This sample contains the contents page and 28 sample pages (Section A) from GCSE Design and Technology for Edexcel: Graphic Products student book, in PDF format. Because this advance material has not yet been through all checking stages, it may still contain minor errors.

Jeon Attwood, 2002

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Introduction

Welcome to this GCSE student book, which has been specially written to support you as you work through your Design and Technology course. If you are following a short-course, check with your teacher to see which sections of the book you need to cover. You can find out information about the full-course and the short-course in the next couple of pages.

How to use this book

This student book will help you develop knowledge and understanding about the specialist materials area you have chosen to study within Design and Technology. It includes sections on:
• the classification and selection of materials
• preparing, processing and finishing materials
• manufacturing commercial products
• design and market influence.

As you work through each section, you will find 'Things to do', which test your understanding of what you have learned. Your teacher may ask you to undertake these tasks in class or for homework.

At the end of each section you will find a number of questions that are similar in style to the ones in the end-of-course exam. In preparation for your exam it is a good idea to put down on a single side of A4 paper all the key points about a topic. Use sub-headings or bullet point lists and diagrams to help you organize what you know. If you do this regularly throughout the course, you will find it easier to revise for the exam.

The book also includes sections that cover the coursework requirements of the full-course and the short-course. These coursework sections will guide you through all the important designing and making stages of your coursework. They explain:
• how to organize your project
• what you have to include
• how the project is marked
• what you have to do to get the best marks.

You should refer to the coursework sections as and when you need.

The GCSE Design and Technology full-course

The GCSE Design and Technology full-course builds on the experience you had of all the five materials areas at Key Stage 3:
• Food Technology
• Textiles Technology
• Resistant Materials Technology
• Graphic Products
• Systems and Control Technology.

Each of the five materials areas will provide opportunities for you to demonstrate your design and technology capability. You should therefore specialize in a materials area that best suits your particular skills and attributes.

What will I study?

Throughout the full-course you will have the opportunity to study:
• materials and components
• production processes
• industrial processes
• social, moral, ethical and environmental issues of products design
• product analysis
• designing and making processes.

The content of this student book will provide you with all the knowledge and understanding you need to cover during the full-course.

You will then apply this knowledge and understanding when designing and making a 3D product and when producing an A3 folder of design work. You should spend up to 40 hours on your coursework project, which accounts for 60 per cent of your Design and Technology course.

At the end of the full course you will be examined on your knowledge and understanding of your chosen materials area. There will be a 1½ hour exam, worth 40 per cent of the total marks. The exam will be made up of four questions, each worth 10 per cent of the marks.

The GCSE Design and Technology short-course

The GCSE Design and Technology short-course is equivalent to half a full GCSE and will probably be delivered in half the time of the full-course. It involves the study of HALF the content of the full GCSE, and the development of HALF the amount of coursework.

The GCSE short-course allows you to work in the materials area you feel best suits your own particular skills and attributes. You can choose from:
• Food Technology
• Textiles Technology
• Resistant Materials Technology
• Graphic Products
• Systems and Control Technology.
The content of this student book will provide you with all the knowledge and understanding you need to cover during the short-course.

You will then apply this knowledge and understanding when designing and making a 3D product and when producing an A3 folder of design work. You should spend up to 20 hours on your coursework project, which accounts for 60 per cent of your Design and Technology course.

At the end of the short-course you will be examined on your knowledge and understanding of your chosen materials area. There will be a 1-hour exam, worth 40 per cent of the total marks. The exam will be made up of three questions.

Managing your own learning during the course
At GCSE level you are expected to take some responsibility for planning your own work and managing your own learning. The ability to do this is an essential skill at Advanced Subsidiary (AS) and Advanced GCE level. It is also highly valued by employers.

In order that you start to take some responsibility for planning your own work, you need to be very clear about what is expected of you during the course. This book aims to provide you with such information. Helpful hints include:

• Read through the whole of the introduction before you start the course so you fully understand the requirements of either the full-course or the short-course.
• Investigate the coursework sections that give you a ‘flavour’ of what you are expected to do.
• Check out how many marks are awarded for each of the assessment criteria. The more marks that are available, the more work you will need to achieve them.
• Discuss the coursework deadlines with your teacher so you know how much time is available for your coursework.

ICT skills
There will be opportunities during the course for you to develop your ICT capability through the use of CAD/CAM. You may have the opportunity to use:

• ICT for research and communications, such as using the Internet, E-mail, video conferencing, digital cameras and scanners
• word-processing, databases or spreadsheets for planning, recording, handling and analyzing information
• CAD software to model, prototype, test and modify your design proposals
• CAM using computer controlled equipment.

Understanding industrial and commercial practice
During your GCSE course you will have the opportunity to develop an understanding of the design and manufacture of commercial products by undertaking product analysis.

You should demonstrate your understanding of industrial practices in your designing and making activities, which could include:

• developing design briefs and specifications
• using market research
• modelling and prototyping prior to manufacture
• producing a working schedule that shows how the product is manufactured
• making a high quality product that matches the design proposal
• testing and evaluating your product against the specification to provide feedback on its performance and fitness-for-purpose.

You should also use the appropriate technical words to describe your work. Many of these words are to be found in this book. When the words first appear they are in bold. This means that you can look up their meaning in the glossary that appears at the end of the book.
Section A:
The classification and selection of materials and components
Paper and boards are the most useful material for the production of graphic products. Wood is the primary raw material for the manufacture of paper and boards because it is widely available and relatively cheap. Other materials can be used such as cotton, straw and hemp, producing papers with different properties.

The production of woodpulp
Wood is made up of fibres that are bound together by a material called lignin. In order to make paper these fibres must be separated from one another to form a mass of individual fibres called woodpulp. This process is carried out at a pulp mill by using either mechanical or chemical pulping. Mechanical pulping is used to produce newsprint for newspapers and chemical pulping produces printing and writing papers.

Quality papers require a pulp that is bright white and will not discolour with age. It is therefore necessary to bleach the pulp using chlorine in order to remove all impurities such as bits of tree bark. Packaging grades such as Kraftliner – used for corrugated board – are, however, left unbleached.

Machine-made paper
The main classification of paper refers to its method of production. Machine-made paper is the most commonly used paper as it is widely available in a range of colours, sizes and finishes for various applications including printing and art and presentation work.

The production of machine-made paper is a continuous process using Fourdrinier machines. Essentially, the woodpulp goes in at one end and passes through a series of rollers, pressers and dryers until eventually rolls of paper come out the other end. Some Fourdrinier machines can be about a mile long!
During this process the opacity, texture, weight and colour of the paper can be determined. For example, during the final stages of production the paper is passed through a series of steel calender rollers. This operation called *calendering* increases the smoothness and gloss of the paper – the more calenders, the higher the gloss.

**Texture and colour**

**Laid paper** is produced by laying rolls of wet paper on a mesh of horizontal or vertical wires. When the paper dries out the striped impression is left. **Wove paper** is produced in a very similar way but on a mesh of woven wires.

A **watermark** can be added to paper in order to create an individual and high quality effect. A raised symbol is placed on the **dandy roll** of the Fourdrinier machine and makes the paper thinner in that shape. Therefore, when held up to the light more light can pass through the watermark than the rest of the paper.

The finish on paper refers to the way its surface has been treated. The roughest finish is called **antique** and is an **uncoated** paper. **Coated** papers include egg-shell and machine finish (MF) paper.

**Coloured dyes** or pigments are added to the wood-pulp during the production of paper to produce a wide range of colours.

**Hand-made paper**

The process of making this type of paper is very slow and expensive as each sheet has to be hand produced. It is usually used for very high quality applications such as letterheads, limited edition books and artists’ paper where unique textures and patterning are important.

**Common thicknesses of paper and board**

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<thead>
<tr>
<th>Sheets</th>
<th>Microns</th>
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<td>200</td>
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<td>3</td>
<td>230</td>
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<tr>
<td>4</td>
<td>280</td>
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<td>6</td>
<td>360</td>
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<td>500</td>
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<tr>
<td>10</td>
<td>580</td>
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<td>12</td>
<td>750</td>
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</table>

**Weight**

Paper is available in different thicknesses or weight which is measured in grams per square metre (gsm). Most paper used in schools will weigh 80 gsm, which is fairly thin. Card and board, on the other hand, are measured in micrometers or microns for short. Mounting board used for presentation work may be as dense as 1000 microns which is pretty thick!

**When does paper become a board?**

Paper usually becomes a board when it is greater than 220 gsm and more often than not is made from more than one ply (sheet). The thickness of card and board can be gauged by the number of plys or sheets it consists of.

**Common sizes**

Paper and board are available in metric ‘A’ sizes. A4 and A3 are the most commonly used in schools and offices (A3 being twice the size of A4). In addition to these there are many other sizes available, including ‘B’ sizes and the old imperial measurements.

