Scheme of Work

Cambridge O Level

Cambridge O Level
Physics

5054
For examination from 2016

Cambridge Secondary 2

CAMBRIDGE
International Examinations

Contents

Introduction

This scheme of work has been designed to support you in your teaching and lesson planning. Making full use of this scheme of work will help you to improve both your teaching and your learners' potential. It is important to have a scheme of work in place in order for you to guarantee that the syllabus is covered fully. You can choose what approach to take and you know the nature of your institution and the levels of ability of your learners. What follows is just one possible approach you could take and you should always check the syllabus for the content of your course.

Suggestions for independent study **(I)** and formative assessment **(F)** are also included. Opportunities for differentiation are indicated as **basic** and **challenging**; there is the potential for differentiation by resource, grouping, expected level of outcome, and degree of support by teacher, throughout the scheme of work. Timings for activities and feedback are left to the judgment of the teacher, according to the level of the learners and size of the class. Length of time allocated to a task is another possible area for differentiation.

Guided learning hours

Guided learning hours give an indication of the amount of contact time you need to have with your learners to deliver a course. Our syllabuses are designed around 130 hours for Cambridge IGCSE courses. The number of hours may vary depending on local practice and your learners' previous experience of the subject. The table below give some guidance about how many hours we recommend you spend on each topic area.

Unit	Topic	Content (syllabus reference)		Teaching time (%)
Unit 1	Matter and measurement	1def 4abcdefghi 2ab 6abcd 5abcdef	Measurement Mass, volume and gravity Speed and velocity Elasticity Moments	8%
Unit 2	Waves and their uses	13abcdef 16abcdefghijk 14abcdefghijklmnopq 15abcde	Wave properties Sound waves Reflection and refraction Electromagnetic waves	13%
Unit 3	Atoms and radioactivity	27abcdefg 26abcdfghijklmn	Atomic structure	7%

Unit	Topic	Content (syllabus reference)		Teaching time (%)
			Radioactivity	
Unit 4	Moving charges	18abcdefghijk 19abcdefghijklmnopqr 20abcde	Electrostatics Current electricity D.C circuits	13%
Unit 5	Energy and energy sources	8abcdefghijklmn	Energy	9%
Unit 6	Thermal energy and matter	9abcdefgh 10abcde 11abcdefghijklm	Thermal energy Temperature Thermal properties	9%
Unit 7	Magnetism and electric current	17abcdefghijk 22abcdef 23abcdefghi	Magnetism Motor effect Electromagnetic induction	11%
Unit 8	Forces and motion	1abc 2cdefghij 3abcdefgh	Vectors and scalars Graphs and motion Newton's laws	10%
Unit 9	Pressure and gases	7abcdefghi 12abcdefg	Pressure Matter and molecules	10%
Unit 10	Practical electricity	21abcdefghi	Using electricity	10%

Unit	Topic	Content (syllabus reference)		Teaching time (%)
		24abcdefghijklm 25abcdefg	Electronics Electronic systems	

Teaching order

The units may be taught in order, 1 to 10. This is not essential, but the following recommendations apply.

(a) It is recommended that Unit 1 is taught as the first unit of the course.

(b) Other units that are suitable for teaching early in the course include Units 4, 5 and 8. Whenever a new unit is taught, it is essential to revise those ideas which were encountered earlier in the course and are required in the new unit.

(c) Some units contain the more conceptually difficult ideas and so are suitable for teaching in the second half of the course; it would be unwise to leave these until the very end, however, when revision is beginning to be a significant factor and when time might be short. These include Units 7 and 2. It is essential, however, that Unit 5 is taught before Unit 6, Unit 8 before Unit 9 and Unit 4 before Unit 10.

(d) It is recommended that the teaching of some skills and concepts are ongoing across all units. These include the use of symbols, formulae, equations, calculations, practical skills, molecular theory and ideas about energy.

Resources

The up-to-date resource list for this syllabus, including textbooks endorsed by Cambridge, is listed at **www.cie.org.uk**
Endorsed textbooks have been written to be closely aligned to the syllabus they support, and have been through a detailed quality assurance process. As such, all textbooks endorsed by Cambridge for this syllabus are the ideal resource to be used alongside this scheme of work as they cover each learning objective.

Teacher Support

Teacher Support **https://teachers.cie.org.uk** is a secure online resource bank and community forum for Cambridge teachers, where you can download specimen and past question papers, mark schemes and other resources. We also offer online and face-to-face training; details of forthcoming training opportunities are posted online. This scheme of work is available as PDF and an editable version in Microsoft Word format; both are available on Teacher Support at **https://teachers.cie.org.uk.** If you are unable to use Microsoft Word you can download Open Office free of charge from **www.openoffice.org**

Websites

This scheme of work includes website links providing direct access to internet resources. Cambridge International Examinations is not responsible for the accuracy or content of information contained in these sites. The inclusion of a link to an external website should not be understood to be an endorsement of that website or the site's owners (or their products/services).

The website pages referenced in this scheme of work were selected when the scheme of work was produced. Other aspects of the sites were not checked and only the particular resources are recommended.

Unit 1: Matter and measurement

Recommended prior knowledge

Little prior knowledge is required here, although learners will need to have encountered the idea of a graph and how, in physics, it is used to represent quantities and the relationships between them. Most of the other ideas are of the sort that many learners will be familiar with at some elementary level, although precise definitions may well be encountered here for the first time.

Context

This unit introduces learners to the ideas of measurement and observation which are so fundamental to all aspects of physics. From the very beginning, learners should be encouraged to be guided in their understanding of the subject by what has been measured and observed. Physics is not a question of opinion or education.

Outline

In this unit learners should learn to make many of the simple, basic measurements which are vital to subsequent units. They should be able to distinguish between weight and mass and so realise that physics will sometimes make distinctions which are not important in ordinary life. Other quantities are also introduced or revised: density, speed/velocity, force, and moment of a force. The concept of a force field is dealt with. Other ideas include: proportionality, equilibrium, centre of mass and graphs. It should be emphasised, from this stage on, that numerical answers must include the appropriate unit.

Classroom organisation and differentiation details: **W**: whole class; **G**: group; **I**: individual

Syllabus ref	Learning objectives	Suggested teaching activities
1(d)	Describe how to measure a variety of lengths with appropriate accuracy using tapes, rules, micrometers and, calipers using a vernier as necessary.	**Basic:** Learners should use all the instruments in 1(d) regularly during the course. Calculate the volume of a wooden lath (~50 cm × ~10 cm × ~1 cm) and use the correct instrument for each dimension. Explain that accuracy comes from the measurements not the calculator. Use calipers with inside diameter, outside diameter and depth gauge facility. Where possible both electronic and conventional instruments should be encountered. (**I G W**) Measuring: **www.bbc.co.uk/skillswise/factsheet/ma22leng-l1-f-length** Using calipers: **http://members.shaw.ca/ron.blond/Vern.APPLET/** Using a micrometer: **www.upscale.utoronto.ca/PVB/Harrison/Micrometer/Micrometer.html**

Syllabus ref	Learning objectives	Suggested teaching activities
		Make learners familiar with SI units even in the normal course of their lives. Distances in km, masses in kilograms and so on. How big is this classroom? What is the volume of air in it? (**W**)
1(e)	Describe how to measure a variety of time intervals using clocks and stopwatches.	Use a stop-clock or stopwatch (learners might well have a digital watch with lap timer and timer facilities) to time pendulums or oscillating weights – simple graphs of period against length or mass of bob may be plotted. Let the learners run upstairs or in races. Calculate speeds and work done and power expended (when dealt with in the course). (**G W**)

Syllabus ref	Learning objectives	Suggested teaching activities
1(f)	Recognise and use the conventions and symbols contained in 'Signs, Symbols and Systematics', Association for Science Education, 2000.	**Basic:** Wherever possible conduct the course with conventional symbols and SI units. Make learners familiar with the more common prefixes: micro- (μ), milli- (m), kilo- (k), mega- (M). (**W**) SI Units: **http://physics.nist.gov/cuu/Units/units.html** and **www.ebyte.it/library/educards/siunits/TablesOfSiUnitsAndPrefixes.html** **Challenging:** Emphasise that units follow the quantity; speed is distance/time and the unit of speed is the distance unit/time unit. Likewise: density is mass/volume and the unit of density is the mass unit/volume unit. Avoid negative index units at this level, e.g. use m/s rather than $m\ s^{-1}$. (**I G W**)
4(a)	State that mass is a measure of the amount of substance in a body.	**Basic:** Explain that in physics mass is different from weight. Learners accept that as an object is moved around the Earth it is the same object, made of the same molecules in the same order and that something about it remains constant. This is the amount of matter or “stuff” it contains. Explain that mass determines how difficult it is to change the motion of a body (e.g. to speed it up); it determines the inertia of the body. (**W**) This unchanging quantity is called the mass and is measured in kilograms. It is the quantity one is usually interested in when buying, say, fruit or vegetables. (**W**) Mass: **http://hyperphysics.phy-astr.gsu.edu/hbase/mass.html** and **www.qrg.northwestern.edu/projects/vss/docs/space-environment/2-what-is-mass.html**
4(b)	State that mass of a body resists change from its state of rest or motion.	
4(c)	State that a gravitational field is a region in which a mass experiences a force due to gravitational attraction.	**Basic:** Learners readily accept that as an object journeys around the Solar System, the force (Unit 6) of attraction to the nearest planet changes with the planet’s proximity and mass. On Earth this force is approximately 10 N for every kilogram of the object’s mass. Emphasise that it varies according to height above sea-level and distance from the Equator. (The actual value is usually somewhere between 9.79 N / kg and

Syllabus ref	Learning objectives	Suggested teaching activities
4(d)	Calculate the weight from the equation *weight = mass × gravitational field strength.*	9.83 N / kg.) (**G W**) Gravity: **http://csep10.phys.utk.edu/astr161/lect/history/newtongrav.html** and **www.esa.int/esaSC/SEMDYI5V9ED_index_0.html** At this stage an appropriate “definition” of the newton is “the weight of an average apple” – use a fruit or vegetable that the learners will be most familiar with. The actual definition is encountered in Unit 8. (**W**) Calculate learners’ weights. (**I G W**) Weight: **www.grc.nasa.gov/WWW/k-12/airplane/weight1.html** and **www.mathsisfun.com/measure/weight-mass.html** **Challenging:** For other planets or on the Moon; use a planet where g is larger than 10 N / kg. On the Moon it is smaller.
4(e)	Explain that weights, and therefore masses, may be compared using a balance.	**Basic:** Emphasise that lever-arm balances compare unknown weights/forces with the weight of a known mass. This is equivalent to comparing masses since $W = mg$. Would such a balance be accurate on the Moon? (**G W**) Lever-arm balances: **www.nuffieldfoundation.org/practical-physics/weighing-air** Spring balances measure the weight and deduce the mass assuming that g = 10 N / kg. This assumption is also valid on the Moon because although g is smaller is cancels out. A top pan balance, however, would need to be recalibrated on the moon. (**G W**) Top-pan balances: **www.csudh.edu/oliver/demos/bal-use/bal-use.htm**
4(f)	Describe how to measure mass and weight by using appropriate balances.	

Syllabus ref	Learning objectives	Suggested teaching activities
		Challenging: The best way of understanding a balance is to use one; let learners see the effect of using the balance on an uneven surface, to use it when leaning on the bench or use it to measure hot objects. (**I G W**)
4(g)	Describe how to use a measuring cylinder to measure the volume of a liquid or solid.	**Basic:** Learners will learn how to do this most readily by actually doing it. Get learners to measure the volume, mass and density of common liquids such as cooking oil, orange juice etc. Use the bottom of the meniscus for such liquids (this is the top of most of the liquid). Measure the volume of bolts and pebbles and coins (use more than one if the volume is small) by immersing in water. Does immersion in oil give a different value? (**I G W**) Calculate the volume of wooden blocks, metal bars, and glass prisms. (**I G W**) **Challenging:** Use large and small measuring cylinders if available. Does the solid object fit into the cylinder? Use a solid that floats in water – a weight is needed to make it sink and the volume of the weight must be subtracted from the value obtained. (**G W**) Measuring cylinders: **www.saburchill.com/chemistry/chapters/chap0021.html** and **www.msnucleus.org/membership/html/k-6/as/scimath/3/assm3_5a.html**
4(h)	Describe how to determine the density of a liquid, of a regularly shaped solid and of an irregularly shaped solid which sinks in water (volume by displacement).	**Basic:** Emphasise that volume and mass are properties of an object. They vary from object to object even when they are of the same material. Density, however, is a property of the material from which the substance is made. (**G W**) **Challenging:** Emphasise the use of both g / cm^3 and kg / m^3. Why does the second unit produce a value 1000 times larger? (**I G**) Density: **www.nyu.edu/pages/mathmol/modules/water/density_intro.html**

Syllabus ref	Learning objectives	Suggested teaching activities
		and www.youtube.com/watch?v=Z1IMgjXin3U and www.cimt.plymouth.ac.uk/projects/mepres/book7/bk7i22/bk7_22i5.htm

Syllabus ref	Learning objectives	Suggested teaching activities
4(i)	Make calculations using the formula *density = mass/volume.*	**Basic:** There are many simple questions on this in past papers and text books. Let learners calculate m, V and ρ. V itself can be calculated from $V = abc$; $\pi r^2 h$ and so on. (**I G W**)
2(a)	State what is meant by speed and velocity.	**Basic:** Learners are probably familiar with these ideas from ordinary situations but emphasise that what they already know can be put into equation form: $v = d/t$ and that the unit of speed follows from the equation: km / h or m / s. (**G W**) **Challenging:** Explain that in physics it is important to separate speed and velocity. Speed ignores the direction travelled but the formal distinction between scalar and vector quantities can wait. Learners can be asked to calculate v, d and t given the other two quantities. (**I G W**) Speed and velocity: www.physicsclassroom.com/class/1dkin/u1l1d.cfm and www.youtube.com/watch?v=qCHnUfZ-W04 and www.youtube.com/watch?v=C0hKJUjUab8 and www.youtube.com/watch?v=c4HH8vVRfY4
2(b)	Calculate average speed using distance travelled/time taken.	
6(a)	State that a force may produce a change in size and shape of a body.	**Basic:** Allow learners to contribute as many words as possible here: twist, stretch, compress, shrink, distort, contort, expand and so on. (**G W**) Let learners suggest their own examples of forces changing sizes and shapes: car crashes, foam rubber, pillows and motorcycle crash helmets. (**I G W**) Change in shape/size:

Syllabus ref	Learning objectives	Suggested teaching activities
		www.factmonster.com/ce6/sci/A0819139.html and www.bbc.co.uk/learningzone/clips/the-use-of-force-to-change-shape/2489.html and www.attano.com/video/5888-Force-can-change-the-shape-of-an-object

Syllabus ref	Learning objectives	Suggested teaching activities
6(b)	Plot, draw and interpret extension-load graphs for an elastic solid and describe the associated experimental procedure.	**Basic:** These experiments can be performed by the learners themselves. Stretch springs, rubber bands and strips of polythene – glue a piece of wood to the bottom of the strip or use a jubilee clip and attach the weights to it. Use springs in parallel and in series. Measure and compare the gradients of the extension-load graphs. (**I G W**)
6(c)	Recognise the significance of the term "limit of proportionality" for an elastic solid (an understanding of the elastic limit is **not** required).	At this level the limit of proportionality and the elastic limit can be assumed to be the same. (**I G W**) Hooke's law: **www.darvill.clara.net/enforcemot/springs.htm** and **www.youtube.com/watch?v=pVdGUTRI49E**
6(d)	Calculate extensions for an elastic solid using proportionality.	**Challenging:** Use $T = kx$ or $mg = kx$. Use these equations to explain proportionality. Also use more domestic examples: the price of fruit ∝ the amount purchased, wages earned ∝ hours worked. In both cases, there can be different constants of proportionality: the unit price and the hourly rate. (**G W**) (Please note that mathematicians sometimes define a different quantity λ – it has different units – and call it the spring constant. In this syllabus, this quantity should never be referred to or asked for.) Proportionality: **www.themathpage.com/ARITH/proportionality.htm** Spring constant: **www.4physics.com/phy_demo/HookesLaw/HookesLawLab.html** and **www.ap.smu.ca/demos/index.php?option=com_content&view=article&id=90&Itemid=85**
5(a)	Describe the moment of a force in terms of its turning effect and relate this to everyday examples.	**Basic:** Learners are likely to be familiar with children of unequal weights balancing on see-saws. Ask how it is done. (**W**)
5(d)	Describe the moment of a force in	Use a metre rule and some small masses balanced on a knife edge to verify the principle of moments. Then

Syllabus ref	Learning objectives	Suggested teaching activities
	terms of its turning effect and relate this to everyday examples.	use it to determine the unknown mass of a small can. Work up through larger objects and measure the mass of a learner balancing on a plank. Measure the mass of the rule by placing a weight at one end and balancing the whole arrangement at a point between the weight and the rule's centre of mass. (**I G**)
5(b)	State the principle of moments for a body in equilibrium.	Even though the value of *g* cancels, it is much better to state the principle using weight rather than mass: $m_1gx_1 = m_2gx_2$ This is because *mgx* is a useful physical quantity whereas *mx* is not. Use traditional weighing machines and balances and the steelyard, the chemical balance and so on. Use examples with which the learners are likely to be familiar. (**I G W**) Moments: **www.bbc.co.uk/schools/ks3bitesize/science/energy_electricity_forces/forces/revise8.shtml** and **www.walter-fendt.de/ph14e/lever.htm** and **http://en.wikipedia.org/wiki/Steelyard_balance**
5(c)	Make calculations using *moment of a force = force × perpendicular distance from the pivot* and the principle of moments.	**Basic:** Use the principle of moments to define the *moment of a force* and emphasise it measures the turning effect of a force. Consider everyday examples: spanners, wrenches, opening tins with screwdrivers and spoons, the steering-wheel, door and window handles, taps, and so on. (**I G W**) Please notice that torque is another name for *moment of a force*; it is also measured in N m. Torque (moment): **http://hyperphysics.phy-astr.gsu.edu/hbase/torq.html** and **www.s-cool.co.uk/gcse/physics/forces-moments-and-pressure/revise-it/moments** and **www.cyberphysics.co.uk/topics/forces/moments.htm**

Syllabus ref	Learning objectives	Suggested teaching activities
		The turning effect of a force is not a measurable quantity; it is just a description of what happens when a force causes a moment. Although the newton metre is equivalent to the joule, the joule is not usually accepted as a unit of moment and moment should not be expressed in joules. State this as a rule. (**W**).

Syllabus ref	Learning objectives	Suggested teaching activities
5(f)	Describe qualitatively the effect of the position of the centre of mass on the stability of simple objects.	**Basic:** Conduct experiments to show the effect. Tip a thick-bottomed glass and a long-stemmed glass over. Place them on a book with a hard cover and gradually open the book; measure the angle where tipping occurs. (**I G W**) At this level it is hard to explain the difference between centre of mass and centre of gravity and so it is best to use only the syllabus term *centre of mass.* Centre of mass: **http://hyperphysics.phy-astr.gsu.edu/hbase/cm.html** and **www.qwerty.co.za/puzzles/mass/cofmcoke.htm** and **www.slideshare.net/danmicksee/centre-of-gravity-and-stability** and **www.youtube.com/watch?v=C-fZA1NJtPA** and **www.youtube.com/watch?v=DY3LYQv22qY**
5(e)	Describe how to determine the position of the centre of mass of a plane lamina.	**Basic:** Use a variety of thick card or thin wood laminas: triangles, squares, rectangles, pentagons, star shapes, L-shapes, O-shapes, rings and squares with square holes. Cut out a map of your country printed on to thick card. Find the centre of gravity. Is this accurate? What about mountains, islands and lakes? (**I G W**) Centres of gravity of laminas: **www.mathematische-basteleien.de/geocentre.htm** and **www.youtube.com/watch?v=PITFilQjvxw**

Past paper and specimen papers
Past paper questions: Nov 12 Paper 21 Q4 Nov 12 Paper 22 Q1 Nov 12 Paper 22 Q2 Jun 12 Paper 22 Q1 Nov 11 Paper 21 Q1 Past question papers available at: **http://teachers.cie.org.uk**

Unit 2: Waves and their uses

Recommended prior knowledge
Learners ought to have encountered Unit 1 before starting this unit. In addition they will need some concept of what is meant by energy, even though it need not be defined exactly at this stage. Learners should be able to use a protractor and to draw simple diagrams neatly. Words such as audible, pitch, vibration, reflection, medium, vacuum, echo, timbre, pre-natal, magnification, lens and spectrum are likely to be used without being separately defined by the teacher.

Context
This unit deals with waves and how they are used. It is to some extent an independent section of the syllabus with only a few other topics depending on it. Consequently those who do not wish to follow through the units in numerical order may include this unit at almost any stage.

