Leaving Certificate Physics

HIGHER LEVEL SYLLABUS

Higher Level Syllabus Objectives

Higher level physics provides a deeper, more quantitative treatment of physics. Students are expected to develop an understanding of the fundamental laws and principles and their application to everyday life.

The objectives of the syllabus are:

1. Knowledge

Students should know

- basic physical principles, terminology, facts, and methods
- how physics is fundamental to many technological developments
- how physics contributes to the social, historical, environmental, technological and economic life of society.

2. Understanding

Students should understand

- basic physical principles
- how physical problems can be solved
- how the scientific method contributes to physics
- how physics relates to everyday life
- the limitations and constraints on physics.

3. Skills

Students should be able to

- measure physical quantities in the appropriate SI units
- work safely in a laboratory
- follow instructions
- use scientific equipment appropriately
- plan and design experiments
- use experimental data appropriately
- apply physical principles to solving problems
- analyse and evaluate experimental results.

4. Competence

Students should be able to

- present information in tabular, graphical, written and diagrammatic form, as appropriate
- report on experimental procedures and results concisely, accurately, and comprehensively
- use calculators
- solve numerical problems
- read scientific prose
- relate scientific concepts to issues in everyday life
- explain the science underlying familiar facts, observations, and phenomena
- suggest scientific explanations for unfamiliar facts, etc.
- make decisions based on the examination of evidence and arguments.

5. Attitudes

Students should appreciate

- the contribution of physics to the social and economic development of society
- the relationship between physics and technology
- that a knowledge of physics has many vocational applications.

(Black text is for Higher level only.)

MECHANICS			
Content	Depth of Treatment	Activities	STS
MOTION			
1. Linear motion	Units of mass, length and time – definition of units not required.		
	Displacement, velocity, acceleration: definitions and units.	Measurement of velocity and acceleration, using any suitable apparatus. Use of distance-time, velocity-time graphs.	Sports, e.g. athletics.
	Equations of motion. Derivation.	Measurement of *g*. Appropriate calculations.	
2. Vectors and scalars	Distinction between vector and scalar quantities.		Vector nature of physical quantities: everyday examples.
	Composition of perpendicular vectors.	Find resultants using newton balances or pulleys.	
	Resolution of co-planar vectors.	Appropriate calculations.	
FORCES			
1. Newton's laws of motion	Statement of the three laws.	Demonstration of the laws using air track *or* tickertape timer *or* powder track timer, etc.	Applications: • seat belts • rocket travel. Sports, all ball games.
	Force and momentum: definitions and units. Vector nature of forces to be stressed. $F = ma$ as a special case of Newton's second law. Friction: a force opposing motion.	Appropriate calculations.	Importance of friction in everyday experience, e.g. walking, use of lubricants, etc.
2. Conservation of momentum	Principle of conservation of momentum.	Demonstration by any one suitable method. Appropriate calculations (problems involving change of mass need not be considered).	Collisions (ball games), acceleration of spacecraft, jet aircraft.

MECHANICS (CONTINUED)			
Content	Depth of Treatment	Activities	STS
3. Circular motion	Centripetal force required to maintain uniform motion in a circle. Definition of angular velocity ω. Derivation of $v = r\omega$ Use of $a = r\omega^2$, $F = mr\omega^2$	Demonstration of circular motion. Appropriate calculations.	
4. Gravity	Newton's law of universal gravitation. $F = \frac{Gm_1m_2}{d^2}$ Weight $= mg$ Variation of g, and hence W, with distance from centre of Earth (effect of centripetal acceleration not required). Value of acceleration due to gravity on other bodies in space, e.g. Moon. Circular satellite orbits – derivation of the relationship between the period, the mass of the central body and the radius of the orbit.	Compare gravitational forces between Earth and Sun and between Earth and Moon. Appropriate calculations. Calculation of weight on different planets. Appropriate calculations.	Solar system. "Weightlessness" and artificial gravity. Presence of atmosphere. Satellites and communications.
5. Density and pressure	Definitions and units. Pressure in liquids and gases. Boyle's law. Archimedes' principle. Law of flotation.	Demonstration of atmospheric pressure, e.g. collapsing-can experiment. Appropriate calculations. Demonstration only. Calculations not required.	Atmospheric pressure and weather. The "bends" in diving, etc. Hydrometers.
6. Moments	Definition. Levers. Couple.	Simple experiments with a number of weights. Appropriate calculations. (Only problems involving co-planar, parallel forces need be considered.)	Torque, e.g. taps, doors. Handlebars on bicycles. Reference to moving-coil meters and simple motor.
7. Conditions for equilibrium	Vector sum of the forces in any direction is zero. The sum of the moments about any point is zero.	Appropriate calculations.	Static and dynamic equilibrium.

MECHANICS (CONTINUED)			
Content	Depth of Treatment	Activities	STS
8. Simple harmonic motion (SHM) and Hooke's law	Hooke's law: restoring force $\propto$ displacement. $F = -ks$ $ma = -ks$ $a = \frac{-ks}{m} = -\omega^2 s$ Systems that obey Hooke's law e.g. simple pendulum, execute simple harmonic motion: $T = \frac{2\pi}{\omega}$	Demonstration of SHM, e.g. swinging pendulum or oscillating magnet. Appropriate calculations.	Everyday examples.
ENERGY			
1. Work	Definition and unit.	Simple experiments. Appropriate calculations involving force and displacement in the same direction only.	Lifts, escalators.
2. Energy	Energy as the ability to do work. Different forms of energy. $E_P = mgh$ $E_k = \frac{1}{2}mv^2$ Mass as a form of energy $E = mc^2$ Conversions from one form of energy to another. Principle of conservation of energy.	Demonstrations of different energy conversions. Appropriate calculations.	Sources of energy: renewable and non-renewable. Mass transformed to other forms of energy in the Sun. Efficient use of energy in the home.
3. Power	Power as the rate of doing work or rate of energy conversion. Unit. Percentage efficiency $= \frac{\text{Power output} \times 100}{\text{Power input}}$	Estimation of average power developed by • person running upstairs • person repeatedly lifting weights, etc. Appropriate calculations.	Power of devices, e.g. light bulbs, motors, etc.