![Common ‘A’ sizes of paper and board](image)

**Things to do**

1. Try making your own hand-made paper.
2. Collect examples of laid and wove papers with watermarks to add to your notes.
There was a rapid growth in the use of plastics during the second half of the twentieth century. They have provided alternatives to or have completely replaced many packaging requirements previously carried out by metal, glass and cardboard.

**Historical background**

Plastics were first commercially introduced in the early twentieth century with a product called Bakelite. This was primarily used for the casings of electrical products such as radios as it had excellent electrical insulation properties. Soon a whole host of commercial products was being produced using different types of plastics.

**Production of plastics**

Plastics are members of a family of substances called polymers which have very large chain-like molecules. Each molecule of a polymer contains smaller units called monomers which are joined together. Polymers occur in the natural world, for example amber, animal horn and tortoiseshell. However, it is synthetic (man-made) polymers that are used for plastics.

Synthetic plastic is produced from crude oil. A system of refining and processing the basic chemicals from crude oil produces monomers. Monomers are converted into polymers which are then made into granules of plastic. The plastic granules are processed in various different ways to produce plastic products.

**Thermoplastics and thermosetting plastics**

Plastics can be divided into two main groups due to their specific properties once heated.

**Thermoplastics**

A thermoplastic is a plastic that once heated can be formed into a variety of interesting shapes using different forming techniques. The shape then remains permanent once the plastic has cooled down. The same thermoplastic can be heated, softened, shaped and cooled many times over.

**Thermosetting plastics**

The main difference between a thermoplastic and a thermosetting plastic is that once they are heated, shaped and cooled, they become permanently hard. A thermosetting plastic therefore, cannot be reheated and reshaped.
**Plastics in packaging**

There are six main plastic materials used for the production of packaging (usually known by their initials): PET, HDPE, PVC, LDPE, PP and PS. All of these are thermoplastics.

Thermoplastics are ideal for use in packaging as they can be reheated, reshaped and can therefore be recycled. Without these plastics we could not make many of the unique and unusual designs in modern packaging.

**Plastics for sheet modelling**

Plastics are available in sheet form and can be used for a wide range of applications for graphic products.

**Plastics for block modelling**

Sheet plastics such as acrylic can be laminated (glued together) in order to produce a thick block for the production of some models. It is, however, expanded polystyrene and Styrofoam that are best used for block modelling.

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**Expanded polystyrene**

Expanded polystyrene can be obtained free from the packaging of electrical products. Blocks can be achieved by gluing several pieces together using PVA glue. It is extremely easy to cut with hot wire cutters but tends to crumble when shaped or sanded.

**Styrofoam**

Styrofoam is a specialist modelling material for producing concept models. The advantages of using Styrofoam over laminated MDF are that it is easier to cut and shape. Because of its density, Styrofoam can be sanded to a very smooth finish and painted using acrylic paints.

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**Things to do**

1. Collect examples of sheet plastics for your notes.
2. Make a concept block model of a computer mouse using styrofoam.

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<thead>
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<th>Material</th>
<th>Properties</th>
<th>Applications</th>
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<td>Product prototypes and concept models</td>
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<td></td>
<td>Range of colours available including transparent and translucent</td>
<td>Structures such as interior and architectural models</td>
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<tr>
<td></td>
<td>Excellent surface finish</td>
<td>Point-of-sale displays, stands and leaflet holders</td>
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<tr>
<td></td>
<td>Easily joined using Tensol cement</td>
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<td>Corrflute</td>
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<td></td>
<td>Easily joined using hot melt glue</td>
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<td>Foamboard</td>
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<td>Structures such as point-of-sale displays, architectural models, etc.</td>
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<tr>
<td>High impact polystyrene (HIP)</td>
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<td>LCD display screen for prototype models</td>
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<td></td>
<td>Available for photocopiers</td>
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<td></td>
<td>Easily cut and scored</td>
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<tr>
<td></td>
<td>Flexible</td>
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<tr>
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<td>Easily joined to a range of materials using hot melt glue</td>
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Sheet plastics
Wood can be extremely useful for producing a range of graphic products from interior design models to product prototypes. It is available in a variety of shapes and sizes with each timber having its own properties.

People have always known the special properties of wood. Early humans used wood for fires, to build shelters and to hunt with. As time went on, wood was used for major engineering tasks such as architecture and shipbuilding and highly decorative uses such as furniture and intricate carvings. Every culture in all parts of the world has used wood in some way to benefit its society.

Woods can be divided into three main categories:

- **hardwoods**
- **softwoods**
- **manufactured boards.**

Both hardwoods and softwoods are produced from naturally growing trees, whereas manufactured boards are man-made using natural timber.

### Hardwoods

Hardwoods are produced from broad-leaved trees whose seeds are enclosed. Examples include elm, oak, beech, balsa, mahogany and walnut.

Hardwood trees grow in warm climates such as Africa and South America and take about 100 years to reach maturity. They are usually tough and strong and provide highly decorative finishes. Because of their age and where they grow, many hardwoods are expensive to buy and may only be used in very high quality products. The exception is Balsa wood, which has been used to make models for many years as it is relatively cheap and easy to work with.

### Softwoods

Softwoods are produced from cone-bearing conifers with needle-like leaves. Examples include Scots pine (red deal), parana pine and whitewood.

As softwoods grow more quickly than hardwoods (30 years) they can be forested and replanted which means they are cheaper. Softwoods are also easier to work with and lightweight which makes them more suitable for model making.

### Balancing kiwis made from farm Radiata Pine

**Production of hardwoods and softwoods**

Once a hardwood or softwood tree has been felled (chopped down), it is transported to the timber mill where it is processed into planks or boards ready for use. The first process is called the conversion of timber where the tree trunk is sawn up into usable sizes using large circular saws.
Manufactured boards

The second stage involves the seasoning of the timber by removing all moisture by drying it in either a kiln or in the open air. This is carried out to increase the strength and stability of the timber and its resistance to decay.

The advantages of using manufactured boards are that they are available in wide boards which is not possible with natural timbers where the width depends on the width of the tree trunk. By running the grain of the veneers at 90 degrees to one another, some boards are given added strength. They are also very much cheaper to buy than natural timber and have greater uses in model making.

There are several types of manufactured boards:
- **plywood**
- **blockboard** and **laminboard**
- **particleboard** (e.g. hardboard)
- **fibreboard** (e.g. medium density fibreboard or MDF).

**Things to do**

1. Collect samples of hardwoods, softwoods and manufactured boards for your notes.
2. Investigate the standard sizes for a range of boards using a timber catalogue.
Metals

Aims

- To understand the importance of metals in packaging.
- To understand the production of aluminium and steel from ores.

Metals in packaging

The use of metal as a packaging material is extremely important in the preservation of food. Fresh food can quickly decay and become rotten which was a problem throughout history. During the early nineteenth century, Napoleon (Emperor of France) had the problem of supplying fresh food to his armies in distant countries. Nicholas Appert discovered a preserving process by firstly cooking the food and then storing it in a sealed tin canister – later shortened to tins or cans. Soldiers could now enjoy a healthier diet even when miles from home.

It wasn’t until the 1920s, however, that the canning industry had real commercial success. During this time the use of fast, automated production lines producing over a thousand cans a minute was introduced. Today, over 13 000 million cans are bought every year!

These are some of the advantages of canned food:

- Cans have a long shelf life if stored in a cool, dry cupboard.
- Cans do not need to be refrigerated, which saves energy and money.
- Canning makes a wide range of foods available all year round.
- Canning and cooking preserve the food so reducing the need for artificial preservatives.

The two main types of metals used in packaging are:

- aluminium
- steel (coated with tinplate).

Canned food
Aluminium

Aluminium is a pure metal which is a naturally occurring element that is mined from beneath the land and sea. It is the most plentiful metal element in the earth's crust and is produced from the ore bauxite.

The production of aluminium requires large amounts of electricity due to the expensive electrolytic process involved. There are two main stages:

1 The production of alumina from bauxite

Once the bauxite has been mined, crushed and dried it is refined into alumina. This is done in two stages. First, the bauxite is dissolved in hot caustic soda and then filtered to remove impurities – aluminium oxide is produced. Secondly, the aluminium oxide is ‘roasted’ in a rotary kiln and a white powder is produced called aluminia.

2 The production of aluminium using an electrolytic reduction cell

In the reduction cell the alumina is dissolved in molten cryolite using a steel furnace. The furnace is lined with carbon (forming a cathode) and additional carbon rods (forming anodes) are suspended above the furnace. When a powerful electric current is passed through the heated mixture, aluminium is liberated and is deposited on the carbon lining. This pure aluminium is periodically tapped off the bottom of the furnace and cast into ingots ready for further processing.

