IB Design Technology

CORE Topics 1-6

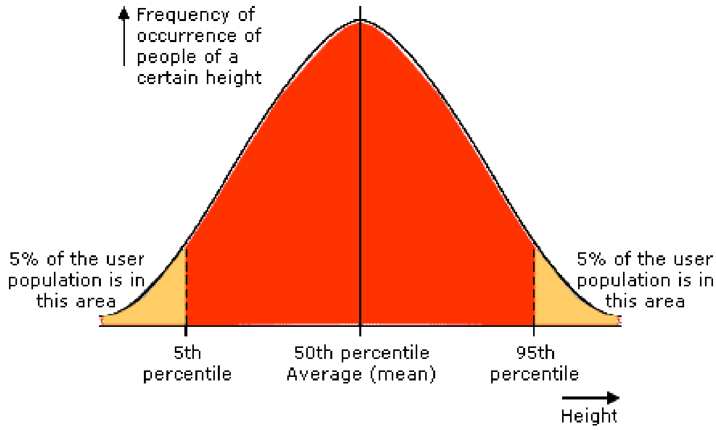
Updated 11th May 2016- John Zobrist

Topic 1
Human Factors and Ergonomics

1.1 Anthropometrics

Design is human centred and, therefore, designers need to ensure that the products they design are the right size for the user and therefore comfortable to use. Designers have access to data and drawings, which state measurements of human beings of all ages and sizes. Designers need to consider how users will interact with the product or service. Use and misuse is an important consideration. Anthropometric data sets can vary significantly between populations. Particularly in the fashion industry, the variance in these data sets impacts the size range of clothes for particular markets.

Define the term '**Human Factors**'	The term **Human Factors** is used for the combination of **ergonomics** and **anthropometrics**
What are the **aims** of Human Factors?	**Human Factors aims** to: • Reduce stress and fatigue on people, as they will be able to do things faster, more easily, more safely and make fewer mistakes (reduce errors) • Increase safety • Increase ease of use • Enhance operational comfort • Improve system performance, reliability and maintenance
What is **Ergonomics**?	The application of scientific information concerning the relationship of human beings to the design of objects, systems and environments.
What do we mean by the term **physical ergonomics**? Give an example.	**Physical ergonomics** most often deals with the work related subjects of: posture; worksite development operating layout; material handling; repetitive stress and movement; repetitive stress injuries and musculoskeletal disorders; and occupational safety and health. The aspect of ergonomics that deals with **body measurements**, particularly those of size, strength and physical capacity.
What do we mean by the term **cognitive ergonomics**? Give an example.	**Cognitive ergonomics** is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system.
What do we mean by the term **organisational ergonomics**? Give an example.	**Organizational ergonomics** subjects include communication, work design, shift (work hours) management, crew resource management, teamwork, virtual organizations, telework, and quality management.
What is **Anthropometric data**?	Anthropometric Data is sub-classified as **Static Data** and **Dynamic Data**.
What is **Structural** Anthropometric data?	**Static Data (**also known as **Structural data**) refers to measurements taken while while the subject is in a fixed or standard position, e.g. height, arm length. **Static data** is much easier to gather, as people are asked to remain still while measurements are taken.
What is **functional** Anthropometric data?	**Dynamic Data** (also known as **Functional data)** refers to measurements taken during physical activities, e.g. crawling height, overhead reach and a range of upper body movements. **Dynamic data** involves people carrying out tasks. People carry out tasks in many different ways. While static data is more reliable, dynamic data is often more useful.
What **tools** can be used to collect Anthropometric Data?	Sliding Callipers,Cloth Tape, Sitting height meters, Stadiometer
Percentiles and percentile ranges	Percentiles are shown in anthropometry tables and they tell you whether the measurement given in the tables relates to the 'average' person, or someone who is above or below average in a certain dimension.

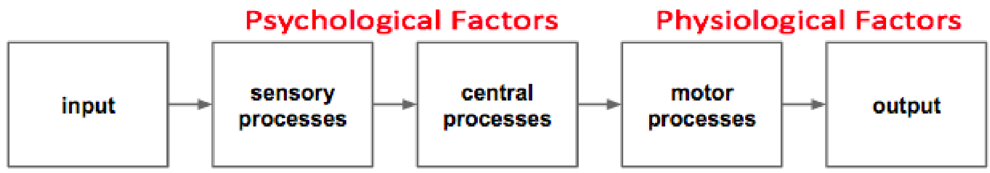
	 There is a great deal of anthropometric data available. You are expected to be able to: -interpret percentile tables in order to calculate dimensions related to a product and consider how products can be adaptable for different markets or adjustable to cater for most -consider the 5th, 50th and 95th percentiles in particular, and percentile ranges such as 2.5th to 97.5th and 5th to 95th -interpret percentile tables based on different national and international populations, gender and age.
What do we mean when we discuss **clearance** in Human Factors?	**Clearance** can be seen as the minimum distance required to, enable the user group into or through an area. This is especially important when designing emergency exits and safety hatches
What do we mean when we discuss **reach** in Human Factors?	**Reach** is also known as the **workspace envelope.** A 'workspace envelope' is a 3-dimensional space within which you carry out physical work activities when you are at a fixed location. Workspace envelopes should be designed for the 5th percentile of the user population, which means that 95% of users will be able to reach everything placed within the envelope.
Why does a designer need to consider **adjustability** when designing seating?	Certain products tend to be available in different **sizes** or with **adjustability** built in as there really is no 'one size fits all'. E.g. Ironing tables can be adjusted to allow for people of a different height to use comfortably. This has an effect on the design of the legs, as this is how the board is adjusted in height.
Explain what is meant by the **range** of sizes versus **adjustability**	Clothing comes in a **range** of sizes. For manufacturers to make clothing fit every individual variance would not be economically possible, thus it tends to come in a range of sizes based on percentile ranges. Children's car seats are **adjustable** to allow for a range of sizes and a growing child.
What is an **ergonome** and when are they used? What are the advantages and disadvantages?	A **2D scaled** physical anthropometric model based on a specific percentile human forms are called **ergonomes**. The ergonomes have been scaled from data taken from specific percentile ranges to form a standard human form. **Ergonomes** are used with drawings of the same scale as the model to consider the relationship between the size of an object and people. They are used with 2D drawings, mainly for orthographic drawings and also modelling to view field of reach, field of vision, etc.
What is a **manikin**? What are the advantages and disadvantages?	A **manikin** is an anatomical **3D model** of the human body. A jointed model of the human body used by artists, especially to demonstrate the arrangement of drapery. Also called lay figure. They are useful for assessing the relationship of body parts to spatial arrangements represented by a 3D model, for example, a chair to a desk. Full scale manikins are generally more expensive than ergonomes and they give a better representation of the overall ergonomics in the design context (such as crash test dummies).

1.2 Psychological Factors

Human beings vary psychologically in complex ways. Any attempt by designers to classify people into groups merely results in a statement of broad principles that may or may not be relevant to the individual. Design permeates every aspect of human experience and data pertaining to what cannot be seen such as touch, taste, and smell are often expressions of opinion rather than checkable fact. The analysis of the human information processing system requires a designer to critically analyse a range of causes and effects to identify where a potential breakdown could occur and the effect it may have.

What is **Cognitive psycholog**y / cognitive ergonomics concerned with?	**Cognitive ergonomics** is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system. • mental processes- such as perception, memory and reasoning • motor response- as they affect interactions among humans and other elements of a system.
What **methods** are there for collecting Psychological factor data?	1. Observation 2. Surveys & Interviews 3. Standardized Testing 4. Case Studies
What is a **Nominal Data Scale**?	Nominal means 'by name'. Used in classification or division of objects into discrete groups. Each of which is identified with a name. The scale does not provide any measurement within or between the categories
What is an **Ordinal Data Scale**?	Deals with the order or position of items. Words, letters, symbols or numbers arranged in a hierarchical order. Quantitative assessment can not be made
What is a **Interval data scale**?	Organised into even divisions or intervals. The intervals are of equal size. There is no zero
What is a **Ratio data scale**?	The difference between a ratio scale and an interval scale is that the zero point on an interval scale is some arbitrarily agreed value, whereas on a ratio scale it is a true zero. For example, 0°C has been defined arbitrarily as the freezing temperature of water, whereas 0 grams is a true zero, that is, no mass. A ratio scale allows you to compare differences between numbers.
What are examples of **Psychological factors**?	**Smell:** important in food, perfumes, candles, deodorants, chemicals. Unpleasant odors are added to chemicals to warn people. **Light:** the level of illumination should increase as the tasks becomes more precise; for example the illumination required for a surgeon is brighter than the illumination needed for a corridor. Lighting in workplaces, safety. For example effects of florescent lighting and rotating parts on machinery. Lighting effect on ambience and mood, e.g. lighting in restaurants – gentle, calming, stimulating. **Sound:** can be used to: • Provide information such as warning signal (fire alarm or alarm). • Sound for reassurance that the product is working ex. Watches • Feedback , whistling kettles, reversing trucks Sound can be positive in the environment such as playing music in an exhibition. Noise can also be negative in a workspace, that's why open plan offices use screens to reduce noise. **Taste:** important in food, it must have a good taste to sell well. Responses to taste are also a factor of culture and experience. **Texture:** shapes and textures improve products and make them easier to use, for example bottle tops, handles fabrics and non-slip floors, smooth worktops in kitchen. **Temperature:** Clothing is an important part of a comfortable work environment but the

<table>
<tr><td></td><td>environment must be controlled regardless of the outside climate. How the user responds to different environmental factors, for example, how warm or cold work environments can affect the performance of an individual. A range of comfort zones will exist based on body mass, manner of dress or even physiological changes that can be developed from exposure to a particular temperature or environment over time.

Value: May be perceived as a function of cost, features, prestige, rarity etc. or a combination of these factors.</td></tr>
<tr><td>What is the Human information processing systems?</td><td>Human information-processing systems, considering inputs, processes (sensory, central and motor) and outputs. A simple representation of a human information-processing system is below.

</td></tr>
<tr><td>What are examples of Environmental factors?</td><td>Environmental factors such as noise, lighting, temperature, humidity, vibration may affect: hearing, vision, general comfort and health.</td></tr>
<tr><td>What are examples of a breakdown with the Human information processing systems?</td><td>Some examples of how the flow process may break down are dependent on the following:
Age, skills level, disability, infirmity or frailty
Young children may not have the size, strength, fine motor control or skill to perform the tasks.
Older people may not have the strength
People with disabilities, such as arthritis or Parkinson's disease, may also not have the fine motor control required.
A physical condition which can include: ALS: Amyotrophic lateral sclerosis, MS: Multiple Sclerosis, Arthritis, Partial paralysis, Parkinson's disease, Repetitive Strain injury, Blindness, Hearing, Reduced sense of feeling</td></tr>
<tr><td>How can you maximise workplace performance?</td><td>An important role in maximising workplace performance and reducing the possibilities of accidents.
<table><tr><td>Management</td><td>Policies, safety education, decision centralization</td></tr><tr><td>Physical environment</td><td>Noise, temperature, pollutants, trip hazards, signage</td></tr><tr><td>Equipment design</td><td>Controls, visibility, hazards, warnings, safety guards</td></tr><tr><td>The work/job itself</td><td>Boredom and repetitiveness, mental and physical workload, musculoskeletal impacts such as force, pressure and repetition)</td></tr><tr><td>Social and psychological environment</td><td>Social group norms, morale</td></tr><tr><td>The worker</td><td>Personal ability, alertness, age, fatigue</td></tr></table></td></tr>
<tr><td>What is Alertness?</td><td>Alertness is the key term and means being aware of what is happening in the vicinity, in order to understand how information, events, and one's own actions will impact goals and objectives, both immediately and in the near future.</td></tr>
</table>

What is a **Human error?**	**Human error** come in several forms but two fundamental categories are **slips** and **mistakes**. Slips result from automatic behaviour, when subconscious actions that are intended to satisfy our goals get waylaid en route. Mistakes result from conscious deliberations.
What are possible ways of **optimizing environmental factors** to maximize workplace performance?	**Lighting:** best lighting is natural lighting or low frequency/brightness depending on task. In medical surgery it would be opposite- bright and sharp to optimise the task **Thermal comfort:** Male and Female have different body temperature. Having the right temperature air/humidity and flow of air/circulation to get best work performance. **Working space**: Space, working envelope, safe **Noise:** Protection of excessive noise (above 85 decibels) **Vibration**: Machines, etc. create vibration and sound and can be annoying
What are some **perception** effects in products?	This principle maintains that the human mind considers objects in their entirety before the perception of their individual parts; **suggesting the whole is seen rather than the sum of its parts.**

Notes:

1.3 Physiological Factors

Designers study physical characteristics to optimize the user's safety, health, comfort and performance. Understanding complex biomechanics and designing products to enable full functionality of body parts can return independence and personal and social well being to an individual.

