IBO

INTERNATIONAL BACCALAUREATE ORGANIZATION

DIPLOMA PROGRAMME

Design Technology

For first examinations in 2003

Design Technology
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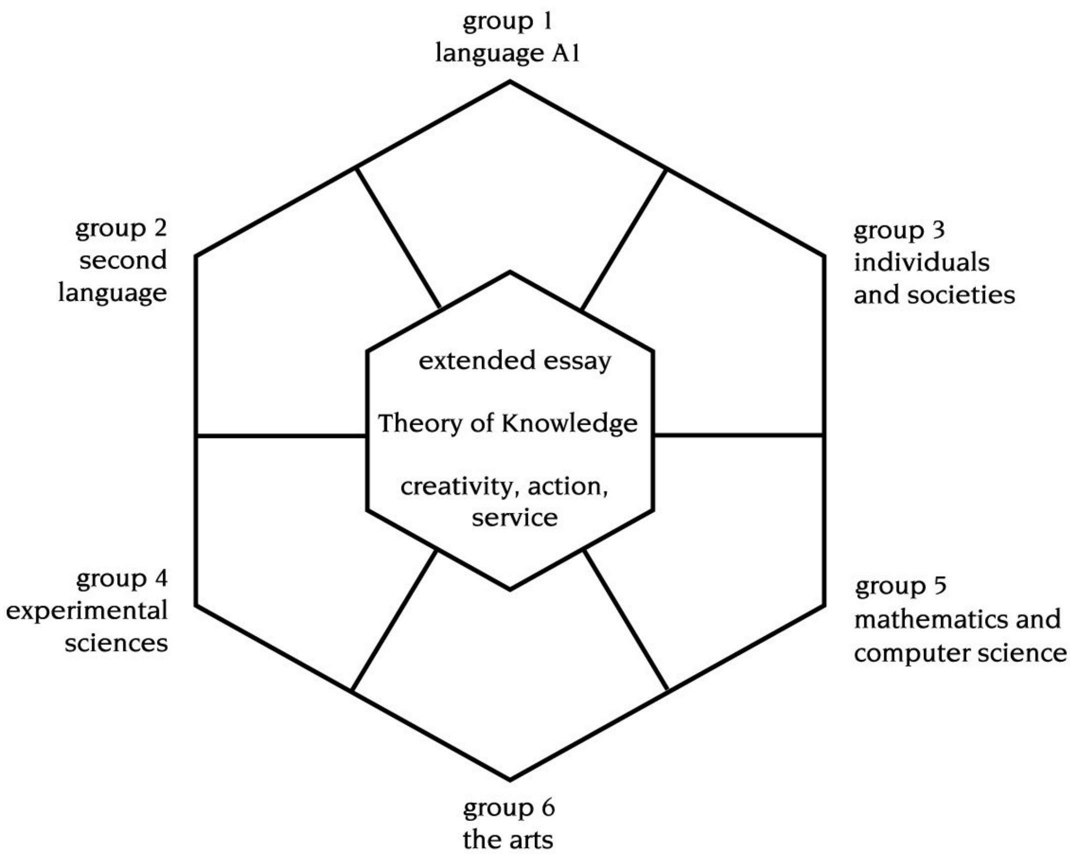
PART 1—GROUP 4

INTRODUCTION

The International Baccalaureate Diploma Programme is a rigorous pre-university course of studies, leading to examinations, that meets the needs of highly motivated secondary school students between the ages of 16 and 19 years. Designed as a comprehensive two-year curriculum that allows its graduates to fulfill requirements of various national education systems, the Diploma Programme model is based on the pattern of no single country but incorporates the best elements of many. The programme is available in English, French and Spanish.

The curriculum is displayed in the shape of a hexagon with six academic areas surrounding the core. Subjects are studied concurrently and students are exposed to the two great traditions of learning: the humanities and the sciences.



Diploma Programme candidates are required to select one subject from each of the six subject groups. At least three and not more than four are taken at higher level (HL), the others at standard level (SL). Higher level courses represent 240 teaching hours; standard level courses cover 150 hours. By arranging work in this fashion, students are able to explore some subjects in depth and some more broadly over the two-year period; this is a deliberate compromise between the early specialization preferred in some national systems and the breadth found in others.

Distribution requirements ensure that the science-orientated student is challenged to learn a foreign language and that the natural linguist becomes familiar with science laboratory procedures. While overall balance is maintained, flexibility in choosing higher level combinations allows the student to pursue areas of personal interest and to meet special requirements for university entrance.

Successful Diploma Programme candidates meet three requirements in addition to the six subjects. The interdisciplinary Theory of Knowledge (TOK) course is designed to develop a coherent approach to learning which transcends and unifies the academic areas and encourages appreciation of other cultural perspectives. The extended essay of some 4000 words offers the opportunity to investigate a topic of special interest and acquaints students with the independent research and writing skills expected at university. Participation in the creativity, action, service (CAS) requirement encourages students to be involved in artistic pursuits, sports and community service work.

For first examinations in 2003

CURRICULUM MODEL

A common curriculum model applies to all the Diploma Programme group 4 subjects: biology, chemistry, environmental systems, physics and design technology. (There are some differences in this model for design technology and these arise from the design project, a unique feature of this subject. A double asterisk (**) indicates where these differences occur.) A core of material is studied by both higher level and standard level students in all subjects, and this is supplemented by the study of options. Higher level students also study additional higher level (AHL) material. Higher level students and SL students both study two options. There are three kinds of options: those specific to SL students, those specific to HL students and those which can be taken by both SL and HL students. Schools wishing to develop their own school-based option should contact the IBCA office in the first instance.

This curriculum model is not designed to favour the teaching of SL and HL students together. The IBO does not support the joint teaching of students at different levels as this does not provide the greatest educational benefit for either level.

Higher level students are required to spend 60 hours, and SL students 40 hours, on practical/ investigative work**. This includes 10 to 15 hours for the group 4 project.

Group 4 Curriculum Model HL **

HL	Total teaching hours	**240**
Theory		**180**
	Core	80
	Additional higher level (AHL)	55
	Options	45
Internal assessment (IA)		**60**
	Investigations	45–50
	Group 4 project	10–15

Group 4 Curriculum Model SL **

SL	Total teaching hours	**150**
Theory		**110**
	Core	80
	Options	30
Internal assessment (IA)		**40**
	Investigations	25–30
	Group 4 project	10–15

Format of the Syllabus Details

Note: The order in which the syllabus content is presented is not intended to represent the order in which it should be taught.

The format of the syllabus details section of the group 4 guides is the same for each subject. The structure is as follows.

Topics or Options

Topics are numbered and options are indicated by a letter (eg Topic 6: Nucleic Acids and Proteins or Option C: Cells and Energy).

Sub-topics

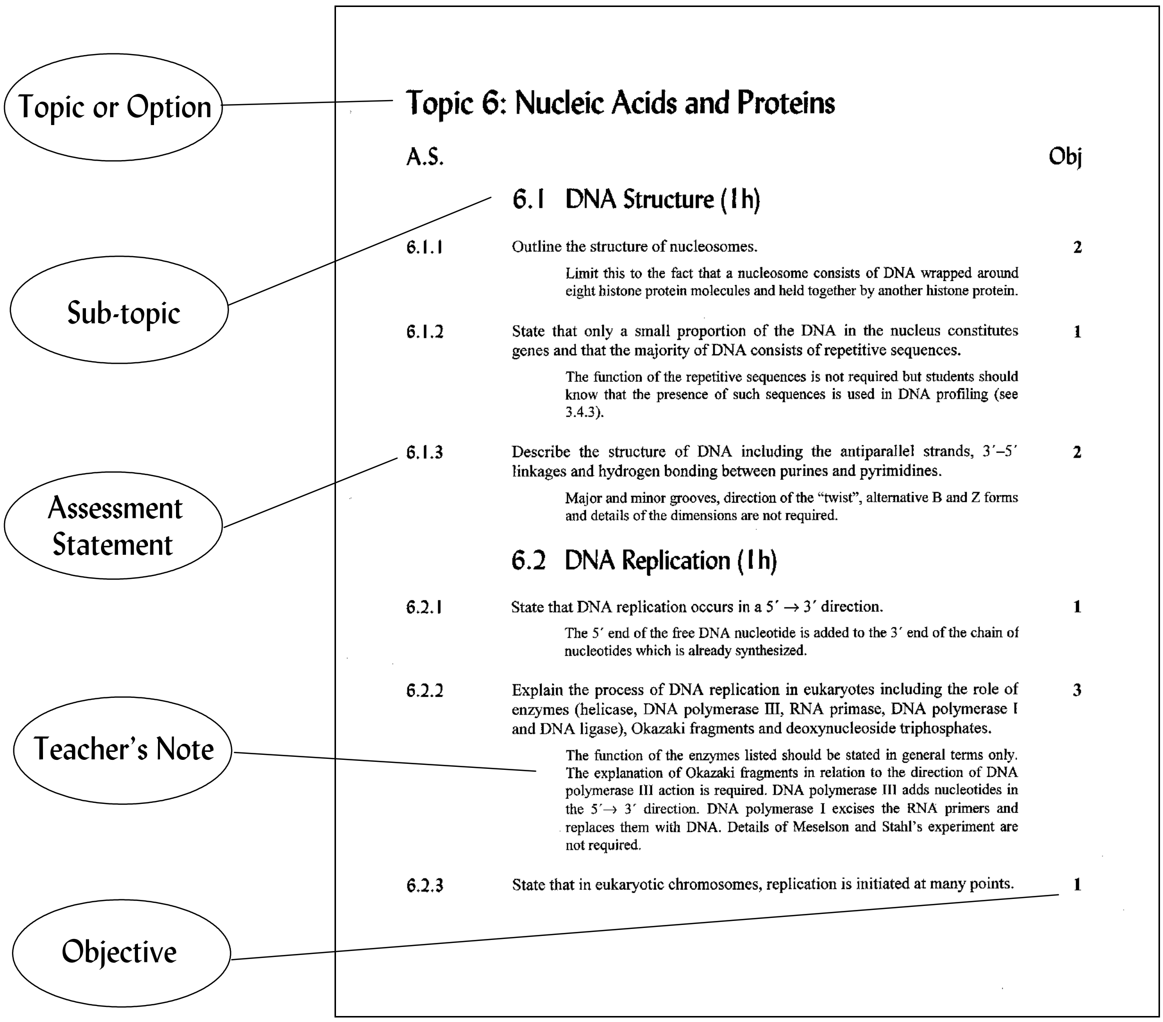
Sub-topics are numbered and the estimated teaching time required to cover the material is indicated (eg 6.1 DNA Structure (1h)). The times are for guidance only and do not include time for practical/investigative work.

Assessment Statements (A.S.)

Assessment statements, which are numbered, are expressed in terms of the outcomes that are expected of students at the end of the course (eg 6.1.1 Outline the structure of nucleosomes). These are intended to prescribe to examiners what can be assessed by means of the written examinations. Each one is classified as objective 1, 2 or 3 (see page 7) according to the action verb(s) used (see page 8). The objective levels are relevant for the examinations and for balance within the syllabus, while the action verbs indicate the depth of treatment required for a given assessment statement. It is important that students are made aware of the meanings of the action verbs since these will be used in examination questions.

Teacher's Notes

Teacher's notes, which are included below some assessment statements, provide further guidance to teachers.



AIMS

Through studying any of the group 4 subjects, students should become aware of how scientists work and communicate with each other. While the "scientific method" may take on a wide variety of forms, it will generally involve the formation, testing and modification of hypotheses through observation and measurement, under the controlled conditions of an experiment. It is this approach, along with the falsifiability of scientific hypotheses, that distinguishes the experimental sciences from other disciplines and characterizes each of the subjects within group 4.

It is in this context that all the Diploma Programme experimental science courses should aim to:

1. provide opportunities for scientific study and creativity within a global context which will stimulate and challenge students
2. provide a body of knowledge, methods and techniques which characterize science and technology
3. enable students to apply and use a body of knowledge, methods and techniques which characterize science and technology
4. develop an ability to analyse, evaluate and synthesize scientific information
5. engender an awareness of the need for, and the value of, effective collaboration and communication during scientific activities
6. develop experimental and investigative scientific skills
7. develop and apply the students' information technology skills in the study of science
8. raise awareness of the moral, ethical, social, economic and environmental implications of using science and technology
9. develop an appreciation of the possibilities and limitations associated with science and scientists
10. encourage an understanding of the relationships between scientific disciplines and the overarching nature of the scientific method.

OBJECTIVES

The objectives for all group 4 subjects reflect those parts of the aims that will be assessed. Wherever appropriate, the assessment will draw upon environmental and technological contexts and identify the social, moral and economic effects of science.

It is the intention of all the Diploma Programme experimental science courses that students should achieve the following objectives.

1. Demonstrate an understanding of:
   a. scientific facts and concepts
   b. scientific methods and techniques
   c. scientific terminology
   d. methods of presenting scientific information.
2. Apply and use:
   a. scientific facts and concepts
   b. scientific methods and techniques
   c. scientific terminology to communicate effectively
   d. appropriate methods to present scientific information.
3. Construct, analyse and evaluate:
   a. hypotheses, research questions and predictions
   b. scientific methods and techniques
   c. scientific explanations.
4. Demonstrate the personal skills of cooperation, perseverance and responsibility appropriate for effective scientific investigation and problem solving.
5. Demonstrate the manipulative skills necessary to carry out scientific investigations with precision and safety.

ACTION VERBS

These action verbs indicate the depth of treatment required for a given assessment statement. These verbs will be used in examination questions and so it is important that students are familiar with the following definitions.

Objective 1

Define	give the precise meaning of a word or phrase as concisely as possible
Draw	represent by means of pencil lines (add labels unless told not to do so)
List	give a sequence of names or other brief answers with no elaboration, each one clearly separated from the others
Measure	find a value for a quantity
State	give a specific name, value or other brief answer (no supporting argument or calculation is necessary)

Objective 2

Annotate	add brief notes to a diagram, drawing or graph
Apply	use an idea, equation, principle, theory or law in a new situation
Calculate	find an answer using mathematical methods (show the working unless instructed not to do so)
Compare	give an account of similarities and differences between two (or more) items, referring to both (all) of them throughout (comparisons can be given using a table)
Describe	give a detailed account, including all the relevant information
Distinguish	give the differences between two or more different items
Estimate	find an approximate value for an unknown quantity, based on the information provided and scientific knowledge
Identify	find an answer from a number of possibilities
Outline	give a brief account or summary (include essential information only)

Objective 3

Analyse	interpret data to reach conclusions
Construct	represent or develop in graphical form
Deduce	reach a conclusion from the information given
Derive	manipulate a mathematical equation to give a new equation or result
Design	produce a plan, object, simulation or model
Determine	find the only possible answer
Discuss	give an account including, where possible, a range of arguments, assessments of the relative importance of various factors or comparisons of alternative hypotheses
Evaluate	assess the implications and limitations
Explain	give a clear account including causes, reasons or mechanisms
Predict	give an expected result
Solve	obtain an answer using algebraic and/or numerical methods
Suggest	propose a hypothesis or other possible answer

INFORMATION AND COMMUNICATION TECHNOLOGY (ICT)

The role of computers in developing and applying scientific knowledge is well established. Scientists make measurements, handle information and model ideas. They need to process information and communicate it effectively.

Why Use Computers in Science?

Skills in handling information are clearly important life skills. The use of ICT will enhance learning, increase awareness of the technology scientists use for processing information and prepare students better for a rapidly changing situation in the real world. Computers enable students to become more active participants in learning and research and offer a valuable resource for understanding the processes of science. Development of ICT skills will allow students to explore rich materials, access information quickly and easily and lead them into areas previously experienced only through the possession of higher order skills. The computer also allows the teacher more flexibility in both approach and presentation of materials. Creating an ICT culture in classrooms is an important endeavour for all schools.

It is for these reasons that the IBO has incorporated a new aim related to ICT for group 4—aim 7: develop and apply the students' information technology skills in the study of science.

When Should Computers be Used?

The use of computers should complement rather than replace hands-on practical work. However computers can be used in areas where a practical approach is inappropriate or limited.

For example: sensors may be used in data-logging to obtain data over long or very short periods of time, or in experiments that otherwise would not be feasible. Simulation software may be used to illustrate concepts and models which are not readily demonstrable in laboratory experiments because they require expensive equipment or materials that are hazardous or difficult to obtain. The experiments may also involve skills not yet achieved by students or which require more time than is available.

What Sort of Technologies are Available?

The technology for processing information includes such tools as word processors, spreadsheets, database programs, sensors and modelling programs.

Spreadsheets

These multipurpose programs may be used for generating results tables from experimental data, data handling, sorting and searching pre-existing data, and producing graphs. Perhaps their most interesting feature is their use in calculations and mathematical modelling.

Databases

Scientists use database programs to handle the vast amounts of data which may be generated in experiments, or to retrieve other scientists' data. The database may be on disc, CD-Rom or downloaded from the Internet. Scientists use their skills and experience to collect, organize and analyse data, look for patterns and check for errors. To appreciate the value of databases to the scientific community, students should be familiar with using a database to store, sort and graph data.

Data-logging

Sensors and control technology can help scientists by monitoring very fast or very slow changes. Data-logging has the advantage that students can see the data recorded in real time. They can therefore focus on the trends and patterns that emerge rather than on the process of gathering the data. Sensors can also measure with more precision allowing students to have greater confidence in their results.

Software for Modelling and Simulations

A wide range of software programs exist to model (amongst other things) photosynthesis, control of blood sugar, chemical equilibria, the cardiovascular system and wave phenomena such as interference and diffraction. Generic programs are also available which allow students to construct models of, for example, motion and gravity, heat loss or populations in an ecosystem. Some of these programs are available via the Internet.

The Internet, CD-Roms, DVDs and Multimedia

The powerful combination of the spoken word, animation and video in these multimedia products clearly motivates and stimulates the user. Interactive multimedia has considerable potential to link different representations and ways of learning to facilitate understanding in science. It provides information that can be selected or rejected, and search facilities allow many different routes through the material which illustrate new links and patterns.

There is clearly added value in the use of interactive multimedia through visualization and differentiation. To be able to represent visually, for example, the dynamic aspects of kinetic theory or electron movements, helps students imagine the situation and aids the learning of difficult concepts. This complements more traditional teaching approaches.

Word Processing and Graphics

Word processing is not merely a means of writing in electronic form. It can improve the quality of written work from the initial listing of ideas, their development and reworking, through to the final product. Drawing programs, scanners, digital cameras, video cameras, desktop publishing, multimedia authoring and CAD/CAM software also have their place, particularly in design technology and perhaps more widely through the group 4 project.

Internationalism

The ease and widespread use of email should encourage the networking of teachers and students, and this replicates the networking activities of the science community. Email (and web sites) could be used to collaborate with other schools world wide, perhaps as part of the group 4 project, or in established collaborative ventures such as the Science Across the World and Globe programs.

Ethical and Moral Dimension

This dimension of the use of ICT need not be made explicit in the group 4 subjects as students will be exposed to it through Theory of Knowledge (TOK), and it will also emerge in the day-to-day experiences of students inside and outside school. Such issues as plagiarism of extended essays, firewalls to prevent access to undesirable web sites, hacking, anti-social behaviour in local networks and on the Internet, privacy of information in databases, freedom of information and web site subscriptions may be encountered.

How to Proceed

Because of the variability of both hardware and software between IB schools, the use of ICT will not be monitored or assessed. For this reason, there is no new objective related to ICT in group 4. However, it is vital to encourage ICT use and to stress its importance in any modern science curriculum. (One common element is the use of graphic calculators in some IB Diploma Programme mathematics courses. This allows for portable, low cost data-logging, modelling and graph plotting.) The IB community can help disseminate ideas and guidance

EXTERNAL ASSESSMENT

The external assessment consists of three written papers.

Paper 1

Paper 1 is made up of multiple-choice questions which test knowledge of the core and additional higher level (AHL) material for higher level (HL) students and the core only for standard level (SL) students. The questions are designed to be short, one- or two-stage problems which address objectives 1 and 2 (see page 7). No marks are deducted for incorrect responses. Calculators are not permitted, but students are expected to carry out simple calculations.

Paper 2

Paper 2 tests knowledge of the core and AHL material for HL students and the core only for SL students. The questions address objectives 1, 2 and 3 and the paper is divided into two sections.

In section A, there is a data-based question which will require students to analyse a given set of data. The remainder of section A is made up of short-answer questions.

In section B, students are expected to answer two questions from a choice of four at HL** or one question from a choice of three at SL. These extended response questions may involve writing a number of paragraphs, solving a substantial problem, or carrying out a substantial piece of analysis or evaluation. A calculator is required for this paper.

Paper 3

Paper 3 tests knowledge of the options and addresses objectives 1, 2 and 3. At HL, students will answer several short-answer questions and an extended response question in each of the two options studied. At SL, students answer several short-answer questions in each of the two options studied. A calculator is required for this paper. (In biology, students will also answer a data-based question in each of the two options studied.)

The assessment specifications at HL and SL are summarized on the next page.

There are some variations in external assessment requirements for design technology, arising from the design project. A double asterisk (**) indicates where these variations occur.

> Note: Wherever possible teachers should use, and encourage students to use, the Système International d'Unites (International System of Units—SI units).

Assessment Specifications—Standard Level**

Component	Overall Weighting (%)	Approximate Weighting of Objectives 1+2	3	Duration (hours)	Format and Syllabus Coverage
Paper 1	20	20		¾	30 multiple-choice questions on the core
Paper 2	32	16	16	1¼	Section A: one data-based question and several short-answer questions on the core (all compulsory) Section B: one extended response question on the core (from a choice of three)
Paper 3	24	12	12	1	several short-answer questions in each of the two options studied (all compulsory)

Assessment Specifications—Higher Level**

Component	Overall Weighting (%)	Approximate Weighting of Objectives 1+2	3	Duration (hours)	Format and Syllabus Coverage
Paper 1	20	20		1	40 multiple-choice questions (± 15 common to SL plus about five more on the core and about 20 more on the AHL)
Paper 2	36	18	18	2¼	Section A: one data-based question and several short-answer questions on the core and the AHL (all compulsory) Section B: two extended response questions on the core and AHL (from a choice of four)
Paper 3	20	10	10	1¼	several short-answer questions and one extended response question in each of the two options studied (all compulsory)

For both SL and HL, calculators are not permitted in paper 1 but are required in papers 2 and 3, where programmable graphic display calculators are allowed.

INTERNAL ASSESSMENT

General Introduction

The internal assessment (IA) requirements are the same for all group 4 subjects, with the exception of design technology which has an additional element. The IA, worth 24% of the final assessment (design technology 36%) consists of an interdisciplinary project, a mixture of short- and long-term investigations (such as practicals and subject-specific projects) and, for design technology only, the design project.

Student work is internally assessed by the teacher and externally moderated by the IBO. The performance in IA at both higher level and standard level is judged against assessment criteria each consisting of achievement levels 0–3.

Rationale for Practical Work

Although the requirements for IA are mainly centred on the assessment of practical skills, the different types of experimental work that a student may engage in serve other purposes, including:

- illustrating, teaching and reinforcing theoretical concepts
- developing an appreciation of the essential hands-on nature of scientific work
- developing an appreciation of the benefits and limitations of scientific methodology.

Therefore, there may be good justification for teachers to conduct further experimental work beyond that required for the IA scheme.

Practical Scheme of Work

The practical scheme of work (PSOW) is the practical course planned by the teacher and acts as a summary of all the investigative activities carried out by a student. Higher level and standard level candidates in the same subject may carry out some of the same investigations and, where more than one group of students is taught in a subject and level, common investigations are acceptable.

Syllabus Coverage

The range of investigations carried out should reflect the breadth and depth of the subject syllabus at each level, but it is not necessary to carry out an investigation for every syllabus topic. However, all candidates must participate in the group 4 project and the IA activities should ideally include a spread of content material from the core, options and, where relevant, AHL material. A minimum number of investigations to be carried out is not specified.

Choosing Investigations

Teachers are free to formulate their own practical schemes of work by choosing investigations according to the requirements outlined. Their choices will be based on:

- subjects, levels and options taught
- the needs of their students
- available resources
- teaching styles.

Teachers should not feel that all investigations must form part of the practical scheme of work, however their scheme must meet the IB requirements. Each scheme must include at least a few complex investigations which make greater conceptual demands on the students. A scheme made up entirely of simple experiments, such as ticking boxes or exercises involving filling in tables, will not provide an adequate range of experience for students.

Teachers are encouraged to use the online curriculum centre to share ideas about possible investigations by joining in the discussion forums and adding resources they use onto the relevant sections of the online subject guides.

> Note: Any investigation or part investigation that is to be used to assess candidates should be specifically designed to match the relevant assessment criteria.

Flexibility

The IA model is flexible enough to allow a wide variety of investigations to be carried out. These could include:

- short laboratory practicals over one or two lessons and long-term practicals or projects extending over several weeks
- computer simulations
- data-gathering exercises such as questionnaires, user trials and surveys
- data analysis exercises
- general laboratory and fieldwork.

The Group 4 Project

The group 4 project is an interdisciplinary activity in which all Diploma Programme science students must participate. The intention is that students analyse a topic or problem which can be investigated in each of the science disciplines offered by a school. The exercise should be a collaborative experience where the emphasis is on the **processes** involved in scientific investigation rather than the **products** of such investigation.

In most cases all students in a school would be involved in the investigation of the same topic. Where there are large numbers of students, it is possible to divide them into several smaller groups containing representatives from each of the science subjects. Each group may investigate the same topic or different topics, ie there may be several group 4 projects in the same school.

Design Technology

In design technology, each student must carry out the design project in addition to several investigations and the group 4 project. Higher level students are required to spend 31 hours on the design project and SL students 19 hours.

Practical Work Documentation

Details of an individual student's practical scheme of work are recorded on **form 4/PSOW** provided in the *Vade Mecum*, section 4. Electronic versions may be used as long as they include all necessary information.

In design technology, each candidate must compile a log book. This is a candidate's record of his/her development of the design project and an informal personal record of investigative activities.

IA Time Allocation

The recommended teaching times for the IB Diploma Programme courses are 240 hours for HL and 150 hours for SL. Higher level students are required to spend 60 hours, and SL students 40 hours, on practical activities (excluding time spent writing up work). These times include 10 to 15 hours for the group 4 project.

Note: For design technology, HL students are required to spend 81 hours, and SL students 55 hours, on practical activities.

The time allocated to IA activities should be spread throughout most of the course and not confined to just a few weeks at the beginning, middle or end. Only 2–3 hours of investigative work can be carried out after the deadline for submission of work to the moderator and still be counted in the total hours for the practical scheme of work.

Guidance and Authenticity

All candidates should be familiar with the requirements for IA. It should be made clear to them that they are entirely responsible for their own work. It is helpful if teachers encourage candidates to develop a sense of responsibility for their own learning so that they accept a degree of ownership and take pride in their own work. In responding to specific questions from candidates concerning investigations, teachers should (where appropriate) guide candidates into more productive routes of enquiry rather than respond with a direct answer.

When completing an investigation outside the classroom candidates should work independently where possible. Teachers are required to ensure that work submitted is the candidate's own. If in doubt, authenticity may be checked by one or more of the following methods:

- discussion with the candidate
- asking the candidate to explain the methods used and to summarize the results
- asking the candidate to repeat the investigation.

Safety

While teachers are responsible for following national or local guidelines which may differ from country to country, attention should be given to the mission statement below which was developed by the International Council of Associations for Science Education (ICASE) Safety Committee.

ICASE Safety Committee

Mission Statement

The mission of the ICASE Safety Committee is to promote good quality, exciting practical science, which will stimulate students and motivate their teachers, in a safe and healthy learning environment. In this way, all individuals (teachers, students, laboratory assistants, supervisors, visitors) involved in science education are entitled to work under the safest possible practicable conditions in science classrooms and laboratories. Every reasonable effort needs to be made by administrators to provide and maintain a safe and healthy learning environment and to establish and require safe methods and practices at all times. Safety rules and regulations need to be developed and enforced for the protection of those individuals carrying out their activities in science classrooms and laboratories, and experiences in the field. Alternative science activities are encouraged in the absence of sufficiently safe conditions.

It is a basic responsibility of everyone involved to make safety and health an ongoing commitment. Any advice given will acknowledge the need to respect the local context, the varying educational and cultural traditions, the financial constraints and the legal systems of differing countries.

Criteria and Aspects

There are eight assessment criteria which are used to assess the work of both higher level and standard level candidates:

- *planning (a)*—Pl (a)
- *planning (b)*—Pl (b)
- *data collection*—DC
- *data processing and presentation*—DPP
- *conclusion and evaluation*—CE
- *manipulative skills*—MS
- *personal skills (a)*—PS (a)
- *personal skills (b)*—PS (b)

Each candidate must be assessed at least twice on each of the eight criteria. The two marks for each of the criteria are added together to determine the final mark out of 48 for the IA component. This will then be scaled at IBCA to give a total out of 24%.

General regulations and procedures relating to IA can be found in the *Vade Mecum*.

Each of the assessment criteria can be separated into two or three **aspects** as shown on the following pages. Descriptions are provided to indicate what is expected in order to meet the requirements of a given aspect **completely (c)** and **partially (p)**. A description is also given for circumstances in which the requirements are not satisfied, **not at all (n)**.

Planning (a)

	ASPECTS		
LEVELS	Defining the problem or research question	Formulating a hypothesis or prediction	Selecting variables
Complete	Identifies a focused problem or research question.	Relates the hypothesis or prediction directly to the research question and explains it, quantitatively where appropriate.	Selects the relevant independent and controlled variable(s).
Partial	States the problem or research question, but it is unclear or incomplete.	States the hypothesis or prediction but does not explain it.	Selects some relevant variables.
Not at all	Does not state the problem or research question **or** repeats the general aim provided by the teacher.	Does not state a hypothesis or prediction.	Does not select any relevant variables.

Planning (b)

	ASPECTS		
LEVELS	Selecting appropriate apparatus or materials*	Designing a method for the control of variables	Designing a method for the collection of sufficient relevant data
Complete	Selects appropriate apparatus or materials.	Describes a method that allows for the control of the variables.	Describes a method that allows for the collection of sufficient relevant data.
Partial	Selects some appropriate apparatus or materials.	Describes a method that makes some attempt to control the variables.	Describes a method that allows for the collection of insufficient relevant data.
Not at all	Does not select any apparatus or materials.	Describes a method that does not allow for the control of the variables.	Describes a method that does not allow any relevant data to be collected.

* suitable diagrams are acceptable

Data Collection

	ASPECTS	
LEVELS	Collecting and recording raw data	Organizing and presenting raw data
Complete	Records appropriate raw data (qualitative and/or quantitative), including units and uncertainties where necessary.	Presents raw data clearly, allowing for easy interpretation.
Partial	Records some appropriate raw data.	Presents raw data but does not allow for easy interpretation.
Not at all	Does not record any appropriate raw data.	Does not present raw data **or** presents it incomprehensibly.

Data Processing and Presentation

	ASPECTS	
LEVELS	Processing raw data	Presenting processed data
Complete	Processes the raw data correctly.	Presents processed data appropriately, helping interpretation and, where relevant, takes into account errors and uncertainties.
Partial	Some raw data is processed correctly.	Presents processed data appropriately but with some errors and/or omissions.
Not at all	No processing of raw data is carried out **or** major errors are made in processing.	Presents processed data inappropriately **or** incomprehensibly.

Conclusion and Evaluation

	ASPECTS		
LEVELS	Drawing conclusions	Evaluating procedure(s) and results	Improving the investigation
Complete	Gives a valid conclusion, based on the correct interpretation of the results, with an explanation and, where appropriate, compares results with literature values.	Evaluates procedure(s) and results including limitations, weaknesses or errors.	Identifies weaknesses and states realistic suggestions to improve the investigation.
Partial	States a conclusion that has some validity.	Evaluates procedure(s) and results but misses some obvious limitations or errors.	Suggests only simplistic improvements.
Not at all	Draws a conclusion that misinterprets the results.	The evaluation is superficial **or** irrelevant.	Suggests unrealistic improvements.

Manipulative Skills

	ASPECTS	
LEVELS	Carrying out techniques safely	Following a variety of instructions*
Complete	Is competent and methodical in the use of the technique(s) and the equipment, and pays attention to safety issues.	Follows the instructions accurately, adapting to new circumstances (seeking assistance when required).
Partial	Requires assistance in the use of a routine technique. Works in a safe manner with occasional prompting.	Follows the instructions but requires assistance.
Not at all	Does not carry out the technique(s) **or** misuses the equipment, showing no regard for safety.	Does not follow the instructions **or** requires constant supervision.

* Instructions may be given in a variety of forms: oral, written worksheets, diagrams, photographs, videos, flowcharts, audiotapes, models, computer programs etc.

Personal Skills (a)

	ASPECTS		
LEVELS	Working within a team*	Recognizing the contributions of others	Exchanging and integrating ideas
Complete	Collaborates with others, recognizing their needs, in order to complete the task.	Expects, actively seeks and acknowledges the views of others.	Exchanges ideas with others, integrating them into the task.
Partial	Requires guidance to collaborate with others.	Acknowledges some views.	Exchanges ideas with others but requires guidance in integrating them into the task.
Not at all	Is unsuccessful when working with others.	Disregards views of others.	Does not contribute.

* A team is defined as two or more people.

Personal Skills (b)

	ASPECTS		
LEVELS	Approaching scientific investigations with self-motivation and perseverance	Working in an ethical manner	Paying attention to environmental impact
Complete	Approaches the investigation with self-motivation and follows it through to completion.	Pays considerable attention to the authenticity of the data and information, and the approach to materials (living or non-living).	Pays considerable attention to the environmental impact of the investigation.
Partial	Approaches the investigation with self-motivation or follows it through to completion.	Pays some attention to the authenticity of the data and information, and the approach to materials (living or non-living).	Pays some attention to the environmental impact of the investigation.
Not at all	Lacks perseverance and motivation.	Pays little attention to the authenticity of the data and information, and the approach to materials (living or non-living).	Pays little attention to the environmental impact of the investigation.

Achievement Level Matrixes

For a particular criterion, a piece of work is judged to see whether the requirements of each aspect have been fulfilled completely, partially or not at all. This can then be translated into an achievement level 0, 1, 2 or 3 using the achievement level matrixes below. The lowest level of achievement is represented by 0, and 3 represents the highest level of achievement.

Planning (a), Planning (b), Conclusion and Evaluation, Personal Skills (a), Personal Skills (b)

The matrix below refers to *planning (a)*, *planning (b)*, *conclusion and evaluation*, *personal skills (a)* and *personal skills (b)*, where each criterion has three aspects.

Level	3			2			2			2			1		
Completely	✓	✓	✓	✓	✓		✓	✓		✓					
Partially						✓					✓	✓	✓	✓	✓
Not at all									✓						
	Aspects			Aspects			Aspects			Aspects			Aspects		

Level	1			1			1			0			0		
Completely	✓			✓											
Partially		✓					✓	✓		✓					
Not at all			✓		✓	✓			✓		✓	✓	✓	✓	✓
	Aspects			Aspects			Aspects			Aspects			Aspects		

Data Collection, Data Processing and Presentation, Manipulative Skills

The matrix below applies to *data collection*, *data processing and presentation*, and *manipulative skills*, where each criterion has two aspects.

Level	3		2		1		1		0		0	
Completely	✓	✓	✓		✓							
Partially				✓			✓	✓	✓			
Not at all						✓				✓	✓	✓
	Aspects		Aspects		Aspects		Aspects		Aspects		Aspects	

Guidance on the Criteria

Planning (a)

It is generally not appropriate to assess *planning (a)* for most experiments or investigations found in standard textbooks, unless the experiments are modified. It is essential that students are given an open-ended problem to investigate. Although the general aim of the investigation may be provided by the teacher, students must be able to identify a focused problem or specific research question.

For example, the teacher might present the aim of the investigation generally in the form "investigate the factors that affect X". Students should be able to recognize that certain factors will influence X and clearly define the aim of the experiment or identify a focused research question. A hypothesis or prediction should then be formulated in the light of any independent variables that have been chosen. Such a hypothesis must contain more than just an expected observation. It must include a proposed relationship between two or more variables, or at least an element of rational explanation for an expected observation, the basis of which can be investigated experimentally. A typical formulation for a hypothesis might be "if *y* is done, then *z* will occur". Other variables that might affect the outcome should also be mentioned, even if they are not to be specifically investigated. Controlled variables should also be selected.

Planning (b)

The student must design a realistic and appropriate method that allows for the control of variables and the collection of sufficient relevant data. The experimental set-up and measurement techniques must be described.

