

UNIT 3: Electric charge

Recommended Prior Knowledge Students should be aware of the two types of charge, charging by friction and by induction. They should be able to distinguish between conductors and insulators using a simple electron model.

Context An understanding of static charge and current electricity in this Unit is an essential prerequisite to further more advanced studies in the A2 course. For students who intend to take only the AS course, then current electricity is an important topic in the general education of any person in this modern world.

Outline Students will become familiar with the basic definitions and equations used in the study of current electricity. The I/V relationships for different circuit components are investigated. Components are then linked together so that practical circuits may be studied. Electric fields and the motion of free charged particles are also studied as further examples of charges in motion.

Learning Outcomes		Suggested Teaching Activities	Resources
	Candidates should be able to		
20.(a)	recall and use appropriate circuit symbols as set out in <i>SI Units, Signs, Symbols and Abbreviations</i> (ASE, 1981) and <i>Signs, Symbols and Systematics</i> (ASE, 1995).	Discussion and revision: <ul style="list-style-type: none"> - why use circuit symbols? - symbols already met 	Reference should be made to the list of textbooks printed in the Syllabus document. Note that some of these texts are more suitable as reference texts for the teacher whilst others are more suitable as student texts. Some Internet sites are shown within certain topics. The list of sites is by no means comprehensive but provides examples of what is available. Material may provide a link with O-level and IGCSE studies, thus providing background experience, as well as reinforcing AS studies. All examples of examination questions are taken from Physics 8702 and 9702 Papers. Handout of symbols based on <i>SI Units, Signs, Symbols and Abbreviations</i> (ASE, 1981) and <i>Signs, Symbols and Systematics</i> (ASE, 1995).

20.(b)	draw and interpret circuit diagrams containing sources, switches, resistors, ammeters, voltmeters, and/or any other type of component referred to in the syllabus.	Drawing circuits: meaning of 'series' and 'parallel' Expt: interpreting and setting up circuits	Circuit diagrams and corresponding components, leads
19.(a)	show an understanding that electric current is the rate of flow of charged particles.	Discussion: what is electric current? Evidence provided by (i) electrolysis (ii) migration of ions Direction of movement of charge - movement of electrons in metals - conventional current	copper voltameter, d.c. supply h.t. supply, leads and croc clips, filter paper, ammonia solution, potassium permanganate crystals
19.(b) 19.(c)	define charge and the coulomb. recall and solve problems using the equation $Q = It$.	Revision of base units - unit of current (amp) is a base unit - unit of time (second) is a base Definition of charge and the coulomb in terms of base units. $Q = It$	Examples sheet including Specimen Paper 1, question 34 Oct/Nov 2001, Paper 1, question 32 Oct/Nov 2001, Paper 1, question 33
19.(d) 19.(e)	define potential difference and the volt. recall and solve problems using $V = W/Q$.	Discussion: charges in motion – where has the energy come from? Potential difference (p.d.) as energy per unit charge transferred from electrical to some other form. $V = W/Q$ Volt defined as joule per coulomb.	
19.(g) 19.(h)	define resistance and the ohm. recall and solve problems using $V = IR$.	Expt: I/V characteristic of a wire. (Note that the experiment is not intended to be rigorous. Rather, it provides practice at circuit building and meter reading) Plot graph for forward and reverse voltage. Discussion: idea of 'resistance' to current flow Resistance and ohm defined - ratio V/I , not the	variable d.c. supply or battery and variable resistance, switch, length of resistance wire, croc clips, leads, ammeter, voltmeter (digital or analogue).