What is **Physiological factors** concerned with?	Physiological factors have more to do with **bodily tolerances** (how much can the body withstand) such as **comfort and fatigue.** When users interact with products, they may put **stress** on their bodies.
What is **Physical ergonomics** concerned with?	Physical ergonomics is concerned with human anatomy, and some of the anthropometric, physiological and biomechanical characteristics as they relate to physical activity. Physical ergonomic principles have been widely used in the design of both consumer and industrial products.
What are some **human values** with types of physiological factors?	It also considers which activities can be carried out and how **human values** (for example, quality of life, improved safety, reduced fatigue and stress, increased comfort levels and job satisfaction) are enhanced.
What is **Fatigue**?	When people get tired they react in different ways. Fatigue is the temporary diminishment of performance. Fatigue can be physical and/or mental. Fatigue can inform design decisions and can affect users.
What is **Comfort**?	**Comfort**: is a qualitative consideration and differs massively between different people. **Comfort** is a physiological factors that inform design decisions and can affect users.
How can designing ergonomically enhanced work environments and products have advantages for the employer and employee?	**Healthy Workforce:** Instead of workers adjusting to standard tools and equipment, ergonomics promotes product designing based on human body structure and requirements. Therefore, these products drastically reduce the strain workers experience due to repetitive use of machines, computers, scanners, industrial apparatus and related instruments. Less strain equates to reduced instance of occupational illnesses and therefore healthier employees. **Enhanced Productivity**: A healthy workforce translates to enhanced productivity. Easy to use equipment keeps the work momentum going on for longer durations. Workers experience less fatigue and are happy to use tools designed especially for them. **Reduced Number of Sick Days Reported:** People with reduced instance of work associated ailments implies they take fewer days off due to sickness and work more number of days in a year. This means lesser number of workdays is lost. **Savings**: By using ergonomic workstations, employers save huge amounts of money otherwise spent in compensation claims, treatments and litigation.
What is **biomechanics** in human factors concerned with?	Biomechanics in human factors includes the research and analysis of the mechanics (operation of our muscles, joints, tendons, etc.) of our human body. With biomechanics, measuring the amount of force put on the muscles and joints of people when working in different positions can be tested by determining which positions make use of an individual's muscular strength. Biomechanics in human factor design deals with four key criteria: • Force • Repetition • Duration • Posture
What are some **factors affecting muscle strength** with human factors?	• Gender • Age - - Greatest around 20's - 5% less in 40's - 20% less in 60's • Pain, Physical training schedule, Immobilization or bed bound

Topic 2
Resource management & sustainable production

2.1 Resource and reserves

Resource management and sustainable production carefully consider three key issues consumption of raw materials, consumption of energy, and production of waste—in relation to managing resources and reserves effectively and making production more sustainable. As non-renewable resources run out, designers need to develop innovative solutions to meet basic human needs for energy, food and raw materials. The development of renewable and sustainable resources is one of the major challenges of the 21st century for designers.

<table>
<tr><td>Resources</td><td>Resources are the stock or supply of materials that are available in a given context.</td></tr>
<tr><td>Renewable resources</td><td>A natural source which can replenish with time they make take place as energy or commodities, some will require careful management i.e. plantation of timber; others are deemed inexhaustible i.e. wind and solar.</td></tr>
<tr><td>Non-Renewable</td><td>A non-renewable resource (also called a finite resource) is a resource that does not renew (replenish) itself at a sufficient rate for sustainable economic extraction, for example, coal, petroleum, natural gas, fossil fuels, minerals and ores.</td></tr>
<tr><td>Comparison of renewable and non-renewable resources</td><td>
<table>
<tr><th>Renewable Resources</th><th>Non Renewable Resources</th></tr>
<tr><td>1.) Are inexhaustible
2.) Are not affected by human activities
3.) Release less carbon emissions
4.) More expensive to implement.
eg. hydroelectric, geothermal, solar, wind, tidal</td><td>1.) Resources are present in fixed and limited quantities.
2.) Are exhaustible.
3.) Release more carbon emissions.
4.) Less expensive to implement.
eg. coal, timber, natural gas, oil, nuclear</td></tr>
</table>
</td></tr>
<tr><td>Reserves</td><td>A natural resource that has been identified in terms of quantity and quality.
Energy reserves are projected on the basis of geologic and engineering data and cannot be obtained at present due to economic or technical reasons; i.e. mining of oil sands is currently uneconomical due to current price structure.</td></tr>
<tr><td>Renewability</td><td>Renewability relates to a resource that can be replenished over time or is inexhaustible, for example wood from trees, and fresh drinking water Conserving resources and technologies that improve energy efficiency.</td></tr>
<tr><td>Impact of development may have on the environment</td><td>The impact of multinational companies when obtaining resources in different countries/ regions can be a significant issue for the local population and have major social, ethical and environmental implications.</td></tr>
<tr><td>The development of renewable and sustainable resources is one of the major challenges of the 21st century for designers.</td><td>The economic and political importance of material and land resources and reserves considering set-up cost, efficiency of conversion, sustainable and constant supply, social impact, environmental impact and decommissioning</td></tr>
</table>

2.2 Waste mitigation strategies

Waste mitigation strategies can reduce or eliminate the volume of material disposed to landfill. The abundance of resources and raw materials in the industrial age led to the development of a throwaway society, and as resources run out, the many facets of sustainability become a more important focus for designers. The result of the throwaway society is large amounts of materials found in landfill, which can be considered as a new source to mine resources from.

Waste mitigation strategies	The abundance of resources and raw materials in the industrial age led to the development of a throwaway society, and as resources run out, the many facets of sustainability become a more important focus for designers. The result of the throwaway society is large amounts of materials found in landfill, which can be considered as a new source to mine resources from. Waste mitigation strategies can reduce or eliminate materials directed to landfill. The prevention, monitoring and handling of waste, coming up with solutions to deal with pollution and waste
Re-use	Reuse of the same product in same context or a different context Examples include Water Bottles, Plastic Bags, Glass Bottles, Toothbrush, Clothes
Repair	The reconstruction or renewal of any part of an existing structure or device. To mend/restore/service faulty equipment, the life-cycle of many products is designed so that they/or parts deteriorate over time. Examples: Washing machine belt, Shoe soles, Lightbulb, Cars - bumpers, lights, Fix an inner tube on a bicycle
Re-engineer	To redesign components or products to improve their characteristics or performance. (speed, energy consumption). Examples include F1 cars - where aerodynamics is changed (shape) or lighter new materials used
Recycle	Recycling refers to using the materials from obsolete products (waste) to create other products. Examples include Glass, Paper, Aluminium cans, Thermoplastics, Newspaper
Recondition	Rebuilding a product so that it is in an "as new" condition, and is generally used in the context of car engines and tyres. Examples include car engines, tyres, bearings, etc
Dematerialisation	Reducing the quantities of materials trying to "do more with less". Looking at the constraints of the materials we use, through reduction and reuse of materials. Examples include the changes made to the new Mac Pro vs the old Mac Pro version. Dematerialization improves product efficiency by saving, reusing or recycling materials and products. It impacts on every stage of the product life cycle: in material extraction; eco-design; cleaner production; environmentally conscious consumption patterns; recycling of waste. It may mean smaller, lighter products and packaging; the replacement of physical products by virtual products (email instead of paper, web pages instead of brochures); home working, and so on.
Methodologies for **waste reduction**	Looking into the current management of waste (i.e landfill, incineration) and pollution (i.e. noise, air pollution). • Developing new bio-fuels, self-decomposing materials, building products from recyclable materials, reconditioning products and building products with a "cradle to cradle" life-cycle. • Making consumers and manufacturers aware of pollutants and the effect on the environment, passing acts/legislation to ban/reduce these pollutants i.e. the EU "Take Back" program and the US "Clean Air Act". Eco-labeling products for consumer awareness. • Following ISO (International standards organisations) 14000 a network of national standards spanning the globe, addressing environmental issues.

Methodologies for **designing out waste**	-The prevention, monitoring and handling of waste, coming up with solutions to deal with pollution and waste. -Product recovery strategies at end-of-life/disposal -Energy from waste, reuse of parts of products, recycling from parts of products. -Circular economy-the use of waste as a resource within a closed loop system -Environmentalists have a large influence on product marketability, designers and manufactures often work together to design products which are deemed as Green/Environmentally friendly.
Product recovery strategies **Recycling**	Recycling refers to using the materials from obsolete products to create other products.
Product recovery strategies **Raw material recovery**	The processes of separating the component parts of a product to recover the parts and materials.
Product recovery strategies **WEEE Recovery**	WEEE is a complex mixture of materials and components from electrical products that because of their hazardous content, and if not properly managed, can cause major environmental and health problems.
Product recovery strategies **Energy recovery**	Waste-to-energy (WtE) or energy-from-waste (EfW) is the process of generating energy in the form of electricity and/or heat from the primary treatment of waste. WtE is a form of energy recovery. Most WtE processes produce electricity and/or heat directly through combustion, or produce a combustible fuel commodity, such as methane, methanol, ethanol or synthetic fuels.
Product recovery strategies **Standard parts at the end of product life**	Reduction of total material and energy throughput of a product or service, and the limitation of its environmental impact through: reduction of raw materials at the production stage; energy and material inputs at the user stage; waste at the disposal stage
Life Cycle Analysis (LCA)	Life-cycle assessment (LCA, also known as life-cycle analysis) is a technique to assess environmental impacts associated with all the stages of a product's life from cradle to grave (i.e., from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling).
Circular economy—the use of waste as a resource within a closed loop system	An economy model in which resources remain in use for as long as possible, from which maximum value is extracted while in use, and the products and materials are recovered and regenerated at the end of the product life cycle.
External drivers and social change	• Increasing supply chain pressure • Public opinion • Energy costs • Waste charges • Take-back legislation • The obligation to provide environment-related information • Norms and standards • Eco-labelling schemes • Subsidies • Environmental competition • Environmental requirements in consumer tests • Environmental requirements for design awards • Increasing cooperation with suppliers

2.3 Energy Utilisation, Storage and Distribution Waste mitigation strategies

There are several factors to be considered with respect to energy and design. Efficient energy use is an important consideration for designers in today's society. Energy conservation and efficient energy use are pivotal in our impact on the environment. A designer's goal is to reduce the amount of energy required to provide products or services using newer technologies or creative implementation of systems to reduce usage. For example, driving less is an example of energy conservation, while driving the same amount but with a higher mileage car is energy efficient.

