GCE AS and A Level Subject Criteria for Science

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Contents

The criteria

Introduction

AS and A level subject criteria set out the knowledge, understanding, skills and assessment objectives common to all AS and A level specifications in a given subject.

They provide the framework within which the awarding organisation creates the detail of the specification.

Aims and objectives

1. AS and A level specifications in a science subject should encourage learners to:

    - develop their interest in and enthusiasm for the subject, including developing an interest in further study and careers in the subject;
    - appreciate how society makes decisions about scientific issues and how the sciences contribute to the success of the economy and society;
    - develop and demonstrate a deeper appreciation of the skills, knowledge and understanding of how science works;
    - develop essential knowledge and understanding of different areas of the subject and how they relate to each other.

Specification content

2. AS and A level Science specifications must build on the skills, knowledge and understanding set out in the *GCSE Criteria for Science*.

3. The skills, knowledge and understanding set out in the appendices for each science subject must comprise for AS approximately 60 per cent of the specification. The skills, knowledge and understanding for AS and A2 combined must comprise approximately 60 per cent of an A level specification.

4. The remainder of both AS and A level specifications allows both for:

    - further consideration of applications and implications of science and the development of scientific ideas;
    - the introduction of different areas of study.

5. AS and A level specifications must include a range of contemporary and other contexts.

6. AS and A level specifications must require learners to cover the areas of the subject as illustrated in the relevant appendix below with the content at A2, shown in bold, organised so that it builds on and extends AS.

7. The skills, knowledge and understanding of how science works must include the requirements set out below, and must be integrated into the mandatory content indicated in the relevant appendix and any content added by the awarding organisation:

    - Use theories, models and ideas to develop and modify scientific explanations.
    - Use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas.
    - Use appropriate methodology, including information and communication technology (ICT), to answer scientific questions and solve scientific problems.
    - Carry out experimental and investigative activities, including appropriate risk management, in a range of contexts.
    - Analyse and interpret data to provide evidence, recognising correlations and causal relationships.
    - Evaluate methodology, evidence and data, and resolve conflicting evidence.
    - Appreciate the tentative nature of scientific knowledge.
    - Communicate information and ideas in appropriate ways using appropriate terminology.
    - Consider applications and implications of science and appreciate their associated benefits and risks.
    - Consider ethical issues in the treatment of humans, other organisms and the environment.
    - Appreciate the role of the scientific community in validating new knowledge and ensuring integrity.

- Appreciate the ways in which society uses science to inform decision making.

8. Development of the skills, knowledge and understanding of the science subjects must include the mathematical requirements set out in Appendix 8.

Assessment objectives

9. These assessment objectives are the same for AS and A level. They apply to the whole specification.

10. Specifications must require, in all assessment units, that learners demonstrate these assessment objectives in the context of the skills, knowledge and understanding prescribed, including using extended prose.

11. Each assessment unit must address one or more aspects of each of the assessment objectives.

12. In the context of these assessment objectives, the following definitions apply:

    - Knowledge includes facts, specialist vocabulary, principles, concepts, theories, models, practical techniques, studies and methods.
    - Issues include ethical, social, economic, environmental, cultural, political and technological.
    - Processes include collecting evidence, explaining, theorising, modelling, validating, interpreting, planning to test an idea and peer reviewing.
    - The assessment objectives are to be weighted in all specifications as indicated. These apply to the whole specification.

Assessment objectives		Weighting		
		AS level	A2 level	A level
AO1	Knowledge and understanding of science and of how science works:	30–40%	20–30%	25–35%

	Recognise, recall and show understanding of scientific knowledge. Select, organise and communicate relevant information in a variety of forms.			
AO2	Application of knowledge and understanding of science and of How science works: Analyse and evaluate scientific knowledge and processes. Apply scientific knowledge and processes to unfamiliar situations including those related to issues. Assess the validity, reliability and credibility of scientific information.	30–40%	40–50%	35–45%
AO3	How science works: Biology, chemistry, physics, geology, electronics and environmental science: Demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods. Make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy. Analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways. How science works – psychology:	20–40%	20–40%	20–40%

	Describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods. Know how to make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy, through using primary and secondary sources. Analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.			

13. Due to the potential age of A level learners and the possible nature of investigative activities in psychology, learners will not be expected to demonstrate the skills of investigation through internal assessment in the 'How science works – psychology' part of assessment objective 3. It is expected, however, that learners should still carry out investigative activities appropriate for the study of psychology at this level.

Scheme of assessment

Number of assessment units

- All of the GCE A levels in science subjects will contain six assessment units, with the exception of the GCE A level in psychology, which will contain four assessment units.
- All units in psychology will be externally assessed.
- In the six-unit GCE A level science subjects, one of the assessment units at AS and one of the assessment units at A2 must be internally assessed. Each of the internally assessed units at AS and A2 must include the assessment of practical skills.

- In the six-unit GCE A level science subjects, the minimum weighting of each internally assessed unit must be between 20 and 30 per cent for each of AS and A2.

Internal assessment

14. Where internal assessment is included, specifications must make clear how reliability and fairness are secured, by setting out requirements that ensure the robustness of each stage of the internal assessment, i.e.:

    - the specific skills to be assessed;
    - setting of tasks;
    - extent of supervision in carrying out of tasks;
    - conditions under which assessment takes place;
    - marking of the assessment and internal standardising procedures;
    - any moderation process.

Synoptic assessment

15. There is a requirement to formally assess synoptically at A2. The definition of synoptic assessment in the context of science is set out below.

16. Synoptic assessment requires learners to make and use connections within and between different areas of the subject at AS and A2, for example by:

    - applying knowledge and understanding of more than one area to a particular situation or context;
    - using knowledge and understanding of principles and concepts in planning, experimental and investigative work and in the analysis and evaluation of data;
    - bringing together scientific knowledge and understanding from different areas of the subject and applying them.

Appendix 1: Biology – knowledge and understanding

17. This appendix must be read in conjunction with sections 2 - 8 of this criteria.

18. The AS knowledge and understanding set out in this appendix should comprise approximately 60 per cent of the AS specification. The AS and A2 knowledge and understanding combined should comprise approximately 60 per cent of an A level specification. The A2 content is shown in **bold**.

19. Biology specifications must ensure that there is an appropriate balance between plant biology, animal biology and microbiology and include an appreciation of the relevance of sustainability to all aspects of scientific developments.

20. Living organisms, including plants, animals and micro-organisms, interact with each other and with the non-living world. The living world can be studied at population, organism, cell and molecular levels. There are fundamental similarities as well as differences between plants, animals and micro-organisms.

	AS	**A2**
Population	Biodiversity	**Ecosystems**
Organism	Exchange and transport	**Control systems**
Cell	Cells	**Cellular control**
Molecular	Biological molecules	**Energy for biological processes**

21. **Biodiversity**

- The variety of life, both past and present, is extensive, but the biochemical basis of life is similar for all living things.
- Biodiversity refers to the variety and complexity of life and may be considered at different levels.
- Biodiversity can be measured, for example within a habitat or at the genetic level.
- Classification is a means of organising the variety of life based on relationships between organisms and is built around the concept of species.

- Originally classification systems were based on observable features but more recent approaches draw on a wider range of evidence to clarify relationships between organisms.
- Adaptations of organisms to their environments can be behavioural or physiological as well as anatomical.
- Adaptation and selection are major components of evolution and make a significant contribution to the diversity of living organisms.

22. **Exchange and transport**

- Organisms need to exchange substances selectively with their environment and this takes place at exchange surfaces.
- Factors such as size or metabolic rate affect the requirements of organisms and this gives rise to adaptations such as specialised exchange surfaces and mass transport systems.
- Substances are exchanged by passive or active transport across exchange surfaces.
- The structure of the plasma membrane enables control of the passage of substances in and out of cells.

