5. Place plotting compasses at different positions around the current-carrying wire and observe the directions of their needles.
6. Reversing the current reverses the direction of the magnetic field.

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. The magnetic field becomes stronger.
2. The magnetic field becomes weaker.
3. The magnetic field becomes stronger when the current is increased; qualitatively, doubling the current increases the field strength.
4. It is strongest close to the conductor.
5. The magnetic field spreads out as the distance from the conductor increases, so its strength decreases.
6. The strength depends on 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 solenoid is a coil of wire consisting of many loops.

2. The magnetic fields from the individual coils add together inside the solenoid.
3. The fields reinforce each other along the centre, producing a strong magnetic field.
4. The field lines inside are approximately parallel and evenly spaced.
5. The magnetic fields from the coils partially cancel outside the solenoid.
6. The fields add inside but largely cancel outside, making the external field much weaker.

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 magnet and the magnetic field produced by the current-carrying conductor causes the force.
3. The magnet experiences an equal and opposite force.
4. The two forces are equal in magnitude and opposite in direction.
5. The force on the conductor disappears when the current is switched off.
6. The conductor and magnet exert equal and opposite forces on each other, demonstrating Newton's third law.

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

1. The interaction between magnetic fields causes magnetic forces.
2. The interacting magnetic fields produce forces on the objects producing the fields.
3. The magnetic field around the conductor interacts with the magnetic field of the magnet.
4. The two magnetic fields interact, producing a force on the conductor.
5. Reversing one field changes the interaction and can reverse the direction of the force.
6. Interacting fields can produce forces that cause objects to attract or repel.

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. Fleming's left-hand rule determines the relative directions of the force, current and magnetic field.
2. The first finger represents the direction of the magnetic field.

3. The second finger represents the direction of conventional current.
4. The thumb represents the direction of the force.
5. It can be applied when the force, current and magnetic field are mutually perpendicular.
6. The force reverses 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 × I × l

1. $F = B \times I \times l$.
2. The conductor must be at right angles to the magnetic field.
3. $F = B \times I \times l = 0.5\ T \times 4\ A \times 0.2\ m = 0.4\ N$.
4. $l = F \div (B \times I) = 6\ N \div (0.3\ T \times 5\ A) = 4\ m$.
5. $B = F \div (I \times l) = 2.4\ N \div (3\ A \times 0.4\ m) = 2\ T$.
6. $I = F \div (B \times l) = 4\ N \div (0.8\ T \times 0.5\ m) = 10\ A$.

12.14P Explain how the force on a conductor in a magnetic field is used to cause rotation in electric motor

1. A current-carrying conductor experiences a force when placed in a magnetic field.
2. Forces act in opposite directions on opposite sides of the current-carrying coil, producing a turning effect.
3. The current flows in opposite directions on the two sides of the coil, so the forces act in opposite directions.
4. The coil rotates because the forces produce a turning effect.
5. The split-ring commutator reverses the current every half-turn so that the forces continue to produce rotation in the same direction.
6. The magnetic field exerts forces on the current-carrying coil; the split-ring commutator reverses the current every half-turn, allowing continuous rotation.

Topic 13 – Electromagnetic induction

13.1P Explain how to produce an electric current by the relative movement of a magnet and a conductor a on a small scale in the laboratory b in the large-scale generation of electrical energy

1. A potential difference is induced when a magnet and conductor move relative to each other. If the conductor forms part of a complete circuit, an induced current flows.
2. A potential difference is induced across the coil. If the circuit is complete, an induced current flows.
3. Connect a coil of wire to a sensitive ammeter and move a bar magnet into and out of the coil. The ammeter shows a current whenever there is relative movement between the magnet and coil.
4. Relative movement causes the magnetic field through the conductor to change, inducing a potential difference across the conductor.
5. Generators use electromagnetic induction to convert mechanical energy into electrical energy. Coils and magnets are rotated relative to each other, inducing an alternating potential difference and current.
6. Mechanical energy is transferred into electrical energy.