MECHANICS: Experiments

1. Measurement of velocity and acceleration.
2. To show that $a \propto F$.
3. Verification of the principle of conservation of momentum.
4. Measurement of g.
5. Verification of Boyle's law.
6. Investigation of the laws of equilibrium for a set of co-planar forces.
7. Investigation of relationship between period and length for a simple pendulum and hence calculation of g.

TEMPERATURE			
Content	Depth of Treatment	Activities	STS
1. Concept of temperature	Measure of hotness or coldness of a body. The SI unit of temperature is the kelvin (definition of unit in terms of the triple point of water not required). Celsius scale is the practical scale of temperature. t /°C = T /K – 273.15		
2. Thermometric properties	A physical property that changes measurably with temperature.	Demonstration of some thermometric properties: • length of liquid column, e.g. length of mercury column • emf of thermocouple • pressure of a gas at constant volume • volume of a gas at constant pressure • resistance • colour.	
3. Thermometers	Thermometers measure temperature. Two thermometers do not necessarily give the same reading at the same temperature. The need for standard thermometers – use any commercial laboratory thermometer as school standard.	Graduate two thermometers at ice and steam points. Compare values obtained for an unknown temperature, using a straight-line graph between the reference points.	Practical thermometers, e.g. • clinical thermometer • oven thermometers • boiler thermometers • temperature gauge in a car.

HEAT			
Content	Depth of Treatment	Activities	STS
1. Concept of heat	Heat as a form of energy that causes a rise in temperature when added or a fall in temperature when withdrawn.		
QUANTITY OF HEAT			
1. Heat capacity, specific heat capacity	Definitions and units.	Appropriate calculations.	Storage heaters.
2. Latent heat, specific latent heat	Definitions and units.	Appropriate calculations.	Heat pump, e.g. refrigerator. Perspiration.
HEAT TRANSFER			
1. Conduction	Qualitative comparison of rates of conduction through solids.	Simple experiments.	*U*-values: use in domestic situations.
2. Convection		Simple experiments.	Domestic hot-water and heating systems.
3. Radiation	Radiation from the Sun. Solar constant (also called solar irradiance).	Simple experiments.	Everyday examples. Solar heating.

HEAT: Experiments

1. Calibration curve of a thermometer using the laboratory mercury thermometer as a standard.
2. Measurement of specific heat capacity, e.g. of water *or* a metal by a mechanical *or* electrical method.
3. Measurement of the specific latent heat of fusion of ice.
4. Measurement of the specific latent heat of vaporisation of water.

WAVES			
Content	Depth of Treatment	Activities	STS
1. Properties of waves	Longitudinal and transverse waves: frequency, amplitude, wavelength, velocity. Relationship $c = f\lambda$	Appropriate calculations.	Everyday examples, e.g. • radio waves • waves at sea • seismic waves.
2. Wave phenomena	Reflection. Refraction. Diffraction. Interference. Polarisation. Stationary waves; relationship between inter-node distance and wavelength. Diffraction effects • at an obstacle • at a slit with reference to significance of the wavelength.	Simple demonstrations using slinky, ripple tank, microwaves, *or* other suitable method.	
3. Doppler effect	Qualitative treatment. Simple quantitative treatment for moving source and stationary observer.	Sound from a moving source. Appropriate calculations without deriving formula.	Red shift of stars. Speed traps.

VIBRATIONS AND SOUND			
Content	Depth of Treatment	Activities	STS
1. Wave nature of sound	Reflection, refraction, diffraction, interference.	Demonstration of interference, e.g. two loudspeakers and a signal generator.	Acoustics. Reduction of noise using destructive interference. Noise pollution.
	Speed of sound in various media.	Demonstration that sound requires a medium.	
2. Characteristics of notes	Amplitude and loudness, frequency and pitch, quality and overtones. Frequency limits of audibility.		Dog whistle.
3. Resonance	Natural frequency. Fundamental frequency. Definition of resonance and examples.	Demonstration using tuning forks *or* other suitable method.	Vocal cords (folds).
4. Vibrations in strings and pipes	Stationary waves in strings and pipes. Relationship between frequency and length. Harmonics in strings and pipes.	Use string and wind instruments, e.g. guitar, tin whistle.	String section and woodwind section in orchestras.
	$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$ for a stretched string.	Appropriate calculations.	
5. Sound intensity level	Sound intensity: definition and unit. Threshold of hearing and frequency response of ear. Sound intensity level is measured in decibels. Doubling the sound intensity increases the sound intensity level by 3 dB. The dB(A) scale is used because it is adapted for the ear's frequency response.	Use of sound-level meter.	Examples of sound intensity level. Hearing impairment. Ear protection in industry, etc.

