Learning Resource Network

INTERNATIONAL AS AND A-LEVEL PHYSICS (6328)

SPECIFICATION

For exams January, May and November onwards
For teaching from September 2021 onwards

THE QUEEN'S AWARDS FOR ENTERPRISE: INTERNATIONAL TRADE 2020

Contents

BACKGROUND TO LRN

Learning Resource Network (LRN) is a recognised Awarding Organisation that offers a range of qualifications to candidates, educational institutes, training providers, schools and employers.

LRN is recognised for its high quality qualifications that enable candidates to progress to other areas of study and employment in their designated fields.

In producing its qualifications, LRN uses the experience and expertise of academics, professionals working in the pertinent industries and assessment practitioners with a wealth of best practice and knowledge of validation, verification, delivery and assessment.

ACCOLADES

Queen’s Award

In April 2020, LRN received the Queen’s Award for Enterprise for International Trade. LRN is one of 220 organisations in the UK to be recognised with this prestigious accolade. This was in recognition of the expansion LRN brought to the overseas qualification market.

MANAGEMENT SYSTEMS

LRN has been awarded international accreditation as part of its quality controls, policies, systems and overall approach to its management systems. These awards are externally validated by the British Assessment Bureau. LRN has achieved accreditation in the form of ISO 9001: Quality Management Systems, ISO 14001: Environment Management Systems and ISO 27001: Information Security Management Systems.

CUSTOMER SERVICE EXCELLENCE

LRN has achieved the prestigious award of Customer Service Excellence. This is in recognition of its customer service practices, approach to managing and dealing with UK and Overseas customer needs, including the diverse needs of its centres.

LRN was the first UK Awarding Organisation to achieve Customer Service Excellence.
Following reaccreditation in 2019, LRN received an award for Customer Service Excellence: Compliance Plus, demonstrating that LRN went above and beyond the delivery of its customer service principles.

British Assessment Bureau UKAS MANAGEMENT SYSTEMS 8289 ISO 9001 QUALITY MANAGEMENT

British Assessment Bureau UKAS MANAGEMENT SYSTEMS 8289 ISO 27001 INFORMATION SECURITY MANAGEMENT

British Assessment Bureau UKAS MANAGEMENT SYSTEMS 8289 ISO 14001 ENVIRONMENTAL MANAGEMENT

CUSTOMER SERVICE EXCELLENCE® CSE

INTRODUCTION

This specification provides an overview to the LRN International AS & A Level Physics[1]. This document is suitable for various users, including candidates, centres, administrators, employers, parents/guardians, teachers (and other educational based staff) and examiners. The specification outlines the key features and administrative procedures required for this international qualification.

OBJECTIVE

The LRN International AS & A Level Physics is designed to enable international candidates to demonstrate their ability, in both practical and theoretical terms across a range of: Newton's Laws, Momentum, density and moments, Stress, strain and the Young Modulus, Electrical current, basic circuits and resistivity, Circular motion and Simple harmonic motion (SHM), Kinetic theory of gases and the ideal gas equation, Photons, photoelectric effect and spectra, Thermodynamics and specific heat capacity/latent heat and Charge-mass-field interactions.

MODE OF DELIVERY

This qualification has been constructed to be delivered within centres. Centres will need to demonstrate to LRN, through the centre recognition processes, that they have the resources, facilities and competence to deliver. However, centres must be able to demonstrate, in line with LRN's criteria, that they have the means, capability, capacity and resources (including suitably qualified centre staff) to deliver by the method chosen by the centre.

PROGRESSION

The LRN International AS & A Level Physics has been designed to reflect the wide variation in candidates' origins, levels of education and career aims. Progression opportunities may, therefore, take a variety of paths. Depending on the level of qualification achieved, it may be appropriate for the candidate to progress to:

1. Similar level 3 qualification in Physics;
2. LRN Level 3 Diploma in Pre-U Foundation Studies;
3. A higher level of any qualification – e.g.; HNC/HND or Degree'
4. Vocationally Related Qualifications

[1] LRN International AS/A Level are globally recognised qualifications designed specifically for international candidates and are available outside the United Kingdom. Candidates based in England refer to the Ofqual register.

QUALIFICATION OVERVIEW

Number	Subject Content	LRN International AS Level	LRN International A Level	AO	Exam
1	Units, prefixes, errors, force and Newton's Laws	√	√	1, 2 and 3	Combination of written exam papers (externally set and marked) and a practical demonstration of skills. **AS Level** **Paper 1:** Multiple Choice, Extended Theory, and practical based skills. Duration: 2 hours Weighting: 50% **Paper 2:** Multiple Choice, Extended Theory, and practical based skills. Duration: 2 hours Weighting: 50% **A Level** **Paper 1:** Multiple Choice, Extended Theory, and practical based skills. Duration: 2 hours Weighting: 40% **Paper 2:** Multiple Choice, Extended Theory and practical based skills. Duration: 2 hours Weighting: 40% **Paper 3:** Essay Questions Duration: 1 hour 15 minutes Weighting: 20%
2	Momentum, density and moments	√	√	1, 2 and 3	
3	Stress, strain and the Young Modulus	√	√	1, 2 and 3	
4	Electrical current, basic circuits and resistivity	√	√	1, 2 and 3	
5	Nuclear physics, fundamental particles and radioactivity	√	√	1, 2 and 3	
6	Circular motion and Simple harmonic motion (SHM)	-	√	1, 2 and 3	
7	Kinetic theory of gases and the ideal gas equation	√	√	1, 2 and 3	
8	Capacitance	-	√	1, 2 and 3	
9	Photons, photoelectric effect and spectra	-	√	1, 2 and 3	
10	Waves, polarisation and Doppler effect	√	√	1, 2 and 3	
11	Refraction, Diffraction, Interference and wave-particle duality	-	√	1, 2 and 3	
12	Energy and work	√	√	1, 2 and 3	
13	Thermodynamics and specific heat capacity/latent heat	√	√	1, 2 and 3	
14	Binding energy, fission and fusion	-	√	1, 2 and 3	
15	Fields and their sources	-	√	1, 2 and 3	
16	Charge-mass-field interactions	-	√	1, 2 and 3	

BREAKDOWN OF ASSESSMENT OBJECTIVES

AO1 - demonstrate knowledge and understanding of:

- scientific ideas
- scientific techniques and procedures

AO2 – apply knowledge and understanding of:

- scientific ideas
- scientific enquiry, techniques and procedures

AO3 – analyse information and ideas to:

- interpret and evaluate
- make judgements and draw conclusions
- develop and improve experimental procedures

ASSESSMENT

The assessment for this qualification consists of (i) written exam papers, and (ii) practical demonstration of skills, set and marked by the LRN.