23. **Cells**

- Organisms usually consist of one or more cells.
- Prokaryotic and eukaryotic cells can be distinguished on the basis of their structure and ultrastructure.
- In complex multicellular organisms cells are organised into tissues, tissues into organs and organs into systems.
- During the cell cycle genetic information is copied and passed to daughter cells.
- Daughter cells formed during mitosis have identical copies of genes while cells produced as a result of meiosis are not genetically identical.

24. **Biological molecules**

- Biological molecules are often polymers and are based on a small number of chemical elements.

- In living organisms nucleic acids (DNA and RNA), carbohydrates, proteins, lipids, inorganic ions and water all have important roles and functions related to their properties.
- Enzymes are proteins with a mechanism of action and other properties determined by their tertiary structure.
- Enzymes catalyse a wide range of intracellular reactions as well as extracellular ones.

25. **Ecosystems**

- **Ecosystems range in size from the very large to the very small.**
- **Energy flows through ecosystems and the efficiency of transfer through**
- **Different trophic levels can be measured.**
- **Micro-organisms play a key role in recycling chemical elements.**
- **Ecosystems are dynamic systems, usually moving from colonisation to climax communities in a process known as succession.**
- **The dynamic equilibrium of populations is affected by a range of factors.**
- **Humans are part of the ecological balance and their activities affect it both directly and indirectly.**
- **Sustainability of resources depends on effective management of the conflict between human needs and conservation.**

26. **Control systems**

- **Homeostasis is the maintenance of a constant internal environment.**
- **Negative feedback helps maintain an optimal internal state in the context of a dynamic equilibrium. Positive feedback also occurs.**
- **Stimuli, both internal and external, are detected leading to responses.**

- **Coordination may be chemical or electrical in nature.**

27. **Cellular control**

    - **The sequence of bases in the DNA molecule determines the structure of proteins, including enzymes.**
    - **Enzymes catalyse the reactions that determine structures and functions from cellular to whole-organism level.**
    - **Transfer of genetic information from one generation to the next can ensure continuity of species or lead to variation within a species and eventual formation of new species.**
    - **Reproductive isolation can lead to accumulation of different genetic information in populations potentially leading to formation of new species.**
    - **Sequencing projects have read the genomes of organisms ranging from microbes and plants to humans. This allows the sequences of the proteins that derive from the genetic code to be predicted.**
    - **Gene technologies allow study and alteration of gene function in order to better understand organism function and to design new industrial and medical processes.**

28. **Energy for biological processes**

    - **ATP provides the immediate source of energy for biological processes.**
    - **In cellular respiration, glycolysis takes place in the cytoplasm and the remaining steps in the mitochondria.**
    - **ATP synthesis is associated with the electron transfer chain in the membranes of mitochondria and chloroplasts.**
    - **In photosynthesis energy is transferred to ATP in the light-dependent stage and the ATP is utilised during synthesis in the light-independent stage.**

AS performance descriptions for Biology

	Assessment objective 1	Assessment objective 2	Assessment objective 3
Assessment objectives	Knowledge and understanding of science and of how science works: ■ Recognise, recall and show understanding of scientific knowledge. ■ Select, organise and communicate relevant information in a variety of forms.	Application of knowledge and understanding of science and of how science works: ■ Analyse and evaluate scientific knowledge and processes. ■ Apply scientific knowledge and processes to unfamiliar situations including those related to issues. ■ Assess the validity, reliability and credibility of scientific information.	How science works: ■ Demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods. ■ Make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy. ■ Analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.
	Learners characteristically:	Learners characteristically:	Learners characteristically:

A/B boundary performance descriptions	demonstrate knowledge and understanding of most principles, concepts and facts from the AS specification; select relevant information from the AS specification; organise and present information clearly in appropriate forms using scientific terminology.	apply principles and concepts in familiar and new contexts involving only a few steps in the argument; describe significant trends and patterns shown by data presented in tabular or graphical form; interpret phenomena with few errors; and present arguments and evaluations clearly; comment critically on statements, conclusions or data; carry out accurately most of the calculations specified for AS; translate successfully data that is presented as prose, diagrams, drawings, tables or graphs from one form to another.	devise and plan experimental and investigative activities, selecting appropriate techniques; demonstrate safe and skilful practical techniques and comment effectively on ethical issues; make observations and measurements with appropriate precision and record them methodically; interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.
E/U boundary	Learners characteristically:	Learners characteristically:	Learners characteristically:

performance descriptions	demonstrate knowledge and understanding of some principles and facts from the AS specification; select some relevant information from the AS specification; present information using basic terminology from the AS specification.	apply a given principle to material presented in familiar or closely related contexts involving only a few steps in the argument; describe some trends or patterns shown by data presented in tabular or graphical form; identify, when directed, inconsistencies in conclusions or data; carry out some steps within calculations; translate data successfully from one form to another, in some contexts.	devise and plan some aspects of experimental and investigative activities; demonstrate safe practical techniques and comment on ethical issues; make observations and measurements and record them; interpret, explain and communicate some aspects of the results of their own and others' experimental and investigative activities, in appropriate contexts.

A2 performance descriptions for Biology

	Assessment objective 1	Assessment objective 2	Assessment objective 3
Assessment objectives	Knowledge and understanding of science and of how science works: ■ Recognise, recall and show understanding of scientific knowledge. ■ Select, organise and communicate relevant information in a variety of forms.	Application of knowledge and understanding of science and of how science works: ■ Analyse and evaluate scientific knowledge and processes. ■ Apply scientific knowledge and processes to unfamiliar situations including those related to issues. ■ Assess the validity, reliability and credibility of scientific information.	How science works: ■ Demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods. ■ Make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy. ■ Analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

A/B boundary performance descriptions	Learners characteristically: demonstrate detailed knowledge and understanding of most principles, concepts and facts from the A2 specification; select relevant information from the A2 specification; organise and present information clearly in appropriate forms using scientific terminology	Learners characteristically: apply principles and concepts in familiar and new contexts involving several steps in the argument; describe significant trends and patterns shown by complex data presented in tabular or graphical form; interpret phenomena with few errors; and present arguments and evaluations clearly; evaluate critically any statements, conclusions or data; carry out accurately most of the calculations specified for A2; and apply the principles of statistical analysis when directed; translate successfully data that is presented as prose, diagrams, drawings, tables or graphs from one	Learners characteristically: devise and plan experimental and investigative activities, selecting appropriate techniques; demonstrate safe and skilful practical techniques and comment effectively on ethical issues; make observations and measurements with appropriate precision and record these methodically; interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts; use an appropriate statistical technique to assess the validity of a hypothesis.

		form to another; select a wide range of facts, principles and concepts from both AS and A2 specifications; link together appropriate facts, principles and concepts from different areas of the specification.	
E/U boundary performance descriptions	Learners characteristically: a) demonstrate knowledge and understanding of some principles, concepts and facts from the A2 specification; b) select some relevant information from the A2 specification; c) present information using basic terminology from the A2 specification.	Learners characteristically: apply given principles or concepts in familiar and new contexts involving a few steps in the argument; describe, and provide a limited explanation of, trends or patterns shown by complex data presented in tabular or graphical form; identify, when directed, inconsistencies in conclusions or data;	Learners characteristically: devise and plan some aspects of experimental and investigative activities; demonstrate safe practical techniques and comment on ethical issues; make observations and measurements and record them; interpret, explain and communicate some of the results of their own and

		carry out some steps within calculations; translate data successfully from one form to another, in some contexts; select some facts, principles and concepts from both AS and A2 specifications; put together some facts, principles and concepts from different areas of the specification.	others' experimental and investigative activities, in appropriate contexts; use a given statistical technique.

Appendix 2: Chemistry – knowledge and understanding

29. This appendix must be read in conjunction with sections 2-8 of this Science criteria. The AS knowledge and understanding set out in this appendix should comprise approximately 60 per cent of the AS specification. The AS and A2 knowledge and understanding combined should comprise approximately 60 per cent of an A level specification. The A2 content is shown in **bold**.

