IOP Institute of Physics
Education *Supporting Teachers*

Advanced physics
Choosing a new GCE specification
March 2008 Supplement

How science works in A-level physics

All of the new GCE physics specifications reprint in an appendix or in some other way the QCA subject criteria relating to "how science works". Curiously, these were not included in the 2005/2006 QCA consultation, which attracted a huge response from science teachers. Instead they were quietly added in afterwards and, unhelpfully, awarding bodies were given little guidance about their implementation. This has resulted in important differences between AS/A2 physics specifications.

Crudely, "how science works" has the following aspects:

- the nature and limitations of scientific knowledge (hypothesis and prediction, links between data and explanation, modelling, and the role of the scientific community in validating new knowledge);
- scientific enquiry skills (experimental skills, data handling and assessing the quality of data);
- communication (using scientific language, mathematical skills and presenting data);
- applications and implications of science (technological decision making in the context of benefit versus risk and ethics).

Of these, the second and third aspects have conventionally been considered essential to any A-level physics course. Depending on the specification, the first and last aspects are more likely to be innovative.

When deciding which specification to adopt, I suggest that you refer to the above list and consider the following key points:

The specification
What "how science works" content statements appear in each assessment unit? In the AQA Physics A specification, for example, these are shown separately in Section 3.7. How clearly are the learning outcomes specified? Will you know what you will have to teach?

GCE specifications put physics teachers in a spin.

The sample assessment material
Are example "how science works" questions included? What mark weighting do they have? Particular questions in sample examinations can help you to interpret specification requirements. If there are no relevant questions, either the awarding body is paying lip service to an aspect of "how science works" or your students may be caught out on a real examination paper.

Useful resources
Two websites, supported by the Institute, can help you to teach "how science works":

- www.practicalphysics.org has briefings on scientific enquiry, with links to many experiments that can be used to develop experimental and data-handling skills. It provides historical case-studies illustrating the nature of science and it is linked to experiments that students can do.
- www.peep.ac.uk (the Physics and Ethics Education Project) is a relatively new website. This shows how tools for ethical analysis can be used to think about controversial issues in science and society. There is a range of case-studies, made interactive by including student activities.

Peter Campbell, *Nuffield Curriculum Centre*

Introduction

Schools and colleges in England, Wales and Northern Ireland will have to start teaching a new A-level specification from September 2008. If you are still undecided as to whether to stick with what you know or to change, we hope that this supplement might help you with your deliberations. The specifications table contains a summary of the seven new courses from five examination boards, outlining the key features of each (pp2–4). There is a brief description of the topics covered in each unit and information about the internal assessments for units three and six.

In addition, Peter Campbell of the Nuffield Curriculum Centre gives some useful advice about "how science works" in the new specifications and what you might want to look out for (p1). Teachers in institutions where they have already made a decision share the reasons for their choice, commenting frankly on their particular circumstances and the constraints that they are working under.

There is also a little more detail about the AQA Physics B (physics in context) course. Some of the examination boards, in conjunction with publishers, are producing resources in a similar format to those produced for the new GCSEs. While some of these are still in development, those for *Advancing Physics* and *Salters Horners Advanced Physics* are in the process of being fully revised, in the light of experience, for the new specifications.

For more details about the individual specifications, and the support and resources on offer, visit the websites of the individual examination boards:

- www.aqa.org.uk
- www.ccea.org.uk
- www.edexcel.org.uk and www.york.ac.uk/org/seg/salters/physics
- www.ocr.org.uk and www.advancingphysics.iop.org
- www.wjec.co.uk

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ADVANCED-LEVEL PHYSICS SPECIFICATIONS