Data Collection

Data collection skills are important in accurately recording observed events and are critical to scientific investigation. Data collection involves all quantitative or qualitative raw data, such as a column of results, written observations or a drawing of a specimen. Qualitative data is defined as those observed with more or less unaided senses (colour, change of state, etc) or rather crude estimates (hotter, colder, etc), whereas quantitative data implies actual measurements.

Investigations should allow students opportunities to deal with a wide range of observations and data. It is important that the practical scheme of work includes:

- the collection of qualitative and quantitative data
- various methods or techniques
- different variables (time, mass, etc)
- various conditions
- subject-specific methods of collection.

In addition:

- attention to detail should be reflected in the accuracy and precision of the data recorded
- use of data collection tables should be encouraged
- methods of collection and the measurement techniques must be appropriate to each other
- units of measurement must be relevant to the task at hand.

Data Processing and Presentation

The practical scheme of work should provide sufficient investigations to enable a variety of methods of data processing to be used.

Students should also be exposed to the idea of error analysis. That is not to say that error analysis must be carried out for every investigation, nor should it overshadow the purpose of an investigation.

Students should show that they can take raw data, transform it and present it in a form suitable for evaluation.

Processing raw data may include:

- subjecting raw data to statistical calculations (eg producing percentages or means), with the calculations correct and accurate to the level necessary for evaluation
- converting drawings into diagrams
- converting tabulated data into a graphical form
- correctly labelling drawings
- sketching a map from measurements and observations in land form
- proceeding from a sketched idea to a working drawing (eg orthographic projection or sectional views).

The data should be presented so that the pathway to the final result can be followed. Features which should be considered when presenting data include:

- quality of layout (eg choice of format, neatness)
- choice of correct presentation (eg leave as a table, convert to a graph, convert to a flow diagram)
- use of proper scientific conventions in tables, drawings and graphs
- provision of clear, unambiguous headings for drawings, tables or graphs.

Conclusion and Evaluation

Once the data has been processed and presented in a suitable form, the results can be interpreted, conclusions can be drawn and the method evaluated.

Students are expected to:

- analyse and explain the results of experiments and draw conclusions
- evaluate the results.

Analysis may include comparisons of different graphs or descriptions of trends shown in graphs.

Students are also expected to evaluate the procedure they adopted, specifically looking at:

- the processes
- use of equipment
- management of time.

Modifications to improve the investigation should be suggested.

Manipulative Skills

Indications of manipulative ability are the amount of assistance required in assembling equipment, the orderliness of carrying out the procedure(s), the ability to follow the instructions accurately and adherence to safe working practices.

Personal Skills (a)

Working in a team is when two or more students work on a task collaboratively, face-to-face, with individual accountability. Effective teamwork includes recognizing the contributions of others, which begins with each member of the team expecting every other member to contribute. The final product should be seen as something that has been achieved by all members of the team participating in the tasks involved. Encouraging the contributions of others implies not only recognizing, but also actively seeking, contributions from reluctant or less confident members of the team.

Personal Skills (b)

Issues such as plagiarism, the integrity of data collection and data analysis, may be considered here. Sources of data should be acknowledged and data must be reported accurately, even when anomalous or when an experiment has not given rise to the results expected. Due attention to environmental impact may be demonstrated in various ways including avoidance of wastage, using proper procedures for disposal of waste, and minimizing damage to the local environment when conducting experiments.

Assessing an Investigation

In assessing an investigation it must be noted that:

- the same standards must be applied to both HL and SL students
- level 3 does not imply faultless performance
- only whole numbers should be awarded, not fractions or decimals.

The work being assessed must be that of the student. For example in work on *planning (a)*, the student should define the problem, formulate the hypothesis and select the variables; this information should not be provided by the teacher. In work on *data collection*, the student must decide how to collect, record, organize and present the raw data. The teacher should not, for instance, specify how the data should be acquired or provide a table in which the data is recorded. This principle extends to the other criteria.

To illustrate the use of the achievement level matrixes, consider the following example. A student's work is assessed against the criterion *data processing and presentation*. The teacher feels that the first aspect, *processing raw data*, is met completely whereas the second aspect, *presenting processed data*, is only achieved partially. Using the achievement level matrix for *data processing and presentation*, this translates to a level of 2.

THE GROUP 4 PROJECT

Summary of the Group 4 Project

The group 4 project allows students to appreciate the environmental, social and ethical implications of science. It may also allow them to understand the limitations of scientific study, for example, the shortage of appropriate data and/or the lack of resources. The emphasis is on interdisciplinary cooperation and the processes involved in scientific investigation, rather than the products of such investigation.

The exercise should be a collaborative experience where concepts and perceptions from across the group 4 disciplines are shared. The intention is that students analyse a topic or problem which can be investigated in each of the science disciplines offered by a school. The topic can be set in a local, national or international context.

Project Stages

The 10–15 hours allocated to the group 4 project, which are part of the teaching time set aside for internal assessment, can be divided into four stages: planning, definition of activities, action and evaluation.

Planning

This stage is crucial to the whole exercise and should last 2–4 hours.

- The planning stage could consist of a single session, or two or three shorter ones.
- This stage must involve all science students meeting to "brainstorm" and discuss the central topic, sharing ideas and information.
- The topic can be chosen by the students themselves or selected by the teachers.
- Where large numbers of students are involved, it may be advisable to have more than one mixed discipline group.

After selecting a topic or issue, the activities to be carried out must be clearly defined before moving from the planning stage to the action and evaluation stages.

Definition of Activities

A possible strategy is that students define specific tasks for themselves, either individually or as members of groups, and investigate various aspects of the chosen topic. Contact with other schools, if a joint venture has been agreed, is an important consideration at this time.

Action

This stage should take 6–8 hours in total and may be carried out over one or two weeks in normal scheduled class time. Alternatively a whole day could be set aside if, for example, the project involves fieldwork.

- The students (as individuals, single subject groups or mixed subject groups) should investigate the topic from the perspective of the individual science disciplines.
- There should be collaboration in the action stage; findings of investigations should be shared with others working on the project. This may be difficult if the action stage takes place during normal lessons, but it is possible to use bulletin boards (either physical or electronic) to exchange information or to use times when students are together, such as lunchtimes. Enthusiastic students will no doubt share information informally.
- During this stage it is important to pay attention to safety, ethical and environmental considerations.

Evaluation

The emphasis during this stage, for which 2–4 hours is probably necessary, is on students sharing their findings, both successes and failures, with other students. How this is achieved can be decided by the teachers, the students or jointly.

- One solution is to devote a morning, afternoon or evening to a symposium where all the students, as individuals or as groups, give brief presentations (perhaps with the aid of an overhead projector, flip charts, posters, video player, computers, etc).
- Alternatively the presentation could be more informal and take the form of a science fair where students circulate around displays summarizing the activities of each student or group.

The symposium or science fair could also be attended by parents, members of the school board and the press. This would be especially pertinent if some issue of local importance has been researched. Some of the findings might influence the way the school interacts with its environment or local community.

In addition to the presentation, each student must show evidence of their participation in the project.

Preparation

The impact the project has on the organization of the school is an important consideration. The key is the formulation of an action plan, perhaps in the form of a list of questions, to help draw up a strategy for all the activities involved. The following are suggestions for such a list (these could be adapted to suit the needs of an individual school).

- How might a topic be selected? Possibilities are a questionnaire to students, discussions with students and/or teacher selection.
- Will teachers from other non-science departments be involved?
- Will people from outside the school be used as a source of ideas for the project? If so, what is their availability?
- What communication methods are available for the coordination of activities, exchange of data and joint presentations?
- When should the project be conducted, and over what time period?
- What are the implications in terms of staff and resources?

Strategies

Considerations

Teachers will find that there are many factors to consider when planning the project work, besides deciding at what point to carry out the project and what the starting and completion dates should be. These factors include:

- the way the school's year is organized into terms or semesters
- the number of sciences offered
- the number of IB students
- whether or not the school wishes to collaborate with other schools either locally, nationally or internationally.

The needs of the students should be of foremost importance when weighing up the advantages and disadvantages of the various possibilities.

Ensuring that carrying out the project is a group experience (not restricted to a single science in group 4) may present organizational problems for some schools. The options may be limited because, for example, there is a small number of students, only one science is offered or other IB schools are some distance away. Teachers should take into account factors specific to their school and the general points made in this section when planning their strategies.

Timing

The time-span for carrying out the project is not a full two years.

- The project must be finished, at the latest, 19 months after starting teaching. Therefore, allowing for the planning stages, there may only be 18 months during which the project can be carried out. In the case of those completing the course in one year, such as anticipated SL candidates, the time available is limited further.
- Before starting work on the project students should, ideally, have some experience of working in a team.
- It is very important that students have reached a point where they have a certain degree of scientific knowledge and skills, and have experience of experimental techniques, before undertaking the project

The 10–15 hours that the IBO recommends should be allocated to the project may be spread over a number of weeks. The distribution of these hours needs to be taken into account when selecting the optimum time to carry out the project. However, it is possible for a group to dedicate a period of time exclusively to project work if all other school work is suspended.

Year 1

In the first year students' experience and skills may be limited and it would be inadvisable to start the project too soon in the course. However, doing the project in the final part of the first year may have the advantage of reducing pressure on students later on. This strategy provides time for solving unexpected problems.

Year 1–Year 2

The planning stage could start, the topic could be decided and provisional discussion in individual subjects could take place at the end of the first year. Students could then use the vacation to think about how they are going to tackle the project and would be ready to start work early in the second year.

Year 2

Delaying the start of the project until some point in the second year, particularly if left too late, increases pressure on students in many ways: the schedule for finishing the work is much tighter than for the other options; the illness of any student or unexpected problems will present extra difficulties. Nevertheless, this choice does mean students know one another and their teachers by this time, have probably become accustomed to working in a team and will be more experienced in the relevant fields than in the first year.

Combined HL and SL

Where circumstances dictate that the project is only carried out every two years, HL beginners and more experienced SL students are combined.

General Strategies

1. Collaborate with other IB schools, including:
   - direct contact with local schools
   - post, fax, telephone, email, video conferencing.

   This is particularly useful for small schools or those with a single science, and where schools have well-established contacts they wish to exploit, or new ones they wish to develop. Where schools in different countries are linked, the importance of internationalism can be reinforced.
2. Carry out the project only every two years so that first- and second-year students can work together to make a larger group, bearing in mind the restriction on timing. (This is perhaps only necessary for small schools and may be difficult in terms of timing.)
3. Encourage IB students to work with non-IB students in the school who may be following courses leading to national or other equivalent qualifications. (This may be useful for small schools or those with a single science.)
4. Encourage participation of local teachers or experts from local industries, businesses, colleges or universities. (This may be helpful to small schools or those distant from other IB schools.)
5. Collaborate with students taking group 3 subjects such as geography, psychology or economics. (This is only relevant to schools not offering the full IB Diploma Programme.)

Selecting a Topic

In most cases all students in a single school will be involved in the investigation of the same topic. Where there are large numbers of students, it is possible to divide them into several smaller groups, each undertaking their own project. The students may choose the topic or propose possible topics; teachers then decide which one is the most viable based on resources, staff availability etc. Alternatively, the teachers select the topic or propose several topics from which students make a choice.

Student Selection

Students are likely to display more enthusiasm and feel a greater sense of ownership for a topic that they have chosen themselves. A possible strategy for student selection of a topic, which also includes part of the planning stage, is outlined below. At this point, subject teachers may provide advice on the viability of proposed topics.

- Identify possible topics by using a questionnaire or a survey of the students.
- Conduct an initial “brainstorming” session of potential topics or issues.
- Discuss, for 10 minutes, two or three topics that seem interesting.
- Select one topic by consensus.
- Examine the topic. Students in each science subject write down relevant aspects that could be studied given the local circumstances, resources etc.
- Each subject group reads out their list and a master copy is made.
- Students in each discipline make a list of potential investigations that could be carried out. All students then discuss issues such as possible overlap and collaborative investigations.

Assessment

The group 4 project forms one part of a candidate's overall practical experience and does not contribute any fixed percentage to internal assessment. A school may choose:

- not to assess the project at all
- to assess the project according to the criteria for the school's local or national requirements
- to assess the project against one or more of the IB Diploma Programme internal assessment criteria.

The project may produce evidence for the full range of criteria, particularly *planning (a)* and *(b)*, and *personal skills (a)* and *(b)*.

Given the diverse nature of the activities associated with the project, it may be difficult for a single teacher to gain a fair overview of an individual student's contribution, especially in regard to *planning* and *personal skills*. It may be necessary for teachers to exchange observations and comments concerning student performance. Group, peer and self-evaluation can also contribute valuable extra information.

Participation

The evidence of a candidate's involvement in the project, required by the IBO in a moderation sample, can take a variety of forms. It must be accompanied by a copy of the written instructions and/or a summary of the verbal instructions given in relation to the project.

For each student in the moderation sample, the evidence may be:

- a statement written by the student about his/her own individual contributions
- a copy of a self-evaluation form
- a copy of a peer-evaluation form
- an individual laboratory report or complete project report
- rough work or a record of data collected by the student
- photographs, eg of a final poster produced by the group.

DESIGN TECHNOLOGY

The Diploma Programme design technology curriculum and assessment models differ from the other group 4 models in some important respects. This is a consequence of the design project, which is unique to this subject.

The design technology curriculum and assessment models are shown below. These are followed by information about the design project and how the common group 4 assessment criteria are to be interpreted during internal assessment of the project by the teacher.

Curriculum and Assessment Models

Design Technology Curriculum Model SL

SL	Total teaching hours	**150**
Theory		**95**
	Core	65
	Options	30
Internal assessment (IA)		**55**
	Investigations	21–26
	Design project	19
	Group 4 project	10–15

Design Technology Curriculum Model HL

HL	Total teaching hours	240
Theory		**159**
	Core	65
	Additional higher level (AHL)	49
	Options	45
Internal assessment (IA)		**81**
	Investigations	35–40
	Design project	31
	Group 4 project	10–15

Design Technology Assessment Specifications—SL

Component	Overall Weighting (%)	Approximate Weighting of Objectives 1+2	3	Duration (hours)	Format and Syllabus Coverage
Paper 1	20	20		¾	30 multiple-choice questions on the core
Paper 2	24	12	12	1	Section A: one data-based question and several short-answer questions on the core (all compulsory) Section B: one extended response question on the core (from a choice of three)
Paper 3	20	10	10	1	one data-based question and several short-answer questions in each of the two options studied (all compulsory)
IA	24			36	teacher choice
Project	12			19	student choice

Design Technology Assessment Specifications—HL

Component	Overall Weighting (%)	Approximate Weighting of Objectives 1+2	3	Duration (hours)	Format and Syllabus Coverage
Paper 1	20	20		1	40 multiple-choice questions (± 15 common to SL plus about five more on the core and about 20 on the AHL)
Paper 2	24	12	12	1¾	Section A: one data-based question and several short-answer questions on the core and the AHL (all compulsory) Section B: one extended response question on the core and AHL (from a choice of three)
Paper 3	20	10	10	1¼	several short-answer questions and one extended response question in **each** of the **two options** studied (all compulsory)
IA	24			50	teacher choice
Project	12			31	student choice

For both SL and HL calculators are not permitted in paper 1 but are required in papers 2 and 3, where programmable graphic display calculators are allowed.

THE DESIGN PROJECT

Introduction

The internal assessment (IA) in design technology is worth 36% of the final assessment and consists of:

- the group 4 project
- a mixture of short- and/or long-term investigations
- the design project.

The recommended teaching times for the IB Diploma Programme courses are 240 hours for HL and 150 hours for SL. For design technology, HL students are required to spend **81** hours and SL students **55** hours on practical activities (excluding time spent writing up work). These times include 10 to 15 hours for the group 4 project.

The design project, which unifies all aspects of the course, is based on topic 1: designers and the design cycle in the *Design Technology* guide and is a compulsory element of the practical course of work and assessment.

The syllabus for HL has more breadth than SL, with **31** hours allocated to the design project as distinct from **19** hours at SL. It is expected, therefore, that HL students should develop a greater knowledge and skill base than SL students, and should demonstrate this through the design project.

Log Book

Each candidate must compile a log book which should be a record of how the design project developed and give an insight into the candidate's thoughts and actions throughout the development period. The log book, which is **not** formally assessed, should include:

- design ideas
- sketches
- evaluations
- notes on meetings and information found
- details of decisions taken during the project.

The entries should be in date order and therefore may not necessarily be in a logical sequence for the design cycle. The log book provides a record on which to base the project summary report. It gives teachers and moderators a "feel" for the continual and sometimes uneven development of the project as the student goes through the design cycle. In addition, the log book is an informal personal record of other investigations undertaken, such as laboratory practicals and mini-projects.

Project Summary Report

Each candidate must submit a project summary report which identifies the key stages of the project development. The report may contain information in the form of text, diagrams, photographs etc, and should explain the process followed and decisions taken.

The project summary report should be compiled in conjunction with the log book while the design project develops, and then be reviewed and finalized at the end of the project. It may refer to pages in the log book to avoid unnecessary duplication.

Assessment

The design project **must** be assessed against all the group 4 internal assessment criteria:

- Planning (a)
- Planning (b)
- Data collection
- Data processing and presentation
- Conclusion and evaluation
- Manipulative skills
- Personal skills (a)
- Personal skills (b).

The project forms part of the internal assessment, but elements of the design cycle are specifically assessed in topic 1.

The following section relates the group 4 internal assessment criteria to the design cycle. It is not intended that the arrangement shown here is followed once only in a linear fashion. Several parts of the cycle are iterative (see sub-topic 1.1). The criteria for the assessment of the project are the same as those for the investigations. The design project ties together all aspects of the course. The use of the design cycle in the approach to a problem is the organizing theme about which the rest of the course revolves. Here, students will employ all the knowledge and skills learned in the course to identify and solve a design problem. In designing for themselves, students come to understand better the work of designers.

Planning (a)

The first two aspects correspond to part (i) of the design cycle, **identifying the problem and the brief** (see A.S. 1.2.2 (i) and Fig 1).

Aspect 1 Defining the problem or research question

This involves describing a particular situation: the context. The context will normally offer a variety of potential problems to solve.

Aspect 2 Formulating a hypothesis or prediction

This involves identifying a need or opportunity, from an analysis of the context, and formulating the brief. The brief is a statement of the problem and intended outcome (see A.S. 1.1.1). Evidence of the need and its importance should be apparent, and the feasibility of the project should be considered including cost, time, facilities and scope.

Aspect 3 Selecting variables

This aspect corresponds to part (ii) of the design cycle, **research and specifications** (see A.S. 1.2.2 (ii) and Fig 1).

The specifications need to be explained in relation to the design brief, and priorities for research and development should also be explained. The design specification should be justified and reasonably complete. It is this list of requirements against which the ideas will be evaluated and the final outcome assessed.

Data Collection

This criterion corresponds to part (iii) of the design cycle, **generating ideas** (see A.S. 1.2.2 (iii) and Fig 1).

Aspect 1 Collecting and recording raw data

This involves collecting data relevant to the solution of the problem. Information or data gathered must be relevant to the specification. A variety of sources should be used including texts, references, magazines, practical work, personal observations, and possibly computer sources such as CD-Roms or Internet sources. Priorities and strategies for collecting and recording data should be clear.

Aspect 2 Organizing and presenting raw data

Data presented in the form of tables, graphs, photographs etc forms a basis for the generation of ideas. This data should outline a range of possible solutions to the design problem.

Students need to acquire research material as the basis for their ideas and, as solutions are generated, further research will be required. The effectiveness of the research will be evident in the range of solutions. For example, a design project with a working prototype as an outcome may require research into properties of different materials: the materials required for manufacturing the prototype and those required if it were to be produced industrially on a larger scale.

This is the conceptual stage of the design cycle with initial ideas supported by research and analysed for feasibility against the specifications.

Data Processing and Presentation

This criterion corresponds to part (iv) of the design cycle, **developing the chosen solution** (see A.S. 1.2.2 (iv) and Fig 1).

Aspect 1 Processing raw data

The raw data needs to be processed into the form of a design solution. This involves testing, experimenting and modelling (including drawing and CAD). The optimum solution needs to be identified and explained in relation to the design brief and specifications.

Aspect 2 Presenting processed data

A variety of suitable presentation techniques should be used to communicate the development stages of the chosen solution, culminating in a detailed design. The detailing must be sufficient for the solution to be realized. Materials and manufacturing techniques will be considered. Alterations to the design specification should be stated in the form of "final specifications".

Planning (b)

This criterion corresponds to part (v) of the design cycle, **planning and realizing the chosen solution** (see A.S. 1.2.2 (v) and Fig 1).

Aspect 1 Selecting appropriate apparatus* / materials

Appropriate materials and equipment should be identified for the various aspects of the realization stage of the design process.

*Suitable diagrams are acceptable.

Aspect 2 Designing a method for the control of variables

A production plan should be prepared which clearly shows the sequence of operations to be carried out for realizing the design. Estimates of time allowance for each operation should be stated.

Aspect 3 Designing a method for the collection of sufficient relevant data

Recognizing that with challenging design work things rarely go exactly as expected, the plan should be adapted accordingly in response to fresh ideas, feedback and advice.

Decisions should be justified. Students need to provide evidence of how the design developed during the realization stage. The evidence may take the form of drawings, photographs, diagrams and text.

Conclusion and Evaluation

This criterion corresponds to part (vi) of the design cycle, **testing and evaluating the chosen solution** (see A.S. 1.2.2 (vi) and Fig 1).

Aspect 1 Drawing conclusions

The design process undertaken should be looked at holistically and a judgment made of the degree of success in managing the whole process.

Aspect 2 Evaluating procedure(s) and results

The procedures adopted at each stage of the design cycle should be evaluated. The outcome should be evaluated against the specifications and its strengths and weaknesses identified using qualitative and quantitative techniques as appropriate. Strategies for evaluation, both subjective and objective, should be clearly stated.

Aspect 3 Improving the investigation

Changes to the procedures should be recommended if appropriate. Having gone through the design cycle at least once, students should be in a position to assess the accuracy of the original specifications and suggest modifications.

Drawings should be used to show how the design may be improved or developed further. A range of designs should be produced, especially when evaluating the success of a prototype as the basis for large-scale production.

Based on the evaluation of the chosen solution (as realized), a modified design specification should be written which addresses the weaknesses in the first solution. Drawings should illustrate the modifications.

Manipulative Skills

Aspect 1 Carrying out techniques safely

A variety of techniques will be relevant to the task. Students should have made astute judgments concerning resource issues for realizing the final solution. Materials, components and equipment must be manipulated to a standard whereby the problem is resolved to a stage that allows for suitable evaluation.

Aspect 2 Following a variety of instructions*

The level of guidance required will depend on the nature of the design project and the experience of the students. Health and safety issues must be given due consideration at all times, with explicit evidence apparent in the documentation.

*Instructions may be given in a variety of forms: oral, written worksheets, diagrams, photographs, videos, flowcharts, audiotapes, models, computer programs, etc.

Personal Skills (a)

Aspect 1 Working within a team*

Most design projects will be carried out by individual students but teamwork will be necessary at various stages.

*A team is defined as two or more people.

Aspect 2 Recognizing the contributions of others

Students will need to collaborate with other people in establishing a “need” when identifying a problem. The project report should show how the contribution of others has influenced the design thinking at each stage of the process.

Aspect 3 Exchanging and integrating ideas

The brief may be produced by consultation with a particular client or as a result of research with potential users/consumers. The views of others are often required during the development stages of the design project and guidance should be sought for dealing with unfamiliar techniques. The more able students often collaborate with fellow students, sharing ideas and assisting each other with tests and experiments.

Personal Skills (b)

Aspect 1 Approaching scientific investigations with self-motivation and perseverance

Design projects which are challenging (but feasible) rarely go exactly to plan. Students need to be tenacious in seeking out opportunities and providing solutions.

Aspect 2 Working in an ethical manner

Students should recognize that many companies have developed an ethical code of practice for the design and manufacture of their products. This is becoming especially important with global consumerism. Ethical considerations may be relevant at various stages of the design process and concern aesthetics, resources, obsolescence, quality and value for money.

Aspect 3 Paying attention to environmental impact

Students should apply some of the concepts and principles taught during the course regarding energy, resources and the impact of design and technology on society and the environment.

Managing the Design Project

The teacher should not isolate work on the design project from other parts of the course, otherwise students may regard the project as extra work which has to be completed solely for assessment rather than to gain a greater understanding of the subject.

One of the most critical elements of the teacher's role is guiding students in the choice of an appropriate problem/topic. The following suggestions may help in managing the design project.

1. Ensure that students understand the assessment criteria and are familiar with the parts of the syllabus relating to the design cycle and the design project.

2. Set specific deadlines for the selection of a problem, the production of the design brief and the submission of the final design project.

3. Identify a problem which is relatively simple in concept but challenging for the student and appropriate to the level of study.

4. Insist that students obtain your approval for project topics. This helps to ensure both variety and suitability of projects.

5. Ensure that sufficient resources are available to students.

6. Insist on good presentation and encourage the use of images, graphs, photographs, sketches, tables, etc only when they add clarity.

7. Ensure that students are clear about the relationship between the log book and the project summary report.

PART 2—DESIGN TECHNOLOGY

NATURE OF THE SUBJECT

To design can be defined as "to conceive a mental plan for something". Design consists of gathering information about the present state of the world around us, processing that information and planning for some kind of intervention either by modifying what is already there or introducing something new. The designer is not just interested in the material environment but also the political, social and economic considerations which affect people's priorities.

The Intent of the Course

IB Diploma Programme design technology is based on a model of learning which incorporates knowledge, skills and design principles in problem solving contexts, while at the same time maximizing the use of local and readily available resources. It assumes no previous experience in either design technology or designing. The intent is not solely the acquisition of knowledge about design and technology, which may change or become outdated, but it is about learning how to adapt to new experiences and approach problems with the appropriate skills and the relevant techniques to identify the important elements and, crucially, to develop the optimum solutions. The **design cycle** is at the core of the course and it is expected that students will use this process in the practical investigative work as well as in the theory. Each element in the cycle represents an aspect of design technology which, when viewed together, constitutes a holistic approach. Any given element is therefore only to be seen in the context of the whole process.

Design Technology within Group 4 (the Experimental Sciences)

Technology relies on the laws and properties of nature to create new products and systems, while at the same time providing the means for the development of new techniques and the acquisition of yet more knowledge about the laws and properties of nature. Design technology sits comfortably in the Diploma Programme experimental sciences because students need to study scientific principles in

The Design Cycle and Group 4

The design cycle is the equivalent of the scientific method. The emphasis is therefore on using the design cycle to solve a problem using scientific information and production techniques. Practical/investigative work centres on the properties of materials, mechanisms, control circuits and production techniques as they apply to constructing an artefact, or developing skills and ideas useful in carrying out such a project.

Design Technology as a Complement to The Arts

The majority of students will have little or no experience of formal courses in technology at the start of the IB Diploma Programme, consequently design technology (SL) is ideally suited to the non-science specialist. It can be used as a bridge between the sciences and the designed world around us. It might be seen as “a spectrum, with ideas at one end and techniques and things at the other, with design as the middle term” (Edwin Layton). Design technology is concerned with people’s needs and what they regard as important. The politics of society, and the cultural, aesthetic and artistic needs and values are given due status. In addition, environmental considerations are given greater emphasis in a new topic 6: green design.

The subject is strongly connected with social issues, making informed choices, and differentiating between information and misinformation in technology. Students are encouraged to study the technologies in different cultures and to understand the forces which have shaped their development. The course is not solely about “high technology” (sophisticated, industrialized, mass production) but also includes the appropriateness of technologies for societies. Diploma Programme design technology emphasizes good technological design, how to exercise judgment and responsibility in the use of technology, how to recognize needs, how to explore a range of conflicting demands and how to produce the optimum solution.

Design technology interfaces well between the sciences and the arts, owing its knowledge base to the former and its emphasis on creative flair to the latter.

Design Technology for the Scientist or Engineer

Where students may be considering a university or college course in science, applied science, technology or engineering, the higher or standard level courses may be taken in conjunction with any other course in group 4. Diploma Programme design technology then provides such students with the opportunity to deal with realistic problems and to synthesize appropriate solutions using the processes practised during the course, in particular through the project.

Overview of Course Structure

The core material provides information about and experience of designing and the role of the designers. At the same time it provides details about materials and processes to allow students to get a feel for the work of designers through investigative and project work.

The additional higher level (AHL) material provides explanations and answers to the “why?” questions arising from the core material (some chemistry and applied physics). It also extends the content into appropriate technologies, and the manufacture and evaluation of final products.

All students must complete a design technology project as an integral part of their internal assessment. This is in addition to some short-term investigations. The project is designed to link together aspects of the course in a problem solving context. It gives students the opportunity to use their skills and knowledge in a situation that is realistic, challenging and open enough to bring all elements of the design process together in the search for a solution capable of meeting the specification.

Possible Teaching Approaches

There are many approaches that can be taken and the syllabus is written in a non-prescriptive way so that the facilities and the location of schools will not be the deciding factor in successfully teaching the course.

The processes at work in design technology activities involve the students continually bouncing their thoughts backwards and forwards between the issues that are being solved and the proposals that are being developed (practical tests, drawings and models) for the solution. It is a dynamic process of clarification—reflective and active—which involves thinking and doing. The subject requires students to experience practical, experimental, investigative and project work in the laboratory, workroom or classroom. This needs to be hands on and not solely taught by demonstration.

Time is allowed in the course to enable the theory to be integrated with practical work experiments and investigations in all topics. The length and frequency of these experiments and investigations has not been specified so that teachers may adapt the course to their particular human and physical resources. The processes involved in design and problem solving are complex: short practical investigations lasting over one or two classes can be used to exemplify aspects of the process in addition to the project. No specific period of the course is stipulated for the project but it is reasonable to consider undertaking it in the second year where sufficient syllabus content has been covered to allow acquired skills and knowledge to be used.

It is likely that, in many schools, the options will be taught after the other parts of the course because knowledge from the core (and also from the AHL for HL) is involved.

The course would also lend itself very well to team teaching. The teaching could be shared with teachers from art and design as well as scientists and technologists.

Resource Requirements

The main emphasis of the course is on the design process and the design cycle, not the hardware required in manufacturing artefacts. The majority of equipment and consumables required by this course can be found in most well-equipped science laboratories. Computers, and access to the Internet, open up further resource avenues rich in materials relevant for design technology. Those schools with other appropriate equipment may wish to teach option E: computer-aided design, manufacture and production, and schools possessing a hygienic area could undertake option D: food technology.

Terminology, Units, Presentation of Data, and Nomenclature

The terminology used in examination papers will be the same as that used in the syllabuses. The majority of the relevant terms, especially if ambiguous, are defined in the glossary of technical terms, or made clear by the assessment statements or accompanying teachers' notes.

Système International (SI) units will be used in questions and should be used by candidates in their answers. Units which are presented on tables and graphs will use the solidus (/) to separate the physical quantity from the SI units, eg energy released / kJ cm^{-2} h^{-1} and speed / m s^{-1}.

SYLLABUS OVERVIEW

The syllabus for the Diploma Programme design technology course is divided into three parts: the core, the additional higher level material (AHL) and the options. A syllabus overview is provided below.

Core [65h]

Topics

		Teaching hours
1	Designers and the design cycle	15
2	The responsibility of the designer	11
3	Materials	6
4	Manufacturing processes and techniques	8
5	Production systems	9
6	Clean technology and green design	16

Additional Higher Level (AHL) [49h]

Topics

		Teaching hours
7	Raw material to final product	15
8	Microstructures and macrostructures	19
9	Appropriate technologies	15

Options

Options SL

		Teaching hours
A	Raw material to final product	15
B	Microstructures and macrostructures	15
C	Appropriate technologies	15

Options SL / HL

D	Food technology	15/22
E	Computer-aided design, manufacture and production	15/22
F	Invention, innovation and design	15/22
G	Health by design	15/22
H	Electronic products	15/22

Standard level candidates are required to study any **two** options from A–H. The duration of each option is 15 hours.

Higher level candidates are required to study any **two** options from D–H. The duration of each option is 22 hours.

SYLLABUS OUTLINE

Core [65h]

			Teaching hours
Topic 1		**Designers and the design cycle**	**[15]**
	1.1	The design process	3
	1.2	The design cycle model (DCM)	2
	1.3	Applications of the DCM	2
	1.4	Generating ideas	2
	1.5	Design communication	6
Topic 2		**The responsibility of the designer**	**[11]**
	2.1	Ergonomics	4
	2.2	Product evaluation	4
	2.3	The designer and society	3
Topic 3		**Materials**	**[6]**
	3.1	Introducing and classifying materials	1
	3.2	Properties of materials	4
	3.3	The IB properties/materials matrix	1
Topic 4		**Manufacturing processes and techniques**	**[8]**
	4.1	Manufacturing processes and techniques	2
	4.2	Selecting materials and techniques	6
Topic 5		**Production systems**	**[9]**
	5.1	Designers and the product cycle	2
	5.2	Scale of production	4
	5.3	Economic considerations	3
Topic 6		**Clean technology and green design**	**[16]**
	6.1	Clean technology	3
	6.2	Green design	3
	6.3	Strategies for green design	4
	6.4	Life cycle analysis	6

Additional Higher Level [49h]

Teaching hours

Topic 7 Raw material to final product [15]

7.1	Timber	3
7.2	Ceramic (glass)	3
7.3	Metal	3
7.4	Textile fibre and plastic	3
7.5	New materials	3

Topic 8 Microstructures and macrostructures [19]

8.1	Structure of matter	1
8.2	Bonding	2
8.3	The IB properties/bonding matrix	2
8.4	The properties of metals and alloys	2
8.5	The properties of thermoplastics and thermosets	2
8.6	The properties of composite materials	3
8.7	Young’s modulus—stress and strain	3
8.8	Forces	2
8.9	The strength and stiffness of structures	2

Topic 9 Appropriate technologies [15]

9.1	Resources and reserves	1
9.2	The technologies	3
9.3	Exploitation of energy resources	4
9.4	Exploitation of material resources	3
9.5	Strategies for sustainable development	4

Options Standard Level

			Teaching hours
Option A	**Raw material to final product**		**[15]**
	A.1	Timber	3
	A.2	Ceramic (glass)	3
	A.3	Metal	3
	A.4	Textile fibre and plastic	3
	A.5	New materials	3
Option B	**Microstructures and macrostructures**		**[15]**
	B.1	Structure of matter	1
	B.2	Bonding	2
	B.3	The IB properties/bonding matrix	2
	B.4	The properties of metals and alloys	2
	B.5	The properties of thermoplastics and thermosets	2
	B.6	The properties of composite materials	3
	B.7	Young's modulus—stress and strain	3
Option C	**Appropriate technologies**		**[15]**
	C.1	Resources and reserves	1
	C.2	The technologies	3
	C.3	Exploitation of energy resources	4
	C.4	Exploitation of material resources	3
	C.5	Strategies for sustainable development	4

Options Standard Level / Higher Level

Standard level students study the core of these options, and higher level students study the whole option (ie the core and the extension material).

			Teaching hours
Option D	**Food technology**		
	Core (SL + HL)		**[15]**
	D.1	Food and nutrition	3
	D.2	Food and people	3
	D.3	Food spoilage and food preservation	3
	D.4	Food processing	3
	D.5	Food labelling, packaging and branding	3
	Extension (HL only)		**[7]**
	D.6	Food security	2
	D.7	Global food production strategies	3
	D.8	Lifestyle issues—food poisoning	2

Option E — Computer-aided design, manufacture and production

		Teaching hours
Core (SL + HL)		**[15]**
E.1	The impact of CAD on the design process	3
E.2	The impact of CAD/CAM on manufacturing	4
E.3	The impact on industry	4
E.4	The impact on the consumer	2
E.5	Mass customization	2
Extension (HL only)		**[7]**
E.6	Global communication systems	2
E.7	Global production systems	3
E.8	The global manufacturer	2

Option F — Invention, innovation and design

Core (SL + HL)		**[15]**
F.1	Invention and innovation	2
F.2	Invention	4
F.3	Innovation in practice—the bicycle	4
F.4	Markets and innovation	3
F.5	Invention, innovation and the environment	2
Extension (HL only)		**[7]**
F.6	The designer in the global marketplace	2
F.7	Global strategies for innovation	3
F.8	The global consumer	2

Option G — Health by design

Core (SL + HL)		**[15]**
G.1	Materials and tissue implants	3
G.2	Vascular grafts—a case study	2
G.3	Spectacles and contact lenses	3
G.4	Hearing aids	3
G.5	The motor car and health	4
Extension (HL only)		**[7]**
G.6	Strategies for global health	3
G.7	Ergonomics in the workplace	2
G.8	Physical disability and the global marketplace	2

Option H Electronic products

		Teaching hours
Core (SL + HL)		[15]
H.1	Electricity and electronic circuits	3
H.2	Building electronic circuits	4
H.3	Control systems	4
H.4	Microprocessors	4
Extension (HL only)		[7]
H.5	Communication systems	2
H.6	Smart cards	3
H.7	Global impacts of converging technologies	2

SYLLABUS DETAILS

Topic 1: Designers and the Design Cycle

The design cycle is central to a student's understanding of design activities and to organizing his/her own investigation work. Each element of the design cycle represents how designers progress through the design process with the design solution becoming progressively more refined at increasingly specific levels of detail.