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. The size of the induced potential difference depends on the speed of relative movement, the strength of the magnetic field and the number of turns in the coil.
2. Increasing the speed of relative movement increases the induced potential difference.
3. Increasing the number of turns in the coil increases the induced potential difference.
4. Increasing the strength of the magnetic field increases the induced potential difference.
5. Reversing the direction of relative movement reverses the direction of the induced potential difference and current.
6. The induced current produces a magnetic field that opposes the change that caused the current to be induced.

13.3P Explain how electromagnetic induction is used in alternators to generate current which alternates in direction (a.c.) and in dynamos to generate direct current (d.c.)

1. An alternator converts mechanical energy into electrical energy by producing an alternating current.
2. Relative rotation between the magnetic field and coil changes the magnetic flux through the coil, inducing a potential difference and current.

3. As the coil or magnetic field rotates, the direction of the change in magnetic flux reverses, so the induced current repeatedly reverses direction.
4. A dynamo converts mechanical energy into electrical energy by producing a direct current.
5. A dynamo uses a split-ring commutator to reverse the connections to the external circuit every half-turn, so the current in the external circuit remains in the same direction.
6. An alternator produces alternating current (a.c.), whereas a dynamo produces direct current (d.c.).

13.4P Explain the action of the microphone in converting the pressure variations in sound waves into variations in current in electrical circuits, and the reverse effect as used in loudspeakers and headphones

1. Sound waves cause a microphone diaphragm to vibrate. The vibrations cause variations in the electrical signal produced by the microphone.
2. Variations in air pressure caused by the sound wave cause the diaphragm to move.
3. The diaphragm moves a component such as a coil in a magnetic field, causing electromagnetic induction and producing variations in current corresponding to the sound wave.
4. An alternating electrical signal causes a coil in a magnetic field to move. The coil moves the diaphragm, producing pressure variations in the air that form sound waves.
5. An electrical signal causes a small diaphragm or coil in the headphones to vibrate, producing sound waves.
6. A microphone converts sound into an electrical signal, while a loudspeaker converts an electrical signal back into sound.

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

1. An alternating current in the primary coil produces a changing magnetic field in the iron core. This changing magnetic field induces a potential difference across the secondary coil, causing a current if the secondary circuit is complete.
2. An alternating current produces a continuously changing magnetic field, which is required to induce a potential difference in the secondary coil.
3. The magnetic field in the core continually changes direction and strength as the primary current alternates.
4. The changing magnetic field passes through the secondary coil and induces a potential difference across it.

5. The coils are electrically separate to prevent a direct electrical connection between the two circuits; energy is transferred through the changing magnetic field.
6. Electrical energy is transferred from the primary circuit to the secondary circuit through the changing magnetic field in the core.

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

1. A transformer increases or decreases the size of an alternating voltage.
2. A transformer changes an alternating voltage.
3. A step-up transformer increases the voltage, while a step-down transformer decreases the voltage.
4. The output voltage is greater than the input voltage.
5. The output voltage is less than the input voltage.
6. A steady direct voltage does not produce a continuously changing magnetic field, so it cannot induce a potential difference in the secondary coil.

13.7P Use the turns ratio equation for transformers to calculate either the missing voltage or the missing number of turns: Ns/Np = Vs/Vp

1. The equation is:
   Ns/Np = Vs/Vp
2. Ns/Np = Vs/Vp
   2000/500 = Vs/12
   4 = Vs/12
   Vs = 4 × 12
   Vs = 48 V
3. Ns/Np = Vs/Vp
   250/1000 = Vs/240
   0.25 = Vs/240
   Vs = 0.25 × 240
   Vs = 60 V
4. Ns/Np = Vs/Vp
   1200/600 = 20/Vp
   2 = 20/Vp
   Vp = 20/2
   Vp = 10 V
5. Ns/Np = Vs/Vp
   Ns/1000 = 46/230
   Ns/1000 = 0.2

Ns = 0.2 × 1000
Ns = 200 turns

6. Ns/Np = Vs/Vp
   400/Np = 24/120
   400/Np = 0.2
   Np = 400/0.2
   Np = 2000 turns

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. Electrical energy is transmitted at high voltages to reduce the current needed for a given power transfer, which reduces energy loss as heat.
2. For a given power, increasing the voltage decreases the current because $P = I \times V$.
3. Heating power is proportional to I^2R, so reducing the current greatly reduces the power dissipated as heat.
4. Electrical resistance in the transmission cables causes electrical energy to be transferred into thermal energy. The power dissipated is given by $P = I^2R$.
5. Lower voltages are used for domestic supplies because they are safer and are suitable for domestic electrical appliances.
6. High-voltage transmission reduces current and therefore reduces heat loss in the cables, increasing the efficiency of energy transmission.