Assessment objectives (AOs)	Weighting		
	Paper 1	Paper 2	Paper 3
AO1	30%	30%	30%
AO2	40%	40%	50%
AO3	30%	30%	20%

GUIDED LEARNING HOURS (GLH)

The LRN International AS Level guided learning hours (GLH) are 180 and 360 guided learning hours for LRN International A Level. Please note the hours stated are indicative.

ENTRIES CODES

One entry per qualification is sufficient and will cover all the question papers including certification.

PRIVATE CANDIDATES

Centres are advised that private candidates are only to be enrolled with prior agreement and confirmation from LRN.

GRADING

The LRN International A Level will be graded on a six-point scale: A*, A, B, C, D and E and LRN International AS Level will be graded on a five-point scale: A, B, C, D and E Candidates who fail to reach the minimum standard for grade E will be recorded as U (unclassified) and will not receive a qualification certificate.

RESULTS

Exam series are in:

- January (results released in March)
- June (results released in August)
- November (results released in January)

RE-TAKES

Whereas candidates can re-take each paper as often as they wish, within the shelf-life of the specification.

CUSTOMER SERVICE STATEMENT

Learning Resource Network (LRN) is committed to ensuring all customers are dealt with promptly and in a professional and helpful manner. In order to guarantee this, we commit to ensuring the following in our day-to-day interactions with candidates, assessment centres and our stakeholder network:

- All customers will be treated equally and with respect.
- All customer information will only be used in a way which has been agreed in advance, unless we are informed of something that places them or others at risk of harm.
- All customers will be treated by staff in a professional manner.

LRN has arrangements in place to provide a telephone and e-mail helpdesk which will be staffed from 09:00 to 17:00 from Monday to Friday. Furthermore, it will respond to each e-mail, letter, or telephone message it receives regarding feedback on its qualifications, centre approvals process or other matters relating to its products and/or services. The timetable for responding is as follows:

- E-mail: 5 working days
- Letter: 5 working days
- Telephone message: 5 working days

DIVERSITY AND EQUALITY

Learning Resource Network (LRN) is committed to ensuring fair and equal access to its qualifications, examinations and support materials. Our Diversity and Equality policy seeks to eliminate unjustifiable discrimination, harassment and/or victimisation and to advance equality of opportunity, thereby ensuring all candidates are treated fairly, in accordance with the protected characteristics of the Equality Act 2010. Specifically, we comply fully with the requirements laid out in the Equality Act 2010. In addition, and within the constraints of this policy, LRN will have due regard for the General data Protection Regulations (GDPR) in the retention of information which is unnecessary.

1	Units, prefixes, errors, force and Newton's Laws		
Aim To demonstrate the correct use of units, SI units and prefixes; the correct methods for calculating errors and combined errors when using formulae and lastly to convey Newton's Laws.			
Learning Outcomes - The learner will:		**Assessment Criteria - The learner can:**	
1	Understand SI units and multiplers	1.1	**Summarise** how to use basic SI units
		1.2	**Analyse** SI units for various quantities
		1.3	**Perform** dimensional analysis on various formulae and use this process to check validity of formulae.
		1.4	**Apply** suitable SI prefixes (such as milli, kilo, nano)
2	Understand errors	2.1	**Differentiate** between precision and accuracy
		2.2	**Critically** compare systematic and random errors
		2.3	**Calculate** absolute, fractional and percentage uncertainties and how to combine these in various situations.
3	Understand scalars, vectors, components and resultants	3.1	**State** examples of quantities with and without direction
		3.2	**Use** vector polygons to find resultant vectors
		3.3	**Calculate** horizontal and vertical components of vectors
		4.2	**Justify** the existence of force as an interaction between two bodies
5	Understand Newton's Laws	5.1	**Identify** each of Newton's Laws in a range of situations

6	Be able to demonstrate a practical application regarding the origin of force and Newton's Laws	6.1	**Contrast** various forces within the classroom (gravitational, reaction, pressure, molecular)
		6.2	**Determine** which of Newton's Laws apply to various phenomena within/visible from the classroom (chairs on floor – N3L; bodies in equilibrium – N2L; birds flying at constant speed – N1L)

2	**Momentum, density and moments**		
Aim To enable the student to understand how momentum is transferred between bodies, the impulse exerted during a collision, the meaning of density and how to analyse turning forces.			
Learning Outcomes - The learner will:		**Assessment Criteria - The learner can:**	
1	Understand momentum transfer between bodies	1.1	**State** the conservation of momentum
		1.2	**Judge** which form of conservation of momentum to use, depending on whether the colliding bodies separate, join, or remain separate upon impact
		1.3	**Perform** calculations based upon the conservation of momentum
		1.4	**Determine** the impulse due to the change in momentum in a given time.
2	Understand density	2.1	**Justify** density as an inherent property of the material, regardless of shape or mass
		2.2	**Calculate** density for a given mass and volume
3	Understand moments	3.1	**Define** a moment as "force times perpendicular distance from a chosen point"
		3.2	**Recommend** an appropriate point about which to take moments when there is more than one pivot point.
		3.3	**Construct** a formula equating clockwise and anticlockwise moments
		3.4	**Perform** calculations using moments to find unknown mass or distance.
4	Be able to demonstrate a practical application of momentum transfer and moments	4.1	**Investigate** a given balanced system, using knowledge of moments to find unknown masses or distances

		4.2	**Investigate** an instance of momentum transfer such as different types of balls bouncing into other moveable objects such as a golf ball colliding with a ping pong ball).