30. Chemistry specifications must ensure that there is an appreciation of the relevance of sustainability to all aspects of scientific developments.

31. Formulae, equations and amounts of substance

- Empirical and molecular formulae.
- Balanced chemical equations (full and ionic).
- The Avogadro constant and the amount of substance (mole).
- Relative atomic mass and relative isotopic mass.
- Calculation of reacting masses, mole concentrations, volumes of gases, per cent yields and atom economies.
- Simple acid–base titrations.
- **Non-structured titration calculations, based solely on experimental results.**

32. **Atomic structure**

- Structure and electronic configuration of atoms (up to Z = 36) in terms of main energy levels and *s, p* and *d* orbitals.
- Ions and isotopes; use of mass spectrometry in determining relative atomic mass and relative abundance of isotopes.

33. **Bonding and structure**

- Interpretation of ionic and covalent bonding in terms of electron arrangements. Examples of simple covalent, giant covalent, ionic and metallic structures.
- Permanent and induced dipole–dipole interactions between molecules, including hydrogen bonding. Electronegativity and its

application to bond type. Interpretation of the physical properties of materials in terms of structure and bonding.

- Shapes of simple molecules and ions with up to six outer pairs of electrons (any combination of bonding pairs and lone pairs). Interpretation in terms of electron pair repulsion theory.

34. Energetics

- Enthalpy changes, including standard enthalpy changes of reaction, formation and combustion. Average bond enthalpies.
- Use of Hess's law to calculate enthalpy changes.
- **Use of energetics, including entropy, to predict the feasibility of reactions.**

35. **Kinetics**

- A qualitative understanding of collision theory. Activation energy and its relationship to the qualitative effect of temperature changes on rate of reaction.
- The role of catalysts in providing alternative routes of lower activation energy.
- **Determination and use of rate equations of the form: *Rate* = *k[A]m[B]n*, where *m* and *n* are integers. Using orders of reactions where appropriate, which may give information about a rate-determining/limiting step.**

36. **Equilibria**

- The dynamic nature of equilibria. For homogeneous reactions, the qualitative effects of temperature, pressure and concentration changes on the position of equilibrium. Equilibrium constants, *Kc*. Calculation of *Kc* and reacting quantities.
- **The effect of temperature changes on *Kc*.**
- **The Bronsted–Lowry theory of acid–base reactions. The ionic product of water, *Kw*; pH and its calculation for strong acids and strong bases.**
- **Dissociation constants of weak acids, *Ka*. Calculation of pH for weak acids. Buffer solutions and their applications.**

37. **Redox**

- Oxidation states and their calculation.
- Oxidation and reduction as electron transfer, applied to reactions of *s, p* and *d* block elements.
- **Electrode potentials and their applications.**

38. Inorganic chemistry and the periodic table

- The organisation of elements according to their proton number and electronic structures. Classification of elements into *s, p* and *d* blocks.
- The characteristic reactions of the elements and compounds of a metallic group and a non-metallic group. Trends in properties of elements and compounds within these groups.
- Trends in properties of elements across a period including:
  - melting point;
  - ionisation energy.
- **The transition metals as *d* block elements forming one or more stable ions that have incompletely filled *d* orbitals. At least two transition metals, chosen from titanium to copper, to illustrate:**
  - **the existence of more than one oxidation state for each element in its compounds;**
  - **the formation of coloured ions in solution and simple precipitation reactions of these;**
  - **reactions with ligands to form complexes and reactions involving ligand substitution;**
  - **the catalytic behaviour of the elements and their compounds.**

39. Organic chemistry

- Functional groups. Structural isomers and stereoisomers (limited to geometric (E–Z) isomerism as a result of restricted rotation about a carbon–**carbon double bond and optical isomerism as a result of chirality in molecules with a single chiral centre).**

- Reactions classified as addition, elimination, substitution, oxidation, **reduction, hydrolysis**, addition polymerisation **and condensation polymerisation.**
- Mechanisms classified as radical substitution, electrophilic addition, nucleophilic substitution, **electrophilic substitution and nucleophilic addition.**
- Single and double covalent bonds, bond polarity and bond enthalpy as factors influencing reactivity, illustrated by reference to appropriate reactions.
- **The structure of, and the bonding in, benzene.**
- Organic synthesis, including characteristic reactions of alkanes, alkenes, halogenoalkanes, alcohols**, arenes, aldehydes, ketones, carboxylic acids, esters, amines, amino acids and amides.**

40. Modern analytical techniques

- The use of mass spectrometry, infrared spectroscopy, **nuclear magnetic resonance spectroscopy and chromatography** in analysis, including techniques for the elucidation of structure.

AS performance descriptions for Chemistry

	Assessment objective 1	Assessment objective 2	Assessment objective 3
Assessment objectives	Knowledge and understanding of science and of how science works: ■ Recognise, recall and show understanding of scientific knowledge. ■ Select, organise and communicate relevant information in a variety of forms.	Application of knowledge and understanding of science and of how science works: ■ Analyse and evaluate scientific knowledge and processes. ■ Apply scientific knowledge and processes to unfamiliar situations including those related to issues. ■ Assess the validity, reliability and credibility of scientific information.	How science works: ■ Demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods. ■ Make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy. ■ Analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

A/B boundary performance descriptions	Learners characteristically: demonstrate knowledge and understanding of most principles, concepts and facts and from the AS specification; select relevant information from the AS specification; organise and present information clearly in appropriate forms; write equations for most straightforward reactions using scientific terminology.	Learners characteristically: apply principles and concepts in familiar and new contexts involving only a few steps in the argument; describe significant trends and patterns shown by data presented in tabular or graphical form; interpret phenomena with few errors; and present arguments and evaluations clearly; comment critically on statements, conclusions or data; carry out accurately most structured calculations specified for AS; use a range of chemical equations; translate successfully data presented as prose, diagrams, drawings, tables or graphs from one form to another.	Learners characteristically: devise and plan experimental and investigative activities, selecting appropriate techniques; demonstrate safe and skilful practical techniques; make observations and measurements with appropriate precision and record these methodically; interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.

E/U boundary performance descriptions	Learners characteristically: demonstrate knowledge and understanding of some principles and facts from the AS specification; select some relevant information from the AS specification; present information using basic terminology from the AS specification; write equations for some straightforward reactions.	Learners characteristically: apply a given principle to material presented in familiar or closely related contexts involving only a few steps in the argument; describe some trends or patterns shown by data presented in tabular or graphical form; identify, when directed, inconsistencies in conclusions or data; carry out some steps within calculations; use simple chemical equations; translate data successfully from one form to another, in some contexts.	Learners characteristically: devise and plan some aspects of experimental and investigative activities; demonstrate safe practical techniques; make observations and measurements and record them; interpret, explain and communicate some aspects of the results of their own and others' experimental and investigative activities, in appropriate contexts.