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

1. Step-up transformers are used at power stations before electricity enters the transmission network.
2. They increase the voltage, reducing the current required to transmit a given power and therefore reducing energy losses in the cables.
3. Step-down transformers are used at substations closer to where electricity is used.
4. They reduce the voltage to a lower, safer voltage suitable for domestic and other users.
5. Increasing the voltage reduces the current for a given power transfer, reducing the power dissipated as heat in the transmission cables.
6. A step-up transformer increases the voltage for efficient long-distance transmission, while step-down transformers reduce the voltage before electricity is supplied to users.

13.10 Use the power equation (for transformers with 100% efficiency): $V_p \times I_p = V_s \times I_s$

1. The equation is:
   $V_p \times I_p = V_s \times I_s$
2. $V_p \times I_p = V_s \times I_s$
   $240 \times 5 = 60 \times I_s$
   $1200 = 60I_s$
   $I_s = 1200/60$
   $I_s = 20$ A
3. $V_p \times I_p = V_s \times I_s$
   $230 \times 2 = V_s \times 10$
   $460 = 10V_s$
   $V_s = 460/10$
   $V_s = 46$ V
4. $V_p \times I_p = V_s \times I_s$
   $240 \times I_p = 12 \times 20$
   $240I_p = 240$
   $I_p = 240/240$
   $I_p = 1$ A
5. $V_p \times I_p = V_s \times I_s$
   $400 \times 3 = 40 \times I_s$
   $1200 = 40I_s$
   $I_s = 1200/40$
   $I_s = 30$ A
6. An ideal transformer has 100% efficiency, so no energy is lost. Therefore, the input power equals the output power.

13.11P Explain the advantages of power transmission in high-voltage cables, using the equations in 10.29, 10.31, 13.7P and 13.10

1. For a fixed power, increasing the voltage decreases the current according to $P = I \times V$. This reduces heating losses in the cables.
2. $P = I \times V$
   $I = P/V$
   Therefore, for a fixed P, increasing V causes I to decrease.
3. $P = I^2 \times R$
   Reducing I reduces the power dissipated as heat by the square of the reduction in current, so heat losses are greatly reduced.
4. The transformer turns ratio is:
   $N_s/N_p = V_s/V_p$
   Increasing the number of secondary turns relative to primary turns produces a higher secondary voltage, allowing a step-up transformer to increase the transmission voltage.

5. A step-down transformer has fewer turns on the secondary coil than on the primary coil, reducing the output voltage before electricity reaches users.
6. A step-up transformer increases the transmission voltage, reducing the current for a given power. The lower current reduces heat loss according to $P = I^2R$, so less electrical energy is wasted and the national grid operates more efficiently.

Yes — using the Topic 14 you provided, with the headings preserved exactly, answers only, and compact calculation working.

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 in a solid are closely packed in a regular arrangement.
2. Particles in a solid vibrate about fixed positions.
3. Particles in a liquid are close together but arranged irregularly.
4. Particles in a liquid move around and can slide past one another.
5. Particles in a gas are far apart and move rapidly in random directions.
6. Solids have closely packed particles that vibrate in fixed positions, liquids have closely packed particles that can move past each other, and gases have widely spaced particles moving rapidly and randomly.