This topic focuses on the strategies designers employ to arrive at a solution to a problem and the varied nature of the skills and knowledge they need to carry out their activities successfully.

A.S. Obj

1.1 The Design Process (3h)

1.1.1 Define *brief*. **1**

The design brief is the formal starting point for the design of a new product. It is a statement of what the product is expected to do. The brief does not provide the design solution, but is a statement of the design problem and sets:

- the design goal (eg a working prototype to be evaluated in terms of its feasibility for volume production)
- the target market for the product (eg children, disabled adults)
- the major constraints (eg should comply with new legislation, have fewer working parts, be cheaper to manufacture) within which it must be achieved
- the criteria by which a good design proposal may be achieved (eg increased value for money and/or cost-effectiveness for manufacture).

1.1.2 Define *specification*. **1**

Developing the specification from the brief is an evolving process, initially generating a specification following the brief, and culminating in a final product design specification (PDS). The PDS states and justifies the more precise limits set for the complete range of performance requirements. The PDS will identify demands (requirements or features which **must** be met) and wishes (requirements which **should** be met if it proves technically or economically feasible). The specification will include a full list of the criteria against which the design can be evaluated.

1.1.3 Explain the role of the designer in the design process. **3**

The designer's role varies depending on the complexity of the process and the intended outcome.

A.S.		Obj
1.1.4	Describe how designers interact with others and how the emphasis of the design process varies depending on the designer's role. Designers often work as members of a team. Priorities will vary depending on the nature of the activity, eg the information required by an architect will be different to that required by an engineer.	**2**
1.1.5	Describe how designers rely upon knowledge from science, philosophy and technology. Science explains how the world is. Philosophy concerns values, culture, politics and aesthetics. Technology includes materials, manufacturing techniques and processes.	**2**
1.1.6	Define *incremental design*.	**1**
1.1.7	Define *radical design*.	**1**
1.1.8	Explain how design work is often a combination of incremental and radical thinking. For example, the use of a new material for a product may be a radical leap forward but the product may look very similar to previous products—a tennis racquet made from carbon fibre is a radical development but the shape and form are similar to previous designs.	**3**

1.2 The Design Cycle Model (DCM) (2h)

1.2.1	State that designers use design cycle models to represent the design process. Design may be described in a variety of ways and degrees of complexity, eg the IB simple design cycle (see 1.2.2, Fig 1) or IB elaborated design cycle (see 1.3.3, Fig 2). The design process usually consists of successive stages that form a systematic, cyclical process which eventually converges to produce a solution to the problem.	**1**
1.2.2	Draw the IB simple design cycle. The IB simple design cycle (see Fig 1) consists of the following stages. **(i) Identifying the problem and the brief** The context of the problem is described and a concise brief stated. The initial design problem is a loose collection of constraints, requirements and possibilities. From this loose collection the designer has to make a coherent pattern. The design brief states the intended outcome and the major constraints within which it must be achieved. **(ii) Researching and specifications** Sources of information are identified and strategies developed for gaining the information. The specifications state all the detailed aspects which the final solution should conform to. There usually needs to be some interaction between writing the design specification and generating ideas because many details of the specifications will be dependent upon the type of ideas.	**1**

A.S. Obj

(iii) Generating ideas

Divergent thinking is used to consider ways in which a problem may be solved. The starting point for the generation of ideas should be the design specification and proposals should be evaluated against this specification with evidence of relevant research used to rate the ideas in terms of their usefulness. A variety of approaches should be used and different possibilities explored and analysed before deciding on the most suitable solution.

(iv) Developing the chosen solution

A final concept is developed taking into account the conflicting needs of the manufacturer and the user, and the requirement of the design as set out in the specifications. A complete proposal is developed based upon the research and the designer's personal ideas.

(v) Planning and realizing the chosen solution

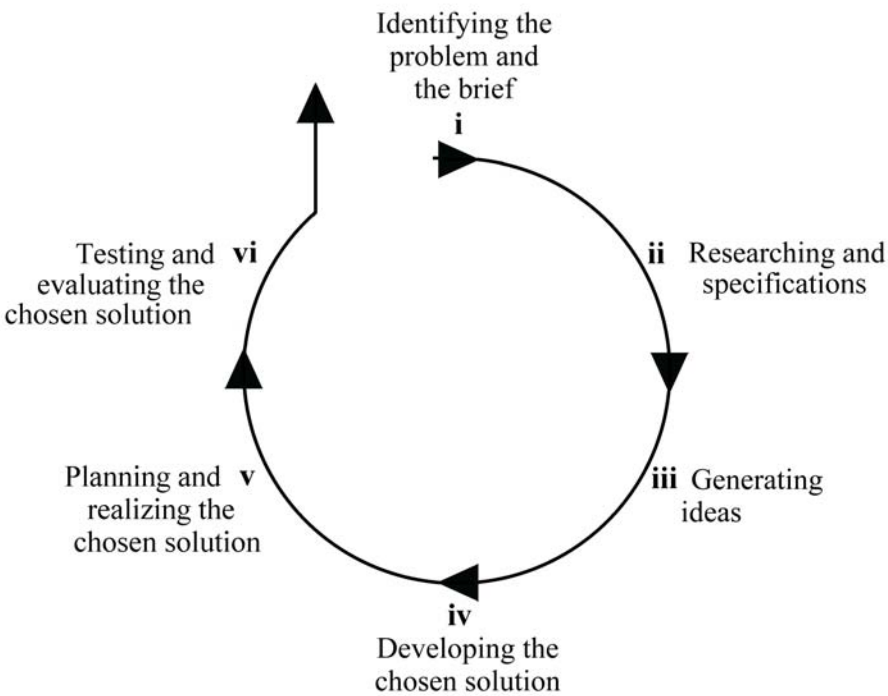
Planning includes factors such as detail drawings (of a style relevant to the task), material lists and costings, as well as a plan for realizing the design in an efficient manner. The appropriate level of skills and knowledge to arrive at the final outcome need to be identified and matched to the resources available and the timescale involved.

(vi) Testing and evaluating the chosen solution

The final outcome is tested and evaluated against the requirements set out in the specification. Recommendations for modifications to the design are made. A reiteration process should now begin.

Each of the elements (i) to (vi) in the cycle contribute to the process inherent in design technology and constitute a holistic approach. Any given element should therefore be viewed in the context of the whole process. Throughout the design technology course, the principles of design are emphasized in a range of contexts which are intended to broaden as the student progresses through the course. The student, as a consequence, grows more confident in the application of such principles to a range of problems.

Fig 1 IB simple design cycle

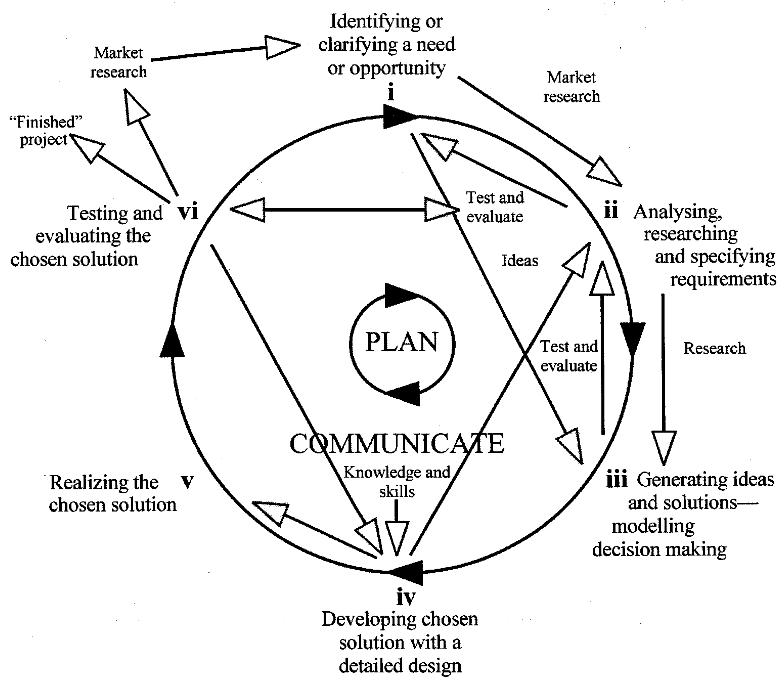


A.S.		Obj
1.2.3	Describe each element in the IB simple design cycle.	**2**
1.2.4	Explain why the IB simple design cycle is not linear, and why it is iterative in practice. The cycle indicates that the process is ongoing. A designer usually finds it necessary to recycle through the procedure until s/he is satisfied with the solutions obtained (iteration). Not all the steps will need to be altered or revisited.	**3**
1.2.5	Describe the overlap between each element in the cycle when it is applied holistically to a design situation. In practice it is impossible to separate the stages of the design process as clearly as the model suggests.	**2**
1.2.6	Explain why elements of the model may differ in importance according to the particular design context. Depending upon the nature of the problem, not all the elements of the cycle carry the same weight in terms of time allocation and complexity. Points to consider include cost, resources, skills, time, original design specification and product modification.	**3**

1.3 Applications of the DCM (2h)

1.3.1	Outline three limitations of the IB simple design cycle. The model suggests that one activity starts only after the previous activity has finished but when the design is looked at in detail it is not clear that the process can still be generalized across the different design vocations.	**2**
1.3.2	Compare the IB simple design cycle with more complex versions used by professional designers. Refer to the IB elaborated design cycle (see Fig 2). A wide variety of more complex models are available, and these split up the process into more diverse elements.	**2**
1.3.3	Explain why the simplified version of the DCM must be modified to make it representative of design thought and action. The more elaborate model has been included to emphasize that designing is not a linear process. Evaluation, for example, will take place at various stages of the process not just at the end. Similarly, ideas for possible solutions are not only generated at stage (iii); some good ideas may develop even as early as identification of the problem (i).	**3**

Fig 2 IB elaborated design cycle



A.S.		Obj

1.4 Generating Ideas (2h)

1.4.1	State that designers use a variety of techniques to develop ideas.	1
1.4.2	Define *constructive discontent*.	1
1.4.3	Describe the relevance of constructive discontent for designers. Creative designers are frequently dissatisfied with what exists and want to make the situation better.	2
1.4.4	Define *adaptation*. If a problem is in a new context a solution may be found by finding something similar from another context and adapting it.	1

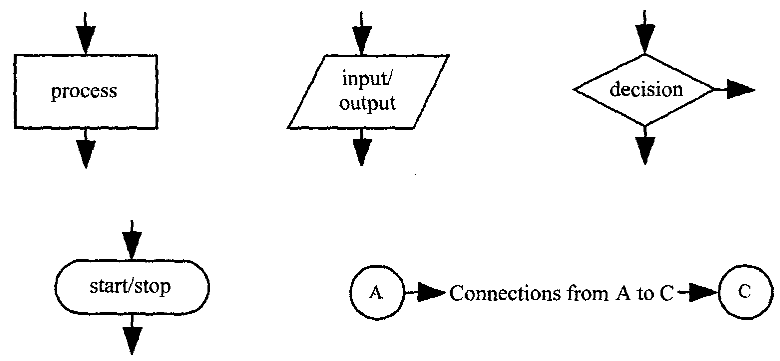
A.S.		Obj
1.4.5	Describe the relevance of adaptation for designers.	**2**
1.4.6	Define *analogy*.	**1**
1.4.7	Describe the relevance of analogies to designers. Odd, remote or strange analogies help to stimulate the mind in new ways, eg "cat's eyes" in the middle of the road or sonar based on communication between marine animals.	**2**
1.4.8	Define *brainstorming*. Participants use the ideas of others to spark off their own ideas and to build upon and combine ideas to produce new ones. No criticism is allowed, even of the most ridiculous ideas.	**1**
1.4.9	Describe the relevance of brainstorming to designers.	**2**
1.4.10	Define *divergent thinking*.	**1**
1.4.11	Define *convergent thinking*.	**1**
1.4.12	Describe the elements of the DCM that reflect convergent and divergent thinking. Convergent thinking is analytical and solution focused, eg used at the research stage and during evaluation. Divergent thinking is conceptual and problem focused, eg used at the ideas generating phase and during development.	**2**
1.4.13	State that the design process is a balance between divergent thinking and convergent thinking at different stages in the design process and in different design contexts. Designers need to be innovative (they need to come up with original ideas) but they also need to work to a brief and provide a marketable solution. Contrast fashion design with engineering design, for example.	**1**

1.5 Design Communication (6h)

1.5.1	Compare two-dimensional (2D) and three-dimensional (3D) drawing techniques. Consider the purpose of the drawings and techniques.	**2**
1.5.2	Define *freehand drawing*.	**1**
1.5.3	Explain the relevance to designers of 2D and 3D freehand drawings. Designers use a range of freehand drawings in the early stages of developing ideas to explore shape and form (3D) and constructional details (2D).	**3**

A.S.		Obj
1.5.4	Describe the importance of annotating freehand drawings. Annotations explain the thinking behind the visual image represented by the drawing. They allow the designer to consider the implications of the ideas for further development.	**2**
1.5.5	Define *orthographic drawing*.	**1**
1.5.6	Explain the purpose of an orthographic drawing. An orthographic drawing shows details and dimensions and can be used as a production drawing.	**3**
1.5.7	Identify the stage of the design process where orthographic drawing is relevant. Orthographic drawings are produced at the final solution stage and are used as working drawings for the realization stage.	**2**
1.5.8	Define *isometric drawing*.	**1**
1.5.9	Explain the purpose of an isometric drawing. An isometric drawing depicts the proposed solution in 3D showing shape and form.	**3**
1.5.10	Define *exploded isometric drawing*.	**1**
1.5.11	Explain the purpose of an exploded isometric drawing. The drawing is exploded to show particular features of the inside of the design.	**3**
1.5.12	Define *perspective drawing*.	**1**
1.5.13	Explain the purpose of perspective drawing. Compare perspective drawings with isometric drawings. Perspective drawings take into account spatial arrangements, eg foreshortening, while isometric drawings are constructed to a set angle (60° to the horizontal).	**3**
1.5.14	State that models are representations of reality.	**1**
1.5.15	Explain that a model represents selected features of a design.	**3**
1.5.16	Explain the difference between physical models and mathematical models. Physical models are made from raw materials and can be handled. Mathematical models use symbols that can be manipulated numerically.	**3**
1.5.17	Outline the advantages and disadvantages of physical and mathematical models. Consider the skills and knowledge required and the involvement of clients or users.	**2**

A.S.		Obj
1.5.18	Define *algorithm.*	1
1.5.19	Define an algorithm to communicate a process. Correct sequencing is important with input, output and feedback.	1
1.5.20	Draw a simple flow chart using symbols. Correct use of symbols to represent activities is important.	1



A.S.		Obj
1.5.21	Analyse a flow chart.	3
1.5.22	Describe three advantages of using models as part of the design process. Designers use models for particular purposes, eg designers of prestige cars may use a full-size clay model of a car at the final concept stage of the design process because at full-size it gives a more realistic view of the intended design and clay allows the shape to be changed easily.	2
1.5.23	Describe three limitations of the use of models in the design process. Designers can easily make assumptions about how accurately a model is representing reality, eg the model may not work like the final product or be made of the same material.	2
1.5.24	Define *computer-aided design* (CAD).	1
1.5.25	State two advantages and two disadvantages of using computer-aided design (CAD) instead of traditional drawing methods. Consider the skills required, storage, complexity and styles of the drawings, interfacing with other aspects of ICT, time, cost and the purpose of the drawings.	1
1.5.26	Explain why designers use a variety of drawing and modelling techniques to represent ideas. Refer to the design process and how designers communicate, both with themselves and other people.	3

Topic 2: The Responsibility of the Designer

The designer, by instigating technological change, is implicated in the resultant social consequences. Commonly these are seen as unexpected or unwanted effects arising from a new product, technique or system. This topic focuses on the designer's responsibilities to the consumer/user, the client or manufacturer and society, and how these responsibilities can sometimes cause conflict.

A common understanding of product analysis and evaluation should be established, possibly through a case study. Students could then develop and apply their own product analysis (possibly to their own design project). Due to the wide variety of possibilities in emphasis and method that can be used, it would be useful for all students to share experiences of their product analyses.

Students need to understand the constraints and opportunities that exist for optimizing the exploitation of resources and renewable energy sources. The aim is to be aware of the need to conserve non-renewable resources and to meet human, environmental and industrial requirements.

A.S.		Obj
	2.1 Ergonomics (4h)	
2.1.1	Define *ergonomics*.	**1**
2.1.2	Define *anthropometrics*.	**1**
2.1.3	Define *percentile range*.	**1**
2.1.4	Identify specific design contexts where the designer would use the 5^{th}–95^{th} range or the 50^{th} percentile range and how these ranges are appropriate for particular user groups. For example, washing machines and cookers are designed around the 50^{th} percentile so they are all a standard height regardless of the brand. Clothes are produced in a range of sizes based on the 5^{th}–95^{th} percentage range of a particular user group.	**2**
2.1.5	Explain why designers use the 5^{th}–95^{th} percentile range rather than the 1^{st}–99^{th} percentile range. With volume production it is important to standardize sizes. It is uneconomical to design for people whose sizes are outside the 5^{th}–95^{th} range.	**3**
2.1.6	Explain the dangers of using the 50th percentile as a means of designing for the "average" person. The 50th percentile refers to one particular dimension. For example, someone may be average in height, but not average in other dimensions.	**3**
2.1.7	Define *manikin*.	**1**
2.1.8	Define *ergonome*.	**1**

A.S.		Obj
2.1.9	Explain the reasons for using manikins and ergonomes when designing. Manikins are two dimensional and are used with orthographic drawings. Ergonomes are three dimensional and are used with objects to consider spatial arrangements.	**3**
2.1.10	Outline the significance of psychological factors (smell, light, sound, taste, texture and temperature) to ergonomics. Individuals react differently to sensory stimuli. Efficiency and comfort are affected by such factors.	**2**
2.1.11	Describe the relevance of bodily tolerances, such as fatigue and comfort, to ergonomic inquiry. The controls for a machine may be designed for correct reach but, if in constant use, may cause fatigue and inefficiency. A car seat may be comfortable for short journeys but not for long journeys.	**2**
2.1.12	Discuss the limitations of collecting ergonomic data. Include static and dynamic data. Consider the difficulty in obtaining accurate, reliable data, especially when collecting functional dimensions, observing users' behaviour or obtaining users' responses. Issues of data collection in terms of comfort and fatigue should be considered.	**3**

2.2 Product Evaluation (4h)

A.S.		Obj
2.2.1	Define *cost-effectiveness*.	**1**
2.2.2	Define *value for money*.	**1**
2.2.3	Outline the general criteria used to evaluate products. Consider performance, reliability, ease-of-use, safety, aesthetics, materials, construction and cost.	**2**
2.2.4	Describe how the criteria outlined in 2.2.3 may be used to evaluate the quality of a product. Use examples to apply the criteria.	**2**
2.2.5	Explain how the relevance of the criteria in 2.2.3 will vary depending on the purpose of the evaluation. For example, car safety is the most important consideration when crash testing.	**3**
2.2.6	Discuss how the purpose of the evaluation is influenced by the objectives of the evaluator. 2.2.1–2.2.2 The purpose of the evaluation must be clearly defined as it determines the criteria to be used and the methodology for gathering information. Value judgments play an important role in product analysis and they vary according to the individual, the time (era) and the circumstances. Consumers often value utility, security, availability, rarity,	**3**

A.S. **Obj**

aesthetics and value for money, while designers may consider function, reliability and ease of manufacture more important. Designers evaluate products to analyse existing solutions to design problems or to generate ideas for new product design prior to the development of a design brief. Manufacturers evaluate products in relation to the feasibility of production (eg cost-effectiveness).

2.2.7 Define *literature search*. **1**

2.2.8 Describe one advantage and one disadvantage of a literature search for data collection. **2**

Many sources of information are available but there may be too much data to sort through and it may be too time consuming to do so.

2.2.9 Evaluate the importance of information and communication technology (ICT) in aiding literature searching. **3**

ICT makes it easier to access information eg via the Internet, and allows for two-way communication. It eliminates the need to travel to gain information, but necessitates access to a computer.

2.2.10 Define *user trial*. **1**

2.2.11 Describe one advantage and one disadvantage of a user trial in collecting ergonomic data. **2**

The “user” is a non-specialist and so user trials are cost-effective and more readily available. However, users may carry out tasks in different ways to those expected.

2.2.12 Define *expert appraisal*. **1**

2.2.13 Describe one advantage and one disadvantage of using expert appraisal to collect ergonomic data. **2**

For example, you gain expert knowledge and advice (compared to a user trial) but the expert may be biased, and it also might be difficult to locate the experts.

2.2.14 Define *performance test.* **1**

The data from a performance test is likely to be more accurate compared to a user trial but the expert may be biased in his/her views.

2.2.15 Describe one advantage and one disadvantage of using a performance test to collect data. **2**

The advantage of a performance test is that it provides data about how the product will perform eg in a car crash, which could not be done in a user trial. Disdvantages are that the test may be time-consuming and costly to perform.

2.2.16 Define *user research*. **1**

A.S.		Obj
2.2.17	Describe one advantage and one disadvantage of using user research to collect data. Data is relatively easy and cheap to obtain but it is largely qualitative.	**2**
2.2.18	Compare user research with user trial. With user research, data is collected by obtaining users' responses to questions. With a user trial, data is collected by observing users' behaviour and is more scientifically based.	**2**
2.2.19	Outline the most appropriate strategies for collecting data for a specified product in order to evaluate it against set criteria. Consider the purpose of the evaluation and the parameters that the evaluator is working within, eg timescale.	**2**

2.3 The Designer and Society (3h)

2.3.1	Explain how legislation can impose constraints on designers. Designers need to be aware of legislation that affects their role, eg safety standards. Local and national requirements should be considered.	**3**
2.3.2	Explain how aesthetic considerations affect the design of products and the built environment. Style is often the main selling point for a product, eg a motor car.	**3**
2.3.3	Outline one example where society places a social responsibility on the work of a designer. Changes in values (eg attitudes to waste and pollution) affect designers' activities.	**2**
2.3.4	Discuss the conflict a designer faces when attempting to balance form and function. There is often a tension between the aesthetic characteristics and functionality, aesthetic characteristics and safety issues and aesthetic characteristics and cost or value for money. To the consumer aesthetic considerations may outweigh functional considerations at the point of sale.	**3**
2.3.5	Define *planned obsolescence*.	**1**
2.3.6	Describe one advantage and one disadvantage of planned obsolescence to the consumer. Advantages—more choice, increased innovation, more competition. Disadvantages—less intrinsic value to products, need to replace products more often.	**2**
2.3.7	Describe one advantage and one disadvantage of planned obsolescence to the manufacturer. Increased wealth from sales but increased research and development requirements.	**2**

A.S.		Obj
2.3.8	Explain how planned obsolescence influences the design specification of a product. Consider materials and construction, durability and ease of maintenance.	**3**
2.3.9	Define *fashion*.	**1**
2.3.10	Compare the influence of fashion and planned obsolescence on the product cycle. Planned obsolescence has a definite timescale; fashion is less predictable. Both may be present in a design (eg a certain colour may be fashionable for a motor car) but this does not affect materials or technological obsolescence.	**2**
2.3.11	Evaluate the influence of fashion and planned obsolescence in relation to the quality and value of a product. Consider whether "designer" products are better quality than cheaper brands of the same product. Consider also the values of a "throw away society".	**3**
2.3.12	Discuss the implications of fashion and planned obsolescence for conserving natural resources, waste and pollution. Consider the influence of fashion and planned obsolescence on the product cycle, ie a shorter cycle means more use of raw materials and energy in obtaining the materials, manufacturing and disposing of the materials. Also consider waste and pollution at each stage of the cycle.	**3**

Topic 3: Materials

This topic aims to ensure understanding of the relationships between materials choice, manufacturing processes and the concepts of designers. Design technology is intimately involved with material properties and the way they interlock with manufacturing processes. The intention of this topic is to gain an overview of this relationship while emphasizing the choices available to designers.

A.S.		Obj
	3.1 Introducing and Classifying Materials (1h)	
3.1.1	State that materials can be classified into groups according to similarities in their microstructures and properties.	**1**
3.1.2	Explain that several classifications are recognized but that no single classification is “perfect”. It is convenient to be able to classify materials into categories (albeit rather crude in nature) which have characteristic combinations of properties.	**3**
3.1.3	State that, for this course, materials are classified into groups: timber, metals, ceramics, plastics, textile fibres, food and composites and that some of these groups have subdivisions. In each group there can be subdivisions, eg for timber (natural wood or composite), metals (ferrous or nonferrous), ceramics (earthenware, porcelain and stoneware), plastics (thermoplastics or thermosets), textile fibres (natural or synthetic), food (vegetable or animal origin) and composites (difficult to classify due to variability and the continual development of new ones). Note: For completeness and because of its importance as a design material, food is included here in the matrix although it is dealt with in detail as an option.	**1**
	3.2 Properties of Materials (4h)	
	Physical properties	
3.2.1	Define the physical properties of *density, electrical resistivity, thermal conductivity, thermal expansion* and *hardness*.	**1**
3.2.2	Explain a design context where **each** of the properties in 3.2.1 is an important consideration. • Density is an important consideration in relation to product weight and size (eg for portability). Pre-packaged food is sold by weight/volume and a particular consistency is required. • Electrical resistivity is an important consideration in selecting particular materials as conductors or insulators for particular design contexts.	**3**

A.S. | Obj

- Thermal conductivity is an important consideration for objects which will be heated, which must conduct heat or which must insulate against heat.
- Thermal expansion (expansivity) is an important consideration where two dissimilar materials are joined, such as glazed metals. These may then experience large temperature changes while staying joined.
- Hardness is an important consideration where resistance to penetration or scratching is required. Ceramic floor tiles are extremely hard and resistant to scratching.

Mechanical properties

3.2.3 Define the mechanical properties of *tensile strength, stiffness, toughness* and *ductility*. **1**

3.2.4 Explain a design context where **each** of the properties in 3.2.3 is an important consideration. **3**

The tensile strength of ropes and cables is an important safety consideration in climbing and in elevators. Stiffness is an important consideration when maintaining shape is crucial to the performance of an object eg aeroplane wing. Toughness is an important consideration where abrasion and cutting may take place. Ductility is an important consideration when metals are extruded (do not confuse this with malleability—the ability to be shaped plastically).

Aesthetic characteristics

3.2.5 Outline the characteristics of taste, smell, appearance, texture and colour. **2**

3.2.6 Explain a design context where **each** of the characteristics in 3.2.5 is an important consideration. **3**

3.2.5–3.2.6 Some of the properties are relevant to only one materials group eg food, while others can be applied to more than one. Although these properties activate peoples' senses, responses to them vary from one individual to another and they are difficult to quantify scientifically, unlike the other properties.

3.3 The IB Properties / Materials Matrix (1h)

3.3.1 Explain how all the groups and sub-groups specified in 3.1 can be organized into a properties/materials matrix. **3**

3.3.1–3.3.2 The matrix is designed to give an overview of the relative values of the properties for each material group.

3.3.2 Explain the relative values of the properties in the **IB properties/materials matrix**. **3**

IB properties/materials matrix

	Timber	Metals	Ceramics	Plastics	Textile Fibres	Food	Composites*
Physical properties							
Density	low	high	medium	low	low	low	
Electrical resistivity	high	v. low	v. high	high	high	medium	
Thermal conductivity	low	v. high	v. low	low	low	medium	
Thermal expansivity	low	high	v. low	low–v. high	low	medium	
Hardness	medium	medium–v. high	v. high	low–medium	low	low	
Mechanical properties							
Tensile strength	medium	high	low	low–medium	medium	low–medium	
Stiffness	medium	high	v. high	low–medium	v. low	low–medium	
Toughness	high	v. high	v. low	medium	medium	low–medium	

* Composites are designed with particular properties in mind and so it is not appropriate to generalize their properties in such a table.

Topic 4: Manufacturing Processes and Techniques

Designers need to understand a wide range of manufacturing processes and techniques to match their knowledge of materials. This topic does not try to encompass all known techniques but outlines and exemplifies the main manufacturing processes and techniques.

It is important to understand how the different processes link together in the manufacture of a product. During manufacture material is usually first shaped crudely and then more precisely into finished parts or components and finally assembled. Some products or components are made by a single process although most require a mixture of processes.

A.S.		Obj
	4.1 Manufacturing Processes and Techniques (2h)	
4.1.1	Define *manufacturing process*. 4.1.1–4.1.2 A finished product may be required in any one of an innumerable number of shapes and sizes, and there are many different techniques by which to produce the final article. These techniques can be categorized into three major groups: shaping, joining and wasting.	**1**
4.1.2	Define *manufacturing technique*.	**1**
4.1.3	Define the process of *shaping*.	**1**
4.1.4	Explain the relevance of bending, moulding, casting and weaving to the process of shaping. Knowledge of how each technique shapes a product is required.	**3**
4.1.5	Define the process of *joining*.	**1**
4.1.6	Explain the relevance of using fasteners, using adhesives, fusing and stitching to the process of joining. Knowledge of how each technique is used to join materials together is required.	**3**
4.1.7	Define the process of *wasting*.	**1**
4.1.8	Explain the relevance of machining, cutting and abrading to the process of wasting. Knowledge is required of how each technique is used to waste a product.	**3**

A.S.		Obj

4.2 Selecting Materials and Techniques (6h)

The selection of materials takes into account economic processing and service requirements. Successful products should be evaluated in terms of efficiency and economy of manufacture, as well as performance.

A.S.		Obj
4.2.1	Define *injection moulding*.	**1**
4.2.2	Describe the technique of injection moulding. An annotated diagram should be used.	**2**
4.2.3	Discuss the advantages and disadvantages of injection moulding. Advantages—no finishing required, volume production, use of different moulds Disadvantages—set up costs reduce suitability for low volume production, limitations to the size, shape, etc	**3**
4.2.4	Identify the relevant properties that make a material suitable for injection moulding. For example, thermal expansivity and toughness.	**2**
4.2.5	Define *lamination*.	**1**
4.2.6	Describe the technique of lamination. The description should include the use of a mould or former, and a method of cramping.	**2**
4.2.7	Discuss the advantages and disadvantages of lamination. Advantages—no finishing required, able to form complex shapes and surfaces, can suit large surfaces, able to combine different materials Disadvantages—labour intensive; may require production of a mould; limitations to the glue, size, clamping, shape and angles of curvature	**3**
4.2.8	Identify the relevant properties that make a material suitable for lamination. For example, toughness and tensile strength.	**2**
4.2.9	Define *sintering*.	**1**
4.2.10	Describe the technique of sintering.	**2**
4.2.11	Discuss the advantages and disadvantages of sintering. Advantages—no surface machining required compared to casting, suitable for high melting-point materials Disadvantages—high energy requirements, limitations to the sizes and shapes that can be produced and the materials that can be used	**3**

A.S.		Obj
4.2.12	Identify the relevant properties that make a material suitable for sintering. For example, thermal conductivity and hardness.	**2**
4.2.13	Define *extrusion*.	**1**
4.2.14	Describe the technique of extrusion. Use of an annotated diagram is essential.	**2**
4.2.15	Discuss the advantages and disadvantages (or limitations) of extrusion. Advantages—no finishing required, volume production, hollow shapes Disadvantages—limitation to the size, shape and detail of extruded products	**3**
4.2.16	Identify the relevant properties that make a material suitable for extrusion. For example, toughness and durability.	**2**
4.2.17	Define *cutting and machining*.	**1**
4.2.18	Describe cutting and machining techniques. Relate the techniques to a wide range of materials.	**2**
4.2.19	Discuss the advantages, disadvantages and limitations of cutting and machining techniques. Advantages—versatility and flexibility, range of material suitability Disadvantages—assembly requirements Limitations—size, joining processes	**3**
4.2.20	Identify the relevant properties that make a material suitable for cutting or machining. For example, toughness and tensile strength.	**2**

Topic 5: Production Systems

This topic is concerned with the commercial aspects of design and manufacture: the management, economics and politics of assimilating products into the market. It explores how the scale and type of production affects the nature, quality and cost of a product.

A.S. Obj

5.1 Designers and the Product Cycle (2h)

5.1.1 Define *product cycle*. **1**

5.1.2 Discuss the role of the designer in the product cycle. **3**

Designing is part of the product cycle: as a need is generated, a product is designed, made and sold, eventually becoming obsolete. The cycle is complicated by distribution and retailing, accountants, production engineers, all of whom have an influence over the cycle. Although the designer is an integral part of the process he/she is not necessarily in control (unlike in the design process). CAD/CAM, where a prototype is produced by the designer from his/her PC, blurs this distinction.

5.1.3 Outline the product life cycle in terms of early, mature and late stages of development. **2**

In the early stages many changes to the product may take place until it develops to the mature stage where it is diffused into the market, gains acceptance and sells well. In the late stage the product begins to decline in need and therefore in sales.

5.1.4 Outline the life cycle of the ballpoint pen and the cassette tape in terms of early, mature and late stages of development. **2**

The ballpoint pen is in the mature stage as it still sells well though the design does not change much. The cassette tape is in the late stage as the compact disk and the mini disk have replaced it.

5.1.5 Compare the design cycle with the product cycle. **2**

The differences should highlight how the design process is aimed at producing a suitable solution to a problem and that the product cycle is concerned with putting that solution into commercial practice.

5.2 Scale of Production (4h)

5.2.1 Define *one-off production, batch production* and *volume production*. **1**

A historical overview would help, ie how craft methods of production became superseded by mechanization after the Industrial Revolution and by automation during the Technological Revolution of the second half of the 20th century.

5.2.2 Describe two advantages and two disadvantages of each scale of production. **2**

These may be related to economic or social considerations.

A.S.		Obj
5.2.3	Explain when it is most appropriate to use each scale of production. Use an example of a product to explain the suitability of each production scale taking into account the needs of the consumer and market conditions.	**3**
5.2.4	Define *craft production, mechanization, automation* and *assembly line production*.	**1**
5.2.5	Describe why most products were manufactured by craft techniques prior to the Industrial Revolution. Refer to the development of skills; sources of materials and power; sales and distribution; and relationship of craftsman/designer with client/consumer.	**2**
5.2.6	Explain how the availability of new sources of power in the Industrial Revolution led to the introduction of mechanization. Refer to water and steam power.	**3**
5.2.7	Explain how the development of computer and information technology in the Technological Revolution led to the introduction of automation. Refer also to the importance of electricity in assembly line procedures.	**3**
5.2.8	Define *CAD/CAM* and *CNC*.	**1**
5.2.9	Describe how CAD/CAM and CNC can contribute to an automated production system. Note the purpose of each when used alone or together as part of a larger system.	**2**
5.2.10	Define *robot*.	**1**
5.2.11	Explain how industrial robots offer greater flexibility to automated production systems. Note the ability to reprogramme and change the physical components to alter the activity.	**3**
5.2.12	Describe an example of a domestic robot. For example, a robotic vacuum cleaner or lawnmower.	**2**
5.2.13	Define *automated guided vehicle* (AGV).	**1**
5.2.14	Explain how AGVs contribute to an automated production system. They are coordinated with the other aspects of the system to ensure maximum efficiency by transporting components or finished products from one part of the factory to another.	**3**
5.2.15	State two advantages and two disadvantages of mechanizing a production process. Consider cost, quality of product, social conditions, labour, etc.	**1**

A.S.		Obj
5.2.16	State two advantages and two disadvantages of automating a production system. Consider cost, flexibility, skills, effect on the workforce, quality, complexity of product and process, type of market, traditions, training and management structures.	**1**
5.2.17	Discuss the advantages and disadvantages of each system from the point of view of the designer, manufacturer and consumer. Relate to different target groups.	**3**
5.2.18	Outline one (different) example of a product manufactured by each mode of production. Consider the characteristics of the product that make it suitable for each method of production.	**2**

5.3 Economic Considerations (3h)

5.3.1	Explain the factors that determine the final cost of a product. Take into account scale of production; complexity of product, material, resources and skills required; quality control; size and weight of product for storage or distribution; type of advertising and marketing; profits and taxes. Include costs of availability and procurement of raw materials, research and development, labour, manufacturing costs, capital costs, overheads, distribution and sales.	**3**
5.3.2	Define *fixed costs* and *variable costs*.	**1**
5.3.3	Identify the costs in 5.3.1 as fixed and variable.	**2**
5.3.4	Explain how the costs in 5.3.1 vary in proportion, depending on the type of product and the mode of production. Some costs are more relevant than others eg raw materials and labour costs will be a significant part of the final cost of an individually crafted mahogany table but for an injection moulded plastic component these costs would be low and the capital cost of machinery high. Quantitative calculations are not required.	**3**

Topic 6: Clean Technology and Green Design

This topic explores the impact of manufacturing processes and products on the environment. Clean technologies have emerged as a result of greater pressure for environmental protection and are supported by legislative frameworks. Green products are designed using green design principles and adopt a “cradle to the grave” approach to product design. Strategies for green design include designing products so that they can be repaired, reused or recycled. Life cycle analysis offers a framework for evaluating the environmental impact of a product at all stages of its life cycle.