3	Stress, strain and the Young Modulus		
Unit Aim To enable the student to understand the meaning of stress and strain within materials; to understand Young Modulus, Hooke's Law; also the different classes of materials and the strengths and weaknesses unique to each.			
Learning Outcomes - The learner will:		**Assessment Criteria - The learner can:**	
1	Understand Hooke's law	1.1	**Define** spring constant and state units
		1.2	**Use** Hooke's law to calculate force, extension or spring constant
		1.3	**Compare** effective spring constant of combined springs when joined in parallel or series
		1.4	**Calculate** spring constant from a graph of Force vs extension
2	Understand stress, strain and the Young Modulus	2.1	**Apply** formulae for stress, strain and the Young Modulus (E) for various given materials under applied force.
		2.2	**Combine** formulae for stress and strain to calculate unknown parameters such as original length or area over which force is applied.
		2.3	**Justify** that the Young Modulus is an inherent property of the material, regardless of size or mass, just like density.
		2.4	**Analyse** graphs of stress vs strain (key terms: yield point, elastic limit, limit of proportionality, breaking point)
		2.5	**Critically compare** graphs of stress vs strain for different materials
3	Understand the different classes of materials	3.1	**Compare** crystalline, amorphous and polymeric materials in terms of structure and bonds

		3.2	**Critically compare** ductile, brittle and elastic materials in terms of behaviour under stress and in terms of strengths and weaknesses unique to each
		3.3	**Determine** the type of material from the stress vs strain graph
4	Be able to demonstrate a practical application of Hooke's law, stress, strain and the Young Modulus	4.1	**Investigate** the behaviour of a simple spring under various loads to find the spring constant with consideration given to error
		4.2	**Investigate** the stress vs strain relationship for various given materials

4	Electrical current, basic circuits and resistivity		
Aim To enable the learner to understand the nature of electric current, drift velocity, the nature of resistance, potential difference; to understand potential divider circuits, series and parallel resistor combinations, variable resistors, specific circuit components (such as thermistors and diodes); to understand Ohm's Law and resistivity of conductive materials.			
Learning Outcomes - The learner will:		**Assessment Criteria - The learner can:**	
1	Understand the nature of electric current	1.1	**Classify** electric current as the rate of flow of electrons with fundamental charge e, across an area.
		1.2	**Define** drift velocity as the mean velocity of electrons through a conductor and derive the formula I = nAve
		1.3	**Apply** the formula Q = I x t to graphs of Q vs t and I vs t
2	Understand Ohm's law	2.1	**Justify** Ohm's law as the proportionality between voltage and current for a fixed resistance.
		2.2	**Analyse** an I-V graph to find the resistance in the circuit
		2.3	**Analyse** graph for non-Ohmic behaviour such as a filament
		2.4	**Define** resistance as the opposition to flow of current which depends on cross sectional area, composition and temperature
3	Understand resistivity	3.1	**Justify** that (for constant temperature) while resistance is a "local" property, depending on shape and size, resistivity (like density) is a "global property" which depends only upon the composition.
		3.2	**Apply** formula for resistivity to find unknown values of area, length, resistance and resistivity with consideration shown to errors

		3.3	**Analyse** graph of resistance vs length of wire, using gradient to find cross-sectional area of the wire or resistivity
4	Understand basic circuits	4.1	**Differentiate** between the terms “across” and “through” when discussing voltage and current in a circuit
		4.2	**Illustrate** a circuit as a diagram of potential “drops” for 2 resistors in series, with drops analogous to waterfalls
		4.3	**Illustrate** a circuit as a diagram of potential “drops” for 2 resistors in parallel
		4.4	**Illustrate** a circuit as a diagram of potential “drops” for 3 or more resistors in a mixture of resistance and parallel
		4.5	**Analyse** any given circuit, using a sketch of voltage drops and Ohm’s law to find unknown voltages, resistances and currents
5	Understand electromotive force and internal resistance	5.1	**Define** electromotive force as the energy converted into electrical energy per unit coulomb
		5.2	**Combine** internal resistance into the circuit as simply another resistor, when calculating voltages, currents and resistances in the circuit
		5.3	**Discriminate** between the voltage dropped across the internal resistor and the total voltage dropped across other components in the circuit
		5.4	**Analyse** graph of V vs I in terms of $y=mx+c$ to find emf of battery and internal resistance values.
6	Be able to demonstrate a practical application of resistivity and basic circuits	6.1	**Investigate** a length of conductive wire, measuring V, I, cross sectional area and length to find the resistivity value with consideration to errors

		6.2	**Investigate** a circuit with at least 4 resistors, using an illustration of the voltage drops to find all the currents, individual voltage drop values and any unknown resistances.

5	Nuclear physics, fundamental particles and radioactivity		
Aim To enable the learner to understand basic nuclear structure of the elements, conservation laws within reactions, the existence of antimatter; to understand the conservation laws behind processes involving fundamental particles in their different classifications; to understand radioactivity as a means to become more stable, the different types of radioactive decay and to deliver an understanding of the means by which to carry out calculations regarding radioactive decay.			
Learning Outcomes - The learner will:		**Assessment Criteria - The learner can:**	
1	Understand basic nuclear physics	1.1	**Justify** the basic structure of the atom from the Rutherford alpha particle scattering experiment results.
		1.2	**Apply** nucleon and atomic numbers when representing an element in a reaction formula
		1.3	**Analyse** nuclear reactions by making use of the conservation laws for charge and nucleon number
		1.4	**Justify** the existence of antiparticles from experimental data showing opposite behaviour to normal matter (travelling in opposite directions in a mass spectrometer – this can be explained in further detail in last topic)
2	Understand fundamental particles	2.1	**Classify** quarks as up, down, top, bottom, charm or strange
		2.2	**Compare** the different categories in terms of quark make-up (Hadrons, Baryons, leptons and mesons)
		2.3	**Apply** conservation laws (charge, baryon number and lepton number) for a variety of interactions/decays
		2.4	**Critically compare** the interaction forces (strong force, weak force and electromagnetic) and the processes unique to each
		2.5	Compare interactions in which quark either changes or stays the same