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

1. $\rho = m/V$
2. The SI unit of density is kg/m^3.
3. $\rho = m/V$
   $\rho = 600/0.5$
   $\rho = 1200\ kg/m^3$
4. $\rho = m/V$
   $m = \rho V$
   $m = 800 \times 2$
   $m = 1600\ kg$
5. $\rho = m/V$
   $V = m/\rho$

$V = 4/2000$
$V = 0.002\ m^3$

6. $\rho = m/V$
$\rho = 1.5/0.002$
$\rho = 750\ kg/m^3$

14.3 Core Practical: Investigate the densities of solid and liquids

1. Measure the mass of the solid and measure its dimensions to calculate its volume. Then calculate density using $\rho = m/V$.
2. Measure the volume of water in a measuring cylinder, submerge the irregular solid, and measure the increase in volume. This increase is the volume of the solid.
3. Measure the mass of a known volume of liquid and calculate its density using $\rho = m/V$.
4. The mass and volume of the solid are required.
5. Repeating measurements allows a mean to be calculated and reduces the effect of random errors.
6. Repeat measurements, calculate means, use suitable measuring equipment and avoid parallax errors when taking 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. Solids are generally denser than gases because their particles are much closer together.
2. Greater spacing between particles means fewer particles occupy a given volume, resulting in a lower density.
3. Liquid particles are generally closer together than gas particles, so liquids usually have a higher density.
4. The closely packed arrangement of particles in a solid means a large amount of mass occupies a relatively small volume.
5. Changing state changes the arrangement and spacing of the particles, changing the volume and therefore the density.
6. Gas particles are widely separated, so a given mass occupies a large volume, giving gases a generally low density.

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. Mass is conserved when a substance changes state.

2. Melting changes a solid into a liquid, while freezing changes a liquid into a solid.
3. Evaporation occurs at the surface of a liquid and can occur below the boiling point, whereas boiling occurs throughout the liquid at its boiling point.
4. Condensation is the change from a gas to a liquid.
5. Sublimation is the change directly from a solid to a gas.
6. Changes of state are physical changes because no new substance is formed and the original properties can be recovered when the change is reversed.

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. Heating transfers energy to the system, increasing the energy stored within it.
2. Heating increases the energy of the particles, increasing their average kinetic energy and therefore raising the temperature.
3. Energy supplied during a change of state is used to change the arrangement or separation of particles rather than increasing their average kinetic energy.
4. The particles gain energy, increasing their kinetic energy or changing their separation and arrangement.
5. During a change of state, energy is used to overcome forces between particles, so the average kinetic energy and temperature remain constant.
6. Energy can be stored as internal energy by changing the arrangement or separation of particles during a change of state without increasing temperature.

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

1. Specific heat capacity is the energy required to raise the temperature of 1 kg of a substance by 1 °C.
2. Specific latent heat is the energy required to change the state of 1 kg of a substance without changing its temperature.
3. Specific heat capacity relates to a change in temperature, whereas specific latent heat relates to a change of state at constant temperature.
4. Temperature increases when energy is transferred according to specific heat capacity.
5. Temperature remains constant when energy is transferred as specific latent heat during a change of state.

6. A high specific heat capacity means a large amount of energy is required to increase the temperature of 1 kg of the substance by 1 °C.

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. c represents the specific heat capacity of the substance.
3. $\Delta Q = m \times c \times \Delta\theta$
   $\Delta Q = 2 \times 4200 \times 10$
   $\Delta Q = 84{,}000$ J
4. $\Delta Q = m \times c \times \Delta\theta$
   $c = \Delta Q/(m \times \Delta\theta)$
   $c = 18{,}000/(3 \times 20)$
   $c = 300$ J/kg °C
5. $\Delta Q = m \times c \times \Delta\theta$
   $\Delta Q = 4 \times 500 \times 15$
   $\Delta Q = 30{,}000$ J
6. $\Delta Q = m \times c \times \Delta\theta$
   $\Delta\theta = \Delta Q/(m \times c)$
   $\Delta\theta = 12{,}000/(2 \times 1000)$
   $\Delta\theta = 6$ °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. L represents the specific latent heat of the substance.
3. $Q = m \times L$
   $Q = 0.5 \times 200{,}000$
   $Q = 100{,}000$ J
4. $Q = m \times L$
   $m = Q/L$
   $m = 600{,}000/300{,}000$
   $m = 2$ kg
5. $Q = m \times L$
   $L = Q/m$
   $L = 800{,}000/2$
   $L = 400{,}000$ J/kg

6. The energy transferred is used to change the arrangement or separation of particles rather than increasing their average kinetic energy, so the temperature remains constant.

