Topics common to Paper 1 and Paper 2

Topic 1 – Key concepts of physics

Students should:		Maths skills
1.1	Recall and use the SI unit for physical quantities, as listed in *Appendix 3*	
1.2	Recall and use multiples and sub-multiples of units, including giga (G), mega (M), kilo (k), centi (c), milli (m), micro (μ) and nano (n)	3c
1.3	Be able to convert between different units, including hours to seconds	1c
1.4	Use significant figures and standard form where appropriate	1b

Use of mathematics

- Make calculations using ratios and proportional reasoning to convert units and to compute rates (1c, 3c).

Topics for Paper 1

Topic 2 – Motion and forces

Students should:		Maths skills
2.1	Explain that a scalar quantity has magnitude (size) but no specific direction	
2.2	Explain that a vector quantity has both magnitude (size) and a specific direction	5b
2.3	Explain the difference between vector and scalar quantities	5b
2.4	Recall vector and scalar quantities, including: a displacement/distance b velocity/speed c acceleration d force e weight/mass f momentum g energy	
2.5	Recall that velocity is speed in a stated direction	5b
2.6	Recall and use the equations: a (average) speed (metre per second, m/s) = distance (metre, m) ÷ time (s) b distance travelled (metre, m) = average speed (metre per second, m/s) × time (s)	1a, 1c, 1d 2a 3a, 3c, 3d
2.7	Analyse distance/time graphs including determination of speed from the gradient	2a 4a, 4b, 4d, 4e
2.8	Recall and use the equation: acceleration (metre per second squared, m/s^2) = change in velocity (metre per second, m/s) ÷ time taken (second, s) $a = \frac{(v - u)}{t}$	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
2.9	Use the equation: (final velocity)^2 ((metre/second)^2, (m/s)^2) – (initial velocity)^2 ((metre/second)^2, (m/s)^2) = 2 × acceleration (metre per second squared, m/s^2) × distance (metre, m) $v^2 - u^2 = 2 \times a \times x$	1a, 1c, 1d 2a 3a, 3c, 3d

Students should:		Maths skills
2.10	Analyse velocity/time graphs to: a compare acceleration from gradients qualitatively b calculate the acceleration from the gradient (for uniform acceleration only) c determine the distance travelled using the area between the graph line and the time axis (for uniform acceleration only)	1a, 1c, 1d 2a 4a, 4b, 4c, 4d, 4e, 4f 5c
2.11	Describe a range of laboratory methods for determining the speeds of objects such as the use of light gates	1a, 1d 2a, 2b, 2c, 2f, 2h 3a, 3c, 3d 4a, 4c
2.12	Recall some typical speeds encountered in everyday experience for wind and sound, and for walking, running, cycling and other transportation systems	
2.13	Recall that the acceleration, g, in free fall is 10 m/s^2 and be able to estimate the magnitudes of everyday accelerations	1d 2h
2.14	Recall Newton's first law and use it in the following situations: a where the resultant force on a body is zero, i.e. the body is moving at a constant velocity or is at rest b where the resultant force is not zero, i.e. the speed and/or direction of the body change(s)	1a, 1d 2a 3a, 3c, 3d
2.15	Recall and use Newton's second law as: force (newton, N) = mass (kilogram, kg) × acceleration (metre per second squared, m/s^2) $F = m \times a$	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
2.16	Define weight, recall and use the equation: weight (newton, N) = mass (kilogram, kg) × gravitational field strength (newton per kilogram, N/kg) $W = m \times g$	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
2.17	Describe how weight is measured	
2.18	Describe the relationship between the weight of a body and the gravitational field strength	1c
2.19	*Core Practical: Investigate the relationship between force, mass and acceleration by varying the masses added to trolleys*	1a, 1c,1d 2a, 2b, 2f 3a, 3b, 3c, 3d 4a, 4b, 4c, 4d

Students should:		Maths skills
2.20	**Explain that an object moving in a circular orbit at constant speed has a changing velocity (qualitative only)**	5b
2.21	**Explain that for motion in a circle there must be a resultant force known as a centripetal force that acts towards the centre of the circle**	5b
2.22	**Explain that inertial mass is a measure of how difficult it is to change the velocity of an object (including from rest) and know that it is defined as the ratio of force over acceleration**	1c,
2.23	Recall and apply Newton's third law **both** to equilibrium situations **and to collision interactions and relate it to the conservation of momentum in collisions**	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
2.24	**Define momentum, recall and use the equation:** **momentum (kilogram metre per second, kg m/s) = mass (kilogram, kg) × velocity (metre per second, m/s)** $p = m \times v$	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
2.25	**Describe examples of momentum in collisions**	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
2.26	**Use Newton's second law as:** **force (newton, N) = change in momentum (kilogram metre per second, kg m/s) ÷ time (second, s)** $F = \frac{(mv - mu)}{t}$	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
2.27	Explain methods of measuring human reaction times and recall typical results	2a, 2b, 2c, 2g
2.28	Recall that the stopping distance of a vehicle is made up of the sum of the thinking distance and the braking distance	1a
2.29	Explain that the stopping distance of a vehicle is affected by a range of factors including: a the mass of the vehicle b the speed of the vehicle c the driver's reaction time d the state of the vehicle's brakes e the state of the road f the amount of friction between the tyre and the road surface	1c, 1d 2b, 2c, 2h 3b, 3c

Students should:		Maths skills
2.30	Describe the factors affecting a driver's reaction time including drugs and distractions	1d 2b, 2h 3c
2.31	Explain the dangers caused by large decelerations **and estimate the forces involved in typical situations on a public road**	1c, 1d, 2c, 2h, 3b, 3c
2.32P	Estimate how the distance required for a road vehicle to stop in an emergency varies over a range of typical speeds	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
2.33P	Carry out calculations on work done to show the dependence of braking distance for a vehicle on initial velocity squared (work done to bring a vehicle to rest equals its initial kinetic energy)	1c, 1d 2b, 2h 3b, 3c