Specification title	Key features	Unit titles	Key topics	Assessment type	Notes and comments
AQA A	The two AS theory units provide alternative starting points for the AS course. Unit 1 starts with particle physics and provides a new interest. Unit 2 gives progression from GCSE and develops topics already familiar to students. There is an optional element in Unit 5. Books and support material available from Nelson Thorne. A choice of two Individual skills assessments is given each year at each level.	PHYA1 Particles, Quantum Phenomena and Electricity.	Particles and radiation; electromagnetic radiation and quantum phenomena; current electricity.	Ext; 75 min; 20%.	6 or 7 structured questions.
		PHYA2 Mechanics, Materials and Waves.	Standard mechanics; simple bulk materials properties and Young's modulus only; longitudinal/transverse; refraction; interference and diffraction.	Ext; 75 min; 20%.	6 or 7 structured questions.
		PHYA3 Investigative and Practical Skills in AS Physics.	PHA3T, centre-marked route T; practical skills assignment (PSA); investigative skills assignment (ISA) or PHA3X, externally marked route X; practical skills verification (PSV – teacher verification); externally marked practical assignment (EMPA).	Int; 10%.	PSA (9 marks); ISA (41 marks) – the same pattern as AQA GCSE Science; EMPA (55 raw marks).
		PHYA4 Fields and Further Mechanics.	Further mechanics (momentum, circular motion, SHM, forced vibrations and resonance); gravitation; electric fields; capacitance; magnetic field.	Ext; 105 min; 20%.	25 multiple choice questions, plus 4/5 structured questions.
		PHA5A; PHA5B; PHA5C; PHA5D.	Section A – nuclear and thermal physics (radioactivity, nuclear energy, thermal physics); Section B – options A – Astrophysics; B – Medical Physics; C – Applied Physics; D – Turning Points.	Ext; 105 min; 20%.	Each section 4/5 structured questions.
		PHYA6 Investigative and Practical Skills in A2 Physics.	PHA6T, centre-marked route T or PHA6X, externally marked route X. As for PHYA3.	Int; 10%.	PSA (9 marks); ISA (41 marks); EMPA (55 raw marks).
AQA B Physics in Context	A context- and applications-led approach with a range of complementary support materials produced in conjunction with Nelson Thorne. The internal assessment arrangements are as for AQA A.	PHYB1 Harmony and Structure in the Universe.	Waves; standing waves; musical tones; analogue and digital; sampling; CD/DVD storage; lasers. Interference; diffraction; optic fibres; radio/satellite communication. Particle physics; wave or particle; Big Bang; Standard Model; stellar evolution.	Ext; 75 min; 20%.	5–8 very short questions plus 3–5 longer questions.
		PHYB2 Physics Keeps Us Going.	Dynamics; momentum; work and power. Energy sources and conversion; current electricity; renewables.	Ext; 75 min; 20%.	5–8 very short questions plus 3–5 longer questions.
		PHYB3 Investigative and Practical Skills in AS Physics.	PHB3T, centre-marked route T; practical skills assignment (PSA); investigative skills assignment (ISA) or PH3X, externally marked route X; practical skills verification (PSV – teacher verification); externally marked practical assignment (EMPA).	Int; 10%.	PSA (9 marks); ISA (41 marks) – the same pattern as AQA GCSE Science; EMPA (55 raw marks).
		PHYB4 Physics Inside and Out.	Gravitation fields; conservation of momentum; ideal gas equation. SHM; circular motion; resonance. Magnetic fields; seismic surveys; medical physics.	Ext; 105 min; 20%.	5–8 long questions.
		PHYB5 Energy under the Microscope.	Molecular theory; Boltzmann constant; absolute zero. Specific heat; thermodynamics. Electric fields; particle accelerators; relativity. The nucleus; decay; capacitance and charge; fission. Fusion.	Ext; 105m; 20%.	5–8 long questions.
		PHYB6 Investigative and Practical Skills in A2 Physics.	PHB6T, centre-marked route T or PHB6X, externally marked route X. As for PHYB3.	Int; 10%.	PSA (9 marks); ISA (41 marks); EMPA (55 raw marks).
CCEA	Traditional-style specification. Internal assessments are similar to traditional practical exams, but marked internally.	AS 1: Forces, Energy and Electricity.	Dynamics; moments; work and power; Young's modulus; current electricity.	Ext; 90 min; 18.5%.	Short-answer questions.
		AS 2: Waves, Photons and Medical Physics.	Waves; lenses; interference and diffraction; sound; CT and MRI scans; photons; de Broglie.	Ext; 90 min; 18.5%.	Short-answer questions.
