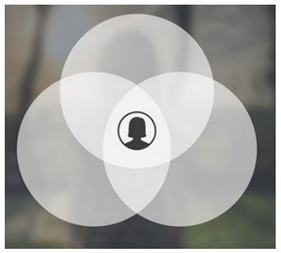
A Level Design and Technology: Product Design

Design Methods and Processes—Iterative Design

Maths/Science Link:
Representation of data used to inform design decisions and evaluation of outcomes.
The use of ergonomic and anthropometric data when designing products for humans and specific applications.

You should be aware of, and able to explain, different approaches to user centred design. That in approaching a design challenge
there is not a single process, but that good design always addresses many issues.

Designing to meet needs, wants or values



Effective user-centred design requires a thorough understanding of your end-user and their needs so that you can tailor your product or service to meet those requirements.

To have the best chance of creating and selling an innovative and commercially successful service or product, you need to have an in-depth understanding of end-users' requirements. End-users are customers or whoever your product or service is aimed at.

User-centred design involves engaging directly with consumers in the early stages of any new product development (NPD) process and keeping them involved throughout. This gives everyone who needs to be involved - such as research, engineering or marketing teams - a clear picture of how their expertise will be called on to benefit the project. Such a unified strategy will reduce the risk of conflicting initiatives wasting your business' time and money.

Traditionally, market testing and user research are done towards the end of the NPD process, but by then significant design changes are not always viable. You will have a much better chance of business success if you actively involve your end-users in the design process.

We should consider people's needs and values because people are more likely to want to use our products if our products meet their needs and match their values. We can find information about a person's needs and values by carrying out research.

Investigations to inform the use of primary and secondary data

Market research
Interviews
Human factors
Identifying physical needs of a specific target group
The physical needs of a target group refers to the size and strengths of the people who will use your product. The needs of babies and infants will be very different from the needs of teenagers and those of pensioners. The needs of physically able people will be different from the needs of people who are physically disabled in some way such as those that are wheel-chair bound or are blind.

Identifying emotional needs of a specific target group
The emotional needs of people includes their likes and dislikes, their ambitions and the way that they would like people to perceive them. So for example, a teenager may want the best roller blades not only because they perform well but also because people will see that he/she is the sort of person that only uses the best and can handle the best.

Identifying intellectual needs of a specific target group
Identifying the intellectual needs of a specific target group means that we should look at the age and the thinking capability of the people that we are designing for. An infant may need simple products to play with but an infant learns quickly and is usually very curious so products designed for infants are usually colourful and are designed to stimulate imagination, learning and play. Products designed for teenagers and adults on the other hand should be more challenging and suited to a more sophisticated level of thinking.

Identifying sociological needs of a specific target group
The sociology of a specific group refers to the behaviour of the people in the group, e.g. members of a particular club like the Scouts, a swimming club, a gang, computer boffins, etc. The needs, likes, dislikes and dress code, hairstyles etc. of the group need to be researched and taken into account when designing.

Using the information in design proposals
When designing for a particular group of people, known as our "target group", we need to use appropriate research methods to find out what the target group likes, dislikes and needs in as much detail as possible. We can then use the information to write a precise design specification for a product that, when manufactured to the specifications, should meet the requirements of the target group.

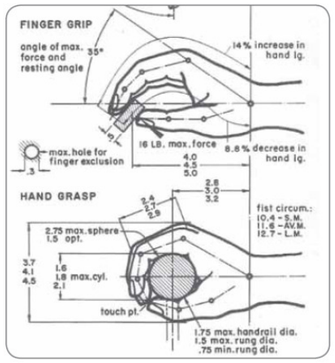
Focus groups
A focus group is used in usability and user research to collect the opinions of a group of users. It consists of a carefully selected group of participants (between 5 and 10), in a comfortable environment with a skilled moderator (facilitator) who uses a script to ask questions of the group, the answers are recorded and then analysed and reported to enable further decision making.

Product analysis and evaluation
Every product is designed in a particular way - product analysis enables us to understand the important materials, processing, economic and aesthetic decisions which are required before any product can be manufactured. An understanding of these decisions can help us in designing and making for ourselves.

What does it do? How does it do it? What does it look like? All these questions, and more, need to be asked before a product can be analysed. As well as considering the obvious mechanical (and possibly electrical) requirements, it is also important to consider the ergonomics, how the design has been made user-friendly and any marketing issues - these all have an impact on the later design decisions.

Companies analyse competitor products in order to understand their products, their material choices and manufacturing methods, amongst others.

The use of anthropometric data and percentiles



Anthropometrics is the use of body measurements to determine the optimum size for products for comfortable and efficient use. Examples of anthropometric data include:
- How far people can reach;
- How much space people need;
- How much force they can exert;
- Height of a person;
- Length of arms/legs etc.

Many production companies use anthropometric data when designing. The designer's aim is to achieve as good an anthropometric match for as many potential consumers as possible.

British Standards Institute (BSI) (www.bsi.org.uk/education) provide data charts relating to measurements for men, women and children.

Statistical data supplied by the BSI is associated with average heights. In this data, 5% of people are below average height and 5% are above average height. Therefore, this anthropometric data covers 90% of the population, for example, if a chair is designed and bought by 100 people, statistically, it will be anthropometrically suited to 90 of the people who purchased it.

This principle is adhered to in the designing of most products.

Biomechanical and anthropometrical data are closely linked when designing products. A number of areas and factors must be considered when planning size and shape of products, especially those related to posture and movement.

The use of ergonomic data
Ergonomics is the study of the interaction between the human body, products and the surrounding environment.
It is a key factor in the design of all products from furniture to handheld gadgets. It is an essential part of the design process.
The main objective for ergonomists is to improve consumer's lives by increasing their comfort when using products.
When ergonomics is incorporated into industrial machinery and tooling it can increase efficiency, productivity and reduce errors and accidents.
The principles of ergonomics involve designers understanding how humans interact and with products. The methods of focussing on human performance take either a quantitative approach or a qualitative approach.
The quantitative approach relates to the physical fit of the human body in relation to speed of performance and workload.
The qualitative approach relates to the overall comfort experienced by the user.
Everyday situations can be hazardous to health by persistently subjecting the human body to positions and situations that are not comfortable. In western countries, musculoskeletal system (e.g. lower back pain) and psychological illness (e.g. stress) lead to the greatest significance of absenteeism from work. These conditions can be caused by poor quality ergonomic design of equipment.
Therefore in the workplace, improved ergonomics can increase productivity.

The development of a design proposal—as in user centred design, the user is consulted throughout the whole process.
The planning and manufacture of a prototype solution—this allows the business to test out the product.
The evaluation of a prototype solution to inform further development.—the solution is evaluated to improve the product further.

A Level Design and Technology: Product Design

Design Theory

You should be aware of, and able to discuss, how key historical design styles, design movements and influential designers that have helped to shape product design and manufacture.

Design Styles and Movements

You should be aware of, and be able to discuss, key design styles and movements and their principles of design.

Arts and craft movement (see https://www.vam.ac.uk/articles/arts-and-crafts-an-introduction for more information)
The birth of the Arts and Crafts movement in Britain in the late 19th century marked the beginning of a change in the value society placed on how things were made. This was a reaction to not only the damaging effects of industrialisation but also the relatively low status of the decorative arts. Arts and Crafts reformed the design and manufacture of everything from buildings to jewellery.

Many of the people who became involved in the Movement were influenced by the work of the designer **William Morris**, who by the 1880s had become an internationally renowned and commercially successful designer and manufacturer.

Morris only became actively involved with the Arts and Crafts Exhibition Society a number of years after it was set up (between 1891 and his death in 1896), but his ideas were hugely influential to the generation of decorative artists whose work it helped publicise. Morris believed passionately in the importance of creating beautiful, well-made objects that could be used in everyday life, and that were produced in a way that allowed their makers to remain connected both with their product and with other people. Looking to the past, particularly the medieval period, for simpler and better models for both living and production, Morris argued for the return to a system of manufacture based on small-scale workshops.

Like many idealistic, educated men of his era, he was shocked by the social and environmental impact of the factory-based system of production that Victorian Britain had so energetically embraced. He wanted to free the working classes from the frustration of a working day focused solely on repetitive tasks, and allow them the pleasure of craft-based production in which they would engage directly with the creative process from beginning to end.

Art Deco (see https://www.vam.ac.uk/articles/an-introduction-to-art-deco for more information)
Arguably Art Deco – a term coined in the 1960s – isn't one style, but a pastiche of different styles, sources and influences. Art Deco designers borrowed from historic European movements, as well as contemporary Avant Garde art, the Russian ballets, folk art, exotic and ancient cultures, and the urban imagery of the machine age.

One of Art Deco's key sources was its forerunner, Art Nouveau, the fin de siècle style that fell out of fashion in the years before the First World War (1914 – 18). Key elements of Art Nouveau's visual language, such as plant and floral forms, were borrowed and adapted to create an updated vision, as seen in the stylised naturalistic fabric designs of the Atelier Martine.

As the 1920s advanced, many designers turned to the new visual language, colour and iconography of the Avant Garde. Movements such as Fauvism, Cubism, Futurism, De Stijl, Suprematism and Constructivism – frequently bundled together under the label of 'Cubism' – were eagerly absorbed by designers seeking to capture the dynamism of the modern world. British and American critics often used the terms 'Moderne', 'Jazz Moderne' or 'Zigzag Moderne' to characterise such work. Geometric forms worked their way into all aspects of life, including everyday small items such as vanity boxes, cigarette cases, and tableware.

The stock market crash of 1929 saw the optimism of the 1920s gradually decline. By the mid 1930s, Art Deco was being derided as a gaudy, false image of luxury. By the outbreak of the Second World War, this hostility had become intense. Despite its demise, however, Art Deco made a fundamental impact on subsequent design.

Modernism, eg Bauhaus

The built environment that we live in today was largely shaped by Modernism. The buildings we inhabit, the chairs we sit on, the graphic design that surrounds us have all been influenced by the aesthetics and the ideology of Modernist design.