Outline
The unit begins by introducing the idea of wave motion in a general sense. This is an idea which though simple at one level, is in fact sometimes difficult to grasp. When sea-waves are considered it is unlikely that much emphasis is given to their transmission of energy and this essential aspect of waves is often neglected by learners. The basic definitions are included and the idea that certain quantities may be represented by an equation is worth underlining for future use. Two specific cases, sound and light, follow on from this and the fundamental properties of all waves are studied in the context of these two examples. The practical importance of the seemingly abstract phenomenon of refraction is illustrated by the inclusion of lenses and by their use in the correction of imperfect vision. Some of the widely varying uses of electromagnetic radiation conclude this unit.

Classroom organisation and differentiation details: **W**: whole class; **G**: group; **I**: individual

Syllabus ref	Learning objectives	Suggested teaching activities
13(a)	Describe what is meant by wave motion as illustrated by vibrations in ropes and springs and by experiments using a ripple tank.	**Basic:** Energy (Unit 5) transfer often involves the net movement of matter but for wave motion it does not. Stretch a long spring or rope between two learners. One can transmit energy to the other (make the second learner's hand move) without transferring matter. Point out the learners' ear drums are being moved (vibrated) without the transfer of matter. (**G W**) A wave transfers energy through a medium without the medium moving as a whole. Use ripple tanks to show water waves transferring energy. A small piece of cork vibrates as the wave passes. Compare with sound and hearing. (**G W**) Waves:

Syllabus ref	Learning objectives	Suggested teaching activities
		www.kettering.edu/~drussell/Demos/waves/wavemotion.html and **www.youtube.com/watch?v=JXaVmUvwxww** and **www.bbc.co.uk/schools/gcsebitesize/science/add_ocr_pre_2011/wave_model/whatarewavesrev1.shtml** Ripple tanks simulation: **www.falstad.com/ripple/**
13(b)	State what is meant by the term *wavefront.*	**Challenging:** The crest line or the trough line is the wavefront. Strictly it is a line (surface) joining points of identical phase but at this level only the best learners will understand what this means. (**W**) Wavefronts: **www.colorado.edu/physics/2000/waves_particles/waves.html**

Syllabus ref	Learning objectives	Suggested teaching activities
13(d)	Describe transverse and longitudinal waves in such a way as to illustrate the differences between them.	**Basic:** Use the long spring to show transverse waves. Get the learners to come up with longitudinal waves. (**G W**) Use these terms: crest, trough, compression, rarefaction, displacement Longitudinal waves include: sound, ultrasound, seismic P-waves, shock waves. Longitudinal waves: **www.bbc.co.uk/schools/gcsebitesize/science/aqa/waves/generalwavesrev2.shtml** and **www.youtube.com/watch?v=f66syH8B9D8** and **www.youtube.com/watch?v=aguCWnbRETU** Transverse waves: **www.youtube.com/watch?v=AtIxBODxWHc** and **www.youtube.com/watch?v=P0Fi1VcbpAI**
13(c)	Define the terms *speed*, *frequency*, *wavelength* and *amplitude* and do calculations using *velocity = frequency × wavelength.*	**Basic:** Define the terms. At this stage speed and velocity can be treated as essentially the same thing. (**W**) **Challenging:** Note that the frequency is the number of waves (**not** necessarily complete waves) passing a point in unit time. Frequency is not necessarily an integer. (**W**) Deduce the formula. (**W**) **Basic:** Use the formula to deduce the speed of radio waves from the published wavelength and frequency of a local radio station. (**I G W**) Wave formula: **www.gcse.com/waves/wave_speed.htm**

Syllabus ref	Learning objectives	Suggested teaching activities
		Wave parts: **www.bbc.co.uk/schools/gcsebitesize/science/aqa_pre_2011/radiation/anintroductiontowavesrev2.shtml** and **www.physicsclassroom.com/class/waves/u10l2c.cfm**

Syllabus ref	Learning objectives	Suggested teaching activities
13(e)	Describe the use of a ripple tank to show (1) reflection at a plane surface refraction due to a change of speed at constant frequency.	**Basic:** Show these experimentally if not in a ripple tank then in a tray of water. (**G W**) Draw diagrams of waves entering a shallow (slower) region at an angle. Show where the waves would have reached if the original medium had continued and then where the waves actually are. They have skewed around as one side slows before the other. (**W**) **Challenging:** Comparison: caterpillar-tracked vehicles cannot steer. By slowing down one track and speeding up the other the vehicle skews round like waves refracting. Similarly soldiers marching shoulder-to-shoulder, reach ground (at an angle) where they travel slower. (**I G W**) Ripple tank reflection: **www.schoolphysics.co.uk/age11-14/Wave%20properties/text/Waves_in_a_ripple_tank/index.html** and **www.youtube.com/watch?v=HFckyHq594I** Ripple tank refraction: **www.youtube.com/watch?v=stdi6XJX6gU** Refraction: **www.nuffieldfoundation.org/practical-physics/marching-model-refraction** and **www.youtube.com/watch?v=Tyzci1qTVL8**
16(a)	Describe the production of sound by vibrating sources.	**Basic:** Consider: a tuning fork, a violin (or local stringed musical instrument), a drum, vibrating rulers, cardboard strips held in the spokes of a bicycle wheel, a loudspeaker and many other examples. Learners should feel the vibrations. (**G W**) Use a loudspeaker and a signal generator to test the frequency range of the learners' hearing. The actual
16(c)	State the approximate range of audible frequencies for the healthy human ear as 20 Hz to 20 000 Hz.	

Syllabus ref	Learning objectives	Suggested teaching activities
16(g)	Explain how the loudness and pitch of sound waves relate to amplitude and frequency.	frequency range varies from person to person but a standard range of 20 → 20 000 Hz is usually taken for a person of normal hearing. Test learners to discover how high a frequency a learner can detect; teenage learners will already find that they cannot detect the highest frequency notes. For adults, the highest detectable frequency will be lower still. Make sure that the loud speaker can produce the high frequency notes. (**W**) **Challenging:** Use a microphone and c.r.o. to show how the trace varies with frequency and with amplitude. Relate these observations to pitch and loudness. (**G W**) Place small particles on a drum or loudspeaker. (**W**) Production of sound: **www.bbc.co.uk/learningzone/clips/understanding-sound-and-vibrations/1604.html** and **www.youtube.com/watch?v=MFLeGJcIQiI** Guitar strings: **www.youtube.com/watch?v=v-sARWEXReY** Drum: **www.youtube.com/watch?v=v4ELxKKT5Rw** Sound and the ear: **www.bbc.co.uk/science/humanbody/body/factfiles/hearing/hearing_animation.shtml** and **http://hyperphysics.phy-astr.gsu.edu/hbase/sound/ear.html** Loudness: **www.engineeringinteract.org/resources/oceanodyssey/flash/concepts/loudness.htm**

Syllabus ref	Learning objectives	Suggested teaching activities
		and www.youtube.com/watch?v=8i6hTU0jw-g Hearing test (this will only work with loudspeakers of appropriate quality): www.youtube.com/watch?v=1yzrx84QWqI Sound pitch, frequency and amplitude: www.youtube.com/watch?v=irqfGYD2UKw
16(b)	Describe the longitudinal nature of sound waves and describe compression and rarefaction.	**Basic:** Use the vibrations of a loudspeaker to explain that the vibration direction is parallel to that of the sound wave. Compare this with a long spring or trolleys joined by springs. (**W**) Sound waves: www.youtube.com/watch?v=27a26e2CnuM and www.physicsclassroom.com/class/sound/
16(d)	Explain why a medium is required in order to transmit sound waves and describe an experiment to demonstrate this.	**Basic:** Show the bell jar experiment if at all possible; the clanger can be seen striking the bell but little or no sound is heard. (**G W**) **Challenging:** Consider: the Sun can be seen but not heard, astronauts on a space-walk can only communicate using radio (or by touching helmets). (**W**) Bell jar experiment: www.gcse.com/waves/sound2.htm and www.youtube.com/watch?v=ce7AMJdq0Gw
13(f)	Describe simple experiments to show the reflection of sound waves.	**Basic:** Demonstrate an echo from the front of a large building or cliff (~100 m away if possible). This can be extended to measure the speed of sound – use two blocks of wood to make a short, distinct clap
16(h)	Describe how the reflection of	

Syllabus ref	Learning objectives	Suggested teaching activities
	sound may produce an echo.	or a loud whistle or a high-pitched feedback sound from a megaphone. Measure the distance with rulers, rope or a pedometer. Clapping in time with the echo from a closer wall (30 m) allows the time taken for the sound to travel to the wall and back to be measured more accurately. (**G W**) Refer to methods involving firing guns or simply observing someone clap the two pieces of wood together from a few kilometres away. (These rely on the speed of light being very much larger than that of sound.) (**G W**) Sound travels much faster in solids and liquids. When a hammer strikes a long length of metal railings, two sounds are heard: one through the railings; one through the air. (**I G W**) Quote speed of sound values for air, liquids and gases. (**W**) **Challenging:** Refraction in sound can be demonstrated/described using a beach-ball filled with CO_2. This can act as a sound lens (later in this unit) and be used to focus sound. (Lenses work by refraction). (**G W**) If filled with He, it would be a diverging lens. (**G W**) Speed of sound: **www.sv.vt.edu/classes/ESM4714/Student_Proj/class95/physics/speed.html** and **www.youtube.com/watch?v=_1Er6v_c43I** Reflection in sound: **www.bbc.co.uk/learningzone/clips/the-reflection-of-sound-to-produce-an-echo/1609.html** Refraction in sound: **www.acs.psu.edu/drussell/Demos/refract/refract.html** and **www.youtube.com/watch?v=eHZJFa055Xo** Speed of sound in materials: **www.absorblearning.com/physics/demo/units/DJFPh083.html#Howfastissound?** and
16(e)	Describe a direct method for the determination of the speed of sound in air and make the necessary calculation.	
16(f)	State the order of magnitude of the speeds of sound in air, liquids and solids.	

Syllabus ref	Learning objectives	Suggested teaching activities
		www.physicsclassroom.com/class/sound/u11l2c.cfm

Syllabus ref	Learning objectives	Suggested teaching activities
16(i)	Describe how the shape of a sound wave as demonstrated by an oscilloscope is affected by the quality (timbre) of the sound wave.	**Basic:** Emphasise that the same note played on different instruments differ only in the shape of the trace on a c.r.o. not in their periodic times. Show this using musical instruments, a microphone and a c.r.o. Show that the amplitude does not affect the shape of the trace. (**W**) Timbre: www.youtube.com/watch?v=BLoM9bBr8lc and www.animations.physics.unsw.edu.au/jw/sound-pitch-loudness-timbre.htm
16(j)	Define *ultrasound*.	**Basic:** Define ultrasound and give a variety of uses: • cleaning sensitive artefacts • quality control, pre-natal scanning • distance measurers (dataloggers in universities/schools). (**W**) Bats use ultrasound to form a picture of their surroundings. Dogs can hear ultrasound (dog whistles). (**G W**) Please note that the uses specified in the syllabus must be taught to learners. Uses of ultra sound: www.odec.ca/projects/2003/guilh3m/public_html/use.html and http://wanttoknowit.com/uses-of-ultrasound/ and www.youtube.com/watch?v=tluZGhzg7Ks
16(k)	Describe the uses of ultrasound in cleaning, quality control and pre-natal scanning.	
14(a)	Define the terms used in reflection including *normal*, *angle of incidence* and *angle of reflection*.	**Basic:** These topics are best covered experimentally; learners may use mirrors and ray-boxes, torches or (optical) pins. (**I**)
14(b)	Describe an experiment to illustrate the law of reflection.	

Syllabus ref	Learning objectives	Suggested teaching activities
14(d)	State that for reflection, the angle of incidence is equal to the angle of reflection and use this in constructions, measurements and calculations.	**Challenging:** The law may be modelled in 3D using rods or rulers to represent the rays and the normal and the desk top to act as a mirror. Observe that there are many rays for which the angle of reflection equals the angle of incidence but the correct one lies in the same plane as the normal and the incident ray. Emphasise that all angles are measured between the ray and the normal. (**I G**) Law of reflection: **http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/fermat.html** Diffuse and specular reflection: **www.khanacademy.org/science/physics/waves-and-optics/v/specular-and-diffuse-reflection** Experiment: **www.youtube.com/watch?v=9aWE4rDw_ks**
14(c)	Describe an experiment to find the position and characteristics of an optical image formed by a plane mirror.	**Basic:** Emphasise that an image is the location from which the light **seems** to come. It has not actually travelled behind the mirror. An eye or a photographic plate placed at the image position would not detect anything. For a mirror hanging on a wall, the image may well be in the next room or building and someone there would not be able to see the person standing in front of the mirror. (**G W**) **Challenging:** Consider more complicated examples such as two mirrors at right-angles or a kaleidoscope. (**I G**) Plane mirror images: **www.youtube.com/watch?v=2ek0EsEMTBc** and **www.youtube.com/watch?v=A8AfxcUNvYw**
14(e)	Define the terms used in refraction including *angle of incidence*, *angle of refraction* and *refractive index*.	**Basic:** Show some simple examples of refraction: the bent stick, apparent reduction in depth, heat haze, pass a ray of light into a tank containing two liquids of different densities – a **very** small amount of paint in the liquids will scatter light so that the path of the ray may be seen. (**G W**) Carry out experiments with a glass block and a ray-box, torch or a slit in a blind/curtain or (optical) pins. Measure *i* and *r*. Plot $i \rightarrow r$. Calculate sin(*i*) and sin(*r*) and calculate sin(*i*)/sin(*r*). (**I G**)
14(f)	Describe experiments to show refraction of light through glass blocks.	

<table>
<tr><th>Syllabus ref</th><th>Learning objectives</th><th>Suggested teaching activities</th></tr>
<tr><td></td><td></td><td rowspan="2">Challenging:
Plot sin(i) → sin(r). Measure the gradient. State that using the gradient gives more emphasis to those points nearest to the average behaviour. Averaging the values of sin(i)/sin(r) does not. (I G)

Refer back to the skewing round of caterpillar tracked vehicles when the tracks are driven at different speeds.

Emphasise that as the light leaves the second face of a rectangular block, it reverses the procedure which occurred at the first and emerges parallel to the incident ray. (I G W)

Refraction:
www.youtube.com/watch?v=OdcHCRF00jM

and
www.bbc.co.uk/bitesize/higher/physics/radiation/refraction/revision/1/

Reflection and refraction:
https://www.o2learn.co.uk/o2_video.php?vid=398</td></tr>
<tr><td>14(g)</td><td>Do calculations using the equation

sini/sinr = constant.</td></tr>
<tr><td>14(i)</td><td>Describe experiments to show total internal reflection.</td><td rowspan="2">Challenging:
Explain that when a ray emerges from glass into air, the emergent angle is larger than the angle at which it strikes the surface. In due course, it emerges at 90° to the lower face. If the angle at which it strikes the surface increases, then the emergent angle exceeds 90° and it passes back into the glass. This is reflection not refraction. Refraction out of the glass is now impossible. (W)

Emphasise the fact that two conditions must be met before T.I.R. can occur:

1) The light must pass from the slow to the fast medium.
2) The angle at the surface must exceed the critical angle.

Pass a ray into the curved face of a semi-circular glass block, into the side face of a glass block or a tank of water. Move the ray. There comes a point at which no light at all emerges through the surface.
(I G W)
Total internal reflection:
www.cyberphysics.co.uk/topics/light/TIR.htm

and
www.youtube.com/watch?v=PrEF9UN98cE</td></tr>
<tr><td>14(h)</td><td>Define the terms critical angle and total internal reflection.</td></tr>
</table>

Syllabus ref	Learning objectives	Suggested teaching activities
		Critical angle: www.youtube.com/watch?v=CF7CJb8XQHw Fish-eye view: www.physicsclassroom.com/mmedia/optics/bp.cfm Retroreflectors: www.youtube.com/watch?v=ktqWZZydijY
14(j)	Describe the use of optical fibres in telecommunications and state the advantages of their use.	**Basic:** Optical fibres rely on T.I.R. Digital pulses (light/no light) transmit the information. (**W**) Advantages include: more information can be sent per second (many phone calls on one line), less prone to interference, less easy to tap into, fewer repeaters. There are transoceanic optical fibre cables and it is possible to have an optical link straight into a personal computer or telephone. **Challenging:** Optical fibres need to be sheathed to prevent light passing from one fibre into the next. (**I G**) Optical fibres: www.bbc.co.uk/schools/gcsebitesize/science/edexcel_pre_2011/waves/sendinginformationrev1.shtml and www.cyberphysics.co.uk/topics/light/FiberOptics/FibreOptics.htm
14(k)	Describe the action of thin lenses (both converging and diverging) on a beam of light.	**Basic:** Pass a ray of light from a ray-box or torch into a lens (ideally curved in only one dimension) and observe the path of rays at different distances from the centre. This is difficult to do with optical pins. (**I G W**) Pass a beam of parallel rays into a lens and observe the convergence. (**I G W**) Define focal length. (**W**) Converging lenses: www.physicsclassroom.com/class/refrn/u14l5da.cfm
14(l)	Define the term *focal length*.	

Syllabus ref	Learning objectives	Suggested teaching activities
		and **http://dev.physicslab.org/Document.aspx?dNovype=3&filename=GeometricOptics_ConvergingLenses.xml** and **www.youtube.com/watch?v=b2h7lc2epWA** focal length: **www.youtube.com/watch?v=AoGDOT6U9pQ** and **http://hyperphysics.phy-astr.gsu.edu/hbase/geoopt/foclen.html**
14(m)	Draw ray diagrams to illustrate the formation of real and virtual images of an object by a converging lens and the formation of a virtual image by a diverging lens.	**Basic:** Emphasise three special rays: (1) Incident, paraxial rays refract through the focal point. (2) Incident rays striking the optical centre emerge undeviated. (3) Incident rays which pass through or seem to have passed through the focal point emerge paraxially. Scale diagrams will only be accurate if drawn carefully. (**I G W**) Start with the object and the lens and find the image or start with the object and the image and find the focal points. (**I G W**) **Challenging:** (1) These three special rays are from one point on the object but all the other rays from that point meet at (or seem to have come from) the equivalent point on the image. It is usual to use the top point of the object as the object point but every other point on the object also produces an image at an equivalent position. (**I G W**) Image formation: **www.nuffieldfoundation.org/practical-physics/image-formation-lens** and **www.physicsclassroom.com/class/refrn/u14l5c.cfm** Linear magnification:
14(n)	Define the term *linear magnification* and draw scale diagrams to determine the focal length needed for particular values of magnification (converging lens only).	

Syllabus ref	Learning objectives	Suggested teaching activities
		http://hyperphysics.phy-astr.gsu.edu/hbase/geoopt/lensdet.html and www.youtube.com/watch?v=ZJn7nSPe9_Y
14(o)	Describe the use of a single lens as a magnifying glass and in a camera, projector and photographic enlarger and draw ray diagrams to show how each forms an image.	**Basic:** Learners can be given incomplete or unlabelled diagrams and instructed to complete them. (**I G W**) Learners should know the position of the object relative to the principal focus in the different devices. (**I G W**) It is helpful if learners have seen these devices operating or partially dismantled. Make a large model of the camera /enlarger using a cardboard box and an appropriate lens. (**G W**) Magnifying glass: www.physics.pomona.edu/sixideas/labs/LRM/LR07.pdf Camera: http://science.howstuffworks.com/camera1.htm and www.schoolphysics.co.uk/age11-14/Light/text/Camera_/index.html Enlarger: http://en.wikipedia.org/wiki/Enlarger
14(p)	Draw ray diagrams to show the formation of images in the normal eye, a short-sighted eye and a long-sighted eye.	**Basic:** A model eye can be made from a fish bowl or a round-bottomed flask with a lens held to the outside with a ring of modelling clay. Fill the bowl or flask with water and a very small amount of paint to scatter the light. Pass light into the model eye. (**G W**) Explain the causes of both short- and long-sightedness and describe the way in which lenses are used to solve the problems. (**W**) Note that although short-sightedness is sometimes called near-sightedness or myopia, these terms are not used in this syllabus. Likewise, long-sightedness is sometimes called hypermetropia, but this term is not used in this syllabus.
14(q)	Describe the correction of short-sight and long-sight.	

Syllabus ref	Learning objectives	Suggested teaching activities
		The eye: **www.physicsclassroom.com/class/refrn/u14l6a.cfm** and **www.cyberphysics.co.uk/topics/medical/Eye/eye.html** Short sight: **www.physicsclassroom.com/class/refrn/u14l6e.cfm** and **www.youtube.com/watch?v=AsKeu4wm3XI** Long sight: **www.cyberphysics.co.uk/topics/medical/Eye/sightCorrection.html** and **www.youtube.com/watch?v=AsKeu4wm3XI** Correcting problems: **www.bbc.co.uk/health/physical_health/conditions/visionproblems1.shtml**
15(a)	Describe the dispersion of light as illustrated by the action on light of a glass prism.	**Basic:** Best shown in practice using a glass/water prism and a ray-box, torch or slit in a blind/curtain. (**I G W**) Light is split up according to its wavelength. This leads to the traditional seven colours of the spectrum/rainbow. The higher the frequency, the greater the extent of the refraction. “Violet refracts violently” or “blue bends best”. (**G W**) Use an infra-red detector (e.g. a thermometer with bulb blackened) to detect radiation beyond the red end of the visible spectrum and show that some sections of the spectrum cannot be detected by the human eye. Remember that only near infra-red can pass through normal glass. (**G W**) List properties shared by all electromagnetic radiations. Include: speed in air, transverse nature, travel in vacuum.
15(b)	State the colours of the spectrum and explain how the colours are related to frequency/wavelength.	