3	Understand the nature of radioactivity	3.1	**Justify** that elements become radioactive when possessing either too many neutrons, too much mass or too much energy – from data of radioactive decay for various elements, focusing on the stability curve of proton number vs neutron number for the elements.
		3.2	**Compare** the three types of radioactive decay – alpha, beta and gamma – and their penetrative power (air, paper, aluminium, lead)
		3.3	**Justify** the presence of background radiation from data collected with a Geiger counter from a radioactive source
		3.4	**Use** the unit of Becquerel for the Activity of a radioactive source (decays per second)
4	Understand radioactive decay	4.1	**Measure** half-life when plotting Activity vs time
		4.2	**Select** the appropriate unit for half-life (seconds, hours, days, years, etc)
		4.3	**Justify** that the decay constant is a constant of proportionality between the number of undecayed nuclei and the rate of decay
		4.4	**Justify** from data that both the number of undecayed nuclei and the activity follow an exponential decay function
		4.5	**Rearrange** exponential decay formula using logarithms
		4.6	**Apply** understanding of the decay formula to derive T(1/2) = ln2/lambda
		4.7	**Recall** that N stands for the number of undecayed nuclei
5	Be able to demonstrate a practical application of fundamental particles and radioactive decay	5.1	**Determine** the identity of a particle from data such as the interaction force, charges and baryon/lepton numbers of the other particles involved

		5.2	**Investigate** a radioactive source using a Geiger counter; selectively plot the data to create a straight-line graph and from this graph determine the decay constant

6	Circular motion and Simple harmonic motion (SHM)		
Aim To enable the learner to understand circular motion and in particular centripetal acceleration; to understand simple harmonic motion, how to model a system performing SHM, damping and resonance.			
Learning Outcomes - The learner will:		**Assessment Criteria - The learner can:**	
1	Understand circular motion	1.1	**Convert** angles between radians and degrees
		1.2	**Compare angular and tangential velocity**
		1.3	**Calculate** centripetal acceleration for a variety of bodies performing circular motion, both with and without a physical connection to the centre of the circle
2	Understand the nature of SHM	2.1	**Apply** the definitive SHM formula (acceleration is directly proportional to the negative of the displacement) to a variety of systems performing SHM
		2.2	**Analyse** a system performing SHM in terms of a straight-line graph with a gradient which is negative and equal to the square of the angular velocity
		2.3	**Justify** from various examples that to perform SHM, a system must be displaced from equilibrium and will thus experience a restoring force to return it to equilibrium.
		2.4	**Apply** the formulae of SHM to theoretical examples of pendulums and springs
3	Understand modelling of SHM	3.1	**Illustrate** the motion of SHM with a cosine or sine wave with a phase shift included if necessary
		3.2	**Rearrange** the sine or cosine function used to model SHM to find unknowns (angular velocity, phase shift, time, Amplitude, period) – focus on correct use of inverse trig functions
		3.3	**Apply** knowledge of gradients to create a velocity-time graph from a displacement-time graph or to create an acceleration-time graph from a velocity-time graph

		3.4	**Calculate** the velocity from the area beneath an acceleration-time graph or the displacement from the area beneath a velocity-time graph
4	Understand damping and resonance	4.1	**Compare** the different types of damping – over, under and critical
		4.2	**Illustrate** the motion of various damped SHM systems.
		4.3	**Analyse** a graph of amplitude (of an SHM system) vs. driving frequency – noting that the maximum amplitude refers to the natural (resonant frequency) of the material.
		4.4	**Critically** compare how resonance is affected by changes to the system, or by damping
		4.5	**Distinguish** between examples of wanted and unwanted resonance
5	Be able to demonstrate a practical application of circular motion, SHM and resonance	5.1	**Investigate** the motion of a freely spinning bicycle wheel with markers along one radius
		5.2	**Investigate** centripetal force by placing a ball inside a spinning drum with a horizontal axis of rotation – when the ball spins fast enough, the ball remains in constant with the drum at all times.
		5.3	**Investigate** a simple pendulum, varying length, mass and material used for the string – calculate the period, compare the data, plot the amplitude-time graph and choose a suitable function to model the behaviour
		5.4	**Investigate** resonance using a musical instrument such as a violin; use the bow to demonstrate how certain notes create a resonance with the neighbouring string.

7	Kinetic theory of gases and the ideal gas equation		
Aim To enable the learner to understand 3 basic assumptions of kinetic theory, as well the fundamental equations we use to model a gas in terms of pressure, volume and temperature; also, to understand the ideal gas equation and how it is applied in various systems.			
Learning Outcomes - The learner will:		**Assessment Criteria - The learner can:**	
1	Understand kinetic theory of gases	1.1	**Perform** calculations involving moles, molar mass, relative molecular mass, Avogadro's constant and the relationships between them
		1.2	**Recall** the 3 basic assumptions of the kinetic theory of an ideal gas
		1.3	**Use** the definition of pressure on a wall (due to gas molecules) to calculate pressure, force or area
		1.4	**Justify** use of root-mean-square, or mean square speed in calculations regarding the gas
		1.5	**Apply** the fundamental formulae (pV=1/3*Nm*man-square speed & p=1/3*density*mean-square speed) to gases of various pressure, volume and mass.
		1.6	**Calculate** the root-mean-square or mean-square speed of gas molecules, when given data of the velocities of various gas particles
2	Understand the ideal gas equation	2.1	**Apply** pV=nRT to various gases to find an unknown
		2.2	**Differentiate** between the terms isovolumetric, isobaric and isothermal
		2.3	**Rearrange** the ideal gas law to show how pV/T = constant can be used to prove if a process is isovolumetric, isobaric or isothermal
		2.4	**Convert** pV=nRT into pV=NkT using k=R/Avogadro's constant

		2.5	**Analyse** p-V graphs to find unknown value of p, V, T or to check is a process is isovolumetric, isobaric or isothermal
3	Be able to demonstrate a practical application of kinetic theory and the ideal gas equation	3.1	**Investigate** how a sealed gas responds to changes in volume and temperature, using appropriate sensors for pressure and temperature.