Modernism was not conceived as a style but a loose collection of ideas. It was a term that covered a range of movements in art, architecture, design and literature, which largely rejected the styles that came before it. The methodology flourished in Germany and Holland, as well as in Moscow, Paris, Prague and New York and was prominent in the years between the World Wars.

At the core of Modernism lay the idea that the world had to be fundamentally rethought. The carnage of the First World War and the Russian Revolution led to widespread utopian fervour, a belief that the human condition could be healed by new approaches to art and design. Focusing on the most basic elements of daily life – housing and furniture, domestic goods and clothes – architects and designers set out to reinvent these forms for a new century.

There was a focus on *affordable housing* and *the use of new technologies*. There was also a focus on *rejecting ornamentation*.

Bauhaus
The Bauhaus was arguably the most influential architecture, art and design school of the 20th century. Founded in Weimar, Germany, in 1919 by architect Walter Gropius, it attracted some of the key figures in the evolution of Modernism.

At first the Bauhaus focused on individual handmade craft, but the school soon shifted to a more industrial focal point, merging art and technology and emphasising mass production. Furnishings created there, such as **Marcel Breuer**'s tubular-steel Club Chair (right) and **Marianne Brandt**'s light fittings (above), fit this ethos of standardisation and uniformity.

Despite its reputation for rigour and excellence, the school was closed by Nazi authorities in 1933. Many of its members went abroad, where they were to disseminate Bauhaus ideas through their work and teaching.

Post modernism, e.g. Memphis (see https://www.vam.ac.uk/articles/what-is-postmodernism for more information)
Postmodernism is one of the most controversial movements in art and design history. Over two decades, from about 1970 to 1990, Postmodernism shattered established ideas about art and design, bringing a new self-awareness about style itself. An unstable mix of the theatrical and theoretical, Postmoderism ranges from the ludicrous to the luxurious – a visually thrilling, multifaceted style.

Postmodernism was a drastic departure from the utopian visions of Modernism, which had been based on clarity and simplicity. The Modernists wanted to open a window onto a new world; Postmodernism's key principles were complexity and contradiction. If Modernist objects suggested utopia, progress and machine-like perfection, then the Postmodern object seemed to come from a dystopian and far-from-perfect future. Postmodern designers salvaged and distressed materials to produce an aesthetic of urban apocalypse.

The excitement and complexity of Postmodernism were enormously influential in the 1980s. As the 'designer decade' wore on and the world economy boomed, Postmodernism became the preferred style of consumerism and corporate culture. Ultimately this was the undoing of the movement. Postmodernism collapsed under the weight of its own success, along with the self-regard that came with it. Yet in the 21st century we are still feeling its affects. It gave us a new way of looking at the world that holds today, and a style that is resurgent.

Memphis
In a decade known for indulgence, the designs that emerged from the Memphis Group defined the boundary-pushing postmodernism of the '80s. The abstract and angular furniture and graphic patterns devised by this Italian-based collective were the antithesis of streamlined, midcentury style; one critic described a room of their work as a series of “flat disks, lozenges, and saw-toothed edges; some resemble slices of lemon, toothbrushes and imaginary animals.”

A Level Design and Technology: Product Design
Designers and their Work

Students should be aware of, and be able to discuss, the work of influential designers and **how their work represents the principles of different design movements,** including:

Phillipe Starck (Postmodernism)

One of the most widely known of artist-designer 'names' in the later 20th and early 21st centuries, Starck is one of France's most fêted designers who has worked across a wide range of media. His work epitomizes the intersection of art and design, its often fanciful qualities attracting both critical approbation and criticism, particularly in such commissions as pasta for Panzani (1987). His clients have included many leading international companies with a commitment to extending the visual syntax of design in Europe, the United States, and the Far East. These have included Alessi, Cassina, Driade, Flos, and Vitra. After attending the École Nissim de Camondo in Paris in the 1960s he established a company for the production of inflatable products in 1968. In the following decade he designed a series of nightclubs, establishing the Starck Product Company in 1979. Starck's celebrity status owed much to the design policies of the French State, following the establishment of the VIA (Valorisation pour l'Innovation dans l'Ameublement) in 1980 under the Ministry of Industry and its involvement with designers such as Martin Szekely, Garouste and Bonetti, and Starck himself. He designed a suite of rooms for President Mitterand at the Élysée Palace in Paris in 1982, a commission that led to considerable media attention. His interest in interior design continued during the rest of the decade with commissions in Japan, Spain, and France, the latter including the Café Costes in Paris in 1984 with a three-legged chair that was put into production by the Italian furniture manufacturer Driade. He also designed a number of hotel interiors, such as those of the Royalton (1988) and Paramount (1990) hotels for the entrepreneur Ian Schrager, and was also involved with the design of the Groningen Museum (1991) in the Netherlands.

His collaboration with Driade commenced in 1985 and, in addition to the Costes Chair, included the Ubik range (1985) and the Lord Yo chair (1994). Another significant collaboration with Italian manufacturing industry was with Alessi, commencing in 1986, and incorporated such iconic products as the Hot Bertaa kettle and Juicy Salif lemon squeezer (1990). Much of his work was highly individualistic, with strong artistic leanings. On occasion his work was literally experimental, as in his competition design of a plastic bottle for the mineral water company Vittel in 1986. On other occasions he paid homage to the fine arts, typified by his celebrated toothbrush (1990) for Fluocaril, a brand name of Goupil Laboratories, its sinuous form paying homage to the work of the sculptor Brancusi. Reference to other fields of creativity embraced film, acknowledging the work of a fashionable director in his design of the Wim Wenders stool (1992) for Vitra. Lighting designs ranged from the intimate to the large scale, such as the playful Miss Sissi table lamps (1991) and Romeo Babe pendant light (1996) for Flos and distinctive street lamps (1992) for Decaux. Industrial designs have also, since 1990, culminated in audio-visual products for Thomson such as the Rock 'n Role CD player, the Lux Lux television, and the Perso mobile phone, as well as the Moto 6.5 motorcycle for Aprilia. Amongst other notable commissions were an imaginary house for Les 3 Suisses and the Good Goods catalogue for La Radoute in which, in 1998, he presented over 200 product ideas.

James Dyson (Postmodernism)

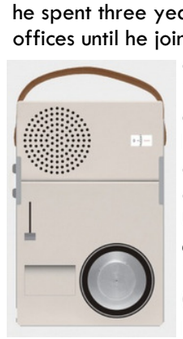
British inventor, entrepreneur, and industrialist Dyson first came to notice with his design of the Ballbarrow, which won a Building Design Innovation Award (1977). Having sold his interests in this product, he developed the innovative G-Force vacuum cleaner. Unable to interest any European manufacturers to invest in its manufacture he worked with a Japanese company that launched it in 1986. His pink, Postmodern design soon attracted critical attention and was included in a number of significant exhibitions of British design. In 1993 Dyson opened a Research Centre and Factory in Chippenham, Wiltshire, producing the DC01 cleaner which became the best-selling cleaner in the market place. Dyson objects have become style icons, reflected in the 1996 launch of the colourful limited edition De Stijl DC02 vacuum cleaner, the standard edition of which was awarded Millenium Product status by the Design Council in 1998. Dyson products may be found in many design collections around the world including London's Design Museum and the Victoria and Albert Museum. They are also widely exhibited around the world, as at the Osaka Design Centre, Japan, in 2003. In 1997 Dyson became a member of the Design Council and a Trustee of the Design Museum. His interest in education is reflected in the establishment of the Design Museum's Dyson Centre for Design Education and Training and his membership of the Council of the Royal College of Art, his alma mater where he studied furniture and interior design in the late 1960s. His company has diversified into washing machines and has subsidiaries in Spain and Japan. More recently he has transferred his manufacturing capacity from Britain to South East Asia.

Margaret Calvert (Modernism)

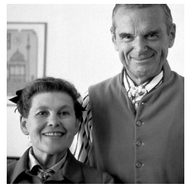
South African-born British typographer and graphic designer Margaret Calvert designed many of the road signs used throughout the United Kingdom with colleague Jock Kinneir. She also designed the Transport font used on road signs and the Rail Alphabet font used on the British railway system. The typeface developed by Calvert and Kinneir was further developed into New Transport and used for the single domain GOV.UK website in the United Kingdom.

Dieter Rams (Modernism)

The clarity of form and minimalist design vocabulary associated with the German designer Dieter Rams is closely identified with the Braun company. Many of his designs for domestic appliances and audio equipment feature in the permanent collections of leading museums that collect and promote design, such as the Museum of Modern Art, New York, which began to collect Braun products in 1958. After studying architecture at the Wiesbaden Academy of Applied Arts from 1947 to 1953 he spent three years as an apprentice cabinetmaker. This was followed by a period in architectural offices until he joined Braun in 1955. The clean, austere appearance associated with a functional aesthetic was epitomized by Rams's and Hans Gugelot's design of the Phonosuper SK4 radiogram of 1956, sometimes dubbed 'Snow White's Coffin'. At this time he was also involved in furniture development with the designer, physicist, and entrepreneur Otto Zapf (born 1931). He became Braun's design director in 1960 and was responsible for establishing a cleanly stated and distinctive aesthetic for a wide range of products from kitchen appliances to alarm clocks, calculators, lighters, and electric razors. This aesthetic was also in tune with the outlook of the Hochschule für Gestaltung at Ulm, a progressive design academy with links to Braun that had been first established in 1954. Other companies with which Rams has been associated include the furniture manufacturer Vitsoe (established 1959), the door handle manufacturer FSB (established 1881), and the lighting producer Tecnolumen (established 1980). His clearly articulated and austere 606 shelf unit for Vitsoe (1960) remained in production for more than 40 years. He has held a number of academic posts including, from 1981, a professorship in industrial design in Hamburg. In 1987 he became president of the German Rat für Formgebung (Design Council), which for many years had promoted the values associated with ideas of 'Good Design'. By this time many of the design values espoused by Rams were increasingly challenged by the content-rich visual language associated with Postmodernism. Dieter Rams has received many international design awards throughout his career.