Energy utilization, storage and distribution	Efficient energy use is an important consideration for designers in today's society. Energy conservation and efficient energy use are pivotal in our impact on the environment. A designer's goal is to reduce the amount of energy required to provide products or services using newer technologies or creative implementation of systems to reduce usage. For example, driving less is an example of energy conservation, while driving the same amount but with a higher mileage car is energy efficient.
Embodied energy	The **embodied energy** in a product accounts for all of the energy required to produce it. It is a valuable concept for calculating the effectiveness of an energy-producing or energy-saving device.
Distributing energy: national and international grid systems	The way in which electricity is distributed along the grid and the energy loss involved from small source collection and delivery, to large scale and the effect on the environment.
Local combined heat and power (CHP)	Combined heat and power (CHP) is an efficient and clean approach to generating electric power and useful thermal energy from a single fuel source. CHP is used either to replace or supplement conventional separate heat and power (SHP). Instead of purchasing electricity from the local utility and burning fuel in an on-site furnace or boiler to produce thermal energy, an industrial or commercial facility can use CHP to provide both energy services in one energy-efficient step. **Advantages of CHP include:** -Reduced energy costs versus separate heat and electrical generation systems -Reduced emissions versus separate heat and electrical generation systems -Where the capture and use of waste heat is not viable, many industrial facilities may still benefit financially via distributed generation (DG)
Systems for individual energy generation	Systems for individual energy generation such as microgeneration includes the small-scale generation of heat and electric power by individuals, small businesses and communities to meet their own needs, as alternatives or supplements to traditional centralized grid-connected power. E.g. solar power, wind turbines or biogas rainwater harvesting, compost toilets and greywater treatments among others.
Quantification of carbon emissions: **Measuring**	• record carbon emissions • discover how much is being produced • discover who/ where it is produced • track your carbon footprint
Mitigation of carbon emissions: **Reducing**	• Humans intervention in the reduction of carbon emissions • These contribute to global warming • Resulting in melting polar caps, rising seas, desertification, • provide 'Sinks' that can reabsorb carbon emissions • A 'Sink' are forests, vegetation or soils.
Batteries, capacitors and capacities considering relative cost, efficiency, environmental impact and reliability.	An electric battery is a device consisting of two or more electrochemical cells that convert stored chemical energy into electrical energy. Batteries and other electronic components (capacitors, chips, etc) have had a great impact on the portability of electronic products and, as new technologies are developed, they can become more efficient and smaller. Batteries are made from important resources and chemicals, including lead, cadmium, zinc, lithium and mercury. It's important to understand the effects of your decisions as batteries are categorised into High, Medium and Low through the use of a sustainable lens (charging, impact on eco-system, etc).

2.4 Clean Technologies

Clean technology seeks to reduce waste/pollution from production processes through radical or incremental development of a production system. Clean technology is found in a broad range of industries, including water, energy, manufacturing, advanced materials and transportation. As our Earth's resources are slowly depleted, demand for energy worldwide should be on every designer's mind when generating products, systems and services. The convergence of environmental, technological, economic and social factors will produce more energy-efficient technologies that will be less reliant on obsolete, polluting technologies.

<table>
<tr><td>Clean Technology</td><td>Products, services or processes that reduce waste and require the minimum amount of non-renewable resources. Clean technology is found in a broad range of industries, including water, energy, manufacturing, advanced materials and transportation. As our Earth's resources are slowly depleted, demand for energy worldwide should be on every designer's minds when generating products, systems and services. The convergence of environmental, technological, economic and social factors will produce more energy efficient technologies that will be less reliant on obsolete, polluting technologies.</td></tr>
<tr><td>Drivers for cleaning up manufacturing</td><td>Manufacturers may respond to current or impending legislation or pressure created by the local community and media. The reasons for cleaning up manufacturing include:
promoting positive impacts
ensuring neutral impact or minimizing negative impacts through conserving natural resources
reducing pollution and use of energy
reducing waste of energy and resources</td></tr>
<tr><td>Breakdown of environmental problems products can cause and their geographical scale</td><td><table>
<tr><th>Geographical scale</th><th>Types of environmental problem</th></tr>
<tr><td>Local</td><td>Noise, smell, air pollution, soil and water pollution</td></tr>
<tr><td>Regional</td><td>Soil and water over-fertilization and pollution, drought, waste disposal, air pollution</td></tr>
<tr><td>Fluvial</td><td>Pollution of rivers, regional waters and watersheds</td></tr>
<tr><td>Continental</td><td>Ozone levels, acidification, winter smog, heavy metals</td></tr>
<tr><td>Global</td><td>Climatic change, sea level rise, impact on the ozone layer</td></tr>
</table></td></tr>
<tr><td>Legislation</td><td>The role and scale of legislation are dependent upon the type of manufacturing and the varied perspectives in different countries. Consider how legislation provides an impetus to manufacturers to clean up manufacturing processes and also how manufacturers react to legislation. Manufacturers may respond to current or impending legislation or pressure created by the local community and media.

Governments, politicians and businesses have to consider the effects of manufacturing on the environment. In recent years raised awareness of environmental issues is increasing pressure on governments to introduce or comply with legislation regarding environmental issues. These requirements bind companies to legislation and if these requirements are not met then financial penalties can be imposed.</td></tr>
</table>

<table>
<tr>
<td>International targets for reducing pollution and waste</td>
<td>Sometimes, agreements are made at an international or continental level to create targets for reducing pollution and waste. These agreements are usually discussed and agreed upon at international summits and meetings. Often conflicts and disagreements arise between countries trying to decide caps or limits on pollution or waste making agreements or settlements difficult to achieve. Some countries may be more affected by such limits than others, and feel that their economy or the profits of companies will suffer as a result.Some recent agreements include Kyoto Protocol, Montreal Protocol and the Carbon Trading Scheme.</td>
</tr>
<tr>
<td>End-of-pipe technologies</td>
<td>An initial response to reducing the emission of pollutants and creation of waste is adding clean-up technologies to the end of the manufacturing process. This is called an end-of-pipe approach. Technology that is used to reduce pollutants and waste at the end of a process. This can entail the treatment of water, air, noise, solid or toxic wastes. Some examples of this approach include: Carbon Capture, Filtration systems, Composting and Catalytic Converters on vehicles
<table>
<tr><th>Incremental solutions</th><th>Radical solutions</th></tr>
<tr><td>Products which are improved and developed over time leading to new versions and generations.</td><td>Where a completely new product is devised by going back to the roots of a problem and thinking about a solution in a different way.</td></tr>
</table>
</td>
</tr>
<tr>
<td>System level solutions</td>
<td>A System level solution embraces the idea of a solution to the problem of pollution and waste as a whole and is concerned with the interrelationship rather than individual elements. It helps policymakers and energy planners understand the impacts of existing and proposed legislation, policy, and plans on renewable energy development and deployment at the local, state, regional, and national levels.

Agreements are made at an international or continental level to create targets for reducing pollution and waste. These agreements are usually discussed and agreed upon at international summits and meetings. Often conflicts and disagreements arise between countries trying to decide caps or limits on pollution or waste making agreements or settlements difficult to achieve. Some countries may be more affected by such limits than others, and feel that their economy or the profits of companies will suffer as a result.</td>
</tr>
</table>

Notes:

2.5 Green Design

Green design integrates environmental considerations into the design of a product without compromising its integrity. The starting point for many green products is to improve an existing product by redesigning aspects of it to address environmental objectives. The iterative development of these products can be incremental or radical depending on how effectively new technologies can address the environmental objectives. When newer technologies are developed, the product can re-enter the development phase for further improvement.

Green Design	The product- role of designer: The starting point for many green products is to improve an existing product by redesigning aspects of it to address environmental objectives. The iterative development of these products can be incremental or radical depending on how effectively new technologies can address the environmental objectives. When newer technologies are developed, the product can re-enter the development phase for further improvement.
Green legislation	Laws and regulations that are based on conservation and sustainability principles, followed by designers and manufacturers when creating green products. Green legislation often encourages incremental, rather than radical approaches to green design. Sustainable products provide social and economic benefits while protecting public health, welfare and the environment throughout their life cycle—from the extraction of raw materials to final disposal. **Incremental innovation** is sometimes referred to as continuous improvement, and the business attitude associated with it is 'inside-the-box' thinking. A simple product may be improved (in terms of better performance or lower costs) through the use of higher performance components or materials. A complex product that consists of integrated technical subsystems can be improved by partial changes to one level of a sub-system. Incremental innovations do not involve major investments or risks. User experience and feedback is important and may dominate as a source for innovation ideas **Radical innovation** involves the development of new key design elements such as change in a product component combined with a new architecture for linking components. The result is a distinctively new product, product-service, or product system that is markedly different from the company's existing product line. A high level of uncertainty is associated with radical innovation projects, especially at early stages.
Timescale to implement green design	Often, legislation requires governments and manufacturers to comply over many years. This can be beneficial to companies and manufacturers as they can adopt incremental approaches to green design therefore minimising the cost, however some environmental concerns, for example carbon dioxide reduction and climate change require immediate action.
Legislation	Environmental legislation has encouraged the design of greener products that tackle specific environmental issues, for example, eliminating the use of certain materials or energy efficiency. Incremental changes to a design and as such is relatively easy to implement, for example, legislation relating to the use of catalytic converters for cars. The timescale for implementing green design is relatively short (typically 2–5 years) and therefore cost-effective.
Consumer Pressure	The public have become aware of environmental issues through media focus on issues such as the destructive effect of chlorofluorocarbons on the ozone layer; acid rain in Northern European forests and the nuclear accident at Chernobyl. Increased public awareness has put pressure on corporations and governments. CFCs were the ideal refrigerants during their time. They were nonflammable, non corrosive, nontoxic, and odorless. Used consumer products during the 70s and 80s, such as refrigerators, cleansing products, and propellants. CFC's were found to be destructive to the Ozone layer.