SOUND: Experiments

1. Measurement of the speed of sound in air.

2. Investigation of the variation of fundamental frequency of a stretched string with length.

3. Investigation of the variation of fundamental frequency of a stretched string with tension.

LIGHT			
Content	Depth of Treatment	Activities	STS
REFLECTION			
1. Laws of reflection		Demonstration using ray box or laser or other suitable method.	
2. Mirrors	Images formed by plane and spherical mirrors. Knowledge that $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ and $m = \frac{v}{u}$	Real-is-positive sign convention. Simple exercises on mirrors by ray tracing *or* use of formula.	Practical uses of spherical mirrors: Concave: • dentists • floodlights • projectors. Convex: • supermarkets • driving mirrors
REFRACTION			
1. Laws of refraction	Refractive index.	Demonstration using ray box *or* laser *or* other suitable method. Appropriate calculations.	Practical examples, e.g. real and apparent depth of fish in water.
	Refractive index in terms of relative speeds.	Appropriate calculations.	
2. Total internal reflection	Critical angle. Relationship between critical angle and refractive index. Transmission of light through optical fibres.	Demonstration. Appropriate calculations.	Reflective road signs. Mirages. Prism reflectors. Uses of optical fibres: • telecommunications • medicine (endoscopes).
3. Lenses	Images formed by single thin lenses. Knowledge that $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ and $m = \frac{v}{u}$ Power of lens: $P = \frac{1}{f}$ Two lenses in contact: $P = P_1 + P_2$ The eye: optical structure; short sight, long sight, and corrections.	Simple exercises on lenses by ray tracing *or* use of formula.	Use of lenses. Spectacles.

LIGHT (CONTINUED)			
Content	Depth of Treatment	Activities	STS
WAVE NATURE OF LIGHT			
1. Diffraction and interference	Use of diffraction grating formula: $n\lambda = d\sin\theta$ Derivation of formula.	Suitable method of demonstrating the wave nature of light. Appropriate calculations.	Interference colours • petrol film, soap bubbles.
2. Light as a transverse wave motion	Polarisation.	Demonstration of polarisation using polaroids *or* other suitable method.	Stress polarisation. Polaroid sunglasses.
3. Dispersion	Dispersion by a prism and a diffraction grating. Recombination by a prism.	Demonstration.	Rainbows, polished gemstones. Colours seen on surfaces of compact discs.
4. Colours	Primary, secondary, complementary colours. Addition of colours. Pigment colours need not be considered.	Demonstration.	Stage lighting, television.
5. Electromagnetic spectrum	Relative positions of radiations in terms of wavelength and frequency. Detection of UV and IR radiation.	Demonstration.	Ultraviolet and ozone layer. Infrared camera: • medical applications • night vision. Greenhouse effect.
6. The spectrometer	The spectrometer and the function of its parts.	Demonstration.	

LIGHT: Experiments

1. Measurement of the focal length of a concave mirror.
2. Verification of Snell's law of refraction.
3. Measurement of the refractive index of a liquid *or* a solid.
4. Measurement of the focal length of a converging lens.
5. Measurement of the wavelength of monochromatic light.

ELECTRICITY			
Content	Depth of Treatment	Activities	STS
CHARGES			
1. Electrification by contact	Charging by rubbing together dissimilar materials. Types of charge: positive, negative. Conductors and insulators. Unit of charge: coulomb.	Demonstration of forces between charges.	Domestic applications: • dust on television screen • static on clothes. Industrial hazards: • in flour mills • fuelling aircraft.
2. Electrification by induction		Demonstration using an insulated conductor and a nearby charged object.	
3. Distribution of charge on conductors	Total charge resides on outside of a metal object. Charges tend to accumulate at points. Point discharge.	Van de Graaff generator can be used to demonstrate these phenomena.	Lightning. Lightning conductors.
4. Electroscope	Structure.		Uses.
ELECTRIC FIELD			
1. Force between charges	Coulomb's law $F = \frac{1}{4\pi\varepsilon}\frac{Q_1 Q_2}{d^2}$ – an example of an inverse square law. Forces between collinear charges.	Appropriate calculations.	
2. Electric fields	Idea of lines of force. Vector nature of electric field to be stressed. Definition of electric field strength.	Demonstration of field patterns using oil and semolina *or* other method. Appropriate calculations – collinear charges only.	Precipitators. Xerography. Hazards: effect of electric fields on integrated circuits.
3. Potential difference	Definition of potential difference: work done per unit charge to transfer a charge from one point to another. Definition of volt. Concept of zero potential.	Appropriate calculations.	

ELECTRICITY (CONTINUED)			
Content	Depth of Treatment	Activities	STS
CAPACITANCE			
1. Capacitors and capacitance	Definition: $C = Q/V$ Unit of capacitance.	Appropriate calculations.	
	Parallel plate capacitor.		Common uses of capacitors: • tuning radios • flash guns • smoothing • filtering.
	Use of $C = \frac{A\varepsilon_0}{d}$	Demonstration that capacitance depends on the common area, the distance between the plates, and the nature of the dielectric. Appropriate calculations.	
	Energy stored in a capacitor.	Charge capacitor–discharge through lamp or low-voltage d.c. motor.	
	Use of $W = \frac{1}{2}CV^2$	Appropriate calculations.	
	Capacitors – conduct a.c. but not d.c.	Demonstration.	
ELECTRIC CURRENT			
1. Electric current	Description of electric current as flow of charge; 1 A = 1 C s^{-1}		
2. Sources of emf and electric current	Pd and voltage are the same thing; they are measured in volts. A voltage when applied to a circuit is called an emf.		Sources of emf: mains, simple cells, lead-acid accumulator, car batteries, dry batteries, thermocouple.
3. Conduction in materials	Conduction in • metals • ionic solutions (active and inactive electrodes) • gases • vacuum • semiconductors. References in each case to charge carriers.	Interpretation of I–V graphs.	Neon lamps, street lights.
	Conduction in semiconductors: the distinction between intrinsic and extrinsic conduction; p-type and n-type semiconductors.		Electronic devices. LED, computers, integrated circuits.