Charles and Ray Eames (Modernism)



Charles and Ray Eames practiced design at its most virtuous and its most expansive. From the 1940s to the 1970s, their furniture, toys, buildings, films, exhibitions, and books aimed to improve society—not only functionally, but culturally and intellectually as well. The Eameses' wholehearted belief that design could improve people's lives remains their greatest legacy. Even more remarkable is how they achieved their seriousness of purpose with elegance, wit, and beauty.

Challenges posed to them by clients or—as with most creative geniuses—posed by themselves, included:

- how to produce affordable, yet high-quality furniture
- how to build economical, yet well-designed space for living and working
- how to help people see beauty in the everyday
- how to help Americans and other cultures understand each other
- how to make fundamental scientific principles accessible to lay people.

The Eameses' vast body of work illustrates their solutions to these challenges. They also demonstrate the ambition and scope of the Eameses' agenda—from the utilitarian chair to complex issues of human perception, understanding, and knowledge.

Marianne Brandt (Modernism)

Marianne Brandt (1 October 1893 – 18 June 1983), German painter, sculptor, photographer and designer who studied at the Bauhaus school and became head of the metal workshop in 1928. Today, Brandt's designs for household objects such as lamps, ashtrays and teapots are considered the timeless examples of modern industrial design.

A Level Design and Technology: Product Design

How technology and cultural changes can impact on the work of designers

Socio-economic Influences

You should be aware of, and able to discuss, how socio economic influences have helped to shape product design and manufacture.

Post WW1: the Bauhaus and development of furniture for mass production

Modernism is a philosophical movement that, along with cultural trends and changes, arose from wide-scale and far-reaching transformations in Western society during the late 19th and early 20th centuries. Among the factors that shaped modernism were the development of modern industrial societies and the rapid growth of cities, followed then by reactions of horror to World War I.

European and American artists turned their back on the old-world past after the mass slaughter of World War One. Not all Modernists found solace in the breakdown of the old order. Writers like T.S. Eliot found much reason to despair. But designers like **Eero Saarinen** and the husband and wife team **Charles and Ray Eames** embraced industrial techniques (like lamination) and mass production to create forward-looking, minimalist furniture and buildings that still define the way we live now.

The use of tubular steel by **Marcel Breuer** is an example of how new methods of designing and making furniture changed thinking.

WW2: rationing, the development of 'utility' products

Utility furniture refers to furniture produced in the United Kingdom during and just after World War II, under a Government scheme which was designed to cope with shortages of raw materials and rationing of consumption. Introduced in 1942, the Utility Furniture Scheme continued into post-war austerity and lasted until 1952.

By 1941 it had become apparent that the combination of a severe lack of timber suitable for furniture making (in which Britain was not self-sufficient) and the increased demand for new furniture due to the losses of housing caused by bombing and to the continuing establishment of new households after marriage, had created a severe furniture shortage.

New furniture was rationed and was restricted to newly-weds and people who had been bombed out, under the "Domestic Furniture (Control of Manufacture and Supply (No 2)) Order 1942" operative from 1 November 1942.

The Committee were genuine believers in the aesthetic qualities of their designs, however, popular hankering for ornament manifested itself almost immediately, and instances were apparently reported of black market utility furniture with added carvings and decoration. Design rules were relaxed in 1948 and the "Diversified" range was announced, drawing on contemporary Scandinavian designs, but the tide of public taste was against it and the Panel was wound down. The scheme was officially closed in 1952, the same year that furniture rationing ceased.

Contemporary times:

In the 1940s and 50s there was significant development in the field of polymers and their moulding techniques, this gave designers new opportunities. **Verner Panton** and **Robin Day** used these new techniques to design and manufacture iconic designs.

During yesteryears, furniture was crafted by hand. It took a long time. This obviously meant all pieces of furniture had a sense of craftsmanship and history to it, which was great, however, it also meant furniture had a price tag that quite simply wasn't attainable for most. And that wasn't the only caveat to what should be such a simple thing; back then, furniture was hard to transport due to fact you couldn't take it apart. If you decided you wanted a piece, it could be weeks before you received it.

Furniture was an outright nuisance, so one certain innovation in the field was welcomed with open arms: Flat Pack Furniture

As somewhat alluded to, in the past furniture was inaccessible; nice looking pieces were almost exclusively for the rich, unless it was an heirloom. That all changed when Swedish IKEA employee, Gillis Lundgren, had to screw his table's legs off to fit in his car. Supposedly when placing the legs in the car Gillis had the epiphany 'Why can't all furniture be like this?'. The rest was history. The fact he was employed by IKEA made the process very easy for him and them.

The innovation of flat pack furniture offered the world choice, suddenly it wasn't so hard to imagine all types of furniture in every one of rooms. You could have a certain aesthetic in one and a different in another. To say the innovation took the world by storm is an understatement; even students could afford a desk, dining room, their own bed, and whatever else their house needed.

A Level Design and Technology: Product Design

Major Developments in Technology

You should be aware of, and able to discuss, how major developments in technology are shaping product design and manufacture.

Microelectronics

Electronic components used to be very large, inefficient and unreliable. The first electronic-based products such as radios were very large and expensive.

Microelectronic devices, packaging designs, and materials have dramatically improved over the past decades. Integrated circuit (IC) chips are now much smaller and faster, and the packaging is more efficient, reliable, and cost-effective.

Microelectronics has touched every aspect of modern life. One cannot imagine a world without personal computers, cell phones, fax machines, camcorders, stereo players, televisions, microwave ovens, calculators, etc. In a way, microelectronics is becoming the central nerve of the modern world.

For example, automotive engines rely on electronic ignition and control systems to increase fuel efficiency and to reduce emissions; "smart" airbags rely on electronic sensing to adjust their inflation to provide collision protection without injuring the passengers; and drivers in unfamiliar streets can rely on global positioning systems to provide instantaneous driving directions. When electronic devices fail to perform these expected tasks, they are considered unreliable. Consumer books on automobiles publish reliability data about every automobile made, and the consumer depends on this information to decide which product to buy.

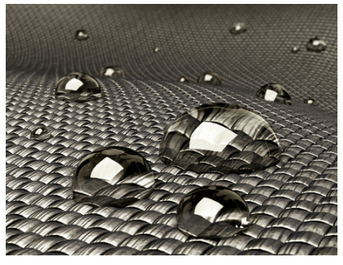
In addition to consumer products, microelectronic devices have also permeated many critical areas in medical, aerospace, and military applications. In such critical applications, reliable performance of electronic packages is extremely important. Failure of a desktop PC in the office may create inconvenience, but the failure of a pacemaker may be fatal. If the electronic navigation system on a jetliner fails to perform reliably, many lives may be endangered. Numerous military weapons systems, such as missiles, jet fighters, and nuclear bombs, are either guided or controlled by electronic devices. The reliability of these electronic devices and systems is so critical that a war between countries may break out if these systems malfunction.

Microelectronics have revolutionised how products are manufactured, they can be found in all CNC machines, including robots and moulding machinery, they can now be easily re-programmed.

New materials

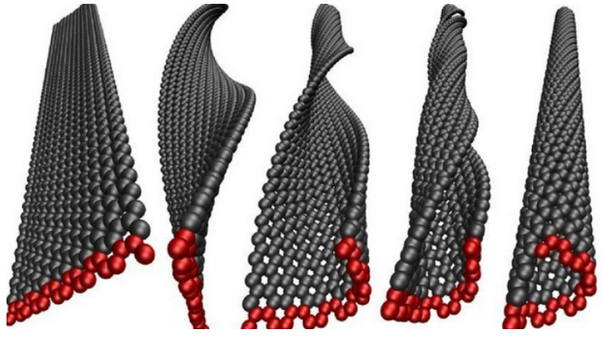
See modern materials/composites;

- Glulam
- Kevlar
- Precious Metal Clay (PMC)



Nanomaterials

Nanotechnology is the precise manipulation of nanomaterials, which are using particles in the size range 1 to 100nm (0.000001mm to 0.0001mm). It is currently used in the form of additives in suncream and cosmetrics. It is often used to coat products.



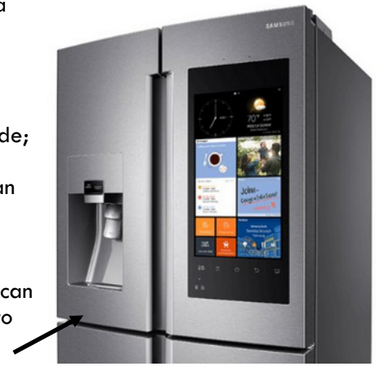
Graphene is a good example of a nanomaterial, it has very high tensile strength and hardness, combined with heat resistance and high electrical conductivity, making it perfect for many applications.

New Methods of Manufacture

The 20th century saw the introduction of massive improvements in our ability to manufacture products. One of the significant consequences of this has been to change the nature of the workforce; **we have moved from needing large numbers of high skilled machine operators, to a much smaller number of highly skilled technicians responsible for computer-based manufacture.**

Other new methods of manufacture, include;

- Electrohydraulic forming, which involves forming sheet metal into a complex form by using a spark in water, removing the need for a two-part mould.
- Direct metal laser sintering (DMLS), a laser is used to sinter (fuse) metal particles layer by layer, very similar to polymer 3D printing. The platform is lowered each time and a roller rolls on a new layer of powdered metal to be sintered. It can achieve undercuts and complex internal details which would be impossible using other manufacturing methods.
- Laser beam welding is now possible. A laser beam is used to join to pieces of metal together using heat. The process is fast and accurate. Advantages include; a wide range of metals can be welded, small heat area, smooth weld, more accurate, no filler rod needed. Disadvantages include; high cost, needs a clean environment and more health and safety concerns.



The internet of things (IoT) is changing the way we live our day-to-day lives. In the home, product such as Amazon Alexa can automate some daily tasks, smart fridges can automatically re-order items that need replenishing. In manufacture, it can be used to automatically order stock for JiT, automatically re-schedule due to breakdowns and automatically trigger maintenance on machines via sensors.