<table>
<tr><td>Drivers for green design
(consumer pressure and legislation)</td><td>Drivers for green design include consumer pressure and legislation, among others. Environmental legislation has encouraged the design of greener products that tackle specific environmental issues, for example, eliminating the use of certain materials or energy efficiency. Unfortunately, many companies value short term profit and value for shareholders over the impact of their activities on the environment. Some companies lobby governments so that they can be exempt from legislation, or to try and persuade them to 'water down' legislation. Sometimes consumer pressure can be just as effective as legislation. Through social media, the bad behaviour of companies can be exposed quickly, reach a wider audience and consumers can decide as a large group to boycott a company. Social media has allowed the influence of consumers to grow exponentially. This can hurt a company's profits greatly, persuading them to clean up their act.</td></tr>
<tr><td>Design objectives for green products</td><td>Design objectives for green products will often address three broad environmental categories.
Materials
Energy
Pollution/Waste
These objectives include:
increasing efficiency in the use of materials, energy and other resources;
minimizing damage or pollution from the chosen materials
reducing to a minimum any long-term harm caused by use of the product
ensuring that the planned life of the product is most appropriate in environmental terms and that the product functions efficiently for its full life
taking full account of the effects of the end disposal of the product
ensuring that the packaging and instructions encourage efficient and environmentally friendly use
minimizing nuisances such as noise or smell
analysing and minimizing potential safety hazards
minimizing the number of different materials used in a product
labelling of materials so they can be identified for recycling.
When evaluating product sustainability, students need to consider:
raw materials used
packaging
incorporation of toxic chemicals
energy in production and use
end-of-life disposal issues
production methods
atmospheric pollutants.</td></tr>
<tr><td>Strategies for designing Green Products</td><td>The environmental impact of the production, use and disposal of a product can be modified by the designer through careful consideration at the design stage. When designing Green product consideration must be made for:
raw materials used
packaging
incorporation of toxic chemicals
energy in production and use
end-of-life disposal issues
production methods
atmospheric pollutants.</td></tr>
<tr><td>Materials</td><td>How much damage is done to the environment in extracting the raw material?
How much energy is needed to process this material?
How long will this material last/will it damage easily?
Can this material be recycled?</td></tr>
<tr><td>Energy</td><td>How can I reduce the amount of energy required to manufacture this product?
How can I reduce the amount of energy required to use this product?</td></tr>
</table>

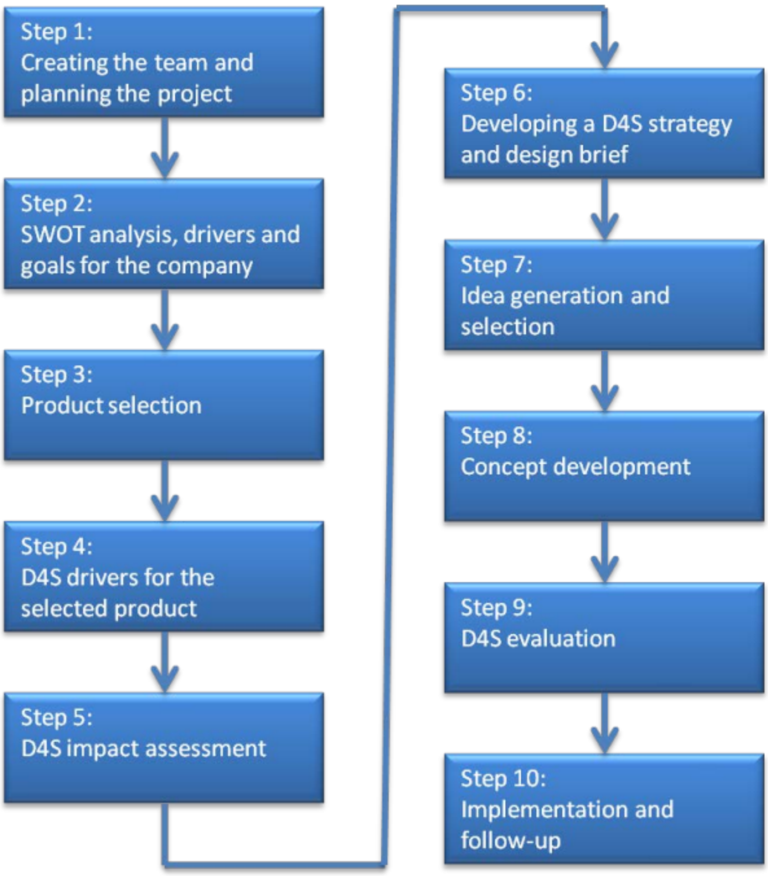
Pollution/Waste	What is likely to happen to this product when it is obsolete? How can I reduce the chances of this product ending up in landfill or sent to incineration? How can I increase the chances of this product being repaired, reused or recycled? How can I reduce the amount of pollution given off by this product?
The **prevention principle**	The **avoidance or minimization** of hazards and waste. It aims to address the occupational health and safety concerns through each stage of the product life cycle. A number of risk assessment tools can be used by companies to **assess their operations for risk** and introduce management systems to **protect the health and safety of employees** and **minimise waste.** • Knowledge based • Actual risk of causing harm can be assessed • Occurrence of damage is probable if no measure is taken • Regulation emission framework defines substantial criteria (eg. emissions thresholds) • Definition of acceptable risk is primarily science based
The **precautionary principle**	The **anticipation of potential problems** in relation to the environmental impact of the production, use and disposal of a product. The precautionary principle permits a lower level of proof of harm to be used in policy-making whenever the consequences of waiting for higher levels of proof may be very costly and/or irreversible. • Uncertainty • Risk cannot be calculated and is only a suspected risk of causing harm • Occurrence of damage is uncertain and cannot be predicted clearly • Regulation through procedural requirements • Social acceptance of the risk is considered

Notes:

2.6 Eco Design

Eco-design considers the design of a product throughout its life cycle (from cradle to grave) using lifecycle analysis. Efficient energy use is an important consideration for designers in today's society. Energy conservation and efficient energy use are pivotal in our impact on the environment. A designer's goal is to reduce the amount of energy required to provide products or services using newer technologies or creative implementation of systems to reduce usage. For example, driving less is an example of energy conservation, while driving the same amount but with a higher mileage car is energy efficient.

<table>
<tr><td>Eco Design</td><td>Eco-design is a more comprehensive approach than green design because it attempts to focus on all three broad environmental categories—materials, energy and pollution/waste. This makes eco-design more complex and difficult to do.</td></tr>
<tr><td>Impact of internal and external drivers for eco-design from an economic perspective</td><td>
<table>
<tr><th>Internal drivers for eco-design</th><th>External drivers for eco-design</th></tr>
<tr><td>Manager's sense of responsibility</td><td>Government</td></tr>
<tr><td>The need for increased product quality</td><td>Market demand</td></tr>
<tr><td>The need for a better product and company image</td><td>Social environment</td></tr>
<tr><td>The need to reduce costs</td><td>Competitors</td></tr>
<tr><td>The need for innovative power</td><td>Trade organisations</td></tr>
<tr><td>The need to increase personnel motivation</td><td>Supplies</td></tr>
</table>
</td></tr>
<tr><td>Cradle to grave</td><td>Cradle to grave design considers the environmental effects of a product all of the way from manufacture to use to disposal</td></tr>
<tr><td>Cradle to the Gate</td><td>Cradle to cradle design is a key principle of the circular economy. Cradle to Cradle® (C2C) is a holistic approach to design popularized by Professor Michael Braungart and William McDonough. Braungart and McDonough offer Cradle to Cradle® certification to products that measure up to the standards they set. According to their website: "The target is to develop and design products that are truly suited to a biological or technical metabolism, thereby preventing the recycling of products which were never designed to be recycled in the first place."</td></tr>
<tr><td>Cradle to the Gate</td><td>Cradle to the Gate (Cradle-to-gate is an assessment of a partial product life cycle from resource extraction (cradle) to the factory gate (i.e., before it is transported to the consumer).</td></tr>
<tr><td>Life Cycle stages:</td><td>Make sure you are able to assess the environmental impact of a given product over its life cycle through LCA (Life Cycle Assessment)-Pre-production, Production, Distribution including packaging, Utilization and Disposal. The complex nature of LCA means that it is not possible for a lone designer to undertake it and a team with different specialism is required. LCA is complex, time-consuming and expensive, so the majority of eco-designs are based on less detailed qualitative assessments of likely impacts of a product over its life cycle. The simplest example is the use of a checklist to guide the design team during a product's design development stages.</td></tr>
<tr><td>UNEP Ecodesign Manual</td><td>In 1996 the United nations released an Eco-design manual also known as Design for Sustainability (D4S). The major concerns outlined in the UNEP Ecodesign Manual were to:
increase recyclability
reduce energy requirements</td></tr>
</table>

	• maximise use of renewable resources • reduce creation and use of toxic materials • reduce material requirements of goods and services • increase product durability and reduced planned obsolescence 
Design for the environment software	CAD Software that allows designers to perform Life cycle analysis (LCA) on a product and assess its environmental impact.
Product life cycle stages: **the role of the designer, manufacturer and user**	The roles and responsibilities of the designer, manufacturer and user at each stage of the product life cycle can be explored through LCA. LCA identifies conflicts that have to be resolved through prioritization. It is not widely used in practice because it is difficult, costly and time-consuming. It is targeted at particular product categories—products with high environmental impacts in the global marketplace, for example, washing machines and refrigerators. However, in the re-innovation of the design of a product or its manufacture, specific aspects may be changed after considering the design objectives for green products, such as selecting less toxic materials or using more sustainable sources. A product may be distributed differently or its packaging may be redesigned.
Environmental impact assessment matrix	Environmental considerations include **water, soil pollution and degradation, air contamination, noise, energy consumption, consumption of natural resources, pollution and effect on ecosystems**
Converging technologies	The synergistic merging of nanotechnology, biotechnology, information and communication technologies and cognitive science. A typical example of converging technology is the smart phone in terms of the materials required to create it, its energy consumption, disassembly, recyclability and the portability of the devices it incorporates.

Topic 3
Modelling

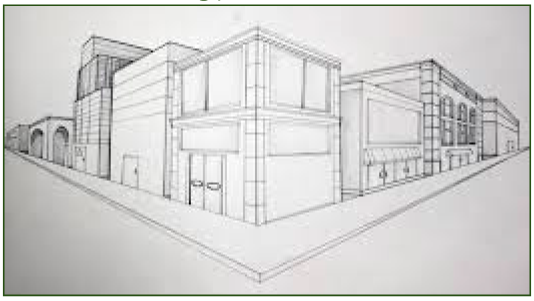
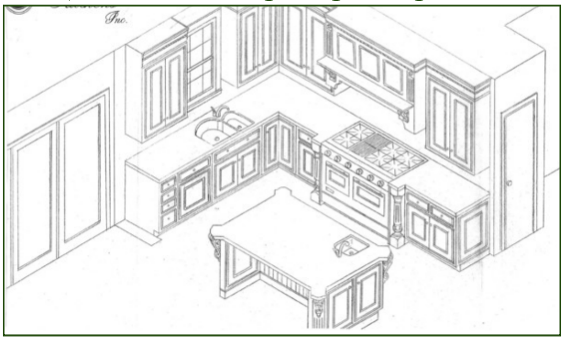
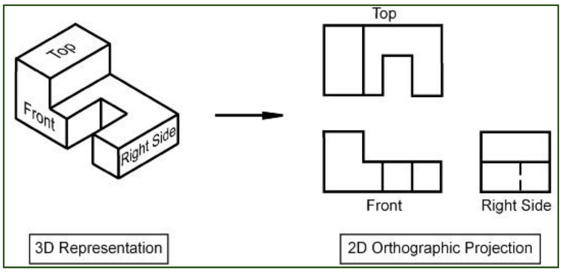
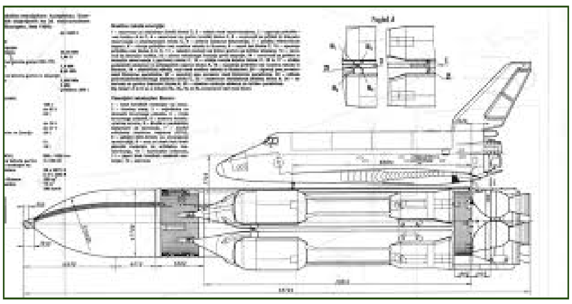
3.1 Conceptual modelling

