Paper 1:

P1: Matter

P1.1 The Particle Model

P1.1a Describe how and why the atomic model has changed over time

1. The plum pudding model.
2. Rutherford discovered that the atom has a very small, dense, positively charged nucleus and that most of the atom is empty space.
3. Most alpha particles passed straight through the gold foil, but some were deflected and a very small number bounced back. This showed that the positive charge and most of the mass were concentrated in a tiny nucleus, disproving the plum pudding model.
4. Bohr proposed that electrons orbit the nucleus in fixed energy levels or shells.
5. The atomic model has changed as new experimental evidence has been discovered. Scientists changed or replaced models when they could no longer explain the experimental results.
6. Thomson's model was a sphere of positive charge containing negative electrons. Rutherford's model had a small positive nucleus surrounded by electrons, with mostly empty space between them. Bohr developed Rutherford's model by placing the electrons in fixed energy levels or shells around the nucleus.

P1.1b Describe the atom as a positively charged nucleus 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.
2. Negative charge.
3. In the nucleus.
4. The radius of the nucleus is much smaller than the radius of the whole atom.
5. An atom consists of a tiny, positively charged nucleus containing protons and neutrons, surrounded by negatively charged electrons.

6. Atoms are mostly empty space because the nucleus occupies only a tiny fraction of the atom's total volume and the electrons are found much further away from the nucleus.

P1.1c Recall the typical size (order of magnitude) of atoms and small molecules

1. Approximately 1 x 10^-10 m.
2. Approximately 10^-10 m.
3. Metres (m), usually expressed using very small powers of ten such as 10^-10 m.
4. Atoms are extremely small, with typical diameters of about 10^-10 m, which is far below what can be resolved by the naked eye.
5. An order of magnitude describes the approximate size of a quantity as a power of ten.
6. It could represent an atom because 1 x 10^-10 m is a typical atomic diameter.

P1.1d Define density

1. Density is the mass per unit volume of a substance.
2. density = mass / volume
3. kg/m^3.
4. Mass and volume.
5. density = 2 / 0.001 = 2000 kg/m^3.
6. Density is a characteristic physical property that can be used to compare and help identify different materials.

P1.1e Explain the differences in density between the different states of matter in terms of the arrangements of the atoms and molecules

1. Solids usually have the greatest density.
2. Gas particles are much further apart, so there is much less mass in a given volume.
3. Liquid particles are close together but are arranged irregularly and can move past one another.
4. In solids, particles are packed closely together, whereas gas particles are widely spaced. Therefore, solids usually contain more mass in the same volume and have a greater density.
5. The closer together the particles are, the greater the density generally is; greater spacing between particles generally results in a lower density.
6. In solids, particles are closely packed in fixed positions. In liquids, particles are also close together but can move past one another. In gases, particles are widely separated. Therefore, solids and liquids are generally much denser than gases.

P1.1f Apply the relationship between density, mass and volume to changes where mass is conserved

1. density = mass / volume
2. volume = mass / density = 4 / 800 = 0.005 m^3.
3. mass = density x volume = 2700 x 0.005 = 13.5 kg.
4. Mass being conserved means the total mass remains unchanged during a process.
5. Its mass remains constant, but its volume may change when it melts. Since density = mass / volume, a change in volume causes its density to change.
6. Its volume decreases while its mass remains constant, so its density increases.

P1.2 Changes of State

P1.2a Describe how mass is conserved when substances melt, freeze, evaporate, condense or sublimate

1. Conservation of mass means that mass is not created or destroyed, so the total mass remains constant.
2. Its mass remains the same.
3. Its mass remains the same.
4. During evaporation and condensation, particles change their arrangement but are not created or destroyed. In a closed system, none of the particles can escape, so the total mass remains constant.
5. Sublimation is when a substance changes directly from a solid to a gas without becoming a liquid.
6. During a change of state, the particles are rearranged but no particles are created or destroyed, so the total mass remains the same.

P1.2b Describe that physical changes differ from chemical changes because the material recovers its original properties if the change is reversed

1. A physical change is a change in which no new substance is formed and the original properties can be recovered if the change is reversed.
2. A chemical change is a change in which one or more new substances are formed.
3. Melting ice is a physical change because no new substance is formed; the liquid water can be frozen again to recover the original solid water.
4. Rusting iron is a chemical change because iron reacts with oxygen to form a new substance, iron oxide.
5. The material recovers its original properties.

6. A physical change does not produce a new substance and can usually be reversed to recover the original properties, whereas a chemical change produces one or more new substances with different properties.

P1.2c Describe how heating a system will change the energy stored within the system and raise its temperature or produce changes of state

1. Its internal energy increases.
2. Its temperature increases.
3. The supplied energy increases the internal energy and is used to change the arrangement of the particles rather than increase the temperature.
4. The energy supplied is used to overcome forces between particles and change their arrangement, rather than increasing their kinetic energy.
5. Heating without a change of state increases the temperature, whereas during a change of state energy is transferred without a temperature increase.
6. The particles gain energy. They usually move or vibrate faster, and if enough energy is supplied, the forces between them can be overcome and the substance changes state.

P1.2d Define the term specific heat capacity and distinguish between it and the term specific latent heat

1. The energy required to raise the temperature of 1 kg of a substance by 1°C.
2. The energy required to change the state of 1 kg of a substance without changing its temperature.
3. Specific heat capacity relates energy transferred to a temperature change, whereas specific latent heat relates energy transferred to a change of state without a temperature change.
4. The energy required to change 1 kg of a substance from solid to liquid without changing its temperature.
5. The energy required to change 1 kg of a substance from liquid to gas without changing its temperature.
6. Energy is required to overcome the forces between particles and change their arrangement, so the internal energy increases even though the temperature remains constant.

P1.2e Apply the relationship between change in internal energy of a material and its mass, specific heat capacity and temperature change to calculate the energy change involved

1. change in thermal energy = mass x specific heat capacity x temperature change

2. The energy required to raise the temperature of 1 kg of a substance by 1°C.
3. energy transferred = 2 x 500 x 10 = 10,000 J.
4. Its internal energy increases by 12,000 J.
5. Different materials have different specific heat capacities, so they require different amounts of energy to produce the same temperature increase.
6. Increasing the mass increases the energy required to produce the same temperature rise. For example, doubling the mass doubles the energy required if specific heat capacity and temperature change remain constant.

P1.2f Apply the relationship between specific latent heat and mass to calculate the energy change involved in a change of state

1. energy transferred = mass x specific latent heat
2. The energy required to change the state of 1 kg of a substance without changing its temperature.
3. energy transferred = 2 x 300,000 = 600,000 J.
4. The supplied energy is used to overcome forces between particles and change their arrangement rather than increase their kinetic energy, so the temperature remains constant.
5. Different substances have different strengths of forces between their particles, so different amounts of energy are required to change their states.
6. Energy used to melt a substance changes its state without changing its temperature, whereas energy used to raise its temperature increases the particles' kinetic energy and therefore increases temperature.

P1.3 Pressure

P1.3a Explain how the motion of the molecules in a gas is related both to its temperature and its pressure

1. The gas particles gain kinetic energy and move faster.
2. Faster particles collide with the container walls more frequently and with greater force, increasing the pressure.
3. Heating increases the particles' kinetic energy and speed. They collide with the walls more frequently and with greater force, increasing the pressure.
4. Gas pressure is produced by gas particles colliding with the surfaces of their container.
5. Higher temperature means the gas particles have greater average kinetic energy and therefore move faster.
6. Cooling reduces the particles' kinetic energy and speed, so collisions with the container walls are less frequent and less forceful, reducing the pressure.

P1.3b Explain the relationship between the temperature of a gas and its pressure at constant volume (qualitative only)

1. The pressure increases.
2. The pressure decreases.
3. The particles gain kinetic energy and move faster, producing more frequent and more forceful collisions with the container walls.
4. Keeping volume constant ensures that the change in pressure is caused by the change in temperature rather than a change in the space available to the particles.
5. At constant volume, increasing temperature increases pressure, while decreasing temperature decreases pressure.
6. Although the volume remains constant, changing the temperature changes the speed and kinetic energy of the particles and therefore changes the frequency and force of their collisions with the walls.

P1.3c Recall that gases can be compressed or expanded by pressure changes and that the pressure produces a net force at right angles to any surface

1. Gas particles have large spaces between them, so they can be pushed closer together.
2. The volume decreases.
3. The volume increases.
4. At right angles, or perpendicular, to the surface.
5. Gas particles collide with the walls of the container. These collisions exert forces on the walls and produce pressure.
6. The particles become closer together and collide with each other and the container walls more frequently.

P1.3d Explain how increasing the volume in which a gas is contained, at constant temperature, can lead to a decrease in pressure

1. The pressure decreases.
2. The particles have more space to move through, so they collide with the container walls less frequently.
3. The frequency of collisions with the container walls decreases.
4. Temperature must remain constant so that the average kinetic energy and speed of the gas particles do not change.
5. At constant temperature, pressure is inversely related to volume: increasing volume decreases pressure and decreasing volume increases pressure.
6. Reducing the volume gives the particles less space, causing more frequent collisions with the container walls and therefore increasing the pressure.

P1.3e Explain how doing work on a gas can increase its temperature

1. Doing work on a gas means transferring energy to it by applying a force that compresses it.
2. Its temperature increases.
3. Work done on the gas transfers energy to its internal energy store, increasing the average kinetic energy of its particles and therefore its temperature.
4. The piston compresses the air, doing work on the gas. The gas gains internal energy and its temperature rises.
5. Energy is transferred mechanically to the gas, increasing its internal energy.
6. Repeated compression means work is done on the air in the pump. Some of this energy increases the internal energy of the gas and pump, causing the pump to become warm.

P1.3f Describe a simple model of the Earth's atmosphere and of atmospheric pressure

1. Atmospheric pressure is the pressure exerted by the Earth's atmosphere.
2. It is caused by air particles colliding with surfaces and by the weight of the atmosphere.
3. Air particles are constantly moving and colliding with surfaces, exerting forces on them.
4. The atmosphere can be modelled as a layer of gas surrounding the Earth, held in place by gravity.
5. Assuming uniform density simplifies the model and makes the behaviour of the atmosphere easier to describe and calculate.
6. Atmospheric pressure is produced by the weight of the air above a surface and by moving air particles colliding with that surface.

P1.3g Explain why atmospheric pressure varies with height above the surface of the planet

1. Atmospheric pressure decreases as height increases.
2. At sea level there is a greater column of air above a surface, so the weight of the air produces a greater pressure.
3. At higher altitudes there is less air above a surface, so the weight of the atmosphere pressing down is smaller.
4. Because most of the atmosphere is below you and there is a smaller column of air above you.
5. Atmospheric pressure decreases as height above the Earth's surface increases.
6. On a mountain there is less atmosphere above the climber, so the weight of air above them is lower and therefore the atmospheric pressure is lower.

P1.3h Describe the factors which influence floating and sinking

1. Floating is when an object remains at or near the surface of a fluid because the upward force balances its weight.
2. Sinking is when an object moves down through a fluid because its weight is greater than the upward force.
3. An object generally floats if its average density is less than the fluid and sinks if its average density is greater than the fluid.
4. A denser liquid can provide a greater upward force, making it easier for an object to float.
5. When the upward force equals the object's weight, the resultant vertical force is zero, so the object does not accelerate upwards or downwards and floats.
6. Whether an object floats or sinks depends on its weight, the upward force from the fluid, and the densities of the object and fluid.