A2 performance descriptions for Chemistry

	Assessment objective 1	Assessment objective 2	Assessment objective 3
Assessment objectives	Knowledge and understanding of science and of how science works: ■ Recognise, recall and show understanding of scientific knowledge. ■ Select, organise and communicate relevant information in a variety of forms.	Application of knowledge and understanding of science and of how science works: ■ Analyse and evaluate scientific knowledge and processes. ■ Apply scientific knowledge and processes to unfamiliar situations including those related to issues. ■ Assess the validity, reliability and credibility of scientific information.	How science works: ■ Demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods. ■ Make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy. ■ Analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

A/B boundary performance descriptions	Learners characteristically: demonstrate detailed knowledge and understanding of most principles, concepts and facts from the A2 specification; select relevant information from the A2 specification; organise and present information clearly in appropriate forms using scientific terminology; write equations for most chemical reactions	Learners characteristically: apply principles and concepts in familiar and new contexts involving several steps in the argument; describe significant trends and patterns shown by complex data presented in tabular or graphical form; interpret phenomena with few errors; and present arguments and evaluations clearly; evaluate critically the statements, conclusions or data; carry out accurately complex calculations specified for A level; use chemical equations in a range of contexts; translate successfully data presented as prose, diagrams, drawings, tables	Learners characteristically: devise and plan experimental and investigative activities, selecting appropriate techniques; demonstrate safe and skilful practical techniques; make observations and measurements with appropriate precision and record these methodically; interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.

		or graphs, from one form to another; select a wide range of facts, principles and concepts from both AS and A2 specifications; link together appropriate facts principles and concepts from different areas of the specification.	
E/U boundary performance descriptions	Learners characteristically: demonstrate knowledge and understanding of some principles and facts from the A2 specification; select some relevant information from the A2 specification; present information using basic terminology from the A2 l reactions.	Learners characteristically: apply given principles or concepts in familiar and new contexts involving a few steps in the argument; describe, and provide a limited explanation of, trends or patterns shown by complex data presented in tabular or graphical form; identify, when directed, inconsistencies in conclusions or data;	Learners characteristically: devise and plan some aspects of experimental and investigative activities; demonstrate safe practical techniques; make observations and measurements and record them; interpret, explain and communicate some aspects of the results of their own and others' experimental and

		carry out some steps within calculations; use some chemical equations; translate data successfully from one form to another, in some contexts; select some facts, principles and concepts from both AS and A2 specifications; put together some facts, principles and concepts from different areas of the specification.	investigative activities, in appropriate contexts.

Appendix 3: Physics – knowledge and understanding

41. This appendix must be read in conjunction with sections 2 - 8 of this Science criteria. The AS knowledge and understanding set out in this appendix should comprise approximately 60 per cent of the AS specification. The AS and A2 knowledge and understanding combined should comprise approximately 60 per cent of an A level specification. The A2 content is shown in **bold**.

42. All Physics specifications should require learners to develop:

- their knowledge of SI units;
- an understanding of the distinction between vector and scalar quantities;
- an awareness of the order of magnitude of physical quantities;
- an awareness of the limitations of physical measurements.

43. All Physics specifications must ensure that there is an appropriate balance between mathematical calculations and written explanations of principles.

44. **Mechanics**

- Vectors:
  - resolution into two components at right angles
  - addition rule for two vectors
  - calculations limited to two perpendicular vectors.
- Kinematics:
  - graphical representation of uniform accelerated motion
  - use of kinematic equations in one dimension with constant velocity or acceleration
  - interpretation of speed and displacement graphs for motion.
- Dynamics
  - use of $F = ma$ when mass is constant;
  - one- and two-dimensional motion under constant force;

- independent effect of perpendicular components with non-uniform acceleration.

- Energy calculation of work done for constant forces, including force not along the line of motion calculation of exchanges between gravitational potential energy and kinetic energy.
- Momentum:
  - **definition, equation;**
  - **principle of conservation of momentum;**
  - **calculations for one-dimensional problems**
- **Circular motion:**
  - **application of F = ma = mv2/r to motion in a circle at constant speed.**
- **Oscillations:**
  - **simple harmonic motion;**
  - **quantitative treatment, limited to $a = -(2\pi f)^2 x$ and the solution $x = A \cos 2\pi ft$;**
  - **velocity as gradient of displacement–time graph;**
  - **qualitative treatment of free and forced vibrations;**
  - **damping and resonance**

45. **Electric circuits**

- Current:
  - electric current as rate of flow of charge, $I = \Delta q / \Delta t$.
- Circuits:
  - conservation of charge and energy in simple circuits;
  - relationships between currents, voltages and resistances in series and parallel circuits;

- potential divider circuits.

- Emf and potential difference:
  - definition of emf and concept of internal resistance;
  - potential difference in terms of energy transfer
- Resistance:
  - definition;
  - resistivity;
  - Ohm's law as a special case;
  - power dissipated.
- **Capacitance:**
  - **definition;**
  - **energy of a capacitor;**
  - **quantitative treatment of discharge curves.**
- Waves:
  - qualitative treatment of polarisation and diffraction;
  - path difference, phase and coherence;
  - graphical treatment of superposition and standing waves

46. **Matter**

- **Molecular kinetic theory:**
  - **ideal gases; $pV = NkT$;**
  - **absolute zero;**
  - **effect of temperature on average molecular kinetic energy;**
  - **energy of an ideal gas.**
- **Internal energy:**

- **idea of internal energy;**
- **energy required for temperature change = $mc\Delta\theta$.**

47. Quantum and **nuclear physics**

- Photons:
  - photon model to explain observable phenomena;
  - evidence supporting the photon model.
- Particles:
  - evidence supporting the quantum model for particles;
  - a study of particle diffraction would provide suitable depth of treatment.
- **Nuclear decay:**
  - **connections between nature, penetration and range of ionising particles;**
  - **evidence for existence of nucleus;**
  - **activity of radioactive sources;**
  - **modelling with constant decay probability leading to exponential decay; idea of half life;**
  - **nuclear changes in decay.**
- **Nuclear energy:**
  - **$E = mc^2$ applied to nuclear processes;**
  - **appreciation that $E = mc^2$ applies to all energy changes;**
  - **simple calculations relating mass difference to energy change;**
  - **descriptions of fission and fusion processes.**

48. **Fields**

- **Force fields c:**

- **concept and definition;**
- **gravitational force and field for point (or spherical) masses;**
- **electric force and field for point (or spherical) charges in a vacuum ;**
- **uniform electric field;**
- **similarities and differences between electric and gravitational fields.**

- **B-fields:**
  - **force on a straight wire and force on a moving charge in a uniform field with field perpendicular to current or motion.**

- **Flux and electromagnetic induction:**
  - **concept and definition;**
  - **Faraday's and Lenz's laws;**
  - **emf as equal to rate of change of magnetic flux and simple calculations.**

AS performance descriptions for Physics

	Assessment objective 1	Assessment objective 2	Assessment objective 3
Assessment objectives	Knowledge and understanding of science and of how science works: ■ Recognise, recall and show understanding of scientific knowledge. ■ Select, organise and communicate relevant information in a variety of forms.	Application of knowledge and understanding of science and of how science works: ■ Analyse and evaluate scientific knowledge and processes. ■ Apply scientific knowledge and processes to unfamiliar situations including those related to issues. ■ Assess the validity, reliability and credibility of scientific information.	How science works: ■ Demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods. ■ Make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy. ■ Analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

A/B boundary performance descriptions	Learners characteristically: demonstrate knowledge of most principles, concepts and facts from the AS specification; show understanding of most principles, concepts and facts from the AS specification; select relevant information from the AS specification; organise and present information clearly in appropriate forms using scientific terminology.	Learners characteristically: apply principles and concepts in familiar and new contexts involving only a few steps in the argument; describe significant trends and patterns shown by data presented in tabular or graphical form; explain and interpret phenomena with few errors and present arguments and evaluations clearly; carry out structured calculations with few errors and demonstrate good understanding of the underlying relationships between physical quantities.	Learners characteristically: devise and plan experimental and investigative activities, selecting appropriate techniques; demonstrate safe and skilful practical techniques; make observations and measurements with appropriate precision and record these methodically; interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.
E/U boundary performance descriptions	Learners characteristically: demonstrate knowledge of some principles and facts from the AS specification;	Learners characteristically: apply a given principle to material presented in familiar or closely related contexts involving only a few steps in the argument;	Learners characteristically: devise and plan some aspects of experimental and investigative activities;

	show understanding of some principles and facts from the AS specification; select some relevant information from the AS specification; present information using basic terminology from the AS specification.	describe some trends or patterns shown by data presented in tabular or graphical form; provide basic explanations and interpretations of some phenomena, presenting very limited evaluations; carry out some steps within calculations.	demonstrate safe practical techniques; make observations and measurements, and record them; interpret, explain and communicate some aspects of the results of their own and others' experimental and investigative activities, in appropriate contexts.