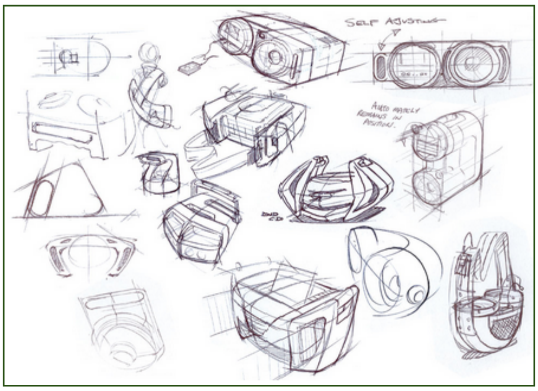
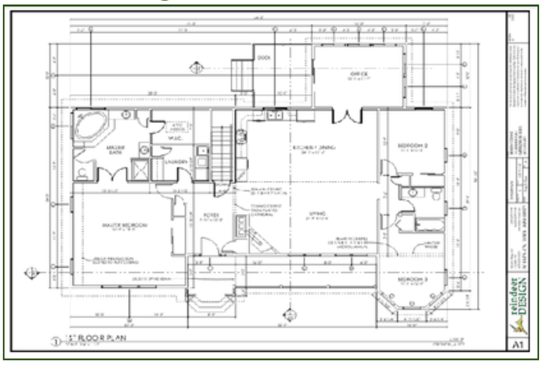
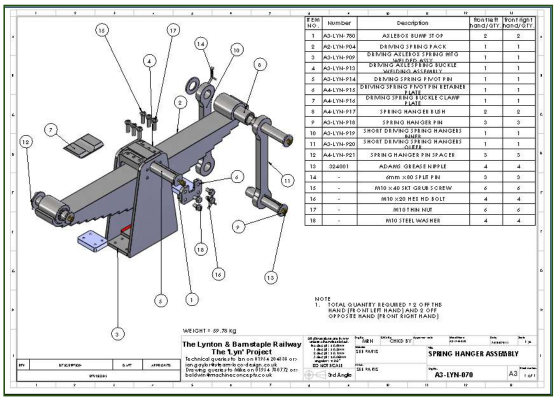
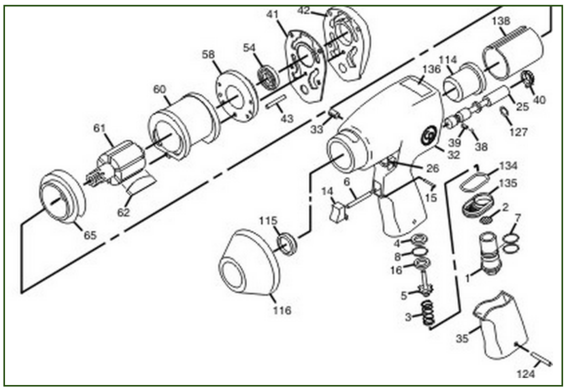
A conceptual model originates in the mind and its primary purpose is to outline the principles, processes and basic functions of a design or system. Designers use conceptual modelling to assist their understanding by simulating the subject matter they represent. Designers should consider systems, services and products in relation to what they should do, how they should behave, what they look like and whether they will be understood by the users in the manner intended.

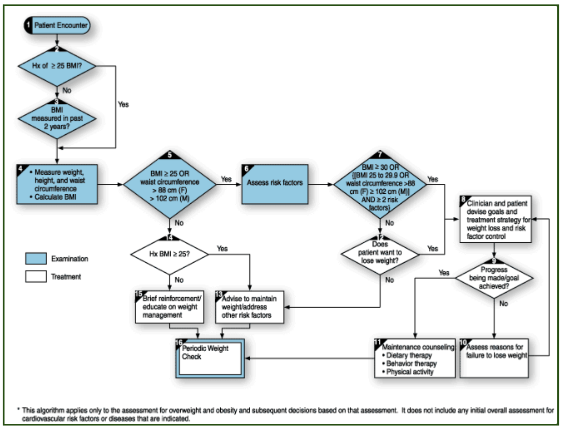
<table>
<tr><td>What is the role of conceptual modelling in design?</td><td>A conceptual model originates in the mind and its primary purpose is to outline the principles, processes and basic functions of a design or system. Conceptual models are used to help us know and understand ideas. Concept models are useful for communicating new ideas that are unfamiliar to people.</td></tr>
<tr><td>How do conceptual models vary in relation to the context?
What are some of the conceptual modelling tools and skills needed?</td><td>Conceptual models may vary in range from the more concrete , such as mental image that appears in mind, to the abstract mathematical models that do not appear directly in mind as an image. Conceptual models also range from scope of the subject they are representing. For example, they can represent either a single model (Statue of Liberty), whole classes of things (f.e. electron) or even a vast domains of subject matter , such as physical universe. Conceptual models are used to help us know and understand, design thinking, ideas, casual relationships, principles, data, systems, algorithms or processes.
Graphical Modelling
Sketches
Drawings
Flow charts
Physical Modelling
Card
Clay
Rapid prototype (3D printing)
Balsa wood
Blue styrofoam
Virtual Modelling:
Computer-Aided Design (CAD) Surface or Solid modelling, FEA, Data modeling</td></tr>
<tr><td>What is service design?</td><td>Service design is the activity of planning and organizing people, infrastructure, communication and material components of a service in order to improve its quality and the interaction between service provider and customers. The purpose to design according to the needs of the customers → so the product is user-friendly, competitive and relevant.</td></tr>
<tr><td>How are conceptual models used to communicate with oneself and others?</td><td>Concept models are used to communicate ideas that might be difficult to imagine otherwise. Designers use conceptual modelling to visualise and communicate ideas by simulating what they want to design.</td></tr>
<tr><td>What are the advantages and disadvantages of using conceptual modelling?</td><td><table><tr><th>Advantage</th><th>Disadvantage</th></tr><tr><td>-Shares ‘Big Picture’
-Makes it easy for non-designers and non-technical people to understand a complex idea
-Communication with clients and users
-Gauge people's reaction to concept or idea</td><td>-Lacks detail
-Can be misinterpreted
-Scale models can be misleading when the product is smaller or larger
-Materials may not reflect the final choice of materials- difficult to emulate</td></tr></table></td></tr>
</table>

3.2 Graphical modelling

Graphical models are used to communicate design ideas. Graphical models can take many forms, but their prime function is always the same—to simplify the data and present it in such a way that understanding of what is being presented aids further development or discussion. Designers utilize graphical modelling as a tool to explore creative solutions and refine ideas from the technically impossible to the technically possible, widening the constraints of what is feasible.

What	What they are used for	What they look like
What is a graphical model?	A graphical model is a 2D and 3D graphical models/visualization of an idea, often created on paper or through software.	They are drawings that convey the designers idea.
Perspective drawings	To show what a product will look like when finished in a more lifelike way.	Informal drawing technique on the 3D view of the design. The lines of a perspective drawing head towards a vanishing point. 
Isometric drawings	Used to accurately show what a product will look like when it is finished	You can recognise these drawings by an angle of the object in the drawing being 30 degrees 
Orthographic Projection	A way of drawing an 3D object from different directions. Usually a front, side and plan view are drawn so that a person looking at the drawing can see all the important sides. Orthographic drawings are useful especially when a design has been developed to a stage whereby it is almost ready to manufacture. Final , can be put to manufacture. Must always have at least 3 views.	
Scale drawings	All drawing techniques that show an object in proportion to its actual size. It is used when something needs to be presented accurately or either for planning or manufacturing.	

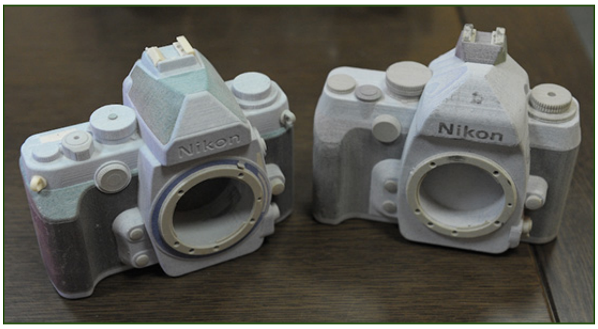
Sketching versus formal drawing techniques	**Sketching:** Spontaneous and free hand representation used very early in the design process. Usually free hand **Adv**: Communicate the ideas very quickly among the colleagues. **Dis**: can't take the idea to manufacture. **Formal drawings:** Ruled out and accurate drawings. The techniques tend to be used in the development phase of a design process. Formal drawings are used to represent a more resolved idea, something that the designer has settled on or wishes to investigate the idea in more detail. **Adv**: Shows in detail sizes of concept, Can be used to construct, Accurate, Different views of object shown that couldn't see from a 3D drawing **Dis**: Time consuming, Requires high level of skill, Specialist drawing equipment needed	**Sketching:**  **Formal drawings:** 
Part drawings	A **part drawing** provides the information to assembly a product in a similar way that an assembly drawing does with additional benefit of having a list of parts [LOP] or Bill of Materials [BOM]. A drawing of individual parts to help know which part is broken and how to repair it.	
Assembly drawings **(Exploded isometric)**	An **assembly drawing** shows how parts of a product fit together. They are often used to show how to assemble parts of model kits and flat-pack furniture. There are two types of assembly drawings. A **fitted assembly drawing** shows the parts put together, and can be drawn in 2D or 3D. An **exploded assembly drawing** that shows the parts separated, but in the correct relationship for fitting together. Exploded views are usually drawn in 3D.	

Algorithm	In mathematics and computer science, an algorithm is a self-contained step-by-step set of operations to be performed. Seen here with a flow chart.	

Notes:

3.3 Physical modelling

A physical model is a three-dimensional, tangible representation of a design or system. Designers use physical models to visualize information about the context that the model represents. It is very common for physical models of large objects to be scaled down and smaller objects scaled up for ease of visualization. The primary goal of physical modelling is to test aspects of a product against user requirements. Thorough testing at the design development stage ensures that an appropriate product is developed.

Term	Definition	Example/advantages & disadvantages
What is **Physical modelling?**	A physical model is a three-dimensional, tangible representation of a design or a system. 'Appearance Model'	 **Advantages:** -They allow the user to visualize the product and identifying any problems with the product easily. -The user can understand how the product would look in a real environment. **Disadvantages**: -It can be a time consuming process to create the physical model. -It can't be manipulated the same way a digital model can be.
Scale models	A **scale model** is a smaller or larger physical copy of an object. Scale models allow visualization, from examining the model, of information about what the model represents. A scale is usually represented e.g. 1:100 A good example of scale models is seen in architecture, whereby a full-size building is modelled at a greatly reduced scale. This enables designers to visualize the structure of the building, but also the exterior and interior aesthetics and lines.	 **Advantages:** -The model can be overviewed easily, especially if the original design is exceptionally large. -As it is scaled, it gives an idea of how large the model will be when it is actually produced/built. **Disadvantages:** -Can be time consuming to create a perfectly scale model. -Apart from providing the user with visual information about the product, it is hard to manipulate it to show how it works.