Advancements in CAD/CAM

CAD and CAM have developed significantly over the years, now 3D CAD can be used to design products, as well as generating the code required for CAM, such as 3D printing.

As the number of CAD packages increases, there is now a trend to use dissimilar file formats so that each software can read one another's file types.

FEA and CFD are now commonplace in commercial CAD packages, this allows the user to complete complex analyses on parts/assemblies, this saves money and time as there is less need for testing physical prototypes.

Cloud-based CAD such as OnShape allows users to access CAD files anywhere in the world, as well as collaborating with others anywhere in the world.

Virtual Reality (VR) is becoming more prominent in CAD, allowing the user to visualise the product in its intended environment. Sensory gloves can also be used to give potential consumers an idea of what the product will be like once manufactured.

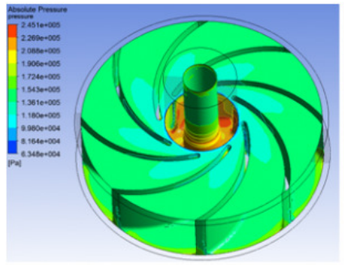


Figure 1 - Impeller CFD model

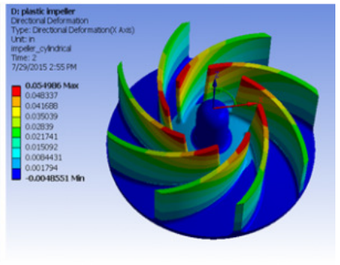


Figure 2 - Impeller FEA model

A Level Design and Technology: Product Design

Social, Moral and Ethical Issues

Students should be aware of, and able to discuss, the responsibilities of designers and manufacturers.

Social issues are those that affect environment, health, poverty, discrimination and unemployment that affect a significant number of people. Moral and ethical issues relate to people's beliefs, such as what they believe is right and wrong.

An example of issues of morality and ethics, is **William Morris** and his rejection of machine-based manufacture.

The need for designers to consider their responsibilities in relation to these issues and how they apply to various products and systems, will vary considerably for different societies and the groups within them. However they have a duty to ensure their practices and designs are appropriate.

Some companies are very aware of their social responsibilities, they often have a Corporate Social Responsibility policy. Lego and Disney are good examples of companies with effective Corporate Social Responsibility practices.

Companies are beginning to reduce the amount of virgin plastic they use and are now often using recycled plastics and using biodegradable alternatives, such as PLA. Many companies are also only using timber that comes from sustainable sources, such as those managed by the Forestry Stewardship Council (FSC).

Companies are now much more criticised for unethical treatment of employees, such as those working in mines.

Designers need to undertake extensive research into what is culturally acceptable around the world, so to avoid any embarrassment and damage to company reputation and sales.

Inclusive Products

Inclusive design is 'the design of mainstream products/services that are accessible to, and usable by, as many people as reasonably possible...without the need for special adaptation or specialised design. The main feature of this is that designers should design products that accommodate a diverse range of people without them being stigmatised in some way.

Good examples of inclusive design are:

- Updated standards for wider doors for wheelchairs in new houses.
- Good Grips by OXO can be used by a wide range of people.
- Many improvements on public transport, including buses with floors that lower for pushchairs and wheelchairs, and bright yellow handrails that can be seen easily.
- Road crossings; bumps on pavement, ramps, audible and tactile feedback.
- Hearing induction loops in public places.
- Large buttons on remote controls

Products that could assist with social problems

Social problems cover a wide range of issues, from what might seem quite trivial to serious issues that affect the lives and wellbeing on lots of people.

An example of a trivial issue is **litter**. A number of bins have been developed that encourage children to throw litter in bins, thus changing habits earlier.

Another issue is that on vehicle accidents involving young people, therefore **black box** recorders are now often installed by insurance companies., which offer discounts, thus encouraging safe driving.

Poverty, Health and Wellbeing

Some designers have worked towards ensuring the declaration of human rights, set out by the UN in 1948, is met.

Trevor Baylis became aware of the unaffordability and unavailability of batteries to power radios in parts of Africa. He developed a wind-up radio that did not require batteries. He sold millions around the world and became an inspiration for other wind-up products.

Yanko Design, a design blog, ran a competition for products aimed at reducing poverty, a number of products were produced as a result:

- Rainwater harvesting system made from plastic bottles
- Homeless shelters
- Mobile storage units for schools in developing countries.

In the field of **Health**, a number of developments have transformed modern medicine:

- Prostheses have become much more sophisticated due t new materials, products and technology.
- Minimally invasive surgery robots have been developed.
- Telehealth allows healthcare professionals to monitor a patient's health remotely.
- MRI and CT scanning allows healthcare professionals to diagnose conditions much more accurately.
- Artificial organs allow a patient to lead an almost normal life.
- 3D printing is now used in health, including, skin, scaffolds to support bone growth, medical equipment e.g. umbilical cord clamps in developing countries and skull repair implants.

Migration

Some products that have been borne out of migration issues, for example mass refugee camps:

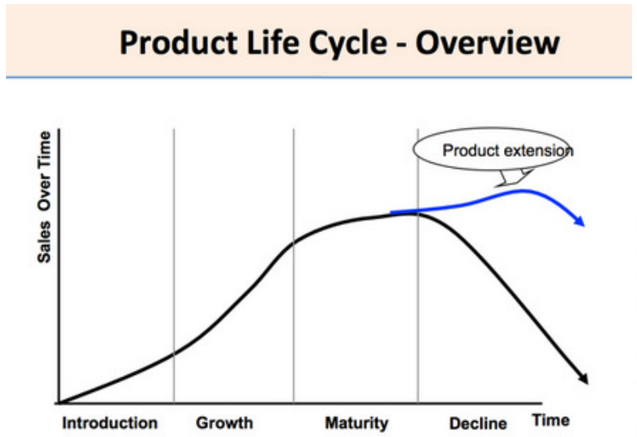
- Trough-style solar cokers.
- Solar based water purification products.
- Used clothes donated to refugees.
- Flat packed shelters for refugees, including solar panels for charging phones and lighting.
- Shipping containers that have been converted into mini hospitals and mini maternity wards.

Fairtrade

Consumers are becoming more aware of the way growers and handicraft products in developing countries are often exploited and dealt with unfairly when trading. The Fairtrade movement seeks to give a better deal to such people. Supermarkets have enormous buying power, this can lead to producers being treated unfairly.

The Fairtrade organisations enters into negotiations with supermarkets and other buyers to ensure a fair, minimum price is set for prodicts and also agrees on a premium which is used to make investments to support developmental projects. The Fairtrade mark is displayed on products that meet its standards.

Product Lifecycle



The product life cycle is an important concept in marketing. It describes the stages a product goes through from when it was first thought of until it finally is removed from the market. Not all products reach this final stage. Some continue to grow and others rise and fall.

What are the main stages of the product life cycle?
The main stages of the product life cycle are:
Research & development - researching and developing a product before it is made available for sale in the market
Introduction – launching the product into the market
Growth – when sales are increasing at their fastest rate
Maturity – sales are near their highest, but the rate of growth is slowing down, e.g. new competitors in market or saturation
Decline – final stage of the cycle, when sales begin to fall
This can be illustrated by looking at the sales during the time period of the product.

Extending the Product Life Cycle

For successful products, a business will want to do all it can to extend the growth and maturity phases of the life cycle, and to delay the decline phase.
What can businesses do to extend the product life cycle?
To do so, it may decide to implement extension strategies - which are intended to extend the life of the product before it goes into decline.
Examples of extension strategies are:
Advertising – try to gain a new audience or remind the current audience
Price reduction – more attractive to customers
Adding value – add new features to the current product, e.g. improving the specifications on a smartphone
Explore new markets – selling the product into new geographical areas or creating a version targeted at different segments
New packaging – brightening up old packaging or subtle changes

A Level Design and Technology: Product Design

Design Processes

You should be aware of, and able to discuss and implement, the stages of a range of design processes in order to apply personal judgement and relevant criteria in the appraisal of products and systems.

Design Brief

A design brief can contain the following:

- A description of the problem or need (often called the situation).
- Images and details of the context, situation or problem.
- An explanation of why existing products are not suitable or do not meet the needs of the user.
- Details of the client or user group.
- An outline or description of the type of product that is to be developed.
- A description of the product's key functions.
- A list of the key areas of focus for the product to be a success.

Investigations and Analysis

Primary Research

Designers carry out investigations (research) using a wide range of techniques; many of these involve **primary research**. Designers often observe people in similar environments using similar products. This can be useful in identifying the weaknesses of existing products and potential areas for improvement. They will also seek the opinion of potential users by using **focus groups** or **questionnaires.**

Analysis of Existing Products

When analysing products, you should use them and then take them apart.

- How does the product function?
- What are the vital components that allow the product to work?
- What are the materials and how has it been manufactured?
- Are there any ergonomic features that make the product easier to use?

You should try to identify what consumer needs are met by the product and what key criteria were used when the product was developed. You can also critically analyse the product by considering its aesthetics and cost. Where possible, you should compare the product with others and comment on function, suitability of materials and manufacturing method, ergonomics, aesthetics and cost.

Investigation and Analysis of Materials

Sometimes designers may need to carry out research into materials, construction methods and finishes so that they can select the most appropriate ones to use in a project. In the commercial world, designers are not likely to be experts in all materials, components and technologies, so it is vital that they carry out practical investigations. This type of testing may be carried out by specialists who make the results available to the designer.

Example tests could be for hardness or brittleness.

Other forms of investigation

- Meeting with the client
- Using internet forums to gauge opinion
- Talking to experts
- Investigating the work of other designers
- Investigating historical influences
- Looking at current trends and styles
- Identifying design constraints such as size, the environment the product will be used in and how it is to be used
- Using British Standards
- Investigating the safe use of materials and components, ensuring COSHH regulations are adhered to
- Analysis of anthropometric data
- Consideration of relevant social, moral, cultural and environmental issues.