Use of mathematics

- Make calculations using ratios and proportional reasoning to convert units and to compute rates (1c, 3c).
- Relate changes and differences in motion to appropriate distance-time, and velocity-time graphs, and interpret lines and slopes (4a, 4b, 4c, 4d).
- **Interpret enclosed areas in velocity-time graphs (4a, 4b, 4c, 4d, 4f).**
- Apply formulae relating distance, time and speed, for uniform motion, and for motion with uniform acceleration, and calculate average speed for non-uniform motion (1a, 1c, 3c).
- Estimate how the distances required for road vehicles to stop in an emergency, varies over a range of typical speeds (1c, 1d, 2c, 2h, 3b, 3c).
- Apply formulae relating force, mass and relevant physical constants, including gravitational field strength, to explore how changes in these are inter-related (1c, 3b, 3c).
- Apply formulae relating force, mass, velocity and acceleration to explain how the changes involved are inter-related (3b, 3c, 3d).
- Estimate, for everyday road transport, the speed, accelerations and forces involved in large accelerations (1d, 2b, 2h, 3c).

Suggested practicals

- Investigate the acceleration, g, in free fall and the magnitudes of everyday accelerations.
- Investigate conservation of momentum during collisions.
- Investigate inelastic collisions with the two objects remaining together after the collision and also 'near' elastic collisions.
- Investigate the relationship between mass and weight.
- Investigate how crumple zones can be used to reduce the forces in collisions.

Topic 3 – Conservation of energy

Students should:		Maths skills
3.1	Recall and use the equation to calculate the change in gravitational PE when an object is raised above the ground: change in gravitational potential energy (joule, J) = mass (kilogram, kg) × gravitational field strength (newton per kilogram, N/kg) × change in vertical height (metre, m) $\Delta GPE = m \times g \times \Delta h$	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
3.2	Recall and use the equation to calculate the amounts of energy associated with a moving object: kinetic energy (joule, J) = $\frac{1}{2}$ × mass (kilogram, kg) × (speed)^2 ((metre/second)^2, (m/s)^2) $KE = \frac{1}{2} \times m \times v^2$	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
3.3	Draw and interpret diagrams to represent energy transfers	1c 2c
3.4	Explain what is meant by conservation of energy	
3.5	Analyse the changes involved in the way energy is stored when a system changes, including: a an object projected upwards or up a slope b a moving object hitting an obstacle c an object being accelerated by a constant force d a vehicle slowing down e bringing water to a boil in an electric kettle	
3.6	Explain that where there are energy transfers in a closed system there is no net change to the total energy in that system	
3.7	Explain that mechanical processes become wasteful when they cause a rise in temperature so dissipating energy in heating the surroundings	
3.8	Explain, using examples, how in all system changes energy is dissipated so that it is stored in less useful ways	
3.9	Explain ways of reducing unwanted energy transfer including through lubrication, thermal insulation	
3.10	Describe the effects of the thickness and thermal conductivity of the walls of a building on its rate of cooling qualitatively	
3.11	Recall and use the equation: $\text{efficiency} = \frac{(\text{useful energy transferred by the device})}{(\text{total energy supplied to the device})}$	1a, 1c, 1d 2a 3a, 3b, 3c, 3d

Students should:		Maths skills
3.12	**Explain how efficiency can be increased**	
3.13	Describe the main energy sources available for use on Earth (including fossil fuels, nuclear fuel, bio-fuel, wind, hydro-electricity, the tides and the Sun), and compare the ways in which both renewable and non-renewable sources are used	2c, 2g
3.14	Explain patterns and trends in the use of energy resources	2c, 2g

Uses of mathematics

- Make calculations using ratios and proportional reasoning to convert units and to compute rates (1c, 3c).
- Calculate relevant values of stored energy and energy transfers; convert between newton-metres and joules (1c, 3c).
- Make calculations of the energy changes associated with changes in a system, recalling or selecting the relevant equations for mechanical, electrical, and thermal processes; thereby express in quantitative form and on a common scale the overall redistribution of energy in the system (1a, 1c, 3c).

Suggested practicals

- Investigate conservation of energy.

Topic 4 – Waves

Students should:		Maths skills
4.1	Recall that waves transfer energy and information without transferring matter	
4.2	Describe evidence that with water and sound waves it is the wave and not the water or air itself that travels	
4.3	Define and use the terms frequency and wavelength as applied to waves	
4.4	Use the terms amplitude, period, wave velocity and wavefront as applied to waves	
4.5	Describe the difference between longitudinal and transverse waves by referring to sound, electromagnetic, seismic and water waves	
4.6	Recall and use both the equations below for all waves: wave speed (metre/second, m/s) = frequency (hertz, Hz) × wavelength (metre, m) $v = f \times \lambda$ wave speed (metre/second, m/s) = distance (metre, m) ÷ time (second, s) $v = \frac{x}{t}$	1a, 1b, 1c, 1d 2a 3a, 3b, 3c, 3d
4.7	Describe how to measure the velocity of sound in air and ripples on water surfaces	2g
4.8P	**Calculate depth or distance from time and wave velocity**	1a, 1b, 1c, 1d 2a 3a, 3b, 3c, 3d
4.9P	Describe the effects of a reflection b refraction c transmission d absorption of waves at material interfaces	5b
4.10	Explain how waves will be refracted at a boundary in terms of the change of direction **and speed**	1c 3c 5b
4.11	**Recall that different substances may absorb, transmit, refract or reflect waves in ways that vary with wavelength**	

Students should:		Maths skills
4.12P	**Describe the processes which convert wave disturbances between sound waves and vibrations in solids, and** **a explain why such processes only work over a limited frequency range** **b use this to explain the way the human ear works**	
4.13P	**Recall that sound with frequencies greater than 20 000 hertz, Hz, is known as ultrasound**	
4.14P	**Recall that sound with frequencies less than 20 hertz, Hz, is known as infrasound**	
4.15P	**Explain uses of ultrasound and infrasound, including** **a sonar** **b foetal scanning** **c exploration of the Earth's core**	1a, 1b, 1c, 2a 3a, 3b, 3c, 3d 5b
4.16P	Describe how changes, if any, in velocity, frequency and wavelength, in the transmission of sound waves from one medium to another are inter-related	1a, 1c, 1d 2a 3a, 3c, 3d
4.17	*Core Practical: Investigate the suitability of equipment to measure the speed, frequency and wavelength of a wave in a solid and a fluid*	2g

Use of mathematics

- Apply formulae relating velocity, frequency and wavelength (1c, 3c).
- Show how changes, if any, in velocity, frequency and wavelength, in transmission of sound waves from one medium to another, are inter-related (1c, 3c).