ELECTRICITY (CONTINUED)			
Content	Depth of Treatment	Activities	STS
	The p-n junction: basic principles underlying current flow across a p-n junction.	Demonstration of current flow across a p-n junction in forward and reverse bias, e.g. using a bulb.	Rectification of a.c.
4. Resistance	Definition of resistance, unit. Ohm's law.	Appropriate calculations.	
	Resistance varies with length, cross-sectional area, and temperature. Resistivity. Resistors in series and parallel. Derivation of formulas.	Use of ohmmeter, metre bridge. Appropriate calculations.	
	Wheatstone bridge.	Appropriate calculations.	Practical uses of Wheatstone bridge for temperature control and fail-safe device.
	LDR – light-dependent resistor. Thermistor.	Demonstration of LDR and thermistor.	
5. Potential	Potential divider.	Demonstration.	Potentiometer as a variable potential divider.
6. Effects of electric current	Heating: $W = I^2Rt$	Demonstration of effect. Appropriate calculations.	Everyday examples. Advantage of use of EHT in transmission of electrical energy.
	Chemical effect – an electric current can cause a chemical reaction.	Demonstration of effect.	Uses of the chemical effect. Everyday examples.
	Magnetic effect of an electric current.	Demonstration of effect.	
7. Domestic circuits	Plugs, fuses, MCBs (miniature circuit breakers). Ring and radial circuits, bonding, earthing, and general safety pre-cautions. RCDs (residual current devices). No drawing of ring circuits required.	Wiring a plug. Simple fuse calculations.	Electricity at home • fuse box • meter, etc. Electrical safety.
	The kilowatt-hour. Uses.	Appropriate calculations.	

ELECTRICITY (CONTINUED)			
Content	Depth of Treatment	Activities	STS
ELECTROMAGNETISM			
1. Magnetism	Magnetic poles exist in pairs. Magnetic effect of an electric current.	Demonstration using magnets, coils, and nails.	Electromagnets and their uses.
2. Magnetic fields	Magnetic field due to • magnets • current in - a long straight wire - a loop - a solenoid. Description without mathematical details. Vector nature of magnetic field to be stressed.	Demonstrations.	Earth's magnetic field – use in navigation.
3. Current in a magnetic field	Current-carrying conductor experiences a force in a magnetic field. Direction of the force. Force depends on • the current • the length of the wire • the strength of the magnetic field. $F \propto I\,l\,B$ Magnetic flux density $B = \frac{F}{I\,l}$ Derivation of $F = qvB$ Forces between currents (non-mathematical treatment). Definition of the ampere.	Demonstration of the force on a conductor and coil in a magnetic field. Appropriate calculations. Appropriate calculations.	Applications in motors, meters, and loudspeakers.
4. Electromagnetic induction	Magnetic flux $\Phi = BA$ Faraday's law. Lenz's law. Change of mechanical energy to electrical energy.	Demonstration of the principle and laws of electromagnetic induction. Appropriate calculations.	Application in generators.

ELECTRICITY (CONTINUED)			
Content	Depth of Treatment	Activities	STS
5. Alternating current	Variation of voltage and current with time, i.e. alternating voltages and currents.	Use oscilloscope to show a.c.	National grid and a.c.
	Peak and rms values of alternating currents and voltages.	Compare peak and rms values.	
6. Concepts of mutual induction and self-induction	Mutual induction (two adjacent coils): when the magnetic field in one coil changes an emf is induced in the other, e.g. transformers.	Demonstration.	
	Self-induction: a changing magnetic field in a coil induces an emf in the coil itself, e.g. inductor.	Demonstration.	
	Structure and principle of operation of a transformer.	Demonstration. Appropriate calculations (voltage).	Uses of transformers.
	Effects of inductors on a.c. (no mathematics or phase relations).		Dimmer switches in stage lighting – uses of inductors.

ELECTRICITY: Experiments

1. Verification of Joule's law (as $\Delta\theta \propto I^2$).
2. Measurement of the resistivity of the material of a wire.
3. To investigate the variation of the resistance of a metallic conductor with temperature.
4. To investigate the variation of the resistance of a thermistor with temperature.
5. To investigate the variation of current (I) with pd (V) for
   (a) metallic conductor
   (b) filament bulb
   (c) copper sulfate solution with copper electrodes
   (d) semiconductor diode.

MODERN PHYSICS			
Content	Depth of Treatment	Activities	STS
THE ELECTRON			
1. The electron	The electron as the indivisible quantity of charge. Reference to mass and location in the atom. Units of energy: eV, keV, MeV, GeV.		Electron named by G. J. Stoney. Quantity of charge measured by Millikan.
2. Thermionic emission	Principle of thermionic emission and its application to the production of a beam of electrons. Cathode ray tube consisting of heated filament, cathode, anode, and screen. Deflection of cathode rays in electric and magnetic fields.	Use of cathode ray tube to demonstrate the production of a beam of electrons – deflection in electric and magnetic fields.	Applications • cathode ray oscilloscope • television. Use of CRO to display signals: • ECG and EEG.
3. Photoelectric emission	Photoelectric effect. The photon as a packet of energy; $E = hf$ Effect of intensity and frequency of incident light.	Demonstration, e.g. using zinc plate, electroscope, and different light sources.	
	Photocell (vacuum tube): structure and operation. Threshold frequency. Einstein's photoelectric law.	Demonstration of a photocell.	Applications of photoelectric sensing devices: • burglar alarms • automatic doors • control of burners in central heating • sound track in films.
4. X-rays	X-rays produced when high-energy electrons collide with target. Principles of the hot-cathode X-ray tube. X-ray production as inverse of photoelectric effect. Mention of properties of X-rays: • electromagnetic waves • ionisation • penetration.		Uses of X-rays in medicine and industry. Hazards.

