TECHNOLOGY IN SPACE

Overview of chapter

Table 4.1 summarises the content and skills covered in this chapter, and Table 4.2 lists the learning outcomes required by the exam specification. The latter are also listed as 'Achievements' in the final section of the chapter in the Student Book.

Table 4.1 Summary of the chapter *Technology in Space*

Outline and reference to student materials			Key points	Skills	Notes
Section 1.1 A space engineer	Introductory article		Self-contained power supplies and temperature control in spacecraft		
Section 1.2 Studying with satellites	Using the Internet and other resources to find information about space missions	Activity 1	Scope and diversity of space research and technology	Use of ICT Study skills	
	Using software to display satellite data	Activity 2	Changes in various parameters as a satellite moves around its orbit	Use of ICT Application of number	This activity is revisited several times during the chapter
Section 1.3 Spacecraft power systems	Interpreting graphical data relating type of power supply to power demands		Use of solar cells and rechargeable batteries in spacecraft	Application of number	
Section 2.1 Solar cells	Measurement of output pd from a solar cell	Activity 3	Qualitative relationship between illumination and voltage output	Practical work	Could be a demonstration plus discussion
	Simple explanation of how a solar cell works		Radiation supplies energy to electrons, enabling them to move through the cell Current as flow of charged particles		
	Data from space: variations in solar array voltage	Activity 4	Variations in voltage related to changes in illumination of satellite	Use of ICT	
	Charge and current, voltage and energy	Additional Sheets 1, 2 and 3	Conservation of charge and energy Definitions, including emf and terminal pd Series and parallel circuits		Revision/ extension of GCSE work
	Joining solar cells	Activity 5	The need for agreed standards Combinations of power sources in series and in parallel	Practical work	

Outline and reference to student materials			Key points	Skills	Notes
Section 2.2 Cells and circuits	Connecting a load to a power supply	Activity 6	Drop in terminal pd with external load	Practical work	Could be demonstrations
	Electrical resistance		Definition of resistance Ohm's law	Practical work Use of ICT	Revision of GCSE work
	An ohmic conductor?	Additional Sheet 4	Error bars and linear graphs	Application of number	
	Combinations of resistors	Activity 7	Conservation of charge and energy Resistors in series and in parallel	Application of number	Revision/ extension of GCSE work
	Internal resistance	Activity 8	Expressions involving internal resistance	Practical work Communication Application of number	Core practical
Section 2.3 Getting the most from your power supply	Reading/discussion of 'effectiveness' in context of space power supply		Idea of maximum power		
	Power in electric circuits		Power and energy		Revision of GCSE work
	Using a spreadsheet and algebra to calculate power output	Activity 9	Expressions involving internal resistance, emf and output power	Application of number Use of ICT	
	Using calculus to derive condition for maximum power	Additional Sheet 5	Differentiation using quotient or product rule	Application of number	Optional extension activity for mathematically inclined students
	Data from space: variations in battery current and voltage	Activity 10	Variations in satellite battery current and voltage are correlated	Use of ICT	
	Discussion: is maximum power the same as maximum efficiency?	Activity 11	Efficiency expressed as fraction and percentage	Communication Application of number	
Section 2.4 Summing up Part 2	Use of key terms from Part 2	Activity 12		Study skills Communication	
	Design a solar power source for a given load	Activity 13			
Section 3.1 Solar cells in space	Reading: use of solar power supplies in spacecraft				
Section 3.2 Explaining solar cells	Observing and explaining the photoelectric effect	Activity 14	Photoelectric emission Photon model		Builds on work from MUS and HFS
	Measuring threshold frequency	Activity 15	Photon energy, work function, stopping potential	Practical work Use of ICT	
Section 3.3 Summing up Part 3	Explaining operation of photocell using photoelectric effect	Activity 16		Study skills Communication	

Outline and reference to student materials			Key points	Skills	Notes
Section 4.1 Facing the right direction	Reading: importance of orientation of solar arrays. Calculations of solar array size	Activity 17	Power input and radiant energy flux Efficiency	Application of number	
	Discussion and demonstration of change in power with orientation of solar cell	Activity 18	Qualitative idea of effective area	Communication	Could be student practical work
Section 4.2 Temperature changes in spacecraft	Discussion of factors affecting spacecraft temperature	Activity 19	Solar heating Electrical heating Radiation losses	Communication	
	Data from space: variations in solar array temperature	Activity 20	Variations in solar array temperature with orientation	Use of ICT	
	Interpreting data on operating temperatures of electrical components		Effect of temperature on electrical components	Application of number	
	Measuring of resistance at different temperatures	Activity 21	Effect of temperature on resistance, including NTC thermistors	Practical work Communication Application of number	
	Modelling resistance		Idea of scientific models, model making and model fitting		
	Comparing own resistance data with simple mathematical model	Activity 22	Temperature coefficient of resistance Graphs and error bars	Application of number Communication	
Section 4.3 Why does resistance change with temperature?	Demonstration of drift speed of ions	Activity 23	Current related to number density and drift speed of charges	Application of number	
Section 4.4 Electronic materials and components	Simple explanation of semiconductor behaviour		Temperature and impurities affect number of free electrons Importance of solid-state physics research		
Section 4.5 Summing up Part 4	Use of key terms and concepts from Part 4	Activity 24		Study skills Communication	
Section 5.1 Conservation of …	Reading about conservation laws and looking for examples	Activity 25	Examples of conservation of mass, charge and energy	Study skills Communication	
Section 5.2 Modelling light	Researching and reporting on the ways in which ideas about the nature of light have changed over time	Activity 26	Wave and photon models	Study skills Use of ICT Communication	
Section 5.3 Questions on the whole chapter	Questions and calculations	Additional Sheet 6		Communication Application of number	Consolidation and revision
Section 5.4 Achievements	Chapter test	Additional Sheet 7 Additional Sheet 8		Communication Application of number	Questions illustrate style of external tests