Suggested practicals

- Investigate models to show refraction, such as toy cars travelling into a region of sand.
- Investigate refraction in rectangular glass blocks.

Topic 5 – Light and the electromagnetic spectrum

Students should:		Maths skills
5.1P	Explain, with the aid of ray diagrams, reflection, refraction and total internal reflection (TIR), including the law of reflection and critical angle	5a, 5b
5.2P	Explain the difference between specular and diffuse reflection	5b
5.3P	Explain how colour of light is related to a differential absorption at surfaces b transmission of light through filters	
5.4P	Relate the power of a lens to its focal length and shape	5b
5.5P	Use ray diagrams to show the similarities and differences in the refraction of light by converging and diverging lenses	5b
5.6P	Explain the effects of different types of lens in producing real and virtual images	5b
5.7	Recall that all electromagnetic waves are transverse, that they travel at the same speed in a vacuum	
5.8	Explain, with examples, that all electromagnetic waves transfer energy from source to observer	
5.9	*Investigate refraction in rectangular glass blocks in terms of the interaction of electromagnetic waves with matter*	
5.10	Recall the main groupings of the continuous electromagnetic spectrum including (in order) radio waves, microwaves, infrared, visible (including the colours of the visible spectrum), ultraviolet, x-rays and gamma rays	
5.11	Describe the electromagnetic spectrum as continuous from radio waves to gamma rays and that the radiations within it can be grouped in order of decreasing wavelength and increasing frequency	1a, 1c 3c
5.12	Recall that our eyes can only detect a limited range of frequencies of electromagnetic radiation	
5.13	**Recall that different substances may absorb, transmit, refract or reflect electromagnetic waves in ways that vary with wavelength**	
5.14	Explain the effects of differences in the velocities of electromagnetic waves in different substances	1a, 1c 3c
5.15P	Explain that all bodies emit radiation, that the intensity and wavelength distribution of any emission depends on their temperature	5c
5.16P	**Explain that for a body to be at a constant temperature it needs to radiate the same average power that it absorbs**	

Students should:		Maths skills
5.17P	**Explain what happens to a body if the average power it radiates is less or more than the average power that it absorbs**	
5.18P	**Explain how the temperature of the Earth is affected by factors controlling the balance between incoming radiation and radiation emitted**	
5.19P	*Core Practical: Investigate how the nature of a surface affects the amount of thermal energy radiated or absorbed*	1a, 1c, 1d 2a, 2c, 2f 3a, 3c, 3d 4a, 4c
5.20	Recall that the potential danger associated with an electromagnetic wave increases with increasing frequency	
5.21	Describe the harmful effects on people of excessive exposure to electromagnetic radiation, including: a microwaves: internal heating of body cells b infrared: skin burns c ultraviolet: damage to surface cells and eyes, leading to skin cancer and eye conditions d x-rays and gamma rays: mutation or damage to cells in the body	
5.22	Describe some uses of electromagnetic radiation a radio waves: including broadcasting, communications and satellite transmissions b microwaves: including cooking, communications and satellite transmissions c infrared: including cooking, thermal imaging, short range communications, optical fibres, television remote controls and security systems d visible light: including vision, photography and illumination e ultraviolet: including security marking, fluorescent lamps, detecting forged bank notes and disinfecting water f x-rays: including observing the internal structure of objects, airport security scanners and medical x-rays g gamma rays: including sterilising food and medical equipment, and the detection of cancer and its treatment	
5.23	**Recall that radio waves can be produced by, or can themselves induce, oscillations in electrical circuits**	
5.24	Recall that changes in atoms and nuclei can a generate radiations over a wide frequency range b be caused by absorption of a range of radiations	

Use of mathematics

- Make calculations using ratios and proportional reasoning to convert units and to compute rates (1c, 3c).
- Apply the relationships between frequency and wavelength across the electromagnetic spectrum (1a, 1c, 3c).
- Construct two-dimensional ray diagrams to illustrate reflection and refraction (qualitative – equations not needed) (5a, 5b).

Suggested practicals

- Investigate total internal reflection using a semi-circular block (glass or plastic).
- Construct devices using two converging lenses of differing focal lengths.
- Construct a simple spectrometer, from a CD or DVD, and use it to analyse common light sources.
- Investigate the areas beyond the visible spectrum, such as the work of Herschel and Ritter in discovering IR and UV respectively.

Topic 6 – Radioactivity

Students should:		Maths skills
6.1	Describe an atom as a positively charged nucleus, consisting of protons and neutrons, surrounded by negatively charged electrons, with the nuclear radius much smaller than that of the atom and with almost all of the mass in the nucleus	5b
6.2	Recall the typical size (order of magnitude) of atoms and small molecules	
6.3	Describe the structure of nuclei of isotopes using the terms atomic (proton) number and mass (nucleon) number and using symbols in the format using symbols in the format $^{13}_{6}C$	1a 3a
6.4	Recall that the nucleus of each element has a characteristic positive charge, but that isotopes of an element differ in mass by having different numbers of neutrons	2g 5b
6.5	Recall the relative masses and relative electric charges of protons, neutrons, electrons and positrons	
6.6	Recall that in an atom the number of protons equals the number of electrons and is therefore neutral	
6.7	Recall that in each atom its electrons orbit the nucleus at different set distances from the nucleus	5b
6.8	Explain that electrons change orbit when there is absorption or emission of electromagnetic radiation	5b
6.9	Explain how atoms may form positive ions by losing outer electrons	5b
6.10	Recall that alpha, β− (beta minus), β+ (positron), gamma rays and neutron radiation are emitted from unstable nuclei in a random process	
6.11	Recall that alpha, β− (beta minus), β+ (positron) and gamma rays are ionising radiations	
6.12	Explain what is meant by background radiation	
6.13	Describe the origins of background radiation from Earth and space	
6.14	Describe methods for measuring and detecting radioactivity limited to photographic film and a Geiger–Müller tube	
6.15	Recall that an alpha particle is equivalent to a helium nucleus, a beta particle is an electron emitted from the nucleus and a gamma ray is electromagnetic radiation	
6.16	Compare alpha, beta and gamma radiations in terms of their abilities to penetrate and ionise	