Steel

Steel is produced from iron ore which is also widely found and mined.

The production of steel

To produce steel iron ore must first be processed into iron. The iron ore, limestone and coke are heated in a blast furnace using very high temperatures. The limestone is used to remove the impurities from the iron ore.

The iron is added to an oxygen furnace where it is converted into molten steel. This molten steel is cast into ingots ready for further processing. In the case of the canning industry, a strip mill will produce large coils of steel as a raw material ready for the making of cans.

Steel is produced from iron ore which is also widely found and mined.
**The pencil**

The ‘lead’ of a pencil is not in fact made of lead but a graphite composite. This composite can be made in varying degrees of hardness and blackness to give hard (H) or soft (B) grade pencils.

**Hard pencils**

These are pencils that range from grades H to 9H. A hard pencil will have more clay and less graphite content in its lead. This means that it can be sharpened to a fine point which will last a long time. Very hard pencils will mostly be used for technical or more precise drawing where accuracy of line is important.

**Soft pencils**

These are pencils that range from grades 9B to HB. A soft pencil will have more graphite and less clay content in its lead. This means that the lead will be richer and darker but the point will soften easily. Soft pencils will be used for sketching and shading. A general purpose pencil that can be used for sketching and drawing is the HB.

**Fine-liner pens**

Fine-liner pens are popular because they have a number of uses – from sketching like a pencil to ‘inking-in’ technical drawings and from shading small areas to adding notes and lettering to design sheets. Fine-liners will give a good quality line if used properly, but over a period of time the nib can become worn and spread out resulting in a poor quality line.

**Marker pens**

Marker pens are available in two main types: water-based and spirit-based. Both types are available in a wide range of colours and nib styles including chisel, brush and bullet point. Some more expensive, professional markers are double ended with both a chisel and brush point – there are even markers that contain all three!

Marker pens are widely used to cover larger areas with colour. A good quality, spirit-based marker will leave a flat and solid colour whereas less expensive, water-based types may ‘streak’ leaving marks of different shades of colour.

Marker pens are excellent for producing presentation drawings where a designer will want to communicate the final look of a product.

**Drawing-boards**

It is important that any designer has a firm, flat surface to work on. A drawing-board should hold your work securely and have a parallel motion (sliding rule) which will aid technical drawing. The standard paper size for GCSE Design and Technology portfolios is A3 so your drawing-board must be able to accommodate this size of paper. For the professional designer and architect, there are larger boards available as big as A0 (3 times larger than A3!).

**Drawing equipment**

There is a wide range of equipment available to aid the drawing of technical graphics.

**Computer software packages**

Computers are increasingly being used to produce technical graphics or illustrations using computer-aided design.

**Photocopier**

Black and white photocopiers are extremely useful for making multiple copies of documents. Special features on photocopiers also make it possible to...
enlarge and reduce your work to the required size. Documents with several pages can also be photocopied back to back, sorted and stapled if necessary. Colour photocopiers are available for copying in full colour, but copies are quite expensive.

**Airbrush**

Airbrushing can create many interesting and decorative finishes on a variety of materials. Airbrushes produce areas of flat colour or intricate details and are ideal for illustrating surface finishes. It requires great skill and practice to achieve good results. Many professional illustrators use airbrushes.

### Things to do

1. Use technical drawing exercises to develop your technical graphics.
2. Render simple 3D drawings using pencils and marker pens to develop your illustration techniques.

![Airbrushed illustration](image)

<table>
<thead>
<tr>
<th>Name</th>
<th>Equipment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set squares</td>
<td><img src="image" alt="Set squares" /></td>
<td>A drafting aid available in 45° or 30/60° used with a drawing-board and parallel motion to produce technical drawings</td>
</tr>
<tr>
<td>Plastic rule</td>
<td><img src="image" alt="Plastic rule" /></td>
<td>A straight edge for drawing lines with a scale (mm) for measuring. A transparent rule is useful for constructing a series of evenly spaced parallel lines, i.e. for cross hatching</td>
</tr>
<tr>
<td>Compasses</td>
<td><img src="image" alt="Compasses" /></td>
<td>For drawing circles and arcs. A spring bow compass is ideal for drawing small circles and a pencil compass for larger circles. Adaptors can be fitted to some compasses allowing them to hold fine-liners</td>
</tr>
<tr>
<td>Eraser</td>
<td><img src="image" alt="Eraser" /></td>
<td>Used to remove construction lines from technical graphics or correcting pencil-drawn mistakes. Many types are available, but always choose one that does not smudge</td>
</tr>
<tr>
<td>Templates</td>
<td><img src="image" alt="Templates" /></td>
<td>A wide range of shapes and sizes available from simple circle and ellipse templates to standard architectural symbols. Templates provide a quick and effective way of drawing rather than by freehand or technical construction methods</td>
</tr>
<tr>
<td>Curves</td>
<td><img src="image" alt="Curves" /></td>
<td>French curves provide a means of repeating a particular curve without having to construct it technically. Usually available in sets of three. A flexi-curve is a plastic strip with a lead core that can be bent into any desired curve</td>
</tr>
</tbody>
</table>
**Paper**
Choice of paper is important in how printed materials look. Choosing the right paper for the job is a combination of personal preference and common sense. The right paper must satisfy:
- the design requirements, i.e. surface finish, colour, size and weight
- the demands of the printing process or surface decoration
- economic considerations (price).

**Grid papers**
Grid papers are available in a range of styles and are extremely useful for generating design ideas when traced through. Apart from the usual squared grid papers used in maths, there are isometric and perspective grid papers to aid drawing in three dimensions.

**Hints and tips**
Gloss-coated inkjet papers have a major advantage over laminated paper because they can be recycled.

<table>
<thead>
<tr>
<th>Paper</th>
<th>Weight</th>
<th>Description</th>
<th>Uses</th>
<th>Advantages</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layout</td>
<td>Around 50 gsm</td>
<td>Thin translucent paper with a smooth surface</td>
<td>Outline sketches of proposed page layouts. Sketching and developing ideas</td>
<td>Translucent property allows tracing through onto another sheet. Accepts most drawing media (except paints)</td>
<td>Relatively expensive</td>
</tr>
<tr>
<td>Tracing</td>
<td>60/90 gsm</td>
<td>Thin transparent paper with a smooth surface. Pale grey in colour</td>
<td>Same as layout paper. Heavier weight preferred by draughtsmen</td>
<td>Allows tracing through on to another sheet in order to develop design ideas</td>
<td>Heavier weight can be quite expensive</td>
</tr>
<tr>
<td>Copier</td>
<td>80 gsm</td>
<td>Lightweight grade of quality paper good</td>
<td>Black and white photocopying and printing from inkjet/laser printers. Smooth finish for colour printing. General use for sketching and writing</td>
<td>Fairly cheap to buy in large quantities. Bright white and available in a range of colours</td>
<td>Inexpensive when bought in bulk</td>
</tr>
<tr>
<td>Cartridge</td>
<td>120–150 gsm</td>
<td>Creamy-white paper. Smooth surface with a slight texture</td>
<td>Good general purpose drawing paper. Heavier weights can be used with paints</td>
<td>Completely opaque. Accepts most drawing media</td>
<td>More expensive than copier paper</td>
</tr>
</tbody>
</table>

**Inkjet papers**

<table>
<thead>
<tr>
<th>Inkjet Paper</th>
<th>Weight</th>
<th>Description</th>
<th>Uses</th>
<th>Advantages</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coated</td>
<td>80–150 gsm</td>
<td>Bright white, high density, ultra-smooth coated paper</td>
<td>Printing photo quality work with a matte finish, i.e. presentation materials, reports, colour reproductions, etc.</td>
<td>Suitable for 1200 dpi colour inkjet and laser printing Quick drying Recyclable</td>
<td>Expensive (usually sold in small packs)</td>
</tr>
<tr>
<td>Photo glossy</td>
<td>140–230 gsm</td>
<td>Bright white, professional quality, specially coated high gloss paper</td>
<td>Vivid photo quality with maximum colour reproduction suitable for photo reproductions, graphic artwork and presentation materials</td>
<td>Special coating makes it ideal for digital or scanned images with high resolution Quick drying Photo quality Heavyweight Two-sided photo gloss paper also available</td>
<td>Expensive (usually sold in small packs)</td>
</tr>
</tbody>
</table>
**Inkjet papers**

Although smooth finished copier paper can be used for black and white printing, there are a number of papers specifically designed for colour printing.

**Card and board**

There is a wide range of card and boards for a variety of applications. These range from stationery uses such as drawing, writing, photocopying and printing to more creative uses with speciality materials.