P1.3i Explain why pressure in a liquid varies with depth and density and how this leads to an upwards force on a partially submerged object

1. Liquid pressure increases as depth increases.
2. A denser liquid produces a greater pressure at the same depth.
3. The bottom of the object is at a greater depth, so the liquid pressure there is greater than at the top.
4. Upthrust.
5. The greater pressure acting upwards on the lower surfaces produces a larger force than the pressure acting downwards on the upper surfaces, resulting in a net upward force.
6. A denser liquid produces a greater pressure difference between the top and bottom of the object, producing a greater resultant upward force.

P1.3j Calculate the differences in pressure at different depths in a liquid

1. pressure difference = liquid density x gravitational field strength x depth
2. Approximately 10 N/kg.
3. pressure difference = 1000 x 10 x 2 = 20,000 Pa.
4. Difference in depth = 4 - 1 = 3 m. Pressure difference = 1000 x 10 x 3 = 30,000 Pa.
5. pressure difference = 800 x 10 x 5 = 40,000 Pa.
6. Increasing either the depth or the density increases the pressure difference proportionally because pressure difference = density x gravitational field strength x depth.

P2: Motion

P2.1 Motion

P2.1a Describe how to measure distance and time in a range of scenarios

1. A ruler or tape measure.
2. A stopwatch or stopclock.
3. Measure the distance using a tape measure or trundle wheel.
4. Use a stopwatch, or light gates connected to a data logger for greater accuracy.
5. To identify anomalous results and calculate a mean, improving the reliability of the results.
6. Measure the distance travelled using an appropriate measuring instrument, measure the time taken with a stopwatch or electronic timer, repeat the measurements and calculate a mean time.

P2.1b Describe how to measure distance and time and use these to calculate speed

1. speed = distance / time
2. m/s (metres per second).
3. speed = 100 / 12.5 = 8 m/s.
4. speed = 450 / 30 = 15 m/s.
5. Measure the distance travelled with a tape measure, measure the time using a stopwatch and calculate the speed using speed = distance / time.
6. Measure the distance travelled and the time taken, then divide the distance by the time to calculate the speed.

P2.1c Make calculations using ratios and proportional reasoning to convert units and to compute rates

1. 5000 m.
2. 180 s.
3. 20 m/s.
4. Time = 5 minutes = 300 s. Speed = 1500 / 300 = 5 m/s.
5. 72 km/h.
6. Units must be consistent. For example, distance should be in metres and time in seconds to obtain speed in m/s.

P2.1d Explain the vector–scalar distinction as it applies to displacement and distance, velocity and speed

1. A quantity with magnitude only.
2. A quantity with both magnitude and direction.
3. Distance has magnitude only and no direction.
4. Displacement includes both the distance moved and the direction.
5. Speed is a scalar quantity, whereas velocity is a vector quantity because it includes direction.
6. Distance travelled = 10 m. Final displacement = 0 m.

P2.1e Relate changes and differences in motion to appropriate distance–time and velocity–time graphs; interpret lines and slopes

1. Speed.
2. The object is stationary.
3. Acceleration.
4. The object is moving at a constant speed.
5. Acceleration is shown by the gradient of the velocity–time graph. A steeper gradient represents a greater acceleration.
6. The graph becomes steeper because a greater gradient represents a greater speed.

P2.1f Interpret enclosed area in velocity–time graphs

1. Distance travelled.
2. Area = base × height.
3. Distance = 8 × 5 = 40 m.
4. Distance = ½ × 6 × 10 = 30 m.
5. Because rectangles and triangles have simple area formulae that can be added together to find the total area.
6. Calculate the area of each rectangle and triangle separately, then add the areas together to find the total distance travelled.

P2.1g Calculate average speed for non-uniform motion

1. Motion in which the speed changes.
2. average speed = total distance / total time
3. Average speed = 600 / 40 = 15 m/s.
4. 5 km = 5000 m. 25 minutes = 1500 s. Average speed = 5000 / 1500 = 3.33 m/s.
5. Instantaneous speed is the speed at one particular moment, whereas average speed is calculated over the whole journey.
6. Total distance = 20 km + 40 km = 60 km = 60,000 m. Total time = 30 min + 45 min = 75 min = 4500 s. Average speed = 60,000 / 4500 = 13.3 m/s.

P2.1h Apply formulae relating distance, time and speed for uniform motion and for motion with uniform acceleration

1. Motion at constant speed.
2. distance = speed × time
3. Distance = 25 × 40 = 1000 m.
4. Time = 300 / 15 = 20 s.
5. Average speed = (4 + 16) / 2 = 10 m/s.
6. Average speed = (0 + 20) / 2 = 10 m/s. Distance = 10 × 8 = 80 m.

P2: Motion

P2.2 Newton's Laws

P2.2a Recall examples of ways in which objects interact

1. An interaction occurs when two objects affect each other by exerting forces on one another.
2. The Earth attracts an object towards its centre, while the object also attracts the Earth.
3. A charged balloon attracting small pieces of paper.
4. Two magnets attracting or repelling each other.
5. Friction and normal contact force.
6. Gravity is a non-contact force. Friction and normal contact force are contact forces.

P2.2b Describe how such examples involve interactions between pairs of objects which produce a force on each object

1. Each object exerts a force on the other object.
2. Forces arise from interactions between two objects, so each object experiences a force from the other.
3. You exert a force on the wall, and the wall exerts an equal and opposite force on you.
4. The Earth pulls the person downwards through gravity, while the ground pushes upwards on the person with a normal contact force.
5. The book pushes down on the table, and the table pushes upwards on the book with an equal and opposite force.
6. Each object exerts a force on the other. These forces are equal in size, opposite in direction and act on different objects.

P2.2c Represent forces as vectors

1. A vector quantity has both magnitude and direction.
2. The size of the force and its direction.
3. By an arrow pointing in the direction of the force.
4. Force is described as a vector because it has both size and direction.
5. Draw a box representing the book, with a downward arrow labelled weight and an equal upward arrow labelled normal contact force.
6. Vector diagrams show the size and direction of forces clearly, allowing the resultant force and whether forces are balanced to be determined.

P2.2d Apply Newton's First Law to explain the motion of an object moving with uniform velocity and also an object where the speed and/or direction change

1. An object remains at rest or continues moving at constant velocity unless acted on by a resultant force.
2. A stationary object remains stationary, while a moving object continues at constant speed in a straight line.
3. The passenger's body continues moving forwards due to inertia when the car slows down.
4. Constant velocity means there is no acceleration, so the resultant force must be zero.
5. The object accelerates, meaning its speed, direction or both change.
6. Although the car's speed may remain constant, its direction changes, so it accelerates towards the centre of the bend. This requires a resultant force towards the centre.

P2.2e Use vector diagrams to illustrate resolution of forces, a net force (resultant force), and equilibrium situations

1. The resultant force is the single force that has the same effect as all the forces acting together.
2. The forces are balanced and the resultant force is zero.
3. Resultant force = 8 - 5 = 3 N in the direction of the 8 N force.
4. Draw two arrows of equal length pointing in opposite directions from the object.
5. Forces can be drawn to scale as arrows. Their directions and lengths can then be combined to determine the resultant force.
6. The forces are equal in size and opposite in direction, so they cancel and produce a resultant force of zero.

P2.2f Describe examples of the forces acting on an isolated solid object or system

1. Weight acts downwards and air resistance acts upwards. Before terminal velocity, weight is greater than air resistance.
2. Driving force acts forwards and resistive forces act backwards. At constant speed, these forces are balanced.
3. Weight acts downwards and the normal contact force from the table acts upwards.
4. The cyclist has a forward driving force, backward air resistance and friction, downward weight and an upward normal contact force.
5. The forces are equal in size and opposite in direction, giving a resultant force of zero.
6. Weight acts downwards and air resistance acts upwards. At terminal velocity, the forces are equal and balanced.

P2.2g Describe, using free body diagrams, examples where two or more forces lead to a resultant force on an object

1. A free body diagram is a diagram showing all the forces acting on one object.
2. It shows each force as a labelled arrow, including its direction and relative size.
3. Draw a box with a forward arrow labelled pushing force, a backward arrow labelled friction, a downward arrow labelled weight and an upward arrow labelled normal contact force.
4. Compare the directions and sizes of the arrows. Forces in opposite directions are subtracted to find the resultant.
5. Draw a longer downward arrow labelled weight and a shorter upward arrow labelled air resistance, showing a resultant force downwards.
6. Draw a downward arrow labelled weight and an equal upward arrow labelled normal contact force.

P2.2h Describe, using free body diagrams, examples of special case where forces balance to produce a resultant force of zero (qualitative only)

1. Balanced forces are equal in size and opposite in direction.
2. Zero newtons.
3. A book resting on a table.
4. Draw equal-length arrows in opposite directions, such as weight downwards and normal contact force upwards.
5. Constant velocity means there is no acceleration, so the resultant force is zero and the forces are balanced.
6. The arrows representing forces in opposite directions are equal in length, showing that they cancel.

P2.2i Apply Newton's Second Law in calculations relating forces, masses and accelerations

1. resultant force = mass × acceleration
2. Force = 5 × 4 = 20 N.
3. Acceleration = 36 / 9 = 4 m/s^2.
4. Mass = 50 / 10 = 5 kg.
5. For a constant force, increasing the mass decreases the acceleration.
6. For the same mass, a larger resultant force produces a proportionally greater acceleration.

P2.2j Explain that inertia is a measure of how difficult it is to change the velocity of an object and that the inertial mass is defined as the ratio of force over acceleration

1. Inertia is the tendency of an object to resist a change in its velocity.
2. A car.
3. A lorry has a greater mass and therefore greater inertia, so a larger force is required to produce the same acceleration.
4. Inertial mass is a measure of how difficult it is to change an object's velocity.
5. inertial mass = force / acceleration
6. Objects with greater mass resist changes in motion more strongly, so they have greater inertia.

P2.2k Define momentum and describe examples of momentum in collisions

1. Momentum is a measure of an object's motion and depends on its mass and velocity.
2. momentum = mass × velocity
3. kg m/s.
4. The total momentum before the collision equals the total momentum after the collision.
5. During a car collision, the vehicles exchange momentum and may change speed or direction.
6. In a closed system, the total momentum remains constant, provided no external resultant force acts.

P2.2l Apply formulae relating force, mass, velocity and acceleration to explain how the changes involved are inter-related

1. force = mass × acceleration
2. momentum = mass × velocity

3. Force = 4 × 3 = 12 N.
4. Momentum = 6 × 5 = 30 kg m/s.
5. Increasing the force increases the acceleration in direct proportion when mass remains constant.
6. Increasing mass reduces acceleration for the same force, but increases momentum for the same velocity.

P2.2m Use the relationship between work done, force, and distance moved along the line of action of the force and describe the energy transfer involved

1. work done = force × distance moved in the direction of the force
2. Joules (J).
3. Work done = 20 × 5 = 100 J.
4. Energy is transferred mechanically to the object's gravitational potential energy store.
5. Energy is transferred from the object's energy stores to the thermal energy stores of the object and surroundings.
6. Work done measures the energy transferred when a force moves an object through a distance.

P2.2n Calculate relevant values of stored energy and energy transfers; convert between newton-metres and joules

1. Joule (J).
2. 15 J.
3. 250 N m.
4. 800 N m.
5. One joule is the work done when a force of 1 N moves an object 1 m in the direction of the force.
6. A force does work by moving an object, transferring energy between stores.