19.(f)	recall and solve problems using $P = VI$, $P = I^2 R$.	<p>gradient of a graph. $R = V/I$.</p> <p>Revision of terms <i>work</i> and <i>power</i> from Unit 2 Derivation of <i>power</i> = $VI = I^2 R$ using $V = W/Q$, $P = W/t$, $Q = It$ and $V = IR$</p>	<p>Examples sheet including Specimen Paper 1, question 35 Oct/Nov 2001, Paper 1, question 34</p> <p>Examples sheet including Specimen Paper 1, question 33 Specimen Paper 2, question 10(a) May/June 2001, Paper 2, question 7(a) Oct/Nov 2001, Paper 2, question 7(a)(i) May/June 2002, Paper 1, question 32 May/June 2002, Paper 2, question 8(b)</p>
19.(i)	sketch and explain the I/V characteristics of a metallic conductor at constant temperature, a semiconductor diode and a filament lamp.	<p>Expt: I/V characteristics of a metallic conductor at constant temperature. Note: forward and reverse voltages. Explanation in terms of constant resistance</p> <p>Expt: I/V characteristics of a semiconductor diode. Note: forward and reverse voltages. Explanation in terms of different resistance values The ideal diode and its I/V characteristic. Expt: I/V characteristics of a filament lamp Note: forward and reverse voltages Explanation in terms of increase of resistance of a metal with temperature</p>	<p>Variable d.c. supply or battery and variable resistance, switch, length of enamelled constantan wire on a former, croc clips, leads, ammeter, voltmeter, (digital or analogue), means of temperature control e.g. water bath and thermometer. Data logger etc (if available)</p> <p>Variable d.c. supply or battery and variable resistance, switch, semiconductor diode with protective resistor, croc clips, leads, ammeter, voltmeter, (digital or analogue) Data logger etc (if available)</p> <p>Variable d.c. supply or battery and variable resistance, switch, filament lamp (e.g. 12 V, 36 W), croc clips, leads, ammeter, voltmeter, (digital or analogue) Data logger etc (if available) See also Specimen Paper 2, question 10(c) May/June 2001, Paper 1, question 31 May/June 2002, Paper 1, question 30</p>

19.(j)	sketch the temperature characteristic of a thermistor.	Expt: temperature characteristic of a thermistor Explanation of graph in terms of large decrease of resistance (c.f. metal) with temperature rise	variable d.c. supply or battery and variable resistance, switch, bead thermistor on insulated leads, croc clips, leads, milliammeter, voltmeter, (digital or analogue), means of temperature control e.g. water bath and thermometer, warm water
19.(k)	state Ohm's law.	Discussion and formalisation of Ohm's law	
19.(l)	recall and solve problems using $R = \rho l/A$.	Discussion and development of $R \propto l$ $R \propto 1/A$ Expt: dependence of resistance on length and area of cross-section. ρ as constant in expression $R \propto l/A$ definition and unit of resistivity Worked examples	variable d.c. supply or battery and variable resistance, switch, croc clips, leads, ammeter, voltmeter, (digital or analogue), resistance wires of same material but different lengths and diameters, metre rule, micrometer screw gauge Examples sheet including May/June 2001, Paper 1, question 32 Oct/Nov 2001, Paper 2, question 7(a)(ii)
19.(m)	define e.m.f. in terms of the energy transferred by a source in driving unit charge round a complete circuit.	Discussion: energy transfer in a battery energy transfer in a resistor $V = W/Q$ applies to both	
19.(n)	distinguish between e.m.f. and p.d. in terms of energy considerations.	distinction between e.m.f. and p.d. e.m.f. as p.d. between terminals on open circuit	
19.(o)	show an understanding of the effects of the internal resistance of a source of e.m.f. on the terminal potential difference and output power.	Discussion: idea of internal resistance of a supply circuit symbol for cell with internal resistance effect on terminal p.d. when current delivered effect on power delivered /dissipated in cell	http://www.mos.org/sln/toe/tennisballs.html

		Expt: Output power of a cell	Cell/battery with a 5Ω resistor strapped to one terminal to simulate internal resistance, $0 \rightarrow 10\Omega$ variable resistor, ammeter, voltmeter, leads
		Worked examples	Examples sheet including May/June 2001, Paper 1, question 33 Oct/Nov 2001, Paper 1, question 35 May/June 2002, Paper 1, question 31
20.(c)	recall Kirchhoff's first law and appreciate the link to conservation of charge.	Discussion: charge conservation leading to statement of Kirchhoff's first law	See also May/June 2002, Paper 1, question 33
20.(d)	recall Kirchhoff's second law and appreciate the link to conservation of energy.	Discussion: energy conservation leading to statement of Kirchhoff's second law	
20.(e)	derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in series.	Derivation of $R = R_1 + R_2 + \dots$ Expt: resistors in series	variable d.c. supply or battery and variable resistance, switch, leads, ammeter, voltmeter, (digital or analogue), various resistors
20.(g)	derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in parallel.	Derivation of $1/R = 1/R_1 + 1/R_2 + \dots$ Expt: resistors in parallel	variable d.c. supply or battery and variable resistance, switch, leads, ammeter, voltmeter, (digital or analogue), various resistors
20.(f)	solve problems using the formula for the combined resistance of two or more resistors in series.		
20.(h)	solve problems using the formula for the combined resistance of two or more resistors in parallel.	Worked examples	Examples sheet including Specimen Paper 1, question 37, 38 Specimen Paper 2, question 10(b) May/June 2001, Paper 2, question 7(b), (c) Oct/Nov 2001, Paper 1, question 37 May/June 2002, Paper 1, question 34 May/June 2002, Paper 2, question 8(a)