8	Capacitance		
Aim To enable the learner to understand both the nature of capacitance and how they operate in a circuit.			
Learning Outcomes - The learner will:		**Assessment Criteria - The learner can:**	
1	Understand the nature of capacitors	1.1	**Describe** the design of a basic capacitor with 2 plates and dielectric between them
		1.2	**Justify** from given data that the charge stored on the plates of a capacitor is directly proportional to the voltage across them, hence Q=VC
		1.3	**Justify** from given data, the relationship between capacitance, area of plates, distance between them and the dielectric constant of the material used
2	Understand capacitors in circuits Understand	2.1	**Calculate** the effective total capacitance when several are joined in either series or parallel (they follow the opposite rules for adding resistors)
		2.2	**Distinguish** whether a capacitor is charging, storing or discharging.
		2.3	**Design** a circuit which can switch between charging and discharging, involving only one battery, one resistor and one capacitor
		2.4	**Analyse** a given circuit in terms of time constant (RC)
		2.5	**Analyse** given discharging data of V or Q vs time
		2.6	**Analyse** given charging data of V or Q vs. time
		2.7	**Rearrange** exponential decay functions (using logs) for charging or discharging to find unknown values of R, C, time, Q or V
3	Be able to demonstrate a practical application of	3.1	**Investigate** a real RC circuit, with switch and battery to collect voltage data for both charging and discharging. Plot appropriate data to create a straight line

	capacitance in circuits		graph from which the time constant can be measured. Give consideration to errors

9	Photons, photoelectric effect and spectra		
Aim To enable the learner to understand the Photoelectric effect and its role in the discovery of the particle nature of light (photons); to understand the various categories within the electromagnetic spectrum and their uses and to understand spectra (both absorption and emission)			
Learning Outcomes - The learner will:		**Assessment Criteria - The learner can:**	
1	Understand the Photoelectric (PE) effect	1.1	**Draw** the apparatus setup for the Photoelectric experiment
		1.2	**Justify** from data that as intensity plays no role in releasing photoelectrons below a certain energy level, that light cannot be acting as a wave
		1.3	**Justify** that a new concept (for light) was necessary to explain the phenomena of the PE
		1.4	**Justify** that modelling light as a particle could explain the PE effect
		1.5	**Apply** the stopping potential concept to find the kinetic energy of the emitted photoelectrons
		1.6	**Determine** work function and max kinetic energy from a graph of KE vs. frequency using a straight line graph
2	Understand the electromagnetic spectrum	2.1	**Use** E=hf and E=hc/lambda in various calculations
		2.2	**Recall** the ranges of typical values of frequency and wavelength for the different categories of electromagnetic radiation
		2.3	**Apply** the unit of electron-volt in calculations regarding the energy of photons.
3	Understand atomic spectra	3.1	**Justify** electron transitions between energy levels as giving rise to the emission or absorption of photons
		3.2	**Compare** the characteristic patterns of these emissions/absorptions to identify elements

		3.3	**Apply** E=hf where E represents the transitions energy between levels inside the atom
		3.4	**Apply** the concept of Ionisation energy when describing the energy level inside the atom
4	Be able to demonstrate a practical application of Photoelectric effect and atomic spectra	4.1	**Investigate** the effect of different wavelengths of radiation on a suitable metal plate on top of a gold leaf electroscope and explain the data using the concept of the photoelectric effect
		4.2	**Illustrate** the concept of spectral analysis using sound instead of light.

10	Waves, polarisation and Doppler effect		
Unit Aim To enable the learner to understand wave types and characteristics, polarisation and Doppler effect			
Learning Outcomes - The learner will:		**Assessment Criteria - The learner can:**	
1	Understand wave types and characteristics	1.1	**Compare** the types of waves: transverse, longitudinal, progressive and stationary
		1.2	**Compare** the nature of waves (either electromagnetic radiation or a collective movement of particles such as sound or water)
		1.3	**Apply** concept of intensity to describe how a wave spreads out over distance
		1.4	**Calculate** wave speed, frequency, wavelength and intensity for various given examples
		1.5	**Illustrate** the effect of multiple polarised filters on unpolarised light
2	Understand stationary waves	2.1	**Define** nodes, antinodes and phase difference
		2.2	**Illustrate** harmonics for a string with nodes at both ends, noting how many wavelengths exist between the ends
		2.3	**Illustrate** the harmonics for open tubes for which there may be a node at one end and an antinode at the other; or antinodes at both ends
3	Understand Doppler effect	3.1	**Justify** that the frequency of sound emitted by a moving body is heard to be a difference frequerncy due to the relative motion.
		3.2	**Apply** the Doppler effect to light to explain the concept of redshift and blueshift.
		3.3	**Calculate** the speed of motion or emitted frequency using given data
5	Be able to demonstrate a practical application of	5.1	**Investigate** the effect of multiple polarised filters on the intensity of light

	polarisation, Doppler effect and stationary waves	5.2	**Investigate** the Doppler effect by swinging a speaker on a length of string and recording the sound from a fixed position outside of the circle.
		5.4	**Investigate** stationary waves by applying a bow to a large instrument such a guitar or double bass – best if viewed against a TV screen to take advantage of the strobe effect. The effect of harmonics can then be investigated by placing a secure clamp at various points on the string.

