

## Higher Physics: Our Dynamic Universe

The left hand column below details the content in which students should develop knowledge and understanding. The middle column contains notes, which give further details of the content.

The right-hand column gives suggested contexts in which knowledge and understanding and skills can be developed.

Content	Notes	Contexts
<b>1. Equations of Motion</b>		
a) Equations of motion for objects with constant acceleration in a straight line.	Candidates should undertake experiments to verify the relationships shown in the equations.	Light gates, motion sensors and software/hardware to measure displacement, velocity and acceleration. Using software to analyse videos of motion.
b) Motion-time graphs for motion with constant acceleration.	Displacement-time graphs. Gradient is velocity. Velocity-time graphs. Area under graph is displacement. Gradient is acceleration. Acceleration-time graphs. Restricted to zero and constant acceleration. Graphs for bouncing objects and objects thrown vertically upwards.	Motion sensors (including wireless sensors) to enable graphical representation of motion.
c) Motion of objects with constant speed or constant acceleration.	Objects in freefall and the movement of objects on slopes should be investigated.	Investigate the variation of acceleration on a slope with the angle of the slope. Motion of athletes and equipment used in sports. Investigate the initial acceleration of an object projected vertically upwards (e.g. popper toy)
<b>2. Forces, energy and power</b>		
a) Balanced and unbalanced forces. The effects of friction. Terminal velocity.	Forces acting in one dimension only. Analysis of motion using Newton's First and Second Laws. Friction as a force acting in a direction to oppose motion. No reference to static and dynamic friction. Tension as a pulling force exerted by a string or cable on	Forces in rocket motion, jet engine, pile driving, and sport. Space flight. Analysis of skydiving and parachuting, falling raindrops, scuba diving, lifts and haulage systems.

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<p>b) Resolving a force into two perpendicular components.</p> <p>c) Work done, potential energy, kinetic energy and power.</p>	<p>another object. Velocity-time graph of falling object when air resistance is taken into account, including changing the surface area of the falling object. Analysis of the motion of a rocket may involve a constant force on a changing mass as fuel is used up.</p> <p>Forces acting at an angle to the direction of movement. The weight of an object on a slope can be resolved into a component acting down the slope and a component acting normal to the slope. Systems of balanced forces with forces acting in two dimensions.</p> <p>Work done as transfer of energy. Conservation of energy.</p>	<p>Vehicles on a slope and ski tows, structures in equilibrium, e.g. supported masts.</p> <p>Investigating energy lost in bouncing balls. Rollercoasters, objects in freefall. Energy and speeding vehicles.</p>
<p><b>3. Collisions and explosions</b></p>		
<p>a) Elastic and inelastic collisions.</p> <p>b) Explosions and Newton’s Third Law.</p> <p>c) Impulse.</p>	<p>Conservation of momentum in one dimension and in which the objects may move in opposite directions. Kinetic energy in elastic and inelastic collisions.</p> <p>Conservation of momentum in explosions in one dimension only.</p> <p>Force-time graphs during contact of colliding objects. Impulse can be found from the area under a force-time graph.</p>	<p>Investigations of conservation of momentum and energy.</p> <p>Propulsion systems – jet engines and rockets</p> <p>Investigating collisions using force sensors and dataloggers. Hammers and pile drivers. Car safety, crumple zones and air bags.</p>

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<b>4. Gravitation</b>		
a) Projectiles and Satellites.	Resolving the motion of a projectile with an initial velocity into horizontal and vertical components and their use in calculations. Comparison of projectiles with objects in free fall. Newton's thought experiment and an explanation of why satellites remain in orbit.	Using software to analyse videos of projectiles  Low orbit and geostationary satellites. Satellite communication and surveying. Environmental monitoring of the conditions of the atmosphere.
b) Gravity and mass.	Gravitational Field Strength of planets, natural satellites and stellar objects. Calculating the force exerted on objects placed in a gravity field. Newton's Universal Law of Gravitation.	Methods for measuring the gravitational field strength on Earth. Using the slingshot effect to travel in space. Lunar and planetary orbits. Formation of the solar system by the aggregation of matter. Stellar formation and collapse. The status of our knowledge of gravity as a force may be explored. The other fundamental forces have been linked but there is as yet no unifying theory to link them to gravity.
<b>5. Special relativity</b>		
a) Introduction to special relativity.	Relativity introduced through Galilean Invariance, Newtonian Relativity and the concept of absolute space. Experimental and theoretical considerations (details not required) leads to the conclusion that the speed of light is the same for all observers. The constancy of the speed of light led Einstein to postulate that space and time for a moving object are changed relative to a stationary observer. Length contraction and time dilation.	Newtonian Relativity can be experienced in an intuitive way. Examples include walking in a moving train and moving sound sources. At high speeds, non-intuitive relativistic effects are observed. Length contraction and time dilation can be studied using suitable animations. Experimental verification includes muon detection at the surface of the Earth and accurate time measurements on airborne clocks. The time dilation equation can be derived from the geometrical consideration of a light beam moving relative to a stationary observer.