Using Inspirational Materials

Designers often collect materials to inspire them, including:

- Mood boards - a collage of images relating to the product.
- Inspiration boxes - swatches, colour samples and existing products.
- Job bags - A collection of cuttings from newspapers, magazines, sketches, material samples, components and products.

Idea Generation Designers can generate ideas in many ways.

Mind maps are often used by designers to help them think about factors that influence the design, and what might be considered when developing the product. These could form a checklist that is worked through when developing designs.

SCAMPER The SCAMPER technique can be used to develop/generate ideas. It involves substituting, combining, adding, multiplying, putting to other uses, eliminating or reversing.

Ideas can be **discussed** with others to get feedback and develop ideas further.

Illustration Methods of illustration can be found on the Design Communication sheet.

Development of a Specification

After carrying out an investigation and analysing research, a design specification can be development.

Typical elements of a specification are:
Function, User, Environment, Sustainability, Maintenance, Size, Weight, Ergonomics, Aesthetics, Cost, Quality and Safety

Modelling Modelling is an important tool used in developing ideas. Modelling is often completed using paper, card, Styrofoam, clay, wire, modelling clay, foam board and balsa. Cardboard and paper are good for creating quick models.

Models can be made to scale, which is helpful in communicating the aesthetics of a product. They can also be used to demonstrate the function of a product. Full size models can be used to check sizes and proportions, for example to test ergonomics.

Evaluation and Testing

Evaluation and testing should be seen as an ongoing activity throughout the design process. For example:

- After completing investigation work, such as disassembly and analysis of products, the designer would evaluate their findings and summarise key points.
- After completing initial design drawings, the designer would evaluate them with the client/potential users.
- When a design proposal is produced, good quality 3D CAD drawings might be shown,. Their comments would be used for further development of the product.
- When models and prototypes are produced, they can be tested with potential users and their feedback used for further development.
- Before making a product, it is good practice to experiment with materials and manufacturing methods, testing construction methods and evaluating their suitability.

When a prototype is completed, it could be evaluated by:

- A detailed comparison of the product against the specification.
- Testing the product in its environment.
- Obtaining third party feedback.
- Obtaining expert opinion.
- Using all findings from testing and evaluation to suggest how the prototype could be developed further.

Iterative Process in Industrial and Commercial Contexts

Collaborative Working Designing and making products often requires the expertise, skills and knowledge of a number of people. In industry, design teams consist of people with different areas of expertise and specialist knowledge. For example, one designer may have particular strengths in product styling or aesthetics, while another may have more expertise in engineering components and be able to focus on the functional aspects. Ergonomists may be involved in the development of the product to ensure that it is usable by the target market. Production designers will also be closely involved because they develop the tooling required to manufacture the product. Design teams work alongside product marketing teams who are responsible for promoting the product, and have a clear idea of the need and wants of potential users of the product When producing your own project, you should try to make use of a range of people who might be able to give you specialist advice and practical help For example, you might be able to contact people who make or sell similar items to the product you are developing. They may offer to give you some guidance or even be involved in evaluating your designs and prototype. You can also use your friends to bounce ideas off and to obtain feedback about your designs.

The cyclic nature of commercial design and manufacture In commercial design and manufacture, designers constantly evaluate their designs with clients and potential users. Using the feedback from clients and people from the target market, designers create new iterations of their designs and again obtain feedback. Similarly, when prototypes are used, designers can test their designs with potential users and obtain feedback. his might be done with a focus group or selected individuals. In addition to this, prototypes are shown to production engineers, to gain feedback about any design changes that would be required for the prototype to be put into production. Finally, when the product goes to market and consumers start to use the product, designers will already be working on new 'improved versions of the product, using feedback from customers and data from sales. Designers working in large businesses and industry are usually involved in a cyclic design process as opposed to a linear model. Working alongside sales and marketing teams, designers will be aware of market trends an will know when their product or product range needs to be refreshed to improve sales.

A Level Design and Technology: Product Design

Critical Analysis and Evaluation

You should be aware of, and able to discuss, your own and commercial products leading to possible improvements/modifications of the original idea.

When designing and making your products, you can compare them to your **specification** throughout the process, leading to a more successful solution.

You are encouraged to study commercial products as part of your primary research.

Testing and Evaluating in Industrial or Commercial Contexts

You should be aware of, and able to discuss, how products are required to undergo rigorous testing, and the testing methods used, before they become commercially available for sale.

Evaluation throughout the design process ensures the product is of a good quality in terms of its design, however it is subject to rigorous testing to ensure it is safe to use. **Product recalls** can be implemented to withdraw faulty products from service, however these are very expensive. The cost of rectifying issues during the design/ manufacture stages are cheap in comparison to recalling products.

Example: one of the most expensive recalls was due to the issue with lithium-ion batteries catching fire on the Boeing 787 Dreamliner. It cost Boeing hundreds of millions of dollars to rectify the issue and a poor standard of testing was blamed.

Use of Third Party Feedback

You should be aware of, and able to discuss, how the use of feedback and testing informs the evaluation process, including:

- informing future modification and development
- the importance of ensuring the views of other interested parties in order to have objective and unbiased feedback.

Third party feedback consists of **objective views** about products that are not involved in the product's design or manufacture.

A number of international organisations exist to monitor the standards of products and services. In the UK, the United Kingdom Accreditation Service (UKAS) is responsible for checking and monitoring the work of the many agencies that certificate testing and inspection of the products, and their manufacture, along with many other sectors. The BSI is the UK's most significant UKAS **accredited** organisation, since it publishes a range of **standards** that are used in the design and manufacture of products. Some examples from BSI are:

- BS 8887 Product manufacture, assembly, disassembly and end-of-life processing.
- BS EN ISO 6506 Brinell hardness testing of metals
- BS 1363 13-amp plugs, sockets and related equipment
- BS 1362 Cartridge fuses for domestic plugs
- BS EN 62031 LED lighting safety specifications.
- ASTM F3078 lead content in paint used for toys and other products.

Each of these standards specifies exactly how manufacture and/or testing must be carried out. For example within ASTM F3078, samples are scraped off products and subjected to x-rays, which facilitate the accurate analysis of all elements present in the sample, thus enabling the calculation of the amount of lead present.

A number of organisations are accredited by UKAS to enable them to carry out the testing necessary to award certification for compliance within standards. The award of appropriate certification enabled manufacturers to display the **CE Mark or BSI Kitemark**.

The UCD (User Centred Design) approach, as explained in Design Methods, is employed to ensure that products are appealing for consumers to buy and use. An important part of this approach is to obtain information from **market research** organisations. Market research organisations are used because they are totally independent of the client companies that use their services. They obtain information relevant to the proposed new product from a number of sources: targeted questionnaires and independent research into a variety of factors such as competitors' products, the state of the market, retailing constraints and brand identity.

One of their key services is to host **focus groups** in which members of the public, from appropriate **demographic groups**, are invited and paid to attend a meeting where they can express their views on existing and proposed products.

Members of focus groups may participate in a variety of activities, which will be recorded in some way. They could even be observed in a one-way mirror.

Typical focus group activities include:

- answering direct questions
- physical interaction with products
- Watching videos/presentations
- Sketching ideas and logos
- Making suggestions for product improvements and desirable features
- Role playing
- Creating mood boards
- Group discussions.

Examples of what might be learned from a focus group include:

- Their attitude towards colours for product finishes
- The level of comfort experiences while holding products
- How easily they can change the batteries in electronic products
- How easy they find it to navigate control panels or screens
- Their level of enjoyment when playing a computer game
- What they feel is an appropriate pricing level for a particular product
- The strength of a brand identity that they recognise

A Level Design and Technology: Product Design
Selecting Appropriate Tools, Equipment and Processes

You should be aware of, and able to discuss and demonstrate, good and safe working practices, including:
- the importance of using the correct tools and equipment for specific tasks
- the importance of ensuring their own safety and that of others when in a workshop situation
- how designs are developed from a single prototype into mass produced products
- the effect on the manufacturing process that is brought about by the need for batch and mass manufacture
- how to select the most appropriate manufacturing process to be able to realise their, or others', design proposals
- the importance of health and safety in a commercial setting including workforce training and national safety standards.

Successful manufacture is influenced by many factors such as the material and manufacture cost, product function, scale of production and proposed retail cost.

Example: yoghurt pots can be made in high volume via the thermoforming or vacuum forming process. Having multiple moulds on one sheet minimises waste, while providing the correct draft angles to enable the product to function. Vacuum forming is less suited to one-off production due to the time taken o produce a mould, as well as the amount of material wasted when producing the parts..

Selecting correct tools and equipment
Selecting the correct tooling involves knowledge of manufacturing processes as well as the materials used in the processes. E.g. if a games manufacturer were to produce a games console controller from a polymer, then only polymer processes would be considered. Blow moulding could be used to create the hollow shape, however this would not create the complex detailing that would be required. Vacuum forming may also be considered to make two halves of the product, however vacuum forming would produce too much waste, as well as a uniform wall thickness issue. Injection moulding would be the most suitable process due to the ability to create different wall thicknesses, as well as creating click fittings and circuit board holders within the mould. Injection moulding uses the same mould repeatedly, so each product wold be identical in quality and accuracy.

Maintaining safety in commercial manufacture
Commercial manufacture involves more staff than bespoke manufacturing, and employers must maintain safety standards across a wide variety of potential situations with a varying numbers of people with difference experience levels. The employer must comply with the **HSWA (Health and Safety at Work Act), COSHH (Control of Substances Hazardous to Health) and Personal Protective Clothing regulations**. Risk assessments for all processes are undertaken and should be carried out, and regularly reviewed and updated to protect those involves directly and indirectly in the manufacturing process.