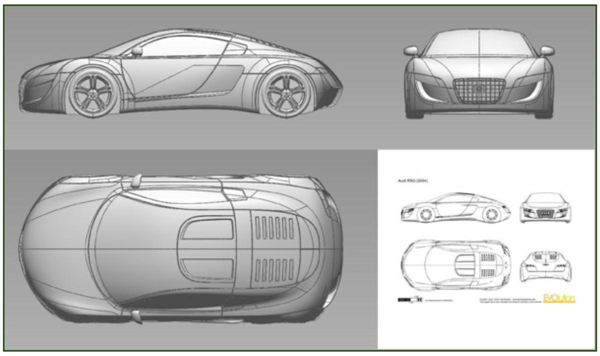
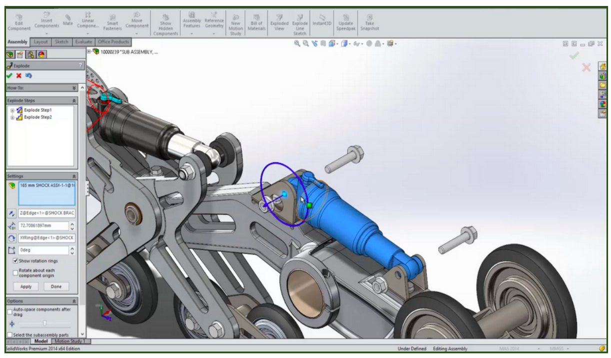
Aesthetic models	**Aesthetic models** are developed to look and feel like the final product. They are used for many purposes including ergonomic testing and evaluating visual appeal. Aesthetic models look like but do not work like the final product. Aesthetic models can be relatively simple, consisting of solid chunks of foam finished and painted to look like the real thing, or they can be more sophisticated, simulating weight, balance and material properties. Usually, aesthetic models are “for show” and are not designed to be handled excessively. They give non-designers a good representation of the feel and look of an object. For example, production engineers can take data to assess feasibility for matching manufacturing systems.	 **Advantages:** -They can be used instead of digital models to give the user an idea of how the product would look like in a real environment. -They can be used to give production engineers data to assess the feasibility of producing the product. **Disadvantages:** -They are non-working models and they only provide a visual model of the product. -They are fairly expensive to produce as the surface finish can be difficult to recreate.
Mock-ups	**Mock-ups** are used to test ideas. They are scale or full-size representation of a product used to gain feedback from users. A mock-up can be considered a prototype if it includes some functionality. Can have 'work-like' mock up and 'look-like' mock up.	 **Advantages**: -Can be used to get feedback from the user. -They are models made to a 1:1 scale and offer a full size representation of the product. **Disadvantages**: -Does not offer as much functionality as a prototype. -Can be difficult and time consuming to create.
Functional Prototypes	A **functional prototype** is a sample or model built to test a concept or process or to act as an object to be replicated or learned from. A prototype is used to test and validate ideas and can be used throughout design development. Prototyping can be used to provide specifications for a real, working product rather than a theoretical one. Prototypes are developed to work from two perspectives: the point of view of the development team, which can learn by creating the product, and the point of view of the user, from whom the development team can learn through user interaction and feedback. A prototype can be developed at different fidelities within a range of user and environment contexts.	 **Advantages:** -Is a semi to fully functioning model of a product and thus it can be used to test the functions of the final product out. -It can provide specifications for the parts involved in a real product and how they would function together. **Disadvantages:** -Can be slightly expensive to make as the prototype needs to be able to function. -Does not take aesthetics into account as it primarily tests the function of the product.

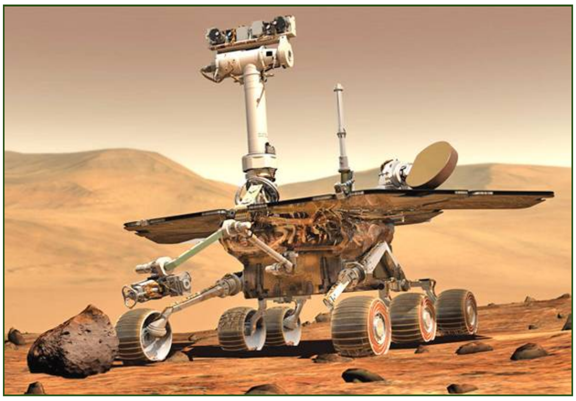
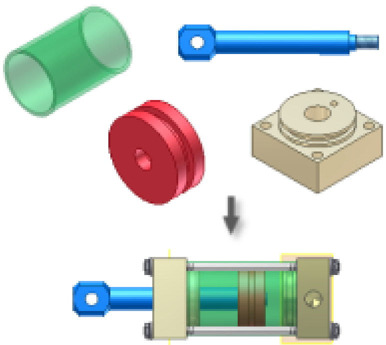
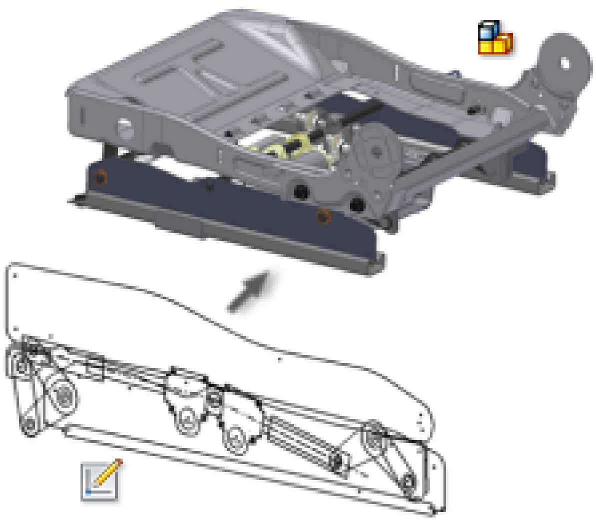
What is the **range of Fidelity**	Fidelity is a measure of the realism of a model or simulation. The range of fidelity is: ▪ **low** fidelity—conceptual representation analogous to the idea ▪ **medium** fidelity—representation of aspects of the idea ▪ **high** fidelity—mock-up of the idea, as close as possible to the final product	The range of contexts is: ▪ restricted—in a controlled environment ▪ general—any user, any environment ▪ partial—final user **or** environment ▪ total—final user **and** environment A combination of fidelity and context provides validation of an idea and/or further insight for development.
Instrumented models	**Instrumented physical models** are equipped with the ability to take measurements to provide accurate quantitative feedback for analysis. They can be used effectively to investigate many phenomena such as fluid flows in hydraulic systems or within wind tunnels, stress within structures and user interaction with a product. For example, an instrumented model of a keyboard can record the actions of the user and provide data on how often keys are used and the number of errors a user makes (that is, the number of times the backspace or delete key is used). These models can be scaled in terms of both geometry and important forces.	 **Advantages:** -Can be used to take accurate measurements related to the performance of the product, and can be used to improve the product further. -Can be used to record the dynamic behaviour of an object, in other words, data can be taken on how the product functions in a controlled environment. **Disadvantages:** -Can take time and be very expensive to set up.

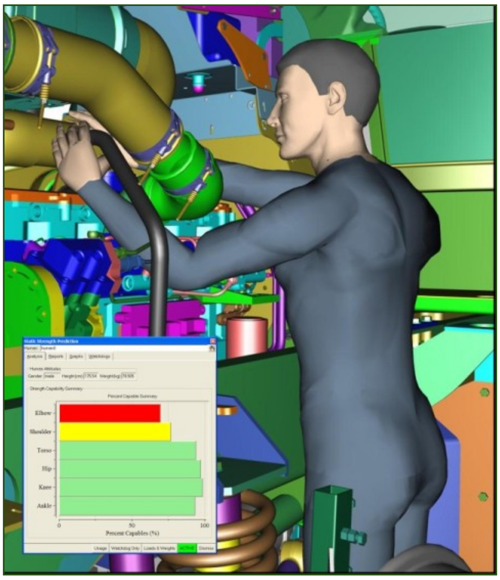
Notes:

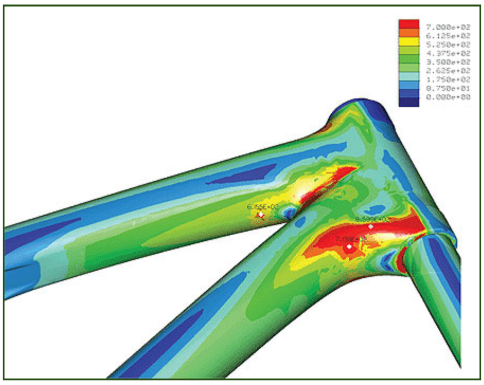
3.4 Computer-aided design (CAD)

A computer-aided design is the generation, creation, development and analysis of a design or system using computer software. As technologies improve and the software becomes more powerful, so do the opportunities for designers to create new and exciting products, services and systems. Greater freedom in customization and personalization of products has a significant impact on the end user. The ability to virtually prototype, visualize and share designs enhances the whole design cycle from data analysis through to final designs.

Term	Definition	Example/advantages & disadvantages
What is **CAD** and what is it used for	Computer-aided design. CAD is used for conceptual design and layout of product and can ultimately eliminate the high costs of testing and manufacturing. CAD is used in fashion, construction, automative, architecture and for planning electrical or mechanical layout.	-A computer-aided design is the generation, creation, development and analysis of a design or system using computer software. The use of CAD to simulate the conditions in which a product will be used allows the designer to gain valuable data at low cost.
Surface modelling	Surface models are photo-realistic images of a product, offering some machining data but no data about the interior of the product.	 -photo-realistic images of a product, offering some machining data -No data about the interior of the product.
Solid modelling	Solid models are clear representations of the final product. They provide a complete set of data for the product to be realized including internal dimensions and volume.	 Solid models are clear representations of the final product. They provide a complete set of data for the product to be realized including internal dimensions and volume.
Data modelling also known as Mathematical modelling/ Statistical modelling	A **data model** explicitly determines the structure of data or structured data including statistical modelling. Typical data models include databases and information systems	

Virtual prototyping	Virtual prototyping involves the use of surface and solid modelling to develop photo-realistic interactive models. These can be considered digital mock-ups.	 Jaguar and Land Rover moving to virtual 3D vehicle prototyping
Bottom-up modelling	When designing using a "bottom-up" strategy, the designer creates part geometry independent of the assembly or any other component. Although some design criteria are often established before modelling the part, this information is not shared between models. Once all part models are completed, they are brought together for the first time in the assembly. For example, the process by which the Mars rover Curiosity was created followed a "bottom-up" strategy. Place existing parts and subassemblies into an assembly file, positioning components by applying assembly constraints, such as mate and flush. If possible, place the components in the order in which they would be assembled in manufacturing.	 Advantage: we know what the parts are. 
Top-down modelling	"Top-down" design is a product-development process obtained through 3D, parametric and associated CAD systems. The main feature of this method is that the design originates as a concept and gradually evolves into a complete product consisting of components and sub-assemblies. "Top-down" begins with the design criteria and create components that meet those criteria. Designers list known parameters and create an engineering layout. The layout can be a 2D design that evolves throughout the design process as shown in the following image.	