		AS 3: Practical Techniques.	A test of practical skills, consisting of four short experimental tests (20 marks) and one question requiring the analysis of experimental results (20 marks).	Int; 90 min; 13%.	Tests will be set and moderated by CCEA, but marked and standardised internally.
		A2 1: Momentum, Thermal Physics, Circular Motion, Oscillations, and Atomic and Nuclear Physics.	Momentum; thermal physics; circular motion; SHM; the nucleus; decay; fission and fusion.	Ext; 90 min; 18.5%.	Short-answer questions plus data-analysis question.
		A2 2: Fields and their Applications.	Gravitational and electric fields; capacitors and discharge; magnetic fields; deflection of particles; accelerators; Standard Model.	Ext; 90 min; 18.5%.	Short-answer questions plus one synoptic long-answer question.
		A2 3: Practical Techniques.	A test of practical skills, consisting of two experimental tests (40 marks) and one question on planning and design (20 marks).	Int; 90 min; 13%.	Synoptic assessment will be assessed through the planning and design question.
EDEXCEL	This specification is provided in two formats: concept-based in a traditional style and context-based following the Salters Horners approach. The materials for this have been fully revised. The content and assessments for both approaches are identical. Edexcel and Pearson are publishing materials for both routes.	Unit 1 Physics on the Go.	Rectilinear motion; forces; energy and power; fluid flow and viscosity; properties of materials and Young's modulus.	Ext; 80 min; 20%.	Objective, short and long questions.
		Unit 2 Physics at Work.	Waves; refraction; polarisation; diffraction; standing waves; Doppler effect; current electricity; photons; wave particle duality.	Ext; 80 min; 20%.	Objective, short and long questions.
		Unit 3 Exploring Physics.	Either a case-study of an application of physics or a physics-based visit (1200–1400 words), both with a related practical. All candidates may do the same case-study or visit identified by the teacher.	Int; 10%.	This can be marked internally or marked by an examiner appointed by the board.
		Unit 4 Physics on the Move.	Momentum; circular motion; electric and magnetic fields; capacitors and discharge; particle physics; Standard Model; de Broglie.	Ext; 95 min; 20%.	Objective, short and long questions.
		Unit 5 Physics from Creation to Collapse.	Thermal energy; specific heat; ideal gas equation; Boltzmann constant; nuclear decay; oscillations; SHM; astrophysics; gravitational fields; cosmology; fusion.	Ext; 95 min; 20%.	Objective, short and long questions.
		Unit 6 Experimental Physics.	Plan (in advance), carry out an experiment, record measurements, analyse their own results and draw conclusions – no longer than two hours.	Int; 10%.	This can be marked internally or marked by an examiner appointed by the board.
OCR A	Traditional-style specification. Heinemann is producing a set of resources to accompany this course. The internal assessment tasks are set by OCR and, although not time-limited, are expected to be one teaching period long each.	Unit G481: Mechanics.	Scalars and vectors; dynamics; forces; work energy and power; Young's modulus.	Ext; 60 min; 15%.	Approximately 7 structured short-answer questions.
		Unit G482: Electrons, Waves and Photons.	Current electricity; waves; interference; diffraction; stationary waves; photons; wave particle duality.	Ext; 105 min; 25%.	Approximately 7 structured short-answer questions, plus a long-answer question.
		Unit G483: Practical Skills in Physics 1.	Qualitative task (10 marks); quantitative task (20 marks); evaluative task (10 marks).	Int; 10%.	Tasks chosen from a selection provided by OCR. Mark schemes provided by OCR.
		Unit G484: The Newtonian World.	Momentum; circular motion; gravitational fields; satellites; Kepler's laws; SHM; thermal physics; specific heat; ideal gas equation; Boltzmann's constant.	Ext; 60 min; 15%.	Approximately 5 structured short-answer questions.
		Unit G485: Fields, Particles and Frontiers of Physics.	Electric and magnetic fields; capacitors and decay; nuclear physics; Standard Model; radioactive decay; fission and fusion; medical imaging; structure and evolution of the universe.	Ext; 105 min; 25%.	Approximately 10 structured short-answer questions, most with a requirement for extended writing.