The safe and appropriate selection of tooling is critical to ensure safe manufacture and safety for employees as well as suitability for the chosen materials. When selecting the right process or tools for the job, , the following factors could be considered:
- Duration of the job: could repeated action lead to a repetitive strain injury (RSI)? Will the works become bored?
- What hazards could be controlled before manufacture begins?
- What hazards has the process introduced to the workplace for both the manufacturer and others?
- Machinery and equipment: is there a safe place to load and unload materials, machinery and equipment? Are safe zones clearly marked?
- Is there a manual handling issue and has training been provided?
- Is machinery and tooling properly maintained in accordance with the manufacturer's specifications?
- Are the appropriate safety guards fitted and in good working order?
- Electrical safety: are power leads tested and tagged? Are circuit breakers used? Are power leads a trip hazard?
- PPE (personal protective equipment): is all the necessary PPE provided to protect working and others in the vicinity? Are there systems in place for maintenance and replacement of PPE as required? Is the necessary signage displayed?
- Emergency equipment: are there fire extinguishers, first aid kits and eye baths available? Has training been provided?

Development of designs from single prototypes to mass produced products
In commercial manufacture, prototype products are often the starting point for future productions of batch or mass-produced products. A prototype is the first generation of a product, which is used to fault find and evaluate prior to future production runs.

The car industry makes use of prototypes to test performance and aesthetics, and to gather market feedback prior to manufacturing a car for retail purposes. Prototypes usually take three main forms prior to production: visual, proof of concept and production.

Visual prototype: this is a sample or model that shows the overall shape and size of the product, but does not usually have any working parts. The materials will not be the materials that would be used if the product were to be mass produced. Often the visual prototype is made from traditional modelling materials such as Styrofoam, or it could be 3D printed. Visual prototypes provide an opportunity to test the visual impact that a product form may have, and enable designers and clients to suggest improvements.

Proof of concept prototype: this shows the key functionality and main technical aspects of the design. It is not intended to look like the final product, and will be a functional model, which may make use of existing off the shelf' components. A proof of concept prototype would not usually be made from production grade materials, but allows the design team to test the functions to see if they work as intended. There may be many proof of concept prototypes made and tested prior to a viable solution being found. Proof of concept prototypes can also be given out to trial or test groups to gain feedback of real world use rather than lab-based experimentation.

Production prototype: this gives a representation of how the mass- produced product would look and shows how the product would function. Off the shelf parts may still be used at this stage, but it is more likely that it will be built from bespoke parts. The materials used will be as close to production grade as possible, unless it is not economically viable, in which case a substitute material may be used. Manufacturers will make use of a presentation prototype to assess any alterations that may be required prior to mass production. These could be materials, positioning of components for a more economic manufacture layout as well as the most suitable manufacturing processes. Production prototypes will also generally be marketed in small user trials prior to a full production run.

In some instances, a company may produce an initial batch of products for testing, trialling and further refining prior to the final product being put into full production James Dyson, who invented the first bagless vacuum cleaner, made use of a huge number of prototypes prior to the first Dyson vacuum cleaners being launched in the retail sector. Over a five-year period, he made 5,12 prototypes before he was satisfied he had a successful and optimally functioning product

Batch or mass manufacture and the effect on the manufacturing process
The number of components or the complexity of the product and the volume of production will determine the type of machinery used to create a product. Before considering the machinery types, the designer must be familiar with the number of products expected from a manufacture process. If a one-off dining table were being made in a workshop, standard tooling such as bandsaws, pillar drills and mortice machines may be utilised. If the dining table were required to be manufactured in a batch of 50, the manufacturer would start to utilise jigs to ensure ease of repeatability and speed of production. Jigs could be used for many processes such as making a mortice and tenon joint for the legs, and the use of a gluing jig could ensure that all the frame joints were assembled quickly and 'square'.

There are three key terms for volume of production: one-off, batch and mass. See scale of production sheet.

Key points:
One off—will use tools for specific processes, each machine would be adjusted for each task.
Batch—jigs would be used to speed up the process and ensure each product is identical. Templates and CNC could also be used. E.g. a depth stop could be used on a pillar drill to ensure each hole is the same depth. Often, workers rotate around different jobs during batch manufacture.
Mass—Uses automation, there is dedicated machinery and CNC such as laser cutters to manufacture the same product many times over. E.g. polymer milk bottles use the blow moulding process via mass production, nuts and bolts. Mass production tends to employ a less skilled workforce.

Process	One-off	Batch of 50
Drilling holes for a dowel joint	Mark out each individual hole. Set up pillar drill for a particular depth and drill each hole.	Use a drilling jig setup on a dedicated pillar drill. The component is placed in the jig and the drill is set to the correct depth. Each component is fed into the jig until all components for the batch have been drilled.

A Level Design and Technology: Product Design

Accuracy in Design and Manufacture

You should be aware of, and able to discuss and demonstrate, the importance of accuracy in manufacturing, whatever the scale of production, including:

- how testing can eliminate errors
- the value in the use of measuring aids, e.g. templates, jigs and fixtures in ensuring consistency of accuracy and the reduction of possible human error.

Accuracy is essential in order to design, manufacture and test products within the **tolerance** specified so that they will function effectively. This can only be achieved by the correct use of appropriate measuring and marking out tools. Additional equipment is also used to reduce the possibility of measuring and marking out errors, particularly in large-scale production.

Using measuring and marking out equipment

Measurement is the process of using tools such as rules, tapes and gauges to check existing **dimensions**. **Marking out** is the transfer of designs onto pieces of material or parts to indicate where features such as edges, holes, slots, recesses and bends have to be made during manufacturing processes

Tools commonly used for measuring and marking out

Marking metal usually requires the use of a high carbon steel **scriber**, which is harder than the metal it is marking, so it is able to scratch the surface. If the scratched lines are difficult to see, it is common for special ink such as **engineer's blue** to be applied to the surface being marked out, so that the lines are more visible. If circles or arcs are required, **dividers** are used, which have two points and function in the same way as a pair of compasses. **Beam compasses**, sometimes called trammels, can be used for larger radii. Various additional tools, such as **external and internal calipers** are used for checking dimensions.

Timber is usually marked out with a **marking knife or pencil**, and there are carpenter's pencils specially designed for the purpose, with a thicker lead to avoid breakages. A marker pen is usually used on polymer sheet, although a scriber is sometimes used if the material is to be cut rather than bent.

Measurement for marking out is normally carried out with a **steel rule**, however distances over a metre usually require the use of a measuring tape. The metric international system of units (SI) is used in every major country in the world, with the USA being one of the last to adopt it for measurement. The metre (m) is the base SI unit, but millimetres (mm) are usually used in product design.

Laser devices such as **cross line levels** are becoming more commonly used for measuring and marking out when large and complicated fabrications are being undertaken, as this method projects a perfectly horizontal and vertical reference line onto objects of any shape

The marking device that is being used usually needs to be guided in some way, since marking out with precision cannot be achieved freehand. A rule is often used, but a number of additional tools are available to provide improved precision.

Surface plates and **gauges** fitted with digital or dial readouts, angle plates and v-blocks are often used when accurate measurement and marking out are required in engineering applications. For this type of work, it is necessary to establish datum surfaces, so that measurements can be accurately referenced from them, in the same way that a face side and edges are marked on timber to ensure 'squareness'.

A **marking gauge** can be used to mark a line at a constant distance from an edge of a piece of timber. It is commonly required to mark lines perpendicular (at a right angle) to an edge, for which there are many types of **try square** available. A **combination square** has the additional advantage of being able to mark out a mitre (45°), and it also has a spirit level to help with checking the horizontal and vertical accuracy

For angles other than a right angle or mitre, a **protractor** of some kind is normally used. These are available in many forms, from a simple protractor to the highly accurate Vernier protractor. When marking out holes for drilling, it is normal practice to a **punch** mark to ensure that the drill centres itself and does not 'wander'. Similar marks are often used to make lines involving heat, such as forging, since scribed lines can be difficult to see when metal has been heated.

High precision work

Micrometers, Vernier calipers and co-ordinate measuring machines are examples of tools used for precise measurement.

Impact of CNC

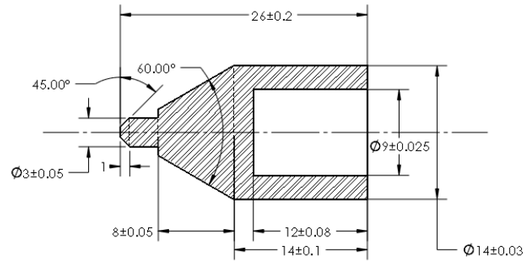
CNC machining processes do not require any marking out since the G-codes generated by the CAD/CAM software control the coordinate of the path of the cutting tool in relation to the workpiece.

The importance of accuracy

Accuracy is the conformity of a measurement to the required value. It is very important that products fit together properly. The designer must decide what the most appropriate **tolerance** is, and it can vary considerably depending on factors such as material, size, function and the need for interchangeability.

Examples of where tolerance is very important:

- Gears in a watch movement
- Threads on nuts and bolts
- Fitting a new glazing unit in a window frame
- Holes for KD fittings in flat packed furniture
- Selecting the correct washer size for a pipe



Sometimes additional tolerances are added to engineering drawings when a small tolerance on a particular feature is required.

Testing and the elimination of errors

The elimination of errors differs for different scales of production, for example:

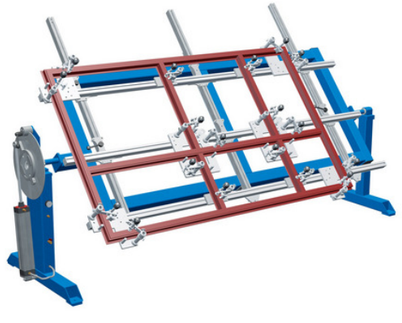
- In the bespoke production of a cast-iron gate, acute accuracy is not considerably important, however a drawing is usually followed for the overall form.
- In the bespoke production of a MDF photo frame, a **rule** and **try square** would be used to ensure the frame was square, a typical tolerance would be ±0.5mm.
- In the mass production of glass bottles for fizzy drinks there would be a range of issues that would need to be considered, for example the checking of the fit between the lid and the bottle is very important, the shape of bottle and the volume of liquid held are all important considerations. **Cameras/scanning systems** would be used as the bottles travel down the line to check for any errors, **go/no go gauges** could be used to check a number of products to check for fit. The weight of the bottle could also be tested using **weighing scales**.
- Testing a mould used in blow moulding. As the moulds wear over time due to the moulding process, it would be necessary to check them regularly. A **digital micrometer** or **Vernier calipers** could be used to check for dimensional accuracy.