**Cartonboard**

Cartonboards are usually used for retail packaging. These boards must be suitable for high quality, high speed printing and for cutting, creasing and gluing using very high speed automated packaging equipment. Advantages of using cartonboard include:

- total graphic coverage and excellent print quality
- excellent protection in structural packaging nets
- relatively cheap to produce and process
- can be recycled.

### Things to do

1. Tear the board on a cereal or soap powder box and you will see its layered structure quite clearly.
2. Collect samples of different types of paper and board to add to your notes.

<table>
<thead>
<tr>
<th>Card/board</th>
<th>Weight</th>
<th>Description</th>
<th>Uses</th>
<th>Advantages</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Card</td>
<td>230–750 microns</td>
<td>A thin variety of board, but thicker than paper</td>
<td>A range of uses from printing and drawing to 3D modelling and presentation work</td>
<td>A large range of colours and surface finishes available including bright and fluorescent colours, duo-tones and metallics and corrugated card types</td>
<td>More expensive than paper. Speciality cards are more expensive than simple white or bright colours</td>
</tr>
<tr>
<td>Mounting board</td>
<td>1000–1500 microns</td>
<td>Extremely thick board with colour on one side only (white on back)</td>
<td>Mounting work for presentations and displays. Work can be mounted flat or behind a frame mounting</td>
<td>Very high quality, strong and rigid board. Available in a range of colours (wide range of pastel colours)</td>
<td>Expensive</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Board</th>
<th>Description</th>
<th>Uses</th>
<th>Advantages</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Folding boxboard</td>
<td>Usually has a top surface of bleached virgin pulp, middle layers made from unbleached pulp and a bleached pulp inside layer</td>
<td>Widely used for the majority of food packaging and for all general carton applications</td>
<td>Excellent for scoring, bending or creasing without splitting Excellent printing surface</td>
<td>Inexpensive</td>
</tr>
<tr>
<td>Corrugated board</td>
<td>Made from sandwiching a fluted paper layer between two paper liners</td>
<td>Protective packaging for fragile goods. The most commonly used box making material</td>
<td>Excellent impact resistance Has excellent strength for its weight Low cost Recyclable</td>
<td>Inexpensive</td>
</tr>
<tr>
<td>White-lined chipboard</td>
<td>Has top layer of bleached wood pulp and a middle and back layer made from waste paper</td>
<td>Food packaging and general carton applications. White-back versions are known as Triplex</td>
<td>Good for high-speed printing of automatically packed cartons</td>
<td>Inexpensive</td>
</tr>
<tr>
<td>Solid white board</td>
<td>Made entirely from pure bleached wood pulp</td>
<td>Packaging for frozen foods, ice-cream, pharmaceuticals and cosmetics</td>
<td>Very strong and rigid Excellent printing surface</td>
<td>Expensive</td>
</tr>
<tr>
<td>Cast-coated board</td>
<td>A heavier and smoother coating applied to white-lined chipboard and solid-white board</td>
<td>Luxury products requiring expensive looking decorative effects</td>
<td>Very strong and rigid Excellent printing surface Higher gloss finish after varnishing</td>
<td>Expensive</td>
</tr>
<tr>
<td>Foil-lined board</td>
<td>Has a laminated foil coating (can be used on all of the above boards)</td>
<td>Cosmetic cartons, pre-packed food packages</td>
<td>Foil available in matt or gloss finish and in silver or gold colours Very strong visual impact Foil provides an excellent barrier against moisture</td>
<td>Expensive</td>
</tr>
</tbody>
</table>

**Common cartonboards**
Choosing plastics

Aims
• To understand why plastics are used for packaging.
• To understand the uses of different plastics for packaging.
• To understand the properties and uses of expanded polystyrene.

Plastics in packaging
Plastics are widely used in packaging because they are:
• versatile
• lightweight
• low cost
• energy saving
• tough and durable
• recycleable.

Plastics can be identified by a coding system usually stamped on to the base of the package or on the label. This is an internationally recognized system that enables plastics to be easily identified for recycling.

For example, a shampoo bottle stamped with the opposite identification mark would be made out of a high density polyethylene plastic and could therefore be sorted visually.

Each plastic has its own useful properties that make it suitable for use in different areas of packaging (see table below).

Plastics versus glass
Glass, once one of the most common materials used for bottling, has increasingly been replaced by the use of plastics. In the obvious case of fizzy drinks bottles, glass is a suitable material, but plastics have proved more successful because they are cheaper, lighter, durable and do not smash if dropped. In the case of the ketchup bottle, the development of a new type of plastic made up of several layers makes it possible to have a squeezable bottle type – unthinkable with glass.

Expanded polystyrene
When we look at a throw-away society we often look towards the USA as a prime example. This is the home of fast food with hundreds of fast-food chains available including the major companies of McDonald’s and Burger King.

Polystyrene is used in fast-food packaging because it is:
• hygienic
• strong, yet lightweight
• efficient
• economical
• convenient.

Hygienic
Tests in the USA (Polystyrene Packaging Council) into the use of disposable polystyrene food service ware such as cups and plates have found that they are more sanitary than reusable service ware. In other words, germs and bacteria are simply thrown away with the rubbish instead of multiplying in a chipped coffee mug.

Strong, yet lightweight
Polystyrene protects against moisture and keeps its strength even after long periods of time. Containers and lids close tightly and prevent any leakage of the contents. It can be moulded into a variety of structural packages which compliment its excellent cushioning properties in protecting the contents of the package.

Efficient
Polystyrene provides excellent insulation. Therefore, hot food can be kept warm for longer periods of time. It also means that the package does not become so hot that it cannot be held in the hand.

Economical
Polystyrene food service products are generally cheaper to buy than disposable paper products and much cheaper than reusable service ware (e.g. china). This is because only about 5 per cent of the foam package is actually plastic – the rest is simply air!

Convenient
This is arguably the major reason for the use of polystyrene in fast-food packaging. With today’s busy lifestyles people want food to be available instantly, and polystyrene is an economical way of serving people with their fast food.

Other uses
Expanded polystyrene has another important use in the protective packaging of many products. It comes in two main forms: loose-fill ‘peanuts’ and shape-moulded packaging. Loose fill ‘peanuts’ allow various sized products such as stationary to be transported in...
the same box without them being damaged. Shape moulded packaging fits snugly around delicate products and the manufacturer’s advertising is clearly printed on the cardboard box into which it fits.

Shop shelves are full of electrical products that are protected by expanded polystyrene but did you know that a Formula 1 racing car can also be packaged for export?

<table>
<thead>
<tr>
<th>Thermoplastic</th>
<th>ID code</th>
<th>Properties</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>PET Polyethylene terephthalate</td>
<td>(a)</td>
<td>Excellent barrier against atmospheric gases and does not allow gas to escape Does not flavour the food or drink contained in it Sparkling ‘crystal clear’ appearance Very tough Light – low density</td>
<td>Carbonated (fizzy drinks bottles) Packaging for highly flavoured food Microwaveable food trays</td>
</tr>
<tr>
<td>HDPE High density polyethylene</td>
<td>(b)</td>
<td>Highly resistant to chemicals Good barrier to water Tough and hard wearing Decorative when coloured Light and floats on water Rigid</td>
<td>Unbreakable bottles (for washing-up liquid, detergents, cosmetics, toiletries, etc.) Very thin packaging sheets</td>
</tr>
<tr>
<td>PVC Polyvinyl chloride</td>
<td>(c)</td>
<td>Weather resistant – does not rot Chemical resistant – does not corrode Protects products from moisture and gases while holding in preserving gases Strong, abrasive, resistant and tough Can be made either rigid or flexible</td>
<td>Packaging for toiletries, pharmaceutical products, food and confectionery, water and fruit juices</td>
</tr>
<tr>
<td>LDPE Low density polyethylene</td>
<td>(d)</td>
<td>Good resistance to chemicals Good barrier to water but not to gases Tough and hard wearing Decorative when coloured Very light and floats on water Very flexible</td>
<td>Stretch wrapping (cling film) Milk carton coatings</td>
</tr>
<tr>
<td>PP Polypropylene</td>
<td>(e)</td>
<td>Lightweight Rigid Excellent chemical resistance Versatile – can be made stiffer than polythene or very flexible Low moisture absorption Good impact resistance</td>
<td>Food packaging – yoghurt and margarine pots, sweet and snack wrappers</td>
</tr>
<tr>
<td>PS Polystyrene</td>
<td>(f)</td>
<td>Rigid polystyrene: • Transparent (clear) • Rigid (can be brittle) • Lightweight • Low water absorption Expanded polystyrene (foam): • Excellent impact resistance • Very good heat insulator • Durable • Lightweight • Low water absorption</td>
<td>Food packaging, (e.g. yoghurt pots), CD cases, jewel cases, audio cassette cases, take-away food packaging, egg cartons, fruit, vegetable and meat trays, cups, etc. Packing for electrical and fragile products</td>
</tr>
</tbody>
</table>

**Things to do**

1. Compile a chart of household plastic bottles and the type of plastics they are made of. Why do you think they are made of this plastic?
2. Expanded polystyrene is a useful packaging material for fast food, but what are its disadvantages?
Choosing wood

Aims
- To understand the qualities of manufactured boards, softwoods and hardwoods in the production of high quality products.
- To understand the need for a suitable mould when vacuum forming.