Students should:		Maths skills
6.17	Describe how and why the atomic model has changed over time including reference to the plum pudding model and Rutherford alpha particle scattering leading to the Bohr model	5b
6.18	Describe the process of β– decay (a neutron becomes a proton plus an electron)	1b, 1c, 3c
6.19	Describe the process of β+ decay (a proton becomes a neutron plus a positron)	1b, 1c, 3c
6.20	Explain the effects on the atomic (proton) number and mass (nucleon) number of radioactive decays (α, β, γ and neutron emission)	1b, 1c, 3c
6.21	Recall that nuclei that have undergone radioactive decay often undergo nuclear rearrangement with a loss of energy as gamma radiation	
6.22	Use given data to balance nuclear equations in terms of mass and charge	1b, 1c, 3c
6.23	Describe how the activity of a radioactive source decreases over a period of time	2g 4c
6.24	Recall that the unit of activity of a radioactive isotope is the Becquerel, Bq	
6.25	Explain that the half-life of a radioactive isotope is the time taken for half the undecayed nuclei to decay or the activity of a source to decay by half	1c, 1d 2a
6.26	Explain that it cannot be predicted when a particular nucleus will decay but half-life enables the activity of a very large number of nuclei to be predicted during the decay process	1c, 3d
6.27	Use the concept of half-life to carry out simple calculations on the decay of a radioactive isotope, including graphical representations	1a, 1b, 1c, 1d 2a, 2g 3a, 3b, 3c, 3d
6.28P	Describe uses of radioactivity, including: a household fire (smoke) alarms b irradiating food c sterilisation of equipment d tracing and gauging thicknesses e diagnosis and treatment of cancer	
6.29	Describe the dangers of ionising radiation in terms of tissue damage and possible mutations and relate this to the precautions needed	
6.30P	Explain how the dangers of ionising radiation depend on half-life and relate this to the precautions needed	

Students should:		Maths skills
6.31	Explain the precautions taken to ensure the safety of people exposed to radiation, including limiting the dose for patients and the risks to medical personnel	
6.32	Describe the differences between contamination and irradiation effects and compare the hazards associated with these two	
6.33P	Compare and contrast the treatment of tumours using radiation applied internally or externally	5b
6.34P	Explain some of the uses of radioactive substances in diagnosis of medical conditions, including PET scanners and tracers	
6.35P	Explain why isotopes used in PET scanners have to be produced nearby	
6.36P	Evaluate the advantages and disadvantages of nuclear power for generating electricity, including the lack of carbon dioxide emissions, risks, public perception, waste disposal and safety issues	
6.37P	Recall that nuclear reactions, including fission, fusion and radioactive decay, can be a source of energy	
6.38P	Explain how the fission of U-235 produces two daughter nuclei and the emission of two or more neutrons, accompanied by a release of energy	1b, 1c, 3c
6.39P	Explain the principle of a controlled nuclear chain reaction	
6.40P	Explain how the chain reaction is controlled in a nuclear reactor, including the action of moderators and control rods	5b
6.41P	Describe how thermal (heat) energy from the chain reaction is used in the generation of electricity in a nuclear power station	
6.42P	Recall that the products of nuclear fission are radioactive	
6.43P	Describe nuclear fusion as the creation of larger nuclei resulting in a loss of mass from smaller nuclei, accompanied by a release of energy, and recognise fusion as the energy source for stars	1b, 1c, 3c
6.44P	Explain the difference between nuclear fusion and nuclear fission	
6.45P	Explain why nuclear fusion does not happen at low temperatures and pressures, due to electrostatic repulsion of protons	
6.46P	Relate the conditions for fusion to the difficulty of making a practical and economic form of power station	

Uses of mathematics

- Make calculations using ratios and proportional reasoning to convert units and to compute rates (1c, 3c).
- Balance equations representing alpha-, beta- or gamma-radiations in terms of the masses and charges of the atoms involved (1b, 1c, 3c).
- **Calculate the net decline, expressed as a ratio, in a radioactive emission after a given number of half-lives (1c, 3d).**

Suggested practicals

- Investigate models which simulate radioactive decay.

Topic 7 – Astronomy

Students should:		Maths skills
7.1P	Explain how and why both the weight of any body and the value of g differ between the surface of the Earth and the surface of other bodies in space, including the Moon	
7.2P	Recall that our Solar System consists of the Sun (our star), eight planets and their natural satellites (such as our Moon); dwarf planets; asteroids and comets	5b
7.3P	Recall the names and order, in terms of distance from the Sun, of the eight planets	
7.4P	Describe how ideas about the structure of the Solar System have changed over time	5b
7.5P	Describe the orbits of moons, planets, comets and artificial satellites	5b
7.6P	Explain for circular orbits how the force of gravity can lead to changing velocity of a planet but unchanged speed	5b
7.7P	Explain how, for a stable orbit, the radius must change if orbital speed changes (qualitative only)	
7.8P	Compare the Steady State and Big Bang theories	5b
7.9P	Describe evidence supporting the Big Bang theory, limited to red-shift and the cosmic microwave background (CMB) radiation	
7.10P	Recall that as there is more evidence supporting the Big Bang theory than the Steady State theory, it is the currently accepted model for the origin of the Universe	
7.11P	Describe that if a wave source is moving relative to an observer there will be a change in the observed frequency and wavelength	5b
7.12P	Describe the red-shift in light received from galaxies at different distances away from the Earth	2g 5b
7.13P	Explain why the red-shift of galaxies provides evidence for the Universe expanding	5b
7.14P	Explain how both the Big Bang and Steady State theories of the origin of the Universe both account for red-shift of galaxies	
7.15P	Explain how the discovery of the CMB radiation led to the Big Bang theory becoming the currently accepted model	