MODERN PHYSICS (CONTINUED)			
Content	Depth of Treatment	Activities	STS
THE NUCLEUS			
1. Structure of the atom	Principle of Rutherford's experiment. Bohr model, descriptive treatment only. Energy levels.	Experiment may be simulated using a large-scale model *or* a computer *or* demonstrated on a video.	Lasers. Spectroscopy as a tool in science.
	Emission line spectra. $hf = E_2 - E_1$	Demonstration of line spectra and continuous spectra.	
2. Structure of the nucleus	Atomic nucleus as protons plus neutrons. Mass number A, atomic number Z, ${}^{A}_{Z}X$, isotopes.		
3. Radioactivity	Experimental evidence for three kinds of radiation: by deflection in electric or magnetic fields or ionisation or penetration. Nature and properties of alpha, beta and gamma emissions. Change in mass number and atomic number because of radioactive decay.	Demonstration of ionisation and penetration by the radiations using any suitable method, e.g. electroscope, G-M tube.	Uses of radioisotopes: • medical imaging • medical therapy • food irradiation • agriculture • radiocarbon dating • smoke detectors • industrial applications.
	Principle of operation of a detector of ionising radiation. Definition of becquerel (Bq) as one disintegration per second.	Demonstration of G-M tube or solid-state detector. Interpretation of nuclear reactions.	
	Law of radioactive decay. Concept of half-life: $T_{1/2}$ Concept of decay constant rate of decay $= \lambda N$ $T_{1/2} = \frac{\ln 2}{\lambda}$	Appropriate calculations (not requiring calculus). Appropriate calculations (not requiring calculus).	

MODERN PHYSICS (CONTINUED)			
Content	Depth of Treatment	Activities	STS
4. Nuclear energy	Principles of fission and fusion. Mass-energy conservation in nuclear reactions, $E = mc^2$.	Interpretation of nuclear reactions. Appropriate calculations.	Fusion: source of Sun's energy. Nuclear weapons.
	Nuclear reactor (fuel, moderator, control rods, shielding, and heat exchanger).	Audiovisual resource material.	Environmental impact of fission reactors. Development of fusion reactors.
5. Ionising radiation and health hazards	General health hazards in use of ionising radiations, e.g. X-rays, nuclear radiation. Environmental radiation: the effect of ionising radiation on humans depends on the type of radiation, the activity of the source (in Bq), the time of exposure, and the type of tissue irradiated.	Measurement of background radiation. Audiovisual resource material.	Health hazards of ionising radiations. Radon, significance of background radiation, granite. Medical and dental X-rays. Disposal of nuclear waste. Radiation protection.

OPTION 1: PARTICLE PHYSICS			
Content	Depth of Treatment	Activities	STS
PARTICLE PHYSICS			
1. Conservation of energy and momentum in nuclear reactions	Radioactive decay resulting in two particles. If momentum is not conserved, a third particle (neutrino) must be present.	Appropriate calculations to convey sizes and magnitudes and relations between units.	
2. Acceleration of protons	Cockcroft and Walton – proton energy approximately 1 MeV: outline of experiment.	Appropriate calculations.	First artificial splitting of nucleus. First transmutation using artificially accelerated particles. Irish Nobel laureate for physics, Professor E. T. S. Walton (1951).
3. Converting mass into other forms of energy	"Splitting the nucleus" $^{1}_{1}H + ^{7}_{3}Li \rightarrow ^{4}_{2}He + ^{4}_{2}He + Q$ 1 MeV 17.3 MeV Note energy gain. Consistent with $E = mc^2$	Appropriate calculations.	
4. Converting other forms of energy into mass	Reference to circular accelerators progressively increasing energy available: proton-proton collisions p + p + energy → p + p + additional particles.	Audiovisual resource material.	History of search for basic building blocks of nature: • Greeks: earth, fire, air, water • 1936: p, n, e. Particle accelerators, e.g. CERN.
5. Fundamental forces of nature	Strong nuclear force: force binding nucleus, short range. Weak nuclear force: force between particles that are not subject to the strong force, short range. Electromagnetic force: force between charged particles, inverse square law. Gravitational force: inverse square law.		

OPTION 1: PARTICLE PHYSICS (CONTINUED)			
Content	Depth of Treatment	Activities	STS
6. Families of particles	Mass of particles comes from energy of the reactions – $m = \frac{E}{c^2}$ The larger the energy the greater the variety of particles. These particles are called "particle zoo". Leptons: indivisible point objects, not subject to strong force, e.g. electron, positron, and neutrino. Baryons: subject to all forces, e.g. protons, neutrons, and heavier particles. Mesons: subject to all forces, mass between electron and proton.	Appropriate calculations.	Pioneering work to investigate the structure of matter and origin of universe. International collaboration, e.g. CERN.
7. Anti-matter	e^+ positron, e^- electron. Each particle has its own anti-particle. Pair production: two particles produced from energy. γ rays $\rightarrow e^+ + e^-$ conserve charge, momentum. Annihilation: Two γ rays from annihilation of particles. $e^+ + e^- \rightarrow 2hf$ (γ rays) conserve charge, momentum.		Paul Dirac predicted anti-matter mathematically.
8. Quark model	Quark: fundamental building block of baryons and mesons. Six quarks – called up, down, strange, charmed, top, and bottom. Charges: $u^{+2/3}$, $d^{-1/3}$, $s^{-1/3}$ Anti-quark has opposite charge to quark and same mass. Baryons composed of three quarks: p = uud, n = udd, other baryons any three quarks. Mesons composed of any quark and an anti-quark.	Identify the nature and charge of a particle given a combination of quarks.	James Joyce: "Three quarks for Muster Mark".