Syllabus ref	Learning objectives	Suggested teaching activities
		Challenging: Some learners will point out that light cannot be a wave as it does not require a medium. One might point out that magnetic and electric fields do pass through a vacuum and that light is an oscillation of such fields. (**I G W**) Prisms: **www.physicsclassroom.com/class/refrn/u14l4a.cfm** and **www.youtube.com/watch?v=NU2r-ECmPr4** Rainbows: **www.cord.edu/faculty/manning/physics215/studentpages/genamahlen.html** and **http://eo.ucar.edu/rainbows/**
15(c)	State that all electromagnetic waves travel with the same high speed in air and state the magnitude of that speed.	**Basic:** c = 3.0 × 10^8 m / s.
15(d)	Describe the main components of the electromagnetic spectrum.	**Basic:** Emphasise that the boundaries between regions are arbitrary and conventional – a snake or an insect have different end wavelengths for their visible regions. (**W**) Emphasise that electromagnetic wave properties change gradually as the frequency changes. (**W**) Avoid referring to “The seven types of electromagnetic radiation”. **Basic/challenging:** This topic provides ideal material for learner projects. The learners can research these areas themselves and then talk to the rest of the class about what they have found. There is a huge amount of information published on the internet and the difficulty is likely to be keeping it accurate and relevant.
15(e)	Discuss the role of the following components in the stated applications: (1) radio waves: radio and television communications (2) microwaves: satellite television and telephone (3) infra-red: household electrical appliances, television controllers and intruder alarms (4) light: optical fibres in medical	

Syllabus ref	Learning objectives	Suggested teaching activities
	uses and telephone (5) ultra-violet: sunbeds, fluorescent tubes and sterilisation (6) X-rays: hospital use in medical imaging and killing cancerous cells, and engineering applications such as detecting cracks in metal (7) gamma rays: medical treatment in killing cancerous cells and engineering applications such as detecting cracks in metal	The electromagnetic spectrum: **http://imagine.gsfc.nasa.gov/docs/science/know_l1/emspectrum.html** and **www.bbc.co.uk/learningzone/clips/the-electromagnetic-spectrum/10676.html** and **http://scienceaid.co.uk/physics/waves/emspectrum.html** Uses of e.m. radiation: **www.s-cool.co.uk/gcse/physics/uses-of-waves/revise-it/electromagnetic-spectrum** and **www.youtube.com/watch?v=snNwE6txxP0**

Past paper and specimen papers
Past paper questions: Nov 12 Paper 21 Q5 Nov 12 Paper 21 Q6 Jun 12 Paper 21 Q5 Jun 12 Paper 21 Q6 Jun 12 Paper 22 Q5 Past question papers available at: **http://teachers.cie.org.uk**

Unit 3: Atoms and radioactivity

Recommended prior knowledge

Learners will have heard about atoms and electrons but are very unlikely to have a very clear idea of what they are. It would be helpful if learners had already encountered atoms as building-bricks in chemistry and had some conception of just how small they are. Similarly, learners will have met electric charge in more domestic circumstances but this quantity is not properly encountered until the next unit and teachers should be aware that, for learners, it is not necessarily a fully understood branch of the subject. Element, ionising and random are words which might well be used freely by the teacher whilst remaining something of a mystery to the learners. The word radioactive will have been encountered mostly in negative and dangerous contexts. Furthermore, some learners will not realise that the Sun is just an ordinary star and this ought to be stated specifically in the final sections.

Context

This unit deals with the structure of ordinary matter and as a result it presents ideas which are vital in many scientific contexts ranging from engineering and materials science to pharmacology. The ideas included will be fundamental to many other sections of the syllabus and if the numerical order of units is not followed, the first parts of this unit must be dealt with at an early stage.

Outline

The first half of this unit describes the structure of an atom and the evidence for the nuclear theory. Learners learn about the three constituent particles which make up atoms and their arrangement within it. Terms like isotope will be explained. The second half deals with radioactivity and the properties of alpha-, beta- and gamma-radiation. The fission of large atoms and the fusion of hydrogen atoms in stars will be explained and, then, some elementary mathematics is needed for the definition of half-life and is used in calculations.

Classroom organisation and differentiation details: **W**: whole class; **G**: group; **I**: individual

Syllabus ref	Learning objectives	Suggested teaching activities
27(a)	Describe the structure of the atom in terms of nucleus and electrons.	**Basic:** Learners have probably heard of atoms and that there are roughly 90 different types which combine to make all substances. They have probably heard about electrons. State that these particles are small objects which carry negative charge. They are important in: ionisation (chemistry), electrostatics (Unit 4), current electricity (Unit 4), electrolysis (chemistry), beta-emission (26(a)) and thermionic emission (Unit 10). (**W**) Electrons occur in: electrical conduction in gases and electrical and thermal conduction in metals (Unit 5). Some of these effects are found in all substances. Electrons are fundamental particles. There are electrons in all atoms.

Syllabus ref	Learning objectives	Suggested teaching activities
		Electrons: **www.aip.org/history/electron/** and **www.youtube.com/watch?v=ky1Awa0pJ0s** Atomic structure: **www.purchon.com/chemistry/atoms.htm** and **www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/atomic/atomstrucrev1.shtml** and **www.youtube.com/watch?v=jRVjDKesnY4**
27(b)	Describe how the Geiger-Marsden alpha scattering experiment provides evidence for the nuclear atom.	**Basic:** Describe the experiment. Three possible results: (1) Nearly all alpha particles pass straight through. The atom is almost entirely empty space. (2) A few particles are deflected through noticeable angles. There is something in the foil. (3) A very few particles rebound through very large angles. There is something in the foil which is very small, very dense and repels alpha particles (positive). (**W**) Emphasise the extreme inequality in the distribution of matter within the atom. ~99.95 % of the mass is concentrated in ~10^{-12} % of the volume. Use a **local** comparison. E.g. a pea in a local football stadium. (**W**)
27(c)	Describe the composition of the nucleus in terms of protons and neutrons.	**Basic:** Since the electrons are negative and easy to remove (electrostatics, ionisation, thermionic emission), they must be in the outer orbits and keep atoms apart. The nucleus is the dense and positive centre of the atom. State that the nucleus is made up of positive and neutral particles of very similar mass. These are protons and neutrons. (**W**) The helium nucleus is four times more massive than that of hydrogen but has only twice the charge. The neutral particles keeping the two protons apart also have mass. (**W**) The nuclear atom: **www.nuffieldfoundation.org/practical-physics/developing-model-atom-nuclear-atom**

Syllabus ref	Learning objectives	Suggested teaching activities
		Protons and neutrons: www.bbc.co.uk/schools/gcsebitesize/science/add_ocr_pre_2011/periodic_table/atomicstructurerev1.shtml
27(d)	Define the terms *proton number* (atomic number), Z and *nucleon number* (mass number), A.	**Basic:** The proton number determines the number of electrons in the neutral atom and so it determines the chemical properties of that substance. It is the atomic number. (**W**) All carbon atoms have 6 protons and all atoms with 6 protons are carbon and so on. The nucleon number determines the mass of the nucleus and is sometimes called the mass number. Avoid the term “neutron number” as it is easily confused with “nucleon number”. (**W**) **Challenging:** Two atoms with the same proton number may have a different number of neutrons. They have the same chemical properties (because they have the same number of electrons in a neutral atom) but are not identical. They are different isotopes of the same atom. Emphasise that the proton number alone determines the chemical properties. ^{12}C and ^{13}C are identical chemically. (Or use another example.) ^{12}C and ^{13}C are **both** isotopes of carbon. Use the nuclide notation here before radioactivity is mentioned. (**G W**) Isotopes: www.colorado.edu/physics/2000/isotopes/index.html and http://hyperphysics.phy-astr.gsu.edu/hbase/nuclear/nucnot.html and www.chem4kids.com/files/atom_isotopes.html
27(f)	Define the term isotope.	
27(g)	Explain, using nuclide notation, how one element may have a number of isotopes.	

Syllabus ref	Learning objectives	Suggested teaching activities
26(k)	Describe how radioactive materials are handled, used and stored in a safe way.	**Basic:** Explain dangers of nuclear radiation, include: burns, sickness, biological cell damage, cancer, cell mutation. (**W**) Rules include: use the minimum activity, keep your distance, insert protective layers. It is essential to state the rules and to **obey** them. Emphasise that alpha-, beta- and gamma-radiation do not make other materials radioactive when they are absorbed. (**W**) Radioactive safety: **www.bbc.co.uk/schools/gcsebitesize/science/ocr_gateway_pre_2011/living_future/4_nuclear_radiation4.shtml**
26(a)	Describe the detection of alpha-particles, beta-particles and gamma-rays by appropriate methods.	**Basic:** Where possible, bring radioactive samples near to a GM tube or a spark counter. Use an old, luminous watch or altimeter or suitable rocks if educational samples are not available. Such substances are emitting something. (**G W**) The radiations can also be detected by a variety of devices. Only one method of detection needs to be learnt by the learners. **Challenging:** State that some substances cause the exposure of nearby photographic plates – this was how radioactivity was discovered. Describe the tracks in a cloud chamber. Detecting radiation: **www.darvill.clara.net/nucrad/detect.htm** and **www.bbc.co.uk/schools/gcsebitesize/science/aqa_pre_2011/radiation/radioactiverev5.shtml** Cloud chamber: **www.youtube.com/watch?v=ltdSjJKmyDY**
26(c)	State for radioactive emissions, their nature, relative ionising	**Basic:** Where possible use a mixed source and show that there are three types of emission which have distinct

Syllabus ref	Learning objectives	Suggested teaching activities
	effects and relative penetrating powers.	properties: Alpha (α) heavily ionising but easily absorbed. Beta (β) less ionising but less easily absorbed. Gamma (γ) weakly ionising but difficult to absorb completely. Tabulate the properties of the three types of radiation. Include: particle/wave, charge, mass, ionising strength, penetration strength, nature, behaviour in electric and magnetic fields. (**W**) Radiation properties: **www.physics.isu.edu/radinf/properties.htm** and **http://web.princeton.edu/sites/ehs/osradtraining/radiationproperties/radiationproperties.htm** Electric field effect: **www.youtube.com/watch?v=ZlFz3AAwwBQ** Magnetic field effect: **www.youtube.com/watch?v=adGVpHvEyUU**
26(d)	Describe the deflection of radioactive emissions in electric fields and magnetic fields.	

Syllabus ref	Learning objectives	Suggested teaching activities
26(b)	State and explain the random emission of radioactivity in direction and time.	**Basic:** Measure the count-rate from a source (background radiation will do). Notice that it varies about an average value. Emphasise that whilst random events are utterly unpredictable individually, on a sufficiently large scale, the behaviour is very accurately predictable. (**G W**) (Half-life ideas lead learners to imagine that the number of atoms falls in some manner such as this: 160 → 80 → 40 → 20 → 10 → what happens now? With numbers this small, of course, the behaviour is unpredictable). **Challenging:** Life assurance works on a similar basis. Individual deaths are unpredictable but with a large enough number of customers, the likely number of deaths in a given time varies very little. (**G W**) Random emission: **www.physicsdaily.com/physics/Random** and **http://serc.carleton.edu/quantskills/activities/PennyDecay.html** and **www.youtube.com/watch?v=Utpi5rFSVe0**
26(e)	Explain what is meant by radioactive decay.	**Basic:** Learners should know that radioactive decay is the random emission of alpha-, beta- or gamma-radiation from unstable nuclei. (**G W**) The emissions are unaffected by temperature, pressure and chemical combination. (**W**) At first, consider only two types of radioactive decay: alpha and beta. Then explain that these may occur on their own or with gamma. (**W**) Radioactive decay: **http://lectureonline.cl.msu.edu/~mmp/applist/decay/decay.htm** and **www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/radiation/atomsisotopesrev3.shtml**

Syllabus ref	Learning objectives	Suggested teaching activities
27(e)	Explain the term nuclide and use the notation $^{A}_{Z}X$ to construct equations where radioactive decay leads to changes in the composition of the nucleus.	**Challenging:** When explaining this notation, make it clear that the element X determines what the number Z is and vice versa. E.g. if *Z* = 7, then X is always an N (nitrogen). (**G W**) The equation for the alpha decay of, say, $^{238}_{92}U$ is fairly straightforward. Emphasise that in beta emission a nuclear reaction occurs first: $n \rightarrow p^{+} + e^{-}$. Hence, the superscript and subscript, in $^{0}_{-1}e$, are present to balance the equation. A beta-particle is not made of −1 proton. Emphasise that after the emission of an alpha- or beta-particle, the nucleus may rearrange itself and emit an electromagnetic wave (gamma-ray). No particle is emitted. (**G W**) Notation such as $^{0}_{0}\gamma$ may confuse learners. Nuclide notation: **www.youtube.com/watch?v=nLIgVpTFoFo**
26(f)	Explain the processes of fission.	Avoid explaining fission and fusion together. The words are very similar but the processes are essentially the reverse of each other. **Basic:** State that $^{236}_{92}U$ is explosively radioactive. Bombarding $^{235}_{92}U$ with neutrons may produce this isotope which may lead to a chain reaction. (**W**) A nuclear power station is like a standard steam turbine station powered by coal, oil or gas. It is simply that the mechanism for boiling the water is different. (**G W**) A block diagram can be drawn as a project in groups and the best group then explains the operation of a nuclear power station to the class. **Challenging:** The chain reaction can be modelled with a vertical array of horizontal matches. Light the lowest match but it is too far away from the ones above to ignite them. If a second array of matches interpenetrates the first, distances are reduced and they can all ignite from the bottom upwards. (**W**)
26(g)	Describe with the aid of a block diagram one type of fission reactor for use in a power station.	

Syllabus ref	Learning objectives	Suggested teaching activities
		Fission: http://hyperphysics.phy-astr.gsu.edu/hbase/nucene/fission.html and www.youtube.com/watch?v=kHXMiYsFSrU and www.youtube.com/watch?v=hKhYc9c2Aqs Nuclear power stations: www.technologystudent.com/energy1/nuclear1.htm
26(m)	Discuss the origins and effect of background radiation.	**Basic:** Measure the count-rate in the laboratory. It is never zero. Two sources: natural background radiation – rocks and space. (**I G W**) Man-made exposure – medical diagnosis (include X-rays but emphasise that they are not actually nuclear in origin), medical treatment, power stations, military tests, flying, travel to areas with higher levels and so on. (**W**) There are risks with all levels of exposure and the risk increases with the absorbed dose. Even the highest natural levels seem to pose few health risks. (**W**) **Challenging:** Learners find it difficult to understand that risky procedures are used in hospitals until it is pointed out that most medical procedures (e.g. cutting holes into a patient) involve some risk but that the treatment is usually less hazardous than the disease. (**W**) Background radiation: www.darvill.clara.net/nucrad/sources.htm and www.bbc.co.uk/schools/gcsebitesize/science/ocr_gateway_pre_2011/living_future/4_nuclear_radiation2.shtml and www.youtube.com/watch?v=TdbzShLU30w

Syllabus ref	Learning objectives	Suggested teaching activities
26(i)	Explain what is meant by the term *half-life*	**Challenging:** Quote a specific example: 1 kg of $^{238}_{92}U$ contains ~2.5×10^{24} atoms and has an activity of ~1.2×10^{7} Bq. 2 kg is made of ~5.0×10^{24} atoms and has an activity of ~2.4×10^{7} Bq etc. Therefore $A \propto N$. Draw the graph of $N \rightarrow t$. As the value of *N* falls so does the rate at which it is falling. This graph has the familiar property of halving in a certain constant time. (**W**) Carry out a standard school laboratory determination of half-life or show videos/DVDs of such experiments. Learners plot the graph and calculate the answer. (**I G W**) Paint one face of a large number of small cubes a distinct colour. Model decay by throwing the cubes from a beaker on to the desk and removing those which land with the painted face upwards. Repeat many times. Plot number of cubes left → number of the throw. (**I G W**) Carry out calculations. Only use whole numbers of half-lives but problems which require a background count correction should be included. Half-lives encompass a very wide range of values: billions of years to milliseconds. (**I G W**) Emphasise that the constant time for halving does not depend on the start point. It also takes one half-life to fall from 80% to 40% or from 96% to 48%. Consequently in half-life experiments, the clock can be started at any convenient value. (**W**) **Basic:** Plot height of water in a burette → time after opening tap. This does not give a particularly good curve (because of surface tension) but at least the height does decrease at a decreasing rate. (**I G W**) Half-life: **http://hyperphysics.phy-astr.gsu.edu/hbase/nuclear/halfli.html** and **www.bbc.co.uk/schools/gcsebitesize/science/aqa_pre_2011/radiation/radioactiverev7.shtml** and **www.youtube.com/watch?v=214cwT4v3D8** Half-life calculations: **www.darvill.clara.net/nucrad/hlife.htm**
26(j)	Make calculations based on half-life which might involve information in tables or shown by decay curves.	

Syllabus ref	Learning objectives	Suggested teaching activities
26(l)	Discuss the way in which the type of radiation emitted and the half-life determine the use for the material.	**Basic:** There are many examples but these include: • Alpha emitters are used to deliver radiation locally in medical procedures (e.g. to a tumour inside the brain) and in smoke detectors. • Beta emitters are used when determining the thickness of paper as it is manufactured and the level of fruit juice in a carton. • Gamma emitters are used when radiation has to leave the human body to be detected for diagnosis or when treating internal organs from outside. The half-life must be long enough for the procedure to be accurate but not so long that is constitutes a health hazard. There are so many examples that it is important to make it clear why a certain procedure needs the particular properties of the radiation chosen and why the others would not be effective. (**W**) Learners can work in groups and prepare a lesson on one particular use and explain it to the class (~20 min. per use). Uses of radiation: **www.bbc.co.uk/schools/gcsebitesize/science/ocr_gateway_pre_2011/living_future/4_nuclear_radiation2.shtml** and **www.darvill.clara.net/nucrad/uses.htm** and **www.gcsescience.com/prad24-radioactivity-uses.htm**
26(n)	Discuss the dating of objects by the use of ^{14}C.	**Challenging:** Emphasise that ^{14}C is continuously produced in the upper atmosphere and passes into living things through photosynthesis and digestion; it only occurs in things which were once alive including: wood, bones, seeds. Learners can be unsure about which things were once alive. Its half-live is ~5730 y and after about 20 000 y, the dating is less accurate as little ^{14}C is left. (**W**) **Very challenging:** The process has to be corrected for fluctuations in the prevailing level of ^{14}C. This is done using the tree rings of ancient redwood trees – dendrochronology. (**I G**)

Syllabus ref	Learning objectives	Suggested teaching activities
		Radiocarbon dating: www.c14dating.com and http://archaeology.about.com/od/rterms/g/radiocarbon.htm and www.youtube.com/watch?v=GfiNewvZA4I
26(f)2	Explain the processes of fusion.	**Basic:** Emphasise that the Sun and all stars have burnt for too long and given off too much energy for their power source to be chemical. It is now known that it is powered by four hydrogen atoms merging into one helium atom. This process is highly exothermic. (**W**) Learners should know that: 2 H + 2 H → He + energy (in some way). (**W**) **Challenging:** Stars are formed when clouds of gas and dust collapse under gravity, the temperature increases until the hydrogen nuclei can fuse. Stars are in balance when the pressure caused by the fusion reaction balances that caused by gravitational attraction. (**W**) Emphasise that both the fusion of small nuclei and the fission of large ones release energy. A different rule applies at the two ends of the periodic table (**W**) Nuclear fusion: www.jet.efda.org/pages/content/fusion1.html and www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/radiation/nuclearfissionrev2.shtml and www.frankswebspace.org.uk/ScienceAndMaths/physics/physicsGCSE/nuclearFusion.htm Star formation: www.s-cool.co.uk/gcse/physics/space/revise-it/life-of-stars and www.gcse.com/eb/star1.htm
26(h)	Discuss theories of star formation and their energy production by fusion.	

Past paper and specimen papers
Past paper questions: Nov 12 Paper 22 Q7 Nov 12 Paper 22 Q8 Nov 11 Paper 21 Q8 Jun 11 Paper 22 Q8 Nov10 Paper 22 Q7 Past question papers available at: **http://teachers.cie.org.uk**

Unit 4: Moving charges

Recommended prior knowledge

Learners will need to have encountered electrons and should know where they are to be found in the atom. Learners are likely to have some basic understanding of electrostatic charging and this will be useful in coming to grips with electric charge in a more general manner. That charge comes in two distinct types which may cancel out is also worth explaining as, frequently, it is just assumed to be true. It would be useful if learners had encountered the idea of electric current in some domestic or more elementary way before it is properly defined here.