P2.2o Explain, with reference to examples, the definition of power as the rate at which energy is transferred

1. Power is the rate at which energy is transferred or work is done.
2. power = energy transferred / time
3. Watt (W).
4. Power = 1200 / 60 = 20 W.
5. A more powerful kettle transfers energy to the water at a greater rate, so the water reaches boiling temperature more quickly.
6. The rate of energy transfer is the amount of energy transferred each second.

P2.2p Recall and apply Newton's Third Law

1. When two objects interact, they exert equal and opposite forces on each other.
2. The second object exerts an equal-sized force in the opposite direction on the first object.
3. A person pushes backwards on the ground, and the ground pushes the person forwards with an equal and opposite force.
4. The rocket pushes exhaust gases downwards, and the gases exert an equal and opposite upward force on the rocket.
5. The swimmer pushes the water backwards, and the water pushes the swimmer forwards with an equal and opposite force.
6. They do not cancel because they act on different objects.

P2.2q Explain why an object moving in a circle with a constant speed has a changing velocity (qualitative only)

1. Its direction of motion continuously changes, so its velocity changes.
2. The direction of velocity changes continuously and is always tangential to the circular path.
3. No. Its speed remains constant.
4. Velocity is a vector quantity because it has both magnitude and direction.
5. A satellite orbiting the Earth.
6. Acceleration is the rate of change of velocity. The direction of velocity changes continuously, so the object is accelerating even though its speed remains constant.

P2: Motion

P2.3 Forces in Action

P2.3a Explain that to stretch, bend or compress an object, more than one force has to be applied

1. Two forces must act in opposite directions to pull the object apart.
2. Two forces must act towards each other to push the object together.
3. A single force would usually move or accelerate the whole spring rather than change its shape.
4. Opposing forces pull on each end of the rubber band.
5. Bending requires forces acting in different directions or at different points so that different parts of the object move differently.

6. Stretching a spring, bending a ruler or compressing a sponge using forces on opposite sides.

P2.3b Describe the difference between elastic and plastic deformation caused by stretching forces

1. Elastic deformation is a temporary change of shape that is reversed when the force is removed.
2. Plastic deformation is a permanent change of shape that remains after the force is removed.
3. It returns to its original shape and size.
4. It remains permanently deformed.
5. A spring or rubber band, provided its elastic limit is not exceeded.
6. Elastic deformation is reversible, whereas plastic deformation is permanent.

P2.3c Describe the relationship between force and extension for a spring and other simple systems

1. The extension increases as the applied force increases.
2. Extension is the increase in length from the spring's original length.
3. Force is directly proportional to extension.
4. It is shown by a straight line through the origin on a force-extension graph.
5. The spring returns to its original length.
6. Before the limit of proportionality, doubling the force doubles the extension. Beyond this limit, the relationship is no longer directly proportional.

P2.3d Describe the difference between linear and non-linear relationships between force and extension

1. A linear relationship is one in which one quantity is directly proportional to the other.
2. A non-linear relationship is one in which the quantities are not directly proportional.
3. Force is directly proportional to extension.
4. The extension is no longer directly proportional to the force.
5. After the limit of proportionality, the material's behaviour changes and each additional increase in force produces a different increase in extension.
6. A linear graph is a straight line, usually through the origin, while a non-linear graph is curved.

P2.3e Calculate a spring constant in linear cases

1. force = spring constant × extension
2. N/m.
3. spring constant = 10 / 0.20 = 50 N/m.
4. force = 400 × 0.05 = 20 N.
5. extension = 15 / 300 = 0.05 m.
6. A large spring constant means the spring is stiff and requires a large force to produce a small extension.

P2.3f Calculate the work done in stretching

1. Work done is the energy transferred when a force moves through a distance.
2. work done = 0.5 × force × extension
3. work done = 0.5 × 12 × 0.30 = 1.8 J.
4. 8 J.
5. It is stored in the elastic potential energy store of the spring.
6. The work done in stretching the spring is equal to the elastic potential energy stored, provided no energy is dissipated.

P2.3g Describe that all matter has a gravitational field that causes attraction, and the field strength is much greater for massive objects

1. A gravitational field is a region in which a mass experiences a gravitational force.
2. All matter has mass, and masses attract each other gravitationally.
3. Objects with very large masses, such as planets and stars.
4. The Earth has much greater mass than the Moon.
5. Greater mass produces a stronger gravitational field.
6. Increasing the mass of an object increases the gravitational attraction it exerts on other objects.

P2.3h Define weight, describe how it is measured and describe the relationship between the weight of an object and gravitational field strength

1. Weight is the force acting on an object due to gravity.
2. A newton meter or force meter.
3. Newtons (N).
4. weight = mass × gravitational field strength
5. Approximately 10 N/kg.
6. The mass remains the same, but the weight changes because gravitational field strength is different on different planets.

P2.3i Recall the acceleration in free fall

1. Free fall is motion under the influence of gravity alone.
2. Approximately 9.8 m/s^2, often taken as 10 m/s^2.
3. A resultant gravitational force acts on them.
4. Gravity.
5. Gravitational acceleration does not depend on the object's mass when air resistance is negligible.
6. Its speed increases as it accelerates towards the Earth.

P2.3j Apply formulae relating force, mass and relevant physical constants, including gravitational field strength

1. weight = mass × gravitational field strength
2. weight = 5 × 10 = 50 N.
3. mass = 120 / 10 = 12 kg.
4. Weight increases in direct proportion to gravitational field strength.
5. Mass is the amount of matter in the object and does not depend on location.
6. The object weighs more on Earth because Earth's gravitational field strength is greater than the Moon's, but its mass is unchanged.

P2.3k Describe examples in which forces cause rotation

1. Rotation is the turning of an object about a pivot or axis.
2. A pivot is the fixed point about which an object turns.
3. Pushing down on the handle of a door causes it to rotate about its hinges.
4. It depends on the direction of the force and the side of the pivot on which it acts.
5. The handle is further from the pivot, producing a greater turning effect for the same force.
6. A force acting at a distance from a pivot produces a turning effect called a moment.

P2.3l Define and calculate the moment of a force

1. The moment of a force is its turning effect about a pivot.
2. moment = force × perpendicular distance from the pivot
3. N m.
4. moment = 20 × 0.5 = 10 N m.
5. force = 15 / 0.3 = 50 N.
6. For a balanced object, the total clockwise moment equals the total anticlockwise moment.

P2.3m Explain how levers and gears transmit the rotational effects of forces

1. A lever is a rigid bar that turns about a pivot.
2. A gear transmits rotational motion and turning forces between rotating shafts.
3. Applying a force further from the pivot produces a larger moment, allowing a smaller force to move a larger load.
4. Different-sized gears can change the speed, direction and turning force of rotation.
5. A small gear driving a larger gear reduces rotational speed, while a large gear driving a smaller gear increases rotational speed.
6. Levers can multiply forces, while gears can change rotational speed, direction and turning effect.

P2.3n Recall that pressure in fluids causes a net force at right angles to any surface

1. At right angles, or perpendicular, to the surface.
2. Yes.
3. Yes.
4. Moving fluid particles collide with the walls and exert forces on them.
5. Fluid particles move randomly and collide with surfaces from all directions.
6. Pressure acting over the area of a surface produces a force perpendicular to that surface.

P2.3o Use the relationship between force, pressure and area in contact

1. pressure = force / area
2. Pascals (Pa), equivalent to N/m^2.
3. pressure = 100 / 0.5 = 200 Pa.
4. force = 5000 × 0.2 = 1000 N.
5. The same force is spread over a larger area, so the force per unit area is smaller.
6. A force applied to a small piston produces pressure in the fluid. This pressure is transmitted through the fluid and acts on a larger piston, producing a larger force because the larger piston has a greater area.

P3: Electricity

P3.1 Static and Charge

P3.1a Describe that charge is a property of all matter and that there are positive and negative charges

1. Electric charge is a property of matter that causes charged objects to exert forces on one another.
2. Positive charge and negative charge.
3. Positive charge.
4. Negative charge.
5. Most bodies contain equal amounts of positive and negative charge, so the charges balance and the net charge is zero.
6. The body is electrically neutral because its overall charge is zero.

P3.1b Describe the production of static electricity, and sparking, by rubbing surfaces, and evidence that charged objects exert forces of attraction or repulsion on one another when not in contact

1. Rubbing two insulating surfaces can transfer electrons from one material to the other, leaving both objects statically charged.
2. An insulating material.
3. They repel each other.
4. They attract each other.
5. A large potential difference can cause electrons to move suddenly through the air, producing a spark.
6. Charge two insulating rods by rubbing them, suspend one rod and bring the other close without touching. The suspended rod moves because of attraction or repulsion, showing that charged objects exert forces at a distance.

P3.1c Explain how transfer of electrons between objects can explain the phenomena of static electricity

1. Electrons.
2. Negative charge.
3. Positive charge.
4. Protons are held securely inside atomic nuclei and cannot move easily between objects.
5. Electrons transfer from one material to the other. The material gaining electrons becomes negatively charged, while the material losing electrons becomes positively charged.
6. Static electricity is produced when electrons are transferred between objects. An excess of electrons produces a negative charge, while a shortage of electrons produces a positive charge.

P3.1d Explain the concept of an electric field and how it helps to explain the phenomena of static electricity

1. An electric field is a region in which a charged object experiences an electric force.
2. Around any electrically charged object.
3. A charged object placed in the field experiences an attractive or repulsive force.
4. The electric field around one charge exerts an attractive force on an opposite charge placed within it.
5. The electric field around one charge exerts a repulsive force on a like charge placed within it.
6. Each charged object produces an electric field. When another charged object enters this field, it experiences a force even though the objects are not touching.

P3.1e Recall that current is a rate of flow of charge and the conditions needed for charge to flow

1. Electric current is the rate at which electric charge flows.
2. Electrons.
3. A closed circuit and a source of potential difference.
4. The potential difference transfers energy to the charges and provides the push that causes them to move around the circuit.
5. A closed circuit provides a complete path through which charge can flow.
6. An open switch breaks the circuit, so there is no complete path for charge and no current flows.

P3.1f Recall that current has the same value at any point in a single closed loop

1. The current has the same value at every point in a single closed loop.
2. 0.4 A.
3. The two ammeters have the same reading.
4. Charge is transferred around the circuit but is conserved; components transfer energy from the charges rather than using up the charge itself.
5. 2.5 A.
6. The current through the cell, both resistors and every other point in the series circuit is the same.

P3.1g Recall and use the relationship between quantity of charge, current and time

1. charge = current × time
2. Coulomb (C).
3. Charge = 3 × 20 = 60 C.
4. Current = 240 ÷ 80 = 3 A.

5. Time = 500 ÷ 4 = 125 s.
6. The quantity of charge transferred increases because charge is directly proportional to current when time remains constant.

P3: Electricity

P3.2 Simple Circuits

P3.2a Describe the differences between series and parallel circuits

1. A series circuit has all components connected in a single loop, so there is only one path for the current.
2. A parallel circuit has components connected on separate branches, providing more than one path for the current.
3. In a series circuit the current is the same through every component. In a parallel circuit the current splits between the branches.
4. In a series circuit the supply potential difference is shared between the components. In a parallel circuit the potential difference across each branch is the same as the supply.
5. An ammeter should be connected in series with the component.
6. A voltmeter should be connected in parallel across the component.