11	Refraction, Diffraction, Interference and wave-particle duality		
Aim To enable the learner to understand how waves move through materials of different density, how they move around obstacles and subsequently interfere with themselves; also, to understand how the same experiments were used to discover the wave properties of electrons which led to the discovery of photon momentum.			
Learning Outcomes - The learner will:		**Assessment Criteria - The learner can:**	
1	Understand refraction	1.1	**Justify** what happens at the boundary between materials when the wave speed changes upon crossing the boundary – in terms of wavelength and frequency
		1.2	**Define** the refractive index for a material
		1.3	**Apply** Snell's law for various entry and exit angles
		1.4	**Illustrate** the critical angle for a combination of materials
		1.5	**Illustrate** total internal reflection and its role in the fibre optic industry
2	Understand diffraction and interference	2.1	**Compare** effect of gap size and wavelength
		2.2	**Justify** the result from Young's fringes experiment using the concept of interference between waves
		2.3	**Analyse** data from Young fringes experiment in terms of path difference
		2.4	**Apply** formula for Young's fringes to find gap spacing, wavelength, fringe spacing or distance to screen
		2.5	**Apply** formula for a diffraction grating to find the gap spacing, wavelength, fringe order or angle
3	Understand wave-particle duality	3.1	**Recall** that when electrons are fired at a diffraction grating, an interference pattern is produced

		3.2	**Justify** from experiment in 3.1 that electrons exhibit wave-like behaviour
		3.3	**Use** equation to calculate momentum of a photon
		3.4	**Justify** use of solar sails for spacecraft by applying concept of photon momentum
4	Be able to demonstrate a practical application of refraction, diffraction and interference	4.1	**Investigate** the refraction of laser light through blocks of various materials (glass, water, Perspex); with a laser pointer held in a clamp to minimise wobble.
		4.2	**Investigate** diffraction by using strings with markers to represent peaks and troughs of light rays.

12	Energy and work		
Aim To enable the learner to understand the various energies within physics, the natures of these energies and to be able to perform calculations when using the appropriate formulae			
Learning Outcomes - The learner will:		**Assessment Criteria - The learner can:**	
1	Understand the nature of energy, work and power	1.1	**Apply** formulae for kinetic energy, gravitational potential energy and elastic potential energy and the conservation of energy.
		1.2	**Compare** the natures of various energies: kinetic depends solely on speed of a body; potential derives from the interaction between a body (or charge) and a field; elastic potential is due to a displacement from equilibrium for an elastic system
		1.3	**Justify** that “work” is an energy which can be applied to many situations.
		1.4	**Calculate** work done for a variety of situations such as a body moving up a slope against friction or pushing a mass on a spring away from equilibrium and releasing it to perform simple harmonic motion
		1.5	**Compare** elastic and inelastic collisions in terms of conservation of kinetic energy
		1.6	**Define** power as energy used over time
		1.7	**Calculate** efficiencies of various systems (heating systems, energy generation systems) when given specific data.
2	Understand energies in Physics	2.1	**Apply** formula for the energy stored in a spring
		2.2	**Apply** formula for the power (P=VI) dissipated in an electric circuit
		2.3	**Apply** the formula for energy stored in a capacitor U = ½ QV

3	Be able to demonstrate a practical application of energies in Physics	3.1	**Investigate** a sequence of events in which energy is changed between KE, GPE and EPE.
		3.2	**Investigate** an RC circuit with meters to monitor voltage and current – perform calculations to find the power dissipated through the resistor and to find the energy stored in the capacitor and compare with known values from literature and compare with other groups in the class

13	Thermodynamics and specific heat capacity/latent heat		
Aim To enable the learner to understand thermodynamic processes, p-V graphs and how materials respond to changes in temperature or combinations of 2 bodies of different temperature.			
Learning Outcomes - The learner will:		**Assessment Criteria - The learner can:**	
1	Understand thermodynamics	1.1	**Define** the internal energy of a gas as the sum of the kinetic energies of the molecules
		1.2	**Apply** the formula for the internal energy to find energy, temperature or number of molecules/moles
		1.3	**Recall** the first law of thermodynamics
		1.4	**Apply** the first law to discuss variety of theoretical processes
		1.5	**Illustrate** processes which are isobaric, isovolumetric or have zero work done ($W=p\Delta V$) using a p-V graph
		1.6	**Calculate** work done for point-to-point processes and loops using a p-V graph
		1.7	**Determine** whether a process is isothermal from a p-V graph
		1.8	**Determine** whether a process is adiabatic from both a p-V graph and the first law
		1.9	**Define** the zeroth law of thermodynamics.
2	Understand specific heat capacity (SHC) / latent heat (LH)	2.1	**Calculate** SHC/LH with correct units for a single mass undergoing either a change in temperature or a change in phase
		2.2	**Analyse** a graph of temperature vs. absorbed heat for water in terms of when to apply the formula for SHC and when to apply the formula for LH
		2.3	**Determine** the reason for the flat sections on a graph of temperature vs. absorbed

			heat for water, in terms of the quantities in the first law.
3	Be able to demonstrate a practical application of thermodynamics and specific heat capacity	3.1	**Investigate** the adiabatic processes such as the “fire-syringe” and the reversible “cloud in a bottle”, calculating approximate values for the work done when performing these experiments
		3.2	**Calculate** the equilibrium temperature when combining a room temperature pan with hot water, taking great care to minimise thermal losses to the environment and compare data with the theoretical value.

14	Binding energy, fission and fusion		
Aim To enable the learner to understand nuclear binding energy and how it changes under both fission and fusion.			
Learning Outcomes - The learner will:		**Assessment Criteria - The learner can:**	
1	Understand binding energy per nucleon and mass defect	1.1	**Calculate** mass defect for various reactions, using the atomic mass unit, u
		1.2	**Use** E=mc^2 for to calculate the energy released in a variety of reactions
		1.3	**Analyse** the graph of binding energy per nucleon vs. nucleon number
		1.4	**Determine** which parts of the binding energy per nucleon vs. Nucleon number graph represent fusion or fission
2	Understand fission and fusion	2.1	**Compare** the current methods for generating energy from fusion or fission (nuclear power stations, tokamaks, fast ignition fusion)
		2.2	**Justify** how both fission and fusion result in an increased of binding energy
		2.3	**Calculate** the energy generated from fusion or fission from the graph of binding energy per nucleon vs. Nucleon number
		2.4	**Devise** a tangible analogy to a reaction in which the binding energy changes.