Context

This very substantial unit is an absolutely essential preliminary for the topics which are met in Units 7 and 10. Electricity is a major constituent of any physics course and it is here that the most fundamental ideas are initially explained. Learners do not find these ideas easy or self-evident and so this unit needs to be tackled with particular care.

Outline

The early sections deal with electrostatic charge and some situations in which it is found. The fundamental link between charge and electrons is made explicit at this stage. The electric field can be treated as another field of force and the idea of force lines can be introduced quite naturally with it. The distinction between conductors and insulators is drawn and this leads directly into the relationship between charge and current. The ampere is defined in some imprecise way at this point. This opens up the topic of electrical circuits and all the fundamental ideas follow from the concept of an electric current. E.m.f. and p.d. are introduced, and power and resistance are defined here. Learners will also become very familiar with circuit diagrams and the symbols for many essential conducting components. This is a large and important unit and it should not be rushed.

Classroom organisation and differentiation details: **W**: whole class; **G**: group; **I**: individual

Syllabus ref	Learning objectives	Suggested teaching activities
18(a)	Describe experiments to show electrostatic charging by friction.	Electrostatic experiments are best included in the curriculum at a time when the climate is likely to be less humid and the air dry and warm. **Basic:** Use a rubbed, insulating rod to deflect a trickle of water, make hair stand on end, pick up dust and small pieces of paper. Rub a balloon and it sticks to the wall. (**I G W**) Recall that clothing sticks to your back on dry days, that walking on nylon carpets, leaving cars and touching TV screens causes small electric shocks. A tingling sensation is felt before lightning storms. Use local examples with which the learner will be familiar as climate has an effect. (**I G W**) Use a Van de Graaf generator to show electrostatic effects. **This high voltage device must only be used by a qualified operator and under conditions of the strictest safety. Ensure that any learner involved**

Syllabus ref	Learning objectives	Suggested teaching activities
		does not have a medical heart condition or other condition preventing them from taking part. (**W**) Theatre of Electricity: **www.mos.org/sln/toe/toe.html** Van de Graaf generator: **www.howstuffworks.com/vdg.htm** and **www.youtube.com/watch?v=sy05B32XTYY**
18(d)	State that unlike charges attract and that like charges repel.	**Basic:** These effects are most easily shown by balancing charged rods on a lens or watch glass. Nylon and cellulose acetate are much easier to use than glass and ebonite). (**I G W**) Use a gold-leaf electroscope to show repulsion of the leaf. (**I G W**) The gold-leaf electroscope is not mentioned in the syllabus but it does show several aspects of electrostatics fairly easily. The Gold-Leaf Electroscope: **www.youtube.com/watch?v=5j4piAI_igE** The Basic Law: **www.youtube.com/watch?v=F6v8wm7_vdQ**

Syllabus ref	Learning objectives	Suggested teaching activities
18(c)	State that there are positive and negative charges and that charge is measured in coulombs.	**Basic:** Use several different charged rods. There are only two types of behaviour and only two types of charge. (**I G W**) Use two rods of different materials together to show a reduced effect. (**I G W**) One type of charge cancels the other and so they may be called positive and negative. (**I G W**) **Challenging:** Set up a series circuit with an EHT supply, two separated metal plates and a very sensitive galvanometer or coulombmeter. A table-tennis ball (with a conducting coating) shuttles between the two plates and a reading is recorded. **The high voltage EHT supply must only be used by a qualified operator and under conditions of the strictest safety.** (**W**) Types of charge: **www.physicsclassroom.com/class/estatics/u8l1c.cfm** and **www.youtube.com/watch?v=45AAlI9_lsc**
18(b)	Explain that charging of solids involves a movement of electrons.	**Basic:** State this as a fact. Learners have probably heard of electrons (even if Unit 3 has not been taught) and know they are negative. Emphasise that the negative charges move and that positive objects have lost electrons. (**W**) A can containing a duster is on a gold-leaf electroscope. Take a nylon rod from the can which rubs against the duster. The leaf deflects. Reinsert the rod. The deflection collapses. Hence the positive charge on one object is equal to the negative charge on the other. (**I G W**) Charging by friction: **www.physicsclassroom.com/class/estatics/u8l2a.cfm** and **www.youtube.com/watch?v=d1RbFxTpn_g**

Syllabus ref	Learning objectives	Suggested teaching activities
18(e)	Describe an electric field as a region in which an electric charge experiences a force.	**Basic:** Emphasise the idea that actions occur near to a charged object: pick up small pieces of paper, dust on polished glass, clothing sticks to back, crackling near overhead power cables. Electric field: http://hyperphysics.phy-astr.gsu.edu/hbase/electric/elefie.html and www.youtube.com/watch?v=WcSSWN4Tnoo
18(f)	State the direction of lines of force and describe simple field patterns.	**Basic:** Plot field patterns with EHT supply, electrodes and semolina grains in cooking oil. **The high voltage EHT supply must only be used by a qualified operator and under conditions of the strictest safety.** (**W**) Avoid comparing electric and magnetic fields at this early stage, it confuses. Learners can become adept at drawing electrostatic fields. (**I G W**) Give them a few rules: • field lines do not cross • field line leave conductors at right angles • arrows point from + to –. Try: ball to ball, plate to plate, ball to plate, cloud to city skyline/trees/ cars. Plotting field patterns: www.physicslab.co.uk/Efield.htm Electric fields: www.colorado.edu/physics/2000/waves_particles/wavpart3.html
18(g)	Describe the separation of charges by induction.	**Basic:** Two metal balls on insulating stands are touching. Bring a rod near to **one** ball. Separate the balls and check the charges using a gold-leaf electroscope. (**I G W**) **Challenging:** Charge a gold-leaf electroscope itself by induction. (**I G W**)

Syllabus ref	Learning objectives	Suggested teaching activities
		Electrostatic Induction: **www.s-cool.co.uk/gcse/physics/static-and-current-electricity/revise-it/static-electricity** and **www.youtube.com/watch?v=U3mxRSTedeY**
18(h)	Discuss the differences between electrical conductors and insulators and state examples of each.	**Basic:** Use a low voltage d.c. circuit with a lamp to test common materials. (**I G W**) Try to discharge a gold-leaf electroscope through these common materials. Can the charge pass through people? (**I G W**) **Do not try to pass electric currents through people.** Standing on a rubber sheet or polythene bag and repeat. (**I G W**) Learners will see that the nearly all the best electrical conductors are metals. Notice that wood does not conduct a current but does discharge an electroscope. **Never use a wooden object to rescue someone who is being electrocuted.** Conductors and insulators: **www.ndt-ed.org/EducationResources/HighSchool/Electricity/conductorsinsulators.htm** Earthing: **www.youtube.com/watch?v=NK-BxowMIfg**
18(i)	State what is meant by "*earthing*" a charged object.	

Syllabus ref	Learning objectives	Suggested teaching activities
18(j)	Describe examples where charging could be a problem, e.g. lightning.	**Basic:** Spark hazard: (1) On oil tankers sailors wear special conducting shoes. (2) Aeroplanes and filling station tanks are electrically connected to the tanker when being filled with fuel. (3) Small shocks in cars or large carpeted shops. Conductors solve these problems, e.g. slightly conducting aeroplane tyres discharge landing planes slowly, lightning conductors. (**I G W**) Lightning: **www.fi.edu/weather/lightning/science.html** and **www.sciencemadesimple.co.uk/page179g.html**
18(k)	Describe examples where charging is helpful, e.g. photocopier and electrostatic precipitator.	**Challenging:** Explain how these devices work. Learners can be given sheets with printed diagrams of different stages in the procedure and can label or complete them. (**I G W**) Concentrate on the charge placed on the photosensitive drum surface and how light enables it to be removed. In a photocopier, a mirror image is formed twice which restores the original pattern. This is an interesting occurrence in its own right. Use as the image something which lacks left/right and top/bottom symmetry. E.g. a large letter F, L or R. Photocopier: **www.bbc.co.uk/schools/gcsebitesize/science/add_gateway_pre_2011/radiation/electrostaticsusesrev1.shtml** Electrostatic precipitator: **www.frankswebspace.org.uk/ScienceAndMaths/physics/physicsGCSE/usingStatic.htm** Electrostatic spraying: **www.youtube.com/watch?v=leapiWpg0Gc** and

<table>
<tr><th>Syllabus ref</th><th>Learning objectives</th><th>Suggested teaching activities</th></tr>
<tr><td></td><td></td><td>www.slideshare.net/awkf2000/16-static-electricity</td></tr>
<tr><td>19(a)</td><td>State that a current is a flow of charge and that current is measured in amperes.</td><td rowspan="3">Basic:
Refer to the shuttling ball experiment. Set up a series circuit with an ammeter, large resistance and a coulombmeter. Plot charge → time. (W)

Use a larger current.

Emphasise that a current is a “loop flow” of charge which is the mechanism for energy (not properly defined until Unit 6) transfer. The bicycle chain is a reasonably good analogy for a current.

Allow learners to predict how current varies at different places in a series circuit. Then allow them to test their predictions. (I G W)

Use the word current rather than amperage.

Challenging:
Measure the current in different branches of parallel circuits. Currents split but the total remains the same. Change the resistance of some branches. Compare with water in supply pipes or the movement of the links in a bicycle chain. (I G W)

Electric current:
http://hyperphysics.phy-astr.gsu.edu/hbase/electric/elecur.html

and
www.physicsclassroom.com/class/circuits/u9l2c.cfm

and
www.bbc.co.uk/schools/ks3bitesize/science/energy_electricity_forces/electric_current_voltage/revise1.shtml</td></tr>
<tr><td>20(b)</td><td>State that the current at every point in a series circuit is the same, and use this in calculations.</td></tr>
<tr><td>20(d)</td><td>State that the current from the source is the sum of the currents in the separate branches of a parallel circuit.</td></tr>
<tr><td>19(b)</td><td>Do calculations using the equation

charge = current × time.</td><td>Basic:
At this stage it is easier to define the ampere as the coulomb/second rather than the more accurate reverse definition. (W)

Some learners find rearranging equations hard, even though in more everyday examples – e.g. 50 km/h for 2 h, distance travelled = 100 km – there seems to be no problem.</td></tr>
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Syllabus ref	Learning objectives	Suggested teaching activities
		Explain that a charged battery stores a certain amount of charge. It can supply 20 A for 2 h or 10 A for 4 h etc. A flat battery cannot supply charge. (**I G W**) Current and charge: **www.youtube.com/watch?v=AIkT78RRM5Q** and **http://physicsnet.co.uk/a-level-physics-as-a2/current-electricity/charge-current-potential-difference/**
19(c)	Describe the use of an ammeter with different ranges.	**Basic:** This will be covered as learners use ammeters in different experiments. Learners should know how to use the ammeters **they** deal with. There is no substitute for experience with the meters themselves. (**I G W**) Using a multimeter: **www.dNovronics.co.uk/meter.htm** and **www.youtube.com/watch?v=bF3OyQ3HwfU**
19(d)	Explain that electromotive force (e.m.f.) is measured by the energy dissipated by a source in driving a unit charge around a complete circuit.	**Basic;** First explain that e.m.f. is the property of a source of electrical energy, include: cells, generators. (**W**) If a circuit is left on for twice as long it transfers, twice as much energy and twice as much charge flows in the circuit (Unit 5). Hence energy/charge is a constant. (**W**) Heat water in a polystyrene cup with a low voltage (this word is hard to avoid) immersion heater. Plot temperature → time; this is equivalent to energy → charge. (**I G W**) Difference between e.m.f and p.d: **www.nuffieldfoundation.org/practical-physics/potential-difference-and-emf** Energy and voltage: **www.bbc.co.uk/bitesize/higher/physics/elect/energy_volts/revision/3/** and **http://hyperphysics.phy-astr.gsu.edu/hbase/electric/elevol.html**

Syllabus ref	Learning objectives	Suggested teaching activities
19(e)	State that e.m.f. is work done/charge.	**Challenging:** There are a variety of analogies possible for this difficult idea: The Coulomb Brothers carry sacks of joules around the circuit. They drop the joules off at the appliance and return with an empty sack. (**G W**) There is a fixed number of joules/coulomb. (**W**) Coal lorries/trains travel in a continuous loop from the coal mine to the power station and travel back empty. There is a fixed amount of energy per lorry. (**W**) P.d: **www.physicsclassroom.com/class/circuits/u9l1c.cfm** and **www.youtube.com/watch?v=-2epDX0mF4I**
19(f)	State that the volt is given by J/C.	
19(g)	Calculate the total e.m.f. where several sources are arranged in series and discuss how this is used in the design of batteries.	**Basic:** Carry out the measurement with a voltmeter. (**I G W**) Consider car batteries (6 × 2.0 V) and PP9s (6 × 1.5 V). Keep a PP9 which has been sawn in half and show the six layers. (**W**) Cells in series and parallel: **www.batteryuniversity.com/partone-24.htm**
19(h)	Discuss the advantage of making a battery from several equal voltage sources of e.m.f. arranged in parallel.	**Basic:** Refer back to 20(d). Charge up a model lead-acid cell for a few minutes. Discharge it through a torch lamp and time how long it takes. Repeat with two lead cells in parallel, each of which was charged for the same time and with the same current as the previous cell. (**I G W**) Several cells in parallel: **www.allaboutcircuits.com/vol_6/chpt_3/3.html** and **http://electronics.howstuffworks.com/everyday-tech/battery6.htm**

Syllabus ref	Learning objectives	Suggested teaching activities
19(i)	State that the potential difference (p.d.) across a circuit component is measured in volts.	**Challenging:** This can be done by referring back to the definition of e.m.f. The p.d. however, is concerned with where the energy ends up, not where it comes from. (**W**) Potential difference: **www.regentsprep.org/Regents/physics/phys03/apotdif/default.htm** and **www.bbc.co.uk/schools/gcsebitesize/design/electronics/calculationsrev1.shtml**
19(j)	State that the p.d. across a component in a circuit is given by the work done in the component/charge passed through the component.	
19(k)	Describe the use of a voltmeter with different ranges.	**Basic:** Learners learn how to use the meters to which **they** have access by carrying out their own experiments. (**I G**) Using a multimeter: **www.dNovronics.co.uk/meter.htm**
19(l)	State that *resistance = p.d./current* and use the equation *resistance = voltage/current* in calculations.	**Basic:** Perform the experiment for a metal/carbon conductor, plot $V \rightarrow I$. Measure the gradient. State "This is a 50 V/A conductor" or whatever value it is. Repeat with other values and plot on the same axes. "These are 20 V/A or 10 V/A conductors." (**I G**) This value tells us how hard it is to send a current through the conductor. The 50 V/A is offers more resistance than the 10 V/A. Resistance is measured in V/A – also called the ohm, Ω. The Ohm Law: **http://phet.colorado.edu/en/simulation/ohms-law** and **http://hyperphysics.phy-astr.gsu.edu/hbase/electric/ohmlaw.html** and **www.youtube.com/watch?v=uLU4LtG0_hc** Current and voltage: **http://jersey.uoregon.edu/vlab/Voltage/**
19(m)	Describe an experiment to measure the resistance of a metallic conductor using a voltmeter and an ammeter and make the necessary calculations.	

Syllabus ref	Learning objectives	Suggested teaching activities
19(q)	Describe the effect of temperature increase on the resistance of a resistor and a filament lamp and draw the respective sketch graphs of current/voltage.	**Basic:** Plot $V \rightarrow I$ for a tungsten filament bulb. Why is it not a straight line? Why is it harder to send a current through the filament when it is hot? (Temperature is not covered until Unit 6 but learners are likely to be aware of elementary kinetic theory). (**I G**) **Challenging:** When filament bulbs blow, why is it when they are switched on? The current surge occurs because the resistance is low when they are switched on. (**I G W**) Use an ohmmeter to measure the resistance of a small low voltage bulb (e.g. 6 V) heated up in a water bath or sprayed with a cooling spray. It requires a little time for the bulb's filament to reach any temperature outside. (**I G W**) Temperature dependence of resistance: **http://physics.info/electric-resistance/** and **www.youtube.com/watch?v=rNsykkSR3wg** and **www.youtube.com/watch?v=LeOTKXBM5KI**
19(n)	Discuss the temperature limitations on Ohm's Law.	
19(o)	Use quantitatively the proportionality between resistance and the length and the cross-sectional area of a wire.	**Basic:** Plot $V \rightarrow I$ for wires of different lengths and compare gradients. Or use an ohmmeter. Use a poor conductor with a significant resistance for a short length. Plot $R \rightarrow x$. (**I G**) Repeat for different cross-sectional areas. (**I G**) Use conducting putty which can be extruded into cylinders of different cross-sectional areas and different lengths. (**I G W**) Dependence on length and area: **www.regentsprep.org/Regents/physics/phys03/bresist/default.htm** and **www.youtube.com/watch?v=R4qFnKnZEOA** and

Syllabus ref	Learning objectives	Suggested teaching activities
		www.youtube.com/watch?v=xg2pEzP-mlQ
19(p)	Calculate the net effect of a number of resistors in series and parallel.	**Basic:** Plot $V \rightarrow I$ for parallel and series combinations. (**I G**) Emphasise: • A thick wire is just many thin ones laid side by side. • A long wire is just many short ones laid end to end. **Challenging:** Measure the resistance of networks made of *n* parallel branches of *n* resistors. How hot do the resistors get? Why do they not get as hot? (**I G W**) Resistors in parallel and series: http://schools.matter.org.uk/Content/Resistors/Default.htm and http://physics.bu.edu/py106/notes/Circuits.html
19(r)	Describe the operation of a light-dependent resistor (LDR).	**Basic:** Measure *R* at different light intensities for a LDR. It is difficult to measure the intensity easily or accurately but definite fractions of a standard intensity can be used by letting the light pass through a variable aperture. E.g. cut ever bigger holes in a piece of cardboard. (**I G W**) LDRs: www.dNovronics.co.uk/ldr_sensors.htm and www.bbc.co.uk/schools/gcsebitesize/design/electronics/componentsrev4.shtml
20(a)	Draw circuit diagrams with power sources (cell, battery or a.c. mains), switches (closed and open), resistors (fixed and variable), light-dependent	**Basic:** These symbols are best learnt gradually in the course of describing experiments or when learners write them up. It is not a good idea to produce a sheet containing all the symbols at the beginning of this section; this

Syllabus ref	Learning objectives	Suggested teaching activities
	resistors, thermistors, lamps, ammeters, voltmeters, magnetising coils, bells, fuses, relays, light-emitting diodes and rectifying diodes.	generates confusion. The teacher might, however, keep a record of the symbols encountered by the learners as the course progresses and give out a full sheet when they have all been encountered separately. **Challenging:** Rectifying diodes do not feature largely elsewhere in this syllabus and it might be sensible to investigate their conduction characteristics at this point. This can be done simply with a d.c. ammeter or a c.r.o. can be used and the effect of an a.c. looked at. (**G W**) Circuit symbols: **www.gcse.com/circuit_symbols.htm** and **www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/electricity/circuitsrev1.shtml**
20(c)	State that the sum of the potential differences in a series circuit is the equal to the potential difference across the whole circuit and use this in calculations.	**Basic:** Reminder: p.d. is concerned with where the energy ends up. Consider two resistors (AB and BC) in series. The energy which ends up between terminal A and C (i.e. in the two resistors) is equal to that which ends up between A and B added to that between B and C. (**W**) Set up a series circuit and show this. Use the opportunity to include a section of circuit with resistors in parallel. Note these resistors all have the full p.d. of that section of the circuit across them which only counts once when finding the total p.d. across the circuit. (**I G W**) p.d.s in series: **www.bbc.co.uk/schools/gcsebitesize/science/add_ocr_pre_2011/electric_circuits/parallelandseriesrev3.shtml**
20(e)	Do calculations on the whole circuit, recalling and using formulae including $R = V/I$ and those for potential differences in series, resistors in series and resistors in parallel.	**Basic/challenging:** Learners will need to practise answering questions starting with simple circuits (one cell, one ammeter and one resistor) and gradually try more complicated arrangements as they become more proficient. (**I G W**) Resistance: **http://hyperphysics.phy-astr.gsu.edu/hbase/electric/resis.html** and **www.physicsclassroom.com/class/circuits/u9l3b.cfm**

Past paper and specimen papers
Past paper questions: Nov 12 Paper 21 Q7 Jun 12 Paper 21 Q7 Jun 12 Paper 22 Q7 Nov 11 Paper 21 Q5 Nov 11 Paper 22 Q6 Past question papers available at: **http://teachers.cie.org.uk**

Unit 5: Energy and energy sources

Recommended prior knowledge

Most learners will have some concept of energy in a general industrial or domestic sense but they are less likely to be as precise in their understanding as the subject demands at this level. An elementary experience of the distinctions between the different forms of energy would be useful even at the start of this unit.

Context

Since energy is one of the fundamental ideas which underpin the whole of this subject, this is another fundamental unit. In the first section, however, one can afford to leave the idea of energy less than properly defined. It does lead into the full and fundamental definition, however, and at that point more care will be needed as the concepts and definitions are used throughout the rest of the course.