Students should:		Maths skills
7.16P	Describe the evolution of stars of similar mass to the Sun through the following stages: a nebula b star (main sequence) c red giant d white dwarf	2g
7.17P	Explain how the balance between thermal expansion and gravity affects the life cycle of stars	
7.18P	Describe the evolution of stars with a mass larger than the Sun	2g
7.19P	Describe how methods of observing the Universe have changed over time including why some telescopes are located outside the Earth's atmosphere	

Topics for Paper 2

Topic 8 – Energy – forces doing work

Students should:		Maths skills
8.1	Describe the changes involved in the way energy is stored when systems change	
8.2	Draw and interpret diagrams to represent energy transfers	1c, 2c
8.3	Explain that where there are energy transfers in a closed system there is no net change to the total energy in that system	
8.4	Identify the different ways that the energy of a system can be changed a through work done by forces b in electrical equipment c in heating	
8.5	Describe how to measure the work done by a force and understand that energy transferred (joule, J) is equal to work done (joule, J)	
8.6	Recall and use the equation: work done (joule, J) = force (newton, N) × distance moved in the direction of the force (metre, m) $E = F \times d$	1a, 1b, 1c, 1d 2a 3a, 3b, 3c, 3d 4f
8.7	Describe and calculate the changes in energy involved when a system is changed by work done by forces	
8.8	Recall and use the equation to calculate the change in gravitational PE when an object is raised above the ground: change in gravitational potential energy (joule, J) = mass (kilogram, kg) × gravitational field strength (newton per kilogram, N/kg) × change in vertical height (metre, m) $\Delta GPE = m \times g \times \Delta h$	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
8.9	Recall and use the equation to calculate the amounts of energy associated with a moving object: kinetic energy (joule, J) = $\frac{1}{2}$ × mass (kilogram, kg) × (speed)^2 ((metre/second)^2, (m/s)^2) $KE = \frac{1}{2} \times m \times v^2$	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
8.10	Explain, using examples, how in all system changes energy is dissipated so that it is stored in less useful ways	

Students should:		Maths skills
8.11	Explain that mechanical processes become wasteful when they cause a rise in temperature so dissipating energy in heating the surroundings	
8.12	Define power as the rate at which energy is transferred and use examples to explain this definition	1c
8.13	Recall and use the equation: power (watt, W) = work done (joule, J) ÷ time taken (second, s) $P = \frac{E}{t}$	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
8.14	Recall that one watt is equal to one joule per second, J/s	1c
8.15	Recall and use the equation: $\text{efficiency} = \frac{(\text{useful energy transferred by the device})}{(\text{total energy supplied to the device})}$	1a, 1c, 1d 2a 3a, 3b, 3c, 3d

Use of mathematics

- Make calculations of the energy changes associated with changes in a system, recalling or selecting the relevant equations for mechanical, electrical, and thermal processes; thereby express in quantitative form and on a common scale the overall redistribution of energy in the system (1a, 1c, 3c).
- Calculate relevant values of stored energy and energy transfers; convert between newton-metres and joules (1c, 3c).
- Make calculations using ratios and proportional reasoning to convert units and to compute rates (1c, 3c).

Suggested practicals

- Investigate power by moving up the stairs, step-ups onto a low platform or lifting objects of different weights.

Topic 9 – Forces and their effects

Students should:		Maths skills
9.1	Describe, with examples, how objects can interact a at a distance without contact, linking these to the gravitational, electrostatic and magnetic fields involved b by contact, including normal contact force and friction c producing pairs of forces which can be represented as vectors	
9.2	Explain the difference between vector and scalar quantities using examples	
9.3	**Use vector diagrams to illustrate resolution of forces, a net force, and equilibrium situations (scale drawings only)**	4a, 5a, 5b
9.4	**Draw and use free body force diagrams**	4a, 5a, 5b
9.5	**Explain examples of the forces acting on an isolated solid object or a system where several forces lead to a resultant force on an object and the special case of balanced forces when the resultant force is zero**	5a
9.6P	Describe situations where forces can cause rotation	
9.7P	Recall and use the equation: moment of a force (newton metre, N m) = force (newton, N) × distance normal to the direction of the force (metre, m)	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
9.8P	Recall and use the principle of moments in situations where rotational forces are in equilibrium: the sum of clockwise moments = the sum of anti-clockwise moments for rotational forces in equilibrium	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
9.9P	Explain how levers and gears transmit the rotational effects of forces	5b
9.10	Explain ways of reducing unwanted energy transfer through lubrication	

Use of mathematics

- Make calculations using ratios and proportional reasoning to convert units and to compute rates (1c, 3c).
- **Use vector diagrams to illustrate resolution of forces, a net force, and equilibrium situations (scale drawings only) (4a, 5a, 5b).**

Suggested practicals

- Investigate levers and gears.

Topic 10 – Electricity and circuits

Students should:		Maths skills
10.1	Describe the structure of the atom, limited to the position, mass and charge of protons, neutrons and electrons	5b
10.2	Draw and use electric circuit diagrams representing them with the conventions of positive and negative terminals, and the symbols that represent cells, including batteries, switches, voltmeters, ammeters, resistors, variable resistors, lamps, motors, diodes, thermistors, LDRs and LEDs	5b
10.3	Describe the differences between series and parallel circuits	
10.4	Recall that a voltmeter is connected in parallel with a component to measure the potential difference (voltage), in volt, across it	
10.5	Explain that potential difference (voltage) is the energy transferred per unit charge passed and hence that the volt is a joule per coulomb	1a, 1c 3c
10.6	Recall and use the equation: energy transferred (joule, J) = charge moved (coulomb, C) × potential difference (volt, V) $E = Q \times V$	1a, 1b, 1c, 1d 2a 3a, 3b, 3c, 3d
10.7	Recall that an ammeter is connected in series with a component to measure the current, in amp, in the component	
10.8	Explain that an electric current as the rate of flow of charge and the current in metals is a flow of electrons	
10.9	Recall and use the equation: charge (coulomb, C) = current (ampere, A) × time (second, s) $Q = I \times t$	1a, 1b, 1c, 1d 2a 3a, 3b, 3c, 3d
10.10	Describe that when a closed circuit includes a source of potential difference there will be a current in the circuit	
10.11	Recall that current is conserved at a junction in a circuit	
10.12	Explain how changing the resistance in a circuit changes the current and how this can be achieved using a variable resistor	
10.13	Recall and use the equation: potential difference (volt, V) = current (ampere, A) × resistance (ohm, Ω) $V = I \times R$	1a, 1d 2a 3a, 3c, 3d
10.14	Explain why, if two resistors are in series, the net resistance is increased, whereas with two in parallel the net resistance is decreased	