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<b>6. The expanding Universe</b>		
a) The Doppler Effect and redshift of galaxies.	<p>The Doppler Effect is observed in sound and light. For sound, the apparent change in frequency as a source moves towards or away from a stationary observer should be investigated. The Doppler Effect causes similar shifts in wavelengths of light. The light from objects moving away from us is shifted to longer wavelengths – redshift. The redshift of a galaxy is the change in wavelength divided by the emitted wavelength. For slowly moving galaxies, redshift is the ratio of the velocity of the galaxy to the velocity of light. (Note that the Doppler Effect equations used for sound cannot be used with light from fast moving galaxies because relativistic effects need to be taken into account.)</p>	<p>Doppler Effect in terms of terrestrial sources e.g. passing ambulances. Investigating the apparent shift in frequency using a moving sound source and datalogger. Applications include measurement of speed (radar), echocardiogram and flow measurement.</p>
b) Hubble’s Law.	<p>Hubble’s Law shows the relationship between the recession velocity of a galaxy and its distance from us. Hubble’s Law leads to an estimate of the age of the Universe.</p>	<p>Measuring distances to distant objects. Parallax measurements and data analysis of apparent brightness of standard candles.</p>
c) Evidence for the expanding Universe.	<p>Measurements of the velocities of galaxies and their distance from us lead to the theory of the expanding Universe. Gravity is the force which slows down the expansion. The eventual fate of the Universe depends on its mass. The orbital speed of the Sun and other stars gives a way of determining the mass of our galaxy. The Sun’s orbital speed is determined almost entirely by the gravitational pull of matter inside its orbit. Measurements of the mass of our galaxy and others lead to the conclusion that there is significant mass which cannot be detected – dark matter. Measurements of the expansion rate of the Universe lead to the conclusion that it is increasing, suggesting that there is something that overcomes the force of gravity – dark energy.</p>	<p>The unit ‘Particles and Waves’ includes an investigation of the inverse square law for light. Centres may wish to include this activity in this topic. In practice, the units used by astronomers include light-years and parsecs rather than SI units. Data analysis of measurements of galactic velocity and distance.</p> <p>The revival of Einstein’s cosmological constant in the context of the accelerating universe.</p>

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<b>7) Big Bang Theory</b>		
<p>a) The temperature of stellar objects.</p>	<p>Stellar objects emit radiation over wide range of wavelengths. Although the distribution of energy is spread over a wide range of wavelengths, each object emitting radiation has a peak wavelength which depends on its temperature. The peak wavelength is shorter for hotter objects than for cooler objects. Also, hotter objects emit more radiation per unit surface area at all wavelengths than cooler objects. Thermal emission peaks allow the temperature of stellar objects to be measured.</p>	<p>Remote sensing of temperature. Investigating the temperature of hot objects using infrared sensors. Change in colour of steel at high temperatures. Furnaces and kilns.</p>
<p>b) Evidence for the Big Bang.</p>	<p>The Universe cools down as it expands. The peak wavelength of cosmic microwave background allows the present temperature of the Universe to be determined. This temperature corresponds to that predicted after the Big Bang, taking into account the subsequent expansion and cooling of the Universe.</p>	<p>History of Cosmic Microwave Background (CMB) discovery and measurement. COBE satellite. Other evidence for the Big Bang includes the observed abundance of the elements hydrogen and helium and the darkness of the sky (Olber's Paradox).</p>

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