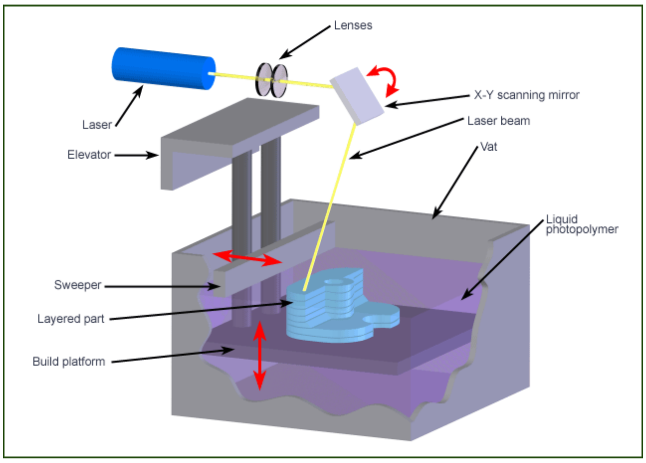
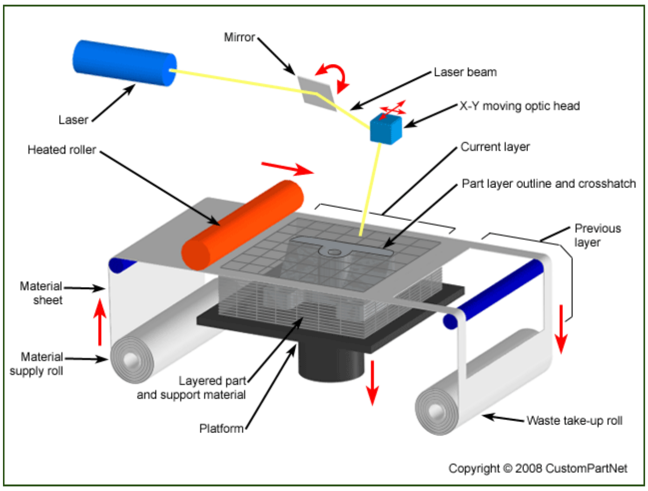
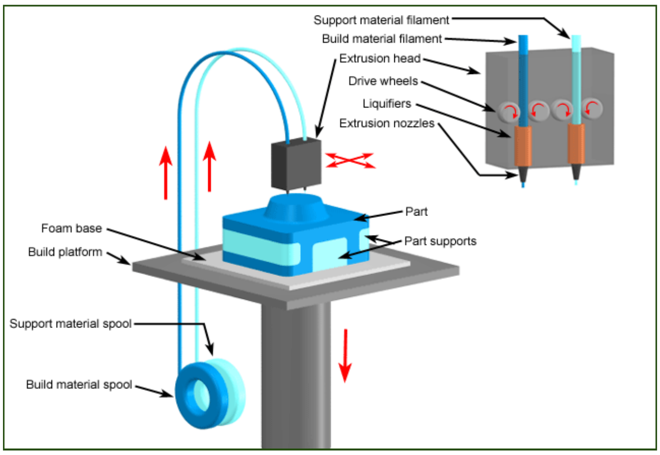
Digital humans	Digital humans are computer simulations of a variety of mechanical and biological aspects of the human body. They can be used to interact with a virtual prototype. Human simulation in product design enables a product to be developed more quickly, as there can be more design iterations in less time. This results in higher product quality that meets human requirements more accurately. Digital prototypes are cheaper to produce than physical prototypes. Products are safer as a result of more thorough analysis of safety aspects. Improved productivity results from enhanced automation of the development process.	
Motion capture	Motion capture is the recording of human and animal movement by any means, for example, by video, magnetic or electro-mechanical devices. A person wears a set of acoustic, inertial, LED, magnetic or reflective markers at each joint. Sensors track the position of the markers as the person moves to develop a digital representation of the motion. Motion capture can reduce the cost of animation, which otherwise requires the animator to draw either each frame or key frames that are then interpolated. Motion capture saves time and creates more natural movements than manual animation, but is limited to motions that are anatomically possible.	"Gollum" from Hobbit is a character formed by using Motion Capture filming technique. This character got an award winning for motion capture model. Compared to Avatar, Gollum appearance reveals all the muscle movements and skin reflection to the light, showing the technology improvement over the years. 
Haptic technology	Haptic technology is a technology that interfaces the user via a sense of touch. Also known as force feedback technology, haptic technology works by using mechanical **actuators** (motor) to apply forces to the user. By simulating the physics of the user's virtual world, it is possible to compute these forces into real time. Haptic technology allows the user to become part of a computer simulation and to interact with it, enabling the designer to observe the user's performance and to design a better outcome. It can also be used in situations where it is difficult to train in the real environment. Haptic technology is also used in feedback devices used in home entertainment consoles.	

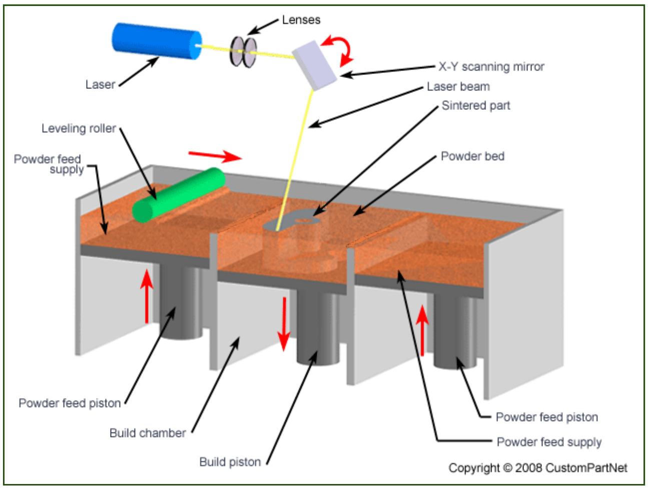
Virtual reality (VR)	Virtual reality is the ability to simulate a real situation on the screen and interact with it in a near-natural way.	
Animation	Animation is the ability to link graphic screens together in such a way as to simulate motion or a process.	
Finite element analysis (FEA)	Finite element analysis involves the calculation and simulation of unknown factors in products using CAD systems, for example, simulating stresses within a welded car part. (virtual model) Uses colour indication to show: -Structural load (stress and strain) -Aerodynamics -Thermodynamics	

Notes:

3.5 Rapid prototyping

Rapid prototyping is the production of a physical model of a design using three-dimensional **CAD data**. The growth in computing power has had a major impact on modelling with computer-aided manufacture. Rapid software and hardware developments allow new opportunities and exciting new technologies to create dynamic modelling of ever-greater complexity. Models can be simulated by designers using software, tested and trialled virtually before sending to a variety of peripheral machines for prototype manufacture in an ever-increasing range of materials. The ease of sending this digital data across continents for manufacture of prototypes has major implications for data and design protection.

What	How it works	Image of process
Stereolithography (SLA) (uses laser or light to set plastic liquid)	It is a form of **3D printing** using a liquid bath of resin combined with an **ultraviolet** laser. The ultraviolet light hits the liquid **hardening** it to form the structure of the object being printed. The **base plate** of the bath then moves down allowing **more liquid** to flow over the previously hardened liquid so the same process can be repeated until the object being printed has been **completed**. The 'Sweeper' seen in the image to the right just helps **even out** the height of the bath every time the laser fires.	
Laminated object manufacturing (LOM)	It takes the sliced **CAD data** from a 3D model and **cuts out each layer** from a roll of material, using a **laser or plotter cutter**. These sliced layers are **glued** together to form the model, which is either built on a **movable platform** below the machine or on locating pins when using card.	
Fused deposition modelling (FDM) (Same as school makerbot and Flashforge)	Uses an "additive" principle by **laying down materials in layers**. **Plastic/metal** is unwound from a coil and sent to an extrusion **nozzle** that can **turn the flow on and off.** The **nozzle is heated** to **melt** the material, nozzle moves in **horizontal and vertical directions** by a numerically controlled mechanism **(CAM)**	

Selective laser sintering (SLS) (uses laser to set plastic powder)	is an **additive** manufacturing technique that uses a **high-power laser** (for example, a carbon dioxide laser) to **fuse small particles of materials** such as plastic, metal (direct metal laser sintering), ceramic or glass powders into a mass that has a desired 3D shape.	
Advantages and Disadvantages of Rapid Prototyping	**Advantages** -Decrease development time -Decrease costly mistake -Increase number of variants of product (since each printed model takes lesser time to produce, the time saved can be used to develop more ideas, thus increase productivity). -Increase product complexity (more complex and difficult shapes can be modelled, which would perhaps not be possible with hand. For eg. sculpting out an accurate sphere in a material). -Increase effective communication (since the model is tangible, various aspects of the design would be easier to explain to others, as compared to CAD. Models can also be tested, which probably would be only possible through artificial simulation for CAD designs, and thus unlike prototypes, this would only give an approximate idea). -Rapid Prototyping can provide with concept proof that would be required for attracting funds (easier to explain, aesthetics can be focused on)	**Disadvantages** -Some people are of the opinion that rapid prototyping is not effective because, in actual, it **fails in replication** of the real product or system. -It could so happen that some important developmental steps could be omitted to get a quick and cheap working model. This can be one of the greatest disadvantages of rapid prototyping. -Another disadvantage of rapid prototyping is one in which many problems are overlooked resulting in endless rectifications and revisions. -One more disadvantage of rapid prototyping is that it may not be suitable for large sized applications. -The user may have very high expectations about prototype's performance and the designer in unable to deliver these. .

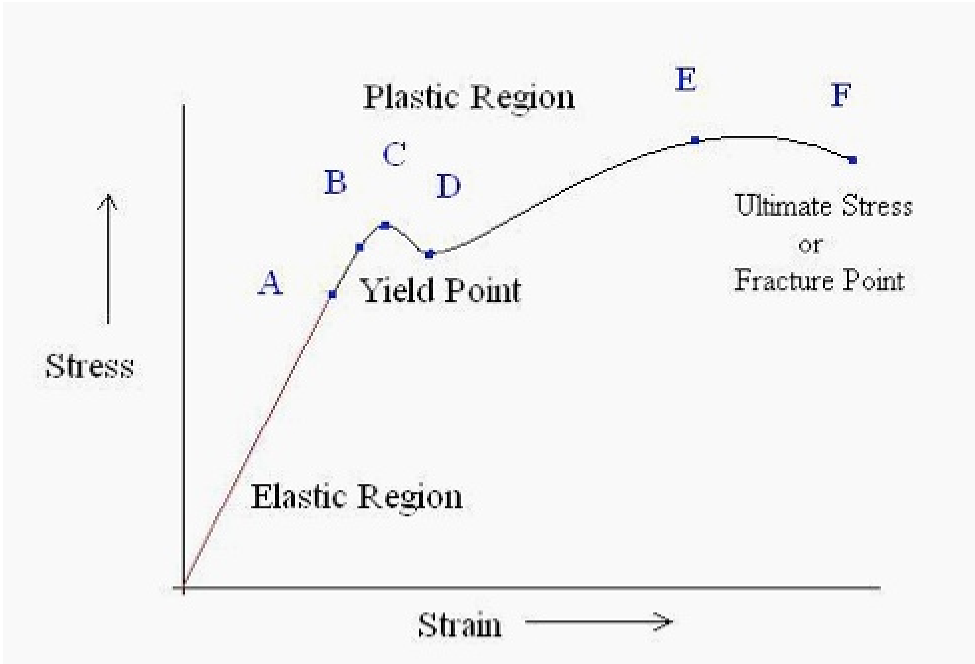
Notes:

Topic 4
Raw material to final product

4.1 Properties of materials

Materials are selected for manufacturing products based primarily on their properties. The rapid pace of scientific discovery and new technologies has had a major impact on material science, giving designers many more materials from which to choose for their products. These new materials have given scope for “smart” new products or enhanced classic designs. Choosing the right material is a complex and difficult task with physical, aesthetic, mechanical and appropriate properties to consider. Environmental, moral and ethical issues surrounding choice of materials for use in any product, service or system also need to be considered.