Table 4.2 Learning outcomes specified for *Technology in Space*

	Statement from Examination Specification	Section(s) in this chapter
1	know and understand the distinction between base and derived quantities and their SI units	2.1, 2.2, 2.3
2	demonstrate their knowledge of practical skills and techniques for both familiar and unfamiliar experiments	2.2, 3.2, 4.2
4	understand the limitations of physical measurement and apply these limitations to practical situations	2.2, 4.2
5	be able to communicate information and ideas in appropriate ways using appropriate terminology	2.4, 4.2, 5.1, 5.2
8	understand the ways in which society uses science to inform decision making	3.1
30	be able to use the equation efficiency = $\frac{\text{[useful energy (or power) output]}}{\text{[total energy (or power) input]}}$	2.3, 4.1
31	understand that electric current is the rate of flow of charged particles and be able to use the equation $I = \frac{\Delta Q}{\Delta t}$	2.1, 4.3
32	understand how to use the equation $V = \frac{W}{Q}$	2.1, 2.2
33	understand that resistance is defined by $R = \frac{V}{I}$ and that Ohm's law is a special case when $I \propto V$ for constant temperature	2.2
34	understand how the distribution of current in a circuit is a consequence of charge conservation	2.1, 2.2
35	understand how the distribution of potential differences in a circuit is a consequence of energy conservation	2.1, 2.2
36	be able to derive the equations for combining resistances in series and parallel using the principles of charge and energy conservation, and be able to use these equations	2.2
37	be able to use the equations $P = VI$, $W = VIt$ and be able to derive and use related equations, e.g. $P = I^2R$ and $P = \frac{V^2}{R}$	2.3
38	understand how to sketch, recognise and interpret current–potential difference graphs for components, including ohmic conductors, filament bulbs, thermistors and diodes	2.2
45	know the definition of *electromotive force* (emf) and understand what is meant by *internal resistance* and know how to distinguish between emf and *terminal potential difference*	2.2
46	CORE PRACTICAL 3: Determine the emf and internal resistance of an electrical cell	2.2
47	understand how changes of resistance with temperature may be modelled in terms of lattice vibrations and number of conduction electrons and understand how to apply this model to metallic conductors, negative temperature coefficient thermistors	4.2
48	Understand how changes of resistance with illumination may be modelled in terms of the number of conduction electrons and understand how to apply this model to LDRs	4.4
70	be able to use the equation intensity of radiation $I = \frac{P}{A}$	4.1
92	understand that the absorption of a photon can result in the emission of a photoelectron	3.2
93	understand the terms *threshold frequency* and *work function* and be able to use the equation $hf = \phi + \frac{1}{2} mv^2_{max}$	3.2
94	be able to use the *electronvolt* (eV) to express small energies	3.2
95	understand how the photoelectric effect provides evidence for the particle nature of electromagnetic radiation	3.2

This chapter uses the context of spacecraft to introduce some work on DC circuits, and to explore the photoelectric effect. This chapter is intended to be taught after *The Sound of Music*, but if desired the two chapters could be taught in parallel, provided basic ideas about waves and photons are covered before students need to use them for the more advanced work in this chapter. Similarly, it is intended that this chapter is taught before *Digging Up the Past*, which builds on DC circuit work, waves, and ideas about wave–particle duality.

This chapter involves quite a bit of GCSE revision as well as new material. If you are confident that your students already have a firm grasp of DC circuits at GCSE level, it would be wise to spend only a short time on the revision activities or omit them altogether. However, going over familiar ground can be valuable, particularly in activities that help develop students' skills in using ICT and working with others.

After the introductory scene-setting of Part 1, Part 2 deals with solar cells and electric circuits (DC circuits, resistance, ohmic behaviour, internal resistance, maximum power transfer). Part 3 deals with the photoelectric effect, and Part 4 with radiation flux and the change of resistance with temperature. Part 5 draws together some key ideas about conservation and about the nature of light, the latter enabling students to explore aspects of how science works.

If the chapter is to be shared between two teachers, one could take the DC work (Parts 2 and 4) while the other covered Part 3, which deals with aspects of radiation.