P3.2b Represent d.c. circuits with the conventions of positive and negative terminals, and the symbols that represent common circuit elements

1. The standard circuit symbol for a cell (one long line and one short line).
2. The standard circuit symbol for an ammeter (a circle containing A).
3. The standard circuit symbol for a voltmeter (a circle containing V).
4. The standard circuit symbols for a fixed resistor and a variable resistor.
5. The standard circuit symbols for a diode, filament lamp, LDR and NTC thermistor.
6. A correctly drawn circuit containing a cell, switch, resistor and ammeter in series, with the positive and negative terminals of the cell shown correctly.

P3.2c Recall that current, I, depends on both resistance, R, and potential difference, V, and the units in which these are measured

1. I.
2. Ampere (A).

3. Ohm (Ω).
4. Volt (V).
5. Potential difference is the energy transferred per unit charge between two points in a circuit.
6. Increasing the potential difference increases the current, while increasing the resistance decreases the current.

P3.2d Recall and apply the relationship between I, R and V, and that for some resistors the value of R remains constant but that in others it can change as the current changes

1. potential difference = current × resistance (V = IR)
2. Potential difference = 6 × 2 = 12 V.
3. Current = 10 ÷ 20 = 0.5 A.
4. Resistance = 12 ÷ 0.4 = 30 Ω.
5. Its resistance does not change as the current changes, provided the temperature remains constant.
6. As the current increases, some components become hotter, changing their resistance.

P3.2e Explain that for some resistors the value of R remains constant but that in others it can change as the current changes

1. It remains constant if the temperature stays constant.
2. A filament lamp.
3. As the filament becomes hotter, its resistance increases.
4. A fixed resistor has a constant resistance, whereas a filament lamp's resistance increases as current increases.
5. Some components change temperature or respond to environmental conditions, causing their resistance to change.
6. Measure the current and potential difference for different values and calculate the resistance using R = V/I. If the resistance stays the same it is constant; if it changes it is not constant.

P3.2f Explain the design and use of circuits to explore such effects

1. Connect the component in series with an ammeter and a variable resistor, with a voltmeter connected across the component.
2. In series with the component.
3. In parallel across the component.
4. Adjusting the variable resistor changes the current flowing through the circuit.
5. Use the circuit to take pairs of current and potential difference readings while changing the current with a variable resistor.

6. Use the same circuit arrangement, replacing the test component with the wire, diode, thermistor or LDR, and measure current and potential difference over a range of values.

P3.2g Use graphs to explore whether circuit elements are linear or non-linear

1. A component whose current is directly proportional to potential difference.
2. A component whose current is not directly proportional to potential difference.
3. A straight line through the origin.
4. Its current-potential difference graph is curved.
5. It shows that the resistance remains constant.
6. Linear components produce a straight-line graph, while non-linear components produce a curved graph.

P3.2h Use graphs and relate the curves produced to the function and properties of circuit elements

1. A straight line through the origin.
2. A curve that becomes less steep as potential difference increases.
3. Almost no current flows in one direction until the threshold is reached; in the opposite direction virtually no current flows.
4. As current increases, the filament becomes hotter and its resistance increases.
5. It shows that current flows easily in only one direction.
6. A straight-line graph indicates a fixed resistor, a curved symmetrical graph indicates a filament lamp, and a graph with current mainly in one direction indicates a diode.

P3.2i Explain why, if two resistors are in series the net resistance is increased, whereas with two in parallel the net resistance is decreased

1. The total resistance increases.
2. The total resistance decreases.
3. The current must pass through both resistors, so both oppose the flow of charge.
4. Adding another branch provides an extra path for current, reducing the overall resistance.
5. The series combination has a greater total resistance than the parallel combination.

6. More available paths allow current to flow more easily, reducing the equivalent resistance.

P3.2j Calculate the currents, potential differences and resistances in d.c. series and parallel circuits

1. Total resistance = 4 + 6 = 10 Ω.
2. Current = 12 ÷ 6 = 2 A.
3. Total current = 0.5 + 0.5 = 1.0 A.
4. Resistance = 8 ÷ 2 = 4 Ω.
5. Potential difference = 10 × 0.3 = 3 V.
6. In a series circuit the current is the same throughout and the potential difference is shared. In a parallel circuit the potential difference is the same across each branch and the current splits between the branches.

P3.2k Explain the design and use of d.c. circuits for measurement and testing purposes

1. Connect the ammeter in series with the component.
2. Connect the voltmeter in parallel across the component.
3. Measure the current and potential difference, then calculate the resistance using R = V/I.
4. It allows the current in the circuit to be varied.
5. Place the LDR in the circuit and measure how current and potential difference change as the light intensity changes.
6. Place the thermistor in the circuit and measure how current and potential difference change as its temperature changes.

P3.2l Explain how the power transfer in any circuit device is related to the potential difference across it and the current, and to the energy changes over a given time

1. power = potential difference × current (P = VI)
2. Electrical power is the rate at which electrical energy is transferred.
3. Power = 12 × 3 = 36 W.
4. Power = 600 ÷ 20 = 30 W.
5. If the current also increases, increasing the potential difference increases the power transferred.
6. Power is the rate of energy transfer, so power = energy transferred ÷ time.

P3.2m Apply the equations relating potential difference, current, quantity of charge, resistance, power, energy, and time, and solve

problems for circuits which include resistors in series, using the concept of equivalent resistance

1. Charge = 2 × 40 = 80 C.
2. Resistance = 12 ÷ 3 = 4 Ω.
3. Power = 6 × 4 = 24 W.
4. Energy = 50 × 30 = 1500 J.
5. Equivalent resistance = 5 + 7 = 12 Ω. Current = 24 ÷ 12 = 2 A.
6. Energy transferred = charge × potential difference = 120 × 10 = 1200 J.

P4: Magnetism and Magnetic Fields

P4.1 Magnets and Magnetic Fields

P4.1a Describe the attraction and repulsion between unlike and like poles for permanent magnets

1. They repel each other.
2. They repel each other.
3. They attract each other.
4. Like magnetic poles repel.
5. Unlike magnetic poles attract.
6. The magnetic field lines join from the north pole of one magnet to the south pole of the other, showing attraction.

P4.1b Describe the difference between permanent and induced magnets

1. A magnet that produces its own magnetic field and remains magnetised.
2. A material that becomes magnetised only when placed in a magnetic field.
3. It usually loses its magnetism.
4. Permanent magnets remain magnetised, whereas induced magnets are only magnetic while in an external magnetic field.
5. The external magnetic field aligns magnetic domains, causing the material to become magnetised.
6. A paperclip becoming magnetic when placed next to a bar magnet.

P4.1c Describe the characteristics of the magnetic field of a magnet, showing how strength and direction change from one point to another

1. The region around a magnet where another magnet or magnetic material experiences a force.
2. From the north pole to the south pole.
3. At the poles of the magnet.
4. The closer the field lines, the stronger the magnetic field.
5. Move the plotting compass around the magnet and mark the direction the needle points at different positions.
6. Draw field lines leaving the north pole and entering the south pole, with arrows showing the direction from north to south and the lines closest together near the poles.

P4.1d Explain how the behaviour of a magnetic (dipping) compass is related to evidence that the core of the Earth must be magnetic

1. It aligns with the Earth's magnetic field.
2. Because the Earth acts like a giant magnet.
3. The Earth has a magnetic field.
4. A compass that can rotate vertically as well as horizontally.
5. It shows that the Earth's magnetic field has both horizontal and vertical components.
6. Since compasses consistently align with the Earth's magnetic field, this provides evidence that the Earth's core produces a magnetic field.

P4.1e Describe how to show that a current can create a magnetic effect and describe the directions of the magnetic field around a conducting wire

1. Place a straight wire through a card, connect it to a power supply and sprinkle iron filings or use plotting compasses around the wire.
2. The compass needle deflects.
3. Concentric circles around the wire.
4. Use the right-hand grip rule.
5. The direction of the magnetic field reverses.
6. Place plotting compasses around the wire and record the direction each compass points to map the circular magnetic field.

P4.1f Recall that the strength of the field depends on the current and the distance from the conductor

1. It increases.
2. It decreases.
3. The magnetic field becomes stronger.
4. The field is stronger close to the wire than further away.
5. The current and the distance from the conductor.

6. Increase the current flowing through the wire.

P4.1g Explain how solenoid arrangements can enhance the magnetic effect

1. A coil of wire.
2. A magnetic field similar to that of a bar magnet.
3. The magnetic field becomes stronger.
4. The magnetic field becomes stronger.
5. The magnetic fields from each turn of the coil combine, producing a much stronger overall field.
6. Increase the current, increase the number of turns of the coil, or add a soft iron core.

P4: Magnetism and Magnetic Fields

P4.2 Uses of Magnetism

P4.2a Describe how a magnet and a current-carrying conductor exert a force on one another

1. A force acts on the conductor.
2. The magnetic field of the magnet and the magnetic field around the current-carrying conductor.
3. The direction of the force reverses.
4. The direction of the force reverses.
5. A current-carrying conductor experiences a force at right angles to both the current and the magnetic field.
6. Place a current-carrying wire between the poles of a magnet. When the current flows, the wire moves because a force acts on it.

P4.2b Show that Fleming's left-hand rule represents the relative orientations of the force, the current and the magnetic field

1. To determine the direction of the force on a current-carrying conductor in a magnetic field.
2. First finger = magnetic field.
3. Second (middle) finger = current.
4. Thumb = force (motion).
5. The force, current and magnetic field are all at right angles (90°) to each other.

6. Point the first finger in the direction of the magnetic field and the second finger in the direction of the current; the thumb then shows the direction of the force.

P4.2c Apply the equation that links the force on a conductor to the magnetic flux density, the current and the length of conductor to calculate the forces involved

1. $F = B \times I \times L$
2. Tesla (T).
3. $F = B \times I \times L = 0.2 \times 4 \times 0.5 = 0.4$ N
4. $B = F \div (I \times L) = 0.6 \div (5 \times 0.4) = 0.3$ T
5. $I = F \div (B \times L) = 1 \div (0.8 \times 0.25) = 5$ A
6. Increasing the current or the length of conductor in the magnetic field increases the force acting on the conductor.

P4.2d Explain how the force exerted from a magnet and a current-carrying conductor is used to cause rotation in electric motors

1. The interaction between the magnetic field and the current-carrying coil.
2. The current flows in opposite directions on opposite sides of the coil.
3. They create a turning moment that rotates the coil.
4. The direction of rotation reverses.
5. The direction of rotation reverses.
6. Opposite forces act on each side of the current-carrying coil, producing a turning effect that causes continuous rotation in an electric motor.

P4.2e Recall that a change in the magnetic field around a conductor can give rise to an induced potential difference across its ends, which could drive a current, generating a magnetic field that would oppose the original change

1. A potential difference.
2. An induced current.
3. Move the magnet relative to the conductor, or move the conductor through the magnetic field.
4. The induced potential difference increases.
5. A magnetic field that opposes the original change.
6. The induced current produces its own magnetic field, which opposes the change in magnetic field that caused the induction (Lenz's Law).

P4.2f Explain how this effect is used in an alternator to generate a.c., and in a dynamo to generate d.c.

1. Alternating current (a.c.).
2. Direct current (d.c.).
3. Rotating a coil in a magnetic field changes the magnetic field through the coil, inducing a potential difference.
4. The induced potential difference repeatedly reverses direction as the coil rotates.
5. A split-ring commutator reverses the connections every half turn to produce a direct current.
6. An alternator produces alternating current, whereas a dynamo produces direct current.