Students should:		Maths skills
10.15	Calculate the currents, potential differences and resistances in series circuits	1a, 1d 2a 3a, 3c, 3d
10.16	Explain the design and construction of series circuits for testing and measuring	
10.17	*Core Practical: Construct electrical circuits to:* *a investigate the relationship between potential difference, current and resistance for a resistor and a filament lamp* *b test series and parallel circuits using resistors and filament lamps*	1a, 1c, 1d 2a, 2b, 2f 3a, 3b, 3c, 3d 4a, 4b, 4c, 4d, 4e
10.18	Explain how current varies with potential difference for the following devices and how this relates to resistance a filament lamps b diodes c fixed resistors	2g 4a, 4b, 4c, 4d, 4e
10.19	Describe how the resistance of a light-dependent resistor (LDR) varies with light intensity	4c, 4d
10.20	Describe how the resistance of a thermistor varies with change of temperature (negative temperature coefficient thermistors only)	4c, 4d
10.21	Explain how the design and use of circuits can be used to explore the variation of resistance in the following devices a filament lamps b diodes c thermistors d LDRs	5b
10.22	Recall that, when there is an electric current in a resistor, there is an energy transfer which heats the resistor	
10.23	Explain that electrical energy is dissipated as thermal energy in the surroundings when an electrical current does work against electrical resistance	
10.24	Explain the energy transfer (in 10.22 above) as the result of collisions between electrons and the ions in the lattice	
10.25	Explain ways of reducing unwanted energy transfer through low resistance wires	
10.26	Describe the advantages and disadvantages of the heating effect of an electric current	

Students should:		Maths skills
10.27	Use the equation: energy transferred (joule, J) = current (ampere, A) × potential difference (volt, V) × time (second, s) $E = I \times V \times t$	1a, 1b, 1c, 1d 2a 3a, 3b, 3c, 3d
10.28	Describe power as the energy transferred per second and recall that it is measured in watt	1c
10.29	Recall and use the equation: power (watt, W) = energy transferred (joule, J) ÷ time taken (second, s) $P = \frac{E}{t}$	1a, 1b, 1c, 1d 2a 3a, 3b, 3c, 3d
10.30	Explain how the power transfer in any circuit device is related to the potential difference across it and the current in it	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
10.31	Recall and use the equations: electrical power (watt, W) = current (ampere, A) × potential difference (volt, V) $P = I \times V$ electrical power (watt, W) = current squared (ampere^2, A^2) × resistance (ohm, Ω) $P = I^2 \times R$	1a, 1b, 1c, 1d 2a 3a, 3b, 3c, 3d
10.32	Describe how, in different domestic devices, energy is transferred from batteries and the a.c. mains to the energy of motors and heating devices	
10.33	Explain the difference between direct and alternating voltage	4c
10.34	Describe direct current (d.c.) as movement of charge in one direction only and recall that cells and batteries supply direct current (d.c.)	
10.35	Describe that in alternating current (a.c.) the movement of charge changes direction	
10.36	Recall that in the UK the domestic supply is a.c., at a frequency of 50 Hz and a voltage of about 230 V	
10.37	Explain the difference in function between the live and the neutral mains input wires	
10.38	Explain the function of an earth wire and of fuses or circuit breakers in ensuring safety	
10.39	Explain why switches and fuses should be connected in the live wire of a domestic circuit	

Students should:		Maths skills
10.40	Recall the potential differences between the live, neutral and earth mains wires	
10.41	Explain the dangers of providing any connection between the live wire and earth	
10.42	Describe, with examples, the relationship between the power ratings for domestic electrical appliances and the changes in stored energy when they are in use	1c 2c

Use of mathematics

- Make calculations using ratios and proportional reasoning to convert units and to compute rates (1c, 3c).
- Apply the equations relating p.d., 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 (1c, 3b, 3c, 3d).
- Use graphs to explore whether circuit elements are linear or non-linear and relate the curves produced to their function and properties (4c, 4d).
- Make calculations of the energy changes associated with changes in a system, recalling or selecting the relevant equations for mechanical, electrical, and thermal processes; thereby express in quantitative form and on a common scale the overall redistribution of energy in the system (1a, 1c, 3c).

Suggested practicals

- Investigate the power consumption of low-voltage electrical items.

Topic 11 – Static electricity

Students should:		Maths skills
11.1P	Explain how an insulator can be charged by friction, through the transfer of electrons	
11.2P	Explain how the material gaining electrons becomes negatively charged and the material losing electrons is left with an equal positive charge	
11.3P	Recall that like charges repel and unlike charges attract	
11.4P	Explain common electrostatic phenomena in terms of movement of electrons, including a shocks from everyday objects b lightning c attraction by induction such as a charged balloon attracted to a wall and a charged comb picking up small pieces of paper	
11.5P	Explain how earthing removes excess charge by movement of electrons	
11.6P	Explain some of the uses of electrostatic charges in everyday situations, including insecticide sprayers	
11.7P	Describe some of the dangers of sparking in everyday situations, including fuelling cars, and explain the use of earthing to prevent dangerous build-up of charge	
11.8P	Define an electric field as the region where an electric charge experiences a force	
11.9P	Describe the shape and direction of the electric field around a point charge and between parallel plates and relate the strength of the field to the concentration of lines	5b
11.10P	Explain how the concept of an electric field helps to explain the phenomena of static electricity	

Suggested practicals

- Investigate the forces of attraction and repulsion between charged objects.