A.S. Obj

6.1 Clean Technology (3h)

6.1.1 Define *clean technology*. **1**

6.1.2 Outline three examples of damage to the natural environment caused by the use of technology. **2**

Examples include:

- climate changes as a result of production of greenhouse gases such as carbon dioxide due to the burning of fossil fuels
- sulfur dioxide from British power stations blowing across the North Sea to Scandinavia causing acid rain which damages forests
- the destruction of the ozone layer by the use of chlorofluorocarbon (CFC) gases as propellants for aerosols, as refrigerants and in the manufacture of plastic foams, thus reducing the protection from harmful ultraviolet radiation and increasing the incidence of skin cancer.

6.1.3 State that initially clean technology was aimed mainly at developing cleaner manufacturing processes. **1**

Clean technologies emerged as a result of greater pressure for environmental protection. They generate less pollution and waste and adopt more efficient use of energy and materials. Smokestack industries, such as iron and steel manufacture, are heavy consumers of raw materials and energy and are heavy polluters.

6.1.4 Outline the reasons for clean technology. **2**

Reasons include promoting positive impacts; ensuring neutral impact or minimizing negative impacts through conserving natural resources, reducing pollution and use of energy; and wastage of energy or resources.

6.1.5 Outline that an initial response to reducing emission of pollutants is adding clean-up technologies to the end of the manufacturing process. **2**

The addition of clean-up technologies to the end of the manufacturing process is termed “end-of-pipe” approach.

A.S.		Obj
6.1.6	Explain that more radical approaches require a rethink of the whole system and may result in significant product and/or process modification, or radically new technologies. For example, the development of renewable energy-based power generation equipment.	**3**
6.1.7	State that legislation relating to cleaning up the manufacturing process acted as an impetus for clean technology.	**1**
6.1.8	Explain that legislation relating to cleaning up the manufacturing process is based on quantitive data relating to pollution and waste.	**3**
6.1.9	Explain that maximum levels of pollution and waste are agreed internationally.	**3**
6.1.10	Explain that the legislation can be policed by monitoring through collection of quantitive data.	**3**
6.1.11	Explain that fines can be imposed for contravention of the legislation. This introduces the concept of the polluter paying.	**3**
6.1.12	Explain that the approaches in 6.1.5 to 6.1.11 are reactive.	**3**
6.1.13	Explain that some major companies have realized that using energy and materials more efficiently can save money and have adopted pro-active environmental policies to avoid problems.	**3**

6.2 Green Design (3h)

A.S.		Obj
6.2.1	Define *green design*. Green design involves taking a "cradle to the grave" approach to the design of a product by considering the adverse impacts of the product on the environment at all stages of its life (design, production, use, disposal), and seeking to minimize those impacts.	**1**
6.2.2	Outline the reasons for green design. In developing the product brief, formulating the product design specification and choosing the material and manufacturing process, the potential environmental impact of the product is assessed with the specific objective of reducing this impact and minimizing it over the longer term.	**2**
6.2.3	State that the impetus for green design comes from consumer pressure. The public have become aware of environmental issues through media focus on issues such as the destructive effect of chlorofluorocarbons on the ozone layer; acid rain in northern European forests and the nuclear accident at Chernobyl. Increased public awareness has put pressure on corporations and governments through purchasing power and voting power.	**1**

A.S.		Obj
6.2.4	Outline design objectives for green products.	2

Objectives include:

- increasing efficiency in the use of materials, energy and other resources
- minimizing damage or pollution from the chosen materials
- reducing to a minimum any long-term harm caused by use of the product
- ensuring that the planned life of the product is the most appropriate in environmental terms and that the product functions efficiently for its full life
- taking full account of the effects of the end disposal of the product
- ensuring that the packaging, instructions and overall appearance of the product encourage efficient and environmentally-friendly use
- minimizing nuisances such as noise or smell
- analysing and minimizing potential safety hazards.

6.2.5	Explain the role of legislation in promoting green design.	3

Raised awareness of environmental issues is increasing legislation in many countries. This can lead to financial penalties on companies who do not demonstrate environmental responsibility. Many people will not behave responsibly unless forced to do so—legislation forces the issue. One problem in relation to the recycling of plastics is knowing what the plastic actually is. Labelling plastic products with the plastic type can help overcome this issue.

6.2.6	Explain how people can be broadly classified according to their attitudes to green issues.	3

People's attitudes to green issues vary. Ecowarriors actively demonstrate on environmental issues, ecochampions champion environmental issues, ecofans enthusiastically adopt environmentally-friendly products and ecophobes actively resent talk of environmental protection.

6.2.7	Explain how eco-labelling and energy-labelling schemes can help consumers compare potential purchases.	3

6.3 Strategies for Green Design (4h)

6.3.1	Describe how designers can modify the environmental impact of the production, use and disposal of their product through careful consideration at the design stage.	2
6.3.2	State that strategies for optimizing resource utilization include reuse, repair, recycling and reconditioning.	1
6.3.3	State that the term *reuse* can refer to the reuse of a product in the same context or in a different context.	1

For example, refilling toner cartridges in photocopiers and printers, designing computers so that the central processing unit can be upgraded, using an ice-cream container as a toy box.

A.S.		Obj
6.3.4	State that "repair" refers to designing a product so that ease of maintenance is a major design consideration.	**1**
6.3.5	State that "recycling" refers to designing products so that, once obsolete, the materials can be used to create another product.	**1**
6.3.6	List three specific materials that can be easily and economically recycled.	**1**
6.3.7	Explain situations where it is appropriate to use each of these materials.	**3**
6.3.8	Outline two specific materials that cannot be easily and economically recycled. Some materials are easier and more economical to recycle than others and some cannot currently be recycled at all. Designers can encourage recycling by their choice of materials. Specific materials implies, for example, copper (not just metal), silica glass (not just glass) etc.	**2**
6.3.9	Discuss how the strategies of reuse, repair and recycle can be applied to the design of products, including packaging. For example, disposable cameras, vacuum cleaners, car tyres.	**3**

6.4 Life Cycle Analysis (6h)

6.4.1	Define *life cycle analysis*.	**1**
6.4.2	State that life cycle analysis provides a framework within which clean production technologies and green design can be evaluated holistically for a specific product.	**1**
6.4.3	State that in life cycle analysis the life cycle stages are categorized as: pre-production, production, distribution including packaging, utilization and disposal.	**1**
6.4.4	State that in life cycle analysis the environmental considerations include: water, soil pollution and degradation, air contamination, noise, energy consumption, consumption of natural resources, pollution and effect on ecosystems.	**1**
6.4.5	Explain how the life cycle stages and the environmental considerations can be organized into an environmental impact assessment matrix.	**3**

Environmental impact assessment matrix

	Preproduction	Production	Distribution	Utilization	Disposal
Water relevance					
Soil pollution and degradation					
Air contamination					
Noise					
Consumption of natural resources					
Effects on ecosystems					

A.S.		Obj
6.4.6	Analyse the environmental impact of refrigerators, washing machines and cars using an environmental impact matrix.	**3**
6.4.7	Explain why elements of the matrix may differ in importance according to the particular design context. For example, in the case of refrigerators and cars the larger part of energy consumption takes place in use rather than in manufacture.	**3**
6.4.8	Identify the roles and responsibilities of the designer, manufacturer and user at each life cycle stage of a product.	**2**
6.4.9	Describe one example of a situation where life cycle analysis identifies conflicts which have to be resolved through prioritization.	**2**

Topic 7: Raw Material to Final Product

This option considers the conversion of some important raw materials (timber, ceramic (glass), metal, textile fibre, plastic and new materials such as mycroprotein and superconductor) to final products. It explores the different ways materials are treated to ensure their suitability for particular applications.

A.S.		Obj
	7.1 Timber (3h)	
7.1.1	Outline that timber can be classified according to the conditions needed for tree growth, namely temperate and tropical conditions. A general knowledge of the geographical distribution of world timber resources is required.	**2**
7.1.2	Outline that conifer trees are referred to as softwoods and that these grow only in temperate regions and have features in common. Recognize the characteristics of softwood trees.	**2**
7.1.3	Outline that deciduous trees are referred to as hardwoods and that these grow in both temperate and tropical regions and have features in common. Recognize the characteristics of hardwood trees.	**2**
7.1.4	Discuss the issues involved in reforestation including time to reach maturity, soil erosion, greenhouse effect and extinction of species. The issues should be placed in local, national and international contexts.	**3**
7.1.5	State that particle board and plywood are examples of composite timbers. Particle board is sometimes referred to as chipboard.	**1**
7.1.6	Compare the characteristics of particle board, a pine wood and plywood with reference to their composition, hardness, tensile strength, resistance to damp environments, and the aesthetic properties of grain, colour and texture. The ability to produce sketches depicting cross-sectional views of the structure of the materials is expected.	**2**
7.1.7	Define *seasoning*.	**1**
7.1.8	Explain the need to season natural timber. Refer to the moisture content of workable timber and the consequences of manufacturing products using seasoned and non-seasoned timber.	**3**
7.1.9	Describe the reasons for treating or finishing wood including reducing attack by organisms and chemicals, enhancing aesthetic properties and modifying other properties. Knowledge of all the finishes and treatments available is not required; understanding the general principles is sufficient.	**2**

A.S.		Obj
7.1.10	Explain three differences in the treatment or finishes of a desk if it were to be made of particle board or pine, with reference to durability, ease of maintenance and aesthetics. It is assumed that the particle board is veneered.	**3**
7.1.11	Identify a different (type of) wood (not particle board or pine) and explain how it is processed and finished to make it appropriate for manufacturing a child's toy. Justify the selection of the timber for this application in relation to the qualities set out in 7.1.6. This refers to the three types of wood. Any toy can be chosen but health and safety considerations must be taken into account.	**2**

7.2 Ceramic (glass) (3h)

7.2.1	State that glass is composed primarily of silicon dioxide (SiO_2), together with some sodium oxide (Na_2O) and calcium oxide (CaO) and small quantities of a few other chemicals. The raw materials come from sand (SiO_2), limestone ($CaCO_3$ for making CaO) and sodium carbonate (Na_2CO_3 for making Na_2O). Knowledge of the mineral ore names or their geographical locations is not required.	**1**
7.2.2	Explain the requirement of large quantities of energy to manufacture glass, and that scrap glass is added to new raw materials to make the process economic. Refer to the very high melting points of the raw materials and the strength of chemical bonds involved (they are ionic). SiO_2 has a melting point of 2000 K. Between 15% and 30% powdered scrap glass is added to the raw materials and this lowers the temperatures needed, the electrical energy used and the time required.	**3**
7.2.3	Explain the characteristics of glass with reference to its brittleness, transparency, hardness, unreactivity and aesthetic properties.	**3**
7.2.4	Explain, with reference to soda glass and pyrex, that the desired characteristics of glass can be accurately determined by altering its composition. Most glasses consist of silica (SiO_2) mixed with metal oxides. High volume products (bottles, windows) are made from soda-lime silica glass. This glass has poor “thermal shock” resistance and, to overcome this, borosilicate (pyrex) glasses are available (with 60–80% SiO_2, 10–25% B_2O_3, 2–10% Na_2O and 1–4% Al_2O_3).	**3**
7.2.5	Outline the differences between toughened and laminated glass with reference to their responses to being deflected and to impact. Toughened glass is made by heating glass almost to the melting point. The surfaces are then cooled while the centre remains hot and plastic. It will shatter into tiny fragments when broken (eg windscreens). Laminated glass has a thin layer of material, usually plastic, between the layers. This prevents cracks from growing and it can even be made bullet proof.	**2**

A.S.		Obj
7.2.6	Explain how a selected glass's composition and finish is modified to make it appropriate for the manufacture of some decorative article.	3

Students should select an appropriate type of glass.

7.3 Metal (3h)

7.3.1 State that iron is a relatively reactive element and so is never found "free". State also that iron ore (mainly hematite: Fe_2O_3 with SiO_2 impurities) is relatively abundant in the earth and that iron has been extracted in blast furnaces since the Industrial Revolution using the raw materials: iron ore (Fe_2O_3), limestone ($CaCO_3$) and coke (C). **1**

Rich deposits of iron ore occur in Russia, Brazil, Australia and China. Extraction of iron from its ore requires some chemistry and energy to extract it from its oxide (ore), and needs treatment to prevent the iron reacting with air (oxygen and water) and reverting back to its oxide. Coke is required to produce the temperature and chemical conditions to reduce iron from its ore. Large scale manufacture of coke commenced during the Industrial Revolution.

Details of blast furnace structure and specific temperatures are not required.

7.3.2 Outline the chemical changes that take place in a blast furnace. **2**

Carbon monoxide (CO) from the carbon (C) is used to reduce the iron oxide to iron metal via the reaction:

$$3CO\ (g) + Fe_2O_3\ (s) \rightarrow 2Fe\ (1) + 3CO_2\ (g)$$

Calcium oxide (CaO) from the limestone ($CaCO_3$) is needed to remove the impurity silicon dioxide (SiO_2) by combining with it to form slag ($CaSiO_3$) via the reactions:

$$CaCO_3\ (s) \rightarrow CaO\ (s) + CO_2\ (g)$$

$$CaO\ (s) + SiO_2\ (s) \rightarrow CaSiO_3\ (l)$$

The iron produced in a blast furnace is an alloy called pig iron which, due to its high carbon (C) content (up to 4%), is very hard and brittle. Pig iron is not much use as an engineering material.

7.3.3 State that because wrought iron had a lower carbon content, was less brittle but had a higher tensile strength than pig iron, it led to an engineering expansion. **1**

Wrought iron has a lower carbon content (<0.03%) and is formed by heating, rolling and laminating hot slabs together. This toughened alloy is a better engineering material than pig iron.

7.3.4 Outline how iron is converted to steel, referring to the use of oxygen to reduce the carbon content by its reaction to form carbon dioxide. **2**

Iron is converted into steel in a furnace where the carbon level in the molten iron is reduced by blowing oxygen through the liquid metal. The carbon forms carbon dioxide which bubbles off. The resulting steel has a higher tensile strength and is tough compared with high-carbon alloys.

A.S.		Obj
7.3.5	Describe iron as an extremely versatile metal since the desired properties can be accurately determined by altering its composition. Refer to mild steel and stainless steel.	**2**
7.3.6	Explain two uses for mild steel (including car bodies) and stainless steel (including cutlery). The demands are mainly mechanical: rigidity, strength, weather protection and corrosion, ease of manufacture and cost. All these contribute to its choice as the main material used for making car bodies. Any other use for mild steel can be chosen. Stainless steel (with 18% Cr and 8% Ni) has good corrosion resistance and is used for situations where the metal must operate in a wet environment but cannot easily be protected with finishes. Any other use for stainless steel can be chosen.	**3**
7.3.7	Explain why steel must be treated or finished. Chemical details of rusting are not required. Iron alloys corrode in the presence of oxygen and water and form soft porous oxides which allow the chemical process to continue until the iron is completely converted to an oxide. Protection is provided by a non-porous material adhering to the surface to keep out oxygen, water or both.	**3**
7.3.8	Explain how mild steel is treated in the two examples chosen in 7.3.6. Possibilities include galvanizing, painting, plastic coatings, vitreous enamel and electroplating.	**3**
7.3.9	Identify another different type of steel (not mild steel) and describe how it is processed and finished to make it appropriate for a stated application. Possibilities include high tensile steel (painted, enamelled or zinc coated), chromium added to steel to make it stainless, and hammer finishes with aluminium suspended in a solvent (used on cast objects).	**2**

7.4 Textile Fibre and Plastic (3h)

7.4.1	Describe cotton and nylon. Cotton is a natural fibre, a cellulose polymer, obtained from the bud of cotton plants that grow in several sub-tropical regions. A general understanding of the geographical distribution of cotton is required. Nylon is a synthetic polyamide fibre, obtained by the polymerization of adipic acid and a diamine. Students should be able to draw a simple zig-zag form to show their understanding of how the molecular form effects the characteristics. Detailed monomer or polymer structure diagrams or chemical details of linkages are not required.	**2**
7.4.2	Explain how cotton bolls are converted into threads. Limit this to harvesting, cleaning, combing and spinning. The detail of each stage of the process is not required. Flow diagrams may be appropriate.	**3**

A.S.		Obj
7.4.3	Explain how nylon threads are manufactured from petroleum. Limit this to the mixing of the two raw materials in a controlled way (each dissolved in a solvent) and the extrusion of the threads.	**3**
7.4.4	Compare the characteristics of cotton and nylon threads with reference to absorbency, strength, elasticity and effect of temperature. Cotton is very absorbent and increases in strength when wet because the degree of alignment of long polymers increases, leading to the strengthening of bonds. Cotton is relatively inelastic, so it wrinkles and creases easily. It is a good conductor of heat and so is little effected by heat and chars rather than melts when exposed to high temperatures.	**2**
7.4.5	Discuss the reasons for treating cotton. Refer to enhancing aesthetic properties, reducing flammability and the need for waterproofing. The general principles of treatments and finishes is required, but not detailed chemical information. Cotton is also degraded by ultraviolet rays, moisture and air pollutants. This is shown as discolouration and then breakdown of fibre. Cotton is also susceptible to attack by microbes.	**3**
7.4.6	Explain that nylon needs little treatment because the desired characteristics can be designed into it.	**3**
7.4.7	Outline clothing as a major use for both cotton and nylon.	**2**
7.4.8	Explain how cotton, nylon or polyester may be incorporated into a composite fabric and how the composition of this fabric determines its characteristics. Refer to socks, shorts and waterproof garments. Knowledge is required of how the properties of fabrics change by mixing fibres in the manufacture to combine the characteristics. Also include how the type of fabric manufacture changes characteristics, eg weave.	**3**
7.4.9	Identify another different textile fibre (apart from cotton and nylon) and explain how it is processed and finished to make it appropriate for the manufacture of a blanket.	**3**

7.5 New Materials (3h)

Mycoprotein—a new food

7.5.1	State that mycoprotein is a food product made from a fungus grown on grain and paper flour wastes and harvested as a mass of threads (mycelium). Quorn™ is an example of such material. Mycoprotein is produced in a sealed fermenter, in the absence of air. It is grown in/on cellulose and other hydrocarbons and the pH and temperature are controlled. No other chemical or biological details are required.	**1**

A.S.		Obj
7.5.2	Describe the advantages of mycoprotein, referring to the nutritional and physical characteristics. Include its ability to be formed into chunks (that can simulate, for example, beef or chicken), its high protein and fibre content, and low salt and cholesterol levels. Mycoprotein is virtually tasteless but can be given almost any flavour before or during cooking. No details of flavourings are required.	**2**
7.5.3	Describe what is necessary for the commercially viable manufacture of mycoprotein. Include cheap substrate (ideally waste materials), safe to eat, easily processed into acceptable food product, no toxicological effects and no residues or contaminants from substrates.	**2**
7.5.4	Explain how mycoprotein can be designed in a range of novel food products. A wide range of examples is possible. For example Quorn™, the product from fermentation is a dough which can be mixed with a binding agent (eg egg white) and flavouring agents and then put through a forming machine to give any required shape (eg chicken thigh shape).	**3**
7.5.5	Discuss the importance of public acceptability in the commercial success of new foods. The look and smell of food gives an initial impression. People need to be able to compare new foods with those they are familiar with. New foods are often first introduced in ready meals and then released as a separate ingredient to incorporate in recipes.	**3**

Superconductor

7.5.6	Define *superconductor*.	**1**
7.5.7	Explain that superconductors are ceramic alloys made from various metal oxides, non-metal oxides and metals, and that they are sintered so there is no need for treatment or finish. No details of specific chemicals or proportions are required. The process allows whatever finish and shape is desired.	**3**
7.5.8	State that the resistivity of superconductors becomes nearly zero at temperatures below about 140 K due to pairs of electrons weakly bonded together, which can move freely at these temperatures. Please note that future technology will change this value to perhaps near room temperature. Note also that superconductors are similar to metals in terms of structure and mode of conduction.	**1**
7.5.9	Explain the advantages of being able to produce superconducting materials that operate at room temperature. Discuss the fact that while superconductors are currently of rather limited use, they are utilized in NMR brain scans and levitating trains (refer to current technological magazines). Advantages include energy savings and less raw material needed since cables can be smaller.	**3**

Topic 8: Microstructures and Macrostructures

The microstructures topic is included to provide students with the concepts used to explain the properties of materials. These concepts also allow a designer to choose, based on a design context, the type of microstructure needed. This allows the designer to specify a type of material and a specific treatment, such as annealing, quenching or case-hardening.

A.S.		Obj
	8.1 Structure of Matter (1h)	
8.1.1	State that all matter is composed of particles.	**1**
8.1.2	Define *atom, molecule* and *ion*. Atoms are the smallest parts into which elements can be chemically divided. All atoms have the same basic structure.	**1**
8.1.3	Outline a bond as a force of attraction between particles.	**2**
8.1.4	Draw an equilibrium position of a particle in a bond using a general potential energy–separation curve.	**1**
8.1.5	Define an *element, compound, pure substance, mixture, alloy* and *composite*. Composites are formed when two or more materials (from any material group) are combined to obtain different properties to those available from the original materials.	**1**
	8.2 Bonding (2h)	
8.2.1	Draw and describe an *ionic bond*, a *covalent bond* and a *metallic bond*. • In an ionic bond the opposing charges of the ions hold the crystal (eg NaCl) together in a lattice. The ions can often be separated easily in water but the electrons stay attached to their respective ions inside the crystal. • In a covalent bond the outer electrons of some atoms can come close enough to overlap and be shared between the nuclei, thereby forming a covalent bond. Each pair of electrons shared is called a covalent bond. Mention of sigma, pi, double or triple bonds is not required. • Metallic bonding involves outer electrons but these are freer and they can flow through the crystalline structure. The bonding is caused by attraction between the positively charged metal atom nuclei and the negatively charged cloud of free electrons, and is spread throughout the lattice—“Positively charged nuclei in a sea of electrons”. Specific arrangements of metal atoms in crystals are not required.	**2**
8.2.2	State that the three bonds in 8.2.1 are called primary bonds and their relative strengths are ionic > metallic > covalent. No quantitative details are required.	**1**

A.S.		Obj
8.2.3	Outline secondary bonds as weak forces of attraction between molecules.	**2**
8.2.4	Explain what is meant by a network covalent (giant) structure, with reference to diamond and sand (SiO_2). In diamond each carbon is covalently bonded to four other carbon atoms, tetrahedrally arranged. The carbons at the edges are attached to hydrogen atoms. In sand (silica, SiO_2) the arrangement is also tetrahedral. Both sand and diamond are very hard.	**3**
8.2.5	Describe a crystal as a regular arrangement of particles (atoms, ions or molecules). Details of types of crystal are not required.	**2**
8.2.6	Define an *amorphous material* and a *fibre structure*. • Amorphous materials do not have regular structures or crystal patterns. Short range order may occur as far as next neighbour atoms. The general appearance of amorphous materials is glossy and they can occur in ceramics, polymers and metals. • Fibres have a length-to-thickness ratio of at least 80 but are generally much longer. Textile fibres and food are made up of polymers.	**1**
8.2.7	Explain melting in terms of the behaviour of particles and the bonding.	**3**
8.2.8	Explain boiling in terms of the behaviour of particles and the bonding.	**3**
8.2.9	Discuss the significance of pure substances melting at a fixed temperature, and mixtures softening over a range of temperatures before melting. The working of materials in a plastic condition is possible because of the range of temperatures over which a mixture softens.	**3**

8.3 The IB Properties / Bonding Matrix (2h)

8.3.1	Explain how the properties specified in the **IB properties/materials matrix** (see 3.3) can be organized into a properties/bonding matrix.	**3**
8.3.2	Describe the relative values of the materials in the **IB properties/bonding matrix** in terms of their bonding.	**2**
8.3.3	Analyse data related to the **IB properties/bonding matrix**.	**3**
8.3.4	Evaluate the importance of the **IB properties/bonding matrix** in a given design context.	**3**

IB properties/bonding matrix

	Ionic	Simple covalent	Network covalent	Metallic
Chemical properties				
Solubility in water	high	low	v. low	v. low
Solubility in organic solvents	v. low	v. high	v. low	v. low
Physical properties				
Electrical resistivity	v. high	high	v. high	v. low
Thermal conductivity	v. low	low	v. low	v. high
Thermal expansion	low	low	v. low	v. high
Hardness	high	v. low	v. high	low–high
Mechanical properties				
Tensile strength	v. low	low	v. high	high
Stiffness	high	low	v. high	high
Toughness	low	medium–high	low	v. high
Materials →	**ceramic**	**plastics food**	**ceramic textile fibres food timber**	**metals**

A.S. Obj

8.4 The Properties of Metals and Alloys (2h)

8.4.1 State that metals (pure or alloyed) exist as crystals. **1**

Details of crystal types are not required.

8.4.2 Draw and describe what is meant by *grain size*. **2**

8.4.3 Explain how grain size can be controlled and modified by the rate of cooling of the molten metal, or by heat treatment after solidification. **3**

Reheating a solid metal or alloy allows material to diffuse between neighbouring grains and the grain structure to change. Slow cooling allows larger grains to form; rapid cooling produces smaller grains. Directional properties in the structure may be achieved by selectively cooling one area of the solid.

8.4.4 Define *plastic deformation*. **1**

A.S.		Obj
8.4.5	Explain in words and diagrams how metals work harden after being plastically deformed. Beyond the yield stress metals and alloys harden when plastically deformed. See 8.7.4 for details.	**3**
8.4.6	Describe in words and diagrams how the tensile strength of a metal is increased by alloying.	**2**
8.4.7	Explain in words and diagrams the effect of alloying on malleability and ductility. 8.4.6–8.4.7 The increased strength and hardness, and reduced malleability and ductility, of alloys compared to pure metals is due to the presence of “foreign” atoms which interfere with the movements of atoms in the crystals during plastic deformation.	**3**
8.4.8	Explain, using words and a diagram, how the movement of free electrons makes metals very good electrical and thermal conductors. The explanation should involve the mobility of the “sea” of electrons.	**3**
8.4.9	Evaluate the importance of bonding and structure to the properties of metals and alloys in a given design context.	**3**

8.5 The Properties of Thermoplastics and Thermosets (2h)

A.S.		Obj
8.5.1	Draw and describe the structure and bonding of a thermoplastic. Thermoplastics are linear chain molecules, sometimes with side bonding of the molecules, but with weak, secondary bonding between the chains.	**2**
8.5.2	Explain the effect of load on a thermoplastic, with reference to orientation of chains. Deformation occurs in two ways: elastic in which initially coiled chains are stretched and plastic at higher loads, where secondary bonds weaken and allow the molecular chains to slide over each other. Creep and flow are important. No quantitative details required.	**3**
8.5.3	Explain the reversible effect of temperature on a thermoplastic, with reference to orientation of chains. Increase in temperature causes plastic deformation, see 8.5.2.	**3**
8.5.4	Draw and describe the structure and bonding of a thermoset. Thermosets are formed by making primary (covalent) bonds which form strong, primary cross-links between adjacent polymer chains. This gives the thermosets a rigid three-dimensional structure.	**2**
8.5.5	Explain the non-reversible effect of temperature on a thermoset. Heating increases the number of permanent cross links and so hardens the plastic.	**3**

A.S.		Obj
8.5.6	Discuss the properties and uses of two thermoplastics including polypropene.	**3**
8.5.7	Discuss the properties and uses of two thermosets including polyurethane.	**3**
8.5.8	Discuss the importance of the properties of plastics on the recycling of plastics.	**3**
8.5.9	Evaluate the importance of the properties of thermoplastics and thermosets on product design.	**3**

8.6 The Properties of Composite Materials (3h)

8.6.1	State that composites are a combination of two or more materials which are bonded together to improve their mechanical, physical, chemical or electrical properties. Recall of specific composites (other than those mentioned in 8.6.2–8.6.6) and details of bonding are not required.	**1**
8.6.2	Describe the structure of wood as a natural composite material. Cellulose fibres in a lignin matrix—the tensile strength is greater along the grain (fibre) than across the grain (matrix).	**2**
8.6.3	Discuss in outline the evolution of synthetic composite materials with reference to wattle-and-daub, mortar, papier mâché, reinforced concrete, glass reinforced plastic (GRP), carbon reinforced plastic (CRP) and high temperature superconductors. Emphasize the historical aspects. The details of bonding or proportions of materials are not required.	**3**
8.6.4	Outline the structure of Kevlar™ (aramid) fibre. Aramid fibre comprises linear chains of hydrocarbon rings. Aramid chains behave like rigid rods and they are aligned along the length of the fibre during the manufacturing process. They have a very high tensile structure.	**2**
8.6.5	Outline two examples where Kevlar™ fibres twisted into ropes and woven into sheets (mats) are used. Rope—light, non-stretch ropes used in sailing boats. Sheets—sails that hold their shape under great stress in high-performance yachts; composite structures with resin eg motor racing cars.	**2**
8.6.6	Explain why Kevlar™ is suited to these applications with reference to its tensile strength, elasticity and water resistance. Kevlar™ fibres do not absorb water, have a high tensile strength and are non-stretch.	**3**
8.6.7	Evaluate the importance of the properties of composite materials in a design context.	**3**

A.S.		Obj

8.7 Young's Modulus—Stress and Strain (3h)

8.7.1	State that stress (load) is force per unit area acting on a body or system. The load on a structural member divided by its cross-sectional area is called the "stress in the member".	1
8.7.2	State that strain is the ratio of a change in dimension to the original value of that dimension. The strain in a material is a measure of the relative change of shape it undergoes when subjected to a load. It is independent of the size of the structural member.	1
8.7.3	Define *yield stress*.	1
8.7.4	Draw and describe a stress/strain graph and identify the elastic region, yield stress, plastic flow region and ultimate stress (UTS). For most materials the elastic region is a straight line which changes to a curved line (plastic region). Quantitative details of specific materials are not required.	2
8.7.5	Explain the relevance of the stress/strain graph identified in 8.7.4 in design contexts.	3
8.7.6	Outline the importance of yield stress. This is the stress at the yield point. Many materials undergo plastic as well as elastic deformation.	2
8.7.7	Describe the difference between elastic and plastic strains. In the straight portion of the stress/strain graph the material behaves elastically, ie if the stress on the material is released before it breaks, the extension (strain) relaxes and the material returns to its original length.	2
8.7.8	Define *Young's modulus*. The stiffness of a material is called the "elastic modulus". In relation to tensile and compressive loads the elastic modulus is called "Young's modulus".	1
8.7.9	Calculate the Young's modulus of a material. $\text{Young's modulus} = \frac{\text{stress}}{\text{strain}}$	2
8.7.10	Explain how knowledge of the Young's modulus of a material affects the selection of materials for particular applications. Use an example where stiffness of a material is important.	3
8.7.11	Evaluate the importance of stress and strain in a design context.	3

A.S.		Obj

8.8 Forces (2h)

8.8.1 Outline what is meant by an external load acting as a structure. **2**

This involves loads where physical contact is made.

8.8.2 Outline what is meant by body load. **2**

This is a load without physical contact, eg a structure's own weight.

8.8.3 Describe the difference between weight and mass. **2**

8.8.4 State the units of weight and mass. **1**

8.8.5 Outline the relationships of external loads to internal forces and the concept of the balance of equilibrium of forces within a structure. **2**

Describe how a structure "works" by interpreting how external loads give rise to internal forces within the structural members. A static structure is in equilibrium, otherwise it would move, ie the forces acting upon it are equal in size and opposite in direction.

8.8.6 Outline the differences between tensile and compressive forces and how they affect equilibrium within a structure. **2**

Tensile loads tend to extend or stretch a structural member. Compressive loads tend to compress or shorten a structural member. Tensile and compressive forces must balance if the structure is to maintain equilibrium. Only forces that are parallel or perpendicular need to be considered. Knowledge of trigonometry or quantitative resolution of vectors into components is not required.

8.8.7 Calculate a tensile or compressive strain given values of force and area. **2**

$$\text{Stress} = \frac{\text{force}}{\text{area}}$$

8.8.8 Calculate a tensile or compressive strain given values of the original dimension and the change in dimension. **2**

$$\text{Strain} = \frac{\text{change of length}}{\text{original length}}$$

8.8.9 Evaluate the importance of forces in a design context. **3**

A.S.		Obj

8.9 The Strength and Stiffness of Structures (2h)

8.9.1	Describe the relationship between deflection and stiffness in structures. If an external load is applied to some part of a structure, that part will be deflected to some extent, depending on the size of the load and the stiffness of the structure.	**2**
8.9.2	Calculate the stiffness of a structure. $\text{Stiffness} = \dfrac{\text{load}}{\text{deflection}}$	**2**
8.9.3	Outline what is meant by "bending moment" in relation to structures.	**2**
8.9.4	Outline what is meant by "moment arm". The load $\times$ distance from the pivot is called the "moment" about the pivot. The distance between the load and the pivot is called the "moment arm".	**2**
8.9.5	Explain the need for a *factor of safety* in structural design. Structures are designed to take higher loads than those they are normally expected to support.	**3**
8.9.6	Calculate the factor of safety for a structure. $\text{Factor of safety} = \dfrac{\text{design load}}{\text{normal maximum load}}$	**2**
8.9.7	Apply the concept of factor of safety to other areas of design. A factor of safety is simply a ratio of the quantitative value of a design (factor) divided by the normal maximum expected value, eg stiffness, fuel tank volumes, electrical resistance, engine acceleration.	**2**
8.9.8	Evaluate the importance of strength and stiffness in a design context.	**3**

Topic 9: Appropriate Technologies

Students need to understand the constraints and opportunities that exist for optimizing the exploitation of resources and renewable energy sources. The aim of this topic is to promote an awareness of the need to conserve non-renewable resources while meeting human, environmental and industrial requirements.

A.S.		Obj

9.1 Resources and Reserves (1h)

9.1.1	State that resources can be classified as renewable and non-renewable.	**1**
9.1.2	Define *renewable resources* and *non-renewable resources*.	**1**
9.1.3	Describe the difference between a resource and a reserve.	**2**
9.1.4	Explain how the market, technology and availability determine whether a reserve is exploited.	**3**

9.2 The Technologies (3h)

9.2.1	Define *appropriate technology*.	**1**
9.2.2	List four characteristics of an appropriate technology. To explain when technology and resources are appropriate, it helps to ask a series of questions. What is the product for? Is it what people need or want? Does it improve the quality of life? Who gains and loses from this technology? Are raw materials available locally? Is the appropriate labour force local? Does it create or destroy jobs? Can the people afford to buy, run and maintain it? What resources/fuel are used? Does it damage or improve the environment? Appropriate technologies are: low in capital cost; use local materials whenever possible; create jobs (employing local skills and labour); involve decentralized renewable energy sources; make technology understandable to the people who use it (and so suggest ideas for further innovations); are flexible so that they can continue to be used or adapted to fit changing circumstances; and are not detrimental to the quality of life or the environment.	**1**
9.2.3	Describe one example of an appropriate technology. For example, the use of local materials as an energy source.	**2**
9.2.4	Define *alternative technology.*	**1**
9.2.5	Describe one example of an alternative technology. For example, small scale organic farming versus large scale energy-intensive cultivation techniques.	**2**

A.S.		Obj
9.2.6	Define *intermediate technology*.	**1**
9.2.7	Describe one example of an intermediate technology. This is a relative term since, for example, in one country the ox-drawn plow is intermediate (more sophisticated than the traditional hoe) but less complex than a tractor. In another country the plow would be considered traditional.	**2**

9.3 Exploitation of Energy Resources (4h)

A.S.		Obj
9.3.1	Outline renewable energy sources. Include wind, wave, solar, biomass, hydroelectric, tidal and geothermal energy sources.	**2**
9.3.2	Outline non-renewable energy sources. Include coal, oil, timber, gas and nuclear.	**2**
9.3.3	Describe two advantages and two disadvantages of using renewable energy sources. Include capital and running costs, social and political consequences, and environmental issues.	**2**
9.3.4	Explain a situation where solar or wind energy sources have been used successfully. Refer to the market, technology and availability of the primary energy source.	**3**
9.3.5	Discuss the advantages and disadvantages of using renewable sources of energy in various parts of the world. Consider continuity of supply, distribution, capital costs, maintenance costs and location effect on the environment.	**3**
9.3.6	State that availability of energy, efficiency of energy conversion, costs and type of energy source affect the choice of manufacturing process.	**1**
9.3.7	Explain how each of the factors in 9.3.6 affect the choice of manufacturing process. Consider siting of manufacturing plant (access to raw materials and waste).	**3**
9.3.8	Explain three ways that energy considerations can influence the design of a product. Consider raw materials used, assembly arrangements, number of components, type of energy used, energy used in production, use and disposal of a product, and lead time.	**3**

A.S.		Obj

9.4 Exploitation of Material Resources (3h)

9.4.1 Discuss the issues surrounding the need to conserve the resources of the planet and the means to do it. **3**

Include reference to “developing versus developed” countries; renewable/non-renewable versus economic considerations; built-in obsolescence versus longevity; aesthetics versus function; and considerations of culture, values and attitudes.