15	Fields and their sources		
Aim To enable the learner to understand the nature of fields and how each type of field can be created and controlled.			
Learning Outcomes - The learner will:		**Assessment Criteria - The learner can:**	
1	Understand the nature of fields	1.1	**Conclude** that all fields are invisible, 3 dimensional and behave as vectors
		1.2	**Justify** that electric and magnetic fields have both sources and sinks while gravitational fields have only sources
		1.3	**Calculate** resultant fields when two or more of the same field type act upon the same point
		1.4	**Illustrate** fields as a combination of field lines and equipotential surfaces
		1.5	**Justify** that energy (work) is required to move an object or charge within a field when moving across equipotential surfaces.
2	Understand gravitational fields	2.1	**Justify** that gravitational fields are always attractive
		2.2	**Apply** the inverse square law to calculate the attractive force between two masses
		2.3	**Calculate** the gravitational field strength at any point
		2.4	**Calculate** the potential at any point around a mass
		2.5	**Calculate** the potential energy of a mass
		2.6	**Conclude** that gravitational potential energy arises when a mass exists within the field of another mass
		2.7	**Calculate** the work done when a mass moves across a gravitational potential difference
3	Understand electric fields and electrostatics	3.1	**Apply** the inverse square law to calculate the attractive force between two charges

		3.2	**Calculate** the electric field strength at any point
		3.3	**Calculate** the potential at any point around a charge
		3.4	**Calculate** the potential energy of a charge
		3.5	**Conclude** that electric potential energy arises when a charge exists within the field of another charge
		3.6	**Calculate** the work done when a charge moves across an electric potential difference
		3.7	**Contrast** ways in which electric fields arise – either sole charges or potential difference (such as capacitors)
		3.8	**Calculate** the force on a charge within an electric field
4	Understand magnetic fields	4.1	**Recall** that magnetic sources and sinks are always present together (unlike gravitational or electric)
		4.2	**Contrast** ways in which magnetic fields arise (magnetic materials or moving charges)
		4.3	**Calculate** the magnetic flux density due to a current in a wire
		4.4	**Calculate** the magnetic flux density due to a current flowing through a solenoid
		4.5	**Apply** the right-hand-grip rule to find the direction of the magnetic field around a current carrying wire
		4.6	**Define** magnetic flux as the product of area and magnetic flux density, when normal to each other.
5	Be able to demonstrate a knowledge of gravitational fields, electric fields and magnetic fields	5.1	**Investigate** planets in our solar system from given data, using knowledge from circular motion, calculate the period of these planets due to gravitational attraction and compare with known values.

		5.2	**Investigate** the effect of an applied electric field on a beam of electrons, by using a cathode ray deflection tube and creating a controlled electric field using 2 metal plates and a voltage supply
		5.3	**Investigate** the effect of magnetism from a solenoid with an iron core, by controlling the supplied current to the solenoid, hold a paperclip to the base of the solenoid and increase the current until the forces of gravity and magnetism are balanced.

16	Charge-mass-field interactions		
Aim To enable the learner to understand the interactions between charges, electric fields and magnetic fields; also how masses interact with gravitational fields to result in projectile motion.			
Learning Outcomes - The learner will:		**Assessment Criteria - The learner can:**	
1	Understand interactions between charges and electric/magnetic fields	1.1	**Calculate** the force on a moving charge in a magnetic field
		1.2	**Compare** scalar and vector products (one produces a scalar and the other a vector perpendicular to the others)
		1.3	**Calculate** force on a charged particle due to a current carrying wire
		1.4	**Calculate** the mutual forces between 2 current carrying wires
		1.5	**Critically compare** Fleming's left and right-hand rule and how they are applied
		1.6	**Recall** Faraday's and Lenz's laws for electromagnetic induction
		1.7	**Apply** Faraday's and Lenz's laws to motors and generators
		1.8	**Summarise** the workings behind transformers and the Hall effect in terms of fields and charges.
		1.9	**Summarise** the workings behind particle accelerators in terms of fields and moving charges.
2	Understand interactions between masses and gravitational fields (projectiles/SUVAT)	2.1	**Recall** the equations of motion
		2.2	**Justify** how all the equations of motion are independent of mass or shape of the projectile
		2.3	**Categorise** workings into horizontal and vertical

		2.4	**Categorise** workings into sections of flight and clearly state the section for which calculations are being carried out
		2.5	**Analyse** displacement-time, velocity-time and acceleration-time graphs and how they relate to one another
		2.6	**Calculate** displacement, velocity or acceleration from graphs of displacement-time, velocity-time and acceleration-time
3	Be able to demonstrate a practical application of charge-mass-field interactions	3.1	**Investigate** the effect of both magnetic and electric fields on a cathode ray deflection tube using an applied electric field and an applied magnetic field by using Helmholtz coils.
		3.2	**Investigate** a projectile by launching an aerodynamic mass (ideally indoors to minimise wind disturbance) and comparing with predicted flight time, height reached, and distance covered.

APPENDIX:

CORE PRACTICAL COMPETENCIES:

Candidates will need to carry out and evidenced internally carried out practical's that include a range of the 5 representative competencies.

Competencies:

1. Follows written instructions:

a. Correctly follows written instructions to carry out experimental techniques or procedures.

2. Applies investigative approaches and methods when using instruments and equipment

a. Correctly uses appropriate instrumentation, apparatus, and materials (including ICT) to carry out investigative activities, experimental techniques and procedures with minimal assistance or prompting.

b. Carries out techniques or procedures methodically, in sequence and in combination, identifying practical issues and adjusting when necessary.

c. Identifies and controls significant quantitative variables where applicable, and plans approaches to take account of variables that cannot readily be controlled.

d. Selects appropriate equipment and measurement strategies to ensure suitably accurate results.

3. Safely uses a range of practical equipment and materials

a. Identifies hazards and assesses risks associated with these hazards, making safety adjustments as necessary, when carrying out experimental techniques and procedures in the lab or field.

b. Uses appropriate safety equipment and approaches to minimise risks with minimal prompting.

4. Makes and records observations

a. Makes accurate observations relevant to the experimental or investigative procedure.

b. Obtains accurate, precise, and sufficient data for experimental and investigative procedures and records this methodically using appropriate units and conventions.

5. Research, references, and reports

a. Uses appropriate software and/or tools to process data, carry out research and report findings.

b. Cites sources of information demonstrating that research has taken place, supporting planning and conclusions.

It is expected through time candidates will demonstrate these competencies consistently throughout subsequent practicals. It is not required that each competency be demonstrated in all practicals.