Outline

At first, the fairly gentle topic of energy transformation and energy sources is dealt with. There are few difficult or abstract ideas here and it lends itself to a less mathematical treatment than many other areas. It is desirable, however, to keep the subject as precise as possible and to make sure that learners do not start using terms like power, energy and force interchangeably. It is essential that when energy is properly defined in the second half of this unit, it is done carefully and that its structural importance as a concept is thoroughly emphasised. The terms kinetic and potential energy can be used quantitatively and the definition of work is included. Efficiency and power can be fully defined here, even if they have featured in previous units. The formula, $E = mc^2$, will excite some learners who will believe that they are now real physicists – encourage them. Finally the environmental consequences of power generation will return them to more straightforward and familiar areas.

Syllabus ref	Learning objectives	Suggested teaching activities
8(a)	List the different forms of energy with examples in which each form occurs.	It is probably best to name and describe the different forms of energy as they occur in the course rather than to list them in a somewhat abstract and artificial way all at once. At some point, however, it makes sense to list the energy forms which have been encountered and to ensure that learners can identify which form of energy is most important in a given change. Energy cannot be properly defined until work done has been defined (later in this unit), but most learners will have some idea of what energy means here. Types of energy: **www.zephyrus.co.uk/energy1.html** and **www.gcse.com/energy/types.htm** and

Syllabus ref	Learning objectives	Suggested teaching activities
		http://powermin.nic.in/kids/types_of_energy.htm
8(b)	State the principle of the conservation of energy and apply this principle to the conversion of energy from one form to another.	Consider some particular examples of energy change. Ask What energy changes occur in a hydroelectric power station? What energy changes occur when electrical energy is used domestically in the cooker? an electric drill? a mobile telephone charger? What energy changes occur in a motor vehicle? When it is going uphill? As it accelerates? What energy changes occur in a nuclear power station? Conservation of energy: **http://hyperphysics.phy-astr.gsu.edu/hbase/conser.html** and **www.physicsclassroom.com/mmedia/energy/ie.cfm** Energy transformations: **www.physicsclassroom.com/mmedia/energy/pe.html** and **www.youtube.com/watch?v=cOqSGP6kpmU** and **www.youtube.com/watch?v=MIqSg4JSJt8**
8(d)	List renewable and non-renewable energy sources.	This can be quite an arid topic if taught conventionally but it does lend itself to project work. Learners might research the whole topic individually or a small group of learners might research one type of renewable energy and then explain their findings to the whole class. It is important that learners remember that this is a physics project and they should make clear the origins of the energy source as well as any environmental benefits; e.g. hydrogen is not a source of renewable energy since it has to be generated by some means. What is the learner proposing as the source of the energy to generate it?
8(e)	Describe the processes by which energy is converted from one form to another, including reference to: (1) chemical/fuel energy (a regrouping of atoms) (2) hydroelectric generation (emphasising the mechanical energies involved)	

Syllabus ref	Learning objectives	Suggested teaching activities
	(3) solar energy (nuclei of atoms in the Sun) (4) nuclear energy (5) geothermal energy (6) wind energy.	Learners should understand that renewable energy does **not** mean that it can be 'used again', rather that it is being renewed as it is used so that it will 'not run out'. Emphasise that the Sun is the ultimate source of most energy consumed on Earth but that this is not true of geothermal energy, nuclear energy and tidal energy. Discuss whether wood is a renewable or non-renewable source of energy. It can be renewed by planting new trees but this is not always done. Non-renewable energy sources: **www.bbc.co.uk/schools/gcsebitesize/geography/energy_resources/energy_rev1.shtml** Renewable energy sources: **www.renewableenergyworld.com/rea/tech/home** and **www.youtube.com/watch?v=kVskMh0Etcs** and **www.factmonster.com/ipka/A0907040.html**
8(j)	Calculate work done from the formula *work = force × distance moved in the line of action of the force*.	Emphasise the difference between doing work and getting tired. A human gets tired supporting a weight at a constant height even though no work is being done. Likewise no work is done against gravity when a suitcase is moved horizontally. Give many examples including: lifting a load vertically upwards, rolling a barrel up a plank at an angle, removing an electron from an atom, excited nuclei rearranging themselves after radioactive decay (gamma-radiation). The formula *mgh* comes from *force × distance.* Doing work is the same as transferring energy and energy is the ability to do work. The two quantities are inextricably intertwined. This is true quantitatively and so they have the same unit. The formula $\frac{1}{2}mv^2$ can be deduced from $F = ma$ and $a = (v^2–u^2)/2s$. It is probably better just to state it at this stage.
8(c)	State that kinetic energy is given by $E_k = \frac{1}{2}mv^2$ and that gravitational potential energy is given by $E_p = mgh$ and use these equations in calculations.	

Syllabus ref	Learning objectives	Suggested teaching activities
8(j)	Calculate the efficiency of an energy conversion using the formula *efficiency = energy converted to the required form/total energy input.*	Mechanical energy is simply the sum of a body's kinetic and potential energies. Work done: **www.physicsclassroom.com/class/energy/u5l1aa.cfm** and **http://tap.iop.org/mechanics/wep/214/page_46390.html** and **www.youtube.com/watch?v=XrPEpCr-uCc** Gravitational potential energy: **http://hyperphysics.phy-astr.gsu.edu/hbase/gpot.html** and **www.bbc.co.uk/schools/gcsebitesize/science/add_gateway_pre_2011/forces/themeridesrev1.shtml** Kinetic energy: **http://hyperphysics.phy-astr.gsu.edu/hbase/ke.html** and **www.physicsclassroom.com/class/energy/u5l1c.cfm** Mechanical energy: **http://hyperphysics.phy-astr.gsu.edu/hbase/ke.html.**
8(g)	Describe the process of electricity generation and draw a block diagram of the process from fuel input to electricity output.	Emphasise that every energy conversion generates some heat which is usually lost to the surroundings. Try to discourage learners from simply writing "…lost as heat, light and sound". Few systems waste energy as light and those which do lose energy as sound, lose very little when compared to the quantity lost as heat. It is always better to say how the energy is being lost. Energy is lost as heat because of friction between the moving parts. Figures on energy input and output are usually available from a local power station and this may even be a convenient place in the course to arrange a visit. A discussion of power station efficiency might include more efficient systems including combined power and heat (C.P.H.) Power station efficiency: **www.bbc.co.uk/schools/g**
8(k)	Discuss the efficiency of energy conversions in common use, particularly those giving electrical output.	
8(l)	Discuss the usefulness of energy output from a number of energy	

Syllabus ref	Learning objectives	Suggested teaching activities
	conversions.	and **www.makingthemodernworld.org.uk/learning_modules/geography/06.TU.06/?section=6**
8(m)	Calculate the power from the formula *power = work done/time taken.*	This definition gives a specific meaning to power which is distinct from energy. Power is always: the rate of change of something measured in joules. Give examples: the rate of doing work, the rate of losing heat, the rate of generating energy, etc. Work and power: **www.physicsclassroom.com/Class/energy/U5L1a.html** and **www.physicsclassroom.com/class/energy/u5l1e.cfm**
8(f)	Explain nuclear fusion and fission in terms of energy releasing processes.	These two opposite processes both release energy but emphasise that fusion only releases energy for small nuclei and fission for large ones. Quote the accurate masses of the proton, neutron and helium nucleus and show that $m_{He} < 2m_p + 2m_n$. Consider a few **specific** examples of fission such as: $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3\,^{1}_{0}n$ Energy in fission and fusion: **www.energyquest.ca.gov/story/chapter13.html**
8(h)	Discuss the environmental issues associated with power generation.	Start a class discussion. Groups put forward the merits of building a particular sort of power station for their country/community. Learners tend to concentrate on the negative aspects of power generation: global-warming, pollution, radioactive discharges and health effects. They should be reminded of the importance of an adequate power supply. Environmental issues: **www.gcse.com/energy/climate_change.htm** and **www.succeedingwithscience.com/resources/energyandtheenvironment/**

Past paper and specimen papers
Past paper questions: Nov 12 Paper 21 Q3 Nov 12 Paper 22 Q3 Jun 12 Paper 21 Q2 Nov 11 Paper 21 Q2 Jun 11 Paper 21 Q3 Past question papers available at: **http://teachers.cie.org.uk**

Unit 6: Thermal energy and matter

Recommended prior knowledge

Learners should have encountered some basic ideas concerning heat and temperature and the difference between them needs to be made clear e.g. a spark has a high temperature but can emit only a little thermal energy whilst the polar sea is cold but the internal energy of all its molecules is large. Many learners will not distinguish between electrical and thermal conduction and will, also, need to be put straight. Learners will need to know terms like insulation and radiation (applied to I.R. radiation). Some elementary kinetic theory is also needed for this unit.

Context

This unit introduces the topic of thermodynamics – another hugely significant area of physics. Many large industries rely on its being understood. This unit could be fitted into a course almost anywhere since it is, to some extent, independent of many of the concepts on which the other units rely. Energy, however, ought to have been properly defined before it is taught. Heat is often referred to as thermal energy.

Outline

The early ideas of conduction and convection are fairly easy to explain and to understand and many learners will already be aware of these two energy transmission mechanisms. Radiation is likely to prove harder and it is worth ensuring that learners have a clear understanding of this topic before moving on. The effective insulation of buildings is dealt with and the manner in which a thermometer functions will be introduced here. Learners will meet these phenomena: expansion, boiling, melting and evaporation. The definitions of heat capacity, specific heat capacity and specific latent heat are included in this unit.

Classroom organisation and differentiation details: **W**: whole class; **G**: group; **I**: individual

Syllabus ref	Learning objectives	Suggested teaching activities
9(a)	Describe how to distinguish between good and bad conductors of heat.	**Basic:** There are many simple examples. Stir hot tea with plastic, wooden, glass, aluminium, stainless steel and silver spoons/rods. (**I G W**) Poke a fire with, or place in a Bunsen flame, iron, brass and copper rods. (**I G W**) Give practical examples: a saucepan should be made from a good conductor whilst its handle is made from a poor one. There are many others. (**W**) There are several types of simple equipment which show comparative thermal conduction properties. (**I G W**) Heat transfer: www.lanly.com/heating.htm

Syllabus ref	Learning objectives	Suggested teaching activities
		and **www.mansfieldct.org/schools/mms/staff/hand/convcondrad.htm** and **www.bbc.co.uk/schools/gcsebitesize/science/aqa_pre_2011/energy/heatrev1.shtml** Thermal conduction: **http://phun.physics.virginia.edu/topics/thermal.html** and **www.youtube.com/watch?v=XbOQCiGHaZE**
9(b)	Describe, in terms of the movement of molecules or free electrons, how heat transfer occurs in solids.	**Basc:** Use a model of a solid structure (balls joined by springs) and show that shaking one end leads to vibrations at the other. (**W**) In a metal, a vibrating atom can propel electrons a very long distance at high speed. They collide with other atoms far off and set them vibrating. This is a much faster process. (**W**) Learners can be linked together in a line using their arms and vibrations can be sent along the line. (**G W**) Compare metallic conduction with kicking a football the entire length of the pitch. (**W**) Conduction by molecules: **www.schoolphysics.co.uk/age11-14/glance/Heat%20energy/Conduction_of_heat/index.html**
9(c)	Describe convection in fluids in terms of density changes.	Use a Bunsen burner to heat a beaker of water at one side, on the bottom. The convection current can be seen using a few tiny crystals of potassium permanganate at the bottom. (**G W**) Special tubes which link back on themselves in a square shape can be used to illustrate convection. (**G W**) **Challenging:** There is a clear series of events which take place in convection: hot water expands → its density falls → it rises → it pushes away the liquid above it and sucks in the liquid next to it → a circulation is set up. Illustrate convection with specific examples: • wind • heat transmitted around a room

Syllabus ref	Learning objectives	Suggested teaching activities
		• the ice box in a refrigerator cools the area below it. (**W**) Convection: www.bbc.co.uk/schools/gcsebitesize/science/aqa_pre_2011/energy/heatrev1.shtml and www.youtube.com/watch?v=6sAFtRQS9XY
9(d)	Describe the process of heat transfer by radiation.	**Basic:** Hot objects emit I.R. radiation (Unit 6). The hotter the object, the more radiation it emits. At equilibrium, an object absorbs just as much as it emits. Be careful to distinguish between absorption and emission. (**I G W**) Absorption experiment: set up a black can of water and a white can of water in direct sunlight. Determine the temperature rises. Wear a black T-shirt and a white one in direct sunlight. What happens? (**I G W**) Emission experiment: set up the two cans filled with boiling water in the shade. Record the temperature drop with time. (**I G W**) Examples include: • energy from Sun to Earth • electric fires (not radiators) • thermal imaging. **Challenging: Trick question:** Why are polar bears white? **Answer:** Camouflage. IR radiation: www.gcse.com/energy/radiation.htm and www.bbc.co.uk/schools/gcsebitesize/science/aqa/heatingandcooling/heatingrev1.shtml Absorption/emission: http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/absrad.html
9(e)	Describe the effect of surface colour (black or white) and texture (dull or shiny) on the emission, absorption and reflection of radiation.	

Syllabus ref	Learning objectives	Suggested teaching activities
		and **http://thermalphysics.weebly.com/radiation.html**
9(f)	Describe how to distinguish between good and bad emitters and good and bad absorbers of infra-red radiation	**Basic:** Simple experiments measuring the temperature drop of a can of water, a warm piece of metal, or even a thermometer itself, lagged in different ways or given a thin black coating from a sooty candle can be used to illustrate the processes. (**I G W**) **Challenging:** The poor conductivity of air does not itself explain insulation, as most buildings are surrounded by many metres of air. Most heat is transferred to or from buildings and rooms by convection in the air. The principle of most insulation mechanisms is to suppress convection. This is done by trapping the air. It is **then** important that air is a poor conductor of heat. A few insulation techniques are not designed to suppress convection. (**W**) Why is white a popular colour for houses in hot countries? Consider the day and the night. (**I G W**) Insulation: **www.bbc.co.uk/bitesize/standard/physics/energy_matters/heat_in_the_home/revision/1/** and **www.school-for-champions.com/science/thermal_insulation.htm**
9(g)	Describe how heat is transferred to or from buildings and to or from a room.	
9(h)	State and explain the use of important practical methods of heat insulation for buildings.	
10(a)	Explain how a physical property which varies with temperature may be used for the measurement of temperature and state examples of such properties.	**Basic:** Make it clear that the property chosen must change significantly, measurably and always in the same direction (prevents ambiguity). Any property which behaves in this way this will do. Mention: • volume of mercury/ethanol • resistance of platinum • thermoelectric e.m.f. of a thermocouple. (**W**) Thermometric parameters: **www.cartage.org.lb/en/themes/Sciences/Physics/Thermodynamics/AboutTemperature/Development/Development.htm**

Syllabus ref	Learning objectives	Suggested teaching activities
10(b)	Explain the need for fixed points and state what is meant by the *ice point* and the *steam point*.	**Basic:** Two points are needed to draw a straight line (on a graph) and two fixed points are needed to specify exactly every particular, intermediate point. Give some idea of how they are obtained in practice. (**W**) Calibrate a thermometer on which no scale has been marked (use rubber bands or a permanent pen to mark the fixed points), or check a laboratory thermometer. (**I G W**) **Challenging:** Emphasise that the ice point is the only temperature at which ice and water can co-exist and the steam point is the only temperature at which water and steam may co-exist – both at standard atmospheric pressure. (**W**) Fixed points: **www.riverdeep.net/current/2001/11/112601_celsius.jhtml** and **http://resources.edb.gov.hk/cphysics/heat/tep/tempe02_e.html**
10(d)	Describe the structure and action of liquid-in-glass thermometers (including clinical) and of a thermocouple thermometer, showing an appreciation of its use for measuring high temperatures and those which vary rapidly.	**Basic:** Let learners see a variety of liquid-in-glass thermometers with different ranges and sensitivities. Get them to explain why one thermometer has a greater range than another or why the graduations on one thermometer are closer than on another. Let them see that the bulbs have different volumes, the bores are different, the lengths are different and the liquids might well be different. Will these thermometers be linear? How were the points marked on the scale? (**I G**) Consider the difficulty of reading a temperature when the thermometer is in someone's mouth. How can this be solved? How would the learners design a clinical thermometer – one that maintains its maximum reading? (**G W**) Describe and show a thermocouple. (**W**) Discuss its advantages and disadvantages. (**G W**) **Challenging:** Will its readings (between 0 °C and 100 °C) agree with those on the liquid-in-glass thermometer?
10(e)	Describe and explain how the structure of a liquid-in-glass thermometer affects its sensitivity, range and linearity.	
10(c)	Discuss sensitivity, range and linearity of thermometers.	

Syllabus ref	Learning objectives	Suggested teaching activities
		Use a thermocouple to observe the cooling of a beaker of hot water. (**I G W**) Thermometers: **www.bbc.co.uk/bitesize/standard/physics/health_physics/use_of_thermometers/revision/1/** Range and sensitivity: **www.physicsclassroom.com/class/thermalP/u18l1b.cfm** and **http://gimi.bpg.hu/gcse-physics/thermometer.html** Thermocouples: **www.youtube.com/watch?v=BB5jjW1V2DI** and **http://olevelphysicsblog.blogspot.co.uk/2010/11/thermocouple-thermometer.html**
11(a)	Describe a rise in temperature of a body in terms of an increase in its internal energy (random thermal energy).	**Basic:** State the increasing speed of the molecules as the temperature rises as a fact but try to justify it, e.g. as temperature rises: • Brownian motion becomes more violent • chemical reactions speed up • the speed of sound in gases rises. (**W**) Kinetic theory: **www.school-for-champions.com/science/matter_kinetic_theory.htm** and **www.youtube.com/watch?v=_rsqBNhFG1Y** and **http://physicsnet.co.uk/gcse-physics/kinetic-theory/**
11(b)	Define the terms *heat capacity* and *specific heat capacity*.	**Basic:** Emphasise that a rise in temperature is a consequence of the transfer of thermal energy. (Cause and effect).

Syllabus ref	Learning objectives	Suggested teaching activities
11(c)	Calculate the heat transferred using the formula *thermal energy = mass × specific heat capacity × change in temperature*	Heat and temperature are not the same thing. (**W**) Heat water in a beaker with an immersion heater or use an electric kettle. Plot $\Delta T \rightarrow t$ (temperature rise → time). The initial straight line reveals that $\Delta T \propto Q$ (heat supplied) since $Q = Pt$. Kettles often have a rated power marked on them. Using this value, determine the specific heat capacity of water. (**I G W**) **Challenging:** Emphasise that heat capacity is measured for a particular object whereas specific heat capacity is the property of a substance. Specific heat capacity deals with temperature changes and it unit includes that of temperature. (**W**) Heat capacity: **http://chemwiki.ucdavis.edu/Physical_Chemistry/Thermodynamics/Calorimetry/Heat_Capacity** Specific heat capacity: **www.bbc.co.uk/schools/gcsebitesize/science/aqa/heatingandcooling/buildingsrev3.shtml** and **www.youtube.com/watch?v=BclB8UaSH4g**
11(d)	Describe melting/solidification and boiling/condensation in terms of energy transfer without a change of temperature.	**Basic:** Cool a test-tube of molten wax (Novadecanol is often used also) and plot $T \rightarrow t$. Notice the shape of the graph and where the wax becomes solid. **Do not melt candle wax or any other inflammable substance with or near a naked flame.** (**I G W**)
11(e)	State the meaning of *melting point* and *boiling point*.	Measure the temperature of water as it is brought to the boil, and keep measuring it as it boils. (**I G W**) Define melting point and boiling point. (**W**) **Challenging:** Specific heat capacity is defined for a single phase changing temperature whilst melting and boiling are phase changes occurring at a single temperature. (**W**) Melting and boiling: **www.bbc.co.uk/schools/gcsebitesize/science/ocr_gateway_pre_2011/energy_home/0_heating_houses2.shtml** and

Syllabus ref	Learning objectives	Suggested teaching activities
		https://sites.google.com/site/gcserevision12/physics/physics-1/melting-and-boiling
11(f)	Explain the difference between boiling and evaporation.	**Basic:** Leave various dishes of water in direct sunlight. Record their maximum temperature. Do they ever reach 100 °C? Tabulate the differences between the two terms. (**I G W**) See 12(e) and 12(g) in Unit 9. Evaporation and boiling: http://hyperphysics.phy-astr.gsu.edu/hbase/kinetic/vappre.html#c2
11(h)	Explain latent heat in terms of molecular behaviour.	**Challenging:** Explain that melting/boiling involves pulling the molecules apart against an attractive force which is holding the molecules together. (**W**) **Basic:** Use a few small balls held together by doubled-sided sticky tape or adhesive strips. Energy is needed (work is done) to separate the balls. (**I**) Vaporisation: http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/phase2.html and http://olevelphysicsblog.blogspot.co.uk/2010/11/latent-heat.html
11(g)	Define the terms *latent heat* and *specific latent heat*.	**Basic:** Measure the specific latent heat of evaporation of water. Use an electric kettle whose power rating is known and let the water boil for five or six minutes. Measure the mass of water which escaped. Leaving the lid off as it boils should prevent an automatic kettle switching itself off at the boiling point. (**I G W**) **Challenging:** The latent heat of steam can be used to transfer heat. Consider a “Bain Marie” or a traditional porringer in cooking or a server in a canteen. (**W**) Latent heat: www.cyberphysics.co.uk/Q&A/KS4/SHC/questionsSHC_GCSE.html and
11(i)	Calculate heat transferred in a change of state using the formula *thermal energy = mass × specific latent heat.*	