9.4.2 Discuss the issues which contribute to the feasibility of recycling including political, economic, social, environmental and conservation issues. **3**

Barriers to recycling include manufacturing capacity, technical factors, economics, product specifications and consumer resistance to using waste-based products. Using the example of paper—features that favour recycling are not using glossy surfaces, ones that cannot be processed by machines or plastic components since they make recycling expensive. More recycled materials can be reintroduced into the industry since recycling reduces the need for purchasing more virgin raw materials. More public subsidies would help to persuade firms to introduce recycled materials. Large paper manufacturers could be encouraged to sell off their stakes in forests in order to encourage their use of recyclable materials.

9.4.3 Discuss the ethical issues surrounding the development of a national policy concerning the exploitation of resources. **3**

Students should try to develop their own policy as a class, as well as considering any (local) national policy.

9.5 Strategies for Sustainable Development (4h)

9.5.1 Define *sustainable development.* **1**

9.5.2 State that global conferences (eg The Earth Summit in Rio de Janeiro 1992) provide a platform for the development of global strategies for sustainable development. **1**

9.5.3 Explain the major proposals that were agreed by participants as part of Agenda 21 at the Rio conference. **3**

The major proposals included promoting: sustainable energy development; safe and environmentally sound transport systems; industrial development that does not adversely impact the atmosphere; agricultural (and forestry) development that does not adversely impact the atmosphere; sustainable resource development and land use; sustainable energy consumption patterns and lifestyles; and preventing stratospheric ozone depletion.

A.S.		Obj
9.5.4	Explain why sustainable development requires systems-level changes in industry and society. For example, the development of a sustainable transport system is likely to involve much more than the green design of cars. It should also consider the fundamental role of transport in human life. To achieve a shift from private car-based travel requires improvement of public transport systems and the increased use of environmentally benign forms of transport (eg bicycles). Much travel is associated with travel to work and revolution in the way people work (eg from home in virtual offices rather than travelling to offices) would replace some travel with electronic communication.	3
9.5.5	Explain how sustainable development requires close cooperation between manufacturers and government.	3
9.5.6	Explain how a close relationship between manufacturers and government can be difficult to achieve because the two parties may have very different perspectives on sustainability and timescales.	3
9.5.7	Explain why it is difficult for governments to introduce legislation to cover all aspects of sustainability.	3
9.5.8	Explain how a shift from energy-intensive smokestack industries and mass production to information-based trading and service sector-based activities reduces the dependence on energy and material resources. The knowledge economy is becoming increasingly synonymous with the weightless economy.	3
9.5.9	Explain how anticipating sources of pollution and eliminating them at the design stage can lead to savings on raw materials and waste treatment.	3
9.5.10	Explain how cost-savings can be achieved by introducing more energy-efficient and less wasteful manufacturing processes.	3
9.5.11	Describe two ways that manufacturers could re-evaluate short-term profitability in favour of long-term sustainability. For example, manufacturers could: design and operate manufacturing and service units on as small a scale as is consistent with efficient use of resources; use technologies that enhance human skills and match the capabilities of local populations; and use clean processes which minimize pollution and waste of non-renewable resources. Production and use should not dehumanize people. The nature of the production process should be such that it helps and liberates human beings rather than sustaining, controlling or mentally or physically damaging them. The production process should be such that it can be controlled by human beings rather than the reverse. Production should aim at the highest technically achievable standards and level of energy efficiency.	2
9.5.12	Explain how consumer attitudes towards sustainability issues have created a market pull situation. From the late 1980s there has been a growing market of “green” consumers wanting environmentally friendly products.	3

A.S.		Obj
9.5.13	Explain how product characteristics can be consistent with sustainable development. A product should be considered for its long-term characteristics rather than its short-term ones. A product should help and liberate human beings rather than sustain, control or mentally or physically damage them. A product should not demand exceptional user skill and should be controlled by human beings rather than the reverse. The use value of a product should be more important than its exchange value. Products for the developing world should provide for mutually non-exploitative relationships with the developed countries. A product should be regarded as part of culture and as such should meet the cultural, historical and other requirements of those who will build and use it. Products should be designed for high durability and repairability. Products should be designed for disassembly so that materials can be reused and recycled. The financial cost to users over the whole of the product cycle should be as low as possible.	**3**
9.5.14	Explain how energy utilization can be consistent with sustainable development. Include using energy in ways that minimize waste, optimize the efficiency of complete systems and maximize the sustainable use of renewable energy.	**3**

Options Outline

Options Standard Level

- A Raw material to final product
- B Microstructures and macrostructures
- C Appropriate technologies

Options Standard Level/Higher Level

- D Food technology
- E Computer-aided design, manufacture and production
- F Invention, innovation and design
- G Health by design
- H Electronic products

Standard level candidates are required to study any **two** options from A–H.
The duration of each option is 15 hours.

Higher level candidates are required to study any **two** options from D–H.
The duration of each option is 22 hours.

Option A: Raw Material to Final Product

This option considers the conversion of some important raw materials (timber, ceramic (glass), metal, textile fibre, plastic and new materials such as mycroprotein and superconductor) to final products. It explores the different ways materials are treated to ensure their suitability for particular applications.

A.S.		Obj
	A.1 Timber (3h)	
A.1.1	Outline that timber can be classified according to the conditions needed for tree growth, namely temperate and tropical conditions. A general knowledge of the geographical distribution of world timber resources is required.	2
A.1.2	Outline that conifer trees are referred to as softwoods and that these grow only in temperate regions and have features in common. Recognize the characteristics of softwood trees.	2
A.1.3	Outline that deciduous trees are referred to as hardwoods and that these grow in both temperate and tropical regions and have features in common. Recognize the characteristics of hardwood trees.	2
A.1.4	Discuss the issues involved in reforestation including time to reach maturity, soil erosion, greenhouse effect and extinction of species. The issues should be placed in local, national and international contexts.	3
A.1.5	State that particle board and plywood are examples of composite timbers. Particle board is sometimes referred to as chipboard.	1
A.1.6	Compare the characteristics of particle board, a pine wood and plywood with reference to their composition, hardness, tensile strength, resistance to damp environments, and the aesthetic properties of grain, colour and texture. The ability to produce sketches depicting cross-sectional views of the structure of the materials is expected.	2
A.1.7	Define *seasoning*.	1
A.1.8	Explain the need to season natural timber. Refer to the moisture content of workable timber and the consequences of manufacturing products using seasoned and non-seasoned timber.	3
A.1.9	Describe the reasons for treating or finishing wood including reducing attack by organisms and chemicals, enhancing aesthetic properties and modifying other properties. Knowledge of all the finishes and treatments available is not required; understanding the general principles is sufficient.	2

A.S.		Obj
A.1.10	Explain three differences in the treatment or finishes of a desk if it were to be made of particle board or pine, with reference to durability, ease of maintenance and aesthetics. It is assumed that the particle board is veneered.	**3**
A.1.11	Identify a different (type of) wood (not particle board or pine) and explain how it is processed and finished to make it appropriate for manufacturing a child's toy. Justify the selection of the timber for this application in relation to the qualities set out in A.1.6. This refers to the three types of wood. Any toy can be chosen but health and safety considerations must be taken into account.	**2**

A.2 Ceramic (glass) (3h)

A.2.1	State that glass is composed primarily of silicon dioxide (SiO_2), together with some sodium oxide (Na_2O) and calcium oxide (CaO) and small quantities of a few other chemicals. The raw materials come from sand (SiO_2), limestone ($CaCO_3$ for making CaO) and sodium carbonate (Na_2CO_3 for making Na_2O). Knowledge of the mineral ore names or their geographical locations is not required.	**1**
A.2.2	Explain the requirement of large quantities of energy to manufacture glass, and that scrap glass is added to new raw materials to make the process economic. Refer to the very high melting points of the raw materials and the strength of chemical bonds involved (they are ionic). SiO_2 has a melting point of 2000 K. Between 15% and 30% powdered scrap glass is added to the raw materials and this lowers the temperatures needed, the electrical energy used and the time required.	**3**
A.2.3	Explain the characteristics of glass with reference to its brittleness, transparency, hardness, unreactivity and aesthetic properties.	**3**
A.2.4	Explain, with reference to soda glass and pyrex, that the desired characteristics of glass can be accurately determined by altering its composition. Most glasses consist of silica (SiO_2) mixed with metal oxides. High volume products (bottles, windows) are made from soda-lime silica glass. This glass has poor "thermal shock" resistance and, to overcome this, borosilicate (pyrex) glasses are available (with 60–80% SiO_2, 10–25% B_2O_3, 2–10% Na_2O and 1–4% Al_2O_3).	**3**
A.2.5	Outline the differences between toughened and laminated glass with reference to their responses to being deflected and to impact. Toughened glass is made by heating glass almost to the melting point. The surfaces are then cooled while the centre remains hot and plastic. It will shatter into tiny fragments when broken (eg windscreens). Laminated glass has a thin layer of material, usually plastic, between the layers. This prevents cracks from growing and it can even be made bullet proof.	**2**

A.S.		Obj
A.2.6	Explain how a selected glass's composition and finish is modified to make it appropriate for the manufacture of some decorative article. Students should select an appropriate type of glass.	3

A.3 Metal (3h)

A.3.1	State that iron is a relatively reactive element and so is never found "free". State also that iron ore (mainly hematite: Fe_2O_3 with SiO_2 impurities) is relatively abundant in the earth and that iron has been extracted in blast furnaces since the Industrial Revolution using the raw materials: iron ore (Fe_2O_3), limestone ($CaCO_3$) and coke (C). Rich deposits of iron ore occur in Russia, Brazil, Australia and China. Extraction of iron from its ore requires some chemistry and energy to extract it from its oxide (ore), and needs treatment to prevent the iron reacting with air (oxygen and water) and reverting back to its oxide. Coke is required to produce the temperature and chemical conditions to reduce iron from its ore. Large scale manufacture of coke commenced during the Industrial Revolution. Details of blast furnace structure and specific temperatures are not required.	1
A.3.2	Outline the chemical changes that take place in a blast furnace. Carbon monoxide (CO) from the carbon (C) is used to reduce the iron oxide to iron metal via the reaction: $3CO\ (g) + Fe_2O_3\ (s) \rightarrow 2Fe\ (l) + 3CO_2\ (g)$ Calcium oxide (CaO) from the limestone ($CaCO_3$) is needed to remove the impurity silicon dioxide (SiO_2) by combining with it to form slag ($CaSiO_3$) via the reactions: $CaCO_3\ (s) \rightarrow CaO\ (s) + CO_2\ (g)$ $CaO\ (s) + SiO_2\ (s) \rightarrow CaSiO_3\ (l)$ The iron produced in a blast furnace is an alloy called pig iron which, due to its high carbon (C) content (up to 4%), is very hard and brittle. Pig iron is not much use as an engineering material.	2
A.3.3	State that because wrought iron had a lower carbon content, was less brittle but had a higher tensile strength than pig iron, it led to an engineering expansion. Wrought iron has a lower carbon content (<0.03%) and is formed by heating, rolling and laminating hot slabs together. This toughened alloy is a better engineering material than pig iron.	1
A.3.4	Outline how iron is converted to steel, referring to the use of oxygen to reduce the carbon content by its reaction to form carbon dioxide. Iron is converted into steel in a furnace where the carbon level in the molten iron is reduced by blowing oxygen through the liquid metal. The carbon forms carbon dioxide which bubbles off. The resulting steel has a higher tensile strength and is tough compared with high-carbon alloys.	2

Chemical details of rusting are not required. Iron alloys corrode in the presence of oxygen and water and form soft porous oxides which allow the chemical process to continue until the iron is completely converted to

A.3.8 Explain how mild steel is treated in the two examples chosen in A.3.6. **3**

Possibilities include galvanizing, painting, plastic coatings, vitreous enamel and electroplating.

A.3.9 Identify another different type of steel (not mild steel) and describe how it is processed and finished to make it appropriate for a stated application. **2**

Possibilities include high tensile steel (painted, enamelled or zinc coated), chromium added to steel to make it stainless, and hammer finishes with aluminium suspended in a solvent (used on cast objects).

A.4 Textile Fibre and Plastic (3h)

A.4.1 Describe cotton and nylon. **2**

Cotton is a natural fibre, a cellulose polymer, obtained from the bud of cotton plants that grow in several sub-tropical regions. A general understanding of the geographical distribution of cotton is required.

Nylon is a synthetic polyamide fibre, obtained by the polymerization of adipic acid and a diamine. Students should be able to draw a simple zig-zag form to show their understanding of how the molecular form effects the characteristics. Detailed monomer or polymer structure diagrams or chemical details of linkages are not required.

A.4.2 Explain how cotton bolls are converted into threads. **3**

Limit this to harvesting, cleaning, combing and spinning. The detail of each stage of the process is not required. Flow diagrams may be appropriate.

A.S.		Obj
A.4.3	Explain how nylon threads are manufactured from petroleum. Limit this to the mixing of the two raw materials in a controlled way (each dissolved in a solvent) and the extrusion of the threads.	3
A.4.4	Compare the characteristics of cotton and nylon threads with reference to absorbency, strength, elasticity and effect of temperature. Cotton is very absorbent and increases in strength when wet because the degree of alignment of long polymers increases, leading to the strengthening of bonds. Cotton is relatively inelastic, so it wrinkles and creases easily. It is a good conductor of heat and so is little effected by heat and chars rather than melts when exposed to high temperatures.	2
A.4.5	Discuss the reasons for treating cotton. Refer to enhancing aesthetic properties, reducing flammability and the need for waterproofing. The general principles of treatments and finishes is required, but not detailed chemical information. Cotton is also degraded by ultraviolet rays, moisture and air pollutants. This is shown as discolouration and then breakdown of fibre. Cotton is also susceptible to attack by microbes.	3
A.4.6	Explain that nylon needs little treatment because the desired characteristics can be designed into it.	3
A.4.7	Outline clothing as a major use for both cotton and nylon.	2
A.4.8	Explain how cotton, nylon or polyester may be incorporated into a composite fabric and how the composition of this fabric determines its characteristics. Refer to socks, shorts and waterproof garments. Knowledge is required of how the properties of fabrics change by mixing fibres in the manufacture to combine the characteristics. Also include how the type of fabric manufacture changes characteristics, eg weave.	3
A.4.9	Identify another different textile fibre (apart from cotton and nylon) and explain how it is processed and finished to make it appropriate for the manufacture of a blanket.	3

A.5 New Materials (3h)

Mycoprotein—a new food

A.5.1	State that mycoprotein is a food product made from a fungus grown on grain and paper flour wastes and harvested as a mass of threads (mycelium). Quorn^{TM} is an example of such material. Mycoprotein is produced in a sealed fermenter, in the absence of air. It is grown in/on cellulose and other hydrocarbons and the pH and temperature are controlled. No other chemical or biological details are required.	1

A.S.		Obj
A.5.2	Describe the advantages of mycoprotein, referring to the nutritional and physical characteristics. Include its ability to be formed into chunks (that can simulate, for example, beef or chicken), its high protein and fibre content, and low salt and cholesterol levels. Mycoprotein is virtually tasteless but can be given almost any flavour before or during cooking. No details of flavourings are required.	**2**
A.5.3	Describe what is necessary for the commercially viable manufacture of mycoprotein. Include cheap substrate (ideally waste materials), safe to eat, easily processed into acceptable food product, no toxicological effects and no residues or contaminants from substrates.	**2**
A.5.4	Explain how mycoprotein can be designed in a range of novel food products. A wide range of examples is possible. For example Quorn™, the product from fermentation is a dough which can be mixed with a binding agent (eg egg white) and flavouring agents and then put through a forming machine to give any required shape (eg chicken thigh shape).	**3**
A.5.5	Discuss the importance of public acceptability in the commercial success of new foods. The look and smell of food gives an initial impression. People need to be able to compare new foods with those they are familiar with. New foods are often first introduced in ready meals and then released as a separate ingredient to incorporate in recipes.	**3**

Superconductor

A.5.6	Define *superconductor*.	**1**
A.5.7	Explain that superconductors are ceramic alloys made from various metal oxides, non-metal oxides and metals, and that they are sintered so there is no need for treatment or finish. No details of specific chemicals or proportions are required. The process allows whatever finish and shape is desired.	**3**
A.5.8	State that the resistivity of superconductors becomes nearly zero at temperatures below about 140 K due to pairs of electrons weakly bonded together, which can move freely at these temperatures. Please note that future technology will change this value to perhaps near room temperature. Note also that superconductors are similar to metals in terms of structure and mode of conduction.	**1**
A.5.9	Explain the advantages of being able to produce superconducting materials that operate at room temperature. Discuss the fact that while superconductors are currently of rather limited use, they are utilized in NMR brain scans and levitating trains (refer to current technological magazines). Advantages include energy savings and less raw material needed since cables can be smaller.	**3**

Option B: Microstructures and Macrostructures

This option offers students the opportunity to explore concepts used to explain the properties of materials. These concepts also allow a designer to choose, based on a design context, the type of microstructure needed. This allows the designer to specify a type of material and a specific treatment, such as annealing, quenching or case-hardening.

A.S. **Obj**

B.1 Structure of Matter (1h)

B.1.1 State that all matter is composed of particles. **1**

B.1.2 Define *atom, molecule* and *ion*. **1**

Atoms are the smallest parts into which elements can be chemically divided. All atoms have the same basic structure.

B.1.3 Outline a bond as a force of attraction between particles. **2**

B.1.4 Draw an equilibrium position of a particle in a bond using a general potential energy–separation curve. **1**

B.1.5 Define an *element, compound, pure substance, mixture, alloy* and *composite*. **1**

Composites are formed when two or more materials (from any material group) are combined to obtain different properties to those available from the original materials.

B.2 Bonding (2h)

B.2.1 Draw and describe an *ionic bond*, a *covalent bond* and a *metallic bond*. **2**

- In an ionic bond the opposing charges of the ions hold the crystal (eg NaCl) together in a lattice. The ions can often be separated easily in water but the electrons stay attached to their respective ions inside the crystal.
- In a covalent bond the outer electrons of some atoms can come close enough to overlap and be shared between the nuclei, thereby forming a covalent bond. Each pair of electrons shared is called a covalent bond. Mention of sigma, pi, double or triple bonds is not required.
- Metallic bonding involves outer electrons but these are freer and they can flow through the crystalline structure. The bonding is caused by attraction between the positively charged metal atom nuclei and the negatively charged cloud of free electrons, and is spread throughout the lattice—“Positively charged nuclei in a sea of electrons”. Specific arrangements of metal atoms in crystals are not required.

A.S. | **Obj**

B.2.2 State that the three bonds in B.2.1 are called primary bonds and their relative strengths are ionic > metallic > covalent. **1**

No quantitative details are required.

B.2.3 Outline secondary bonds as weak forces of attraction between molecules. **2**

B.2.4 Explain what is meant by a network covalent (giant) structure, with reference to diamond and sand (SiO_2). **3**

In diamond each carbon is covalently bonded to four other carbon atoms, tetrahedrally arranged. The carbons at the edges are attached to hydrogen atoms. In sand (silica, SiO_2) the arrangement is also tetrahedral. Both sand and diamond are very hard.

B.2.5 Describe a crystal as a regular arrangement of particles (atoms, ions or molecules). **2**

Details of types of crystal are not required.

B.2.6 Define an *amorphous material* and a *fibre structure*. **1**

- Amorphous materials do not have regular structures or crystal patterns. Short range order may occur as far as next neighbour atoms. The general appearance of amorphous materials is glossy and they can occur in ceramics, polymers and metals.
- Fibres have a length-to-thickness ratio of at least 80 but are generally much longer. Textile fibres and food are made up of polymers.

B.2.7 Explain melting in terms of the behaviour of particles and the bonding. **3**

B.2.8 Explain boiling in terms of the behaviour of particles and the bonding. **3**

B.2.9 Discuss the significance of pure substances melting at a fixed temperature, and mixtures softening over a range of temperatures before melting. **3**

The working of materials in a plastic condition is possible because of the range of temperatures over which a mixture softens.

B.3 The IB Properties/Bonding Matrix (2h)

B.3.1 Explain how the properties specified in the **IB properties/materials matrix** (see 3.3) can be organized into a properties/bonding matrix. **3**

B.3.2 Describe the relative values of the materials in the **IB properties/bonding matrix** in terms of their bonding. **2**

B.3.3 Analyse data related to the **IB properties/bonding matrix**. **3**

B.3.4 Evaluate the importance of the **IB properties/bonding matrix** in a given design context. **3**

IB properties/bonding matrix

	Ionic	Simple covalent	Network covalent	Metallic
Chemical properties				
Solubility in water	high	low	v. low	v. low
Solubility in organic solvents	v. low	v. high	v. low	v. low
Physical properties				
Electrical resistivity	v. high	high	v. high	v. low
Thermal conductivity	v. low	low	v. low	v. high
Thermal expansion	low	low	v. low	v. high
Hardness	high	v. low	v. high	low–high
Mechanical properties				
Tensile strength	v. low	low	v. high	high
Stiffness	high	low	v. high	high
Toughness	low	medium–high	low	v. high
Materials →	**ceramic**	**plastics food**	**ceramic textile fibres food timber**	**metals**

A.S. Obj

B.4 The Properties of Metals and Alloys (2h)

B.4.1 State that metals (pure or alloyed) exist as crystals. **1**

Details of crystal types are not required.

B.4.2 Draw and describe what is meant by *grain size*. **2**

B.4.3 Explain how grain size can be controlled and modified by the rate of cooling of the molten metal, or by heat treatment after solidification. **3**

Reheating a solid metal or alloy allows material to diffuse between neighbouring grains and the grain structure to change. Slow cooling allows larger grains to form; rapid cooling produces smaller grains. Directional properties in the structure may be achieved by selectively cooling one area of the solid.

B.4.4 Define *plastic deformation*. **1**

B.4.5 Explain in words and diagrams how metals work harden after being plastically deformed. **3**

Beyond the yield stress metals and alloys harden when plastically deformed. See B.7.4 for details.

B.4.6 Describe in words and diagrams how the tensile strength of a metal is increased by alloying. **2**

B.4.7 Explain in words and diagrams the effect of alloying on malleability and ductility. **3**

B.4.6–B.4.7 The increased strength and hardness, and reduced malleability and ductility, of alloys compared to pure metals is due to the presence of "foreign" atoms which interfere with the movements of atoms in the crystals during plastic deformation.

B.4.8 Explain, using words and a diagram, how the movement of free electrons makes metals very good electrical and thermal conductors. **3**

The explanation should involve the mobility of the "sea" of electrons.

B.4.9 Evaluate the importance of bonding and structure to the properties of metals and alloys in a given design context. **3**

B.5 The Properties of Thermoplastics and Thermosets (2h)

B.5.1 Draw and describe the structure and bonding of a thermoplastic. **2**

Thermoplastics are linear chain molecules, sometimes with side bonding of the molecules, but with weak, secondary bonding between the chains.

B.5.2 Explain the effect of load on a thermoplastic, with reference to orientation of chains. **3**

Deformation occurs in two ways: elastic in which initially coiled chains are stretched and plastic at higher loads, where secondary bonds weaken and allow the molecular chains to slide over each other. Creep and flow are important. No quantitative details required.

B.5.3 Explain the reversible effect of temperature on a thermoplastic, with reference to orientation of chains. **3**

Increase in temperature causes plastic deformation, see B.5.2.

B.5.4 Draw and describe the structure and bonding of a thermoset. **2**

Thermosets are formed by making primary (covalent) bonds which form strong, primary cross-links between adjacent polymer chains. This gives the thermosets a rigid three-dimensional structure.

B.5.5 Explain the non-reversible effect of temperature on a thermoset. **3**

Heating increases the number of permanent cross links and so hardens the plastic.

B.5.6	Discuss the properties and uses of two thermoplastics including polypropene.	**3**
B.5.7	Discuss the properties and uses of two thermosets including polyurethane.	**3**
B.5.8	Discuss the importance of the properties of plastics on the recycling of plastics.	**3**
B.5.9	Evaluate the importance of the properties of thermoplastics and thermosets on product design.	**3**

B.6 The Properties of Composite Materials (3h)

B.6.1	State that composites are a combination of two or more materials which are bonded together to improve their mechanical, physical, chemical or electrical properties. Recall of specific composites (other than those mentioned in B.6.2–B.6.6) and details of bonding are not required.	**1**
B.6.2	Describe the structure of wood as a natural composite material. Cellulose fibres in a lignin matrix—the tensile strength is greater along the grain (fibre) than across the grain (matrix).	**2**
B.6.3	Discuss in outline the evolution of synthetic composite materials with reference to wattle-and-daub, mortar, papier mâché, reinforced concrete, glass reinforced plastic (GRP), carbon reinforced plastic (CRP) and high temperature superconductors. Emphasize the historical aspects. The details of bonding or proportions of materials are not required.	**3**
B.6.4	Outline the structure of Kevlar™ (aramid) fibre. Aramid fibre comprises linear chains of hydrocarbon rings. Aramid chains behave like rigid rods and they are aligned along the length of the fibre during the manufacturing process. They have a very high tensile structure.	**2**
B.6.5	Outline two examples where Kevlar™ fibres twisted into ropes and woven into sheets (mats) are used. Rope—light, non-stretch ropes used in sailing boats. Sheets—sails that hold their shape under great stress in high-performance yachts; composite structures with resin eg motor racing cars.	**2**
B.6.6	Explain why Kevlar™ is suited to these applications with reference to its tensile strength, elasticity and water resistance. Kevlar™ fibres do not absorb water, have a high tensile strength and are non-stretch.	**3**
B.6.7	Evaluate the importance of the properties of composite materials in a design context.	**3**

B.7 Young's Modulus—Stress and Strain (3h)

B.7.1	State that stress (load) is force per unit area acting on a body or system. The load on a structural member divided by its cross-sectional area is called the "stress in the member".	**1**
B.7.2	State that strain is the ratio of a change in dimension to the original value of that dimension. The strain in a material is a measure of the relative change of shape it undergoes when subjected to a load. It is independent of the size of the structural member.	**1**
B.7.3	Define *yield stress*.	**1**
B.7.4	Draw and describe a stress/strain graph and identify the elastic region, yield stress, plastic flow region and ultimate stress (UTS). For most materials the elastic region is a straight line which changes to a curved line (plastic region). Quantitative details of specific materials are not required.	**2**
B.7.5	Explain the relevance of the stress/strain graph identified in B.7.4 in design contexts.	**3**
B.7.6	Outline the importance of yield stress. This is the stress at the yield point. Many materials undergo plastic as well as elastic deformation.	**2**
B.7.7	Describe the difference between elastic and plastic strains. In the straight portion of the stress/strain graph the material behaves elastically, ie if the stress on the material is released before it breaks, the extension (strain) relaxes and the material returns to its original length.	**2**
B.7.8	Define *Young's modulus*. The stiffness of a material is called the "elastic modulus". In relation to tensile and compressive loads the elastic modulus is called "Young's modulus".	**1**
B.7.9	Calculate the Young's modulus of a material. $\text{Young's modulus} = \frac{\text{stress}}{\text{strain}}$	**2**
B.7.10	Explain how knowledge of the Young's modulus of a material affects the selection of materials for particular applications. Use an example where stiffness of a material is important.	**3**
B.7.11	Evaluate the importance of stress and strain in a design context.	**3**

Option C: Appropriate Technologies

Students need to understand the constraints and opportunities that exist for optimizing the exploitation of resources and renewable energy sources. The aim of this topic is to promote an awareness of the need to conserve non-renewable resources while meeting human, environmental and industrial requirements.

A.S.		Obj
	C.1 Resources and Reserves (1h)	
C.1.1	State that resources can be classified as renewable and non-renewable.	**1**
C.1.2	Define *renewable resources* and *non-renewable resources*.	**1**
C.1.3	Describe the difference between a resource and a reserve.	**2**
C.1.4	Explain how the market, technology and availability determine whether a reserve is exploited.	**3**
	C.2 The Technologies (3h)	
C.2.1	Define *appropriate technology*.	**1**
C.2.2	List four characteristics of an appropriate technology. To explain when technology and resources are appropriate, it helps to ask a series of questions. What is the product for? Is it what people need or want? Does it improve the quality of life? Who gains and loses from this technology? Are raw materials available locally? Is the appropriate labour force local? Does it create or destroy jobs? Can the people afford to buy, run and maintain it? What resources/fuel are used? Does it damage or improve the environment? Appropriate technologies are: low in capital cost; use local materials whenever possible; create jobs (employing local skills and labour); involve decentralized renewable energy sources; make technology understandable to the people who use it (and so suggest ideas for further innovations); are flexible so that they can continue to be used or adapted to fit changing circumstances; and are not detrimental to the quality of life or the environment.	**1**
C.2.3	Describe one example of an appropriate technology. For example, the use of local materials as an energy source.	**2**
C.2.4	Define *alternative technology.*	**1**
C.2.5	Describe one example of an alternative technology. For example, small scale organic farming versus large scale energy-intensive cultivation techniques.	**2**

A.S.		Obj
C.2.6	Define *intermediate technology*.	1
C.2.7	Describe one example of an intermediate technology. This is a relative term since, for example, in one country the ox-drawn plow is intermediate (more sophisticated than the traditional hoe) but less complex than a tractor. In another country the plow would be considered traditional.	2

C.3 Exploitation of Energy Resources (4h)

C.3.1	Outline renewable energy sources. Include wind, wave, solar, biomass, hydroelectric, tidal and geothermal energy sources.	2
C.3.2	Outline non-renewable energy sources. Include coal, oil, timber, gas and nuclear.	2
C.3.3	Describe two advantages and two disadvantages of using renewable energy sources. Include capital and running costs, social and political consequences, and environmental issues.	2
C.3.4	Explain a situation where solar or wind energy sources have been used successfully. Refer to the market, technology and availability of the primary energy source.	3
C.3.5	Discuss the advantages and disadvantages of using renewable sources of energy in various parts of the world. Consider continuity of supply, distribution, capital costs, maintenance costs and location effect on the environment.	3
C.3.6	State that availability of energy, efficiency of energy conversion, costs and type of energy source affect the choice of manufacturing process.	1
C.3.7	Explain how each of the factors in C.3.6 affect the choice of manufacturing process. Consider siting of manufacturing plant (access to raw materials and waste).	3
C.3.8	Explain three ways that energy considerations can influence the design of a product. Consider raw materials used, assembly arrangements, number of components, type of energy used, energy used in production, use and disposal of a product, and lead time.	3

A.S.		Obj

C.4 Exploitation of Material Resources (3h)

C.4.1 Discuss the issues surrounding the need to conserve the resources of the planet and the means to do it. **3**

Include reference to "developing versus developed" countries; renewable/non-renewable versus economic considerations; built-in obsolescence versus longevity; aesthetics versus function; and considerations of culture, values and attitudes.

C.4.2 Discuss the issues which contribute to the feasibility of recycling including political, economic, social, environmental and conservation issues. **3**

Barriers to recycling include manufacturing capacity, technical factors, economics, product specifications and consumer resistance to using waste-based products. Using the example of paper—features that favour recycling are not using glossy surfaces, ones that cannot be processed by machines or plastic components since they make recycling expensive. More recycled materials can be reintroduced into the industry since recycling reduces the need for purchasing more virgin raw materials. More public subsidies would help to persuade firms to introduce recycled materials. Large paper manufacturers could be encouraged to sell off their stakes in forests in order to encourage their use of recyclable materials.

C.4.3 Discuss the ethical issues surrounding the development of a national policy concerning the exploitation of resources. **3**

Students should try to develop their own policy as a class, as well as considering any (local) national policy.

C.5 Strategies for Sustainable Development (4h)

C.5.1 Define *sustainable development*. **1**

C.5.2 State that global conferences (eg The Earth Summit in Rio de Janeiro 1992) provide a platform for the development of global strategies for sustainable development. **1**

C.5.3 Explain the major proposals that were agreed by participants as part of Agenda 21 at the Rio conference. **3**

The major proposals included promoting: sustainable energy development; safe and environmentally sound transport systems; industrial development that does not adversely impact the atmosphere; agricultural (and forestry) development that does not adversely impact the atmosphere; sustainable resource development and land use; sustainable energy consumption patterns and lifestyles; and preventing stratospheric ozone depletion.

A.S.		Obj
C.5.4	Explain why sustainable development requires systems-level changes in industry and society. For example, the development of a sustainable transport system is likely to involve much more than the green design of cars. It should also consider the fundamental role of transport in human life. To achieve a shift from private car-based travel requires improvement of public transport systems and the increased use of environmentally benign forms of transport (eg bicycles). Much travel is associated with travel to work and revolution in the way people work (eg from home in virtual offices rather than travelling to offices) would replace some travel with electronic communication.	**3**
C.5.5	Explain how sustainable development requires close cooperation between manufacturers and government.	**3**
C.5.6	Explain how a close relationship between manufacturers and government can be difficult to achieve because the two parties may have very different perspectives on sustainability and timescales.	**3**
C.5.7	Explain why it is difficult for governments to introduce legislation to cover all aspects of sustainability.	**3**
C.5.8	Explain how a shift from energy-intensive smokestack industries and mass production to information-based trading and service sector-based activities reduces the dependence on energy and material resources. The knowledge economy is becoming increasingly synonymous with the weightless economy.	**3**
C.5.9	Explain how anticipating sources of pollution and eliminating them at the design stage can lead to savings on raw materials and waste treatment.	**3**
C.5.10	Explain how cost-savings can be achieved by introducing more energy-efficient and less wasteful manufacturing processes.	**3**
C.5.11	Describe two ways that manufacturers could re-evaluate short-term profitability in favour of long-term sustainability. For example, manufacturers could: design and operate manufacturing and service units on as small a scale as is consistent with efficient use of resources; use technologies that enhance human skills and match the capabilities of local populations; and use clean processes which minimize pollution and waste of non-renewable resources. Production and use should not dehumanize people. The nature of the production process should be such that it helps and liberates human beings rather than sustaining, controlling or mentally or physically damaging them. The production process should be such that it can be controlled by human beings rather than the reverse. Production should aim at the highest technically achievable standards and level of energy efficiency.	**2**
C.5.12	Explain how consumer attitudes towards sustainability issues have created a market pull situation. From the late 1980s there has been a growing market of “green” consumers wanting environmentally friendly products.	**3**

A.S.		Obj
C.5.13	Explain how product characteristics can be consistent with sustainable development. A product should be considered for its long-term characteristics rather than its short-term ones. A product should help and liberate human beings rather than sustain, control or mentally or physically damage them. A product should not demand exceptional user skill and should be controlled by human beings rather than the reverse. The use value of a product should be more important than its exchange value. Products for the developing world should provide for mutually non-exploitative relationships with the developed countries. A product should be regarded as part of culture and as such should meet the cultural, historical and other requirements of those who will build and use it. Products should be designed for high durability and repairability. Products should be designed for disassembly so that materials can be reused and recycled. The financial cost to users over the whole of the product cycle should be as low as possible.	**3**
C.5.14	Explain how energy utilization can be consistent with sustainable development. Include using energy in ways that minimize waste, optimize the efficiency of complete systems and maximize the sustainable use of renewable energy.	**3**

Option D: Food Technology

Food is essential for human life as it provides the requisite nutrients to maintain health. Ensuring food security—the basic right of people to have the food they need—is perhaps the greatest challenge facing the global community. Achieving sustainable increases in food production requires global agricultural strategies to ensure an appropriate range of food commodities. Food technologists apply different processing techniques to modify the physico-chemical properties of food commodities and produce an enormous range of food products with suitable storage properties to minimize food spoilage (a major cause of food wastage) and maximize shelf life. Food presents a wealth of design opportunities through adaptation of the nutritional, microbiological, eating and storage characteristics of foods to meet the needs of the global consumer.