Candidates should have gained experience from at least 10 practicals across the 2-year course.

Representative of the following skills:

Practical techniques to be completed by candidates

- Use appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature, length, voltage and current)
- Use appropriate instrumentation to record quantitative measurements (such as Vernier callipers for length)
- Correct design of circuits and meters
- Produce appropriate graphs of the collected data

A centre will need to demonstrate candidates have met these competencies, this will be done through regular moderation processes once every 2 years for quality assurance to ensure standards are maintained and assessed accurately.

This will require communication from a LRN moderator, evidence will need to be submitted to gain approval from the moderator to pass the centre and complete the endorsement process.

A video lesson may need to be recorded and submitted also additionally for international centres where visitation is not a viable option.

Additional guidance and training are available.

MATHEMATICAL REQUIREMENTS

Calculators may be used in all parts of the examination.

Candidates should be able to:

1. Complete equations involving addition, subtraction, multiplication, and division
2. Understand and use the symbols: =, <, <<, >>, >, ∝, ~.
3. Calculate percentages
4. Calculate percentage change
5. Translate information between graphical, numerical and algebraic forms
6. Manipulate a range of formula to identify the unknown variable.
7. Deduce and determine uncertainties in measurements.
8. Carry out unit conversions
9. Solve algebraic equations using substitution and appropriate units.
10. Judge appropriate orders of magnitude and scale.
11. Use a calculator to find and use power, exponential and logarithmic functions.
12. Calculate circumferences, surface area and volume of a range of shapes circle, square, rectangle and triangle
13. Calculate rate of change from graphs
14. Apply standard form to data
15. Able to sufficiently round data correctly
16. Provide answers to significant figures
17. Present values in line with equipment measurements
18. Understand that y = mx + c represents a linear relationship

19. Determine the intercept of a graph
20. Rearrange log and exponential formulae
21. Derive useful data from both gradient and area beneath certain graphs

SAFETY IN PRACTICAL INVESTIGATIONS

Candidates should be able to:

1. Identify relevant hazards and associated risks of equipment used
2. Carry out practical procedures carefully and thoroughly applying good practice
3. Identify risks associated with high voltages and currents.

The safety of candidates and staff are the responsibility of the centre involved, full guidance can be found on https://www.cleapss.org.uk/ (Members only).

FORMULAE INCLUDED IN DATA BOOKLET FOR BOTH AS AND A LEVEL EXAMINATIONS

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

$v = u+at$

$x=\frac{1}{2}(u+v)t$

$x=ut+\frac{1}{2}at^2$

$v^2=u^2+2ax$

$\Sigma F=ma$

$p = mv$

$W= Fx\cos\theta$

$E=\frac{1}{2}kx^2$

$$E = \frac{1}{2} m v^2$$

$$P = \frac{W}{t} = \frac{\Delta E}{t}$$

$F = kx$

$$\sigma = \frac{F}{A}$$

$$\varepsilon = \frac{\Delta l}{l}$$

$$E = \frac{\sigma}{\varepsilon}$$

$$W = \frac{1}{2} F x$$

$$I = \frac{\Delta Q}{\Delta t}$$

$$I = nAve$$

$$R = \frac{V}{I}$$

$$P = IV$$

$$R = \frac{\rho l}{A}$$

$$V = E - Ir$$

$$\frac{V}{V_{total}} = \frac{R}{R_{total}}$$

$$T = \frac{1}{f}$$

$$c = f\lambda$$

$$\lambda = \frac{a\Delta y}{D}$$

$$d\sin\vartheta = n\lambda$$

$$n = \frac{c}{v}$$

$$n_1 v_1 = n_2 v_2$$

$$n_1 \sin\vartheta_1 = n_2 \sin\vartheta_2$$

$$n_1 \sin\vartheta_C = n_2$$

$$E_{k\,max} = hf - \varphi$$

$$p = \frac{h}{\lambda}$$

$$\omega = \frac{\vartheta}{t}$$

$$v = \omega r$$

$$a = \omega^2 r$$

$$a = \frac{v^2}{r}$$

$$F = \frac{mv^2}{r}$$

$$a = -\omega^2 x$$

$$x = A\cos(\omega t + \varepsilon)$$

$$T = \frac{2\pi}{\omega}$$

$$v = -A\omega\sin(\omega t + \varepsilon)$$

$$T = 2\pi\sqrt{\frac{m}{k}}$$

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

$$pV = nRT$$

$$pV = NkT$$

$$p = \frac{1}{3}\rho\bar{c}^2$$

$$p = \frac{1}{3}\frac{N}{V}m\bar{c}^2$$

$$k = \frac{R}{N_A}$$

$$U = \frac{3}{2}nRT$$

$$U = \frac{3}{2}NkT$$

$$W = p\Delta V$$

$$\Delta U = Q - W$$

$$Q = mc\Delta\theta$$

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

$$C = \frac{\varepsilon_0 A}{d}$$

$$E = \frac{V}{d}$$

$$U = \frac{1}{2}QV$$

$$Q = Q_0\left(1 - e^{\frac{-t}{RC}}\right)$$

$$Q = Q_0 e^{\frac{-t}{RC}}$$

$$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$$

$$F = \frac{GM_1 M_2}{r^2}$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$

$$g = \frac{GM}{r^2}$$

$$V_E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$

$$PE = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r}$$

$$V_g = \frac{-GM}{r}$$

$$PE = \frac{-GM_1 M_2}{r}$$

$$W = q\Delta V_E$$

$$W = m\Delta V_g$$

$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$

$$A = \lambda N$$

$$N = N_0 e^{-\lambda t}$$

$$A = A_0 e^{-\lambda t}$$

$$N = \frac{N_0}{2^x}$$

$$A = \frac{A_0}{2^x}$$

$$\lambda = \frac{ln2}{T_{\frac{1}{2}}}$$

$$E = mc^2$$

$$F = BIlsin\theta$$

$$F = Bqvsin\theta$$

$$B = \frac{\mu_0 I}{2\pi a}$$

$$B = \mu_0 n I$$

$$\Phi = ABcos\theta$$