Syllabus ref	Learning objectives	Suggested teaching activities
		www.bbc.co.uk/bitesize/standard/physics/energy_matters/heat_in_the_home/revision/3/ Specific latent heat: www.s-cool.co.uk/a-level/physics/temperature-and-thermal-properties/revise-it/specific-latent-heat and http://physicsnet.co.uk/a-level-physics-as-a2/thermal-physics/thermal-energy/
11(j)	Describe qualitatively the thermal expansion of solids, liquids and gases.	**Basic:** Demonstrate specific examples. Solids: ball and hoop, the bimetallic strip, (**I G W**) Liquids: completely fill a flask with coloured water, insert a bung with a narrow tube and immerse the flask in hot water. At first the water level in the tube falls as the glass expands but then the level rises. (**I G W**) Gases: use the flask with the bung and tube empty and invert the equipment and put free end of the tube under water. Bubbles emerge when the flask is held in warm hands. (**I G W**) Expansion of solids, liquids and gases: www.docbrown.info/page03/3_52states.htm and www.youtube.com/watch?v=EkQ2886Sxpg
11(k)	Describe the relative order of magnitude of the expansion of solids, liquids and gases.	**Challenging:** In a liquid-in-glass thermometer, both the liquid and the glass expand. It is possible sometimes to see a fall in the liquid level before it rises since the glass expands first. Eventually the liquid expands more and the liquid rises in the tube even though the tube has expanded. (**I G W**) All ideal gases expand at the same rate as each other which is much larger than the rate at which liquids expand. (**W**) Galilean thermometers work on the same principle. As the temperature rises, the liquid expands more than the solid and so the density of the liquid falls faster. The balls sink. (**W**) Thermal expansion: www.youtube.com/watch?v=EkQ2886Sxpg

Syllabus ref	Learning objectives	Suggested teaching activities
		and www.cyberphysics.co.uk/topics/heat/expansion.htm
11(l)	List and explain some of the everyday applications and consequences of thermal expansion.	**Basic:** Ask learners to collect photographs or make drawings of anywhere that thermal expansion is good or bad and them talk about them to the class (**I G W**) All of these are used: the bimetallic strip is the basis of the thermostat, riveting and fitting metal rims on train wheels, expansion has to be allowed for in tall buildings, overhead power cables, bridges, roads and railway lines. (**W**) The thermal expansion of liquids is the basis of the liquid-in-glass thermometer. (**W**) **Challenging:** Fuel is cooled so that more can be put into a racing-car's tank of a given volume. (**W**) Expansion causes problems: www.scienceclarified.com/everyday/Real-Life-Physics-Vol-2/Thermal-Expansion-Real-life-applications.html#b and http://scienceuniverse101.blogspot.co.uk/2012/02/useful-applications-of-thermal.html
11(m)	Describe qualitatively the effect of a change of temperature on the volume of a gas at constant pressure.	**Basic:** Demonstrate this effect by trapping air in a capillary tube with an index of oil or concentrated sulfuric acid. Put the tube into a beaker of hot water and as the gas expands, it pushes the index up. If a class set is available learners can plot a graph of the length of the air column against temperature and extrapolate the graph backwards to zero length. (**I G W**) Charles' Law: www.youtube.com/watch?v=IkRIKGN3i0k and www.schoolphysics.co.uk/age14-16/Heat%20energy/Gases/text/Charles_law/index.html

Past paper and specimen papers
Past paper questions: Nov 12 Paper 21 Q2 Nov 12 Paper 22 Q4 Nov 12 Paper 22 Q5 Jun 12 Paper 21 Q4 Jun 12 Paper 22 Q3 Past question papers available at: **http://teachers.cie.org.uk**

Unit 7: Magnetism and electric current

Recommended prior knowledge

Learners are likely to have some elementary ideas concerning magnetism and the Earth's magnetic field but many will be convinced that all metals are magnetic and will need to be shown otherwise. The first section of this unit is free-standing and could be taught at several stages in the course. It links in well, however, with the second part of the unit which could not properly be taught without a significant amount of current electricity preceding it; this is dealt with in Unit 4.

Context

The unit deals with magnetism and electromagnetism and it follows on from and extends ideas met in Unit 4. The use of electricity in motors and loudspeakers and the generation of electricity by generators are hugely significant features of the modern world. Physics has changed the human condition enormously and electricity has been a significant factor in this achievement.

Outline

At the beginning of the unit, the phenomenon of permanent magnetism and magnetic materials is dealt with and this is essential for the understanding of the topics and devices in the second half. Learners will learn about three related magnetic effects. These are the production of a magnetic field by a current, the motor effect and the dynamo effect. Their understanding of these is enhanced by studying particular field patterns, the d.c. motor and the a.c. generator. All these ideas are brought together to explain the operation of a transformer and the use of transformers in power supply systems concludes the unit.

Classroom organisation and differentiation details: **W**: whole class; **G**: group; **I**: individual

Syllabus ref	Learning objectives	Suggested teaching activities
17(a)	Describe the forces between magnetic poles and between magnets and magnetic materials.	**Basic:** Learners should experiment with magnets. Many probably know that like poles repel and that unlike poles attract. (**I G**) Emphasise "north pole" is an abbreviation for "north-seeking pole". Use flat magnets whose flat faces are the poles. To avoid confusion with the geographical locations, some teachers refer only to N-poles and S-poles. (**W**) Learners should investigate magnetic behaviour experimentally themselves. Law of magnetism: **www.zephyrus.co.uk/magneticpoles.html** and **www.youtube.com/watch?v=IW7BCTQDY_g**

Syllabus ref	Learning objectives	Suggested teaching activities
17(c)	State the difference between magnetic, non-magnetic and magnetised materials.	**Basic:** Learners often think that all metals are magnetic. Try attracting copper, aluminium, brass, nickel (chemical spatulas are often made of nickel), carbon, nylon or wood to a magnet. (**I G W**) Given a magnet how would you tell whether a piece of steel was magnetised or unmagnetised? (**I G W**) Why are permanent magnets and compass needles made of steel? (**I G W**) Why are the cores of electromagnets made of iron? (**I G W**) Although iron is often said to be magnetically soft, real iron often retains some residual magnetisation. Find out how stainless steel behaves. (**I G W**) Magnetic materials: **www.zephyrus.co.uk/magneticmaterials.html** Permanent/temporary magnets: **www.miniphysics.com/2012/03/o-level-temporary-and-permanent-magnets.html**
17(f)	State the differences between the properties of temporary magnets (e.g. iron) and permanent magnets (e.g. steel).	
17(b)	Describe induced magnetism.	**Basic:** Pick up chains of iron nails or paper-clips end to end. Remove the original magnet. (**I**) Induced magnetism: **www.phy6.org/earthmag/inducemg.htm** and **www.youtube.com/watch?v=SI-x1dWMu54**
17(e)	Describe the plotting of magnetic field lines with a compass.	**Basic:** Plot the field patterns of different arrangements of one or two magnets using iron filings (keep the magnet in a plastic bag to keep it clean). (**I G**) Find the neutral point where appropriate. Also use plotting compasses. (**I G**)

Syllabus ref	Learning objectives	Suggested teaching activities
		Learners can become adept at plotting these patterns. Avoid mentioning electric fields here as this causes confusion and if learners use phrases like *the charged end of a magnet*, be clear to separate electric terms from magnetic ones. Plotting magnetic fields: **www.practicalphysics.org/go/Experiment_313.html?topic_id=7&collection_id=41** and **www.youtube.com/watch?v=JUZC679CwKs**
17(d)	Describe electrical methods of magnetisation and demagnetisation and other methods of demagnatisation.	**Basic:** Wrap wire around a brass, iron and steel nail. Pass a current through the wire. Note the different behaviour as you try to pick up paper clips. (**I G W**) What is the core of an electromagnet made from? Why? (**W**) Uses include: motors, loudspeakers, generators, dynamos, speedometers, medical scanners, maglev trains, tape-recorders and video recorders. The phenomenon of electromagnetic induction needs to be taken on trust here as it is not encountered until later in the unit. Learners make their own electromagnet and see how many paper-clips, *N*, can be picked as the current changes. Plot $N \rightarrow I$. (**I G W**) **Challenging:** Note that there are three uses of the term induction in this syllabus: • electrostatic induction • magnetic induction • electromagnetic induction. Learners need to be certain of the differences. (**W**) **Challenging:** Magnetised objects can be demagnetised by inserting them into and then removing them slowly from a solenoid carrying a large alternating current. The solenoid should be aligned east-west when doing this. Where possible, the magnetisation can be eliminated by heating to red-heat and allowing to cool in an east-west direction or by hammering the object violently, again with the object lying east-west. (**I G W**)
17(g)	Describe uses of permanent magnets and electromagnets.	
17(i)	Describe the use of magnetic materials in audio/video tapes.	

Syllabus ref	Learning objectives	Suggested teaching activities
		Electromagnets: www.bbc.co.uk/learningzone/clips/electromagnets/289.html Magnetic tape: http://hyperphysics.phy-astr.gsu.edu/hbase/audio/tape2.html Uses of magnets: www.howmagnetswork.com/uses.html
17(h)	Explain the choice of material for, and use of, magnetic screening.	**Basic:** Notice that this syllabus uses the phrase *magnetic screening,* other physicists might use the term *magnetic shielding*. Attach a magnet to the top of a match-box. Remove the drawer and place paper-clips at the bottom surface. See how many paper-clips can be held. Put into the gap blocks of various materials: polythene, copper, wood, aluminium, brass, steel, iron. How is the number of paper clips affected? (**I G W**) The strength of the magnet (the number of flux lines emerging) is relatively constant. These lines cannot be destroyed or absorbed but they may be channelled away from the protected area; materials which do this are called permeable. All such materials are themselves **magnetic**. (**W**) **Challenging:** Do not confuse with the Faraday cage which screens the protected region from **electric** fields and is not in this syllabus. Magnetic screening can be used to prevent the magnetic component of a radio-frequency electromagnetic wave from reaching a given location. (**W**) Magnetic Screening: www.exploratorium.edu/snacks/magshield/ Uses of magnetic screening: www.magneticshield.com/ and www.nuffieldfoundation.org/practical-physics/magnetic-shielding

Syllabus ref	Learning objectives	Suggested teaching activities
17(j)	Describe the pattern of the magnetic field due to currents in straight wires and in solenoids and state the effect on the magnetic field of changing the magnitude and direction of the current.	**Basic:** Use standard equipment to plot the patterns caused by current-carrying straight wires, flat coils, solenoids. If possible allow learners to plot the fields with compasses or iron filings. (**I G W**) **Challenging:** Plot the field pattern caused by a Helmholtz pair of coils. Notice how uniform it is in the middle. (**I G W**) Fields due to currents: **http://schools.matter.org.uk/Content/MagneticFields/Default.htm** and **http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/magcur.html** and **www.youtube.com/watch?v=3KkOqVEa1oI**
17(k)	Describe applications of the magnetic effect of a current in relays and circuit-breakers.	**Basic:** Get learners to use a relay to switch one circuit on and off using another circuit. (**I G W**) Examples include the car ignition system. These ideas can prepare learners for circuitry using transistors. Trip switches and relays can be demonstrated in class. (**I G W**) Relays: **www.technologystudent.com/elec1/relay1.htm** and **www.youtube.com/watch?v=qje8LhZXwO0** Circuit breakers: **http://hyperphysics.phy-astr.gsu.edu/hbase/electric/bregnd.html**
22(a)	Describe experiments to show the force on a current-carrying conductor, and on a beam of charged particles, in a magnetic field, including the effect of reversing	**Basic:** Possible experiments include: Lay an unwound paper-clip on top of two parallel rails (also unwound paper-clips) which lie between the poles of a strong magnet (field downwards). Pass a current into one rail and out of the other. This is the catapult effect. (**I G W**)

Syllabus ref	Learning objectives	Suggested teaching activities
	(1) the current (2) the direction of the field.	Pass a current through a strip of aluminium foil in a magnetic field. The foil moves. (**I G W**)
22(b)	State the relative directions of force, field and current.	Reverse the current and the field both separately and together. (**I G W**) The motor effect is a 3D effect and the relative directions are not easy to describe or memorise. Fleming's left-hand rule is a useful way of remembering it but it is not a law of physics. **Challenging:** Apply these principles to a beam of electrons. Where possible show a fine-beam tube or a Maltese Cross tube. (**W**) Draw the circular field pattern surrounding a straight wire and add the uniform, straight field pattern of a permanent magnet. On one side of the wire they reinforce whilst on the other side they cancel. Hence there are more field lines on the first side and fewer on the other. The lines behave like stretched rubber bands and so eject the wire in the direction predicted. (**W**) The motor effect: **www.bbc.co.uk/schools/gcsebitesize/science/edexcel_pre_2011/electricityworld/thecostofelectricityrev1.shtml** and **www.cyberphysics.co.uk/topics/magnetsm/electro/Motor%20Effect.htm** and **www.youtube.com/watch?v=tE8hQJrA_XY** Fleming's left hand rule: **www.s-cool.co.uk/a-level/physics/forces-in-magnetic-fields/revise-it/the-motor-effect-and-flemings-left-hand-rule** and **www.le.ac.uk/se/centres/sci/selfstudy/mam12.htm** and **www.youtube.com/watch?v=9Zy0VHBXxLU**

Syllabus ref	Learning objectives	Suggested teaching activities
17(k)	Describe applications of the magnetic effect of a current in loudspeakers.	**Basic:** Let the learners see dismantled loudspeakers. (**G W**) Hand out sheets showing incomplete or unlabelled diagrams and let the learners complete them. (**I G**) Make a large, cardboard model (~50 cm diameter) to show the shape and position of the components. Learners can make coils of fine wire (enamel covered), attach them to a cone of paper, place near a bar magnet and when a.c. from a signal generator passes through sound is heard. (**W**) **Challenging:** Link in with sound waves (Unit 2) and alternating current (later in this unit). (**W**) An a.c. produces an alternating force and the diaphragm vibrates. (**W**) Loudspeakers: **http://hyperphysics.phy-astr.gsu.edu/hbase/audio/spk.html** and **www.youtube.com/watch?v=oGrlz6t28XE**
22(c)	Describe the field patterns between currents in parallel conductors and relate these to the forces which exist between the conductors (excluding the Earth's field).	**Basic:** Pass a current through two parallel strips of aluminium foil – no magnet needed. Like currents attract. Reverse the current in one strip. Unlike currents repel. Consider the field of one strip and its effect on the current in the other. (**I G W**) Draw the field patterns for parallel wires carrying currents in the same directions and then in the opposite directions. Notice, in each case, where the two fields cancel out. (**I G W**) Parallel wires: **www.youtube.com/watch?v=43AeuDvWc0k** and **www.s-cool.co.uk/a-level/physics/forces-in-magnetic-fields/revise-it/force-on-parallel-wires**
22(d)	Explain how a current-carrying coil in a magnetic field experiences a turning effect and that the effect is increased by	**Basic:** Illustrate the effect with a large (~50 cm × ~50 cm), non-functioning cardboard model. The magnetic poles are painted cardboard boxes. Use real, thick wire but paint arrows to show the current and use drinking straws with arrowheads to show the forces on the two sides of the coil.

Syllabus ref	Learning objectives	Suggested teaching activities
	increasing (1) the number of turns on the coil (2) the current.	Wind a simple coil and place it between the poles of a magnet. Its plane lies in the field. It rotates through a quarter turn and stops when perpendicular to the field. (**G W**) Torque on coil: www.youtube.com/watch?v=MosMfPI1MNA
22(e)	Discuss how this turning effect is used in the action of an electric motor.	**Basic:** Use the cardboard model to show that if the current is reversed when the coil is perpendicular to the field then it will continue to rotate in the same direction. Make a "commutator" from aluminium foil and a cardboard tube and fit it to the model. Use two other lengths of wire to rub against the commutator. (**G W**) Explain that a soft-iron core magnifies and concentrates the magnetic field. (**W**) Make a simple motor from wire, flat magnets, a former on which to wind the coil and show that it can be made to rotate. (**I G W**) The electric motor: www.bbc.co.uk/schools/gcsebitesize/science/edexcel_pre_2011/electricityworld/thecostofelectricityrev1.shtml and www.youtube.com/watch?v=pKAb7GCkoWo
22(f)	Describe the action of a split-ring commutator in a two-pole, single coil motor and the effect of winding the coil on to a soft-iron cylinder.	
23(a)	Describe an experiment which shows that a changing magnetic field can induce an e.m.f. in a circuit.	**Basic:** Insert a bar magnet into a solenoid connected to a sensitive meter (needle meter or mirror galvanometer). Withdraw it. Repeat with the other pole and repeat using the other end of the solenoid. (**I G W**) Insert two or three identical magnets taped together. Vary the rate of insertion. (**I G W**) A coil with more turns may well have a greater resistance. If this is so, it will produce a similar meter reading. Show the dependence on the number of turns, *N*, using the same piece of wire wound into more or fewer turns. Other experiments include: (1) Move a wire up and down between two poles of a magnet. (2) Rotate a copper disc between the two poles and measure the e.m.f. between axle and circumference.
23(b)	State the factors affecting the magnitude of the induced e.m.f.	

Syllabus ref	Learning objectives	Suggested teaching activities
		In both cases use a sensitive galvanometer. (**G W**) Electromagnetic induction: **http://micro.magnet.fsu.edu/electromag/java/faraday2/** and **www.bbc.co.uk/schools/gcsebitesize/science/add_ocr_pre_2011/electric_circuits/mainsproducedrev1.shtml** and **https://www.o2learn.co.uk/o2_video.php?vid=405**
23(c)	State that the direction of the current produced by an induced e.m.f. opposes the change producing it (Lenz's Law) and describe how this law may be demonstrated.	**Challenging:** Consider the only two possible current directions when inserting a magnet into a coil. Both make the coil into a magnet: One attracts the magnet → larger current → stronger field → faster magnet → even larger current. Ever larger amounts of energy come from nowhere. This is impossible. The other repels the magnet → smaller current → weaker field → slower magnet → even smaller current. A small amount of energy is generated by a small initial push. This, of course, is what happens. (**W**) This shows that the Lenz Law is an inevitable consequence of the Principle of the Conservation of Energy. (**W**) **Challenging:** Demonstrate the direction of the current induced by moving a wire up through the gap between two poles of a strong magnet. The directions are given by Fleming's right-hand rule or by using the left-hand rule and remembering Lenz's Law. (**I G W**) Lenz's Law: **http://micro.magnet.fsu.edu/electromag/java/lenzlaw/** and **http://hyperphysics.phy-astr.gsu.edu/hbase/electric/farlaw.html**

Syllabus ref	Learning objectives	Suggested teaching activities
		and www.youtube.com/watch?v=sPLawCXvKmg and www.youtube.com/watch?v=HNmgE0rJ_xk
23(d)	Describe a simple form of a.c. generator (rotating coil or rotating magnet) and the use of slip rings where needed.	**Basic:** Use a large cardboard model to show the arrangement of the parts (similar to the motor model in 22(e) and (f)). Place small arrows on the coil to show the direction of the current induced. Make a set of slip rings from aluminium foil and some cardboard tubes. (**W**) **Challenging:** Show an old, cut-up a.c. generator or make a model a.c. generator. Rotate it at a constant rate. A c.r.o. displays the output. (**W**) The a.c. generator: www.animations.physics.unsw.edu.au/jw/electricmotors.html#mandg and www.youtube.com/watch?v=d_aTC0iKO68
23(e)	Sketch a graph of voltage output against time for a simple a.c. generator.	**Challenging:** Connect an a.c. generator to a c.r.o. (Unit 10) and look at the trace. Measure the periodic time and the amplitude. (**I G W**) An a.c. supply: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/electricity/mainselectrev5.shtml and www.frankswebspace.org.uk/ScienceAndMaths/physics/physicsGCSE/dcac.htm
23(f)	Describe the structure and principle of operation of a simple iron-cored transformer.	**Basic;** Make a simple electromagnet (an iron nail wound with wire connected to a supply). Insert it into a coil connected to a galvanometer. Withdraw it. Place the electromagnet into the coil and switch off the supply. This is like withdrawing it. Switch on. Use an a.c. supply (this is like switching it on and off very fast) and replace the galvanometer with a c.r.o. (Unit 10). (**W**) Construct a transformer from an iron bar and wind two coils on it. (This is not very efficient). (**I G W**)
23(g)	Recall and use the equation $(V_p/V_s) = (N_p/N_s)$	

Syllabus ref	Learning objectives	Suggested teaching activities
		Use a transformer kit with a laminated iron core. (**I G W**) The transformer: **http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/transf.html** and **http://people.clarkson.edu/~svoboda/eta/plots/transformer.html**
23(h)	State the advantages of high voltage transmission.	**Basic:** Use a model power lines demonstration with torch lamps at the beginning and end. Transmit at 3 V. Then step up to 12 V, transmit and step down to 3 V. (**W**) **Do not use high voltages on bare wire which the teacher or learners can come into contact with.** Power lines: **www.practicalphysics.org/go/Experiment_352.html**
23(i)	Discuss the environmental and cost implications of underground power transmission compared to overhead lines.	**Basic:** Overhead: cheaper to build, cheaper to maintain, cheaper to inspect, no insulation needed, they stay cool, ugly, a hazard for helicopters, hang-gliders, children with kites. (**G W**) Underground: the reverse of the above but a hazard for diggers may ignite gas supplies in earthquakes, problems in flooding. (**G W**) Many other considerations are involved not least the cost. Always make it clear why the cost is more and whether it is the cost of installation or the cost of running the system that is the problem. (**G W**) Environmental effects: **www.emfs.info/Sources+of+EMFs/Underground/**

Past paper and specimen papers
Past paper questions: Nov 12 Paper 21 Q7 Jun 12 Paper 21 Q8 Nov 11 Paper 21 Q6 Nov 11 Paper 22 Q5 Nov 11 Paper 22 Q7 Past question papers available at: **http://teachers.cie.org.uk**

Unit 8: Forces and motion

Recommended prior knowledge

This unit introduces some of the most basic concepts in mechanics. The learners will, by this stage in the course, be used to dealing with the idea of force but here for the first time its exact definition is presented. Acceleration is a quantity which learners will struggle with, even though they might well have some intuitive conception of what it means. A failure fully to understand it is often betrayed by an inability to deduce or even consistently to use its correct unit. Similarly terminal velocity is a term which many learners will believe they are acquainted with but which few will fully understand at first.