		Unit G486: Practical Skills in Physics 2.	Qualitative task (10 marks); quantitative task (20 marks); evaluative task (10 marks).	Int; 10%.	Tasks chosen from a selection provided by OCR. Mark schemes provided by OCR.
OCR B	Advancing Physics. A distinctive structure with a mixture of context- and concept-based approaches. For each year of the course there is a students' book and CD-ROM plus a website (advancingphysics.iop.org) maintained by the Institute of Physics. The materials have been fully revised for the new specification. Internal assessments are coursework style.	Unit G491: Physics in Action.	Communication: imaging; digitising; refraction; lenses; sampling; sound spectra; pixels. Sensing: current electricity. Designer materials: structure of materials; Young's modulus.	Ext; 60 min; 15%.	Short and structured questions.
		Unit G492: Understanding Processes, Experimentation and Data Handling.	Waves and quantum behaviour: standing waves; interference; diffraction; photons; "many paths"; electron diffraction. Space, time and motion: linear dynamics; work; energy and power.	Ext; 105 min; 25%.	Short and structured questions plus questions on an advanced notice article.
		Unit G493: Physics in Practice.	Quality of measurement: a measurement or study of a physical relationship, focusing on improving the quality of measurement and making inferences from data. Physics in use: a presentation on the use, properties and structure of a material.	Int; 10%.	Quality of measurement (20 marks); Physics in use (10 marks).
		Unit G494: Rise and Fall of the Clockwork Universe.	Capacitance and radioactive decay; SHM; resonance; gravitational fields; origins of the universe; Hubble's constant. Molecular theory; Boltzmann factor.	Ext; 75 min; 15%.	Short and structured questions.
		Unit G495: Field and Particle Pictures.	Magnetic fields; magnetic machines; transformers. Electric fields and potential. Atomic structure; alpha scattering; nuclear structure; Standard Model; fission and fusion; radiation measurement.	Ext; 120 min; 25%.	Short and structured questions plus questions on an advanced notice article.
		Unit G496: Researching Physics.	Practical investigation: an extended investigation of a practical problem related to physics or its applications. Research briefing: a short written and verbal report based on a topic of physics of the candidates own choosing.	Int; 10%.	Practical (20 marks); approx two weeks' study time. Research (10 marks); approx one week's study time.
WJEC	Traditional-style specification with small optional element in Unit 5. The internal assessments are similar to traditional practical exercises, but internally marked and WJEC moderated.	PH1 Motion, Energy and Charge.	Units; forces; moments; linear dynamics; work energy and power; static and current electricity.	Ext; 75 min; 20%.	Approximately 7 structured questions.
		PH2 Waves and Particles.	Waves; interference; diffraction; polarisation; refraction; photons; lasers; energy levels. Nuclear atom; Standard Model; black-body radiation; Wien's law and stellar investigation.	Ext; 75 min; 20%.	Approximately 7 structured questions.
		PH3 Practical Physics.	Experimental tasks, three short and one long, performed under controlled conditions, set by WJEC.	Int; 90 min; 10%.	Three tasks x (8 marks), plus one task x (24 marks).
		PH4 Oscillations and Fields.	Momentum; circular motion; SHM; resonance; molecular kinetic theory; ideal gas; Boltzmann constant; internal energy; specific heat. Electric and gravitational fields; potential. Solar system; Kepler's laws; Doppler effect.	Ext; 75 min; 18%.	Approximately 7 questions. Includes synoptic assessment.
		PH5 Electromagnetism, Nuclei and Options.	Capacitance and discharge; magnetic fields; electromagnetic induction; radioactive decay; binding energy; fission and fusion. Options: Further Electromagnetism and Alternating Currents; Revolutions in Physics; Materials; Biological Measurement and Medical Imaging; Energy Matters.	Ext; 105 min; 22%.	Approximately 5 questions (60 marks); case-study advanced notice (20 marks). Option (20 marks).
		PH6 Experimental Physics.	An experimental task plus data-analysis task performed under controlled conditions and set by WJEC.	Int; 120 min; 10%.	Experimental task (25 marks), and a data-analysis task (25 marks).