P4.2g Explain how the effect of an alternating current in one circuit, in inducing a current in another, is used in transformers

1. Alternating current (a.c.).
2. The magnetic field continually changes direction and strength.
3. The changing magnetic field induces a potential difference in the secondary coil.
4. Because a steady magnetic field does not induce a continuous potential difference.
5. To provide a path for the magnetic field between the coils.
6. The alternating current in the primary coil produces a changing magnetic field in the iron core, which induces a potential difference and current in the secondary coil.

P4.2h Explain how the ratio of the potential differences across the two coils in a transformer depends on the ratio of the numbers of turns in each

1. The ratio of the number of turns on the secondary coil to the number of turns on the primary coil.
2. A transformer that increases potential difference.
3. A transformer that decreases potential difference.
4. The potential difference increases.
5. The potential difference decreases.
6. $V_p / V_s = N_p / N_s$

P4.2i Apply the equations linking the potential differences and numbers of turns in the two coils of a transformer

1. $V_p / V_s = N_p / N_s$

2. Vs = (Ns ÷ Np) × Vp = (500 ÷ 100) × 12 = 60 V
3. Ns = (Vs × Np) ÷ Vp = (23 × 1000) ÷ 230 = 100 turns
4. Vs = (Ns ÷ Np) × Vp = (50 ÷ 200) × 240 = 60 V
5. Secondary turns : Primary turns = 24 : 240 = 1 : 10
6. A transformer is step-up if the secondary potential difference (and number of turns) is greater than the primary, and step-down if it is smaller.

P4.2j 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.
2. The moving coil cuts magnetic field lines, inducing a potential difference.
3. They cause the diaphragm and coil to vibrate, producing a varying current.
4. The coil moves back and forth in the magnetic field.
5. The cone vibrates, producing sound waves in the air.
6. A microphone converts sound energy into electrical energy by electromagnetic induction, while a loudspeaker converts electrical energy back into sound by using the force on a current-carrying coil in a magnetic field.

P5: Waves in Matter

P5.1 Wave Behaviour

P5.1a Describe wave motion in terms of amplitude, wavelength, frequency and period

1. The maximum displacement of a point on a wave from its rest position.
2. The distance between two consecutive corresponding points on a wave (e.g. crest to crest).
3. The number of complete waves passing a point each second.
4. The time taken for one complete wave.
5. The wave becomes taller (greater maximum displacement from the rest position).
6. Amplitude is the height from the rest position to a crest (or trough), and wavelength is the distance between two consecutive crests (or troughs).

P5.1b Define wavelength and frequency

1. The distance between two corresponding points on successive waves.
2. Metres (m).
3. The number of complete waves passing a point each second.
4. Hertz (Hz).
5. 50 complete waves pass a point every second.
6. Wavelength is the length of one wave, whereas frequency is the number of waves passing a point each second.

P5.1c Describe and apply the relationship between wavelength, frequency and wave velocity

1. Wave velocity = frequency × wavelength.
2. The wavelength decreases.
3. The frequency decreases.
4. Wave velocity = frequency × wavelength = 10 × 2 = 20 m/s.
5. Wavelength = wave velocity ÷ frequency = 300 ÷ 100 = 3 m.
6. At constant wave velocity, wavelength and frequency are inversely proportional.

P5.1d Apply formulae relating velocity, frequency and wavelength

1. Wave velocity = frequency × wavelength.
2. Wave velocity = 25 × 4 = 100 m/s.
3. Frequency = wave velocity ÷ wavelength = 600 ÷ 3 = 200 Hz.
4. Wavelength = wave velocity ÷ frequency = 340 ÷ 170 = 2 m.
5. Wave velocity = 2500 × 0.12 = 300 m/s.
6. Wave velocity = frequency × wavelength.

P5.1e Describe differences between transverse and longitudinal waves

1. A wave in which the vibrations are perpendicular to the direction of travel.
2. A wave in which the vibrations are parallel to the direction of travel.
3. Perpendicular to the direction of travel.
4. Parallel to the direction of travel.
5. Transverse: light wave. Longitudinal: sound wave.
6. In transverse waves the vibrations are perpendicular to the direction of travel, whereas in longitudinal waves they are parallel.

P5.1f Show how changes, in velocity, frequency and wavelength, in transmission of sound waves from one medium to another, are inter-related

1. The velocity can increase or decrease.

2. The frequency remains the same.
3. The wavelength changes.
4. The wavelength decreases because the velocity decreases while the frequency remains constant.
5. The wavelength increases because the velocity increases while the frequency remains constant.
6. Wave velocity = frequency × wavelength. Since the frequency stays constant when a sound wave enters a different medium, any change in velocity causes the wavelength to change proportionally.

P5.1g Describe the effects of reflection, transmission, and absorption of waves at material interfaces

1. Reflection is when a wave bounces off a surface.
2. Transmission is when a wave passes through a material.
3. Absorption is when a material takes in the wave's energy.
4. It may be reflected, transmitted or absorbed.
5. Reflected ultrasound waves are detected and used to create an image.
6. Sound waves reflect from underwater objects and the reflected waves are used by sonar to determine their position.

P5.1h Describe, with examples, processes which convert wave disturbances between sound waves and vibrations in solids

1. Vibrating the solid causes the surrounding air to vibrate, producing sound waves.
2. Sound waves make the solid vibrate.
3. The eardrum vibrates.
4. Vibrations pass through the ear bones to the inner ear.
5. The loudspeaker cone vibrates, pushing and pulling the air to produce sound waves.
6. Sound waves can make the eardrum vibrate, while vibrations of a loudspeaker cone produce sound waves in the air.

P5.1i Explain why such processes only work over a limited frequency range, and the relevance of this to human hearing

1. The range of frequencies that humans can hear.
2. The ear only responds to a limited range of frequencies.
3. Approximately 20 Hz to 20 000 Hz.
4. They are outside the hearing range of the human ear.
5. Ageing usually reduces the ability to hear high-frequency sounds.
6. The ear can only convert sound waves into nerve signals over a limited range of frequencies, so sounds outside this range cannot be heard.

P5.1j Describe how ripples on water surfaces are used to model transverse waves whilst sound waves in air are longitudinal waves, and how the speed of each may be measured

1. The vibrations are perpendicular to the direction the wave travels.
2. The vibrations are parallel to the direction the wave travels.
3. Measure the wavelength and frequency of the ripples, then calculate speed using: wave velocity = frequency × wavelength.
4. Measure the distance travelled and the time taken, then calculate speed using: speed = distance ÷ time.
5. Wavelength and frequency.
6. Water surface waves model transverse waves because the vibrations are perpendicular to the direction of travel, whereas sound waves are longitudinal because the vibrations are parallel.

P5.1k Describe evidence for the cases of ripples on water surfaces and for sound waves in air that it is the wave that travels and not the water or the air

1. Energy.
2. No.
3. It bobs up and down but does not move across the tank with the wave.
4. No.
5. Air particles vibrate backwards and forwards about their fixed positions.
6. Waves transfer energy through a medium while the particles of the medium only oscillate about their positions and do not travel with the wave.

Paper 2:

P5.2 The Electromagnetic Spectrum

P5.2a Recall that electromagnetic waves are transverse and are transmitted through space where all have the same velocity

1. Transverse waves.
2. Yes.
3. Approximately 3×10^8 m/s.
4. They travel at the same speed in a vacuum.
5. Electromagnetic waves do not require a medium, so they can travel through empty space.

6. All electromagnetic waves are transverse and travel through a vacuum at approximately 3 × 10^8 m/s.

P5.2b Explain that electromagnetic waves transfer energy from source to absorber

1. Energy.
2. The source emitting the electromagnetic wave.
3. The energy is transferred to the absorber.
4. Infrared radiation from a heater warms an object.
5. Infrared radiation is absorbed by the object, increasing its internal energy.
6. When electromagnetic radiation is absorbed, its energy is transferred to the absorbing material.

P5.2c Apply the relationships between frequency and wavelength across the electromagnetic spectrum

1. Wavelength decreases.
2. Radio waves.
3. Gamma rays.
4. Radio waves have long wavelengths and low frequencies, whereas gamma rays have short wavelengths and high frequencies.
5. At the same wave speed, frequency and wavelength are inversely proportional.
6. Wave velocity = frequency × wavelength. Since all electromagnetic waves travel at the same speed in a vacuum, a shorter wavelength means a higher frequency.

P5.2d Describe the main groupings of the electromagnetic spectrum and that these groupings range from long to short wavelengths and from low to high frequencies

1. Radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, gamma rays.
2. Radio waves.
3. Gamma rays.
4. Red, orange, yellow, green, blue, indigo, violet.
5. Infrared, microwaves, ultraviolet.
6. From radio waves to gamma rays, wavelength decreases while frequency increases.

P5.2e Describe that our eyes can only detect a limited range of the electromagnetic spectrum

1. Visible light.
2. Red.
3. Violet.
4. No.
5. No.
6. The human eye can only detect visible light, which is a small part of the electromagnetic spectrum.

P5.2f Recall that light is an electromagnetic wave

1. An electromagnetic wave.
2. Transverse.
3. Yes.
4. Approximately 3×10^8 m/s.
5. Between infrared and ultraviolet in the electromagnetic spectrum.
6. It is a transverse wave and can travel through a vacuum.

P5.2g Give examples of some practical uses of electromagnetic waves in the radio, microwave, infrared, visible, ultraviolet, X-ray and gamma ray regions

1. Radio broadcasting; television broadcasting.
2. Satellite communications; cooking food in microwave ovens.
3. Infrared: remote controls. Visible light: photography.
4. Sterilising equipment; security marking.
5. Medical imaging; airport security scanners.
6. Treating cancer; sterilising medical equipment.

P5.2h Describe how ultraviolet waves, X-rays and gamma rays can have hazardous effects, notably on human bodily tissues

1. They can damage skin cells.
2. Skin cancer.
3. They are ionising radiation that can damage cells and DNA.
4. They are highly penetrating ionising radiation that can damage living tissue.
5. To reduce the risk of cell damage, mutations and cancer.
6. Ultraviolet can damage skin, while X-rays and gamma rays are ionising radiations that can damage cells and increase the risk of cancer.

P5.2i Explain, in qualitative terms, how the differences in velocity, absorption and reflection between different types of waves in solids and liquids can be used both for detection and for exploration of

structures which are hidden from direct observation, notably in our bodies

1. Different tissues absorb waves by different amounts, creating image contrast.
2. Bone absorbs X-rays much more than soft tissue.
3. Reflected ultrasound waves are detected to produce an image.
4. Thermal imaging.
5. Gamma camera imaging using radioactive tracers.
6. Differences in wave velocity, absorption and reflection allow structures inside the body to be detected and imaged without direct observation.

P5.2j Recall that radio waves can be produced by, or can themselves induce, oscillations in electrical circuits

1. By an oscillating electrical circuit.
2. Oscillating charges (alternating current).
3. They can induce oscillations in the circuit.
4. An alternating current is induced.
5. Oscillating charges produce changing electric and magnetic fields that radiate as radio waves.
6. Radio waves induce oscillations in a receiving circuit, allowing signals to be received.