Context

The ideas here fit in neatly with those of energy but there is not a huge amount of overlap and, as long as the term force has been taken on trust at an early stage, the proper definition can wait until here with few disadvantages. It need hardly be said that these quantities and concepts form the basis of many types of engineering and yet again this branch of the subject is economically and socially very important indeed.

Outline

The unit begins by distinguishing between scalar and vector quantities and it teaches learners to combine vectors. Kinematics and the definition of acceleration are dealt with by introducing the appropriate graphs. An understanding of the phenomenon of air resistance enables learners to tackle terminal velocity. The importance of the idea of resistive forces, such as friction, should not be overlooked as it explains why things behave so differently from what a simple interpretation of Newton's Laws might lead one to expect. Newton's Second and Third Laws of Motion are covered in this unit and the newton is properly defined. The unit concludes with the phenomenon of motion in a circle and the need for a centripetally directed force to enable it to happen.

Syllabus ref	Learning objectives	Suggested teaching activities
1(a)	Define the terms *scalar* and *vector*.	Explain that forces cause movement (acceleration) and that an object can only move one way even when several forces act and so several forces must be the equivalent of one total force. Consider two forces cancelling and then opposite forces producing a non-zero, resultant force. Consider two forces which are perpendicular and add them graphically. Introduce the parallelogram rule and the triangle of forces.
1(b)	Determine the resultant of two vectors by a graphical method.	
1(c)	List the vectors and scalars from distance, displacement, length, speed, velocity, time, acceleration, mass and force.	Forces are not the only quantities which behave like this; any quantity which has direction is a vector: displacement, velocity, acceleration and force. The distinctions between distance and displacement or between speed and velocity are arbitrary conventions in physics which have to be learnt. They are conveniently illustrated by estimating them for a racing car travelling at uniform speed at various points around a racing track – especially after a whole number of laps.
2(e)	Recall that deceleration is a negative acceleration	Consider the distance-time graph and take its gradient. Emphasise that any quantity which makes sense when followed by a direction word is a vector. Both a force

Syllabus ref	Learning objectives	Suggested teaching activities
		of 3.0 N **upwards** and a displacement of 0.45 m **west** make sense; but a temperature of 47 °C **sideways** does not. Simple experiments using forces tables or weights hung from strings can verify the rule. Use newtonmeters. Use scale drawings for velocities and displacements. Scalars and vectors: **http://webphysics.iupui.edu/JITTworkshop/152Basics/vectors/vectors.html** and **www.physicsclassroom.com/Class/1DKin/U1L1b.html** Vector addition: **http://hyperphysics.phy-astr.gsu.edu/hbase/vect.html** and **www.youtube.com/watch?v=bPYLWjcY9wA**
2(f)	Plot and interpret speed-time and distance-time graphs.	Learners often find rates of anything difficult. Plot graphs of learner's height → time, or volume of water in bath → time or any quantity with a single unit → time. Talk about metres/year, litres/minute or somethings/second. With a flying start, measure the time for a learner to run or bicycle 10 m, 20 m, 30 m etc. and plot distance → time graphs. Consider a motorbike moving away from the traffic lights, its velocity is increasing. The rate will be measured in (m / s) / s. Consider numerical values. Calculate *a*. Calculate the gradient of a speed-time graph. Consider the distance-time graph of an accelerating body. Run across the classroom accelerating from rest. Then decelerate. Introduce the unit m / s² and consider objects falling from cliffs; notice that they travel further in each subsequent second. Use 10 m / s² to calculate the velocities and displacements for falling objects. For a uniformly accelerating object the average velocity = $(u+v)/2$. Acceleration: **www.physicsclassroom.com/mmedia/kinema/acceln.cfm** and
2(c)	State what is meant by *uniform acceleration* and calculate the value of an acceleration using change in velocity/time taken.	
2(i)	State that the acceleration of free-fall for a body near the Earth is constant and is approximately 10 m / s².	

Syllabus ref	Learning objectives	Suggested teaching activities
		http://library.thinkquest.org/10796/ch3/ch3.htm and www.youtube.com/watch?v=0ROHAAj7y00 Freefall: www.youtube.com/watch?v=5gh1NDRis58&feature=related and www.youtube.com/watch?v=6MVPUUHzGlk&feature=related Non-uniform acceleration: http://physics.info/motion-graphs/ Speed-time graphs: www.bbc.co.uk/learningzone/clips/speed-time-graphs/10673.html and www.bbc.co.uk/schools/gcsebitesize/science/add_gateway_pre_2011/forces/accelerationrev2.shtml
2(j)	Describe qualitatively the motion of bodies with constant weight falling with and without air resistance (including reference to terminal velocity).	An object reaching terminal velocity is a good example to consider. Emphasise the distinction between a decreasing acceleration and a deceleration (negative acceleration). Consider the motion of a falling parachutist. Set up a tube containing a viscous liquid and drop ball-bearings into it. Or consider a rocket which accelerates at an increasing rate as its mass decreases. ($F = ma$ is dealt with later.) Consider the speed-time graph in both cases. Make sure that distance-time and speed-time graphs and their gradients are understood. Set up a large pendulum ($l \sim 3$ m) and observe its motion when moving with a large amplitude; try to plot an approximate speed-time graph. Terminal velocity: http://hyperphysics.phy-astr.gsu.edu/hbase/airfri2.html and
2(d)	Discuss non-uniform acceleration.	
2(g)	Recognise from the shape of a speed-time graph when a body is (1) at rest (2) moving with uniform speed (3) moving with uniform acceleration (4) moving with non-uniform acceleration.	

Syllabus ref	Learning objectives	Suggested teaching activities
		www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/forces/forcemassact.shtml
2(h)	Calculate the area under a speed-time graph to determine the distance travelled for motion with uniform speed or uniform acceleration.	Learners will probably be able to use the formula $x = vt$ in ordinary situations – when travelling for 3 h at 5 km / h one moves 15 km. Use these ideas in the case of a speed-time graph for a body moving at constant speed. Emphasise that area does not mean cm^2 of graph paper but area **according to the two axes**. This has unit of m/s × s: m. Area under the graph: **www.bbc.co.uk/schools/gcsebitesize/science/add_gateway_pre_2011/forces/accelerationrev2.shtml** and **www.physicsclassroom.com/class/1dkin/u1l4e.cfm**
3(a)	State Newton's third law.	Emphasise that forces always occur in **pairs**; single forces never exist. The horse pulls the cart, the cart restrains the horse. Suspend a hook from a support or the ceiling by friction alone. Suspend a weight from the hook. Gradually increase the weight supported. As the hook exerts a larger force on the weight, the weight exerts a larger force on the hook which is eventually pulled from its support. Get two learners to lean against each other back to back at an angle. As **A** supports **B**, so **B** supports **A**. Stand a learner on a set of scales. As the weight pushes down on the scales and is recorded, so the scales push upwards on the learner, who does fall to the floor but stays a few centimetres (the thickness of the scales) above it. Emphasise that two third law forces never act on the **same** body. The forces are always of the form: the force on **A** due to **B** and the force on **B** due to **A**: $${}_{B}F_{A} = -{}_{A}F_{B}$$ Two forces acting on the same body may well be equal in size, opposite in direction and of the same nature, but they cannot be a third law pair. Learners are likely to use the formulation*: to every action there is an equal and opposite reaction*. This is unhelpful. By the terms *action* and *reaction*, Newton meant that quantity which we call *force*. In other words, quantities that we measure in newtons. We tend not to use the term *action* to mean this anymore and only

Syllabus ref	Learning objectives	Suggested teaching activities
		use the term *reaction* in this sense rarely. The third law: **www.physicsclassroom.com/class/newtlaws/u2l4a.cfm** and **www.youtube.com/watch?v=cP0Bb3WXJ_k** and **www.youtube.com/watch?v=D4j5bcaV2Ws**
3(c)	Describe the ways in which a force may change the motion of a body.	A body experiencing no resultant force will have zero acceleration (constant velocity, but not necessarily zero velocity). Consider: ice-hockey pucks, snooker balls, maglev trains, hovercraft and space-craft. The Voyager probes are still travelling in straight lines at huge velocities long after their engines stopped working. Get the learners to contribute as many appropriate words as possible: speeding up, slowing down, stopping, changing direction, reversing, swerving, lifting and so on. Show that acceleration is the consequence of a resultant force. Pull a trolley along a track using a falling weight and a pulley. If possible use tickertape timers, (or motion sensors and dataloggers) and trolleys to show: $a \propto F$ and $a \propto 1/m$. So $F = kma$ but that in SI, $k = 1$; this defines the newton. Examples of zero resultant force acting on a stationary body are numerous. A school resting on its foundations, a book resting on a table, an exhausted athlete lying on a trampoline (here the stretching of the support can be noticed; in the other two cases it is too small to observe). Friction free motion: **www.bbc.co.uk/schools/scienceclips/ages/8_9/friction.shtml** and **www.fearofphysics.com/Friction/friction.html** F = ma: **www.dynamicscience.com.au/tester/solutions/flight/velocity/force.htm** and
3(b)	Describe the effect of balanced and unbalanced forces on a body.	
3(d)	Do calculations using the equation *force = mass × acceleration.*	

<table>
<tr><th>Syllabus ref</th><th>Learning objectives</th><th>Suggested teaching activities</th></tr>
<tr><td></td><td></td><td>www.youtube.com/watch?v=WzvhuQ5RWJE</td></tr>
<tr><td>3(e)</td><td>Explain that friction is a force that impedes motion and produces heating.</td><td rowspan="2">Emphasise that the consequence of a constant, resultant force is a constant acceleration not a constant velocity. Emphasise that when cars, trains and aeroplanes are travelling at constant velocity, the tractive force is used to cancel frictional forces.

Consider the effect of reducing or increasing friction between the road and vehicle: oil spills and ice on roads or gravelled escape lanes for lorries on steep hills.

Consider the effect of reduced visibility (night, fog, rain) or the driver's condition (intoxication, tiredness, lack of concentration).

Stopping distances:
www.bbc.co.uk/schools/gcsebitesize/science

and
www.cyberphysics.co.uk/topics/forces/stopping_distance.htm</td></tr>
<tr><td>3(f)</td><td>Discuss the effects of friction on the motion of a vehicle in the context of tyre surface, road conditions (including skidding), braking force, braking distance, thinking distance and stopping distance.</td></tr>
<tr><td>3(g)</td><td>Describe qualitatively motion in a circular path due to a constant perpendicular force, including electrostatic forces on an electron in an atom and gravitational forces on a satellite. (F = mv²/r is not required.)</td><td rowspan="2">Pass a thin piece of string (~50 cm) through a narrow length of glass tubing. Attach an object (small ball) to one end of the string and a laboratory weight to the other end. Hold the tube and set the object moving in a circle; a balance is reached when the weight supplies the correct tension in the string to keep the object moving in a circle. Cut the string and observe the object fly off in a tangential direction. Make sure that the object moves in a safe direction with no risk of anyone being injured. A force is needed for circular motion and when it is removed, the object reverts to straight line motion with constant velocity.

Consider a motorbike travelling around a curve hitting a patch of spilled oil. The removal of friction allows the motorbike to carry on in a straight line and to hit the outside of the curve.

Consider: a bucket of water rotated in a vertical circle, holding on to a roundabout or throwing the hammer in athletics.

Relate these ideas to the force needed to keep a moving electron in a circular orbit or a moving satellite in orbit around the Earth. The word centripetal – if used at all – must be used as a direction word (just like downwards). Gravitational and electrostatic attractions are forces of physics which in these cases act in a centripetal direction.

Centripetal motion:
http://hyperphysics.phy-astr.gsu.edu/hbase/cf.html</td></tr>
<tr><td>3(h)</td><td>Discuss how ideas of circular motion are related to the motion of the planets in the solar system.</td></tr>
</table>

Syllabus ref	Learning objectives	Suggested teaching activities
		and **www.phy.ntnu.edu.tw/oldjava/circularMotion/circular3D_e.html** Electrons: **www.colorado.edu/physics/2000/waves_particles/wavpart2.html**

Past paper and specimen papers
Past paper questions: Nov 12 Paper 21 Q1 Jun 12 Paper 21 Q1 Jun 12 Paper 22 Q2 Jun 11 Paper 21 Q2 Nov10 Paper 21 Q2 Past question papers available at: **http://teachers.cie.org.uk**

Unit 9: Pressure and gases

Recommended prior knowledge

This unit introduces pressure and many learners will have encountered this quantity in one way or another. By this stage in the course, learners will already have met the idea of force but, even if they have not, it can be taken on trust prior to its being properly defined. Gas pressure and the pressure caused by solid objects in contact are not, to all learners, obviously related ideas and it would be useful if some were aware of this connection. Some understanding of the kinetic theory of matter will be necessary in explaining the properties of gases.

Context

This unit contains various ideas which involve pressure and the properties of gases but which are not, at first sight, obviously related. These ideas are useful in mechanics and thermodynamics but to learners they may well appear to be topics which are not central to the syllabus as a whole. Undermine this impression by emphasising, whenever appropriate, the relationships of the concepts included here to those elsewhere in the course.

Outline

This unit defines pressure and then applies it to situations involving solids, liquids and gases. Two simple pressure-measuring instruments are described and the operation of hydraulic machines explained. At this stage, Boyle's Law is introduced and used. This leads to a more thorough look at gases and how the behaviour of their molecules can explain their properties. Evaporation is re-examined in molecular terms at the conclusion of the unit.

<table>
<tr><th>Syllabus ref</th><th>Learning objectives</th><th>Suggested teaching activities</th></tr>
<tr><td>7(a)</td><td>Define the term pressure in terms of force and area, and do calculations using the equation

pressure = force/area.</td><td rowspan="2">Basic;
Use an inflating balloon to lift weights. Two square holes of different sizes are cut in the flat upper surface of a thin wooden box. A large balloon is placed in the box. The sections which were cut out of the box are placed back in the holes. As the balloon inflates, the small wooden platforms rise up lifting weights placed on them. The larger area platform can lift a larger weight. (I G W)

Show the effect of pressure in experiments. Place heavy cones on sand, both upright and inverted, or construct a "bed" of nails (~25 cm × ~25 cm) and stand on it carefully. (I G W)

Many simple examples illustrate the significance of pressure:
• the ineffectiveness of a blunt knife
• walking on snow in ordinary shoes – use snowshoes
• a nail or drawing pin has a large area at one end and a smaller one at the other
• heavy vehicles on soft ground need large area caterpillar tracks,
compare elephants and women in stiletto heels. (I G W)

Pressure:
www.youtube.com/</td></tr>
<tr><td>7(b)</td><td>Explain how pressure varies with force and area in the context of everyday examples.</td></tr>
</table>

Syllabus ref	Learning objectives	Suggested teaching activities
		and **http://hyperphysics.phy-astr.gsu.edu/hbase/press.html** Simple experiments: **http://outreach.phys.uh.edu/pressureexperiments.htm** and **www.youtube.com/watch?v=2VHneRg0mhI** Examples: **http://hyperphysics.phy-astr.gsu.edu/hbase/kinetic/patm.html**
7(d)	Explain quantitatively how the pressure beneath a liquid surface changes with depth and density of the liquid in appropriate examples.	**Challenging:** Deduce the formula $p = hdg$ by considering the weight of a certain depth of liquid acting on the base of a tank. Consider specific examples: • the increase of pressure with depth (1 atm. /10 m) • the pressure divers encounter at 20 m • the pressure at a depth of 10 000 m (the Mindanao trench). (**I G W**) **Basic:** Let water escape out of narrow tubes at different levels in the side of a cylinder of height ~50 cm, filled with water. The lowest jet squirts the furthest. (**W**) Lower a sensitive pressure gauge into water and observe the reading. (**I G W**) Pressure in liquids: **http://hyperphysics.phy-astr.gsu.edu/hbase/pflu.html** and **www.youtube.com/watch?v=ZUfQmjcz2vg** and **www.youtube.com/watch?v=ww5Rynzgpdw** Pressure in the sea:
7(e)	Do calculations using the equation for hydrostatic pressure $p = hdg$.	

Syllabus ref	Learning objectives	Suggested teaching activities
		www.grc.nasa.gov/WWW/k-12/WindTunnel/Activities/fluid_pressure.html
7(c)	Describe how the height of a liquid column may be used to measure the atmospheric pressure.	**Basic:** Consider inverting a 1.0 m tube full of mercury into a small mercury bath (wear thin plastic gloves to prevent mercury absorption through the skin). Calculate the pressure at the base of the column of mercury. It exceeds atmospheric pressure. The mercury flows out of the tube until the pressure of the mercury equals that of the atmosphere. What happens as the atmospheric pressure changes? (**W**) Describe a manometer and make a simple one to measure the excess pressure of the gas main. (**I G W**) Measure how hard a learner can blow. A water manometer will need to be ~3.0 m tall for this. (**I G W**) To make a barometer with water would need plastic tubing of length 10 m; it is what Torricelli did. It can be done. (**W**) Torricelli's experiment: http://fyzweb.cuni.cz/piskac/pokusy/torr/ Making a barometer: www.youtube.com/watch?v=GgBE8_SyQCU
7(f)	Describe the use of a manometer in the measurement of pressure difference.	**Challenging:** Pour water into a U-tube. Into one limb pour a less dense liquid. The top levels in the limbs are unequal. This is especially surprising if the second liquid can mix with water (e.g. ethanol). (**W**) Manometer: www.youtube.com/watch?v=5QEAHhXAu3M and http://olevelphysicsblog.blogspot.co.uk/2010/08/gas-pressure.html
7(g)	Describe and explain the transmission of pressure in hydraulic systems with particular reference to the hydraulic press and hydraulic brakes on vehicles.	**Basic:** Make a model hydraulic jack with two vertical syringes of different diameters. The syringes are half-filled with oil and their jets joined with tubing (filled with oil – water can be used but forms bubbles of air). Pushing down one piston lifts the other. Use a small weight on the smaller syringe to lift a greater one on the larger syringe. A small force is being magnified. Compare the distances through which the two weights move. (**I G W**)

Syllabus ref	Learning objectives	Suggested teaching activities
		Challenging: Solids transmit forces, whereas liquids and gases transmit pressures. Hand out incomplete or unlabelled diagrams of these devices and let the learners complete them. (**W**) Hydraulic brakes or press: www.darvill.clara.net/enforcemot/pressure.htm and www.youtube.com/watch?v=ANsFhXhfXao Hydraulic brakes: www.youtube.com/watch?v=LYetGatzWjM
7(h)	Describe how a change in volume of a fixed mass of gas at constant temperature is caused by a change in pressure applied to the gas.	**Basic:** Learners will know that reducing the volume of a gas increases its pressure. Place a finger over the end of a bicycle pump; it takes a large force to compress the gas. (**I G W**) Use a standard piece of equipment to demonstrate Boyle's Law. (**G W**) Consider examples such as: • bubbles released from sinking ships • the volume of a free diver's lungs at ~70 m below sea level • partially inflated meteorological balloons released from the earth's surface. (**W**) **Challenging:** Explain the law in molecular terms. In a larger volume the molecular density is lower and so there are fewer collisions with the walls of the vessel per second. The pressure falls. (**W**) Boyle's Law: www.grc.nasa.gov/WWW/K-12/airplane/aboyle.html and www.youtube.com/watch?v=J_I8Y-i4Axc and www.s-cool.co.uk/gcse/physics/forces-moments-and-pressure/revise-it/forces-and-pressure
7(i)	Do calculations using $p_1V_1 = p_2V_2$.	