Product modelling
The most important role wood has to play in a graphic product is in the manufacture of a 3-dimensional (3D) prototype. MDF is an ideal material for producing a high quality product because it:
- can be shaped easily
- has an excellent surface finish.

When designing a product such as a mobile phone, computer mouse or FM radio, MDF can be formed into smooth streamlined shapes essential for modern looking products. MDF is available in sheets usually 9–24 mm in thick but can be glued together (laminated) using PVA to achieve greater thicknesses.

The MDF block can be cut to a rough shape by marking on the plan and side profiles and cut on a bandsaw. Your teacher will have to cut the shape out using the bandsaw as it is illegal for you to do so.

When the rough shape is cut out, it is possible to shape the MDF using tools such as surforms to achieve the desired product styling.

Shaping MDF using a surform

The prototype model can then be sanded extremely smooth using various grades of glasspaper.

Hints and tips
At this stage the MDF has to be sealed using a sanding sealer so that any surface finish applied will not soak into the fibres. Once dry, lightly sand the surface to achieve a smooth and level surface.

A quality finish is achieved by using an acrylic spray primer and sanding it back gently using wet and dry paper. Good quality acrylic car paints are available in a wide range of colours to apply a professional looking top coat.

Achieving a professional looking finish using acrylic car paints

Some products will be circular in shape and will therefore need to be turned using a wood lathe. Softwoods such as pine can be used for such product models because they are available in square sections. Once mounted on a wood lathe it is possible to create some very interesting shapes indeed.
In the photo below, the student first turned the main shape on a wood lathe and then carved the detail of the sweeping speaker grill using a gouge.

The suitable mould needs careful consideration when designing and making. The mould must:
• be very smooth,
• have slightly angled sides (usually 5 degrees),
• have rounded or ‘radiused’ corners and edges.

This will ensure that the mould can be easily removed once vacuum formed.

**Interior and architectural modelling**
A variety of woods can be used for the production of an interior or architectural model. Manufactured boards are useful when creating walls or partitions, whereas the use of hardwoods can give high quality details.

In the photo below, the student has constructed an architectural model using birch-veneered plywood to give a high quality finish.

Hardwoods are not usually used for product modelling as they are expensive and difficult to shape. They are usually used for products where their excellent surface finish is desirable, for example furniture.

**Vacuum forming moulds**
MDF and pine can also be used for the production of moulds for vacuum forming, usually for the purpose of blister packaging. In much the same way as producing a product model, a mould can be cut and shaped to create interesting shapes. MDF is the most suitable wood because it has no grain. This means that the mould will not leave an imprint on the vacuum-formed plastic shape.

**Hints and tips**
Cheaper manufactured boards such as hardboard could also be used and painted or covered in brick-effect paper to give an alternative finish.

**Things to do**
1. Collect examples of each enhancement technique described in this section.
2. Discuss the reasons why a manufacturer may use expensive enhancement techniques on their products.
Aluminium or steel?

Metal packaging is mainly used in closures (screw caps, etc.), food cans and beverage cans. Closures and food cans are usually made from steel and beverage cans are divided equally between aluminium and steel (quantities and percentages vary on a yearly basis).

Steel is commonly used for packaging drinks, aerosols, processed and powdered foods, chocolate and biscuits, paints, adhesives and chemicals, health and beauty products, giftware and closures.

Aluminium is commonly used for packaging drinks, aerosols, health and beauty products, tamper-proof closures and screw caps.

There are several advantages in using both aluminium and steel for packaging:

- Security – sealed cans cannot be tampered with.
- Packages can be made in a variety of shapes and sizes including cylindrical, rectangular and hexagonal.
- Packages can be embossed to provide surface detail.
- Metal can be directly printed on to or a paper label added.
- The packaging itself offers point-of-sale display with all over decoration (product recognition).

Metal appeal

Metal packaging suggests quality, and manufacturers will often use it for special promotions. For example, during the Christmas period many brands of chocolate and biscuits will be available in large and highly decorative metal tins. Some biscuit tins dating from the nineteenth century have even become collectors’ items.
The production of metal cans

Two types of cans widely used are:

- the three-piece welded can (tinplate) used for processed food, for example baked beans
- the two-piece drawn and wall ironed can (either tinplate or aluminium) for beverages, for example soft or alcoholic drinks.

Cold forming an aluminium drinks can

The forming of the two-piece drinks can involves two main stages:

1 **Drawing** – an aluminium disc is pressed under high pressure into a die to form a shallow cup shape.

2 **Ironing** – the aluminium cup shape is drawn down into a deeper die to form the base profile. At the same time an ironing ring thins out the walls of the drinks can.

Advantages of the aluminium drinks can

- Paper thin walls (0.1 mm) save materials and energy.
- Aluminium with internal lacquered coating does not react with the contents.
- Able to withstand the high internal pressures of a fizzy drink.
- Lightweight.
- Relatively inexpensive to produce in quantity.
- Design can be printed directly on to the outside of the can once formed.

As materials technology has developed, can manufacturers have been able to reduce the amount of materials used in the manufacture of a single can. By calculating the stresses acting upon the can the thickness of the material has been reduced and a tapered neck saves even more material without lessening its structural ability.

Things to do

1 Research pictures of old metal packaging and see how they compare with modern metal packaging.
2 Test the strength of a drinks can by (a) crushing the sides using one hand and (b) putting all your weight on top of it (use two friends either side of you to help you balance).
Choosing glass

Aims

- To understand the properties of glass as a packaging material.
- To understand the strong brand identity created by Coca-Cola using the glass ‘hobbleskirt’ bottle.

Glass has many properties that make it ideal for use as a packaging material:
- It is relatively cheap when mass produced.
- It is resistant to mechanical shock.
- It has excellent product visibility.
- It offers excellent protection against contamination.
- Its contents can be preserved through high-temperature processing.
- The lid provides an air tight seal
- It can be re-used and recycled.

Colour

In its purest form, glass has a greenish tint. By adding chemicals in varying quantities to the raw mixture of sand, soda and limestone different colour glass can be produced. This is useful when designing glass containers for a specific product. For example, beer is usually packaged in green or brown glass to protect it from direct sunlight.

<table>
<thead>
<tr>
<th>Colourant</th>
<th>Glass colour(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>Green, brown, blue</td>
</tr>
<tr>
<td>Manganese</td>
<td>Purple</td>
</tr>
<tr>
<td>Chromium</td>
<td>Green, yellow, pink</td>
</tr>
<tr>
<td>Vanadium</td>
<td>Green, blue, grey</td>
</tr>
<tr>
<td>Copper</td>
<td>Blue, green, red</td>
</tr>
<tr>
<td>Carbon and sulphur</td>
<td>Amber, brown</td>
</tr>
</tbody>
</table>

Glass versus plastics

Glass has one major advantage over the use of plastics – it looks expensive and therefore has the image of sophistication. For example, to use a plastic bottle for an expensive vintage champagne would be inappropriate. Glass can be formed into interesting shapes that resemble expensive crystal glasses and give the product a look of quality.

The Coca-Cola ‘hobbleskirt’ bottle

The use of glass in packaging is perhaps best illustrated by the Coca-Cola bottle. Who could mistake the shape of the Coca-Cola bottle? Even in silhouette, this classic bottle design is easily recognizable. Modern plastic (PET) Coca-Cola bottles have been designed to resemble the glass bottle because of its strong brand identity.

Could an expensive product like champagne be packaged in any material other than glass?

The Coca-Cola ‘hobbleskirt’ bottle has become an icon of the twentieth century.
John Pemberton, who invented Coca-Cola in 1886, originally used plain bottles with paper labels to sell the Coca-Cola syrup to shops or ‘soda fountains’. At fountains the syrup was mixed with plain water and served to customers. Later, carbonated water was used and bottled so that people could enjoy the soft drink away from the soda fountains.

The early bottles were not marked with the Coca-Cola trademark. Instead, they simply used existing bottles from various manufacturers. By the end of the nineteenth century, a variety of bottles had been introduced, some of which had the Coca-Cola trademark blown into the glass during the forming process.