OPTION 2: APPLIED ELECTRICITY			
Content	Depth of Treatment	Activities	STS
APPLIED ELECTRICITY			
1. Current in a solenoid	Electromagnetic relay.	Demonstration.	Uses.
2. Current in a magnetic field	Simple d.c. motor. Principle of operation of moving-coil loudspeaker. Principle of moving-coil galvanometer. Conversion of a galvanometer to • an ammeter • a voltmeter • an ohmmeter.	Demonstration. Appropriate calculations for ammeter and voltmeter (not ohmmeter).	Uses of motors and meters.
3. Electromagnetic induction	Induction coil.	Demonstration.	Callan. Electric fences.
4. Alternating current	Structure and principle of operation of simple a.c. generator. Factors affecting efficiency of transformers. Principle of induction motor. Rectification – use of bridge rectifier.	Demonstration. Demonstration.	Uses of generator and transformer.
5. Applications of diode	P-n diode used as half-wave rectifier. Light-emitting diode (LED); principle of operation. Photodiode.	Use of a bridge rectifier and a capacitor to obtain smooth d.c. Use of LED.	Conversion of a.c. to d.c. Practical applications. LED: optical display. Fibre optic receiver.
6. The transistor	Basic structure of bi-polar transistor. The transistor as a voltage amplifier – purpose of bias and load resistors. The transistor as a voltage inverter.	Demonstration. Demonstration.	Applications of the transistor as a switch should be indicated, e.g. to switch a relay.
7. Logic gates	AND, OR and NOT gates.	Establish truth tables for AND, OR and NOT gates. Use of IC in demonstrating circuits.	Relate NOT to transistor. Boole.

Mathematical Requirements

Black text is for Higher level only.

1. Use of calculators

Students will be expected to have an electronic calculator conforming to the examination regulations for the duration of the course and when answering the examination paper. It is recommended that students have available the following keys:

ORDINARY LEVEL

+, –, x, ÷, π, x^2, $\sqrt{x}$, $\frac{1}{x}$, x^y, EE or EXP; sine, cosine and tangent and their inverses in degrees and fractions of a degree; memory.

HIGHER LEVEL

as above and $\log_{10} x$, 10^x, ln x.

In carrying out calculations, students should be advised to show clearly all expressions to be evaluated using a calculator. The number of significant figures given in the answer to a numerical problem should match the number of significant figures given in the question.

2. Mathematical requirements

The physics syllabus does not require Higher level mathematics. Higher level physics may include some of the optional work of Ordinary level mathematics. There is no requirement for the use of calculus techniques.

Arithmetic

Students should be able to

- understand the concept of significant figures
- recognise and use significant figures as appropriate
- recognise and use expressions in decimal and standard form (scientific) notation
- recognise and use prefixes indicating multiplication by 10^{-12}, 10^{-9}, 10^{-6}, 10^{-3}, 10^{3}, 10^{6}, 10^{9}
- use an electronic calculator for addition, subtraction, multiplication and division and for finding arithmetic means, reciprocals, squares, square roots, sines, cosines and tangents, exponentials, logarithms, and their inverses
- make approximate evaluations of numerical expressions and use such approximations to check calculator calculations.

Algebra

Students should be able to

- change the subject of an equation
- solve simple algebraic equations
- substitute for physical quantities in physical equations using consistent units
- formulate simple algebraic equations as mathematical models of physical situations
- comprehend and use the symbols >, <, ∝, =, x, Δx.

Geometry and Trigonometry

Students should be able to

- calculate the area of right-angled triangles, circumference and area of circles, surface area and volume of rectangular blocks, cylinders and spheres
- use Pythagoras' theorem, similarity of triangles, the angle sum of a triangle
- use sines, cosines and tangents in physical problems
- recall that $\sin\theta \approx \tan\theta \approx \theta$/radians, and $\cos\theta \approx 1$ for small θ
- translate between degrees and radians and ensure that the appropriate system is used.

Vectors

Students should be able to

- find the resultant of two perpendicular vectors, recognising situations where vector addition is appropriate
- obtain expressions for components of a vector in perpendicular directions, recognising situations where vector resolution is appropriate.

Graphs

Students should be able to

- translate information between numerical, algebraic, verbal and graphical forms
- select appropriate variables and scales for graph plotting
- determine the slope of a linear graph and allocate appropriate physical units to it
- choose by inspection a straight line that will serve as the best straight line through a set of data presented graphically.

Notations and Symbols

Standard units, signs and symbols should be used throughout the syllabus. In this section, selected abbreviations are given. The physical quantities, their symbols and units are given. The common electrical circuit symbols are shown.

Abbreviations

The following abbreviations should be used:

potential difference	pd	electromotive force	emf
light-emitting diode	LED	light-dependent resistor	LDR
proton	p	neutron	n
electron	e^-	positron	e^+
neutrino	ν		

quarks:

up	u	down	d
strange	s	charmed	c
top	t	bottom	b

antiquarks:

up	$\bar{u}$	down	$\bar{d}$
strange	$\bar{s}$	charmed	$\bar{c}$
top	$\bar{t}$	bottom	$\bar{b}$

Basic units

The international system of units (SI) should be used. The required base units are given in the table below.

Physical quantity	Name of SI base unit	Symbol for unit
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K

Physical quantities, symbols, and units

The physical quantities, their units and the appropriate symbols required by the syllabus are shown below. Some non-SI units are required. These are indicated by an asterisk*.