A.S.	*Core Material—SL and HL*	Obj

D.1 Food and Nutrition (3h)

D.1.1 Define *essential*, *micronutrient deficiency* and *malnutrition*. **1**

D.1.2 State that food can be considered as being composed of macronutrients and micronutrients; that macronutrients include protein, fat and carbohydrate; and that micronutrients include vitamins and minerals. **1**

- Fat, protein and carbohydrate are termed macronutrients, ie they are nutrients required in large amounts. Energy can be provided by the metabolism of fat (37 kJ g^{-1}), carbohydrate (16 kJ g^{-1}), protein (17 kJ g^{-1}) or alcohol (29 kJ g^{-1}). Protein is made up of amino acids which are classed as essential or non-essential. Proteins are categorized as high biological value when they contain the right balance of essential amino acids. High biological value protein foods tend to be of animal origin. Plant foods often lack one or more essential amino acids. However complementation of plant foods can overcome individual amino acid deficiencies. Fat, *per se*, is not essential except in terms of energy provision. However, the body does need certain polyunsaturated fatty acids termed essential fatty acids, and fat acts as a source of fat-soluble vitamins.
- Vitamins and minerals are termed micronutrients. Vitamins are defined as organic substances required in minute amounts to maintain health. Vitamins are classified as fat-soluble (A, D, E and K) and water-soluble (B vitamins and C). Deficiency of a particular vitamin leads to a specific deficiency disease, eg vitamin C deficiency causes scurvy. Minerals are inorganic compounds derived from foods and classified as major minerals, eg calcium and iron, and trace elements, eg iodine and zinc. Knowledge of specific deficiency diseases are not required.

D.1.3 State that fibre is essential for human health. **1**

Dietary fibre is unavailable carbohydrate, ie polysaccharides such as cellulose, which cannot be broken down as it passes through the digestive system. Low dietary fibre intake has been implicated in a number of diseases common in developed countries, eg diverticular disease, constipation and large bowel cancer.

A.S.	*Core Material—SL and HL*	Obj
D.1.4	Explain what is meant by a balanced diet and how various food-group systems can be used to help achieve a balanced diet.	**3**

A balanced diet can be described as one which provides an adequate amount of energy; optimum amounts of protein, starch and fat; adequate amounts of essential fatty acids, vitamins and minerals; and sufficient dietary fibre. The terms adequate, optimum and sufficient for an individual will vary according to age, health, size, sex and activity. Foods are not pure substances but are mixtures of different nutrients in varying proportions. Milk is the most complete food and most closely approaches the overall optimum provision of each nutrient (although it is deficient in iron and vitamin C).

Various food-group systems can make it easier to achieve a balanced diet. A three-group system classifying foods as body building foods (protein rich), protective foods (rich in vitamins) and fuel foods (contributing energy) is one way of making it easier to achieve a balanced diet. More complex systems are possible, eg a six food-group system (cereals and starchy foods, fruit and vegetables, meat and alternatives, milk and milk products, sugars and sugary foods, fats and oils) in which eating foods from each of the first four groups and limiting foods in the last two creates a balanced diet. The traffic lights system is good for promoting healthy eating in children: red foods (stop and think—eg sugar, sweets, chocolate, cakes, pastries, fat), amber (go carefully—eg high fat cheeses) and green (go right ahead—eg fresh fruits and salads, fish and seafoods, poultry, potatoes). A balanced diet is not the same as a prudent diet that limits sugar, fat, cholesterol, salt and alcohol intake while maximizing dietary fibre intake to try to avoid certain diseases associated with affluent developed societies.

D.1.5	Explain how nutritional requirements and food choice change as a person gets older.	**3**
D.1.6	Discuss how health awareness affects food choice with reference to fat (quality and quantity), fibre, sugar and salt content.	**3**

Consumer awareness of acute and chronic health issues has a major impact throughout the food chain from food production to food manufacture and distribution. Understanding of such issues and the health impacts has a considerable influence on the patterns of food consumption.

D.1.7	Outline five aesthetic/organoleptic properties of food.	**2**

These cover how food impacts on the individual consumer and include: flavour, smell, appearance, texture and sound (for fruit and vegetables and certain cereal and snack products).

D.1.8	Explain how the organoleptic properties of foods are designed for particular segments of the market with reference to bread and snack products.	**3**

Organoleptic properties are modified to ensure that products match particular markets. For example, snack products have flavouring agents added to increase their appeal to particular markets (children versus adults). Texture is also modified according to the dentition of the individual consumer, eg homogenized products for babies.

A.S.	*Core Material—SL and HL*	Obj

D.2 Food and People (3h)

D.2.1 Outline four cultural factors that affect food choice. **2**

Culture refers to the beliefs, behaviour, language and way of life (including customs, ceremonies and traditions) of a particular group of people. Such groups may be defined by racial, religious, socio-economic, ethical or lifestyle parameters. Mention could be made of the public's perception of "risk" in relation to possible disease from food—one example would be the "BSE in beef" scare that began in 1996. The importance of public confidence and the roles of governments can be investigated.

D.2.2 Discuss how one cultural factor affects food choice and its effect on health. **3**

D.2.3 Explain how a given lifestyle factor has led to the development of new food products, such as snack foods and individual convenience foods. **3**

Lifestyle factors (eg employment status, leisure activities, living arrangements, health consciousness) can drive new food product development (eg individual convenience foods which can be microwaved, snack products (crisps, candies), sports products) thus reflecting different market niches.

D.2.4 Explain how food manufacturers gain evidence to support the development of a new ice cream, including the acquisition of data and its collation, analysis and comparison with existing products. **3**

A product is designed initially as a bench-top prototype and key parameters such as texture and flavour determined. Tasting panels are often used. Following confirmation of the product specification the product would be scaled up from bench scale to pilot plan scale so that a larger volume of product can be made and wider market testing could be undertaken. Satisfactory results could result in scaling up further to a full industrial scale. At each stage data would be acquired (eg from structured interviewing and questionnaires) and analysed. Comparison with existing products is particularly important.

D.2.5 Construct a specification for an ice cream. **3**

Include specifications such as nutrients and energy content, size, colour, texture, smell, ease and cost of manufacture, storage properties and packaging.

D.2.6 Evaluate food products against specifications. **3**

D.3 Food Spoilage and Food Preservation (3h)

D.3.1 Define *food spoilage.* **1**

D.3.2 Explain that food spoilage can be caused by physical spoilage, chemical spoilage or microbiological spoilage. **3**

A.S.	*Core Material—SL and HL*	Obj
D.3.3	State that physical damage to the protective outer layer of food during harvesting, processing or distribution increases the chance of chemical or microbiological spoilage.	1
D.3.4	Explain that the two principal causes of chemical spoilage of food are enzymic spoilage and rancidity.	3
D.3.5	Outline the changes that take place in enzymic spoilage.	2

Many foods are made up of intact cells containing enzymes. After slaughter or harvesting the enzymes continue to function. This often brings about desirable changes, eg conditioning of meat during hanging, or ripening of fruit. However, if a product is stored for too long enzymic activity can become undesirable and result in spoilage. Autolytic (self-breakdown) enzymes destroy the desirability of foods. As the cellular nature of the food disintegrates, water and other nutrients are released onto the surface and the risk of microbial spoilage occurs. Enzymic spoilage can be slowed down by reducing the temperature and in some cases by altering the gaseous environment (the ratio of oxygen to carbon dioxide). However, the reactions do not cease and therefore vegetables, if stored frozen for a long period of time, need to be blanched (ie plunged into boiling water) to denature the enzymes.

D.3.6	Explain that enzymes are responsible for some browning reactions during food preparation.	3

The enzyme polyphenol oxidase in fruits and vegetables, eg apples and potatoes, oxidizes phenolic substances (eg the amino acid tyrosine) to produce polymerized brown pigments. This is particularly important after cell damage has taken place, such as at cut surfaces. In undamaged cells the phenolic substances and the enzyme are separate and so browning does not occur. Enzymic browning in fruits and vegetables during preparation can be reduced by several methods: heat treatment (to denature the enzymes) as in the manufacture of fruit juices and purées and the blanching of fruits and vegetables prior to freezing; sulphur dioxide gas or sodium metabisulphite solutions are used for the preparation of pre-peeled potatoes. Excluding oxygen from cut surfaces by immersing food in water can prevent browning but can leach out water-soluble vitamins such as vitamin C. Alteration of pH, eg by the use of citric acid in lemon juice, can also prevent browning. Enzymic browning is actively encouraged in the fermentation of tea and coffee by keeping the dried tea leaves or coffee beans at 25°C.

D.3.7	Define *rancidity*, *preservative* and *antioxidant*.	1
D.3.8	Describe three types of rancidity and outline how rancidity can be prevented.	2

- **Absorption rancidity** is when fats or oils are stored near strong smelling chemicals (eg cleaning chemicals) or foods (eg onions or mackerel).
- **Hydrolytic rancidity** is caused by the breakdown into glycerol and free fatty acids of triacylglycerols (triglycerides) found in fats and oils. Free fatty acids with a chain length of less than 14 carbon atoms can give food an unpleasant rancid flavour, eg in cream, nuts and some biscuits.

A.S.	*Core Material—SL and HL*	Obj

- **Oxidative rancidity** is the most common type of rancidity and occurs due to the oxidation of double bonds present in unsaturated fatty acids found in triglycerides and the formation of aldehydes and ketones which give the fat a tallowy flavour. To prevent oxidation lipids are best stored in non-metal containers in cool, dark conditions. Antioxidants, eg ascorbyl palmitate, are often added to oils to prevent them going rancid. Snack products, eg potato crisps, should be stored in cool, dark conditions to prevent oxidative rancidity.

D.3.9 Define *water activity* (a_w). **1**

The water activity of a food is not the same as its water content. Most foods have a water activity in the range 0.2 to 0.99. Water activity refers to how available the water in a food is to support microbial growth. Moist foods are likely to have a greater water activity than dry foods but this is not always so.

D.3.10 State that microbial spoilage can be caused by bacteria, moulds and yeasts. **1**

Growth of bacteria, moulds or yeasts on food causes surface slime, discolouring, decomposition and the possible production of toxins or poisons. The number and type of micro-organisms in or on food is known as the microbial load. Raw foods generally have a higher microbial load than processed or cooked foods. The micro-organisms on the food produce extracellular enzymes which break down the food into a form that can be utilized by the organism for growth. Food quality deteriorates and spoilage becomes detectable.

Bacteria are the fussiest but fastest growing spoilage organisms and their growth can be prevented by low pH or water activity. Moulds are the least fussy but slowest growing spoilage organisms. They are aerobic organisms and grow on the surface of foods such as bread and fruit. Yeasts tolerate quite high levels of sugar and can spoil high-sugar products such as jams (jellies) and syrups.

D.3.11 Explain the factors that influence the ease of microbial spoilage. **3**

Foods such as milk and meat spoil quickly and are termed perishable. Those that do not spoil quickly, eg sugar and flour, are termed non-perishable. Some semi-perishable foods (root vegetables and fruits) are in between and, if stored properly, will keep for many months.

Properties of a food influencing its ease of spoilage include pH (acid foods spoil less easily), a_w (dried foods or those with sugar added have a low a_w and spoil less easily), nutrient content (foods containing a wider range of nutrients tend to spoil more rapidly) and temperature (foods kept at lower temperature spoil less rapidly).

D.3.12 Explain that the aim of food preservation is to extend the safe storage life of food. **3**

Prevention of microbial spoilage is based on three broad principles: minimizing contamination of foods, killing or removing micro-organisms and preventing microbial growth.

- Minimizing contamination of foods through good hygiene standards or by food packaging.

A.S.	*Core Material—SL and HL*	Obj

- Killing micro-organisms with heat through pasteurization, cooking, canning, or sterilization. Irradiation of foods can be used to kill micro- organisms. Micro-organisms can also be removed physically (eg filtration of wines and beers or water supplies or by washing food products).
- Preventing microbial growth through temperature reduction, dehydration, chemical preservation and control of food atmosphere.

  Temperature reduction can be achieved using cellar storage for fruit and root vegetables etc, refrigeration (1–4°C), for meat and milk etc, and freezing (-6, -12, -18°C).

  Dehydration is used because micro-organisms can survive but not grow without free liquid water, which can be made unavailable for growth by adding sugar or salt. Total water content can be reduced by dehydration, for example, spray drying of milk.

  Chemical preservation includes sulfur dioxide to inhibit microbial growth on processed vegetables, nitrates and nitrites to cure meat, organic acid in soft drinks and acetic acid in pickling.

  Control of food atmosphere is achieved by storing food in an atmosphere containing extra carbon dioxide to slow down the rate of ripening and hence deterioration.

D.3.13 Outline five methods of preserving food including freezing, irradiation, vacuum packing and dehydrating. **2**

Different methods of food preservation include: pickling, cooking, chilling, vacuum packing, freezing, dehydrating, canning, curing and irradiation. The effect of each method on the micro-organisms' access to and growth on food is important. Many methods alter the water activity of foods and thus affect microbial growth.

D.3.14 Explain how food preservation methods affect the organoleptic properties of fruit. **3**

The method of food processing used for a particular food affects the organoleptic properties of the food, eg freezing fruit affects cellular structure and therefore texture and adding sugar for bottling fruit affects flavour.

D.3.15 Explain how food processing methods affect the nutritional properties of bread. **3**

Food processing modifies nutritional properties in a number of ways. Refining cereal products reduces their dietary fibre content and can affect the vitamin and iron content. Cereal products are often fortified with vitamins and iron to ensure that the processed food is nutritionally equivalent to the unprocessed product. However, food processing is not always deleterious to the nutritional content of the product and can make nutrients more available.

A.S.	*Core Material—SL and HL*	Obj

D.4 Food Processing (3h)

D.4.1 Define *primary processing* and *secondary processing*. **1**

D.4.2 Outline how wheat grain is primary processed to produce flour and secondary processed to produce bread. **2**

Flow charts are a useful way of representing food production processes.

D.4.3 Explain three factors that determine a need for primary and/or secondary processing. **3**

Factors could include storage properties, volume, weight or energy considerations.

D.4.4 Define *aeration, coagulation of protein* and *gelatinizing (gelling)*. **1**

D.4.5 Explain how the processes of aeration, protein coagulation and gelatinization have been used to affect the physical and/or chemical properties of bread. **3**

Bread is a staple food in most cultures and is used as the example. It comes in a variety of forms. Aeration alters the density of bread. To make bread, flour is mixed with water causing the formation of an extended gluten network which contributes to the elastic nature of the bread dough. Yeast produces carbon dioxide aerating the dough. The final stable structure of the bread is achieved by baking the bread which coagulates the protein and gelatinizes the starch.

D.4.6 Explain the control systems used in the manufacturing process of bread. **3**

Large-scale food processing requires a consistent final product that meets a particular specification. Production processes can be classified into three stages.

- Input—entry of raw materials for processing. Monitoring the quality of raw materials to ensure a consistent starting point for food processing (particular key parameters are met).
- Process—procedures that convert the raw materials to the final product.
- Output—the final product. The quality of the final product is determined by all stages so each stage needs quality control.

D.4.7 Outline the influence of scale of production on the organoleptic properties of bread. **2**

Craft-produced breads are generally more expensive because they are labour intensive. They are made from raw ingredients (flour, water, yeast and salt) rather than bread mixes, mixed by hand or with minimal use of machines, and tend not to contain additives. The crust is usually chewier and the texture will be less uniform than for mass-produced breads. A number of designer breads are produced by craft bakers, eg walnut bread, banana bread.

A.S.	*Core Material—SL and HL*	Obj
D.4.8	Explain how food processing enhances the value of food commodities. The value of farm products is increased by cleaning and cooling, processing, packaging and distributing. Compare the cost of potatoes with potato crisps. A farmer sells potatoes to a food manufacturer and the food manufacturer makes the profit. Most of the "food dollar" comes from secondary processing of food products.	**3**
D.4.9	Explain how local farm cooperatives and on-farm processing can enhance farm sustainability. Processing raw products on the farm results in the production of higher value consumer-ready products and gives farmers the opportunity to retain income and enhance farm sustainability. Farmers can then capture a larger share of the "food dollar". Small-scale food processing tends to be embedded in the local community, creating local jobs, distributing products locally and recirculating the income in the local economy. However technology transfer issues and other start-up costs cannot be ignored.	**3**

D.5 Food Labelling, Packaging and Branding (3h)

D.5.1	Outline the purpose of food labels and the information provided on them. Include nutritional content, sell-by-date, storage and using information, ingredients, warnings, volume/mass etc. Exclude promotional details. Only a qualitative treatment is required.	**2**
D.5.2	Discuss the impact and effectiveness of legislation governing what should appear on food labels as a means of altering diet. Diets are resistant to change due to cultural issues and habit. Food labels can provide information on sugar content, fibre content, fat content etc, but unless individuals choose to change, labels are unlikely to have much impact. Government initiatives may focus on low fat or high fibre diets to counter heart disease.	**3**
D.5.3	Outline how different packaging materials affect food with reference to paper, plastic, glass and metal. These common packaging materials can be used alone or in combination (depending upon the food product) and are selected to minimize their interaction with and contamination of food. Sometimes the cost of packaging material is a significant proportion of the final product cost. Transport considerations are also important, eg plastic containers weigh less than glass containers.	**2**
D.5.4	Explain the impact of alternative packaging decisions on the product cost and the environment. Packaging solutions that use considerable non-biodegradable and non-recyclable raw materials, much energy for their production and are used once and thrown away, wreak most havoc on the environment. Altering any of these elements reduces environmental impact.	**3**

A.S.	*Core Material—SL and HL*	Obj
D.5.5	Outline how food packaging is used as a promotional tool for other products.	**2**
D.5.6	Explain how packaging of food products contributes to the development of brands.	**3**
D.5.7	Discuss the global impact of branded products, eg Coca-Cola.	**3**

A.S.	*Extension Material—HL only*	Obj

D.6 Food Security (2h)

D.6.1	Define *food insecurity*, *undernourishment*, *undernutrition*, *stunting*, *vulnerability* and *wasting*.	1
D.6.2	State that undernourishment and undernutrition are distinct measures used to estimate numbers of hungry people.	1
D.6.3	Explain how undernourishment and undernutrition are calculated.	3

Undernourishment is estimated from existing data about numbers of people and the amount of food available to them. The method for calculating undernourishment is described in detail in *The Sixth World Food Survey* (FAO, 1996). It relies on calculating the energy available from local food production, trade and stocks. It then calculates an average minimum energy requirement for the whole population based on the energy requirements of different age and gender groups and the proportion of the population each group represents. The total number of calories are divided by the number of people in the country. A coefficient for distribution is factored in to take account of inequality of access to land. The information is combined to construct the distribution of the food supply within the country and gives the percentage of the population whose food intake falls below the minimum requirement. Multiplying by the size of the population gives the number of undernourished people.

Undernutrition is determined from data about people's weight, height and age. Ratios from these measurements indicate the outcome of inadequate food intake and also of poor health and sanitation conditions that may prevent people from deriving full nutritional benefit from what they eat.

D.6.4	State that achieving food security means that sufficient food is available, supplies are relatively stable and those in need of food can obtain it.	1
D.6.5	State that approximately 800 million people in developing countries and approximately 34 million people in developed countries are chronically undernourished.	1
D.6.6	Explain the importance of local, national, international and global strategies in combating food insecurity.	3
D.6.7	Discuss the ethical issues surrounding the development of a global policy concerning food security.	3
D.6.8	Explain the role of the Food and Agriculture Organization (FAO) of the United Nations in combating food insecurity.	3

The FAO hosted the World Food Summit in November 1996 in Rome.

A.S.	*Extension Material—HL only*	Obj
D.6.9	Evaluate the progress of the work of the FAO following the World Food Summit in 1996. The FAO publishes annual reports on the state of food insecurity in the world. The publication draws on the FAO's ongoing work programme to monitor and analyse food insecurity and the nutritional status of people world-wide. The World Food Summit mandated the establishment of a Food Insecurity and Vulnerability Information and Mapping Systems (FIVIMS) initiative to provide information. FIVIMS operates at national and global levels.	**3**

D.7 Global Food Production Strategies (3h)

D.7.1	Outline how a knowledge of genetics can enable selective breeding and enhance yields. Selective breeding (eg of chickens) has resulted in increased yield and quality.	**2**
D.7.2	Evaluate the principle of intensive farming techniques in terms of yield and ethical issues. Intensive farming techniques (for plants and animals) can ensure that yields are maximized relative to inputs. Intensive poultry farming controls the health of hens and minimizes movement to achieve the maximum egg or meat production, but ethical issues are also very important.	**3**
D.7.3	Define *organic agriculture*. The International Federation for Organic Agricultural Movements (IFOAM) was established in the early 1970s and represents 600 members and associate institutes working in over 100 countries. It defines organic as referring to the particular farming system described in its basic standards. Other definitions prevail, eg the US Department of Agriculture definition and the Codex Alimentarius Commission definition.	**1**
D.7.4	State that in some countries the word "organic" is legally protected and in some organic agriculture, "organic" is increasingly associated with sustainable agriculture.	**1**
D.7.5	Explain that the interest in organic agriculture is due to the problems associated with existing agricultural practices which threaten food security. Problems include degradation of soil quality; pollution of soil, water and food with pesticides and nitrates; health effects on farmers, farm workers, farm families and rural communities; resistance of pests to pesticides and dependence on off-farm agricultural inputs that can increase less well-off farmers' dependence on credit facilities which in turn decreases local food security and self-reliance.	**3**
D.7.6	Outline how acceptable yields can be achieved on organic farms. New, higher yielding plant varieties can be used to ensure that yields on organic farms fall within acceptable ranges.	**2**

A.S.	*Extension Material—HL only*	Obj
D.7.7	Define *genetically modified organism (GMO).* The US definition of GMO refers to plants and animals containing genes transferred from one species to another to produce certain characteristics.	1
D.7.8	Outline the objectives of genetic modification of foods. The primary objectives of genetic modification are to produce products with longer shelf lives and better nutritional properties, and to use less insecticide.	2
D.7.9	Outline how genetic modification is undertaken.	2
D.7.10	Outline the use of genetic modification to enhance food production, using tomatoes and Roundup Ready™ crops as examples. Flavr-Savr™ tomatoes are available to the public; they ripen but stay firm because their over-ripening gene is blocked. Roundup Ready crops can only be efficiently cultivated using high levels of Roundup, an insecticide produced by Monsanto.	2
D.7.11	Discuss the ethical issues arising from the use of GMOs.	3
D.7.12	Discuss the acceptance by the general public of GMO foods.	3

D.8 Lifestyle Issues—Food Poisoning (2h)

D.8.1	Outline how travel, the media and lifestyle factors have led to increased consumption of foods from other cultures and the development of an international cuisine. Traditionally, eating patterns were dependent on local products and cooked to local recipes. Today food commodities are distributed internationally and are assembled into dishes from across the world, eg Chinese food, Indian curries, Italian pizza and pasta dishes.	2
D.8.2	Explain how (ironically) many of the most popular ethnic dishes consumed in the developed world were traditional staple foods. Curry, for example, has become very popular in developed countries. There are few cities around the world that do not have Indian and Chinese restaurants where food is cooked by migrants using their culinary expertise to earn money. The impact of Indian and Chinese cuisine on local eating patterns through “takeaway” consumption should not be underestimated.	3
D.8.3	Explain how lifestyle factors in developed countries cause more people to eat outside their own homes with a resulting increase in food poisoning.	3
D.8.4	State that illnesses carried by food are termed “food-transmitted diseases” and are considered in two main categories: food-borne infections and food poisoning. In developed countries food poisoning is a far greater hazard than food-borne infections. However, in the context of world tourism food-borne infections are important.	1

State that foods which can support the growth of food-poisoning bacteria are termed “high-risk foods” and that, to prevent the growth of food-poisoning 1

A.S.	*Extension Material—HL only*	Obj
D.8.14	Outline the temperature danger zone for bacterial growth. The temperature danger zone is between 10°C and 63°C. Food-poisoning bacteria will not usually grow below 10°C because there is insufficient warmth and the bacteria are inactive. Above 63°C food-poisoning bacteria, but not their spores, are killed by the heat.	**2**
D.8.15	Explain that cooking is an important means of controlling bacterial growth. Proper cooking depends upon four considerations: sufficiently high cooking temperature, sufficient time for cooking, the size of the food being cooked (food is a poor conductor of heat therefore large items of food need longer cooking times than small ones), and the initial temperature of the food (some frozen foods, eg frozen poultry which can be contaminated with Salmonella, need to be defrosted before cooking otherwise the centre temperature will never be high enough to kill any bacteria present).	**3**
D.8.16	Explain how an understanding of food poisoning influences the design of individual convenience foods.	**3**

Option E: Computer-aided Design, Manufacture and Production

This option is concerned with understanding how computer-based technologies have transformed the nature of the design and manufacture of products. It considers the impact of the application of such technologies on the role of the designer and manufacturer and the associated implications for the consumer. The development of CAD/CAM has radically changed production processes causing a fundamental rethink of the relationship between designer, manufacturer and consumer.

A.S.	*Core Material—SL and HL*	Obj
	E.1 The Impact of CAD on the Design Process (3h)	
E.1.1	State that many CAD software packages exist, each of which offer particular facilities and advantages. Consider the range of packages for different design applications, eg for architecture where the software package can calculate the building costs or for engineering and product design applications.	1
E.1.2	Discuss the advantages and disadvantages of these packages for designers.	3
E.1.3	State that there are a number of different computer modelling techniques. Spreadsheet packages can be used for numeric modelling, 2D and 3D modelling techniques, and exploded views.	1
E.1.4	Explain the criteria that enable designers to select appropriate computer modelling techniques.	3
E.1.5	Define *animation* and *virtual reality*.	1
E.1.6	Compare animation with virtual reality. Consider the advantages and disadvantages of each for particular design contexts.	2
E.1.7	Describe a design context where the use of virtual reality helps to conserve resources. Consider time, materials, energy and cost.	2
E.1.8	Explain how various input devices can be used by a CAD system including a scanner, digital camera, graphics tablet and video camera. Details of how these devices function or communicate with the computer are not required.	3
E.1.9	Explain how various output devices can be used by a CAD system, including a printer and plotter.	3

A.S.	*Core Material—SL and HL*	Obj
	E.2 The Impact of CAD/CAM on Manufacturing (4h)	
E.2.1	Explain how a numerically controlled (NC) machine aids manufacturing with reference to the quality of reproduction, the reduction in the need for operators, and speed. Use an example to illustrate the improvement on previous practices.	**3**
E.2.2	Explain how a computer numerically controlled (CNC) machine further aids manufacturing. Refer to greater flexibility, reprogrammability and multi-machine control.	**3**
E.2.3	Explain how CAD and CNC can be interfaced to produce a CAD/CAM system. Graphics produced on a CAD system are translated to a set of programming coordinates which instruct the CNC machines how to manufacture the design seen on the screen.	**3**
E.2.4	Outline how sewing machines, knitting machines and looms can be interfaced in a CAD/CAM system to produce textile products. No detail of baud and code is needed. Refer to scanning, layers, management of materials and interface.	**2**
E.2.5	Explain how lathes, milling machines or shapers can be interfaced in a CAD/CAM system to produce metal, plastic or wood products. Refer to the interface; x, y, z axis coordinates and management of materials.	**3**
E.2.6	Outline how an engraver is interfaced in a CAD/CAM system to produce printed circuit boards (PCBs). Refer to x, y axis coordinates, interface, accuracy, detail and size.	**2**
E.2.7	Define *computer integrated manufacturing* (CIM).	**1**
E.2.8	Outline one example of a CIM system.	**2**
E.2.9	Discuss the advantages and disadvantages of CIM to both consumers and manufacturers. Advantages: more choice, can design in own requirements, more consistent quality, cheaper products, parts easily manufactured and changed, random introduction of parts, less lead time, less labour and waste, better machine utilization, improvements in productivity and quality control, greater consistency, fewer errors and waste, and higher quality of finish. Disadvantages: high initial investment and personnel, training cost, job losses, lack of individuality.	**3**

A.S.	*Core Material—SL and HL*	Obj

E.3 The Impact on Industry (4h)

E.3.1	Define *Just-in-time* (JIT) and *Just-in-case* (JIC).	**1**
E.3.2	Explain the advantages and disadvantages of JIT to manufacturing. Advantages: saving on storage space, increased efficiency, reduced capital investment, reduced work in progress and fewer unsold items Disadvantages: possible stoppages due to non-delivery of external components, communication breakdown, distribution and transport breakdown	**3**
E.3.3	Explain the advantages and disadvantages of JIC to manufacturing. Advantages: “buffer”, goods-in-stock in case of unforeseen circumstances (eg non-delivery of supplies) and rapid changes in demand Disadvantages: unsold stock, space needed for storage and capital investment	**3**
E.3.4	Discuss the impact of CAD/CAM on working conditions and work force. Include the number of employees, their skills required, organization of the work place and the working environment (health and safety).	**3**
E.3.5	Discuss the impact of CAD/CAM and its associated processes on quality control.	**3**
E.3.6	Compare two manufacturers that produce similar products one of whom is using CAD/CAM. E.3.6–E.3.7 Advantages of CAD/CAM: Quality control including greater consistency, fewer errors, reduction of waste and the higher quality of finish. Greater variety of choice, opportunity to design in their own requirements, get more consistency of quality, cheaper products. Families of parts easily manufactured and changed. Random introduction of parts, less lead time, better machine utilization, less labour, productivity improvements, less waste, quality control. Disadvantages of CAD/CAM: High initial investment, training personnel. Job losses, lack of individuality. Changes in the number of employees, their skills required, organization of the work place and the working environment (health and safety).	**2**
E.3.7	Define *patent* and *copyright*.	**1**
E.3.8	Discuss the implications of computerized manufacture on the infringement of copyright and patent laws. Include ease of copying and changing designs.	**3**
E.3.9	Outline a product which can be manufactured either by CAD/CAM or by a more traditional process. For example, flat pack or self-assembly furniture compared to traditional cabinet making techniques, children’s toys, spaghetti production and commercial products.	**2**

A.S.	*Core Material—SL and HL*	Obj
E.3.10	Compare the two manufacturing processes for the product chosen in E.3.9. Refer to skills involved, efficiency of production, quality control, precision and wastage, ability to change the product during manufacture, variety, quantity, complexity and economics.	**2**
E.3.11	Evaluate the product manufactured in E.3.9 by the two manufacturing processes. Refer to complexity of design, consistency of design, quality and cost.	**3**

E.4 The Impact on the Consumer (2h)

E.4.1	Explain how CAD/CAM has improved the type and range of products available to the consumer. Many common artefacts require such precision in their manufacture that without CAD/CAM it would not be possible to produce them.	**3**
E.4.2	Discuss how CAD/CAM has affected consumer choice. Include interior design packages to model environments before choosing and implementing, eg kitchen design available in retailer showrooms, and car showrooms that enable you to input option and colour requirements and have those passed directly to manufacturing tracks.	**3**
E.4.3	Discuss how the CAD/CAM system can be designed to allow for the needs of individual consumers. Include consumer culture and society, obsolescence, energy, individual needs, waste, lifestyles and recycling.	**3**
E.4.4	Discuss the impact of CAD/CAM on consumerism. Refer to recycling wastage, energy, individual needs and cultural aspects.	**3**

E.5 Mass Customization (2h)

E.5.1	Define *mass customization*.	**1**
E.5.2	Outline how mass customization is transforming the relationship between the manufacturer and the consumer. In mass customization the manufacturer produces products in response to customer orders.	**2**
E.5.3	Discuss the impact of mass customization on production systems.	**3**
E.5.4	Discuss the advantages and disadvantages of mass customization for manufacturers and consumers.	**3**

A.S.	*Extension Material—HL only*	Obj

E.6 Global Communication Systems (2h)

E.6.1	State that information is now regarded as a separate commodity which is handled by computers and associated equipment.	1
E.6.2	Define *optical fibre, analogue signal, digital signal, satellite communication* and *the Internet*.	1
E.6.3	Outline how fibre optics are able to transmit information in large quantities.	2
E.6.4	Compare the effectiveness of information transfer in optical fibres and copper wires.	2
E.6.5	Describe how fibre optic technology allows for a wide variety of input and output devices. For example, videoconferencing, televisions and computers.	2
E.6.6	Discuss the opportunities that fibre optic technology offers to global communications systems.	3
E.6.7	Outline how satellite systems are able to transmit information.	2
E.6.8	Describe the opportunities offered by satellite technology for global communications systems. The signals cover the globe; standardization is critically important.	2
E.6.9	Compare fibre optics and satellite technologies. Consider capacity, reliability, infrastructure, speed, cost etc.	2
E.6.10	Explain how the Internet can assist designers with market research. Designers can gain access to information without the need to carry out research themselves. The views of experts can be easily sought.	3
E.6.11	Explain how the Internet can assist designers with design development. Designers can show others their ideas and evaluate their views.	3
E.6.12	Discuss the implications of the Internet on design protection. You cannot copyright or patent a design once you have shared it with anyone.	3

A.S.	*Extension Material—HL only*	Obj

E.7 Global Production Systems (3h)

A.S.	Assessment statement	Obj
E.7.1	Define *flexible manufacturing system* (FMS), *design for manufacture* (DfM), *design for disassembly* and *lean production*.	1
E.7.2	Outline the benefits of FMS to manufacturers. It reduces labour, shortens lead times, improves productivity and quality, and reduces costs.	2
E.7.3	State that DfM can be a dominating constraint on the design brief and that it can be conveniently split into design for materials, design for process and design for assembly.	1
E.7.4	Explain design for materials. This is designing in relation to materials during processing, rather than designing for the final desired properties of the end product in use.	3
E.7.5	Explain design for process. This is designing to match an existing manufacturing process, eg injection moulding.	3
E.7.6	Explain design for assembly. This is designing to take account of assembly at various levels, eg component to component, parts into sub-assemblies, and sub-assemblies into complete products.	3
E.7.7	Discuss three strategies designers could employ for DfM. Strategies could include minimizing the number of parts, using standard components, designing parts which are multi-functional or for multi-use, designing parts for ease of fabrication, minimizing handling, using standard sub-assemblies, or minimizing component variation.	3
E.7.8	Discuss two strategies designers could employ to design for disassembly. Strategies could include designing components made from one material, using adhesives that lose their properties easily when reheated, designing snap-fittings instead of welding and gluing.	3
E.7.9	Compare lean production with mass production. Lean production uses less of everything compared to mass production: less human effort, less manufacturing space, less manufacturing time, fewer defects and less storage of components and products.	2
E.7.10	Describe the implications of lean production for the workforce. The car manufacturer Toyota pioneered lean production in the 1950s to compete with companies such as Ford which used mass production. Workers need to be professionally skilled and must be able to diagnose problems, repair equipment and undertake their own quality control without supervision. They must work well in a team and take responsibility for their work.	2

A.S.	*Extension Material—HL only*	Obj

E.8 The Global Manufacturer (2h)

E.8.1	Outline the importance of lean production to the global car manufacturer. Lean production allowed Japanese manufacturers to become world leaders, eg in 1950 Ford was mass producing 7000 cars per day and Toyota had only produced 2685 cars in total after 13 years of manufacturing. By 1990 Toyota had become the third biggest car manufacturer in the world by employing lean production.	2
E.8.2	Explain why global manufacturers from the West have found it difficult to adapt to lean production. Consider constraints of traditional working practices, the views of the workforce, training, costs of new machinery, the challenge of zero defects and a wide variety of products and cultural influences.	3
E.8.3	Define *multi-national* (transnational) *company*.	1
E.8.4	Discuss two reasons for the growth of multi-national companies. Consider mobility of capital ie increased foreign investment, expansion of international trade, worldwide markets (and competition), global manufacturing outlets, reduction in trade boundaries, advertising, rapid communication systems, and international movement of money and people.	3
E.8.5	Explain why global manufacturers establish production units in different parts of the world. Consider distribution of products, trade agreements, trade tariffs and incentives from governments.	3
E.8.6	Discuss the advantages and disadvantages for countries of hosting the production units of global manufacturers. Consider imported expertise and technologies, employment, image, their effects on the local and/or national economy, the influence of multi-national companies, and the effect on the environment, culture and working practices.	3

Option F: Invention, Innovation and Design

The pace of technological development is always accelerating. Many interesting inventions fail to become innovations due to unfavourable social, economic and political conditions. Innovations that do succeed may have negative effects as well as positive ones. This option looks at the conditions that allow successful innovation and the influence of design in promoting the continuation of the innovation. It is also concerned with the role of individuals in the innovation cycle and strategies for the implementation of innovation along with the impact of innovation on consumerism and the environment.