However, these early bottles did not give Coca-Cola a strong brand image and the need for a standardized bottle was finally considered. A Coca-Cola company executive at the time stated: ‘We need a bottle which a person can recognize as a Coca-Cola bottle when he feels it in the dark’. Bottle manufacturers were invited to submit designs for the new bottle and the winner was chosen at the annual 1916 Coca-Cola Bottlers Convention.

The winning design was based upon the shape of a cocoa pod with an exaggerated bulge around the middle. The original prototypes had to be modified in order to fit automatic bottling equipment by slimming the bottle to its now classic contour shape.

By 1920, the new standardized bottle – called a hobbleskirt bottle because its shape resembled a dress fashion of the day – was in widespread use throughout the United States.

**Things to do**

1. Make a list of all the products you can think of that use glass packaging. Explain why the manufacturer has used glass rather than any other material.
2. Find out if there are any glass recycling schemes in your local area.
3. Design a new glass bottle for the packaging of a new soft drink.
Aesthetic components

There is a range of components available for adding surface detail and texture to block models in order to make them look more realistic.

### Component Table

<table>
<thead>
<tr>
<th>Component</th>
<th>Example</th>
<th>Applications</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modellers' raised plastic letters</td>
<td><img src="example.png" alt="Example" /></td>
<td>Professional looking raised numbers or lettering for prototype models</td>
<td>Gives the appearance of low relief moulding on models as produced by the injection moulding process</td>
<td>Expensive. Tricky to remove from sprue and apply to surface of model</td>
</tr>
<tr>
<td>Self-adhesive paper labels</td>
<td><img src="example.png" alt="Example" /></td>
<td>For adding surface texture or decoration to models, e.g., representing grip texture</td>
<td>Available in a range of different styles and colours. Cheap.</td>
<td>Tricky to apply in straight lines to emulate grip texture on models.</td>
</tr>
<tr>
<td>Dry-transfer letters</td>
<td><img src="example.png" alt="Example" /></td>
<td>Rub-down lettering for adding flat numbers and lettering to the surface of block models or paper and card models</td>
<td>Relatively easy to apply. Available in a wide range of fonts, colours and sizes and in architectural symbols, textures, vehicles and people.</td>
<td>Expensive – the use of computer-generated text may be an alternative.</td>
</tr>
</tbody>
</table>

### Functional components

<table>
<thead>
<tr>
<th>Component</th>
<th>Example</th>
<th>Applications</th>
<th>Hints and tips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper fasteners</td>
<td><img src="example.png" alt="Example" /></td>
<td>Creating pivots for card mechanisms or ergonomes.</td>
<td>Do not tighten. Allow all moving parts to move freely.</td>
</tr>
<tr>
<td>Paper clips</td>
<td><img src="example.png" alt="Example" /></td>
<td>Temporarily attaching pieces of paper and card, e.g., securing tracing paper over a drawing when copying.</td>
<td>Avoid marking paper with one of points or crinkling paper.</td>
</tr>
<tr>
<td>Drawing pins</td>
<td><img src="example.png" alt="Example" /></td>
<td>Attaching presentation work to display boards.</td>
<td>Press firmly into material without bending the drawing pin.</td>
</tr>
<tr>
<td>Mapping pins</td>
<td><img src="example.png" alt="Example" /></td>
<td>Attaching presentation work to display boards. Indicating the positions of important information, e.g., on a map or diagram. Securing the jointing of foamboard walls on a model while gluing.</td>
<td>Use only on soft display board material (will bend in hard material). Use various colours to indicate different features.</td>
</tr>
</tbody>
</table>
Functional components
Many graphic products require the use of components for securing and fixing graphic media such as paper and card. All of those described opposite are inexpensive to buy.

Binding methods
There are five main methods of binding a brochure, magazine or book. Some of these will be suitable when producing printed materials in your projects.

<table>
<thead>
<tr>
<th>Method</th>
<th>Picture</th>
<th>Description</th>
<th>Applications</th>
<th>Application in schools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saddle-wire stitched</td>
<td>(a)</td>
<td>The simplest method of binding by stapling the pages together through the fold</td>
<td>Documents for presentation</td>
<td>Use a long-arm stapler to enable you to staple the document through the fold</td>
</tr>
<tr>
<td>Side-wire stitched</td>
<td>(b)</td>
<td>Staples are passed through the side of the document close to the spine. Used when the document is too thick for saddle-wire stitching</td>
<td>Documents for presentation</td>
<td>Use an ordinary stapler to staple the document along its side</td>
</tr>
<tr>
<td>Perfect binding</td>
<td>(c)</td>
<td>Pages are held together and fixed to the cover by means of a flexible adhesive. This method produces a higher quality presentation and the spine can also be printed on</td>
<td>High quality documents for presentation, magazines, less expensive books</td>
<td>Not possible in school. Take document to a commercial printer for binding</td>
</tr>
<tr>
<td>Hard-bound or case-bound</td>
<td>(d)</td>
<td>Usually combines sewing and gluing to create the most durable method of commercial binding. Stiff board is used on the cover and back to protect the pages</td>
<td>Books</td>
<td>Not possible in school. Take document to a commercial printer for binding</td>
</tr>
<tr>
<td>Spiral or comb-binding</td>
<td>(e)</td>
<td>Pages are punched through with a series of holes along the spine. A spiralling steel or plastic band is inserted through the holes to hold the sheets together</td>
<td>Documents for presentation</td>
<td>Use a comb binding machine</td>
</tr>
</tbody>
</table>

**Things to do**
1. Make a simple card linkage mechanism using paper fasteners as pivots.
2. Use a binding method to present a product analysis report.
Glass is one of the earliest materials used for containing food and drink and continues to be used for a range of packaging uses.

The ingredients of the most common commercial glasses are sand, limestone and soda. These ingredients are heated at a temperature of around 1500°C and react to form a liquid. This liquid can then be moulded into shape and allowed to cool so it forms a hard, inert and transparent material. However, glass can be made in a variety of ways containing different chemicals to produce glasses with different properties and colours for varying uses.

**Food storage**
Glass containers have been used since Roman times as a means of storing food. It was not, however, until the nineteenth century that glass was used to help preserve foods. It was discovered that certain foodstuffs such as fruit, meat, fish and vegetables when heated at high temperatures and sealed in glass jars could be preserved for long periods of time. Glass was an ideal material as air could not penetrate through it and spoil the food.

**Bottles for soft drinks**
Until the beginning of the seventeenth century, nearly all bottles were made of earthenware, metal, wood or leather. Early stoppers were made out of wax, later replaced by cork. The earthenware bottles used by the early mineral water manufacturers were unsatisfactory as the gas could escape at high pressures. In 1814 the first egg-shaped glass bottle was patented for bottles of artificial mineral water or ‘pop’ which had a much greater resistance to internal pressures. Later, the now famous Codd bottle was introduced. It contained a glass marble that was kept pressed against a rubber ring in the neck of the bottle by the internal gas pressure resulting in an air tight seal. Nowadays, most glass bottles either have a crown cap or screw cap for convenience.

**Milk bottles**
Until World War 1, milk was sold from churns pushed around the streets in hand carts. This could be extremely unhygienic, so shortly after the war milk was pasteurised (sterilized to kill bacteria by heating) and sold in sealed glass bottles. Milk is still available in glass bottles with aluminium tops, but this is becoming increasingly uncommon due to the availability and cost of large plastic milk bottles in supermarkets.

**Manufacturing glass containers**
Early glass containers were blown by hand by craftsmen, but they were usually thick and heavy because the blower could not control the glass distribution. Modern manufacture uses automatic processes for mass production.

---

**Aims**
- To understand the importance of glass as a packaging material throughout history.
- To understand the manufacturing processes of glass containers.

---

**Things to do**
1. Discuss the reasons why glass milk bottles have become increasingly uncommon.
2. List a range of products that are still packaged using glass containers.
Raw materials are automatically mixed and fed into the furnace where they are heated and fused at approximately 1500°C. Molten glass is fed into a machine where it is automatically blown. Bottles are made in two stages. First, a parison shape is blown. This is transferred to a second mould in which the bottle is blown to its final form. Bottles are inspected and despatched for filling, capping and labelling.

Glass melting furnace

Tunnel called a lehr in which bottles are reheated and gradually cooled to prevent stresses developing.