A2 performance descriptions for Physics

	Assessment objective 1	Assessment objective 2	Assessment objective 3
Assessment objectives	Knowledge and understanding of science and of how science works: ■ Recognise, recall and show understanding of scientific knowledge. ■ Select, organise and communicate relevant information in a variety of forms.	Application of knowledge and understanding of science and of how science works: ■ Analyse and evaluate scientific knowledge and processes. ■ Apply scientific knowledge and processes to unfamiliar situations including those related to issues. ■ Assess the validity, reliability and credibility of scientific information.	How science works: ■ Demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods. ■ Make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy. ■ Analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

A/B boundary performance descriptions	Learners characteristically: demonstrate detailed knowledge of most principles, concepts and facts from the A2 specification; show understanding of most principles, concepts and facts from the A2 specification; select relevant information from the A2 specification; organise and present information clearly in appropriate forms using scientific terminology	Learners characteristically: apply principles and concepts in familiar and new contexts involving several steps in the argument; describe significant trends and patterns shown by complex data presented in tabular or graphical form;, interpret phenomena with few errors, and present arguments and evaluations clearly and logically explain and interpret phenomena effectively, presenting arguments and evaluations; carry out extended calculations, with little or no guidance, and demonstrate good understanding of the underlying relationships between physical quantities; select a wide range of facts, principles and concepts from both	Learners characteristically: devise and plan experimental and investigative activities, selecting appropriate techniques; demonstrate safe and skilful practical techniques; make observations and measurements with appropriate precision and record these methodically; interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.

		AS and A2 specifications; link together appropriate facts principles and concepts from different areas of the specification.	
E/U boundary performance descriptions	Learners characteristically: demonstrate knowledge of some principles and facts from the A2 specification; show understanding of some principles and facts from the A2 specification; select some relevant information from the A2 specification; present information using basic terminology from the A2 specification.	Learners characteristically: apply given principles or concepts in familiar and new contexts involving a few steps in the argument; describe, and provide a limited explanation of, trends or patterns shown by complex data presented in tabular or graphical form; provide basic explanations and interpretations of some phenomena, presenting very limited arguments and evaluations; carry out routine calculations, where guidance is given;	Learners characteristically: devise and plan some aspects of experimental and investigative activities; demonstrate safe practical techniques; make observations and measurements and record them; interpret, explain and communicate some aspects of the results of their own and others' experimental and investigative activities, in appropriate contexts.

		select some facts, principles and concepts from both AS and A2 specifications; put together some facts, principles and concepts from different areas of the specification.	

Appendix 4: Psychology – knowledge and understanding

49. This appendix must be read in conjunction with sections 2- 8 of the Science criteria. The AS knowledge and understanding set out in this appendix should comprise approximately 60 per cent of the AS specification. The AS and A2 knowledge and understanding combined should comprise approximately 60 per cent of an A level specification. The A2 content is shown in **bold**.

50. There are no prior knowledge requirements for AS level specifications in Psychology.

51. AS and A level specifications must require learners to have a basic understanding of the scope of different areas in psychology and the breadth of different approaches in psychology.

52. AS level specifications must require learners to develop knowledge and understanding from all of the following areas of psychology:

    - cognitive;
    - social;
    - developmental;
    - individual differences;
    - biological.

53. AS level specifications must also require learners to develop knowledge and understanding of research methods in psychology including:

    - methods and techniques for collection of quantitative and qualitative data including experimentation, observation, self-report and correlation;
    - experimental design including independent measures and repeated measures;
    - descriptive statistics including measures of central tendency dispersion and graphical presentation of results.

54. In 52 and 53 above, there is a minimum requirement to relate to the following:

    - specialist vocabulary and terminology;

- psychological theories, concepts and studies;
- ethical issues in psychology;
- the collection and analysis of both quantitative and qualitative data in psychology, including the use of descriptive statistics;
- the strengths and weaknesses of methods of research and investigation in psychology;
- the contribution of psychology to an understanding of individual, social and cultural diversity.

55. **In addition to the AS level requirements, A level specifications must require learners to further develop knowledge and understanding from at least two of the core areas (from cognitive, social, developmental, individual differences and biological psychology).**

    Learners must have an understanding of the major approaches in psychology including cognitive, biological, behavioural and psychodynamic. Knowledge and understanding must be related to:

    - **the applications and implications of psychology to cultural, social and contemporary issues;**
    - **the interrelationship between different areas of psychology;**
    - **the scientific nature of psychology;**
    - **the selection and application of knowledge and understanding of theories, concepts and approaches to the solution of problems;**
    - **the design and reporting of investigations and drawing valid conclusions from them;**
    - **the collection and analysis of both quantitative and qualitative data including the use of inferential statistics;**
    - **the selection and application of knowledge and understanding of principles and perspectives;**
    - **an appreciation of issues and/or debates in psychology.**

56. Examples of synoptic assessment tasks might include the following.

- a piece of written work, assessed through external examination, in which the learners draw on a range of theoretical approaches to consider a contemporary debate in psychology, for example the issues of free will and determinism, or the controversies surrounding behavioural genetics;
- a piece of written work, assessed through external examination, in which the learners use their knowledge and understanding of a range of psychological applications and concepts to suggest how a novel problem might be explained or dealt with, for example considering what psychology can contribute to our understanding of car accidents;
- a piece of written work, assessed through external examination, in which the learners consider a piece of psychological research and critique it by considering a range of other theoretical or methodological approaches to the same research issue. The critique might consider the connections and contrasts between a number of different approaches in psychology.

AS performance descriptions for Psychology

	Assessment objective 1	Assessment objective 2	Assessment objective 3
Assessment objectives	Knowledge and understanding of science and of how science works: ■ Recognise, recall and show understanding of scientific knowledge. ■ Select, organise and communicate relevant information in a variety of forms.	Application of knowledge and understanding of science and of how science works: ■ Analyse and evaluate scientific knowledge and processes. ■ Apply scientific knowledge and processes to unfamiliar situations including those related to issues. ■ Assess the validity, reliability and credibility of scientific information.	How science works: ■ Demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods. ■ Make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy. ■ Analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

A/B boundary performance descriptions	Learners characteristically: demonstrate relevant, accurate and detailed knowledge of a range of psychological concepts, theories, studies, research methods, applications, principles and perspectives from the AS specification; show understanding of most principles and concepts from the AS specification; select relevant information from the AS specification; organise and present information clearly, using psychological terminology in appropriate contexts.	Learners characteristically: apply principles and concepts in familiar and new contexts involving only a few steps in the argument; engage with the issue, using relevant analysis and evaluation of psychological theories, concepts, studies and research methods; describe significant trends and patterns shown by data presented in tabular or graphical form and interpret phenomena with few errors and present arguments and evaluations clearly; comment critically on statements, conclusions or data; successfully translate data presented as prose, diagrams, drawings, tables or graphs from one form to another.	Learners characteristically: show sound knowledge and understanding of the principles of research design; comment effectively on strengths, limitations and ethical issues in research design; interpret and draw appropriate conclusions from data.

E/U boundary performance descriptions	Learners characteristically: demonstrate basic knowledge of theories, concepts, studies and research methods from the AS specification; show basic understanding of some relevant information; present information, using basic psychological terminology from the AS specification terminology.	Learners characteristically: apply a given principle to material presented in familiar or closely related contexts involving only a few steps in the argument; make some attempt to focus on the issue, showing a rudimentary analysis and evaluation of psychological theories, concepts, studies and research methods; describe some trends or patterns shown by data presented in tabular or graphical form; when directed, identify inconsistencies in conclusions or data; successfully translate data from one form to another in some contexts.	Learners characteristically: show basic knowledge and understanding of the principles of research design; comment on strengths, limitations and ethical issues in research design; interpret or draw conclusions from data.