14.10 Explain ways of reducing unwanted energy transfer through thermal insulation

1. Thermal insulation reduces the rate of unwanted thermal energy transfer by reducing conduction, convection or radiation.
2. Trapped air is a poor conductor of thermal energy and reduces convection when it is unable to circulate freely.
3. Increasing the thickness of insulation generally decreases the rate of thermal energy transfer.
4. Loft insulation traps air and reduces thermal energy transfer through the roof.
5. Double glazing traps an insulating layer of air or gas between two panes, reducing thermal energy transfer through the window.
6. Reducing unwanted thermal energy transfer helps buildings retain thermal energy and reduces energy use for heating.

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, use an electrical heater of known power, measure the temperature rise over a measured time, and use $\Delta Q = m \times c \times \Delta\theta$ with energy transferred calculated from power × time.
2. The mass of water, initial and final temperatures, power supplied and heating time are required.
3. The power supplied determines the rate at which energy is transferred to the water, allowing the energy transferred to be calculated.
4. Measure the temperature of the ice-water mixture at regular time intervals while heating and plot temperature against time.
5. A horizontal section where the temperature remains constant indicates that the ice is undergoing a change of state.
6. Use insulation, a lid and suitable apparatus to reduce heat loss to the surroundings.

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

1. A gas exerts pressure because its particles collide with the walls of its container.

2. Collisions transfer momentum to the walls and exert forces on them.
3. The change in momentum of particles during collisions produces a force on the container walls.
4. Gas particles move randomly in all directions, so they collide with all surfaces of the container.
5. Increasing the frequency of collisions increases the gas pressure.
6. Gas pressure is caused by the random motion of gas particles and their collisions with the walls of the container.

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. Increasing the temperature increases the average velocity of gas particles.
2. Faster particles collide with the walls more frequently and with greater changes in momentum.
3. The pressure of a fixed mass of gas increases when its temperature increases at constant volume.
4. Decreasing the temperature decreases the average velocity of the particles.
5. Cooling reduces the speed and energy of collisions with the container walls, reducing the pressure at constant volume.
6. Increasing temperature causes more frequent and more energetic collisions, increasing the force exerted on the container walls and therefore increasing pressure.

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

1. Absolute zero is −273 °C.
2. Absolute zero represents the theoretical temperature at which particles have no movement.
3. Particle movement decreases as a substance approaches absolute zero.
4. Absolute zero corresponds to the minimum possible thermal energy because particle motion is at its minimum.
5. Absolute zero is −273 °C.
6. At absolute zero, the particle model describes particles as having no movement.

14.15 Convert between the kelvin and Celsius scales

1. Temperature in kelvin = temperature in °C + 273.
2. 27 °C + 273 = 300 K
3. 300 K − 273 = 27 °C

4. −73 °C + 273 = 200 K
5. 100 K − 273 = −173 °C
6. 0 °C + 273 = 273 K

14.16P Explain that gases can be compressed or expanded by pressure changes

1. Increasing external pressure decreases the volume of a gas.
2. Gases can be compressed more easily because their particles have large spaces between them.
3. Reducing external pressure allows the gas to expand and increase in volume.
4. When a gas is compressed, the spacing between its particles decreases.
5. When a gas expands, the spacing between its particles increases.
6. Changing external pressure changes the forces acting on the gas, causing the particles to become closer together or further apart.

14.17P Explain that the pressure of a gas produces a net force at right angles to any surface

1. Gas pressure produces a force when particles collide with a surface.
2. The force acts at right angles, or perpendicular, to the surface.
3. Particle collisions transfer momentum perpendicular to the surface, producing a force at right angles to it.
4. Increasing gas pressure increases the force on a given surface area.
5. For a given pressure, increasing the area of a surface increases the total force.
6. Individual gas particles move randomly, but their many collisions produce a net force on the surface that acts perpendicular to it.