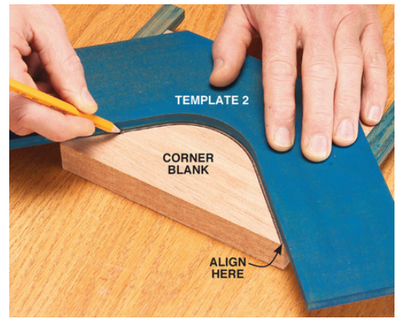
Using measuring aids

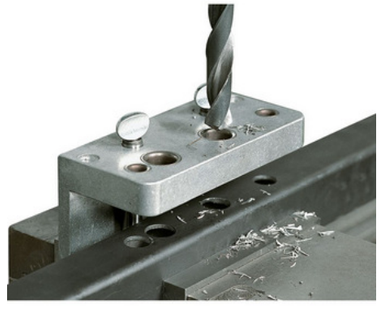
Jigs can be used to control the motion of a tool relative to a workpiece. The most common is a drilling jig, used to ensure holes are drilled in the correct location every time. These are often clamped on to the workpiece. No high skill level required.

Fixtures are robust frames with holding points and clamps that are used to hold workpieces firmly in place when machining, welding and other manufacturing operations take place. It is important workpieces are held in the correct position every time.

Templates consist of rigid shapes or patterns, often made of thin manufactured board or sheet metal which is used to transfer a design onto a workpiece. By using a template, a manufacturer can ensure each of the products are identical.







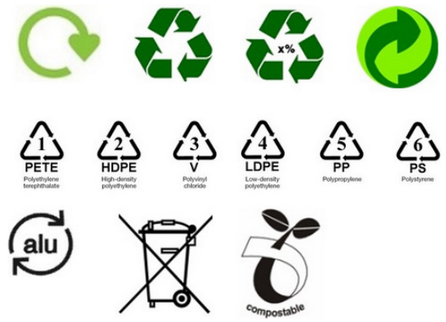
A Level Design and Technology: Product Design

Responsible Design

You should be aware of, and able to discuss, the importance environmental issues in design and manufacture, including:
• the responsibilities of designers and manufacturers in ensuring products are made from sustainable materials and components
• the environmental impact of packaging of products, e.g. the use of excessive packaging and plastics.

You should be aware of, and able to discuss, the concept of a circular economy, including:
• how products are designed to conserve energy, materials and components
• the design of products for minimum impact on the environment including raw material extraction, consumption, ease of repair, maintenance and end of life
• sustainable manufacturing including the use of alternative energy and methods to minimise waste
• the impact of waste, surplus and by-products created in the process of manufacture including reuse of material off-cuts, chemicals, heat and water
• cost implications of dealing with waste
• the impact of global manufacturing on product miles.

Environmental Issues
The starting point for many environmental decisions regarding product design is the **six R's of sustainability** (see earlier sheet).



Reduce - Cut down on the amount of material and energy used to make and package the product.
E.g. reducing polymers used in bottled water.
Reuse - At the end of a product's life, reuse the product for the same or another purpose.
E.g. using a used coffee jar again by using refill packs.
Recycle - Conversion of waste products into new materials for new products.
Recycling happens in three ways; primary, secondary and tertiary. Primary recycling involves the use of functioning second-hand products such as those in charity shops, free-cycling or items found in local recycling centres. Secondary recycling involves recycling the materials of a product to make different products. Tertiary recycling involves completely breaking down a product and reformulating it via a chemical process. For example, making fleece from plastic bottles.

Products that can be recycled should have symbols printed onto or moulded into the product.

Repair - When a product or component fails, fix it rather than throwing it away.
Refuse - Exercise consumer choice as to whether to buy a product or not.
E.g. a consumer using a reusable bottle instead of multiple single-use water bottles.
Rethink - Rethink the way products are designed and manufactured so that they carry out the same function, but more efficiently.
E.g. Use of click fittings and reducing the number of parts.

How a designer could use the Six R's when designing a TV remote:
Reduce: Make walls as thin as possible, smaller, design only for essential buttons, use solar or human power rather than batteries, use renewable energy when manufacturing

Reuse: At the end of the products life, reuse the casing for another remote control, reuse the electrical components

Recycle: Use recycled polymers, ensure it is made from materials that can be recycled, use recycled and recyclable copper and solder, mould recycling codes into casing and provide instructions.

Repair: Ensure the components can be fixed.

Refuse: Use recycled polymer to attract consumers and use substances that are not banned under RoHS directive.

Rethink: Make the product as simple to operate as possible, rethink the number of essential buttons, make the controller multi-purpose so that one product can operate all devices.

Using sustainable materials and components - The use of finite materials needs to stop. Many companies and individuals wish to reduce their **carbon footprint** and their subsequent impact on the environment. The carbon footprint is the total amount of CO_2 released as a result of the activities of an individual, community or organisation. **Primary carbon footprint** measures the direct emissions of CO_2 from burning fossil fuels. **Secondary carbon footprint** measures the CO_2 released as a result of the products we use.

The environmental impact of packaging - Packaging is important for making food last longer and keeping accessories with a product. Examples of how companies have reduced packaging is removing polymers, charging for carrier bags and offering bag-for-life schemes. A good example is M&S redesigning cardboard **pizza packaging** to become shrink wrapped with a thin cardboard sleeve. M&S also redesigned their **Easter egg packaging** to remove plastic, and instead created a card net that protected the chocolate egg. Using **concentrated liquids** instead of diluted, reduces the amount of packaging used. **Reusable cups** are also good examples, so less disposable cups are used. **Offering discounts** for reusing containers is a good way of encouraging consumers to reuse waste.

Conservation of energy and resources - Energy use is a major factor in both the manufacture and day-to-day running of products. A number of energy resources are **non-renewable** such as oil, coal and natural gas, and as such, alternative energy resources (**renewables**) must be found to provide enough energy to meet demands of the modern world. Examples include, wind, hydro, solar PV, wave, tidal, geothermal and biomass.

When designing products, designers must ensure the minimum amount of material is used to save resources and energy in production. **Nesting** and **tessellation** are good examples of minimising waste from sheet materials when laser cutting and routing.

Advantages of renewable energy:
- Sustainable and will never run out.
- Requires less maintenance than traditional generators.
- Fuel from natural resources reduces operational costs.
- Little or no waste, such as CO_2 or other chemical pollutants, is produced, meaning minimal environmental impact. Renewables are considered clean energy.
- Social and economic benefits - a renewable energy project can bring benefits through employment.

Disadvantages of renewable energy:
- Can be difficult to generate the large quantities of electricity that are produced by fossil fuels. More facilities may need to be built as a result.
- Renewable energy often relies on the weather for its source of power, and if the supply is unreliable or inconsistent, the energy production will be unreliable too. E.g. wind turbines need wind and solar panels need sun.
- Renewable energy cannot be stores in large quantities due to battery technology.
- Renewable energy is currently more expensive than traditional fossil fuel or nuclear energy, due to large capital costs.

Conserving energy, materials and components - Sprues can be included in injection moulding to mould a number of components at once. E.g. As a huge manufacturer, **Apple** has a big impact on the environment, as such, they use hydro-electric powered smelting facilities for aluminium. During manufacture, water cooling may be used, therefore **rain water** could be used.

Product Miles - Product miles are the total lifetime distance that a product is transported from its place of production to the place of use by the consumer. A typical product may travel as follows: raw material → processing plant → manufacturing facility → distribution → retail → user's home → recycling centre.

Companies can reduce emissions by sending products directly from the manufacturing facilities to retail. Electric trains can also be used to transport goods rather than by road, further reducing emissions. Using manufacturing facilities in the country of intended use also reduces emissions.

Circular economy - A **circular economy** aims to use materials in a way that ensures a continual cycle of reuse and remanufacture, without utilising wasteful resources or having products end their life in landfill. A circular economy approach anticipates and designs for biological and technical 'nutrients' to be continuously reused at the same quality, dramatically reducing the dependency on sourcing new materials. Good examples of initiatives are; **product leasing** and **take-back.**

A circular economy considers two 'nutrient' types. Biological nutrients: organic non-toxic materials that can be composted e.g. shampoos and wood and technical nutrients: man-made materials including polymers and alloys, designed to be used repeatedly at the same high quality with minimal energy and no adverse environmental effects. They are designed to be used and then recycled.

Principles: Preserve and enhance natural capital, optimise resource yields and foster system effectiveness.

Importance: work against unsustainable 'take, make, dispose' culture, promote resource productivity, reduce finite resources, reduce waste, avoid pollution, deliver more competitive UK economy, reduce environmental impact.

A Level Design and Technology: Product Design

Design for Manufacture and Project Management

Planning for Accuracy and Efficiency

You should be aware of, and able to discuss and demonstrate, the importance of planning for accuracy when making prototypes and making recommendations for small, medium and large scale production.

It is important to design against a specification and regularly review the specification throughout the design process. CAD and physical modelling can help check against this criteria.

Successful manufacture of a product on any scale of production requires a clear manufacturing plan, with deadlines and quality control inspections embedded into the schedule; the nature of the inspection will depend on the scale of production.