A.S.	*Core Material—SL and HL*	Obj

F.1 Invention and Innovation (2h)

F.1.1	Define *invention* and *innovation*.	1
F.1.2	Discuss the importance of science to invention. Scientific research uncovers new possibilities for a product or process.	3
F.1.3	Explain why the majority of inventions fail to become innovations. Consider marketability, financial support, marketing, the need for the invention and price.	3
F.1.4	Outline the stages of innovation. Developing an idea into a viable product; its production, marketing and sales; followed by redesign—and the cycle or spiral continues.	2
F.1.5	Explain the relevance of design to innovation. For continued innovation (re-innovation), products and processes are constantly updated (re-designed) to make them more commercially viable and to give consumers choice and improved products.	3
F.1.6	Define *dominant design*, *diffusion into the marketplace*, *market pull* and *technology push*.	1
F.1.7	Explain why it is difficult to determine whether market pull or technology push is the impetus for the design of new products. “Push” and “Pull” are present in most successful innovations. The explanation should apply only to the first origin of the idea or where the idea appears to have been generated.	3

A.S.	*Core Material—SL and HL*	Obj

F.2 Invention (4h)

F.2.1 Define *lone inventor*. **1**

F.2.2 Discuss why it is becoming increasingly difficult to be a successful lone inventor. **3**

Most products are now quite complex and rely on expertise from various disciplines. The amount of investment required is often too much for one individual.

F.2.3 Explain why lone inventors often find it difficult to work in the design departments of large companies. **3**

They are often used to setting their own targets rather than working as a member of a team. They can be dogmatic in their methodology and less flexible than team workers.

F.2.4 Define *product champion*. **1**

F.2.5 Compare the lone inventor with the product champion. **2**

The lone inventor might lack the business acumen to push the invention through to innovation. The product champion is often a forceful personality with much influence in a company. He/she is more astute at being able to push the idea through the various business channels and is often able to consider the merits of the invention more objectively.

F.2.6 Define *entrepreneur*. **1**

F.2.7 Explain why entrepreneurs may have difficulty in obtaining financial support for an invention. **3**

Most people with money to invest will be inclined to wait until it is clearer whether or not an invention is going to be successful before investing—part of the task of the entrepreneur is to get them to take the risk.

F.2.8 State that Thomas Edison was an example of an inventor–entrepreneur. **1**

F.2.9 Outline the stages in Edison's invention of the electric light bulb. **2**

1878—idea for an incandescent lamp from a new kind of generator which had been developed to power a small arc light system. Experimented with materials for the filament to find one which would permit a bright glow without burning up too quickly.

1879—first working model (thread of carbonized cotton bent into the shape of a horse shoe and mounted inside a glass vacuum bulb). Worked on a refinement for better vacuums, improved generators and distribution systems.

1880—first full-scale use of electric light on the steamship *Columbia*.

1881—first commercial installation of complete electric light system (Hinds, Ketcham & Co, New York).

A.S.	*Core Material—SL and HL*	Obj
F.2.10	Explain why Edison is considered an inventor–entrepreneur. His reputation for commercially successful inventions was so high that within a few weeks of announcing his intention to develop electric lighting financiers were clamouring to invest.	**3**
F.2.11	State one other example of an invention by Edison. For example, the phonograph.	**1**
F.2.12	State one example of an incremental design based on Edison's incandescent lamp. For example, the fluorescent lamp or halogen lamp.	**1**

F.3 Innovation in Practice—the Bicycle (4h)

Students will not be expected to know all the historical details of the bicycle's evolution but should be aware of the scientific principles and technological developments that were important in creating the original invention, and the socio-economic considerations that allowed the invention to become a successful innovation. Attention should be paid to how the original design has changed giving the product much wider appeal than initially expected.

F.3.1	Discuss how scientific inventions were important in the development of the bicycle (including wheels, gearing, brake systems, steering and chain systems). Basic understanding is required of the key scientific inventions which later underpinned technological developments—these inventions were created for their own sake and not necessarily linked to the product in focus.	**3**
F.3.2	Discuss how technological developments (materials, processes and production systems) were important in the development of the bicycle. An understanding is required of how technological developments provided designers with the opportunity to re-arrange components, devise new forms of assembly and use new materials. Include tyres, frames, suspensions, alloys, carbon fibres, manufacturing techniques, and mass production and/or automation.	**3**
F.3.3	Discuss how social and economic demands were important in the development of the bicycle as a successful innovation (including ergonomics, aesthetics, environmental considerations, fashion, planned obsolescence, health and lifestyle influences). Only a minority of inventions become innovations because success depends on the economic and social conditions being exactly right. Creating inventions is usually the least expensive part of the innovation process; developing these ideas into a marketable device or system is much more expensive. An innovation is, initially, rarely very important to society and for it to have any significant impact the innovation has to be	**3**

A.S.	*Core Material—SL and HL*	Obj

adopted by a large number of individuals and organizations. Apart from the characteristics of the innovation itself, the nature of the market into which it is being sold is important. Many innovations fail because they are inconsistent with existing values, skills and the past experiences of the potential consumers.

F.4 Markets and Innovation (3h)

F.4.1 Define *technophile*, *technocautious* and *technophobe*. **1**

F.4.2 Explain why people can be broadly classified according to their reactions to technological change (refer to issues of morality or ethics, security and privacy, and economic circumstances). **3**

People's reactions to technological change vary depending on their values and personal circumstances. First order effects and second order effects should be taken into account, eg personal gains in owning a motor car versus social and environmental considerations.

F.4.3 Discuss why there is often resistance to innovation by companies. **3**

Research and development is expensive. Innovation involves disturbance and change and so tends to be resisted by individuals within organizations.

F.4.4 Define *corporate strategy*. **1**

F.4.5 State that large companies develop some form of corporate strategy for innovation. **1**

F.4.6 Discuss the corporate strategy referred to as "pioneering". **3**

Pioneering means being ahead of competitors by introducing a new product first. It is the most risky (costly) strategy but one with potential for large gains.

F.4.7 Discuss the corporate strategy referred to as "imitative". **3**

The imitative strategy aims to develop a product similar to the "pioneered" product as quickly as possible. It takes advantage of research and development invested by others and is less risky, but is based on a strong development capability.

F.4.8 Discuss the Sony Walkman™ as an example of "pioneering" innovation. **3**

Include strong research and development from a company already successful and financially secure and a forceful "product champion" in the president, Akio Morita.

F.4.9 Discuss the development of many "imitative" personal stereo innovations following from the Sony Walkman™ of 1979. **3**

Compare the design of the various examples with the original innovation and, in doing so, consider the advantages and disadvantages of "pioneering" and "imitative" strategies.

A.S.	*Core Material—SL and HL*	Obj
F.4.10	Describe two examples where technological innovations have been abused (one example should be nuclear energy). Technical innovations sometimes have negative aspects. The scale of social and economic disruption likely to be involved means that it might be prudent to slow down the technological change to give society time to adjust and to control the ever-escalating process of technological competition.	**2**

F.5 Invention, Innovation and the Environment (2h)

F.5.1	State that technological innovation can make a major contribution to safeguarding the environment by replacing damaging processes and products with environmentally more benign ones.	**1**
F.5.2	State that some companies have decided to adopt pro-active environmental policies to avoid problems and regulations that may emerge in the future.	**1**
F.5.3	Explain the criteria for a pro-active environmental policy for a company. Consider the environmental factors from the design brief and specifications onwards; life-cycle analysis; environmental factors considered together with all other factors (design, marketing, manufacturing); and balancing environmental factors against performance, cost and appearance.	**3**

A.S.	*Extension Material—HL only*	Obj

F.6 The Designer in the Global Marketplace (2h)

F.6.1	Explain the increased importance of market research in establishing the design need in the global marketplace. With such a large market the risks of being unsuccessful are great. Consider various cultures and attitudes from different parts of the world.	**3**
F.6.2	State two conditions that allow for sustainability of innovation in a global society. Include easy and fast travel; rapid communication system; or economic and trading arrangements that allow fast international movement of money, people and goods across national boundaries without hindrance. For sustainability these conditions have to apply not just for each individual project, but to all goods and services produced and consumed by the world's population.	**1**
F.6.3	Discuss the increased responsibilities of designers in the global marketplace. Responsibilities are on a much larger scale. Consider the environment, quality control, safety and people's needs.	**3**
F.6.4	Explain the contribution development of new technologies has made to the pace of innovation. More research and development leads to more innovation, eg more materials and manufacturing techniques.	**3**
F.6.5	State that as the pace of innovation increases the product life cycle decreases.	**1**
F.6.6	Discuss the issues associated with controlling innovation on a global scale. Include crossing national boundaries; world-wide policing and monitoring; differing cultures, legislation and values; power of large organizations; and costs involved.	**3**

F.7 Global Strategies for Innovation (3h)

F.7.1	State that companies adopt a variety of strategies for innovation.	**1**
F.7.2	Define *market penetration*, *market development*, *product development* and *diversification*.	**1**
F.7.3	Outline a different example of innovation for each of the strategies defined in F.7.2. For example: market penetration (advertising an existing product), market development (nylon was originally developed for parachutes), product development (replacing mechanical with microelectronic controls in domestic products) and diversification (different types of electrical plugs).	**2**

A.S.	*Extension Material—HL only*	Obj
F.7.4	State that most companies adopt different innovation strategies at different times and in different circumstances.	**1**
F.7.5	Define *market sector* and *market segmentation*.	**1**
F.7.6	Discuss two ways in which markets may be segmented. Income, age group, lifestyle, geographical location, etc.	**3**
F.7.7	Define *robust design* and *design family*.	**1**
F.7.8	Explain an example of a robust design which evolved into a product family. Such as the mobile phone or personal stereo.	**3**

F.8 The Global Consumer (2h)

F.8.1	State that the global consumer has access to an ever-widening range of products.	**1**
F.8.2	Explain the circumstances which allow for the statement in F.8.1. For example, Internet shopping.	**3**
F.8.3	Discuss two advantages and two disadvantages of global shopping for consumers. Advantages—increased choice, more information on products, no hard sell from sales staff, cheaper products and access any time and any day. Disadvantages—difficulty of returning faulty goods, no direct dialogue with sales staff, and time scale between ordering and delivering.	**3**
F.8.4	Outline the effects of global consumerism on national culture. Include breakdown of shopping centres and town centres, cross-cultural influences, one global culture, the effect on traditions (eg buying from the local market) and global legislation ignoring national cultural values.	**2**
F.8.5	Discuss the issues surrounding global consumerism for developed and developing countries. Developed—increased wealth as the major providers of the communications systems and products, increased power with global influence and increased responsibility (eg sustainability). Developing—distribution systems, reliability of computer links, political stability, dominance of western culture, environmental impact, high expectations of consumers and trade regulations.	**3**
F.8.6	Describe the benefits of global shopping for people with disabilities. Include greater access to information and products, reduced need for a carer to help with shopping, no transport requirements, assistance with communication and being in control of the situation, ie no problems with access to shops.	**2**

Option G: Health by Design

The human body is a system. Inputs from the sensory organs (eye, ear, nose, mouth and skin) are processed in the brain to provide some form of output, for example, movement. Design interventions can augment the natural function of the body (eg through optical and hearing aid technologies) and enhance lifestyle. Continued developments in materials technology bring new opportunities for tissue implants. CAD/CAM and new materials technology have reduced the cost of lens replacement operations and have had a major impact on the health and wellbeing of people in developing countries.

The importance of scale of production and the Internet in facilitating response to disability issues on a global basis should not be underestimated.

The role of the designer in reducing vehicle emissions and the associated impact on the environment and health has been paramount. However, the research and development required in the design process is expensive and legislation is critical for convincing manufacturers to respond to vehicle emissions and will also be critical to the evolution of the electric car.

A.S. *Core Material—SL and HL* **Obj**

G.1 Materials for Tissue Implants (3h)

G.1.1 Identify alternative strategies for producing implant materials. **2**

- Autografts are tissue such as bone taken from elsewhere in a patient's body (eg the pelvis). The technique involves two operations: one to harvest material and the other to graft the harvested material into place. The patient benefits by having compatible living cells in the defect area, however the harvesting operation can cause chronic pain, blood loss, risk of infections and longer hospitalization.
- Allografts use material from the body of another human or other animal. This removes the risk of harvesting but the grafted tissue may not be compatible with the host tissue and may be rejected.
- Alternative, synthetic grafts have been approved. This includes the bone graft substitute, Pro Osteon.

G.1.2 Outline developments in biomedical implants for the human body. **2**

In the early 1970s the only biomedical implants were joint replacements. Artificial joints were made of non-reactive materials and usually combined metals and polymers. Artificial joint life was in the order of 10 years. Nowadays bioactive materials are used which elicit specific biological responses at the interface of the materials and the tissues, and provide a framework for the growth of new tissue. Ideally the framework is resorbable and disappears as the new tissue grows.

G.1.3 List materials commonly used for implants in the human body. **1**

Metals, polymers, ceramics and glasses are commonly used as implant materials.

A.S.	*Core Material—SL and HL*	Obj
G.1.4	Identify applications for metals, polymers and ceramics/glasses in tissue implants. • Titanium, platinum and alloys, eg stainless steel for the ball of the joint used in hip replacement. Also intermetallic compounds (a mixture which has particular properties at a specific composition), eg silver–mercury amalgam which is used as a dental filling compound. • Thermoplastics, eg polyester used for repairing damaged arteries. • Thermosets, eg cyanoacrylates—superglues used as dental resins. • Elastomers (defined as polymers with some infrequent interlinking of chains) do not melt or dissolve but are soft and extensible, eg silicones for shaping ear and nose prostheses. • Ceramic coated metals used in hip replacement.	2
G.1.5	Define *biocompatability*.	1
G.1.6	Explain how implant materials are tested for biocompatability.	3
G.1.7	Outline why regulatory bodies, eg the Food and Drugs Authority in the USA, do not approve materials in isolation but approve medical devices made from these materials for specific purposes. There is no absolute biocompatability. A material appropriate for one application may not be safe for another application.	2
G.1.8	Explain how Pro Osteon can act as a temporary framework for bone regrowth. Pro Osteon is produced by chemically treating coral and converting the coral to hydroxyapatite which is the same material as human bone. Its pore structure is very similar to that of human bone and the pores remain intact following chemical treatment, providing a matrix through which new bone tissue can grow. Pro Osteon is ready for use off the shelf and can be shaped to fill bone defects of various shapes. It mimics the internal structure of human bone. In the first days of implantation blood vessels grow into the pores of the hydroxyapatite which provides support for healing tissue. Unlike a permanent bone plate or hip and knee prosthesis the hydroxyapatite implant is designed to function temporarily while new bone is regenerated. The implant acts as a temporary trellis (although it is often regarded as permanent from a clinical perspective because it is visible on an X-ray for a long period of time). To enhance the resorbability, modified treatment of the coral produces only a very thin layer of hydroxyapatite which lines the inner surface of the calcium carbonate pores. The requisite thickness of the hydroxyapatite layer that will stall the rate of resorption is only approximately 4 µm or about one-half the thickness of a cell.	3

A.S.	*Core Material—SL and HL*	Obj

G.2 Vascular Grafts—A Case Study (2h)

G.2.1 Define *prosthesis*. **1**

G.2.2 Outline the importance of vascular prostheses. **2**

Increasing numbers of patients with vascular disease and better diagnosis have increased the number of operations which require the replacement of arteries. Today, large diameter arteries can be easily replaced, but small diameter arteries pose more of a problem. Autografts (removing and using the patient's veins) have been used. The development of synthetic vascular grafts with identical chemical and physical properties to real arteries can eliminate the need for autografts and has been continuing since the mid-50s. Research is multi-disciplinary and involves surgeons and specialists from the medical products and textile industries.

G.2.3 Outline materials used in vascular grafts. **2**

Early attempts to replace arteries with rigid plastic tubes failed because of stresses at the joint between the artery and the graft resulting in thrombosis or hemorrhage. Woven textile structures and plastic foams, being more impermeable to blood and more flexible and compliant than rigid plastic tubing, provoked much interest during the 1950s and 1960s. Elastic fibres were used but did not have adequate mechanical and physical properties. Paraffined silver tubes have also been tried. The first crimped nylon graft was inserted in the mid-50s. Nylon is still used, but polyester is chosen more frequently because of its good mechanical and chemical properties, its low moisture absorption also gives good resistance to fast deterioration. To give more elasticity to the tube, elastomeric yarns can be blended with the polyester. Tubes can be woven, knitted or braided.

G.2.4 Outline the specification for the design of a textile vascular graft. **2**

A graft needs to satisfy the following engineering and functional criteria.

1. The graft's surface should not encourage the formation of blood clots.
2. The graft should incorporate elements to impart compliance and elasticity.
3. The graft should be designed to maintain long-term tensile strength.
4. The graft must be biocompatible or have the ability to be healed by the patient.
5. The graft must be easy to handle.
6. The graft should have the capacity for uniform volume production.
7. The graft should be able to withstand a long shelf storage.
8. The graft should be able to withstand repeated sterilization.
9. The graft should be available in a variety of sizes.

A.S.	*Core Material—SL and HL*	Obj
G.2.5	Explain the steps in the manufacture of a textile vascular prosthesis.	3

Step 1: Choose the polymer. Polyester is the most commonly used because it is available in a wide range of linear densities. Polyurethane is another polymer especially used for its elasticity.

Step 2: Choose the type of yarn. Commercial prostheses contain either single- or two-ply yarns, usually with a round cross-section. However, trilobal yarns have been used which have a larger surface area that makes preclotting easier and faster, although these are more prone to fatigue and mechanical damage.

Step 3: Select a manufacturing technique—either weaving or knitting.

Weaving—The original commercial prostheses were woven and this method is still widely used. They are woven in a circular manner so that there is no seam and the artery is more uniform. Plain woven fabrics are dimensionally stable, have a high bursting strength, and have a good fatigue resistance and low permeability which reduces bleeding. Weaving is not as useful for arterial grafts. Woven prostheses are stronger but have a tendency to fray at the cut ends. They also lack compliance and may be too stiff.

Knitting—knitted prostheses have better flexibility and compliance than woven prostheses and are easier to suture. However, they are very porous and have high water permeability. To overcome this they are preclotted with the patient's blood before implantation. A type of knitted prosthesis (the velour prosthesis) was developed to improve healing. The fabric is thicker and has more loops so that new cells can adhere to the wall more easily. Knitted prostheses are successful for by-pass procedures of the abdominal aorta and peripheral arteries. They are not well suited for large diameter vessel replacement or locations of high stress because they have a weak construction and are not as dimensionally stable as woven prostheses. They sometimes get a permanent radial deformation due to blood flow and pressure which leads to a mismatch in diameter between the prosthesis and the host artery. To improve the permeability of knitted structures, the fabric is shrunk by chemical swelling agents or thermal processing. This is called compaction and often results in better healing.

Crimping—Crimping can be used to overcome the limited longitudinal stretch of vascular prostheses. Crimp reduces the stress at the suture line and minimizes local fluctuations in blood pressure. Crimping is a heat-set process that reduces the likelihood of thrombosis.

G.2.6	Explain developments in the design and manufacture of textile vascular prostheses.	3

Developments include production of a collagen framework on a Teflon tube (like the steel-beam skeleton of a skyscraper); and incubation of some smooth muscle cells from the patient on the collagen superstructure to produce a user-friendly, rejection-resistant artery. Eventually the collagen would dissolve but the muscle cells of the new artery would thrive and continually renew themselves according to the established structural pattern. Arteries have to withstand intense, pulsing pressures and so it is necessary to replicate the ribbed construction and circumferential strength of the natural artery. Computer models are used to optimize the design and simulate fabrication. Computer modelling suggests that arteries should be more thickly walled at the ends to make them easier to attach.

A.S.	*Core Material—SL and HL*	Obj

G.3 Spectacles and Contact Lenses (3h)

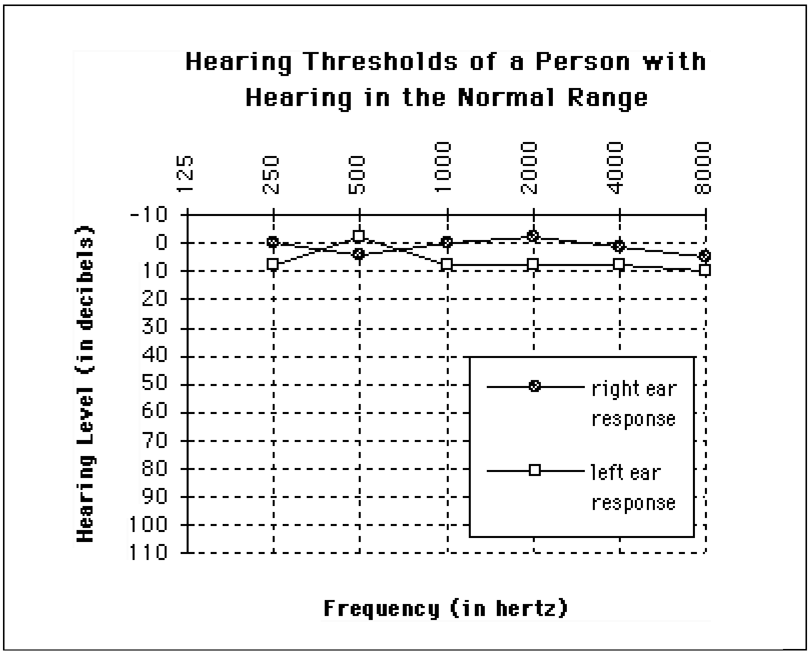
G.3.1	Define *hypermetropia* and *myopia*.	**1**
G.3.2	Explain how myopia in the human eye can be corrected with a spectacle lens. Detailed structure of the eye is not required, the only detail required is that the eyeball is too long and so rays from distant objects are focused in front of the retina and therefore cannot be seen clearly. Only near objects can be focused clearly. Correction is by a concave lens that "opens out" the rays so that they focus on the retina.	**3**
G.3.3	Explain how hypermetropia can be corrected with a spectacle lens. The eyeball is too short so rays from near objects are focused behind the retina. Only objects at a distance can be focused. Correction is by a convex lens that converges the rays onto the appropriate part of the retina.	**3**
G.3.4	Explain how spectacle wearers have benefited from the development of high refractive index glass. Lenses can be thinner so that spectacles weigh less and are more comfortable.	**3**
G.3.5	Outline the advantages of evaporated metal surface coatings. Include harder surfaces and protection against the sun's rays.	**2**
G.3.6	Compare the two main types of contact lens (hard and soft) including material, size, comfort and duration of wear.	**2**
G.3.7	Discuss the advantages and disadvantages of the one-day disposable contact lens compared with earlier forms.	**3**
G.3.8	Discuss the impact of improvements in material technology on the availability of contact lenses for a wider range of optical defects. Contact lenses are now available for treating astigmatism. Enhancement in materials technology has made thicker lenses more permeable and enables oxygen to diffuse through the lens to the surface of the eye.	**3**
G.3.9	Evaluate the issues surrounding the impact on individuals of developments in spectacles and contact lenses. Consider lifestyle, safety, medical factors, economics, cosmetic factors, fashion, obsolescence, environment and resources.	**3**

G.4 Hearing Aids (3h)

G.4.1	Define *user-centred design*.	**1**
G.4.2	Discuss design contexts in which user-centred design is particularly applicable. Include disability and lifestyle issues.	**3**

A.S.	*Core Material—SL and HL*	Obj
G.4.3	Outline the major stages in the development of hearing aids.	**2**
G.4.4	Outline the role of audiograms in graphically representing hearing deficiencies.	**2**

An audiogram is a graphical representation of the results of a hearing test. The x axis on an audiogram represents pitch or frequency, measured in Hertz (Hz). An audiogram runs from 125 Hz to 8000 Hz. 125 Hz is a very low pitched sound. 8000 Hz is a much higher pitched sound. The most important pitches for speech are 500–3000 Hz. The y axis on the audiogram represents loudness or intensity, measured in decibels (dB). The loudness required for hearing at each frequency is plotted for each ear. Thresholds of 0–25 dB are considered normal: 24–25 dB represents mild hearing loss, 40–70 moderate hearing loss, 70–90 severe hearing loss and 90–110 profound hearing loss. The frequency and volume of human speech can be represented on the audiogram and so the hearing augmentation required by the hearing aid can be determined.



G.4.5	Explain that an individual may have normal hearing at some frequencies and may have severe hearing loss at other frequencies.	**3**
G.4.6	State that hearing problems are grouped according to the type of damage to the ear.	**1**

In conductive hearing loss sound waves are blocked by damage or obstruction in the outer or middle ear—voices and sounds may sound faint and/or distorted. Conductive losses are treated medically or surgically.

Sensi-neural or nerve type hearing loss is commonly associated with aging due to a reduction in the efficiency with which the auditory nerve delivers signals from the ear to the brain due to damage or improper function. Sensi-neural losses account for 80% of hearing problems and are treated with hearing aids.

A.S.	*Core Material—SL and HL*	Obj
G.4.7	Outline that modern hearing aids are categorized as behind-the-ear, eyeglass aid, in-the-ear, completely-in-the-canal or microcanal. These are selected according to the needs of particular users and to fit in with lifestyles. Behind-the-ear (BTE) aids fit behind the ear. Users can take advantage of dual microphones which are able to help in noisy situations. BTEs are generally used where hearing loss is severe. Very few people use eyeglass hearing aids and little research is going into these products. In-the-ear (ITE) or in-the-canal (ITC) hearing aids fit an individual's ear canal. The ITE fills the entire outer bowl (the concha) of the ear with the instrumentation contained in the case fitted into the ear canal. ITEs can have dual microphones. The ITC is smaller and usually fills about 50% of the concha. It fits a little deeper into the ear canal. Completely-in-canal (CIC) aids are also custom made and fit completely into the ear canal. Microcanal aids are even smaller and fit more deeply into the ear canal. Both CIC and microcanal aids have a nylon string attached to them to enable extraction from the canal. These two hearing aids are the most popular. Because they are placed further down the ear they can give the client better understanding without needing as much power. Less power results in less distortion. Most CICs do not have any user-controlled volume controls. Some do have toggle switches or can be adjusted for volume using a remote control. BTE aids are a good choice if the user has any difficulty handling small objects although they are a nuisance for spectacle wearers. Both ITE and ITC users have difficulties using a telephone due to feedback when anything is held too close to the microphone. However, since ITE and ITCs are larger they are able to hold larger power circuits. CIC and microcanal aids can be used with a telephone without causing any feedback noise.	**2**
G.4.8	Outline that hearing aids which need to fit an individual's ear canal are fitted inside a custom-made shell. On–off production is used to make the shell. The circuitry that fits inside is not custom made.	**2**
G.4.9	Discuss the issues of planned obsolescence, reuse, repair and recyclability in the context of hearing aids. Include reuse of custom-made hearing aid shells through replacement of hearing aid circuitry, battery life and rechargeability of batteries.	**3**
G.4.10	Explain that digital hearing aids are able to divide incoming sound into distinct bands which are individually selected for amplification. Details of the circuity are not required. Amplification can be tailored to an individual's hearing loss. Hearing aids utilize programmable integrated circuits which can be programmed according to the needs of the individual user.	**3**

A.S.	*Core Material—SL and HL*	Obj

G.5 The Motor Car and Health (4h)

A.S.	Core Material—SL and HL	Obj
G.5.1	Discuss the role of the motor car in developed countries. Include advantages and disadvantages, the role of the motor car for rural communities, the role of the motor car in providing independence of public transport systems and the freedom that a car provides. Marketing of cars plays on status implicit by ownership of particular cars. Discuss also urban motoring (getting people in and out of cities) and roads destroying countryside.	**3**
G.5.2	State that motor cars pose significant threats to human health. For example, increase in motor traffic leads to increased atmospheric pollution, noise pollution and stress of traffic congestion.	**1**
G.5.3	List three pollutants present in vehicle exhausts.	**1**
G.5.4	Explain three effects of exhaust gases from motor vehicles. For example, air quality, acid rain, asthma, pH poisoning, greenhouse effect, smog.	**3**
G.5.5	Explain the effect of particulates on the health of people and the growth of trees and plants in cities. Include bronchitis, asthma and various pneumoconioses.	**3**
G.5.6	Outline the structure and function of a catalytic converter.	**2**
G.5.7	Outline the design development of catalytic converters.	**2**
G.5.8	Discuss the role of legislation in the development of the catalytic converter. Consider the impact of European and Japanese standards on the development and uptake of the catalytic converter. Legislation on vehicle emissions has raised consumer awareness and generated a market pull situation.	**3**
G.5.9	Evaluate the catalytic converter as a means of reducing pollution. Consider pollution at a local, national and international level.	**3**
G.5.10	Explain that, in terms of sustainable development, the catalytic converter represents an end-of-pipe solution to the issue of atmospheric pollution by motor cars rather than a clean technology which would require a more fundamental reappraisal of the motor car.	**3**
G.5.11	Explain the role of legislation in encouraging motor vehicle research and development. Research and development costs are expensive. Legislation encourages major motor car manufacturers, eg multinational companies, to invest in research and development to meet the higher standards (eg on vehicle emissions).	**3**

A.S.	*Core Material—SL and HL*	Obj
G.5.12	Discuss the evolution of electric vehicles. The research and development required to make electric vehicles a reality is expensive. Governments, through emissions legislation, will continue to increase the pressure on car manufacturers until it becomes cost-effective for them to invest in research and development of electric vehicles. The issues in relation to electric vehicles are energy source and recharging or swapping the battery, increased range, increased weight and cost (very expensive). There are also implications for performance. Cars are sold on performance figures, therefore an electric vehicle needs to have good performance in order to sell.	**3**

A.S.	*Extension Material—HL only*	Obj

G.6 Strategies for Global Health (3h)

G.6.1 State that poverty is the world's biggest killer in its own right and contributes to disease and death through the greater likelihood of living in a poor environment. **1**

G.6.2 Outline the importance of targeted policy interventions (eg agrarian reform policies), a focus on sewers and water systems, and concerted initiatives to address infectious diseases and enhance life expectancy and health of poor communities. **2**

Rising incomes generally mean more and better food, housing and clothing as well as improved access to health care. Wealthier people tend to be better educated and therefore more informed about the disease process and its prevention. Actions which impact on health include improving hygiene, immunizing children against common diseases or seeking oral rehydration therapy to treat diarrhoea. Improvements in maternal education are strongly linked with improvements in family health.

G.6.3 Explain the importance of clean fuels and improved stove design in reducing indoor air pollution (one of the four most critical environmental problems in developing countries), and the implications for health. **3**

Some people in developing countries rely on biomass fuels for cooking and heating, and air pollution inside some homes in developing countries can be higher than in the world's most congested cities. Women and children are more likely than men to be exposed to indoor air pollution from biomass fuels as many women in developing countries spend hours per day indoors cooking near an open fire often with a child strapped to their backs. Indoor air pollution weakens the body's defences and can damage lungs contributing to acute lower respiratory infections, chronic lung disease, lung cancer, asthma, low birth weight and heart disease.

G.6.4 Outline the non-health benefits of the transition to cleaner fuels. **2**

The time formerly used for fuel collection is now available for child care, agriculture and income-generating activities. Also, reduced use of wood fuels results in less deforestation, soil erosion and losses in soil fertility.

G.6.5 State that improvements in water supply and sanitation services, and the implementation of low-cost, simple technology systems, can reduce the incidence of water-related diseases. **1**

G.6.6 Explain the role of pricing policies in improving water services. **3**

In many cities the less well-off pay proportionately more for less water. More-wealthy people sometimes over use water because they are not charged the full price of the water they receive. One pricing policy that addresses equity concerns provides all consumers with a basic amount of water at low cost and charges greater amounts for any additional water.