P5: Waves in Matter

P5.3 Wave Interactions

P5.3a Recall that different substances may absorb, transmit, refract, or reflect electromagnetic waves in ways that vary with wavelength

1. Absorption is when a material takes in the energy of an electromagnetic wave.
2. Transmission is when an electromagnetic wave passes through a material.
3. Reflection is when an electromagnetic wave bounces off a surface.
4. Refraction is the change in direction of an electromagnetic wave as it enters a different substance because its speed changes.
5. Different wavelengths interact differently with materials, so some wavelengths are transmitted while others are absorbed.
6. Electromagnetic waves can be absorbed, transmitted, reflected or refracted depending on the material and the wavelength of the radiation.

P5.3b Explain how some effects are related to differences in the velocity of electromagnetic waves in different substances

1. The velocity can increase or decrease.
2. Refraction is the change in direction of a wave when it enters a different medium because its speed changes.
3. Because its velocity changes as it enters the new substance.
4. The speed of light decreases.
5. The light slows down and bends towards the normal.
6. Differences in the velocity of electromagnetic waves in different substances cause refraction.

P5.3c Use ray diagrams to illustrate reflection, refraction and the similarities and differences between convex and concave lenses (qualitative only)

1. Reflected ray leaves the surface with the angle of reflection equal to the angle of incidence.
2. The ray bends towards the normal as it enters the glass block.
3. Parallel rays converge to a focal point.
4. Parallel rays diverge and spread out.
5. A convex lens converges parallel rays, whereas a concave lens diverges them.
6. Convex lenses are used to correct long-sightedness, while concave lenses are used to correct short-sightedness.

P5.3d Construct two-dimensional ray diagrams to illustrate reflection and refraction (qualitative only – equations not needed)

1. Draw an incident ray, a normal at 90° to the surface, and a reflected ray.
2. The angle of incidence is between the incident ray and the normal. The angle of reflection is between the reflected ray and the normal.
3. Draw the ray bending towards the normal as it enters the glass.
4. Draw the ray bending away from the normal as it leaves the glass.
5. It bends towards the normal.
6. Draw the ray bending towards the normal as it enters the glass block and away from the normal as it leaves, emerging parallel to the original ray.

P5.3e Explain how colour is related to differential absorption, transmission and reflection

1. Because it reflects certain wavelengths of visible light and absorbs the others.
2. It reflects red light and absorbs the other colours.

3. They are absorbed.
4. It transmits only certain wavelengths while absorbing the rest.
5. Specular reflection is regular reflection from a smooth surface, whereas scattering is reflection in many directions from a rough surface.
6. The colour we see depends on which wavelengths are reflected or transmitted to our eyes and which wavelengths are absorbed.

P6: Radioactivity

P6.1 Radioactive Emissions

P6.1a Recall that atomic nuclei are composed of both protons and neutrons, that the nucleus of each element has a characteristic positive charge

1. Protons and neutrons.
2. Positive charge.
3. No charge; it is neutral.
4. The nucleus contains positively charged protons and neutral neutrons, so it has an overall positive charge.
5. The number of protons in the nucleus.
6. Protons have a relative charge of +1, whereas neutrons have a relative charge of 0.

P6.1b Recall that atoms of the same elements can differ in nuclear mass by having different numbers of neutrons

1. Atoms of the same element with the same number of protons but different numbers of neutrons.
2. They have the same number of protons.
3. They have different numbers of neutrons.
4. They contain different numbers of neutrons, so their mass numbers are different.
5. They are isotopes of the same element.
6. The identity of an element is determined by its number of protons, so changing only the number of neutrons does not change the element.

P6.1c Use the conventional representation for nuclei to relate the differences between isotopes

1. The number of protons in the nucleus.
2. The total number of protons and neutrons in the nucleus.

3. Number of neutrons = mass number − atomic number.
4. Number of neutrons = 23 − 11 = 12.
5. Isotopes have the same atomic number but different mass numbers.
6. Isotopes have the same atomic number because they have the same number of protons, but different mass numbers because they have different numbers of neutrons.

P6.1d Recall that some nuclei are unstable and may emit alpha particles, beta particles, or neutrons, and electromagnetic radiation as gamma rays

1. A nucleus that may spontaneously decay and emit radiation.
2. Alpha particles, beta particles, neutrons and gamma rays.
3. Gamma radiation.
4. An alpha particle.
5. A beta-minus particle.
6. It may emit radiation or particles and change into a more stable nucleus, often forming a different isotope or element.

P6.1e Relate the emission of alpha particles, beta particles, gamma radiation and neutrons to possible changes in the mass or the charge of the nucleus, or both

1. The mass number decreases by 4.
2. The atomic number decreases by 2.
3. The atomic number increases by 1, while the mass number stays the same.
4. Gamma emission causes no change to the mass number or atomic number.
5. Neutron emission decreases the mass number by 1 but does not change the atomic number.
6. Alpha emission changes both mass number and charge; beta-minus emission changes the charge but not the mass number; gamma emission changes neither; neutron emission changes the mass number but not the charge.

P6: Radioactivity

P6.1 Radioactive Emissions

P6.1f Use names and symbols of common nuclei and particles to write balanced equations that represent radioactive decay

1. $^{4}_{2}He$
2. $^{0}_{-1}e$
3. $^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$
4. $^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}e$
5. Mass number and atomic number (charge) must be conserved.
6. Example: $^{226}_{88}Ra \rightarrow ^{222}_{86}Rn + ^{4}_{2}He$.

P6.1g Balance equations representing the emission of alpha, beta or gamma radiation in terms of the masses, and charges of the atoms involved

1. The mass number decreases by 4.
2. The atomic number decreases by 2.
3. The mass number stays the same and the atomic number increases by 1.
4. Neither the mass number nor the atomic number changes.
5. Subtract 4 from the mass number and 2 from the atomic number of the original nucleus.
6. Balance nuclear equations by conserving both mass number and atomic number.

P6.1h Recall that in each atom its electrons are arranged at different distances from the nucleus, that such arrangements may change with absorption or emission of electromagnetic radiation and that atoms can become ions by loss of outer electrons

1. In energy levels (electron shells) around the nucleus.
2. It can move to a higher energy level.
3. It returns to a lower energy level.
4. Electromagnetic radiation (a photon).
5. Ionisation is the gain or loss of electrons to form an ion.
6. An atom becomes a positive ion by losing one or more outer electrons.

P6.1i Recall that changes in atoms and nuclei can also generate and absorb radiations over a wide frequency range

1. Electromagnetic radiation.
2. They can absorb electromagnetic radiation.
3. From across the electromagnetic spectrum.
4. Gamma rays.
5. Electrons absorb or emit electromagnetic radiation when changing energy levels.
6. Changes in atoms and nuclei can generate or absorb electromagnetic radiation over a wide range of frequencies.

P6.1j Explain the concept of half-life and how this is related to the random nature of radioactive decay

1. The time taken for half the radioactive nuclei in a sample to decay.
2. Half of the original undecayed nuclei remain.
3. Because radioactive decay is random.
4. Because it is impossible to predict when any individual nucleus will decay.
5. Roll dice repeatedly and remove those showing a chosen number after each roll to model random decay and half-life.
6. Half-life can be used to determine the age of archaeological and geological samples by measuring the remaining radioactive isotope.

P6.1k Calculate the net decline, expressed as a ratio, during radioactive emission after a given (integral) number of half-lives

1. 1/2
2. 1/8
3. 500 radioactive nuclei.
4. 80 Bq.
5. 1/16
6. 100 Bq.

P6.1l Recall the differences in the penetration properties of alpha particles, beta particles and gamma rays

1. Alpha radiation.
2. Gamma radiation.
3. Paper, skin or a few centimetres of air.
4. A thin sheet of aluminium.
5. Thick lead or several metres of concrete.
6. Alpha is the least penetrating and is stopped by paper or skin; beta is moderately penetrating and is stopped by thin aluminium; gamma is the most penetrating and is reduced by thick lead or concrete.

P6: Radioactivity

P6.2 Uses and Hazards

P6.2a Recall the differences between contamination and irradiation effects and compare the hazards associated with these two

1. Radioactive contamination is the unwanted presence of radioactive material on or inside an object or person.
2. Irradiation is exposure to radiation from a radioactive source.
3. Contamination involves radioactive material being transferred onto or into an object; irradiation does not involve transfer of radioactive material.
4. The contaminating material remains present and continues to emit radiation until it is removed or decays.
5. Irradiation does not make an object radioactive because no radioactive material is transferred to it.
6. Contamination can cause prolonged internal or external exposure, whereas irradiation only occurs while the source is present, although both can damage living cells.

P6.2b Explain why the hazards associated with radioactive material differ according to the half-life involved

1. It decays rapidly.
2. Many nuclei decay each second, producing a high activity.
3. It decays slowly and can remain radioactive for a long time.
4. The half-life must be long enough for the isotope to perform its function but not so long that it remains hazardous unnecessarily.
5. It needs a sufficiently long half-life to remain effective for many years without frequent replacement.
6. Short-half-life materials can have high activity but become safe more quickly; long-half-life materials usually have lower activity but remain hazardous for much longer.

P6.2c Describe the different uses of nuclear radiations for exploration of internal organs, and for control or destruction of unwanted tissue

1. A radioactive substance introduced into the body so its movement or concentration can be monitored.
2. It is taken into the body and its radiation is detected to show how the organ is working.
3. Using an external detector such as a gamma camera.
4. The use of ionising radiation to treat disease, particularly cancer.
5. A controlled dose of radiation is directed at the unwanted tissue to damage or destroy its cells.
6. Tracers use small amounts of radiation for diagnosis and monitoring, while radiotherapy uses larger targeted doses to destroy unwanted tissue.

P6.2d Recall that some nuclei are unstable and may split, and relate such effects to radiation which might emerge, to transfer of energy to other particles and to the possibility of chain reactions

1. The splitting of a large unstable nucleus into two smaller nuclei.
2. A neutron.
3. It splits into two smaller daughter nuclei.
4. Neutrons, gamma radiation and energy.
5. The released neutrons can be absorbed by other unstable nuclei, causing further fission reactions.
6. Fission transfers energy to the daughter nuclei, neutrons and radiation; the released neutrons can trigger further fissions, producing a chain reaction.

P6.2e Describe the process of nuclear fusion

1. The joining of two small atomic nuclei to form a larger nucleus.
2. They combine.
3. A larger, heavier nucleus.
4. Some mass is lost.
5. The lost mass is converted into energy.
6. In fusion, small nuclei join to form a larger nucleus; a small decrease in mass is converted into energy, which is released mainly as radiation and kinetic energy.

P7: Energy

P7.1 Work Done

P7.1a Describe for situations where there are energy transfers in a system, that there is no net change to the total energy of a closed system (qualitative only)

1. Energy cannot be created or destroyed; it can only be transferred between stores or pathways.
2. A closed system is one in which no energy enters or leaves the system.
3. The total energy remains constant.
4. No. Energy cannot be created or destroyed in a closed system.
5. Energy is simply transferred between different energy stores, so the total amount of energy stays the same.

6. Energy may be transferred between kinetic, gravitational, thermal, chemical or other stores, but the total energy of the closed system remains constant.

P7.1b Describe all the changes involved in the way energy is stored when a system changes for common situations

1. Kinetic → Gravitational potential → Thermal (and sound) as it falls back down.
2. Kinetic → Thermal (and sound) energy stores.
3. Chemical → Kinetic energy stores (or electrical → kinetic for an electric motor).
4. Kinetic → Thermal energy stores of the brakes, tyres, road and surroundings.
5. Chemical/Electrical → Thermal energy store of the water.
6. Kinetic → Gravitational potential while moving uphill, then gravitational potential → Thermal as it comes to rest due to friction.