A2 performance descriptions for Psychology

	Assessment objective 1	Assessment objective 2	Assessment objective 3
Assessment objectives	Knowledge and understanding of science and of how science works: ■ Recognise, recall and show understanding of scientific knowledge. ■ Select, organise and communicate relevant information in a variety of forms.	Application of knowledge and understanding of science and of how science works: ■ Analyse and evaluate scientific knowledge and processes. ■ Apply scientific knowledge and processes to unfamiliar situations including those related to issues. ■ Assess the validity, reliability and credibility of scientific information.	How science works: ■ Demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods. ■ Make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy. ■ Analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

A/B boundary performance descriptions	Learners characteristically: demonstrate relevant, accurate and detailed knowledge of a range of psychological concepts, theories, studies, research methods, applications, principles and perspectives from the A2 specification; show understanding of most principles and concepts from the A2 specification; select relevant information from the A2 specification; organise and present information clearly, using psychological terminology in appropriate contexts.	Learners characteristically: apply principles and concepts in familiar and new contexts involving several steps in the argument; directly address the issue, showing effective analysis and evaluation when considering psychological concepts, theories, studies, research methods, applications, principles and perspectives; describe significant trends and patterns shown by complex data presented in tabular or graphical form, interpret phenomena with few errors and present arguments and evaluations clearly; critically evaluate statements, conclusions or data; successfully translate data presented	Learners characteristically: show sound knowledge and understanding of the principles of research and design; give clearly reasoned justification for design decisions; comment effectively on strengths, limitations and ethical issues in research design; comment effectively on the issues of the reliability and validity of data; interpret and draw appropriate conclusions from data.

		as prose, diagrams, drawings, tables or graphs from one form to another; select a wide range of facts, principles and concepts from both AS and A2 specifications; link together appropriate facts principles and concepts from different areas of the specification.	
E/U boundary performance descriptions	Learners characteristically: demonstrate basic knowledge of appropriate psychological concepts, theories, studies, research methods, applications, principles and perspectives from the A2 specification; show understanding of some principles from the A2 specification; select some relevant information from the A2 specification;	Learners characteristically: apply given principles or concepts in familiar and new contexts involving a few steps in the argument; partially address the issue, showing basic analysis and evaluation of psychological concepts, theories, studies, research methods, applications, principles and perspectives; describe, and provide a limited	Learners characteristically: show basic knowledge and understanding of the principles of research design; justify some design decisions; comment on strengths, limitations and ethical issues in research design; comment on the reliability or validity of data;

	present information using some psychological terminology from the A2 specification.	explanation of, trends or patterns shown by complex data presented in tabular or graphical form; when directed, identify inconsistencies in conclusions or data; successfully translate data from one form to another in some contexts; select some facts, principles and concepts from both AS and A2 specifications; put together some facts, principles and concepts from different areas of the specification.	interpret or draw conclusions from data.

Appendix 5: Geology – knowledge and understanding

57. This appendix must be read in conjunction with sections 2 - 8 of the Science criteria. The AS knowledge and understanding set out in this appendix should comprise approximately 60 per cent of the AS specification. The AS and A2 knowledge and understanding combined should comprise approximately 60 per cent of an A level specification. The A2 content is shown in **bold**.

58. All specifications must require learners to develop:

- a broad understanding of geological processes operating at a range of scales in space and time;
- geological investigation skills and knowledge, and an understanding of how these are applied in practical and/or field geology;
- a scientific understanding of the Earth, its evolution and its sustainable development.

59. Global tectonics

- Evidence for the structure and composition of the Earth.
- Earthquakes.
- Geomagnetism.
- Continental drift, seafloor spreading.
- Plate tectonics.

60. Surface processes and sedimentary rocks

- Weathering, erosion and transport.
- Depositional processes.
- Lithification.

61. Internal processes, igneous and metamorphic rocks

- Magma generation.
- Igneous processes (intrusive/extrusive).
- Metamorphism.

- Rock deformation, folds and faults.

62. Geological time

- Principles of dating.

63. **Geological data**

- **Collection and interpretation of geological data including maps and photos, logs and other data.**

64. **Life on Earth**

- **The nature, distribution, analysis and interpretation of fossils.**

65. **Earth materials and resources**

- **Sustainability and environmental issues related to resources, including water and energy.**

66. **Climate change**

- **Evidence and impacts over varying timescales, past climates and their interpretation in the rock record.**

AS performance descriptions for Geology

	Assessment objective 1	Assessment objective 2	Assessment objective 3
Assessment objectives	Knowledge and understanding of science and of how science works: ■ Recognise, recall and show understanding of scientific knowledge. ■ Select, organise and communicate relevant information in a variety of forms.	Application of knowledge and understanding of science and of how science works: ■ Analyse and evaluate scientific knowledge and processes. ■ Apply scientific knowledge and processes to unfamiliar situations including those related to issues. ■ Assess the validity, reliability and credibility of scientific information.	How science works: ■ Demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods. ■ Make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy. ■ Analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

A/B boundary performance descriptions	Learners characteristically: demonstrate knowledge of most principles, concepts and facts from the AS specification; show understanding of most principles, concepts and facts from the AS specification; select relevant information from the AS specification; organise and present information clearly in appropriate forms using scientific terminology.	Learners characteristically: apply principles and concepts in familiar and new contexts involving only a few steps in the argument; describe significant trends and patterns shown by data presented in tabular or graphical form and interpret phenomena with few errors and present arguments and evaluations clearly; explain and interpret phenomena with few errors and present arguments and evaluations clearly; carry out structured calculations with few errors.	Learners characteristically: devise and plan experimental and investigative activities, selecting appropriate techniques; demonstrate safe and skilful practical techniques; make observations and measurements with appropriate precision and record these methodically; interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.

E/U boundary performance descriptions	Learners characteristically: demonstrate knowledge of some principles and facts from the AS specification; show understanding of some principles and facts from the AS specification; select some relevant information from the AS specification; present information using basic terminology from the AS specification.	Learners characteristically: apply a given principle to material presented in familiar or closely related contexts involving only a few steps in the argument; describe some trends or patterns shown by data presented in tabular or graphical form; provide basic explanations and interpretations of some phenomena, presenting very limited evaluations; carry out some steps within calculations.	Learners characteristically: devise and plan some aspects of experimental and investigative activities; demonstrate safe practical techniques; make observations and measurements, and record them; interpret, explain and communicate some aspects of the results of their own and others' experimental and investigative activities, in appropriate contexts.

A2 performance descriptions for Geology

	Assessment objective 1	Assessment objective 2	Assessment objective 3
Assessment objectives	Knowledge and understanding of science and of how science works: ■ Recognise, recall and show understanding of scientific knowledge. ■ Select, organise and communicate relevant information in a variety of forms.	Application of knowledge and understanding of science and of how science works: ■ Analyse and evaluate scientific knowledge and processes. ■ Apply scientific knowledge and processes to unfamiliar situations including those related to issues. ■ Assess the validity, reliability and credibility of scientific information.	How science works: ■ Demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods. ■ Make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy. ■ Analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

A/B boundary performance descriptions	Learners characteristically: demonstrate detailed knowledge of most principles, concepts and facts from the A2 specification; show understanding of most principles, concepts and facts from the A2 specification; select relevant information from the A2 specification; organise and present information clearly in appropriate forms using scientific terminology.	Learners characteristically: apply principles and concepts in familiar and new contexts involving several steps in the argument; describe significant trends and patterns shown by complex data presented in tabular or graphical form, interpret phenomena with few errors, and present arguments and evaluations clearly and logically; explain and interpret phenomena effectively, presenting arguments and evaluations; carry out extended calculations, with little or no guidance; select a wide range of facts, principles and concepts from both AS and A2 specifications;	Learners characteristically: devise and plan experimental and investigative activities, selecting appropriate techniques; demonstrate safe and skilful practical techniques; make observations and measurements with appropriate precision and record these methodically; interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.

		link together appropriate facts principles and concepts from different areas of the specification.	
E/U boundary performance descriptions	Learners characteristically: demonstrate knowledge of some principles and facts from the A2 specification; show understanding of some principles and facts from the A2 specification; select some relevant information from the A2 specification; present information using basic terminology from the A2 specification.	Learners characteristically: apply given principles or concepts in familiar and new contexts involving a few steps in the argument; describe, and provide a limited explanation of, trends or patterns shown by complex data presented in tabular or graphical form; provide basic explanations and interpretations of some phenomena, presenting very limited arguments and evaluations; carry out routine calculations, where guidance is given; select some facts, principles and concepts from both AS and A2	Learners characteristically: devise and plan some aspects of experimental and investigative activities; demonstrate safe practical techniques; make observations and measurements and record them; interpret, explain and communicate some aspects of the results of their own and others' experimental and investigative activities, in appropriate contexts.

		specifications; put together some facts, principles and concepts from different areas of the specification.	