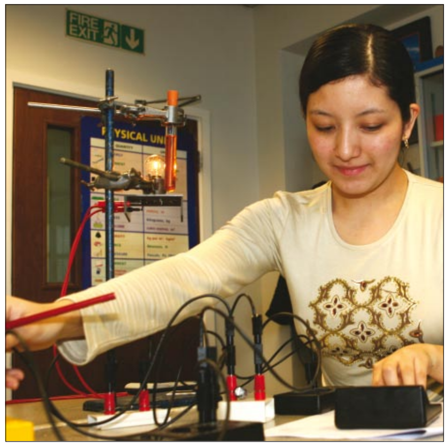
A-level specification choices

Edexcel (SHAP) GCE

A decade ago, our girls' comprehensive was one of the original pilot schools for the *Salters Horners Advanced Physics* (SHAP) course, so it is true to say that SHAP holds a special place in our hearts. Sentimentality aside, we have decided to stick with it and do SHAP Mk II in the next academic year.

Like most departments, I imagine, we have taken the opportunity to take stock of our course and peruse other offerings, but none blew us away with a fervent wish to leave the SHAP fold. With so much other change afoot in the 11–18 curriculum, the "if it ain't broke, don't fix it" mantra is plenty reason for us to stay loyal.

An interesting session at the ASE Annual Conference 2008 held in Liverpool focused on context-led versus more traditional teaching approaches to A-levels, and research evidence about the merits of the different methodologies hasn't made us want to switch.



Staying loyal to the Edexcel (SHAP) specification.

While the shiny new textbooks will probably be slightly thinner due to the reduction in content, the major change for us is likely to be in assessment. An assessed visit, which our students have always enjoyed, can continue to be part of internal procedures, and the demise of longer, open-ended practical investigative work means relief from the administrative headache of juggling limited resources.

An incoming new head of physics may have other plans about the nature of the A-level physics course we should be offering, but the proof will ultimately come down to student option choices and examination success once on board with our course. Our school's small but perfectly formed A-level groups have thrived on a Salters Horners diet, and we expect this to continue with *Advanced Physics* Mk II.

Ian Francis

OCR Physics B

Sherborne School is a boys' boarding school in Dorset, and we have been teaching OCR Physics B (advancing physics) since its introduction in 2000. The staff and pupils have found it a refreshing change from standard GCSE topics, and the context-led approach has proved popular with the large number of boys who continue to read engineering subjects at university. It has not put off a few students from studying physics at university either.

The course has roots in the former Nuffield A-level physics, and the boys enjoy the coursework investigations in particular, which I am pleased to see remain in the new course. We have had to build up a good stock of equipment for investigations, including Pasco data-logging equipment and a set of laptop computers, which now get excellent use around coursework time in both the lower- and upper-sixth forms. We are fortunate to have a separate project lab, where investigations can be set up and left. In the past we have managed without, but it does make life much easier.

Although we find it a valuable exercise, we have had some concerns about plagiarism in the research coursework, and this has made it a more onerous task to assess and moderate properly. I am pleased to see that it still exists in the new course, albeit in a more concise package that should make it more manageable to mark and much less likely to include large passages quoted directly from the internet.

The resources available on the teacher's CD-ROM are wide-reaching and provide lots of opportunities to extend the most able through extra reading or extension questions. Pupils did find the original course textbooks rather difficult to revise from, but an "Exam Café" revision CD-ROM is available for the new course, which I am hoping will be the final piece in the puzzle.

Ben Ryder, *Sherborne School, Dorset*

OCR Physics A

We are a state grammar school for boys with about 35% of our students opting to do A-level physics. We have decided to go with OCR A for the following reasons:

- With more than 70 students a year doing physics, the coursework demands of *Advancing Physics* or the SHAP physics-based visit would be impractical for us.
- Our students, on the whole, like mathematics and enjoy "traditional" conceptual teaching, so this ruled out a context-led course.
- We have been affected in the past by "guess what the examiner is thinking" questions on other specifications, where particular words or definitions are needed to get the mark but are not specified as vital in the specification or approved textbook.
- Previous experience at another school with OCR examiners has been positive.
- In choosing between AQA A and OCR A, we felt that the material was both more accessible and more able to stretch the most academic students with OCR A.

We were slightly disappointed that this decision means that students won't get a choice of options but we feel that this is a secondary matter. With regard to coursework we believe that OCR A will be both manageable and rigorous.

Anton Machacek, *RGS High Wycombe*

I teach at a large sixth-form college on the south coast. We have a significant number of international students for whom context-led courses may be difficult because they come from such varied backgrounds, so we have decided to opt for OCR A. This is a change of examination board, but we were unhappy with some aspects of the coursework administration with our previous board. The type of coursework and its management is a significant issue for us because we have more than 100 students and only two teachers to manage it. We hope that the new course will provide good progression from the new GCSE science courses, in particular with regard to the "how science works" component. With students coming from a variety of different 11–16 schools, it is difficult to tell whether or not a particular choice of specification will enhance the attractiveness of the course.

Glen Thomas, *Worthing College*

WJEC

Reigate Grammar School has made the decision to change its examination structure so that pupils will only sit public exams in year 13. The intention is to free up a lot of teaching time, which we plan to make the most of. WJEC has options at A2 and, with our extra time in the summer of year 12, we are planning to offer two of the options instead of just the mandatory one. This will help students to make more informed choices come the UCAS season.