Physical quantity	Symbol	Name of SI unit	Symbol for unit
mass	m	kilogram	kg
length	l	metre	m
distance	d		
radius	r, R		
diameter	d		

Physical quantity	Symbol	Name of SI unit	Symbol for unit
time	t	second	s
periodic time	T		
displacement	s	metre	m
speed, velocity	v, u	metre per second	$m\ s^{-1}$
acceleration	a	metre per second squared	$m\ s^{-2}$
acceleration of free fall (due to gravity)	g		
gravitational field strength	g	newton per kilogram	$N\ kg^{-1}$
momentum	p	kilogram metre per second	$kg\ m\ s^{-1}$
force	F	newton	N
angle	θ	*degree	^{o}
		radian	rad
angular velocity	ω	radian per second	$rad\ s^{-1}$
weight	W	newton	N
gravitational constant	G	newton metre squared per kilogram squared	$N\ m^{2}\ kg^{-2}$
area	A	square metre	m^{2}
volume	V	cubic metre	m^{3}
density	ρ	kilogram per cubic metre	$kg\ m^{-3}$
pressure	P, p	pascal	Pa
		newton per square metre	$N\ m^{-2}$
moment of a force	M	newton metre	N m
torque, moment of a couple	T	newton metre	N m
work	W	joule	J
energy	E	joule	J
		*kilowatt-hour	kW h
		*electronvolt	eV
potential energy	E_p	joule	J
kinetic energy	E_k	joule	J
power	P	watt	W
temperature	T	kelvin	K
	t	degree Celsius	^{o}C
	θ	degree Celsius	^{o}C
temperature change	$\Delta\theta$	degree Celsius	^{o}C
heat energy	Q	joule	J
heat capacity	C	joule per kelvin	$J\ K^{-1}$
specific heat capacity	c	joule per kilogram kelvin	$J\ kg^{-1}\ K^{-1}$
		kilojoule per kilogram kelvin	$kJ\ kg^{-1}\ K^{-1}$
latent heat	L	joule	J
specific latent heat	l	joule per kilogram	$J\ kg^{-1}$
		kilojoule per kilogram	$kJ\ kg^{-1}$
frequency	f	hertz	Hz

Physical quantity	Symbol	Name of SI unit	Symbol for unit
amplitude	A	metre	m
wavelength	λ	metre	m
velocity of a wave	c	metre per second	$m\ s^{-1}$
tension in a wire	T	newton	N
mass per unit length	μ	kilogram per metre	$kg\ m^{-1}$
sound intensity	I	watt per square metre	$W\ m^{-2}$
sound intensity level	$I.L.$	*decibel	dB
focal length	f	metre	m
object distance	u	metre	m
image distance	v	metre	m
magnification	m	no unit	
angle of incidence	i	degree	^{o}
angle of reflection	r	degree	^{o}
angle of refraction	r	degree	^{o}
refractive index	n	no unit	
critical angle	C	degree	^{o}
power of lens	P	per metre	m^{-1}
grating spacing	d	metre	m
slit separation	d	metre	m
speed of electromagnetic waves	c	metre per second	$m\ s^{-1}$
charge	Q, q	coulomb	C
permittivity	ε	farad per metre	$F\ m^{-1}$
permittivity of free space	ε_0	farad per metre	$F\ m^{-1}$
relative permittivity	ε_r	no unit	
electric field strength	E	newton per coulomb	$N\ C^{-1}$
		volt per metre	$V\ m^{-1}$
potential difference	V	volt	V
capacitance	C	farad	F
electric current	I	ampere	A
emf	E	volt	V
resistance	R	ohm	Ω
resistivity	ρ	ohm metre	Ω m
electrical energy	W	joule	J
magnetic flux density	B	tesla	T
magnetic flux	Φ	weber	Wb
rms value of alternating emf	E_{rms}	volt	V
peak value of alternating emf	E_0	volt	V
rms value of alternating current	I_{rms}	ampere	A
peak value of alternating current	I_0	ampere	A
number of turns	N	no unit	
electronic charge	e	coulomb	C
Planck constant	h	joule second	J s

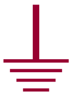
Physical quantity	Symbol	Name of SI unit	Symbol for unit
mass number	A	no unit	
atomic number	Z	no unit	
activity of radioactive source	A	becquerel	Bq
radioactive decay constant	λ	per second	s^{-1}
half-life	$T_{1/2}$	second	s

Electrical circuit symbols

The use of standard symbols (BS 3939) is recommended.
The common symbols required by the syllabus are given below.

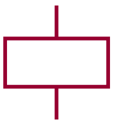

conductors crossing with no connection


junction of conductors


earth


normally open switch

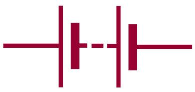

normally closed switch


relay coil

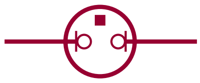

relay contact

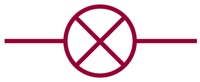
} electro magnetic relay

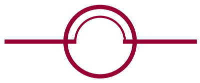

primary or secondary cell


battery of cells

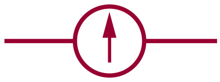

power supply

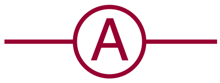

neon lamp


signal lamp


filament lamp

voltmeter

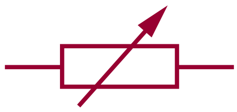

galvanometer

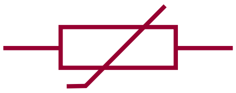


ammeter

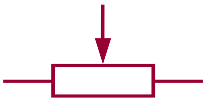

fuse


fixed resistor


variable resistor



thermistor

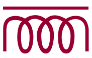


potential divider

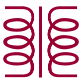
capacitor

electrolytic capacitor

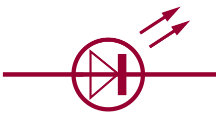
inductor



inductor with ferromagnetic core



transformer with ferromagnetic core



light-emitting diode LED

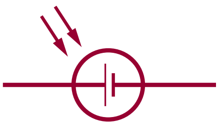
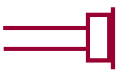
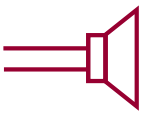