Appendix 6: Electronics – knowledge and understanding

67. This appendix must be read in conjunction with sections 2 - 8 of the Science criteria. The AS knowledge and understanding set out in this appendix should comprise approximately 60 per cent of the AS specification. The AS and A2 knowledge and understanding combined should comprise approximately 60 per cent of an A level specification. The A2 content is shown in **bold**.

68. System synthesis

- Recognise that simple systems consist of an input, a process, an output and possibly feedback analyse and design system diagrams.
- Represent complex systems in terms of sub-systems.

69. Logic systems

- Identify and use NOT, AND, NAND, OR, NOR and EOR gates.
- Construct and recognise truth tables for these gates and simple combinations of them use combinations of one type of gate to perform other logic functions.
- Generate the Boolean expression for a system from a truth table.
- Simplify a logic system.

70. Voltage (*V*), current (*I*)

- Define resistance as *V*/*I* and resistance (*R*).
- Calculate the combined resistance of resistors connected in series and/or parallel.

71. Power

- Define power as *VI*.
- Apply the formula to calculate power dissipation in a circuit.

72. Resistive input transducers

- Describe the use of LDRs, negative temperature coefficient thermistors and switches in a voltage divider circuit to provide analogue signals.

- Interpret and use the characteristic curves of the above devices.

73. Transistors

- Describe their use as switches.

74. Diodes

- Describe the use of light-emitting diodes, silicon diodes and zener diodes and carry out relevant calculations.

75. Output devices

- Describe the use of a buzzer, a loudspeaker, a motor and a seven-segment display in a system.

76. Op-amps

- Recall the characteristics of an ideal op-amp and be aware that these may be different for a typical op-amp; understand and explain the use of an op-amp in a comparator circuit.
- Recall how the output state depends on the relative value of the two input states draw and recognise an inverting amplifier circuit.
- Use the formula:

$$\frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$$

- Draw and recognise a non-inverting amplifier circuit.
- Use the formula:

$$\frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_1}$$

77. Timing circuits

- Explain how capacitors can be used to form the basis of timing circuits.
- Calculate the value of the time constant for RC circuits.
- Recall that a monostable circuit has one stable state and one unstable state.

- Recall that a monostable circuit can be used to form a simple time-delay circuit.
- Recall that an astable circuit has two unstable states recall that an astable circuit can be used to form a simple pulse-generator circuit.

78. Sequential logic sub-systems

- Construct and use timing diagrams to explain the operation of sequential logic circuits recall and describe the operation of a binary ripple up-counter.
- Design binary ripple up-counters that reset after *N* counts.

79. **Microprocessor control systems**

- **Recall and describe a microprocessor control system as a programmable assembly of memory, input ports, output ports and interrupt inputs.**
- **Recall and explain the use of interrupts to allow an external device to be serviced on request.**
- **Recall and describe the application of a microprocessor control system.**

80. **Interfacing systems**

- **Explain the need for signal conversion between analogue and digital form in areas such as communication systems and microprocessor systems.**
- **Describe and explain how a DAC can be used to convert a digital signal into an analogue signal.**
- **Describe and explain how an ADC can be used to convert an analogue signal into a digital signal.**

81. **Communication systems**

- **Recall that communication is the transfer of meaningful information from one location to another recall and describe the transfer of data by various carriers and media.**
- **Recall and explain the relationship between bandwidth, data rate and capacity to carry information.**

- **Explain the need to multiplex a number of signals onto one transmission medium; describe the principles of frequency OR time division multiplexing.**
- **Recall and describe the difference between noise and distortion.**
- **Recall and describe how a Schmitt trigger can be used to regenerate a digital signal.**

82. **Radio transmission**

- **Recall and explain the use of the radio spectrum for the transmission of different types of data.**
- **Describe and explain the use of one common method of modulation.**

83. **Radio reception**

- **Describe and explain the function of the sub-systems within a simple radio receiver consisting of an aerial, tuned circuit, detector and earphone.**
- **Calculate the resonant frequency of a tuned circuit.**
- **Describe and explain how the sensitivity and selectivity of a simple radio receiver can be improved.**
- **Describe and explain the function of the sub-systems in a superhet radio receiver consisting of an aerial, rf amplifier, mixer, local oscillator, if filter, if amplifier, demodulator/detector, af amplifier and loudspeaker.**

AS performance descriptions for Electronics

	Assessment objective 1	Assessment objective 2	Assessment objective 3
Assessment objectives	Knowledge and understanding of science and of how science works: ■ Recognise, recall and show understanding of scientific knowledge. ■ Select, organise and communicate relevant information in a variety of forms.	Application of knowledge and understanding of science and of how science works: ■ Analyse and evaluate scientific knowledge and processes. ■ Apply scientific knowledge and processes to unfamiliar situations including those related to issues. ■ Assess the validity, reliability and credibility of scientific information.	How science works: ■ Demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods. ■ Make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy. ■ Analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

A/B boundary performance descriptions	Learners characteristically: demonstrate knowledge and understanding of most principles, concepts and facts from the AS specification; select relevant information from the AS specification; organise and present information clearly in appropriate forms using scientific terminology.	Learners characteristically: apply principles and concepts in familiar and new contexts involving only a few steps in the argument; describe significant trends and patterns shown by data presented in tabular or graphical form; interpret and explain phenomena with few errors and present arguments and evaluations clearly; carry out structured calculations with few errors; design a system to perform a stated function for most situations within the context of the AS specification.	Learners characteristically: devise and plan experimental and investigative activities, selecting appropriate techniques; demonstrate safe and skilful practical techniques; make observations and measurements with appropriate precision and record these methodically; interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.

E/U boundary performance descriptions	Learners characteristically: demonstrate knowledge and understanding of some principles and facts from the AS specification; select some relevant information from the AS specification; present information using basic terminology from the AS specification.	Learners characteristically: apply a given principle to material presented in familiar or closely related contexts involving only a few steps in the argument; describe some trends or patterns shown by data presented in tabular or graphical form; provide basic explanations and interpretations of some phenomena, presenting very limited evaluations; carry out some steps within calculations; design a simple system to perform a stated function for some situations within the context of the AS specification.	Learners characteristically: devise and plan some aspects of experimental and investigative activities; demonstrate safe practical techniques; make observations and measurements and record them; interpret, explain and communicate some of the results of their own and others' experimental and investigative activities, in appropriate contexts.