Ensuring accuracy of prototype designs

Pre-production: accuracy in prototype development relies heavily on a UCD process (see earlier), with client feedback playing a major part in the success of the prototype. QA procedures may include: **CAD simulations, working drawings with tolerances, mock up models, client feedback and peer review.**

Production: QC checks may include: **visual checks, dimension checks with flexible measuring equipment e.g. Vernier calipers, measuring individual parts or an overall product, machine tooling and alignment checks, assembly checks of multiple components and quality checks of the finish.**

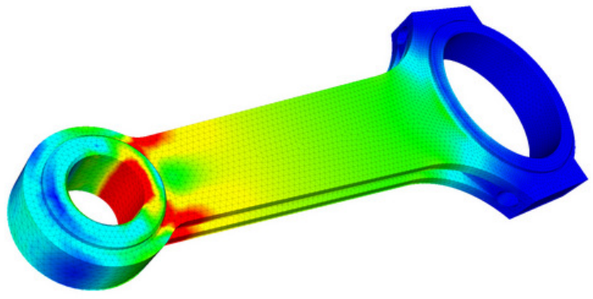
Ensuring accuracy during small, medium and large-scale production

Pre-production: It is cheaper to solve problems before production. Techniques such as **CAD simulations and costings, working drawings with tolerances, sample prototypes, templates, jigs and fixtures produced, focus groups and surveys and NDT (non destructive testing) and destructive testing.**

Quality Assurance (QA) - Quality Assurance (QA) refers to the procedures and policies put in place to reduce waste, and to ensure manufactured products are produced accurately within set acceptable tolerances. By using effective QA procedures, a manufacturer is aiming to produce products 'right first time, every time' which is ambitious. QA checks must be included.

E.g.

- Only sourcing materials and components from suppliers that hold the ISO 9001 Quality Management Standard.
- Setting specific temperature ranges for moulding to ensure effective filling of cavities and speeds of cooling.
- Setting rigid maintenance schedules for machinery to ensure cutters are machining within tolerances.



If QA is increased, then QC issues and waste is reduced.

Pre-production:

- Use CAD to model and check if components fit. This could also be done with exploded diagrams.
- FEA
- CFD

Project Management Systems - Effective project management is essential in all design and manufacture activities, to ensure that they are completed within budget and to agreed time scales. Management systems aim to improve efficiency and reduce waste within all the activities.

Total Quality Management - TQM is an approach to project management in use since the 1950s. The main aims of TQM stem from QA, with the ambition to remove waste and produce products right first time.

Companies that use TQM strive for continual improvement. They value the views of the workforce, and encourage the workforce to participate in teams where individuals can problem solve and contribute to the effectiveness of production.

Scrum - Scrum (agile manufacture) is a method of project management first used in software development. The main focus of Scrum is to work in a team to reach goals in short timescale 'sprints'. The team works on the goal and attends daily scrum updates where individuals feed back on their progress.

Six Sigma - Motorola introduced the Six Sigma system - a set of techniques and tools for process improvement which is designed to minimise defects. The aim is to reduce product failures to less than 3.4 in every million.

The five stages of Six Sigma:

- Define: what is the issue?
- Measure: measure the extent of the issue.
- Analyse: where do the issues occur?
- Improve: rectify the issues.
- Control: ensure the new procedures are implemented and maintained.

Lean Manufacture - Lean manufacture is an approach to production which aims to eliminate waste. Waste can come from many areas: transport, inventory, movement, waiting, over-production , over-processing and defects (TIMWOOD).

Critical Path Analysis

CPA is a project management method used to analyse all individual stages within a project, and to plan the effective and time efficient completion of each element within the desired schedule.

Analysing each task individually allows manufacturers to find out where time is wasted. See your booklet for more details on CPA.

Quality Control

QC refers to the monitoring, checking and testing of materials, components, equipment and products throughout production to ensure they confirm to acceptable tolerances specified within the QA policies within the company.

QC checks take place throughout the production process, and are performed in conjunction with strict guidance documentations produced by the company and client, to ensure that the products fit the specified requirements of the client.

Material Checks

Materials must be checked before manufacture, compared to the company's specifications. **Simple visual checks, chemical analysis and colour matching** may be used.

Dimensional Accuracy Checks

Digital Measuring Devices

Dimensional accuracy checks may be carried out with flexible measuring equipment, such as **Vernier calipers or micrometers**, where a range of measurements can be checked and exact readings recorded. This tends to be done with **interval sample testing**, where a small sample are checked during production. **Vernier calipers** can be used to check external, internal and depth measurements. Micrometers are only normally used for diameters or thicknesses due to their shape.

Go/no go gauge

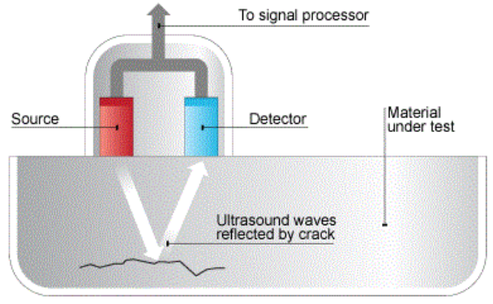
When checking dimensional accuracy on a production line, a specific measuring instrument is often used such as a go/no go gauge, which checks whether a single measurement fits between set tolerances. This is quicker than using Vernier calipers or micrometers. It never needs adjustment or recalibrating.

Co-ordinate measuring machinery

CMMs such as a probe scanner, allows manufacturers to check a range of predefined measurements on finished components. The accuracy of this technique is extremely high and the data is automatically compared against a 3D CAD model. Recently, manufacturers have started to use laser scanning to log lots of dimensions and compare them with a CAD model. **CMM can be used to check tooling for dimensional accuracy during maintenance, this may lead to tooling changes.**

Non-destructive testing

NDT refers to methods used to check the internal structure of materials, often after joining through processes such as welding. Two main methods are **x-ray** and **ultrasound analysis**. They material is subjected to radiation or ultrasonic waves to check for refraction of the signals, which indicates faults.



A Level Design and Technology: Product Design

National and International Standards

You should be aware of, and able to discuss, the importance of national and international standards in product design.

British Standards Institution

British Standards Institution (BSI) is a national organisation formed to devise agreed standard procedures for performing a wide range of tasks. The range of standards exceed 30,000. The kite symbol (pictured) can be displayed when a standard has been met.

If a British Standard has been accepted by a European standardisation organisation, it will carry the prefix “BS EN”.

Examples of British Standards: BS EN 71-1:2014 Safety of toys. Mechanical and physical properties. BS EN 62115: Electric toys. Safety.

International Standards Organisation

BSI is one of 150 national standards bodies that are part of the **International Standards Organisation (ISO)**, where internationally recognised standards are agreed and put into place. With many companies increasingly trading internationally, it is essential that they conform to international standards.

CE

Standards for management services such as ISO 9001, which deals with quality management, is applied worldwide, with many companies only dealing with those that have met the standard.

The presence of the CE Mark means a product conforms to all relevant European safety standards. It is mandatory to display the CE mark when a product is sold within the EU.

Restriction of Hazardous Substances Directive

The **Restriction of Hazardous Substances (RoHS)** directive (2002/95/EC) is a European directive that restricts the use of specific materials found in electronic and electrical products. As of July 2006, all relevant producrs sold in the EU were required to be RoHS complaint. This directive aims to prevent hazardous substances from entering the production process in order to prevent damage to human health and the environment.

Four restricted substances are: lead, mercury, cadmium and chromium.

Battery Directive

The **battery directive** (2013/56/EU) is an amendment of the directive (2006/66/EC) which, in combination with the RoHS and **Waste from Electrical and Electronic Equipment (WEEE)** directives, deals specifically with the restriction of hazardous substances and safe disposal of batteries and accumulators (such as capacitors). The directive states that a limit of 0.0005% mercury is allowed in batteries and accumulators, including button cells like watch batteries. It also restricts the volume of cadmium in portable batteries and accumulators to 0.002%. This also includes power tools.

The directive states that the symbol (pictured) is included on the product. Clear instructions for safe removal and disposal must be provided with the product.

Polymer Codes for Identifying and Recycling

The Mobius Loop is an internationally recognised symbol of three arrows, which shows a product can be recycled. The loop may include a percentage, or on a polymer product, an SPI (Society of Plastics Industry) code to state the polymer resin used in the product, so that during recycling, the polymers can be separated.

Packaging Directives

The EU packaging and packaging waste directive (94/62/EC) aims to limit the production of, and prompt the recycling and reuse of, packaging materials. The directive covers all areas of packaging from commercial to household.

At least 60% of packaging waste must be recovered or incinerated at waste incinerators with energy recovery. All packaging must be marked with the specific materials used to assist in identification and classification.

WEEE Directive

The **Waste from Electrical and Electronic Equipment (WEEE)** directive (2002/96/EC) is a mandatory European directive that covers the end of life of electric and electronic equipment, whereas RoHS details the materials that can be used in the product. The directive came into force in August 2006, and all relevant products must also carry the wheelie bin sticker.

EC Energy Label

The EC energy label is a compulsory system required on a wide range of household appliances. The label must be displayed by manufacturers and retailers to assist customers in making purchasing decisions. The use of coloured scale from A (most efficient) to G (least efficient) gives consumers an easy method of comparison. Due to the compulsory rules, this has forced manufacturers to make their products more efficient.

Eco-labelling

Eco-labels are a wide range of **voluntary** environmental certifications given to companies/products that are seen to meet specific environmental targets set for a product category.

The EU Ecolabel is a label of environmental excellence that is awarded to products and services meeting high environmental standards throughout their life-cycle, from raw material extraction to production, distribution and disposal.

The energy efficiency label and logo

The energy efficiency label is a certification mark issued by the energy saving trust as a recommendation for only the most energy efficient products within specific categories. The certification is available for appliances such as washing machines and fridges, light bulbs, central heating boilers and insulation products.

Forest Stewardship Council®

The **Forest Stewardship Council (FSC)** logo can be found on products made from timber, paper or other forest products which are sourced from well-managed forests and/or recycled materials. FSC certified forests are managed in an environmentally appropriate, socially beneficial, and economically viable manner, protecting the wildlife and people who live there and rely on the forest for their way of life. The workers within the forest must be local, and FSC guarantee that they are trained and work in a safe environment for a fair wage. Most importantly, when trees are harvested, they are replaced or allowed to regenerate, preventing deforestation.

EU ENERGY STAR®

The EU ENERGY STAR® program was developed from an agreement between the EU and US to standardise how IT equipment was labelled to show the energy used. Products are assessed on their power usage when idle and in sleep mode, and these figures are collated in a database to allow customers to make informed decisions on product choices.

The scheme covers the following types of equipment:

- Computers: including desktops, laptops and tablets
- Displays: including monitors and signage displays
- Imaging equipment: including printers, scanners and copiers.