Topic 12 – Magnetism and the motor effect

Students should:		Maths skills
12.1	Recall that unlike magnetic poles attract and like magnetic poles repel	
12.2	Describe the uses of permanent and temporary magnetic materials including cobalt, steel, iron and nickel	
12.3	Explain the difference between permanent and induced magnets	
12.4	Describe the shape and direction of the magnetic field around bar magnets and for a uniform field, and relate the strength of the field to the concentration of lines	5b
12.5	Describe the use of plotting compasses to show the shape and direction of the field of a magnet and the Earth's magnetic field	5b
12.6	Explain how the behaviour of a magnetic compass is related to evidence that the core of the Earth must be magnetic	5b
12.7	Describe how to show that a current can create a magnetic effect around a long straight conductor, describing the shape of the magnetic field produced and relating the direction of the magnetic field to the direction of the current	5b
12.8	Recall that the strength of the field depends on the size of the current and the distance from the long straight conductor	
12.9	Explain how inside a solenoid (an example of an electromagnet) the fields from individual coils a add together to form a very strong almost uniform field along the centre of the solenoid b cancel to give a weaker field outside the solenoid	5b
12.10	**Recall that a current carrying conductor placed near a magnet experiences a force and that an equal and opposite force acts on the magnet**	5b
12.11	**Explain that magnetic forces are due to interactions between magnetic fields**	
12.12	**Recall and use Fleming's left-hand rule to represent the relative directions of the force, the current and the magnetic field for cases where they are mutually perpendicular**	5b

Students should:		Maths skills
12.13	**Use the equation:** **force on a conductor at right angles to a magnetic field carrying a current (newton, N) = magnetic flux density (tesla, T or newton per ampere metre, N/A m) × current (ampere, A) × length (metre, m)** $F = B \times I \times l$	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
12.14P	**Explain how the force on a conductor in a magnetic field is used to cause rotation in electric motors**	5b

Use of mathematics

- Make calculations using ratios and proportional reasoning to convert units and to compute rates (1c, 3c).

Suggested practicals

- Construct an electric motor.

Topic 13 – Electromagnetic induction

Students should:		Maths skills
13.1P	**Explain how to produce an electric current by the relative movement of a magnet and a conductor** **a on a small scale in the laboratory** **b in the large-scale generation of electrical energy**	
13.2	**Recall the factors that affect the size and direction of an induced potential difference, and describe how the magnetic field produced opposes the original change**	5b
13.3P	**Explain how electromagnetic induction is used in alternators to generate current which alternates in direction (a.c.) and in dynamos to generate direct current (d.c.)**	5b
13.4P	**Explain the action of the microphone in converting the pressure variations in sound waves into variations in current in electrical circuits, and the reverse effect as used in loudspeakers and headphones**	5b
13.5	**Explain how an alternating current in one circuit can induce a current in another circuit in a transformer**	
13.6	**Recall that a transformer can change the size of an alternating voltage**	
13.7P	**Use the turns ratio equation for transformers to calculate either the missing voltage or the missing number of turns:** $\frac{\textit{potential difference across primary coil}}{\textit{potential difference across secondary coil}} = \frac{\textit{number of turns in primary coil}}{\textit{number of turns in secondary coil}}$ $\frac{V_p}{V_s} = \frac{N_p}{N_s}$	1a, 1c, 1d 2a 3a, 3b, 3c, 3d 5b
13.8	Explain why, in the national grid, electrical energy is transferred at high voltages from power stations, and then transferred at lower voltages in each locality for domestic uses as it improves the efficiency by reducing heat loss in transmission lines	
13.9	Explain where and why step-up and step-down transformers are used in the transmission of electricity in the national grid	

Students should:		Maths skills
13.10	Use the power equation (for transformers with100% efficiency): potential difference across primary coil (volt, V) × current in primary coil (ampere, A) = potential difference across secondary coil (volt, V) × current in secondary coil (ampere, A) $V_P \times I_P = V_S \times I_S$	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
13.11P	**Explain the advantages of power transmission in high-voltage cables, using the equations in 10.29, 10.31, 13.7P and 13.10**	1a, 1c, 1d 2a 3a, 3b, 3c, 3d 5b

Use of mathematics

- Make calculations using ratios and proportional reasoning to convert units and to compute rates (1c, 3c).
- **Apply the equations linking the p.d.s and numbers of turns in the two coils of a transformer, to the currents and the power transfer involved, and relate these to the advantages of power transmission at high voltages (1c, 3b, 3c).**
- Make calculations of the energy changes associated with changes in a system, recalling or selecting the relevant equations for mechanical, electrical, and thermal processes; thereby express in quantitative form and on a common scale the overall redistribution of energy in the system (1a, 1c, 3c).

Suggested practicals

- Investigate factors affecting the generation of electric current by induction.

Topic 14 – Particle model

Students should:		Maths skills
14.1	Use a simple kinetic theory model to explain the different states of matter (solids, liquids and gases) in terms of the movement and arrangement of particles	
14.2	Recall and use the equation: density (kilogram per cubic metre, kg/m^3) = mass (kilogram, kg) ÷ volume (cubic metre, m^3) $\rho = \frac{m}{V}$	1a, 1b, 1c, 1d 2a 3a, 3b, 3c, 3d 5c
14.3	*Core Practical: Investigate the densities of solid and liquids*	1a, 1b, 1c, 1d 2a, 2c, 2f 3a, 3b, 3c, 3d 4a, 4c 5c
14.4	Explain the differences in density between the different states of matter in terms of the arrangements of the atoms or molecules	5b
14.5	Describe that when substances melt, freeze, evaporate, boil, condense or sublimate mass is conserved and that these physical changes differ from some chemical changes because the material recovers its original properties if the change is reversed	
14.6	Explain how heating a system will change the energy stored within the system and raise its temperature or produce changes of state	
14.7	Define the terms specific heat capacity and specific latent heat and explain the differences between them	
14.8	Use the equation: change in thermal energy (joule, J) = mass (kilogram, kg) × specific heat capacity (joule per kilogram degree Celsius, J/kg °C) × change in temperature (degree Celsius, °C) $\Delta Q = m \times c \times \Delta\theta$	1a, 1b, 1c, 1d 2a 3a, 3b, 3c, 3d
14.9	Use the equation: thermal energy for a change of state (joule , J) = mass (kilogram, kg) × specific latent heat (joule per kilogram, J/kg) $Q = m \times L$	1a, 1b, 1c, 1d 2a 3a, 3b, 3c, 3d
14.10	Explain ways of reducing unwanted energy transfer through thermal insulation	