P7.1c Describe the changes in energy involved when a system is changed by heating, by work done by forces, and by work done when a current flows

1. The thermal energy store increases.
2. A higher specific heat capacity means more energy is needed to raise the temperature by the same amount.
3. Work done transfers energy, for example from a chemical store to a kinetic store when pushing an object.
4. Electrical energy is transferred to the thermal energy store of the heating element and surroundings.
5. Work done transfers energy between stores, such as increasing an object's kinetic or gravitational potential energy.
6. Heating transfers energy to thermal stores, forces transfer energy to kinetic, gravitational or elastic stores, and electric currents transfer energy from electrical stores to other energy stores.

P7.1d Make calculations of the energy changes associated with changes in a system

1. Work done = Force × Distance
   $W = Fd$
2. Energy transferred = Charge × Potential difference
   $E = QV$

3. Change in thermal energy = Mass × Specific heat capacity × Temperature change
   $\Delta E = mc\Delta\theta$
4. Work done = 50 × 4 = 200 J
5. 3.6 MJ = 1 kWh
6. 2.0KWh

P7.1e Calculate the amounts of energy associated with a moving body, a stretched spring and an object raised above ground level

1. Kinetic energy = $\frac{1}{2}mv^2$
2. Elastic potential energy = $\frac{1}{2}ke^2$
3. Gravitational potential energy = mgh
4. KE = $\frac{1}{2} \times 5 \times 4^2 = 40$ J
5. EPE = $\frac{1}{2} \times 200 \times 0.10^2 = 1$ J
6. GPE = 10 × 9.8 × 5 = 490 J (accept 500 J if using g = 10 N/kg).

P7: Energy

P7.2 Power and Efficiency

P7.2a Describe, with examples, the process by which energy is dissipated, so that it is stored in less useful ways

1. Energy being dissipated means it is transferred to the thermal energy stores of the surroundings, where it becomes less useful.
2. No. Dissipated energy is not destroyed; it is transferred to less useful energy stores.
3. Friction between car brakes and wheels transfers kinetic energy to the thermal energy stores of the brakes and surroundings.
4. The thermal energy store of the surroundings increases.
5. The energy is spread out in the surroundings, making it more difficult to use for useful work.
6. As a moving vehicle slows down, its kinetic energy is transferred mainly to the thermal energy stores of the brakes, tyres, road and surrounding air (with some sound).

P7.2b Describe how, in different domestic devices, energy is transferred from batteries or the a.c. from the mains

1. The chemical energy store of the battery.

2. Energy is transferred electrically by an alternating current (a.c.) from the mains supply.
3. Electrical → Thermal energy stores of the heating element and water.
4. Electrical → Kinetic energy stores.
5. Some energy is transferred to the thermal energy store of the motor and surroundings (and sometimes sound).
6. Electrical energy is transferred into useful energy stores (such as kinetic, light or thermal) while some is dissipated to the surroundings as thermal energy and sound.

P7.2c Describe, with examples, the relationship between the power ratings for domestic electrical appliances and how this is linked to the changes in stored energy when they are in use

1. The power rating is the rate at which an appliance transfers energy.
2. Watt (W).
3. It transfers 2000 joules of energy every second.
4. The 1500 W appliance.
5. It transfers more energy each second, so the water heats up faster.
6. The greater the power rating, the faster energy is transferred and the more quickly energy stores change.

P7.2d Calculate energy efficiency for any energy transfer

1. Efficiency = Useful energy output ÷ Total energy input (×100% for percentage).
2. Efficiency = 400 ÷ 500 = 0.80 (80%).
3. Efficiency = (1500 ÷ 2000) × 100 = 75%.
4. Useful energy = 0.80 × 1000 = 800 J.
5. Total input = 600 ÷ 0.75 = 800 J.
6. Useful energy = 0.60 × 2500 = 1500 J.
   Wasted energy = 2500 − 1500 = 1000 J.

P7.2e Describe ways to increase efficiency

1. Increasing efficiency means a greater proportion of the input energy is transferred usefully.
2. Lubrication reduces friction, so less energy is dissipated as thermal energy.
3. Thermal insulation reduces energy transfer by heating, so more energy remains useful.
4. Less energy is dissipated as sound, leaving more available for useful transfers.

5. Examples: lubricate moving parts and add thermal insulation (accept streamlined designs or low-friction bearings where appropriate).
6. Reducing unwanted energy transfers means less energy is wasted, so a greater proportion becomes useful output.

P7.2f Explain ways of reducing unwanted energy transfer

1. Lubrication reduces friction, so less energy is transferred to unwanted thermal energy stores.
2. Thermal insulation slows the transfer of energy by heating to the surroundings.
3. Cavity wall insulation traps air, reducing energy transfer through the walls.
4. Loft insulation reduces energy transfer through the roof, keeping more thermal energy inside the building.
5. Reducing friction means less kinetic energy is dissipated as thermal energy.
6. Unwanted energy transfer from a building can be reduced by cavity wall insulation and loft insulation (accept double glazing, floor insulation or draught proofing).

P7.2g Describe how the rate of cooling of a building is affected by the thickness and thermal conductivity of its walls (qualitative only)

1. Thermal conductivity is a measure of how easily energy is transferred through a material by heating.
2. Increasing the wall thickness reduces the rate of cooling.
3. Lower thermal conductivity reduces the rate of energy transfer, so the building cools more slowly.
4. A material with low thermal conductivity is the better thermal insulator.
5. Thick walls made from materials with low thermal conductivity reduce the transfer of thermal energy to the surroundings.
6. The building with thicker, better-insulated walls cools more slowly because less thermal energy is transferred through the walls.

P8: Global Challenges

P8.1 Physics on The Move

P8.1a Recall 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 1.5 m/s.
2. A typical running speed is 3 m/s.
3. A typical cycling speed is 6 m/s.
4. The approximate speed of sound in air is 340 m/s.
5. A typical speed for a car travelling on a road is 30 m/s (about 70 mph).
6. Walking is slowest, followed by running, cycling, road transport, wind (typically around 10–20 m/s), while sound travels much faster at about 340 m/s.

P8.1b Estimate the magnitudes of everyday accelerations

1. Acceleration is the rate of change of velocity.
2. The unit of acceleration is m/s^2.
3. A reasonable acceleration for a car pulling away from traffic lights is about 2 m/s^2.
4. A reasonable deceleration for a bicycle coming to a stop is about 2–3 m/s^2.
5. A rapidly accelerating car would usually have the greater acceleration.
6. Everyday accelerations are usually between 1 and 5 m/s^2, depending on the vehicle and situation.

P8.1c Make calculations using ratios and proportional reasoning to convert units and to compute rates

1. 72 km/h = 20 m/s
2. 15 m/s = 54 km/h
3. Average speed = 150 ÷ 2.5 = 60 km/h
4. Time = 20 min = 1200 s
   Speed = 6000 ÷ 1200 = 5 m/s
5. Distance = 25 × 40 = 1000 m
6. Acceleration = (30 − 10) ÷ 5 = 4 m/s^2

P8.1d Explain methods of measuring human reaction times and recall typical results

1. Reaction time is the time taken to respond to a stimulus.
2. A ruler is dropped without warning and the distance fallen before it is caught is measured.
3. A typical human reaction time is about 0.2–0.3 seconds.
4. Repeating the experiment improves the reliability of the results.
5. Reliability can be improved by repeating the test, calculating a mean and ignoring anomalous results.
6. A greater distance fallen means a longer reaction time, because the ruler has been falling for longer before being caught.

P8.1e Explain the factors which affect the distance required for road transport vehicles to come to rest in emergencies and the implications for safety

1. Thinking distance is the distance travelled during the driver's reaction time.
2. Braking distance is the distance travelled after the brakes are applied until the vehicle stops.
3. Stopping distance = Thinking distance + Braking distance
4. Thinking distance is increased by tiredness, alcohol/drugs and distractions (e.g. using a phone).
5. Braking distance is increased by wet/icy roads, worn tyres and poor brakes.
6. Higher speed increases both thinking and braking distance, while tiredness, alcohol, poor road conditions and worn tyres all increase stopping distance, making collisions more likely.

P8.1f Estimate how the distances required for road vehicles to stop in an emergency varies over a range of typical speeds

1. Thinking distance increases directly with speed.
2. Braking distance increases much more rapidly as speed increases.
3. Doubling the speed more than doubles the stopping distance because braking distance increases approximately with the square of the speed.
4. A car travelling at 60 mph requires a much greater stopping distance than one travelling at 30 mph.
5. Braking distance increases rapidly because the vehicle has much more kinetic energy that must be removed.
6. Stopping-distance data show that higher speeds require much longer stopping distances, especially above typical town-driving speeds.

P8.1g Explain the dangers caused by large decelerations

1. Deceleration is negative acceleration (slowing down).
2. Large decelerations produce large forces on passengers.
3. Seat belts increase the time taken to stop, reducing the force on the body.
4. Airbags increase the stopping time and spread the force over a larger area.
5. Crumple zones absorb energy and increase the time over which the vehicle stops.
6. Increasing the stopping time reduces the force because the same change in momentum occurs over a longer time.

P8.1h Estimate the forces involved in typical situations on a public road

1. Force = mass × acceleration (F = ma)
2. Force = 1000 × 2 = 2000 N
3. Force = 1500 × 4 = 6000 N (opposite to the direction of motion)
4. A typical force accelerating a family car is around 2000–5000 N.
5. A heavier vehicle needs a greater force to produce the same acceleration because it has a larger mass.
6. Estimate the force by multiplying the vehicle's approximate mass by its acceleration.

P8.1i Estimate, for everyday road transport, the speed, accelerations and forces involved in large accelerations

1. A reasonable speed for a fast-moving car is about 30 m/s (≈70 mph).
2. A rapidly accelerating car may have an acceleration of about 5 m/s^2.
3. F = ma
4. Force = 1200 × 5 = 6000 N
5. Large accelerations produce large resultant forces because force is proportional to acceleration.
6. A typical car may travel at around 30 m/s, accelerate at 5 m/s^2, and experience a force of around 6000 N during rapid acceleration.

P8: Global Challenges

P8.2 Powering the Earth

P8.2a Describe the main energy sources available for use on Earth, compare the ways in which they are used and distinguish between renewable and non-renewable sources

1. A renewable energy resource is one that is naturally replenished, so it will not run out on a human timescale.
2. A non-renewable energy resource is one that is finite and will eventually run out because it is used faster than it is replaced.
3. Renewable resources: wind, solar, hydroelectric, tidal, wave, geothermal and biofuel.
   Non-renewable resources: coal, oil, natural gas and nuclear fuel.

4. Fossil fuels are burned to heat water, producing steam that turns a turbine connected to a generator. Nuclear power stations use nuclear fission to heat water and produce steam.
5. Wind, hydroelectric and tidal power use moving air or water to turn turbines. Solar cells convert light energy directly into electrical energy.
6. Renewable resources are sustainable and usually produce less carbon dioxide, but many depend on weather conditions. Non-renewable resources provide reliable electricity generation but are finite and can cause pollution or produce radioactive waste.