Part of module five is a "case-study, synoptic in nature, based upon open-source material". This will encourage teachers to think, throughout the course, about the context in which we teach physics. Furthermore, there is currently no exam board-endorsed textbook. This will allow us to choose one all-purpose reference book that is not confined to the course and will allow pupils to get used to using large books. Extension topics will be accompanied by written material from the examination board.

The course as a whole is very well put together. Topics are not mixed about in different units, leaving teachers to make connections where they are required. It will be possible for pairs of teachers to teach sections of the same module without treading on each others toes.

The only down side is, as a school, we do not have the space or the technician power to teach an A-level specification that does project work, which I feel is best for the pupils. We hope that our future new-build and lab refurbishment will give us that element of choice. However, WJEC has kept a practical examination in which pupils will be expected to do a series of experimental tasks, which we welcome as a department.

As I understand it, the writers of the specification feel that there is very little wrong with the old syllabus and so have tried to change as little as possible. They are a very tight-knit group and continuity with the examiners is fantastic. The quality of care by the physicists at WJEC is of a consistently high standard too.

Alastair McGilchrist, *Reigate Grammar School*

AQA Physics A

Richmond upon Thames College is a general FE college in Outer London with about 5000 full-time equivalent students in 2007/2008, including 105 AS physics students and 54 A2 physics students.

The department has one full-time and four part-time physics lecturers, two part-time technicians, extensive but ageing practical equipment and interactive whiteboards in each teaching room, but limited access to computers in teaching laboratories.

We already offer AQA Physics A, which we have taught since the Curriculum 2000 reforms. We are graded as "good" by OFSTED and are classed as successful but with room for improvement.

We held a team meeting to discuss the choice of new specifications in December 2007. Points raised included:

- Context-led syllabuses can be more difficult for weaker students.
- Having to learn in a different way would be good if we had more time.
- Stability is important and technicians are already busy, so we've chosen the new A2 applied science investigations in physics.
- AQA has papers online.

We felt that chemistry and biology, which have switched to context-led courses, have had two significant outcomes:

- A large amount of work, preparation and training, therefore also high monetary cost.
- Results that dip then recover.

The decisions were:

- Keep to the AQA A specification.
- Consider a context-led syllabus again in two years after resolving existing problems.

In essence, we chose stability over change because our main weaknesses at present don't relate to the choice of specification. In terms of numbers of students, we already have to turn some away. We are only limited by the number of teaching laboratories but we're hoping to build a brand-new college in the future.

Jon Clarke, *Richmond upon Thames College*

AQA Physics B

The Assessment and Qualifications Alliance (AQA) has designed two new GCE physics specifications that will be available for teaching from autumn 2008 onwards.

Physics B (physics in context) is a new development designed for teachers and students who will appreciate an approach to physics that places the subject firmly in a range of different settings. It aims to introduce students to novel and stimulating areas of physics as well as to develop essential knowledge and understanding through context and application.

In developing this specification, the AQA has drawn on varied settings in which physics plays a key role, as well as the many resources available to enhance the teaching of physics at this level.

Both of the AQA specifications are supported by detailed complementary materials, produced in conjunction with Nelson Thornes.

David Baker, *senior subject officer, physics and electronics, AQA*

CCEA

At Foyle & Londonderry College, we have chosen to continue delivering the Northern Ireland CCEA specification at A-level. It has always provided candidates with a broad experience of the subject and has proved to be a sound foundation for further study and/or a valuable skills-base for many careers. CCEA covers classical and modern physics, encompassing theory and practical applications, such as in medical imaging (AS Unit 2).

Having considered the recent changes, we feel that constructive amendments have been made. Notably, all four written papers are now of 90 minutes duration. Also, the synoptic elements at A2 have been scaled down from substantial, discrete questions to become embedded within questions. Both of these provide more scope for pupils to demonstrate their knowledge, understanding and application of the topics that they have studied. Practical skills will now be examined through teacher-assessed tasks, with no coursework.

There is progression from AS to A2 level, obvious in both the level of difficulty of the material and the demands of the questions. Students may benefit from the modular system, entering for the winter and/or summer series of examinations. In our experience, CCEA quality control is consistently at a very high level, and we have confidence in its marking and awarding procedures.

Sandra O'Connell, *Foyle & Londonderry College*