Students should:		Maths skills
14.11	*Core Practical: Investigate the properties of water by determining the specific heat capacity of water and obtaining a temperature-time graph for melting ice*	1a, 1b, 1c, 1d 2a, 2b, 2f 3a, 3b, 3c, 3d 4a, 4c, 4e
14.12	Explain the pressure of a gas in terms of the motion of its particles	5b
14.13	Explain the effect of changing the temperature of a gas on the velocity of its particles and hence on the pressure produced by a fixed mass of gas at constant volume (qualitative only)	5b
14.14	Describe the term absolute zero, −273 °C, in terms of the lack of movement of particles	
14.15	Convert between the kelvin and Celsius scales	1a 2a
14.16P	Explain that gases can be compressed or expanded by pressure changes	
14.17P	Explain that the pressure of a gas produces a net force at right angles to any surface	
14.18P	Explain the effect of changing the volume of a gas on the rate at which its particles collide with the walls of its container and hence on the pressure produced by a fixed mass of gas at constant temperature	5b
14.19P	Use the equation: $P_1 \times V_1 = P_2 \times V_2$ to calculate pressure or volume for gases of fixed mass at constant temperature	1a, 1b, 1c, 1d 2a 3a, 3b, 3c, 3d
14.20P	**Explain why doing work on a gas can increase its temperature, including a bicycle pump**	

Use of mathematics

- Make calculations using ratios and proportional reasoning to convert units and to compute rates (1c, 3c).
- Make calculations of the energy changes associated with changes in a system, recalling or selecting the relevant equations for mechanical, electrical, and thermal processes; thereby express in quantitative form and on a common scale the overall redistribution of energy in the system (1a, 1c, 3c).
- Calculate relevant values of stored energy and energy transfers; convert between newton-metres and joules (1c, 3c).
- Apply the relationship between density, mass and volume to changes where mass is conserved (1a, 1b, 1c, 3c).
- 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; apply the relationship between specific latent heat and mass to calculate the energy change involved in a change of state (1a, 3c, 3d).

Suggested practicals

- Investigate the temperature and volume relationship for a gas.
- Investigate the volume and pressure relationship for a gas.
- Investigate latent heat of vaporisation.

Topic 15 – Forces and matter

Students should:		Maths skills
15.1	Explain, using springs and other elastic objects, that stretching, bending or compressing an object requires more than one force	
15.2	Describe the difference between elastic and inelastic distortion	
15.3	Recall and use the equation for linear elastic distortion including calculating the spring constant: force exerted on a spring (newton, N) = spring constant (newton per metre, N/m) × extension (metre, m) $F = k \times x$	1a, 1c, 1d 2a 3a, 3b, 3c, 3d
15.4	Use the equation to calculate the work done in stretching a spring: energy transferred in stretching (joules, J) = 0.5 × spring constant (newton per metre, N/m) × (extension (metre, m))^2 $E = \frac{1}{2} \times k \times x^2$	1a, 1c, 1d 2a 3a, 3b, 3c, 3d 4c, 4e, 4f
15.5	Describe the difference between linear and non-linear relationships between force and extension	4c, 4e
15.6	*Core Practical: Investigate the extension and work done when applying forces to a spring*	1a, 1c, 1d 2a, 2b, 2c, 2f 3a, 3b, 3c, 3d 4a, 4b, 4c, 4d
15.7P	Explain why atmospheric pressure varies with height above the Earth's surface with reference to a simple model of the Earth's atmosphere	
15.8P	Describe the pressure in a fluid as being due to the fluid and atmospheric pressure	
15.9P	Recall that the pressure in fluids causes a force normal to any surface	
15.10P	Explain how pressure is related to force and area, using appropriate examples	1c
15.11P	Recall and use the equation: pressure (pascal, Pa) = force normal to surface (newton, N) ÷ area of surface (square metre, m^2) $P = \frac{F}{A}$	1a, 1b, 1c, 1d 2a 3a, 3c, 3d 5b, 5c
15.12P	Describe how pressure in fluids increases with depth and density	1c

Students should:		Maths skills
15.13P	**Explain why the pressure in liquids varies with density and depth**	1c
15.14P	**Use the equation to calculate the magnitude of the pressure in liquids and calculate the differences in pressure at different depths in a liquid:** **pressure due to a column of liquid (pascal, Pa) = height of column (metre, m) × density of liquid (kilogram per cubic metre, kg/m^3) × gravitational field strength (newton per kilogram, N/kg)** $P = h \times \rho \times g$	1a, 1b, 1c, 1d 2a 3a, 3b, 3c, 3d
15.15P	**Explain why an object in a fluid is subject to an upwards force (upthrust) and relate this to examples including objects that are fully immersed in a fluid (liquid or gas) or partially immersed in a liquid**	5b
15.16P	**Recall that the upthrust is equal to the weight of fluid displaced**	
15.17P	**Explain how the factors (upthrust, weight, density of fluid) influence whether an object will float or sink**	5b

Use of mathematics

- Make calculations using ratios and proportional reasoning to convert units and to compute rates (1c, 3c).
- **Calculate the differences in pressure at different depths in a liquid (1c, 3c).**
- Calculate relevant values of stored energy and energy transfers; convert between newton-metres and joules (1c, 3c).
- Make calculations of the energy changes associated with changes in a system, recalling or selecting the relevant equations for mechanical, electrical, and thermal processes; thereby express in quantitative form and on a common scale the overall redistribution of energy in the system (1a, 1c, 3c).

Suggested practicals

- Investigate the upthrust on objects in different liquids.
- Investigate the stretching of rubber bands.