A2 performance descriptions for Electronics

	Assessment objective 1	Assessment objective 2	Assessment objective 3
Assessment objectives	Knowledge and understanding of science and of how science works: ■ Recognise, recall and show understanding of scientific knowledge. ■ Select, organise and communicate relevant information in a variety of forms.	Application of knowledge and understanding of science and of how science works: ■ Analyse and evaluate scientific knowledge and processes. ■ Apply scientific knowledge and processes to unfamiliar situations including those related to issues. ■ Assess the validity, reliability and credibility of scientific information.	How science works: ■ Demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods. ■ Make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy. ■ Analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

A/B boundary performance descriptions	Learners characteristically: demonstrate detailed knowledge and understanding of most principles, concepts and facts from the A2 specification; select relevant information from the A2 specification; organise and present information clearly in appropriate forms using scientific terminology.	Learners characteristically: apply principles and concepts in familiar and new contexts involving several steps in the argument; describe significant trends and patterns shown by complex data presented in tabular or graphical form; interpret and explain phenomena effectively, presenting arguments and evaluations clearly and logically; carry out extended calculations, with little or no guidance; design a system to perform a stated function for most situations in the context of the A2 specification; select a wide range of facts, principles and concepts from both AS and A2 specifications;	Learners characteristically: devise and plan experimental and investigative activities, selecting appropriate techniques; demonstrate safe and skilful practical techniques; make observations and measurements with appropriate precision and record these methodically; interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.

		link together appropriate facts, principles and concepts from different areas of the specification.	
E/U boundary performance descriptions	Learners characteristically: demonstrate knowledge and understanding of some principles and facts from the A2 specification; select some relevant information from the A2 specification; present information using basic terminology from the A2 specification.	Learners characteristically: apply given principles or concepts in familiar and new contexts involving a few steps in the argument; describe, and provide a limited explanation of, trends or patterns shown by complex data presented in tabular or graphical form; provide basic explanations and interpretations of some phenomena, presenting very limited arguments and evaluations; carry out routine calculations, with guidance; design a simple system to perform a	Learners characteristically: devise and plan some aspects of experimental and investigative activities; demonstrate safe practical techniques; make observations and measurements and record them; interpret, explain and communicate some of the results of their own and others' experimental and investigative activities, in appropriate contexts.

		stated function for some situations within the context of the A2 specification; select some facts, principles and concepts from both AS and A2 specifications; put together some facts, principles and concepts from different areas of the specification.	

Appendix 7: Environmental Science – knowledge and understanding

84. This appendix must be read in conjunction with sections 2- 8 of the Science criteria. The AS knowledge and understanding set out in this appendix should comprise approximately 60 per cent of the AS specification. The AS and A2 knowledge and understanding combined should comprise approximately 60 per cent of an A level specification. The A2 content is shown in **bold**.

85. AS and A level specifications must require learners to develop knowledge and understanding of Earth's life-support systems and the principle of sustainability, the Earth's physical resources and their use, and to explore a range of environmental issues, making use of the scientific evidence available.

86. AS and A level specifications must require learners to have an understanding of the breadth of different aspects of environmental science and to draw on the aspects of the wide range of sciences, including biology, chemistry, geology and physics. Learners must have an understanding of how humans affect and interact with the environment.

87. Learners must investigate the evidence for human impact on the environment (both positive and negative), environmental problems, solutions and their validity to enable informed discussion and decision making.

Areas of study

- Biodiversity.
- Conservation.
- Energy, and renewable and non-renewable resources.
- Cycles and systems.
- **Human population and resource exploitation balance.**
- **Pollution and wastes.**
- **Analysis of environmental risks associated with human activity.**

88. The approaches to the study of these areas must apply to both AS and A2 studies and include:

- an exploration of the underlying science;
- an interdisciplinary focus;
- a study of the environmental impact of human activities;
- the use of relevant and contemporary examples to illustrate issues;
- a consideration of these areas on a range of different magnitudes and timescales.

Appendix 8: Mathematical content for science subjects

89. In order to be able to develop their skills, knowledge and understanding in science, learners need to have been taught, and to have acquired competence in, the appropriate areas of mathematics relevant to the subject as indicated in the table of coverage below.

90. Arithmetic and numerical computation

    90.1 Recognise and use expressions in decimal and standard form.

    90.2 Use ratios, fractions and percentages.

    90.3 Make estimates of the results of calculations (without using a calculator).

    90.4 Use calculators to find and use power, exponential and logarithmic functions.

    90.5 Use calculators to handle sin *x,* cos *x,* tan *x* when *x* is expressed in degrees or radians.

    90.6 Use hexadecimal and binary systems.

91. Handling data

    91.1 Use an appropriate number of significant figures.

    91.2 Find arithmetic means.

    91.3 Construct and interpret frequency tables and diagrams, bar charts and histograms.

    91.4 Understand simple probability.

    91.5 Understand the principles of sampling as applied to scientific data.

    91.6 Understand the terms mean, median and mode.

    91.7 Use a scatter diagram to identify a correlation between two variables.

    91.8 Use a simple statistical test.

    91.9 Make order of magnitude calculations.

92. Algebra

92.1 Understand and use the symbols: =, <, <<, >>, >, $\propto$, ~.

92.2 Change the subject of an equation.

92.3 Substitute numerical values into algebraic equations using appropriate units for physical quantities.

92.4 Solve simple algebraic equations.

92.5 Use logarithms in relation to quantities that range over several orders of magnitude.

93. Graphs

93.1 Translate information between graphical, numerical and algebraic forms.

93.2 Plot two variables from experimental or other data.

93.3 Understand that $y = mx + c$ represents a linear relationship.

93.4 Determine the slope and intercept of a linear graph.

93.5 Calculate rate of change from a graph showing a linear relationship.

93.6 Draw and use the slope of a tangent to a curve as a measure of rate of change.

93.7 Understand the possible physical significance of the area between a curve and the x axis and be able to calculate it or measure it by counting squares as appropriate.

93.8 Use logarithmic plots to test exponential and power law variations.

93.9 Sketch simple functions including $y = k/x$, $y = kx^2$, $y = k/x^2$, $y = \sin x$, $y = \cos x$, $y = e^{-x}$.

94. Geometry and trigonometry

94.1 Appreciate angles and shapes in regular 2D and 3D structures.

94.2 Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects.

94.3 Understand the symmetry of 2D and 3D shapes.

94.4 Calculate areas of triangles, circumferences and areas of circles, surface areas and volumes of rectangular blocks, cylinders and spheres.

94.5 Use Pythagoras' theorem, and the angle sum of a triangle.

94.6 Use sin, cos and tan in physical problems.

94.7 Understand the relationship between degrees and radians and translate from one to the other.

Table of coverage

	Appendix 1 Biology	Appendix 2 Chemistry	Appendix 3 Physics	Appendix 4 Psychology	Appendix 5 Geology	Appendix 6 Electronics	Appendix 7 Environmental Science
90.1	✓	✓	✓	✓	✓	✓	✓
90.2	✓	✓	✓	✓	✓	✓	✓
90.3	✓	✓		✓	✓		✓
90.4	✓	✓	✓			✓	✓
90.5			✓			✓	
90.6						✓	
91.1	✓	✓	✓	✓	✓		✓
91.2	✓	✓	✓	✓	✓		✓
91.3	✓			✓	✓		✓
91.4	✓			✓	✓		✓
91.5	✓			✓	✓		✓
91.6	✓			✓	✓		✓
91.7	✓			✓	✓		✓
91.8	✓			✓	✓		✓
91.9			✓	✓	✓		✓
92.1		✓	✓	✓	✓	✓	✓
92.2	✓	✓	✓			✓	
92.3	✓	✓	✓	✓	✓	✓	✓
92.4		✓	✓			✓	
92.5		✓					
93.1	✓	✓	✓	✓	✓	✓	✓
93.2	✓	✓	✓	✓	✓	✓	✓
93.3		✓	✓		✓		✓
93.4		✓	✓		✓	✓	
93.5	✓	✓			✓		
93.6		✓	✓			✓	
93.7			✓				
93.8			✓				
93.9			✓				
94.1		✓					
94.2		✓			✓		✓
94.3		✓					
94.4			✓		✓		✓
94.5			✓				
94.6			✓				
94.7			✓				

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