20.(i)	apply Kirchhoff's laws to solve simple circuit problems.	Worked examples	Examples sheet including May/June 2001, Paper 1, question 36 Oct/Nov 2001, Paper 2, question 7(b)
20.(j)	show an understanding of the use of a potential divider as a source of variable p.d.	Discussion: 'sharing' p.d. between two resistors in series. Theory leading to $V/E = R_1/(R_1 + R_2)$ Demonstration: The potential divider	d.c. supply or battery, two variable resistors, three voltmeters, leads
20.(k)	explain the use of thermistors and light-dependent resistors in potential dividers to provide a potential difference that is dependent on temperature and illumination respectively.	Demonstration: Potential divider incorporating a thermistor Discussion: the light-dependent resistor (LDR) - basic properties Demonstration: Potential divider incorporating an LDR	d.c. supply or battery, bead thermistor, 1 k Ω resistor, voltmeter, leads d.c. supply or battery, LDR, 1 k Ω resistor, voltmeter, leads Examples sheet including Specimen Paper 1, question 1 Specimen Paper 1, question 36 May/June 2001, Paper 1, question 34 May/June 2001, Paper 1, question 35 Oct/Nov 2001, Paper 1, question 36 May/June 2002, Paper 1, question 35
20.(l)	recall and solve problems using the principle of the potentiometer as a means of comparing potential differences.	Discussion: p.d. along a current-carrying uniform wire, $V \propto I$, with conditions Demonstration: potentiometer wire Use of galvanometer for null position Expt: comparing the e.m.f.s. of two cells Worked examples	Potentiometer wire, driver cell and variable resistor, voltmeter, jockey, metre rule, leads Potentiometer wire, driver cell and variable resistor, galvanometer, jockey, metre rule, leads Examples sheet

17.(a)	show an understanding of the concept of an electric field as an example of a field of force and define electric field strength as force per unit positive charge.	Discussion: what is a field of force? electric field of force definition of electric field strength	
17.(b)	represent an electric field by means of field lines.	Discussion: representation of an electric field - electric field lines Demonstration: electric field lines Properties of field lines including spherical charge approximating to a point charge	H.T. supply, various shapes of electrode, olive oil, semolina, petri dish, OHP (if available) See also Specimen Paper 1, question 32 May/June 2002, Paper 1, question 37 May/June 2002, Paper 2, question 6(a)
17.(c)	recall and use $E = V/d$ to calculate the field strength of the uniform field between charged parallel plates in terms of potential difference and separation.	Field due to parallel plates, mention of edge effect. Field strength = V/d in centre region	
17.(d)	calculate the forces on charges in uniform electric fields.	Discussion: $force = Eq$ is constant for constant E Discussion: force on particle gives rise to acceleration	See also May/June 2002, Paper 1, question 6(b)
17.(e)	describe the effect of a uniform electric field on the motion of charged particles.	Use of equations of motion for calculating motion along the direction of the field. Trajectory motion – electric field at right angles to original direction of motion Demonstration:	'Teltron' tube
5(a)	describe the forces on mass and charge in uniform gravitational and electric fields, as appropriate.	Discussion of similarities and differences including relative magnitudes of forces on an electron and a proton in the Earth's field and the electric field between parallel plates. Worked examples	Examples sheet including May/June 2001, Paper 1, question 37, 38 Oct/Nov 2001, Paper 1, question 38 May/June 2002, Paper 1, question 36