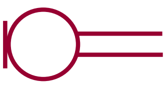
photo-voltaic cell



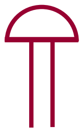
earphone



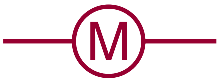
loudspeaker



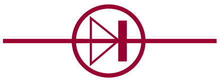
microphone



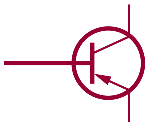
electric bell



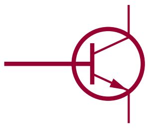
motor



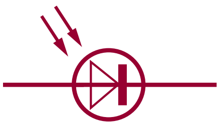
diode/rectifier



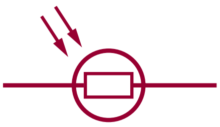
p n p junction transistor



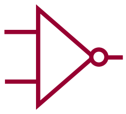
n p n junction transistor



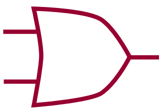
light-sensitive diode
photodiode



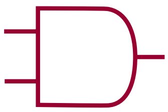
light-dependent resistor LDR



invert or NOT gate



OR gate



AND gate

Reference: Association for Science Education.
Signs, Symbols and Systematics.
The ASE Companion to 5-16 Science.
Hatfield: ASE, 1995.

Formulas

Students should know and be able to use the following formulas. At Ordinary level no derivations are required.
Equations in black text apply to Higher level only.
Those marked with † should be derived at Higher level.

Mechanics

Linear motion with constant acceleration: †$v = u + at$

†$s = ut + \frac{1}{2}at^2$

†$v^2 = u^2 + 2as$

Momentum of a particle = mu †$F = ma$

Conservation of momentum $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

Angle in radians $\theta = \frac{s}{r}$

Angular velocity $\omega = \frac{\theta}{t}$

†Relationship between linear velocity and angular velocity $v = r\omega$

Centripetal acceleration $a = r\omega^2 = \frac{v^2}{r}$

Centripetal force $F = mr\omega^2 = \frac{mv^2}{r}$

Newton's law of gravitation $F = \frac{Gm_1m_2}{d^2}$

Weight $W = mg$

†$g = \frac{GM}{R^2}$ †$T^2 = \frac{4\pi^2R^3}{GM}$

Density $\rho = \frac{m}{V}$

Pressure: $p = \frac{F}{A}$ Pressure at a point in a fluid: $p = \rho gh$

Boyle's law pV = constant

Moment = force x perpendicular distance Couple $T = Fd$

Hooke's law: $F = -ks$ Simple harmonic motion: $a = -\omega^2 s$

Periodic time $T = \frac{1}{f} = \frac{2\pi}{\omega}$

Simple pendulum $T = 2\pi\sqrt{\frac{l}{g}}$

Work $W = Fs$

Potential energy: $E_p = mgh$ Kinetic energy: $E_k = \frac{1}{2}mv^2$

Mass-energy equivalence $E = mc^2$

Power $P = \frac{W}{t}$

Percentage efficiency $= \frac{\text{Power output} \times 100}{\text{Power input}}$

Heat and Temperature

Celsius temperature $t\,/\,^\circ\mathrm{C} = T\,/\mathrm{K} - 273.15$

Heat energy needed to change temperature $Q = mc\Delta\theta$ $Q = C\Delta\theta$

Heat energy needed to change state $Q = ml$ $Q = L$

Waves

Velocity of a wave $c = f\lambda$

Doppler effect $f' = \dfrac{fc}{c \pm u}$

Fundamental frequency of a stretched string $f = \dfrac{1}{2l}\sqrt{\dfrac{T}{\mu}}$

Mirror and lens formula $\dfrac{1}{f} = \dfrac{1}{u} + \dfrac{1}{v}$

Magnification $m = \dfrac{v}{u}$

Power of a lens $P = \dfrac{1}{f}$

Two lenses in contact $P = P_1 + P_2$

Refractive index:

$n = \dfrac{\sin i}{\sin r}$ $n = \dfrac{\text{real depth}}{\text{apparent depth}}$

$n = \dfrac{1}{\sin C}$ $n = \dfrac{c_1}{c_2}$

†Diffraction grating $n\lambda = d \sin\theta$

Electricity

Coulomb's law $F = \frac{1}{4\pi\varepsilon}\frac{Q_1 Q_2}{d^2}$

Capacitance $C = \frac{Q}{V}$

Electric field strength $E = \frac{F}{Q}$

Parallel-plate capacitor $C = \frac{A\varepsilon_0}{d}$

Potential difference $V = \frac{W}{Q}$

Energy stored in capacitor $W = \frac{1}{2} CV^2$

$V = IR$

Resistivity $\rho = \frac{RA}{l}$

†Resistors in series $R = R_1 + R_2$

†Resistors in parallel $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

Wheatstone bridge $\frac{R_1}{R_2} = \frac{R_3}{R_4}$

Joule's law $W = I^2 Rt$

Power $P = VI$

Force on a current carrying conductor $F = I\,l\,B$

Magnetic flux $\Phi = BA$

†Force on a charged particle $F = qvB$

Induced emf $E = \frac{-\mathrm{d}\Phi}{\mathrm{d}t}$

Transformer $\frac{V_i}{V_o} = \frac{N_p}{N_s}$

Alternating voltage and current $V_{rms} = \frac{V_0}{\sqrt{2}}$ $I_{rms} = \frac{I_0}{\sqrt{2}}$

Modern Physics

Energy of a photon $E = hf$

Einstein's photoelectric equation $hf = \Phi + \frac{1}{2}mv^2_{max}$

Law of radioactive decay rate of decay $= \lambda N$

Half-life $T_{1/2} = \frac{\ln 2}{\lambda}$

Mass-energy equivalence $E = mc^2$