14.18P Explain the effect of changing the volume of a gas on the rate at which its particles collide with the walls of its container and hence on the pressure produced by a fixed mass of gas at constant temperature

1. Decreasing the volume increases the frequency of collisions with the container walls.
2. Compressing a gas increases the collision rate with the walls, increasing the pressure at constant temperature.
3. Increasing the volume decreases the frequency of collisions with the walls.
4. Expanding a gas reduces the collision rate with the walls, decreasing the pressure at constant temperature.

5. When volume decreases, particles have less distance to travel before colliding with the walls.
6. At constant temperature, decreasing volume increases the collision rate and pressure, while increasing volume decreases the collision rate and pressure.

14.19P Use the equation: $P_1 \times V_1 = P_2 \times V_2$ to calculate pressure or volume for gases of fixed mass at constant temperature

1. $P_1 \times V_1 = P_2 \times V_2$
2. $P_1V_1 = P_2V_2$
   $100 \times 4 = P_2 \times 2$
   $400 = 2P_2$
   $P_2 = 200$ kPa
3. $P_1V_1 = P_2V_2$
   $200 \times 3 = 100 \times V_2$
   $600 = 100V_2$
   $V_2 = 6\ m^3$
4. $P_1V_1 = P_2V_2$
   $150 \times 2 = P_2 \times 5$
   $300 = 5P_2$
   $P_2 = 60$ kPa
5. $P_1V_1 = P_2V_2$
   $80 \times 6 = 120 \times V_2$
   $480 = 120V_2$
   $V_2 = 4\ m^3$
6. $P_1V_1 = P_2V_2$
   $400 \times 0.5 = 100 \times V_2$
   $200 = 100V_2$
   $V_2 = 2\ m^3$

14.20P Explain why doing work on a gas can increase its temperature, including a bicycle pump

1. Doing work on a gas transfers energy to the gas, increasing its internal energy and temperature.
2. The internal energy of the gas increases when work is done on it.
3. Compressing a gas transfers energy to it, increasing the energy of its particles and therefore increasing its temperature.
4. When a bicycle pump is operated rapidly, work is done to compress the air, causing the pump and compressed air to become warmer.
5. Rapid compression increases the energy of the gas particles.

6. During compression, mechanical energy is transferred to the gas as internal energy, increasing particle energy and therefore increasing temperature.

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. Two or more forces are required so that the forces act on different parts of the object and change its shape.
2. The spring stretches because the opposing forces pull its ends away from each other.
3. Two forces acting in opposite directions at different positions can produce a turning effect that changes the shape of the object.
4. Opposing forces can push different parts of an object towards each other, reducing its length or volume.
5. The object changes shape, for example by becoming longer, shorter, curved or compressed.
6. Forces acting in different directions or at different points are needed to produce a change in shape such as stretching, bending or compression.

15.2 Describe the difference between elastic and inelastic distortion

1. Elastic distortion is a change in shape that is reversed when the deforming forces are removed.
2. Inelastic distortion is a permanent change in shape that is not completely reversed when the deforming forces are removed.
3. It returns to its original shape.
4. It remains permanently deformed.
5. Remove the applied force and observe whether the object returns to its original shape.
6. The object undergoes permanent deformation and does not return fully to its original shape.

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. N/m

3. $F = k \times x$
   $F = 200 \times 0.05$
   $F = 10$ N
4. $k = F \div x$
   $k = 12 \div 0.03$
   $k = 400$ N/m
5. $x = F \div k$
   $x = 6 \div 150$
   $x = 0.04$ m
6. $k = F \div x$
   $k = 16 \div 0.08$
   $k = 200$ N/m

15.4 Use the equation to calculate the work done in stretching a spring: energy transferred in stretching (joules, 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. $E = 0.5 \times 100 \times 0.2^2$
   $E = 0.5 \times 100 \times 0.04$
   $E = 2$ J
3. $E = 0.5 \times 250 \times 0.04^2$
   $E = 0.5 \times 250 \times 0.0016$
   $E = 0.2$ J
4. $k = 2E \div x^2$
   $k = (2 \times 9) \div 0.3^2$
   $k = 18 \div 0.09$
   $k = 200$ N/m
5. $x = \sqrt{(2E \div k)}$
   $x = \sqrt{(16 \div 400)}$
   $x = \sqrt{0.04}$
   $x = 0.2$ m
6. The energy transferred increases by a factor of 4 because energy is proportional to x^2.