Syllabus ref	Learning objectives	Suggested teaching activities
12(a)	State the distinguishing properties of solids, liquids and gases.	**Basic:** Learners will be very familiar with these properties. This is a sensible time to tabulate them. Include: solids transmit forces; liquids and gases transmit pressures. (**I G W**) Solids, liquids and gases: **www.youtube.com/watch?v=v12xG80KcZw** and **www.youtube.com/watch?v=3qAs1Nt0Fjk**
12(b)	Describe qualitatively the molecular structure of solids, liquids and gases, relating their properties to the forces and distances between molecules and to the motion of the molecules.	**Basic:** Show learners models of solid structures. Balls joined together by springs and balls glued together directly. Use glass beads in a tube with a vibrating base to simulate the three states. (**W**) Learners can act out the behaviour of solids, liquids and gases as they behave like molecules themselves. (**W**) **Challenging:** Show the Brownian motion of smoke particles. (**W**) Calculate or give values for the separation of molecules in liquids and solids. (**W**) Calculate the separation of molecules in air at room temperature. (**W**) Note that Brownian motion is the motion of the suspended particles not the motion of the atoms or molecules. Brownian motion: **www.youtube.com/watch?v=cDcprgWiQEY** and **www.youtube.com/watch?v=3EHQf3HRiDc** and **www.youtube.com/**
12(c)	Describe the relationship between the motion of molecules and temperature.	**Basic:** State as a fact that molecules travel faster at higher temperatures. (**W**)

Syllabus ref	Learning objectives	Suggested teaching activities
		Molecules in solids vibrate but in gases they travel in straight lines between collisions. (**W**) **Challenging:** Ask learners to explain why: • the speed of sound in air increases with temperature • the pressure of a trapped gas rises with temperature. Take a hollow, copper sphere with a pressure gauge attached. The pressure increases with its temperature. (**I G W**) Moving molecules: **http://id.mind.net/**
12(d)	Explain the pressure of a gas in terms of the motion of its molecules.	**Basic:** Explain that the collisions of extremely tiny molecules travelling at very high speeds causes many minute impacts whose spread out effect is detected on a macroscopic scale as pressure. (**W**) A football can be kept in the air by constantly punching it from below. Many tiny impacts cause a single force. (**W**) Balloons burst as a party progresses, it gets hotter in the room and the pressure in the balloons rises. (**W**) Explain that gas cylinders explode in fires. (**W**) Pressure and temperature: **http://m.everythingscience.co.za/** and **http://hyperphysics.phy-astr.gsu.edu/hbase/kinetic/idegas.html**
12(e)	Describe evaporation in terms of the escape of more energetic molecules from the surface of a liquid.	**Basic;** The faster molecules escape and so the liquid left behind is cooler. (**W**) Place a glass beaker or a copper can on another one which is upside down. Put a small amount of water between them. In the top vessel pour a small amount of a volatile liquid. Force air rapidly through the liquid so that it evaporates quickly. The water freezes and the lower vessel can be lifted up with the upper one. (**G W**)
12(g)	Explain that evaporation causes cooling.	

Syllabus ref	Learning objectives	Suggested teaching activities
		Cooling by evaporation: • refrigerators • perspiration • panting dogs • wiping ether on an arm before an injection wrapping butter or ice cream in wet paper to keep it cool. Evaporation: **http://hyperphysics.phy-astr.gsu.edu/hbase/kinetic/vappre.html** and **www.bbc.co.uk/schools/gcsebitesize/science/aqa/heatingandcooling/heatingrev5.shtml** and **www.youtube.com/watch?v=G0nWby2f0ok** Refrigerators: **http://physics.info/refrigerators/**
12(f)	Describe how temperature, surface area and draught over a surface influence evaporation.	**Basic:** Carry out some experiments to determine these effects. Use a volatile liquid or use water over several days. (**I G W**) How is the shape of a cooking pan determined by what is being cooked? Why does an evaporating dish have a large surface area? (**W**) Rate of evaporation: **www.vtaide.com/png/evaporation.htm** and **www.youtube.com/watch?v=1AfkJ5KB34Y**

Past paper and specimen papers
Past paper questions: Jun 12 Paper 21 Q3 Jun 12 Paper 22 Q4 Nov 11 Paper 22 Q3 Jun 11 Paper 21 Q4 Jun 11 Paper 22 Q1 Past question papers available at: **http://teachers.cie.org.uk**

Unit 10: Practical electricity

Recommended prior knowledge

Learners tackling this unit ought to be acquainted with the concept of energy from Unit 5, the basic ideas of current electricity in Unit 4, electromagnetism in Unit 7. This unit ought to be taught near the end of the course. Learners are quite likely to have been aware of the installation of mains electricity or the rewiring of a house but may not be very familiar with the physics which lies behind much of what they have seen. Similarly, the use of the c.r.o. in medical establishments will be familiar but they are unlikely to know how it works.

Context

This unit applies the rather theoretical aspects of electricity, which have already been dealt with, to more practical circumstances which learners will be quite familiar with. The supply of electricity to homes, offices and industry is a major convenience of the modern world and the electricity supply industry is important in every country in the world. The use and operation of the c.r.o. leads on to some electronic devices and circuits. These are the very foundation of both the electronics industry and the information revolution for which the use of computers and modern communications have been essential.

Outline

The unit begins with some of the uses of electrical energy on a domestic scale. The formula for power can be used to calculate the rating for the fuse which a particular appliance requires; circuit breakers are dealt with here. The mechanics of charging for electricity is explained and so is the wiring of plugs and the dangers posed by selected electrical hazards. The cathode-ray oscilloscope is described in some detail. Potential dividers, capacitors and reed relays are explained and then used in certain electronic circuits. The last section describes logic gates, transistors, bistable circuits and astable circuits, which are an optional part of the course and may only be of interest to some teachers or learners.

Classroom organisation and differentiation details: **W**: whole class; **G**: group; **I**: individual

Syllabus ref	Learning objectives	Suggested teaching activities
21(a)	Describe the use of electricity in heating, lighting and motors.	**Basic:** Emphasise that the overwhelming majority of electrical energy is used in this way. Consider industrial and domestic uses: kettles, furnaces, cookers, street lights, table lights, theatre lights, illuminated signs, lighting in greenhouses and zoos, drills, lifts, food-mixers, saw-mills. Consider less obvious and mixed examples: refrigerators, washing machines and so on. Learners can make their own list and report to the class on the Physics principles by looking around their home or neighbourhood. (**I G W**) Can these operate on an a.c. supply? (**W**) Are there other uses of electricity – charging batteries, operating electronics? (**I G W**)

Syllabus ref	Learning objectives	Suggested teaching activities
		Can these use an a.c. supply? (**W**) Uses of electricity: **www.youtube.com/watch?v=eUoviiylEmQ**
21(b)	Do calculations using the equation *power = voltage × current*, and *energy = voltage × current × time.*	**Basic:** Consider: *energy* = *voltage* × *charge* (Unit 4) and divide both sides by *time.* The definition: $V = P/I$ is just as satisfactory as the more traditional: $V = E/Q$ and the volt may be taken as the watt/ampere. In some ways these definitions are superior as learners are more likely to be familiar with current than with charge. (**W**) Since $E = Pt$ so $E = VIt$. Electrical power: **www.kpsec.freeuk.com/power.htm** and **www.bbc.co.uk/schools/gcsebitesize/**
21(e)	Explain the use of fuses and circuit breakers and fuse ratings and circuit breaker settings.	**Basic:** Produce in class some domestic devices: kettle, drills, radios. Read the power from the label and calculate the current drawn. What fuse rating is required? Consider car headlamps (12 V) and rechargeable appliances. (**I G W**) Buy a reel of low rating fuse wire (~2A) and allow learners to see it blow or measure how the fusing current depends on the length of fuse wire. (**I G W**) **Challenging:** Consider R.C.C.B.s (residual current circuit breakers) Fuses and circuit breakers: **http://hyperphysics.phy-astr.gsu.edu/** and **www.gcsescience.com/pme9.htm**
21(c)	Calculate the cost of using electrical appliances where the	**Basic:** Learners realise that the cost of electricity is likely to depend on the power of the device and the time for

Syllabus ref	Learning objectives	Suggested teaching activities
	energy unit is the kWh.	which it is used. Hence it depends on $P \times t$. Electricity suppliers tend to use the kW h but emphasise that this is a special non-SI unit which equals 3.6 MJ. (**G W**) Show learners an electricity meter and read it. Explain that it keeps a running tally of the energy used. (**W**) Allow learners to heat up water electrically, measuring power and time, and then calculate the cost of heating up a cup of coffee or tea or a swimming-pool. (**I G W**) Show learners an actual and recent bill and explain how the final cost is calculated. (**I G W**) **Challenging:** Are there any standing charges? Is there any cheap rate electricity at night? Are there any taxes? Electricity bills: **www.gcse.com/energy/kWh5.htm** and **www.bbc.co.uk/schools/gcsebitesize/**
21(g)	State the meaning of the terms *live*, *neutral* and *earth*.	**Basic:** Explain that the earth wire is a safety feature; the device can function without it although it is not safe to let it do so. It is the live and neutral wires which constitute the circuit. (**W**) **Challenging:** Emphasise that earthing (the term *grounding* in used in some places but it is not used in this syllabus) operates in conjunction with the fuse; a live metal case connected to earth is **not** safe until the large earth current drawn through the live blows the fuse. (**W**) Appliances with double plastic cases have nothing to earth and do not need to be earthed. Show them the double square symbol on such a device. (**W**) Some devices have a plastic “earth” pin. This operates the safety shield on the socket. (**W**) The live wire is the one whose voltage varies and this is responsible for the current. The neutral wire (~0 V) completes the circuit. (**W**) This is why it is the live connection must be broken to make a device safe. (**W**)
21(f)	Explain the need for earthing metal cases and for double insulation.	
21(i)	Explain why switches, fuses and circuit breakers are wired into the live conductor.	

Syllabus ref	Learning objectives	Suggested teaching activities
		Mains wiring: **www.frankswebspace.org.uk/ScienceAndMaths** Earthing: **www.bbc.co.uk/schools/** and **www.bbc.co.uk/schools/gcsebitesize/s** Double insulation: **http://olevelphysicsblog.blogspot.co.uk/2010/12/dangers-of-electricity.html**
21(h)	Describe how to wire a mains plug safely. Candidates will not be expected to show knowledge of the colours of the wires used in a mains supply.	**Basic:** Allow the learners to wire plugs. (**Keep a special set for the learners with a screw drilled through it so that it cannot be inserted into a socket. This prevents a learner who has wired the plug incorrectly from inserting it into a socket.**) (**I G W**) Draw attention to the dangers of frayed wires and cut insulation. Explain that domestic water is quite a good conductor. Do not trail leads under carpets. (**W**) Electrical safety: **www.youtube.com/watch?v=-IddGWFBbWI**
21(d)	State the hazards of damaged insulation, overheating of cables and damp conditions.	
24(a)	State that electrons are emitted by a hot metal filament.	**Basic:** State this as a fact. It can be shown by thermionic diodes connected to sensitive galvanometers – if available. Or in the fine beam tube the low pressure hydrogen indicates the path taken by the emitted electrons.(**W**) **Challenging:** The path of an electron beam in an electric field can be shown by appropriate thermionic tubes if available but emphasise that the path of the electrons will not be circular in a uniform electric field. The positive plate attracts the negative electrons into a (parabolic) path. (**W**) Thermionic emission: **www.matter.org.uk/tem/electron_gun/electron_gun_simulation.htm** and **www.youtube.com/watch?v=pw9c-X6JCdI**
24(b)	Explain that to cause a continuous flow of emitted electrons requires (1) high positive potential and (2) very low gas pressure.	
24(c)	Describe the deflection of an electron beam by electric fields and magnetic fields.	

Syllabus ref	Learning objectives	Suggested teaching activities
		Thermionic diodes: www.nationmaster.com/encyclopedia/Thermionic-valve and www.st-andrews.ac.uk/~jcgl/Scots_Guide/audio/part9/page1.html Electric field deflection: http://physics.bu.edu/~duffy/PY106/Electricfield.html **Challenging:** The magnetic deflection is in accordance with Fleming's left-hand rule, bearing in mind that electrons are negatively charged. Emphasise that a uniform magnetic field can deflect an electron beam into a circular path whereas a uniform electric field cannot. (**W**) Electrons carry negative charge in the direction of travel which is equivalent to taking positive charge in the opposite direction. (**W**) Magnetic field deflection: www.regentsprep.org/Regents/physics/phys03/cdeflecte/default.htm Negative electrons: www.kpsec.freeuk.com/electron.htm
24(d)	State that the flow of electrons (electron current) is from negative to positive and is in the opposite direction to conventional current.	**Challenging:** Compare receiving electrons with receiving a bill; a bill is negative money and receiving one is a financial loss. (**W**) Electron current: http://academic.pgcc.edu/ent/

Syllabus ref	Learning objectives	Suggested teaching activities
24(e)	Describe the use of an oscilloscope to display waveforms and to measure p.d.s and short intervals of time (the structure of the oscilloscope is **not** required).	**Basic:** Show the learners a dismantled, old c.r.o. if available. Emphasise that two pairs of parallel, charged plates deflect the electron beam. (**W**) Emphasise that the left to right motion is controlled by an internal circuit whilst the up and down motion of the beam is controlled by the externally applied voltage. (**W**) Use a c.r.o. to display different waveforms from a signal generator. A medical c.r.o. must have a voltage input. There must be an electrical transducer in a heart monitor. Explain how time intervals can be obtained from distances measured across the screen and the timebase setting. Learners will need to practice with specific values. (**W**) **Challenging:** The speed of sound in a short, metal rod or even air can be obtained by using a c.r.o. to measure the small time interval. (**G W**) C.R.O: www.nuffieldfoundation.org/practical-physics/using-cro-show-rectification-diode and www.youtube.com/watch?v=0tPEoRSXUIY C.R.O. settings: www.kpsec.freeuk.com/cro.htm
24(f)	Explain how the values of resistors are chosen according to a colour code and why widely different values are needed in different types of circuit.	**Basic:** This just has to be explained but point out that the colours are almost but not quite the traditional seven colours of the rainbow which learners are likely to know. (**I G W**) Make a set of resistors on cards and allow learners to read their values. (**I G W**) Give examples of using different values for different purposes but remember that the resistance and e.m.f. determines the current. This, in turn, determines the power generated within the resistor. (**W**) **Challenging:** Doubling the length and the cross-sectional area of a resistor keeps its resistance constant but both the mass to be heated and its surface area will be larger. It stays cooler. (**W**)
24(g)	Discuss the need to choose components with suitable power ratings.	

Syllabus ref	Learning objectives	Suggested teaching activities
		Resistor colour code: **www.uoguelph.ca/~antoon/gadgets/resistors/resistor.htm**
24(h)	Describe the action of thermistors and light-dependent resistors and explain their use as input sensors (thermistors will be assumed to be of the negative temperature coefficient type).	**Basic/challenging:** State these behaviours as a fact but emphasise that both the heat in (NTC) thermistors and the light in LDR.s are used to free electrons from the structure which in turn reduces the resistance. It helps learners to remember how the resistance changes. PTC thermistors behave differently and are not in this syllabus. (**W**) Set up a circuit and show that the total p.d. across two unequal resistors is unequally divided. (The mouse ends up with the mouse's share; the lion takes the lion's share.) (**I G**) Use a variable resistor as one of the resistors and adjust it. What happens to the voltage of the middle point? (**I G W**) Use a switch, a thermistor and an LDR instead of the variable resistor. (**I G W**) Try to avoid using a variable resistor on its own as a potential divider until the idea is properly understood. When it is used the resistance of one end increases whilst that of the other end becomes smaller. This is confusing at first. Thermistors and LDRs: **www.bbc.co.uk/schools/gcsebitesize/s** and **http://physicsnet.co.uk/gcse-physics/non-ohmic-devices/** Thermistors: **www.youtube.com/watch?v=FGt_mAWtV1Q** LDRs: **www.youtube.com/watch?v=NIkjito8yEA**
24(i)	Describe the action of a variable potential divider (potentiometer).	
24(j)	Describe the action of a diode in passing current in one direction only.	**Challenging:** Use a reed switch to switch on a circuit. Operate the reed switch with a bar magnet. Operate it with a clearly separate solenoid. See how close the solenoid has to be to the reed switch before the current in the solenoid

Syllabus ref	Learning objectives	Suggested teaching activities
24(k)	Describe the action of a light-emitting diode in passing current in one direction only and emitting light.	will operate the reed switch. (**W**) Emphasise that a reed relay is a reed switch with its own built-in solenoid. Show one being used. Use a d.c. circuit containing the solenoid to operate a low voltage a.c. motor. Emphasise the presence of two distinct circuits which are only linked magnetically. (**W**) Use circuits with switches, thermistors or LDRs in series with the solenoid of the reed relay. (**I G W**) A reed switch could be used to switch on a light when a door is opened or closed. The magnet is fixed to the door. (**W**) Reed switch: **www.eleinmec.com/article.asp?23** Reed relay: **www.cougarelectronics.com/relays/reedrelays.htm** and **www.youtube.com/watch?v=L9eiQOhT1fU**
24(l)	Describe and explain the action of relays in switching circuits.	
24(m)	Describe and explain circuits operating as light-sensitive switches and temperature-operated alarms (using a relay or other circuits).	**Basic:** Set up a circuit containing either an LDR or a thermistor and show that the current rises as the light intensity or temperature rises. With a reed relay in the circuit, a point is reached where the current closes the switch inside the reed relay. (**I G W**) This switch can be in an electrically different circuit that contains a bell or buzzer that rings when the circuit is closed – that is when a certain level of light intensity or temperature is reached. (**I G W**)
25(a)	Describe the action of a bipolar npn transistor as an electrically operated switch and explain its use in switching circuits.	**Challenging:** Set up a transistor switching circuit. E.g. use an LDR/resistor potential divider to control the base current and use the collector current to power a lamp. Emphasise that the transistor is being used as a switch in one circuit powered by the current in the other – just like the reed relay. (**I G W**) Transistor switching circuits: **http://hyperphysics.phy-astr.gsu.edu/hbase/electronic/transwitch.html**

Syllabus ref	Learning objectives	Suggested teaching activities
25(b)	State in words and in truth table form, the action of the following logic gates, AND, OR, NAND, NOR, and NOT (inverter).	**Basic:** Model AND and OR gate behaviour using switches in series or parallel in one circuit to operate a reed relay in a second circuit (which includes a lamp). Emphasise that the second circuit has its own power supply as do all logic gates. (**I G W**) Model NOT, NAND and NOR gate behaviour by using the reed relay to switch off the second circuit. Emphasise that when the first circuit is switched off the second is powered by its own supply; likewise when the input to a NOT gate is 0, the logic gate's own power supply produces the output voltage. (**I G W**) **Challenging:** Compare with logic gate circuits and emphasise that a logic gate has its own power supply. A NOT gate does not magically turn 0 V (0) into say 6 V (1). (**W**) It is worth setting up a few logic gate circuits and explaining how they work: Use a NOT gate and an LDR to switch on a light when it is dark. (**W**) Use an AND gate to switch on a heater when it is cold and dark. (**W**) Logic gates: **www.kpsec.freeuk.com/gates.htm** and **www.youtube.com/watch?v=flO8wARVDY4**
25(c)	State the symbols for the logic gates listed above (American ANSI Y 32. 14 symbols will be used).	
25(d)	Describe the use of a bistable circuit.	**Challenging:** Set up a bistable circuit with two NAND gates (or a transistor bistable circuit). Put an LED at one output and a buzzer at the other. Use push switches. Observe that one switch switches the buzzer on and the LED off, whilst the other has the reverse effect. (**I G W**) Such a circuit can be used as a burglar alarm or an emergency off switch for an escalator. The switch to turn it back on it located elsewhere; the public may only switch it off. (**W**) Explain that the circuit "can remember" which switch was most recently operated. (**W**) Bistable circuits: **www.sphaera.co.uk/bistable.htm** and
25(e)	Discuss the fact that bistable circuits exhibit the property of memory.	

Syllabus ref	Learning objectives	Suggested teaching activities
		www.youtube.com/watch?v=0tR5nwfENb4
25(f)	Describe the use of an astable circuit (pulse generator)	**Challenging:** Set up an astable circuit with NOR gates and capacitors (or a transistor astable circuit). Connect the output to a buzzer or an LED. Observe the pulsating sound or the flashing light. Vary the value of the resistors and observe the effect on the pulsing frequency. Vary the value of the capacitors and repeat the observation. Check for inverse proportionality in each case. (**I G W**) Astable circuit: www.bbc.co.uk/schools/gcsebitesize/design/electronics/integratedrev2.shtml and www.youtube.com/watch?v=tJMN5CR6aPw
25(g)	Describe how the frequency of an astable circuit is related to the values of the resistive and capacitative components.	

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Cambridge International Examinations
1 Hills Road, Cambridge, CB1 2EU, United Kingdom
tel: +44 1223 553554 fax: +44 1223 553558
email: **info@cie.org.uk** **www.cie.org.uk**

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