Making glass containers by automatic process

1. Gob dropped into blank mould
2. Plunger presses blank shape
3. Blank pressed
4. Blank shape
5. Blank transferred to blow mould
6. Final shape blown
7. Finished jar

The automatic press and blow process

1. Gob dropped into blank mould
2. Neck formed
3. Blank blown
4. Blank shape
5. Blank transferred to blow mould
6. Final shape blown
7. Finished bottle

The automatic blow and blow process
1. Packaging is an important part of a product.
   a. Complete the table below by:
      i. naming three more packaging materials
      ii. providing a specific example for the use of the named material. (6 marks)

<table>
<thead>
<tr>
<th>Packaging material</th>
<th>Example of packaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper and boards</td>
<td>Easter egg boxes</td>
</tr>
<tr>
<td>Corrugated card</td>
<td></td>
</tr>
<tr>
<td>Expanded polystyrene</td>
<td></td>
</tr>
<tr>
<td>Solid board</td>
<td></td>
</tr>
</tbody>
</table>

b. Corrugated card and expanded polystyrene are often used to package electrical products. For each of these materials describe its application and characteristics that makes it useful for this purpose. (6 marks)

c. Solid board is another material used for packaging electrical products. Give two advantages and one disadvantage of its use instead of corrugated card. (3 marks)

2. The diagram below shows a shop window display for the promotion of a new video release.

   a. Two points of specification are:
      • the Astro-man figure should be life sized
      • the whole display should be lightweight for easy installation/transportation.

   Give two more points of specification which would be in the specification for this display. (2 marks)

b. Name the type of material suitable for:
   i. printing the computer graphic on
   ii. making the Astro-man figure
   iii. making the Astro-man lettering. (3 marks)

c. Give one property associated with one of the materials you have named in (b) and explain how this property makes it suitable for this application. (4 marks)

3. A plastic drinks bottle is shown to the right.

   a. Medium density fibreboard (MDF) or polystyrene block may have been used for making a prototype of this bottle.
      i. Give two advantages of MDF over polystyrene for this purpose. (3 marks)
      ii. Give one advantage of polystyrene over MDF for this purpose. (1 mark)

   b. The bottle is made from PET. Describe three properties of PET that relate to its intended use. (6 marks)
Section B:
Preparing, processing and finishing materials

The Rocky 4 Mars Pathfinder Rover prototype goes through its paces at the jet propulsion laboratory. The Pathfinder Mission to Mars in 1997 was a much publicized success.
Corrugation

**Aims**
- To show that corrugation is a strengthening technique.
- To illustrate the various forms of corrugated board and their properties.

**The basic principle**
Corrugation is a strengthening technique where a sheet of material is shaped into alternate ridges and grooves. For example, a flat sheet of card is very easy to bend, but when bent into a series of ‘V’ shapes it becomes rigid and harder to bend.

**Making corrugated board**
There are three main stages in the manufacture of corrugated board:
1. Processing of wood to produce semi-chemical paper, then forming the paper into flutes.
2. Processing of wood to produce Kraft papers for liners.
3. Bonding the fluting and liners together.

**Fluting**
Semi-chemical paper is used for making the fluting in corrugated board. Birch hardwood is usually used in Europe as it is quick growing and easy to farm. The birch trees are fed through machines to produce wood chips and the fibres are separated using both mechanical and chemical methods. The fibres are then made into paper using a papermaking machine.

Semi-chemical fluting requires heat, moisture and pressure in the corrugator roll nip to bend and move the fibres into the flute shape (see diagram).

**Corrugated board**
Corrugated board is made from layers of paper. The top and bottom surfaces are called liners and the corrugated internal layer is known as fluting. There are three main combinations of corrugated board: single, double and triple wall board. They each have different properties.

<table>
<thead>
<tr>
<th>Board</th>
<th>Characteristics</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single wall board</td>
<td>Calm – high stacking strength from large flute profile</td>
<td>Containers for transporting and storing goods, point-of-sale displays</td>
</tr>
<tr>
<td></td>
<td>Fine – good printing surface; uses less fluting than coarse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extra fine – very good printing surface from closely pitched flutes</td>
<td></td>
</tr>
<tr>
<td>Double wall board</td>
<td>Very good stacking strength from rigid board</td>
<td>Containers for transporting heavy weight goods and goods needing maximum protection</td>
</tr>
<tr>
<td></td>
<td>Very good resistance to shock and puncture</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Good printing surface</td>
<td></td>
</tr>
<tr>
<td>Triple wall board</td>
<td>Very good stacking strength from very rigid board</td>
<td>Transportation of bulk food, chemicals, heavy engineering components, automotive parts, electrical and electronic equipment</td>
</tr>
<tr>
<td></td>
<td>Very good resistance to tear and puncture</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Long life (up to 10 years’ storage capability)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Multi-trip container (reusable)</td>
<td></td>
</tr>
</tbody>
</table>

*Corrugated boards and their characteristics*
The paper must have an 8–9 per cent moisture content as it is fed through heated corrugator rolls at 180°C. The nip pressure at these rollers then forms the paper into the distinctive flute profile. The flute profile can be altered to produce various flute types and sizes.

**Recycled paper**

The use of recycled paper for making both the liner and fluting is now very common. Recycled paper is made from waste paper such as old corrugated cases, newsprint and magazines which are mixed with water, broken up in a pulper, cleaned and processed. They can be made into new single-ply or multi-ply papers.

**Bonding**

The liners are bonded with the internal fluting by the use of a starch adhesive. Starch is produced from maize, wheat or potatoes, and chemicals are added to reduce the point at which it gels (or becomes a solid adhesive).

The flute tips pick up the starch from an applicator roll and the starch absorbs into the flutes. The liner must be warm and damp when the liner and flute tips are pressed together firmly. The starch then gels and the moisture moves out of the starch and into the papers to form a secure bond.

<table>
<thead>
<tr>
<th>Flute</th>
<th>Flute height</th>
<th>Tip radius</th>
<th>Valley radius</th>
<th>Pitch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse</td>
<td>3.2–4.8 mm</td>
<td>105–145</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fine</td>
<td>2.1–3.00 mm</td>
<td>150–185</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extra fine</td>
<td>1.0–1.8 mm</td>
<td>290–320</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Kraftliners**

The liners are made from Kraft papers which have a smooth outer printing surface and a slightly coarser inner gluing surface. Kraftliner is made from at least 80 per cent new softwood pulp and processed into paper at the paper mill.

The wood pulp is sometimes dyed brown to give its distinctive colour or made from bleached fibres to give a bright white appearance. Alternatively, a layer of bleached white fibres can be added to a layer of brown fibres in the papermaking machine or a clay/latex coating can be added.

**Type** | **Ply** | **Printing surface** | **Cost**
---|---|---|---
Brown Kraft (unbleached) | Single ply or multi-ply at least 80% new fibre | Fairly good | Expensive
White Kraft (bleached) | Single ply or multi-ply strong new fibre | Very good | Very expensive
White-top Kraft (bleached top ply) | Multi-ply strong new fibre | Very good | Expensive, but cheaper than bleached Kraft of same weight
Coated Kraft | Clay/latex coating on bleached Kraft and white-top Kraft papers | Excellent | Very expensive

**Kraftliner types**

**Things to do**

1. Try making your own corrugated board from two pieces of paper as liners and a concertinaed piece of paper to act as the internal fluting.
2. Look out for the use of single, double and triple walled board in corrugated cases.

**Hints and tips**

- Coarser flutes have greater stacking strength.
- Finer flutes produce a better printing surface.
- Double wall board combines both advantages.
- Triple wall board has a very high stacking strength and is long-lasting.
Laminating

Aims
- To describe the properties of laminating in wood, plastics and paper.
- To explain the characteristics of materials used in laminates for packaging.

The basic principle
Lamination is both a strengthening and decorative technique. This process is used in a range of products and in different materials.

Laminating wood
Timber is a useful structural material which has two major disadvantages:
- It is not uniform in strength due to knots and other defects.
- It is not always available in large sizes and, when available, is costly.

Defects can be overcome by laminating – taking a number of thin pieces (veneers) and gluing them together to form beams or sheets (plywood).

In the case of plywood the layers are placed with the grain running in alternate directions to give strength in both directions. By bending laminated layers of ply around a former it is possible to create curved shapes.

Laminating plastics
The lamination of thermoplastics such as acrylic can add strength (acrylic is very brittle) or more importantly add a decorative effect. By laminating several pieces of acrylic sheet together using Tensol cement, it is possible to create a multi-coloured ‘liquorice allsort’ effect. The block can then be finished and polished to a high sheen.
Laminating paper and card
Laminating paper or thin card can enhance the appearance and add protection to printed materials. The plastic surface finish makes the card more durable, such as bus passes where the card is used regularly, and also gives it a wipe-clean surface for use on menus in restaurants.

Packaging laminates
Laminates are used in packaging to great effect. Plastic films or coatings are added to materials in order to produce different characteristics.

Plastic coatings are added to cartons to give extra protection. A layer of polythene is added which protects the food or liquid contents from contamination by air or moisture. For an even longer life, a layer of aluminium foil is added.

Aluminium foil
Aluminium foil is an important part of packaging laminates. It is used for a variety of products from chocolate wrappers, tea, coffee and biscuits to pharmaceuticals and healthcare products.