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

1. A linear relationship means that force is directly proportional to extension.
2. It is a straight line with a constant gradient, passing through the origin if there is no initial extension.

3. A non-linear relationship means that force is not directly proportional to extension.
4. A curved force-extension graph indicates a non-linear relationship.
5. It indicates that the spring constant is constant and force is proportional to extension.
6. The stiffness of the object may change as it is stretched, causing the force required for each additional extension to change.

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

1. Measure the spring's original length, apply a known force, measure its new length and calculate extension using: extension = new length − original length.
2. The applied force and the extension of the spring should be measured.
3. Add known masses to the spring and use their weight to provide different forces.
4. Calculate the energy transferred using $E = 0.5 \times k \times x^2$, or determine the area under the force-extension graph.
5. Stretching beyond the elastic limit can cause permanent deformation, making the results unreliable and preventing the spring from returning to its original length.
6. Plot force against extension. A straight-line section indicates a linear relationship, while a curved section indicates a non-linear relationship.

15.7P Explain why atmospheric pressure varies with height above the Earth’s surface with reference to a simple model of the Earth’s atmosphere

1. Atmospheric pressure decreases as height above Earth's surface increases.
2. There is more air above a location near Earth's surface, so the weight of the air produces greater pressure.
3. More air particles above a location means a greater weight of air and therefore greater pressure.
4. The air becomes less compressed at greater heights, so its density decreases.
5. There is less air above a point at higher altitude, so the weight of the air above it is smaller.
6. The atmosphere can be modelled as particles of air surrounding Earth. At greater heights there are fewer particles above a given point, so the weight of air above the point and therefore atmospheric pressure decrease.

15.8P Describe the pressure in a fluid as being due to the fluid and atmospheric pressure

1. The pressure is due to atmospheric pressure plus the pressure caused by the fluid above the object.
2. Atmospheric pressure is the pressure exerted by the atmosphere on surfaces.
3. The weight of the fluid above a point produces pressure on that point.
4. The fluid exerts pressure because its particles exert forces on surfaces and because the fluid has weight.
5. The total pressure is the atmospheric pressure plus the pressure due to the fluid.
6. The fluid itself produces additional pressure due to the weight of the fluid above the point.

15.9P Recall that the pressure in fluids causes a force normal to any surface

1. The force acts perpendicular to the surface.
2. Normal means perpendicular to the surface.
3. Fluid pressure acts equally in all directions, so the force on a surface acts perpendicular to that surface.
4. The pressure produces forces perpendicular to the walls of the container.
5. The force on the surface increases.
6. The pressure force remains perpendicular to the surface, so its direction changes with the orientation of the surface.

15.10P Explain how pressure is related to force and area, using appropriate examples

1. Increasing the force on a fixed area increases the pressure.
2. Increasing the area for a fixed force decreases the pressure.
3. A sharp object has a small contact area, so a given force produces a high pressure.
4. Wide tyres spread the force over a larger area, reducing the pressure on the ground.
5. The same weight acts over a smaller area when standing on one foot, so the pressure is greater.
6. Pressure depends on both force and area: increasing force increases pressure, while increasing area decreases pressure.

15.11P Recall and use the equation: pressure (pascal, Pa) = force normal to surface (newton, N) ÷ area of surface (square metre, m^2) P = F/A

1. P = F ÷ A
2. Pascal (Pa)
3. P = F ÷ A
   P = 500 ÷ 2
   P = 250 Pa
4. F = P × A
   F = 20,000 × 0.5
   F = 10,000 N
5. A = F ÷ P
   A = 800 ÷ 40,000
   A = 0.02 m^2
6. P = F ÷ A
   P = 120 ÷ 0.03
   P = 4000 Pa

15.12P Describe how pressure in fluids increases with depth and density

1. Liquid pressure increases as depth increases.
2. Liquid pressure increases when the density of the liquid increases.
3. There is more fluid above the point, so its weight produces a greater pressure.
4. A high-density liquid produces greater pressure at the same depth.
5. Greater weight of fluid above a point produces greater pressure.
6. Pressure increases with both depth and fluid density.