P8.2b Explain patterns and trends in the use of energy resources

1. The use of renewable energy resources has generally increased, while the use of fossil fuels such as coal has decreased.
2. Renewable energy use has increased because it reduces carbon dioxide emissions and renewable resources will not run out.
3. Coal use has decreased because it produces large amounts of carbon dioxide and other pollutants.
4. Different countries use different energy resources depending on their geography, climate, natural resources and energy demand.
5. Improvements in technology have made renewable energy sources more efficient and cheaper to use.
6. When interpreting data on energy resources, describe the trend, compare different resources and support your answer with figures from the data.

P8.2c Recall that, in the National Grid, electrical power is transferred at high voltages from power stations, and then transferred at lower voltages in each locality for domestic use

1. The National Grid is a network of cables and transformers that transfers electrical power from power stations to homes and businesses.
2. Electricity is transferred through the National Grid at a high potential difference (high voltage).
3. High voltages reduce the current needed to transfer the same amount of power.
4. Before electricity reaches homes, transformers reduce the potential difference to about 230 V.
5. Electricity is generated in power stations before entering the National Grid.
6. Electrical power is generated, stepped up to a high potential difference, transferred through transmission cables and then stepped down to about 230 V before entering homes.

P8.2d Recall that step-up and step-down transformers are used to change the potential difference as power is transferred from power stations

1. A step-up transformer increases the potential difference.
2. A step-down transformer decreases the potential difference.
3. Step-up transformers are used immediately after electricity is generated at power stations.
4. Step-down transformers are used near towns, villages and homes before electricity is supplied to consumers.
5. High transmission voltages would be dangerous for homes, so the potential difference must be reduced before domestic use.
6. Electricity is stepped up for efficient transmission and stepped down again to provide a safe domestic supply.

P8.2e Explain how the National Grid is an efficient way to transfer energy

1. Electrical energy is dissipated as heat because transmission cables have resistance.
2. The wasted energy is transferred to the thermal energy stores of the cables and surroundings.
3. Increasing the potential difference decreases the current needed to transfer the same power.
4. A lower current produces less heating in the transmission cables.
5. Less heating means less energy is wasted during transmission.
6. The National Grid transfers electricity efficiently because it uses very high potential differences, reducing the current and therefore reducing energy losses in the transmission cables.

P8.2f Link the potential differences and numbers of turns of a transformer to the power transfer involved; relate this to the advantages of power transmission at high voltages

1. Primary potential difference ÷ Secondary potential difference = Primary number of turns ÷ Secondary number of turns.
2. If the secondary coil has more turns than the primary coil, the transformer is a step-up transformer.
3. Primary power = Secondary power (for an ideal transformer).
4. Primary power = Potential difference × Current
   = 230 × 4
   = 920 W
   Secondary current = Power ÷ Secondary potential difference

= 920 ÷ 920
= 1 A

5. As the potential difference increases, the current decreases for the same power transfer.
6. Using a high potential difference reduces the current, so less energy is dissipated as heat in the transmission cables, making the National Grid more efficient.

P8.2g Recall that the domestic supply in the UK is a.c. at 50 Hz and about 230 volts

1. The UK mains electricity supply is alternating current (a.c.).
2. The frequency is 50 Hz.
3. The potential difference is approximately 230 V.
4. A frequency of 50 Hz means the current changes direction 50 times every second.
5. The domestic electricity supply has a potential difference of about 230 V and a frequency of 50 Hz.
6. UK mains electricity is an alternating current supply with a potential difference of about 230 V and a frequency of 50 Hz.

P8.2h Explain the difference between direct and alternating voltage

1. A direct voltage (d.c.) has a constant polarity and drives current in one direction only.
2. An alternating voltage (a.c.) continually changes its polarity and size.
3. Batteries provide direct voltage.
4. The UK mains supply provides alternating voltage.
5. A d.c. voltage stays constant with time, whereas an a.c. voltage repeatedly changes from positive to negative.
6. Direct voltage causes current to flow in one direction only, while alternating voltage causes current to repeatedly reverse direction.

P8.2i Recall the differences in function between the live, neutral and earth mains wires, and the potential differences between these wires

1. The live wire carries the alternating potential difference from the supply to the appliance.
2. The neutral wire completes the circuit and is close to 0 V.
3. The earth wire is a safety wire connected to the metal case of an appliance.
4. The potential difference between the live wire and the neutral wire is about 230 V.
5. The potential difference between the neutral wire and Earth is approximately 0 V.

6. The live wire carries the dangerous supply, the neutral wire returns the current, and the earth wire provides a safe path for current if a fault develops.

P8.2j Explain that a live wire may be dangerous even when a switch in a mains circuit is open, and explain the dangers of providing any connection between the live wire and earth

1. The live wire remains at about 230 V relative to Earth even when a switch is open.
2. The switch should always be connected in the live wire so that opening it disconnects the appliance from the live supply.
3. Touching the live wire while connected to Earth can allow a large current to pass through the body, causing a potentially fatal electric shock.
4. Connecting the live wire directly to Earth creates a very large current.
5. The earth wire provides a low-resistance pathway that allows the fuse to melt or the circuit breaker to disconnect the supply if a fault occurs.
6. Good insulation prevents contact with the live wire, while the earth wire and fuse or circuit breaker protect users by disconnecting the electricity supply if a fault causes the live wire to contact the metal case of an appliance.

P8.3 Beyond Earth

P8.3a Explain the red-shift of light as seen from galaxies which are receding (qualitative only). The change with distance of each galaxy's speed is evidence of an expanding universe

1. Red-shift is the increase in the wavelength of light from an object moving away from the observer.
2. The wavelength of light from a galaxy moving away from Earth increases.
3. As light is red-shifted, its frequency decreases.
4. Red-shift shows that distant galaxies are moving away from the Earth.
5. The further away a galaxy is, the faster it is receding from the Earth.
6. Since almost all distant galaxies show red-shift, it provides evidence that the Universe is expanding.

P8.3b Explain how red-shift and other evidence can be linked to the Big Bang model

1. The Big Bang model states that the Universe began from an extremely hot, dense state about 13.8 billion years ago and has been expanding ever since.

2. Red-shift provides evidence because it shows that most galaxies are moving away from each other, meaning the Universe is expanding.
3. Cosmic microwave background (CMB) radiation is low-energy microwave radiation found throughout the Universe.
4. The CMB is evidence for the Big Bang because it is thought to be the remaining thermal radiation from the early Universe.
5. If the Universe is expanding now, then in the past it must have been much smaller, hotter and denser.
6. Together, red-shift and the cosmic microwave background radiation provide strong evidence supporting the Big Bang model.

P8.3c Recall that our Sun was formed from dust and gas drawn together by gravity and explain how this caused fusion reactions, leading to equilibrium between gravitational collapse and expansion due to the energy released during fusion

1. The Sun was originally formed from a cloud of dust and gas called a nebula.
2. Gravity caused the dust and gas to be drawn together.
3. As the material collapsed, gravitational potential energy was converted into thermal energy, increasing the temperature and pressure.
4. When the temperature became sufficiently high, nuclear fusion began.
5. A stable star exists because the inward pull of gravity is balanced by the outward pressure produced by energy released during fusion.
6. Gravity caused the nebula to collapse, increasing the temperature until hydrogen nuclei fused into helium. The energy released produced outward pressure which balanced gravity, creating a stable equilibrium.

P8.3d Explain that all bodies emit radiation, and that the intensity and wavelength distribution of any emission depends on their temperatures

1. All bodies emit electromagnetic radiation, mainly infrared radiation.
2. As the temperature of an object increases, the intensity of the radiation emitted increases.
3. As temperature increases, the radiation emitted has a shorter peak wavelength.
4. Hot objects emit a continuous range of electromagnetic radiation because charged particles inside the object are constantly accelerating and vibrating.
5. A hot object emits more radiation and a greater proportion of shorter wavelengths than a cooler object.

6. As temperature increases, both the amount of radiation emitted increases and the peak wavelength becomes shorter, changing the wavelength distribution.

P8.3e Recall the main features of our solar system, including the similarities and distinctions between the planets, their moons, and artificial satellites

1. The eight planets in order from the Sun are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune.
2. A natural satellite is an object that naturally orbits a planet, for example the Moon.
3. An artificial satellite is a human-made object placed into orbit around the Earth or another celestial body.
4. A minor planet is a small body, such as an asteroid, that orbits the Sun but is not classified as a planet.
5. A geostationary satellite remains above the same point on the Earth's surface, whereas a polar satellite passes over the Earth's poles as the Earth rotates beneath it.
6. Planets orbit the Sun, natural satellites orbit planets naturally, while artificial satellites are launched by humans for purposes such as communication, weather forecasting and navigation.

P8.3f Explain for circular orbits, how the force of gravity can lead to changing velocity of a planet but unchanged speed (qualitative only)

1. Gravity keeps a planet moving in orbit around the Sun.
2. A planet has a changing velocity because its direction is constantly changing.
3. Its speed can remain constant because only the direction changes, not the magnitude of the velocity.
4. The gravitational force always acts towards the centre of the orbit.
5. Velocity is a vector quantity, so changing direction means the velocity changes even if the speed stays the same.
6. Gravity continually changes the direction of the planet's motion, producing a changing velocity while the speed remains constant in a circular orbit.

P8.3g Explain how, for a stable orbit, the radius must change if this speed changes (qualitative only)

1. The radius of an orbit is the distance from the centre of the object being orbited to the orbiting object.
2. A stable orbit is one in which an object continues to orbit without crashing into the central body or escaping into space.

3. If the speed of an orbiting object changes, the orbital radius must also change for the orbit to remain stable.
4. For stable orbits, smaller orbital radius means higher orbital speed, while larger orbital radius means lower orbital speed.
5. Changing the speed of a satellite changes the balance between gravity and its motion, causing it to move into a different orbit.
6. A change in orbital speed changes the gravitational force needed for a stable orbit, so the orbital radius changes until a new stable balance is reached.

P8.3h Explain how the temperature of a body is related to the balance between incoming radiation absorbed and radiation emitted; illustrate this balance using everyday examples and the example of the factors which determine the temperature of the Earth

1. If a body absorbs radiation faster than it emits radiation, its temperature increases.
2. If a body emits radiation faster than it absorbs radiation, its temperature decreases.
3. The temperature remains constant when the rate of radiation absorbed equals the rate of radiation emitted.
4. A hot drink cools because it emits more infrared radiation than it absorbs from its surroundings.
5. The Earth's atmosphere allows most incoming visible radiation from the Sun to reach the surface but absorbs and re-emits some outgoing infrared radiation emitted by the Earth.
6. The Earth's temperature depends on the balance between incoming solar radiation absorbed and outgoing infrared radiation emitted. If more energy is absorbed than emitted, the Earth warms; if more is emitted than absorbed, it cools.

P8.3i Explain, in qualitative terms, how the differences in velocity, absorption and reflection between different types of waves in solids and liquids can be used both for detection and for exploration of structures which are hidden from direct observation, notably in the Earth's core and in deep water

1. P waves are longitudinal seismic waves that travel through both solids and liquids. S waves are transverse seismic waves that travel only through solids.
2. Seismic waves change speed and direction as they travel through different layers of the Earth, allowing scientists to investigate its internal structure.

3. S waves cannot travel through liquids, while P waves slow down when entering liquids. This provides evidence that the Earth's outer core is liquid.
4. Reflected seismic waves allow scientists to identify boundaries between different layers inside the Earth.
5. Sonar sends out sound waves and measures the reflected waves to detect underwater objects and measure water depth.
6. Differences in the velocity, absorption and reflection of seismic waves and sound waves allow scientists to investigate the Earth's core and explore structures hidden beneath the Earth's surface or deep underwater.