Thin, clear plastic foils are often used in packaging laminates to:
- sandwich and protect a printed surface
- provide an attractive surface finish
- provide an excellent barrier against moisture
- add durability and strength
- enable the product to be heat sealed for hygiene, i.e. air-tight seal to prevent contamination and keep product fresh.

For example, some coffee packaging (filter coffee) uses laminates of polyester films and aluminium foil. The print is protected by printing it on the underside of the film, so it is sandwiched between the film and the foil. The laminate can also be vacuum moulded into a block shape for easy shelf stacking.

Paper, foil and polythene laminates
Paper, foil and polythene laminates combine the characteristics of all three materials into a single package. In general:
- foil provides a barrier to moisture
- polythene can be heat sealed
- paper provides excellent print quality.

Things to do
1 Examine curved pieces of wood to determine whether they have been formed using laminated plywood.
2 Make a laminated key fob shape from small pieces of sheet acrylic of different colours.
3 Tear a laminated package to see the cross-section of the laminate.
There are four main printing processes used in commercial printing:
• lithography
• letterpress
• gravure
• screen printing (this is looked at on pages 36–37).

Each has its own characteristics that make it suitable for different applications.

**Lithography**
Lithography is the most widely used process in commercial printing because it is economical, versatile and capable of printing high quality images on a wide variety of papers.

**The basic principle**
The lithographic process literally means stone writing. The basic principle is that water and grease do not mix. Originally, a grease crayon was used to draw the image on a slab of limestone and then dampened with a water solution. The greasy image rejects the solution and the surrounding area accepts the solution. When the ink is applied to the stone the image area accepts the ink and the surrounding area rejects the ink. The image is then transferred with a press from the stone to the paper.

**Modern offset litho**
In modern offset litho (lithography) the flat stone has been replaced by three cylinders: the plate, blanket and impression cylinders. In operation, the aluminium printing plate is dampened with a water solution that the image rejects and the surrounding area accepts. When the plate is inked the image area accepts the ink. The inked image is then transferred from the plate cylinder to the blanket cylinder which ‘offsets’ or prints on to the paper as it passes between the blanket and impression cylinders.

**Letterpress**
Letterpress is the oldest printing process of the four but has been widely replaced by offset litho. Letterpress produces higher quality printed text due to the dense ink used, whereas lithography uses a diluted ink.

*The offset litho printing process*
The basic principle
Letterpress is a relief printing process which means that the image to be printed is raised above the non-printing background. A dense ink is applied to the raised image and transferred with a press from the printing plate to the paper.

Modern rotary letterpress
The most common form of letterpress in modern commercial printing is the rotary letterpress. Here the printing plate is made from a flexible metal or plastic and clamped to a cylinder. The plate cylinder revolves against ink rollers and in turn makes an impression on the paper that is continuously fed between the plate and impression cylinders.

Gravure
Gravure is used to produce high quality photographic images because of its excellent reproduction of fine detail. Its main disadvantage, however, is that it is a high cost process mainly due to the expense of making the original printing plate.

The basic principle
Gravure is opposite to letterpress in the fact that the printing image is recessed or lower than the non-printing surface. The image is engraved into a copper printing plate creating cells which are filled with a thin, spirit-based ink. The paper is pressed into the ink-filled cells to produce the printed image.

Modern web-fed gravure
Most modern gravure printing is done with web-fed machines which use large reels of paper. The cells are filled with liquid ink and a blade is pulled across the cylinder to remove any excess. As the paper is fed continuously through the press by a rubber covered cylinder, it is pressed into the cells to pick up drops of ink to form the final printed image. The spirit-based ink dries through evaporation immediately after printing.

Things to do
1. What does the term ‘offset’ mean in the offset lithographic process.
2. What is the difference between web-fed and sheet-fed printing processes?
Screen printing
Screen printing is an extremely versatile printing process because it can be used on virtually any type of material.

The basic principle
A stencil is supported on a screen, originally made of silk but now often a synthetic fibre, and stretched tightly over a frame. A thick ink is spread across the screen using a rubber squeegee forcing the ink through the screen and the stencil’s printing area on to the paper. The non-printing area of the stencil stops the ink from passing through it and prevents the background from being printed.

By rotating the carousel several times with screens containing different portions of the image and by using several coloured inks, the completed full colour image is built up.

Aims
- To understand the screen printing and flexographic printing processes.
- To understand the advantages and disadvantages of printing processes and the correct printing process for specific materials.

Other printing processes
In addition to the four main printing processes, there are a number of other processes in operation for specific uses. For example, when printing directly onto glass, ceramic decoration is used. This is basically a screen printing process using enamels (instead of inks) that are baked at very high temperatures. The most widely used of the other printing processes is flexography.

Flexography
Flexography is similar to letterpress in using a relief plate, but as the name suggests, it uses a flexible plastic or rubber printing plate instead. Flexography is used mainly for packaging where materials other than paper are used such as PVC for shrink sleeves or foil and foil laminates. It can, however, be used to print any material that will pass through the printing press. Its major application is in the printing of local and national newspapers and less expensive magazines because of high printing speeds and the quick make up of printing plates. Its speed and cheapness have also made it ideal for printing paperback books which, in turn, have enabled paperbacks to become widespread and be sold relatively cheaply.
Each printing process has its advantages and disadvantages that make it suitable for various printing applications.

**Things to do**

1. Find out more information on ceramic decoration for printing directly on to glass and dry-offset for printing directly on to metals.

2. Make a set of stencils, cut from card, to simulate the screen printing of an image using three colours.

### Printing processes on different materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Commercial printing process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastics</td>
<td>On to paper labels – lithographic, gravure, letterpress, screen printing&lt;br&gt;On to shrink sleeves – as above&lt;br&gt;On to stretch labels – as above&lt;br&gt;Directly on to plastic – heat transfer labels, gravure, screen printing, dry-offset</td>
</tr>
<tr>
<td>PVC shrink sleeves</td>
<td>Gravure – reverse printed&lt;br&gt;Flexographic – reverse printed</td>
</tr>
<tr>
<td>Glass</td>
<td>On to paper labels – lithographic, gravure, letterpress, screen printing&lt;br&gt;On to polypropylene (PP) labels – as above&lt;br&gt;Directly on to glass – ceramic decoration</td>
</tr>
<tr>
<td>Metals</td>
<td>On to paper labels – lithographic, gravure, letterpress, screen printing&lt;br&gt;Directly on to metal – dry-offset print, reprotherm (transfer system for full colour photographic image)</td>
</tr>
<tr>
<td>Solid board</td>
<td>Lithographic&lt;br&gt;Flexographic&lt;br&gt;Screen printing&lt;br&gt;Gravure</td>
</tr>
<tr>
<td>Foil/film laminates</td>
<td>Flexographic&lt;br&gt;Gravure</td>
</tr>
</tbody>
</table>

### Printing processes

<table>
<thead>
<tr>
<th>Process</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithography</td>
<td>Good reproduction quality especially photographs&lt;br&gt;Cheap printing process&lt;br&gt;Able to print on a wide range of papers&lt;br&gt;High printing speeds&lt;br&gt;Widely available</td>
<td>Colour variation due to water/ink mixture&lt;br&gt;Paper can stretch due to dampening</td>
<td>Business cards, stationery, menus, brochures, posters, magazines, newspapers</td>
</tr>
<tr>
<td>Letterpress</td>
<td>Dense ink gives good printing quality&lt;br&gt;Less wastage of paper than other processes</td>
<td>High cost&lt;br&gt;Slow process</td>
<td>Books with large amounts of text, letterheads and business cards</td>
</tr>
<tr>
<td>Gravure</td>
<td>Consistent colour&lt;br&gt;High speed&lt;br&gt;Ink dries on evaporation&lt;br&gt;Good results on cheaper paper</td>
<td>High cost of printing plates and cylinders&lt;br&gt;Only good for long print runs</td>
<td>High quality art and photographic books, postage stamps, packaging, expensive magazines</td>
</tr>
<tr>
<td>Screen printing</td>
<td>Economical for short runs&lt;br&gt;Stencils easy to produce&lt;br&gt;Can print on virtually any material</td>
<td>Difficult to achieve fine detail&lt;br&gt;Low output&lt;br&gt;Print requires long drying time</td>
<td>T-shirts, posters, plastic and metal signage, point-of-sale displays</td>
</tr>
<tr>
<td>Flexography</td>
<td>High speed&lt;br&gt;Relatively cheap to set up&lt;br&gt;Can print on same presses as letterpress</td>
<td>Difficult to reproduce fine detail&lt;br&gt;Colour may not be consistent</td>
<td>Less expensive magazines, paperbacks, newspapers, packaging</td>
</tr>
</tbody>
</table>