A.S.	*Extension Material—HL only*	Obj
G.6.7	Explain the importance to health of controlling disease vectors. Vector-borne diseases, such as malaria, yellow fever and schistosomiasis, cause enormous suffering throughout the developing world. Vaccines to prevent these diseases would be ideal, however, these diseases are not generally a priority for pharmaceutical companies. Some diseases can be controlled by housing improvements, eg replacing palm-thatched roofs with tiles and removing the hiding places for the insect vectors that spread disease. This can improve ventilation and reduce indoor air pollution simultaneously. Septic tanks and latrine pits can be made mosquito-proof at low cost with polystyrene beads which float and prevent female mosquitos from laying their eggs.	**3**
G.6.8	Explain the significance of blindness to survival in the developing world. In the Himalayas eyesight is so crucial to survival that a blind person seldom lives longer than three years. The World Health Organization estimates that more than 42 million people in the world are currently blind, and cataracts cause approximately half of all blindness.	**3**
G.6.9	Define *cataract*.	**1**
G.6.10	Outline the importance of public education campaigns in helping people to understand that simple surgery can restore sight.	**2**
G.6.11	Outline the role of intra-ocular lens implantation in the treatment of cataract.	**2**
G.6.12	Outline the importance of CAD/CAM in the production of low-cost intra-ocular lens implants.	**2**

G.7 Ergonomics in the Workplace (2h)

G.7.1	Define *repetitive stress injury* (RSI).	**1**
G.7.2	State that RSIs result from a mismatch between the physical requirements of a job and the physical capacity of the human body.	**1**
G.7.3	Explain how proper consideration of ergonomics can prevent RSIs.	**3**
G.7.4	State that particular occupations are associated with particular RSIs. For example, the increase in computer use and flat light-touch keyboards has resulted in an epidemic of injuries to the hands, arms and shoulders. Typical RSIs associated with computer use include: carpal tunnel syndrome (nerves running through the wrist get trapped by the inflamed muscles around them causing tingling, numbness and loss of sensation) and thoracic outlet syndrome (a compression of nerves and vessels in the neck and shoulders possibly caused by hunched or raised shoulders and leading to pains in the wrist or hand and lack of pulse in the affected arm, etc). Repetitive and heavy lifting can also lead to RSIs.	**1**

A.S.	*Extension Material—HL only*	Obj
G.7.5	Explain that RSI accounts for an increasing proportion of work-related illness. According to the US Bureau of Labour Statistics, RSI accounted for 14% of work-related illness in 1978 and 56% in 1990.	3
G.7.6	Explain that money spent on preventing RSI can have an excellent return on investment through enhanced productivity, reduction in sickness leave and reduction in staff turnover.	3
G.7.7	Explain the ergonomic considerations associated with the design of an office workstation. For example, see British Standard 3044—*Guide to Ergonomic Principles in the Design and Selection of Office Furniture*. See also national Health and Safety Legislation for Display Screen Regulations.	3

G.8 Physical Disability and the Global Marketplace (2h)

G.8.1	Define *economy of scale*.	1
G.8.2	Explain the impact of economy of scale on the cost and availability of products.	3
G.8.3	Outline that in the past designing for disability was an example of craft production as disabled people were seen as a minority group.	2
G.8.4	State that on a global basis disabled people represent a large but widely distributed user group that poses particular challenges in relation to the design, marketing and distribution of products.	1
G.8.5	Identify the benefits that the global marketplace and the Internet provide for designers and manufacturers of disability products. The Internet has made the global marketplace a reality. Through the Internet disabled people have access to more products and can obtain better value for money. Involvement with the designer and manufacturer can inform product development. The Internet facilitates all aspects of information collection, market research, marketing and distribution strategies.	2
G.8.6	Explain the economic benefits of considering disability issues early in the design cycle. For example, consider disability issues in the design briefs for public access buildings, street layouts (ramps, etc) and street furniture. Considerations of disability (eg access routes, door widths, lifts) do not cost more. However, if they are not considered in the initial brief then adaptation for disability at a later stage can be very expensive.	3
G.8.7	Explain how the computer can be used to augment speech for disabled people.	3
G.8.8	Discuss the benefits of technological augmentation for disabled people. For example, the use of computers for environmental control.	3

	Explain how resistors and other devices (eg digital switches, magnetic reed switches, light-dependent resistors and thermistors) can be arranged to	**3**
H.1.5	Explain the difference between a digital and an analogue signal and how a digital signal can be generated from an analogue signal.	**3**
H.1.6	Describe one example of a digital input sensor.	**2**
H.1.7	State what is meant by digital logic and a digital logic gate.	**1**

A.S.	*Core Material—SL and HL*	Obj
H.1.8	State that common logic gates include **NOT**, **AND**, **OR**, **EX-OR**, **NAND** and **NOR**.	**1**
H.1.9	State the symbols, truth tables, Boolean algebraic expressions and a statement for each of the logic gates listed in H.1.8. (Note: American standard gate symbols should be used as they are universally recognized.)	**1**
H.1.10	Explain how logic can be used in the design process.	**3**
H.1.11	Analyse design problems and generate a solution containing a circuit with the appropriate logic gates.	**3**

H.2 Building Electronic Circuits (4h)

H.2.1	Explain how a systems approach can be applied to the design of electronic circuits. Electronic systems can be described in terms of block diagrams. The simplest block diagram is based on three elements: input, process and output.	**3**
H.2.2	Define *amplifier*, *gain*, *memory*, *clock pulse* and *shift register*.	**1**
H.2.3	Explain why the op-amp is a suitable device for outputting a digital signal from an analogue input or inputs.	**3**
H.2.4	Draw a comparator circuit and describe two examples where a comparator is used (including light) and two examples where a threshold detector is used (including temperature). Such detectors are made when one input is set to a fixed value. Investigate comparators and threshold detectors in practical circuits, eg temperature threshold, light comparators.	**2**
H.2.5	Describe how inverting op-amps and non-inverting op-amps operate with the aid of circuit diagrams.	**2**
H.2.6	Calculate the gain of op-amps in practical circuits and the values of resistors in op-amp circuits to achieve specific gains.	**2**
H.2.7	Discuss one practical use for both an inverting and non-inverting op-amp circuit in the design of an electronic system.	**3**
H.2.8	Calculate the overall amplification of a system made up of a combination of elements.	**2**
H.2.9	Describe the function of a summing amplifier, draw a circuit diagram to represent a summing amplifier, and calculate the output from a summing amplifier.	**2**

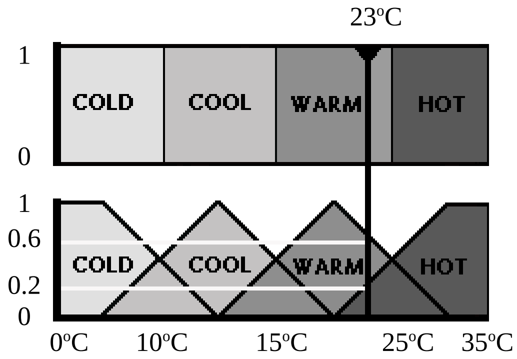
A.S.	*Core Material—SL and HL*	Obj
H.2.10	Explain a practical situation where a summing amplifier is used.	3
H.2.11	Explain the need for memory in a logic system. Sequential logic provides a form of memory. Outputs depend on the state of the inputs and the order in which they change. A system with memory has two stable states, ie it is a bi-stable. There are several types of bi-stables but the J–K type is one of the most versatile.	3
H.2.12	State that a type-D flip-flop or latch is the simplest form of memory—it can store a single digital signal. A type-D or data flip-flop has a single input line. After a clock pulse its output reflects the state of the data line before or during the clock pulse. Type-D flip-flops are sometimes called latches because they latch (or freeze) the state of the line at the instant of the clock pulse.	1
H.2.13	Identify a digital counter as a device that converts a clock pulse into a binary sequence of numbers and describe, with the aid of a diagram, the operation of a digital counter.	2
H.2.14	State what is meant by the terms serial processing and parallel processing. Information is stored temporarily in a register constructed from bi-stables. Binary numbers are often stored in this way in calculations before being passed to combinational logic for processes, such as adding. The J–K flip-flop configured to act as a type-D bi-stable is often used to perform the function of a register.	1
H.2.15	Describe one important use for a shift register.	2

H.3 Control Systems (4h)

H.3.1	Define *cybernetics*, *feedback*, *control system* and *on–off position control system*.	1
H.3.2	Explain the difference between closed-loop and open-loop control and one example of each type of control system.	3
H.3.3	Explain the difference between positive and negative feedback.	3
H.3.4	State one example of each type of feedback.	1
H.3.5	Explain the need for negative feedback in a fully automated closed-loop control system.	3
H.3.6	Describe how electronic feedback is often used to control a device. For example, control of a heating or air-conditioning system or controlling the movement of an elevator based on inputs from sensors and people pushing buttons.	2

A.S.	*Core Material—SL and HL*	Obj
H.3.7	State that sensors are often used to provide electronic feedback.	**1**
H.3.8	Draw block diagrams to represent a heating or air-conditioning system.	**1**
H.3.9	Define *overdamping* and *underdamping*.	**1**
H.3.10	Draw a diagram and graph to illustrate the importance of critical damping in a position control servo-system, and identify overdamping and underdamping. Critical damping is the closest possible to ideal. Overdamping occurs when excessive friction and/or a low gain amp is used. Underdamping occurs when the load has a high moment of inertia, a high gain amplifier, low friction, or a combination of these. Overshooting and oscillations are caused because the load has inertia and cannot be brought to rest instantly. Friction in the system means that small input signals will not cause the system to move. Only when a minimum input is reached will the motor react. The range of signals for which no motion is caused is known as the dead band.	**2**
H.3.11	Define *fuzzy logic*.	**1**
H.3.12	State that fuzzy logic provides a simple way of drawing definite conclusions from vague, ambiguous or imprecise information and can be used in control and information processing systems resulting in better control performance. Traditional control systems trade off response time and suffer from overshoot. Fuzzy logic uses rules and membership functions to achieve more precise control.	**1**
H.3.13	Explain that a fuzzy logic controller works like a conventional system accepting an input value, performing some calculations and generating an output value. A fuzzy controller works in three steps: fuzzification, rule evaluation and defuzzification. This is called the fuzzy inference process. In fuzzification a crisp input is translated into a fuzzy value. In rule evaluation fuzzy output truth values are computed. In defuzzification the fuzzy output is translated to a crisp value.	**3**
H.3.14	Explain how simple words are used to label the input values in the fuzzification step. The first step in designing a fuzzy controller is to characterize the range of values for the input and output variables of the controller. (Refer to the diagram overleaf.) Words such as cold, cool, warm and hot act as the labels which refer to the set of overlapping values. These triangular-shaped values are called membership functions. In this example, 23°C is 60% warm and 20% hot. During the fuzzification step the crisp temperature value of 23°C is input and translated into fuzzy truth values. 23°C is fuzzified into warm with truth value 0.6 (or 60%) and hot with truth value 0.2 (or 20%).	**3**

A.S.	*Core Material—SL and HL*	Obj



Words such as zero, low, medium and high are used to describe the output, in this case the fan speed.

H.3.15 Explain how simple IF–THEN rules are used to define the control system. **3**

The temperature controller above can be defined in four simple IF–THEN rules:

1. IF temperature IS cold THEN fan speed IS high.
2. IF temperature IS cool THEN fan speed IS medium.
3. IF temperature IS warm THEN fan speed IS low.
4. IF temperature IS hot THEN fan speed IS zero.

Inside the controller all temperature regulation will be based on how the current room temperature falls into these ranges and the rules describing the system's behaviour. The controller's output will vary continuously to adjust the fan speed. During the rule evaluation step the entire set of rules is evaluated and some rules may fire up. For 23°C only the last two of the four rules involving warm and hot will fire. Specifically, using rule three the fan speed will be low with degree of truth 0.6. Similarly, using rule four the fan speed will be zero with degree of truth 0.2.

H.3.16 Explain how a precise output value is calculated in the defuzzification step. **3**

During the defuzzification step the 60% low and 20% zero labels for the fan speed are combined using a calculation method called the centre of gravity (COG) in order to produce a precise output.

H.3.17 Explain the benefits of fuzzy logic. **3**

Include performance, simplicity, lower cost, productivity, reduction in time to market for commercial applications.

H.3.18 Explain how fuzzy logic can be used to control the wash cycle in a washing machine. **3**

A.S.	*Core Material—SL and HL*	Obj

H.4 Microprocessors (4h)

A.S.	Assessment statement	Obj
H.4.1	Identify the two major semiconductor materials and outline the effect of adding impurities (doping). Consider the effect of doping to create n-type and p-type semiconductors.	2
H.4.2	Identify a semiconductor diode as a two-terminal device that lets electric current pass in one direction only and a transistor as a three-terminal semiconductor device. The three terminals are labelled base, emitter and collector.	2
H.4.3	Explain that a light-emitting diode (LED) is a special type of diode, and how LEDs are used in digital switching circuits. Details of an LED's operation are not required, however students should understand the need for a protection resistor.	3
H.4.4	State that an integrated circuit (IC) is a complex circuit of components fabricated on to a single slice of silicon (silicon chip).	1
H.4.5	Outline the process used to produce integrated circuits.	2
H.4.6	Define *programmable system*.	1
H.4.7	State that a microprocessor is a multi-purpose, programmable, integrated circuit (PIC) capable of a wide range of functions.	1
H.4.8	Explain that a microprocessor provides the central controlling operations for a wide range of digital electronic devices. For example, a washing machine or calculator.	3
H.4.9	State that a bus is a link that transports information within a micro-electronic system.	1
H.4.10	Describe a simplified block diagram of a microprocessor integrated circuit (IC). An understanding of the role of each element is required along with an appreciation that each block is itself a complex digital circuit. Circuit details are not required.	2
H.4.11	Identify a wide range of electronic devices that can incorporate micro-processors. Examples to consider are calculators, washing machines, microwave ovens, traffic-light controllers and game machines. Systems should be analysed as block diagrams and input and outputs identified with the microprocessor as the central controlling element. Circuit details are not required.	2

A.S.	*Core Material—SL and HL*	Obj
H.4.12	State that a hard-wired digital control system uses digital logic circuits to perform a controlling operation. This operation is fixed by the circuit and cannot be changed without changing the circuitry.	**1**
H.4.13	Explain the advantages and disadvantages of software-controlled programmable systems compared to hard-wired systems.	**3**
H.4.14	Explain how microprocessors are used for the central programming unit (CPU) of a personal computer. Use a block diagram approach.	**3**
H.4.15	Explain how programmable integrated circuits (PICs) are able to help in design realization through providing control units for electronic products.	**3**
H.4.16	Discuss the impact on society of the miniaturization of electronic products.	**3**

A.S.	*Extension Material—HL only*	Obj

H.5 Communications Systems (2h)

H.5.1	Explain the major developments in mass communications systems. Include Osgood and Wheatstone, Morse, Alexander Graham Bell and the telephone, optical fibres, etc.	3
H.5.2	Define *telecommunications*.	1
H.5.3	Explain how electrical signals representing information from, for example, a microphone, television camera or computer can be sent from one place to another either through fixed cables or broadcast as electromagnetic waves through the air.	3
H.5.4	State that modulation is the process of coding a signal with a carrier so that it can be transmitted effectively and that demodulation is the process of decoding a signal following its transmission.	1
H.5.5	Identify the propagation medium as the channel along which the signal is sent.	2
H.5.6	Describe a generic block diagram for a communication system which includes information source, modulator, transmitter, propagation medium, receiver, demodulator and receptor of information.	2
H.5.7	Explain how multiplexing allows many information signals to be sent along the same communication channel.	3
H.5.8	Evaluate a range of communication systems in relation to the generic block diagram. For example, telephone, television, radio broadcasting and radio communication system.	3
H.5.9	Explain that information may be stored, transmitted and received in digital or analogue form, and that a system may include both types of signal.	3
H.5.10	Discuss the benefits of digital information storage, transmission and processing systems compared to analogue systems. Include greater storage capacity, enhanced flexibility through inter-connectivity of different digital systems, more clearly defined signals, faster transmission and increased range.	3

H.6 Smart Cards (3h)

H.6.1	Define *smart card*.	1
H.6.2	State that there are two types of smart cards relating to how they are read and written: contact smart cards and contactless smart cards.	1

A.S.	*Extension Material—HL only*	Obj

- Contact smart cards have to be inserted into a smart card reader to be read. They have a small gold plate about 1.2 mm in diameter in the front, instead of a magnetic strip on the back like a credit card. When inserted into a reader the plate makes contact with the electrical connectors that read and write data to the chip.
- Contactless smart cards are passed near an antenna to be read. They get their power by induction rather than through one of the contacts. Contactless smart cards look like plastic credit cards except they have an electronic microchip and antenna embedded inside. These allow the card to communicate with an antenna/coupler unit without making physical contact.
- There are also combination cards which are a combination of the above two.

H.6.3 Explain that contactless smart cards are the ideal solution for applications such as quick transactions and information "tags". **3**

For example, transactions on public transport need to be processed quickly, "tags" can hold information on gas bottles, cars etc.

H.6.4 State that functionally smart cards can be divided into those with on-card processing power and those without (memory cards). **1**

H.6.5 State that memory cards have no sophisticated processing power and cannot manage files dynamically. **1**

There are three primary types of memory card:

Straight Memory Cards

These cards just store data and have no data-processing capabilities. They have the lowest cost per bit for user memory and should be regarded as floppy disks of varying sizes without the lock mechanism. These cards cannot identify themselves to the reader, so the host system has to know what type of card is being inserted into the reader.

Protected or Segmented Memory Cards

These cards have built-in logic to control the access to the memory of the card. Sometimes referred to as intelligent memory cards, these devices can be set to write protect some or all of the memory array. Some of these cards can be configured to restrict access to both reading and writing. This is usually done through a password or system key. Segmented memory cards can be divided into logical sections for planned multi-functionality.

Stored Value Memory Cards

These cards are designed for the specific purpose of storing value or tokens. The cards are either disposable or rechargeable. Most cards of this type incorporate permanent security measures at the point of manufacture. These measures can include password keys and logic that are hard-coded into the chip by the manufacturer. The memory arrays on these devices are set up as decrements or counters. There is little or no memory left for any other function. For simple applications such as a telephone card the chip has 60 or 12 memory cells: one for each telephone unit. A memory cell is cleared each time a telephone unit is used. Once all the memory units are used, the card becomes useless and is thrown away. This process can be reversed in the case of rechargeable cards.

A.S.	*Extension Material—HL only*	Obj
H.6.6	Explain that reading or writing to smart cards is done by a reader or a terminal.	3
	The industry has adopted the following definitions: a "reader" is used to describe a unit that interfaces with a PC for the majority of its processing requirements; a "terminal" is a self-contained processing device. Readers come in many forms and in a wide variety of capabilities. The easiest way to describe a reader is by the method of its interface to a PC. Smart card readers are available which interface to RS232 serial ports, USB ports, PCMCIA slots, floppy disk slots, parallel ports, infrared IRDA ports and keyboards and keyboard wedge readers. Another difference in reader types is the on-board intelligence and capabilities or lack thereof. Extensive price and performance differences exist between an industrial strength intelligent reader that supports a wide variety of card protocols and a home style win-card reader that only works with microprocessor cards and performs all processing of the data in the PC. The options in terminal choice are just as wide. Most units have their own operating systems and development tools. They typically support other functions such as magstripe reading, modem functions and transaction printing.	
H.6.7	Explain the importance of international standards for smart cards.	3
	Smart card standards govern physical properties and communication characteristics of the embedded chip and are covered through ISO 7816. Open system card interoperability should apply at several levels: the card itself, its access terminals (readers), the networks and the card issuers' own systems. This will only be achieved by conformance to international standards. Various standards exist: ISO standards, CEN standards, industry initiatives such as EMV, the Open Card Framework and PC/SC specifications. All these organizations are active in smart card standardization. ISO 7816 is the international standard for smart cards that use electrical contacts. It has six parts: some have been completed; others are currently in draft stage. Part 1 relates to the physical characteristics, their resistance to static electricity, electromagnetic radiation and mechanical stress and describes the physical location of a smart card's magnetic stripe and embossing area. Part 2 describes the dimensions and location of contacts. Part 3 defines the voltage and current requirements for the electrical contacts. Part 4 establishes a set of commands for CPU to provide access, security and transmission of card data including commands to read, write and update records. Part 5 establishes standards for application identifiers (AIDs). An AID has two parts: the first is unique to the vendor; the second is a variable length field that can be used to identify specific applications). Part 6 details the physical transportation of device and transaction data, answer to reset and transmission protocols.	
H.6.8	Outline that smart cards are used for a number of different applications including cell phones, credit card functions and electronic purses.	2
H.6.9	Explain that smart card functions can be embedded into other everyday objects, eg keyrings, watches, earrings.	3

A.S.	*Extension Material—HL only*	Obj
H.6.10	Explain how multiple applications can be programmed onto the same card. Multifunction smart cards allocate card memory into independent sections assigned to a specific function or application. The card has a microprocessor or microcontroller chip that manages this memory allocation and file access. This type of chip is similar to those found inside all personal computers and, when implanted in a smart card, manages data in organized file structures via a card operating system (COS). Unlike other operating systems, this software controls access to the on-card user memory. This capability permits different and multiple functions and/or different applications to reside on the card, allowing businesses to issue and maintain a diversity of “products” through the card. One example of this is a debit card that also enables building access on a college campus.	**3**
H.6.11	Discuss the benefits of using multiple applications on a smart card to users. Multifunction cards benefit issuers by enabling them to market their products and services via state-of-the-art transaction technology. Specifically, the technology permits information updates without replacement of the installed base of cards, greatly simplifying program changes and reducing costs. For the card user, multifunction means greater convenience and security, and ultimately, consolidation of multiple cards down to a select few that serve many purposes.	**3**

H.7 Global Impacts of Converging Technologies (2h)

H.7.1	Define *converging technology*.	**1**
H.7.2	State that the key to convergence of technologies is digital technology.	**1**
H.7.3	Explain the technologies that are converging in the mobile phone. Initially a mobile phone only used microwave technology. Now mobile phones incorporate a calculator, stop watch, alarm clock and range of other features. Mobile phones can be linked to a portable computer to enable fax, email and Internet connection.	**3**
H.7.4	Explain the importance of standards in the development of mobile phones and other technologies. Consider the initial lag period before all the transmitters were erected and mobile phones could be used everywhere. The US case study of mobile phones emphasizes the importance of adopting standards—pan-European communication networks were available long before pan-US networks. The case of VHS and Beta-max in video recorders is another example of the importance of standards.	**3**
H.7.5	Explain the benefits of mobile phones for users and providers. Include world-wide communications overcoming social and technical barriers. The more convenient the phone is the more it is likely to be used and the more money the providers will make.	**3**

A.S.	*Extension Material—HL only*	Obj
H.7.6	Outline the benefits of converging technologies for electronic products for the user. Benefits include miniaturization, ability to use the handset from one on another, more stylish, less cluttered, more uniformity of design across the range of products.	**2**
H.7.7	Outline the benefits of converging technologies for electronic products for the manufacturer. Benefits include less materials, promotes product loyalty, wider range for designer, wider market, cheaper to distribute (less weight, size, etc).	**2**
H.7.8	Describe how MP3 technology enables users to download music from the Internet. Music and graphics files have traditionally been very large. MP3 allows compression of music files to produce very small files. MP3 technology enables the downloading of music files from the Internet for recording onto portable MP3 players.	**2**
H.7.9	Outline the benefits of MP3 technology for users. Include: access for the user to world music, users don't have to wait for the music to be imported (which may not happen for minority tastes) and high-quality (near-CD) quality reproduction. Internet sites allow access to a global music library; users can create their own compilations of music to listen to at their own convenience.	**2**
H.7.10	Discuss the implications for the traditional music industry of downloading music from the Internet. Include issues for recording companies and sustainability of the traditional music industry.	**3**

GLOSSARY

adaptation	An existing technology or solution to a problem in one field is used to provide a new idea for a solution in another.
aeration	The incorporation of gas into a food product. It may be air, which is often beaten in, or carbon dioxide which can be introduced under pressure, eg to aerated water or by the action of yeast (in bread, etc).
algorithm	A sequence of instructions to describe a set of actions.
alloy	A mixture that contains at least one metal. This can be a mixture of metals or a mixture of metals and non-metals.
alternative technology	A technology that involves new types of equipment or organizational forms, and which represents a viable alternative to the existing mainstream technologies of today.
amorphous material	A solid that is not crystalline.
amplifier	An electronic device for which the output of the device is a function of the input.
analogue signal	A signal that may change continuously to represent a physical property. There will be a mathematical relationship between the change in the physical property and the change in the signal.
analogy	Drawing on a similar situation for solutions, eg an ultrasonic focusing system for cameras was based on how bats navigate in the dark.
animation	The ability to link graphic screens together in such a way as to simulate motion or a process.
anthropometrics	The aspect of ergonomics that deals with body measurements, particularly those of size, strength and physical capacity.
antioxidant	A food additive which is very easily oxidized and protects chemicals in food from oxidation.

appropriate technology	Technology appropriate to the context in which it is applied. Appropriate technologies are low in capital cost, use local materials wherever possible, create jobs using local skills and labour, involve decentralized renewable energy sources, make technology understandable to the people who use it, are flexible and not detrimental to quality of life or the environment.
assembly line production	The mass production of a product via a flow line based on the interchangeability of parts, pre-processing of materials, standardization and work division.
astigmatism	An inability of the eye to see clearly because of its shape.
atom	The smallest part of an element that can exist chemically.
automated guided vehicle (AGV)	A robot vehicle that moves over a “shop floor” guided by means of painted lines, IR rays or cables laid beneath the surface.
automation	A volume production process involving machines controlled by computers.
batch production	Limited volume production (a set number of items to be produced).
biocompatability	Not harmful or toxic to living tissue and thus able to be introduced into the human body, eg a prosthesis.
brainstorming	A group of people generating divergent ideas to try to solve a problem. The ideas may be random. No criticism is allowed. Evaluation of the ideas comes at a later stage.
brief	The formal starting point for the design of a product. It is a clarification of what a new product is expected to be and to do. It is the instruction to the designer from a client to take on a project.
cataract	Opacity of the lens of the eye.
clean technology	An approach to manufacturing or production which uses less resources and causes less environmental damage (by reducing the exploitation of natural resources, minimizing waste and preventing pollution) than an alternative means with which it is economically competitive.
clock pulse	An electrical signal consisting of a series of pulses at regularly spaced time intervals.
coagulation of protein	The exposure of a protein to heat or acid which results in irreversible changes that reduce solubility and change optical characteristics.

comparator circuit	An op-amp configured to compare two or more input signals and produce an output signal which is a function of the comparison.
composite	A mixture composed of two or more substances (materials) with one substance acting as the matrix or glue.
compound	A substance formed by the combination of elements in fixed proportions. They may be bonded ionically or covalently.
computer-aided design (CAD)	The use of computers to aid the design process.
computer-aided manufacturing (CAM)	The use of computers to aid manufacturing.
computer numerically controlled (CNC)	A numerical control system within which a dedicated, stored-program computer is used to perform some or all of the basic numerical control functions.
computer integrated manufacture (CIM)	Computer integrated manufacturing is the total integration of the various individual CAD, CNC, robotics, computer-aided process planning, computer-aided quality control and materials handling. In a fully developed CIM system a CAD system will be networked with computer controlled manufacturing systems which might include CNC machines, robots and a materials-handling component. All components of the system will share the same database and have instant access to it.
constructive discontent	Analysing a situation which would benefit from re-design, and working out a strategy for improving it.
control system	A system which controls the operation of a machine or manufacturing process.
convergent thinking	The ability to analyse information in order to select an answer from alternatives.
converging technology	The melding of media (audio, text, video, data and images) by converting them into digital format, thereby opening up new avenues of communication.
copyright	The right in law to be the only producer (or seller) of a book, play, film, design, etc.
corporate strategy	Long-term aims and objectives of a company and ways of achieving them by allocation of resources.
cost-effectiveness	The most efficient way of designing and producing a product from the manufacturer's point of view.

craft production	A small-scale production process centred on manual skills.
cutting and machining	Cutting a material into shape and finishing it by machines.
cybernetics	The acquisition, processing and communication of information and its use in controlling the behaviour of natural and manufactured systems.
density	The mass per unit volume of a material.
design family	The evolution of a design into a variety of products that will appeal to a wide range of customers.
design for disassembly	Designing a product so that when it becomes obsolete it can easily and economically be taken apart, the components reused or repaired and the materials recycled.
design for manufacture (DfM)	The existing manufacturing capability is the dominant factor of DfM. Designers design specifically for optimum use of this capability.
diffusion into the marketplace	The wide acceptance (and sales) of a product.
digital signal	An encoded signal; the simplest being binary. The signals are often converted from the analogue signals into discrete values—high, low or on, off.
divergent thinking	Using creative ability to produce a wide range of possible solutions to a problem.
diversification	Involves a company in both the development of new products and in selling those products to new companies.
dominant design	The design containing those implicit features of a product which are recognized as essential by a majority of manufacturers and purchasers.
ductility	The ability of a material to be drawn or extruded into a wire or other extended shape.
economy of scale	Generally the larger the volume of production, the more fixed costs are balanced by variable costs and the better the unit price.
electric current	The flow of electrons past a fixed point in a circuit, measured in amperes (A).
electrical resistance	The ratio of the potential difference across a conductor to the current flowing through it. The property of a material whereby it obstructs the flow of electric current through it by dissipating the energy in another form such as heat.

electrical resistivity	This is a measure of a material's ability to conduct electricity. A material with a low resistivity will conduct electricity well.
element	A substance that cannot be decomposed into simpler substances.
entrepreneur	An individual committed to the development of a particular new product or process, and prepared to provide or persuade others to provide the necessary finance to turn the invention into an innovation.
ergonome	A three-dimensional, physical, scaled model based on a specific percentile with moving parts. Used to establish spatial ergonomic considerations between people and products or environments.
ergonomics	The application of scientific information concerning the relationship of human beings to the design of objects, systems and environments.
essential	A compound which cannot be made in the body but has to be provided ready-made in the diet, eg vitamins, essential fatty acids and essential amino acids.
expert appraisal	The reliance on the knowledge and skills of an expert in the operation of the product.
exploded isometric drawing	An isometric drawing of an object with more than one component which depicts how the parts of assemblies fit together.
extrusion	Forcing material through a shaped die to produce a shaped rod or tube of material, eg wire, pasta.
fashion	A style or trend.
feedback	The property of a closed loop control system which permits the output to be compared with the input so that an appropriate control action may be performed.
fibre structure	A fibre structure is used to describe the elongation of the crystals in a cold worked metal, or any type of filament material from which yarns and fabrics are manufactured by spinning, weaving, knitting, bonding, or any filament material/molecule in food products.
fixed costs	The costs that must be paid out before production starts, eg machinery. These costs do not change with the level of production.

flexible manufacturing system (FMS)	Any computer-controlled manufacturing system which is capable of dealing with several different products and offers users an opportunity to obtain the benefits of economies of scale in small batch production. Manufacturing equipment which can automatically change product tooling and software.
food hygiene	All aspects of the processing, preparing, storing, cooking and serving of food to make sure it is safe to eat.
food insecurity	Low levels of food intake which can be transitory (as a result of crisis), seasonal or chronic (when it occurs on a continuing basis).
food spoilage	Food becoming unfit for consumption.
freehand drawing	The spontaneous representation of ideas on paper without the use of technical aids.
fuzzy logic	A series of weighted algorithms or models programmed into a computer to simulate human thought.
gain	The ratio of the output voltage of an amplifier to its input voltage.
gelatinizing (gelling)	The formation of a gel by using gelatin or by the heat treating of starch and water to break open the starch granules, eg custard.
genetically modified organism	A plant or animal in which the DNA has been altered through the insertion of genetic material from another source. Genetic modification is most often used in agricultural crops to increase the resistance to herbicides or to engineer pesticides into crops.
green design	Designing in a way that takes account of the environmental impact of the product throughout its life.
hardness	The resistance a material offers to penetration or scratching.
hypermetropia	Long-sightedness caused by the lens of the eye bringing light rays to a focus behind the retina.
incremental design	Small changes to the design of a product which seem trivial but the cumulative effect of these changes over a longer period can be very significant.
injection moulding	The direct introduction of molten plastic under pressure into a die which then cools rapidly allowing the formed object to be released from the mould.
innovation	The business of putting an invention in the marketplace and making it a success.

intermediate technology	A relative term that stands between traditional and modern technology.
Internet	A global network connecting millions of computers.
invention	The process of discovering a principle. A technical advance in a particular field often resulting in a novel product.
ion	A positively or negatively charged atom or molecule caused by the loss or gain of electrons from an atom or atoms.
isometric drawing	A three-dimensional representation of an object drawn with the horizontal plane at 30° to the vertical plane.
joining	The putting together of two or more components or materials.
Just-in-case (JIC)	A situation where a company keeps a small stock of rare components (or complete items) or ones that take a long time to make, just in case of a rush order.
Just-in-time (JIT)	A situation where a firm does not allocate space to the storage of components or completed items, but instead orders them (or manufactures them) when required. Large storage areas are not needed and items that are not ordered are not made.
lamination	Building up a thick layer of material using thin layers of the material joined with adhesives.
lean production	Combining the advantages of craft and mass production while avoiding the high cost of the former and the inflexibility of the latter. Lean producers employ teams of multi-skilled workers at all levels of the organization and use highly flexible automated machines to produce volumes of products in enormous variety.
life cycle analysis	The assessment of the effect a product has on the environment from the initial concept to disposal.
literature search	The use of consumer reports and newspaper items to follow historical development. Useful sources of information could include CD-Roms, such as encyclopedias and newspapers, or more specific disks, subject-specific magazines and manufacturers' information.
lone inventor	An individual working outside or inside an organization who is committed to the invention of a novel product and often becomes isolated because s/he is engrossed with ideas which imply change and are resisted by others.
malnutrition	The physiological condition resulting from inadequacy or imbalance in food intake or from poor absorption of food consumed.

manikin	A two-dimensional physical anthropometric model based on a specific percentile, which is used with drawings of the same scale as the model to consider the relationship between the size of an object and people.
manufacturing process	A general term for making products. It covers a range of techniques.
manufacturing technique	A specific manufacturing term, sometimes relating to one material group only.
market development	Finding new applications for existing products thereby opening up new markets.
market penetration	Increasing sales to existing customers or finding new customers for an existing product.
market pull	The initial impetus for the development of a new product is generated by a demand from the market.
market sector	A broad way of categorizing the kinds of market the company is aiming for.
market segmentation	Markets divide up into smaller segments where the purchasers have similar characteristics and tastes.
mass customization	A sophisticated CIM system which manufactures products to individual customer orders. The benefits of economy of scale are gained whether the order is for a single item or for thousands.
mechanization	A volume production process involving machines controlled by humans.
memory	A digital storage device.
micronutrient deficiency	Lack of essential vitamins and minerals resulting from unbalanced food intake and specific problems of food absorption.
mixture	A substance made of two or more substances that can be separated by physical means, ie not chemically bonded together.
molecule	Two or more atoms which are normally bonded together covalently.
multi-national company	A company which not only trades internationally but has manufacturing outlets in a number of countries.
myopia	Short-sightedness caused by the lens of the eye bringing light rays to a focus in front of the retina.

non-renewable resources	Resources that take too long (say more than one human lifetime?) for natural processes to replenish them.
one-off production	An individual (often craft produced) article or a prototype for larger scale production.
on–off position control system	Simple electromechanical system for control involving two states: on and off.
optical fibre	A cable that can transmit huge quantities of digital information at very high speed in both directions by means of light waves.
organic agriculture	A system of farming in which organic products and techniques are used and the use of synthetic chemicals, eg fertilizers and pesticides, is precluded.
orthographic drawing	A series of flat views of an object showing it exactly as it is in shape and size.
overdamping	Excessive negative feedback so that the response time is large as in a servo mechanism.
patent	An agreement from a government office to give someone the right to make or sell a new invention for a certain number of years.
percentile range	That proportion of a population with a dimension at or less than a given value.
performance test	Observations and their record of users.
perspective drawing	A three-dimensional drawing which realistically represents an object by utilizing foreshortening and vanishing points (usually imaginary ones).
planned obsolescence	A conscious act either to ensure a continuing market or to ensure that safety factors and new technologies can be incorporated into later versions of the product.
plastic deformation	The permanent deformation of a solid subjected to a stress.
potential difference	The difference of electrical potential between two points (measured in volts).
preservative	A food additive which prevents microbial food spoilage.
primary processing	The conversion of a crop into a product that may or may not be consumed directly, eg flour.
product champion	An influential individual, usually working within an organization, who develops an enthusiasm for a particular idea or invention and "champions" it within the organization.

product cycle (product life cycle)	This refers to a product's introduction, growth, maturity and decline and to its general pattern of production and profitability.
product development	The creation of new, modified or updated products aimed mainly at a company's existing customers.
programmable system	A system which can be programmed to follow a particular set of actions.
prosthesis	An artificial limb, tooth or other part of the body manufactured to take the place of a missing or dysfunctional one.
pure substance	A substance made of only one element or compound.
radical design	Where a completely new product is devised by going back to the roots of a problem and thinking about a solution in a different way.
rancidity	An unpleasant taste or smell caused by decomposition of an oil or fat.
renewable resources	Resources that are naturally replenished in a short time.
repetitive stress injury (RSI)	A disease of a particular part of the musculo-skeletal system produced by gradual build up of tiny amounts of damage on a daily basis as a result of repetitive motions or sustained postures.
robot	A mechanical device controlled by computer that can perform human-like tasks.
robust design	Flexible designs which can be adapted to changing technical and market requirements.
satellite communication	Telecommunication whereby radio waves are transmitted from one part of the globe to a satellite in space which amplifies the signal and retransmits it to a receiver in another part of the globe.
seasoning	The process of drying out timber after conversion.
secondary processing	The conversion of an intermediate product into a food product.
shaping	The process by which materials are formed into shape by particular techniques.
shift register	A device which holds a string of bits which can be moved one place to the right or left on command.
sintering	The fusing of solid particles together by heat and pressure without completely liquifying the particles.

smart card — A small electronic device about the size of a credit card that contains electronic memory and possibly an embedded integrated circuit.

specification — A set of precise limits for the complete range of performance requirements for the design of a product.

stunting — Low height-for-age reflecting a sustained past episode or episodes of undernutrition.

superconductor — A composite material with the unique property of having almost zero resistance at very low temperatures.

sustainable development — Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

technocautious — Someone who needs some convincing before embracing technological change.

technology push — Where the impetus for a new design emanates from a technological development.

technophile — Someone who immediately welcomes a technological change.

technophobe — Someone who resists all technological change.

telecommunications — Any form of data transmission, from voice to video.

tensile strength — The ability of a material to withstand pulling forces.

thermal conductivity — A measure of how fast heat is conducted through a slab of material with a given temperature difference across the slab.

thermal expansion (expansivity) — A measure of the degree of increase in dimensions when an object is heated. This can be measured by an increase in length, area or volume. The expansivity can be measured as the fractional increase in dimension per Kelvin increase in temperature.

toughness — The ability of a material to resist the propagation of cracks.

transducer — A device for converting a non-electric signal into an electric signal, or vice versa.

underdamping — Insufficient negative feedback leading to overshooting and oscillations in a servo mechanism.

undernourishment — Chronic food insecurity in which food intake is insufficient to meet basic energy requirements on a continuing basis.

undernutrition	Result of prolonged low level of food intake and/or poor absorption of food consumed. Manifestations include wasting, stunting or underweight, reduced cognitive ability, poor health status and low productivity.
user research	Obtaining users' responses.
user trial	The observation and analysis of comments made by people who have used a particular product.
user-centred design	A design methodology in which designers do not rely on their tacit knowledge of the user or user group but instead use the users as a resource to increase their understanding.
value for money	A concept that takes account of the relation between what something, eg a product, is worth and the cash amount spent on it.
variable costs	Costs that vary with output, eg fuel or raw materials.
virtual reality	The ability to simulate a real situation on the screen and interact with it in a near natural way.
volume production	Continuous flow, large-scale production.
vulnerability	The presence of factors that place people at risk of becoming food insecure or malnourished.
wasting	The process by which hand tools and machines are used to fabricate materials by the removal of waste.
wasting	Low weight-for-height, generally the result of weight loss associated with a recent period of starvation or a severe disease.
water activity (a_w)	The water in food, which is not bound to food molecules, which can support the growth of bacteria, yeasts and fungi. The term water activity or a_w refers to this unbound water and is measured on a scale of 0 (bone dry) to 1.0 (pure water).
weaving	The carrying of a continuous thread back and forth across a set of length-wise threads to form an interlaced fabric.
yield stress	The stress at which plastic deformation begins.
Young's modulus	The stiffness of a material.

MATHEMATICAL REQUIREMENTS

It is assumed that candidates will be competent in the techniques listed below. Candidates will not be expected to remember any equations. All equations will be provided in the examination paper.

- Perform basic arithmetic functions and understand/recognize basic geometric shapes.
- Make simple calculations and approximations within an appropriate context involving averages (means), decimals, fractions, percentages, ratios, approximations, reciprocals and scaling.
- Take account of accuracy in calculations, handling them so that significant figures are neither lost unnecessarily nor carried out beyond what is justified.
- Express fractions as percentages and vice versa.
- Recognize and use expressions in decimal and standard form notation.
- Use logarithms to base 10, powers, roots, reciprocals, direct proportion and inverse proportion.
- Solve simple algebraic equations, given the appropriate formula.
- Comprehend the meanings of, and use, common mathematical symbols and/or notations.
- Display and interpret frequency data in the form of bar charts, column graphs and histograms, and interpret pie charts and nomograms.
- Select suitable scales and axes, plot and interpret graphs involving two variables which show linear and non-linear relations.
- Plot and interpret scatter diagrams to identify a correlation between two variables and appreciate that the existence of a correlation does not establish a causal relationship.
- Select appropriate variables and scales for plotting a graph, especially to obtain a graph of the form $y = mx + c$.
- Determine and interpret the slope and intercept of linear graphs, and extrapolate graphs.