15.13P Explain why the pressure in liquids varies with density and depth

1. Increasing depth increases the height and therefore the weight of liquid above a point, increasing pressure.
2. A denser liquid has more mass and therefore greater weight for the same volume, producing greater pressure.
3. Increasing the mass of liquid above a point increases the force due to its weight and therefore increases pressure.
4. Increasing depth means there is a greater column of liquid above the point, so its weight increases.
5. A denser liquid has greater mass for the same volume, so it produces greater pressure at the same depth.

6. In the particle model, the liquid has weight and exerts pressure. A greater depth means more liquid above the point, while greater density means more mass in the same volume, so both increase pressure.

15.14P Use the equation to calculate the magnitude of the pressure in liquids and calculate the differences in pressure at different depths in a liquid: pressure due to a column of liquid (pascal, Pa) = height of column (metre, m) × density of liquid (kilogram per cubic metre, kg/m^3) × gravitational field strength (newton per kilogram, N/kg) $P = h \times \rho \times g$

1. $P = h \times \rho \times g$
2. $P = 5 \times 1000 \times 10$
   $P = 50{,}000$ Pa
3. $P = 4 \times 800 \times 10$
   $P = 32{,}000$ Pa
4. $\rho = P \div (h \times g)$
   $\rho = 30{,}000 \div (3 \times 10)$
   $\rho = 1000\ kg/m^3$
5. Difference in depth = 7 − 2 = 5 m
   $\Delta P = h \times \rho \times g$
   $\Delta P = 5 \times 1000 \times 10$
   $\Delta P = 50{,}000$ Pa
6. $h = P \div (\rho \times g)$
   $h = 48{,}000 \div (1200 \times 10)$
   $h = 4$ m

15.15P Explain why an object in a fluid is subject to an upwards force (upthrust) and relate this to examples including objects that are fully immersed in a fluid (liquid or gas) or partially immersed in a liquid

1. Upthrust is an upwards force exerted by a fluid on an object immersed in it.
2. Fluid pressure increases with depth, so the pressure acting on the bottom of an immersed object is greater than the pressure acting on its top.
3. The bottom of the object is at a greater depth, where the fluid pressure is greater.
4. The greater pressure on the bottom produces a larger upward force than the downward force on the top, resulting in a net upward force.
5. The fluid pressure acting on the submerged part of the object produces an upward force.
6. Gases also exert pressure, and the pressure difference between the lower and upper surfaces of an object can produce an upward force.

15.16P Recall that the upthrust is equal to the weight of fluid displaced

1. Upthrust is equal to the weight of fluid displaced by the object.
2. The fluid displaced is the fluid that would have occupied the volume taken up by the immersed part of the object.
3. Mass of water = ρ × V
   Mass = 1000 × 0.02
   Mass = 20 kg
   Weight = m × g
   Weight = 20 × 10
   Weight = 200 N
   Upthrust = 200 N
4. Upthrust = weight of displaced fluid = 50 N
5. Increasing the volume of fluid displaced increases the upthrust.
6. A greater volume of displaced fluid has a greater weight, so the upthrust is greater.

15.17P Explain how the factors (upthrust, weight, density of fluid) influence whether an object will float or sink

1. If the weight is greater than the upthrust, the object sinks.
2. If the upthrust is greater than the weight, the object accelerates upwards.
3. For an object to float in equilibrium, the upthrust must equal its weight.
4. An object with a lower average density than the fluid tends to float, while an object with a greater average density tends to sink.
5. A lower-density object has less weight for its volume and can displace enough fluid for the upthrust to balance its weight.
6. A higher-density object has greater weight for its volume, so it cannot displace enough fluid to produce an upthrust equal to its weight before becoming fully submerged.