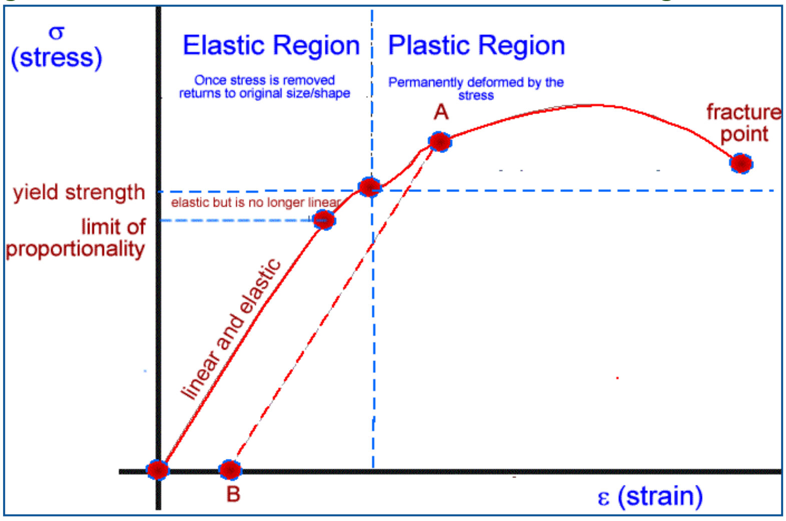
Define **Physical properties**	These properties tend to be the characteristic of materials that can be identified through testing that is considered to be **non-destructive**, although some deformation is required to test hardness. This exception is often why hardness is often catergorised as a mechanical property.
Definitions	**Mass-** relates to the amount of matter that is contained with a specific material. It is is often confused with weight understandably as we use Kg to measure it. Mass is a constant whereas weight may vary depending upon where it is being measured. **Weight-** relies on mass and gravitational forces to provide measurable value. Weight is technically measure as a force, which is the Newton, ie a mass of 1Kg is equivalent to 9.8 Newtons [on earth]. **Volume-** is the quantity of three-dimensional space enclosed by some closed boundary, for example, the space that a substance solid, liquid, gas, or shape occupies or contains. **Density-** is the mass per unit volume of a material. It’s importance is in portability in terms of a product’s weight and size. Design contexts include, pre-packaged food (instant noodles) is sold by weight and volume, packaging foams. **Electrical resistivity-** This is a measure of a material’s ability to conduct electricity. A material with a low resistivity will conduct electricity well. It's particularly important in selecting materials as conductors or insulators. **Thermal conductivity-** A measure of how fast heat is conducted through a slab of material with a given temperature difference across the slab. It's important for objects that will be heated or must conduct or insulate against heat. **Thermal expansion** (expansivity)- A measure of the degree of increase in dimensions when an object is heated. This can be measured by an increase in length, area or volume. The expansivity can be measured as the fractional increase in dimension per kelvin increase in temperature. It's important where two dissimilar materials are joined. These may then experience large temperature changes while staying joined. **Hardness-** The resistance a material offers to penetration or scratching. Hardness is important where resistance to penetration or scratching is required. Ceramic floor tiles are extremely hard and resistant to scratching.

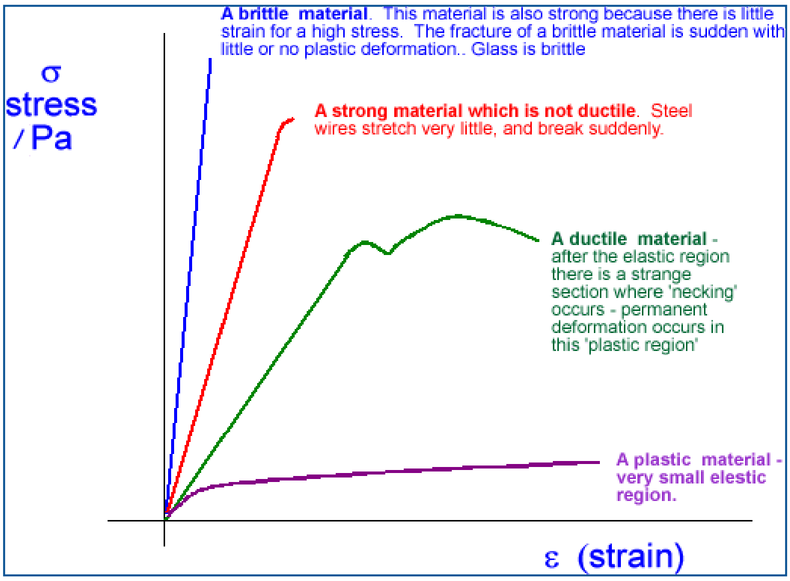
Mechanical properties	**Tensile strength**- The ability of a material to withstand pulling forces. **Tensile** strength is important in selecting materials for ropes and cables, for example, for an elevator. **Compressive strength-** Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size, **Stiffness-** The resistance of an elastic body to deflection by an applied force. **Stiffness** is important when maintaining shape is crucial to performance, for example, an aircraft wing. **Toughness-** The ability of a material to resist the propagation of cracks. Good with resisting high impact of other objects- e.g. hammer **Ductility-** The ability of a material to be drawn or extruded into a wire or other extended shape. **Ductility** is important when metals are extruded (not to be confused with malleability, the ability to be shaped plastically). **Malleability** is the ability for materials to be shaped easily. The property of a substance that makes it capable of being extended or shaped by hammering or by pressure from rollers.
What is **Young's modulus**, stress and strain What is elasticity on the graph. Which part? What does it mean? Give an example. What is plasticity on the graph. Which part? What does it mean? Give an example.	**Young's Modulus** - also known as the tensile modulus or elastic modulus, is a measure of the stiffness of an elastic material and is a quantity used to characterize materials. It is defined as the ratio of the stress (force per unit area) along an axis to the strain (ratio of deformation over initial length) along that axis in the range of stress.  Stress = $\frac{\text{Force}}{\text{Cross Sectional Area}}$ Strain = $\frac{\text{Change in Length}}{\text{Original Length}}$ This straight line region is known as **elastic region** and the material can regain its original shape after removal of load. The stress and strain are directly proportional up to point A. Point B is known as the **Yield Point**. Once the material has crossed the Yield Point the material will not return to it's original shape, this is known as the plastic region. The line between AC is not a straight line and strain increases faster than stress. The material will change in length faster at these points than at any other point.

At this point C the cross sectional area of the material starts decreasing. At point D the workpiece changes its length with a little or without any increase in stress up to point E.

Point F is called **ultimate stress point** or fracture point. A material is considered to have completely failed once it reaches the ultimate stress.

Measuring when a material reaches it's Yield Point is called the Young's Modulus.



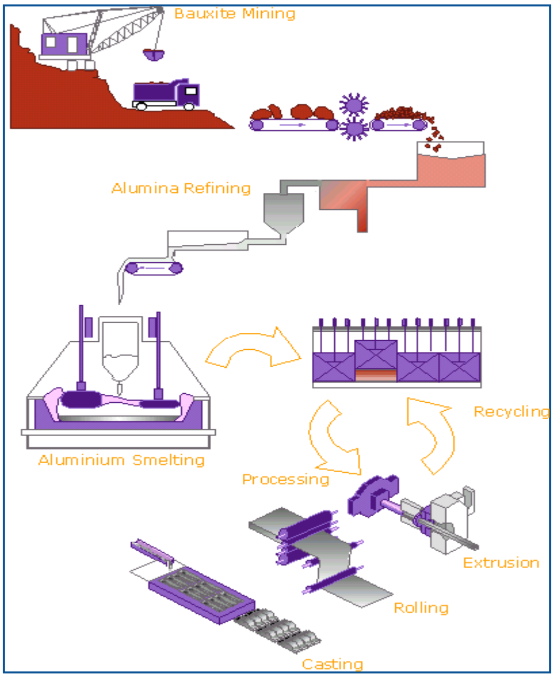
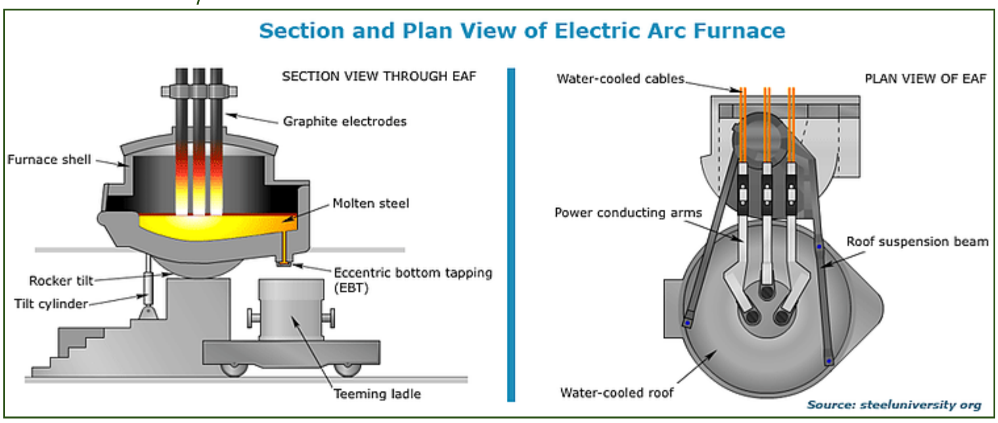


Aesthetic characteristics	Some aesthetic characteristics are only relevant to food, while others can be applied to more than one material group. Aesthetic characteristics of products make them interesting, appealing, likeable, or unattractive and are based completely on personal preferences. These personal views are affected by mood, culture, experience, activation of the senses, values, beliefs, etc. They are very difficult to quantify scientifically and people's **reactions to taste, smell, appearance and texture** are very different.
Definitions	**Taste** - the ability to detect the flavour of substances such as food and poisons. **Smell** - the ability of humans and other animals to perceive odors. Consider the scene in *Ratatouille (film)* where he experiences the taste of food in vibrant technicolor, think about how smells evoke memories, the smell of fresh bread when you enter a supermarket, food smells making you hungry, etc. **Appearance** - related to how something looks. What a product looks like. Is it colourful? masculine? feminin? funny? sexy? sleek? minimal? clean? busy? etc. The appearance of a product appeals to different demographics such as age, gender, culture, ethnicity, etc. Shopper place a large emphasis on colour, so does brand recognition IE Coca Cola **Texture** - the properties held and sensations caused by the external surface of objects received through the sense of touch. e.g. smoothness of kitchen work surfaces for reasons of hygiene, tiles around a swimming pool (i.e. roughened surface to prevent slipping when wet). Hard, Soft, Abrasive, Smooth. Wood has a grain pattern, metal has a cold texture. **Colour-** is the visual perceptual property corresponding in humans to the categories of colours. • Optical e.g. opaque, translucent, transparent • Colour e.g Hot, Cold, Warm, Mellow, Bright, Vivid, Cool • Effects on emotions. e.g. sense of 'warmth' and 'coldness' i.e. 'warm' red/orange/yellow 'cool' violet/green/blue. The use and application of such knowledge in the designed environment. e.g. decoration, symbols, artefacts.

Smart Materials	Smart materials have one or more properties that can be dramatically altered, for example, viscosity, volume, conductivity. The property that can be altered influences the application of the smart material.	
Type of Smart Material	**How it works/what it can do**	**Design contexts where properties of smart materials are exploited**
Piezoelectricity	is a term that is derived from the greek meaning for piezo, squeeze or pressure where electricity is generated when piezoelectric material is deformed, **The pressure acting upon the material it gives off a small electrical discharge.**	When a **piezoelectric** material is deformed, it gives off a small electrical discharge. When an electric current is passed through it, it increases in size (up to a 4% change in volume). These materials are widely used as sensors in different environments. Piezoelectric materials are used in the airbag sensor on a car as it senses the force of an impact on the car and sends an electric charge to activate the airbag.
Shape memory alloy (SMA's)	Metals that exhibit pseudo-elasticity and shape memory effect due to rearrangement of the molecules in the material. **Pseudo-elasticity occurs without a change in temperature or electrical voltage**. The load on the SMA causes molecular rearrangement, which reverses when the load is decreased and the material springs back to its original shape.	They can be used to make products for durable and harder to break. i.e. Glasses frames The shape memory effect allows severe deformation of a material, which can then be returned to its original shape by heating it.
Photochromicity	Material that can described as having a **reversible change of colour when exposed to light**. One of the most popular applications is for colour-changing sunglass lenses, which can darken as the sun light intensifies. A chemical either on the surface of the lens or embedded within the glass reacts to ultraviolet light, which causes it to change form and therefore its light absorption spectra.	welding goggles/ mask. cool tee shirts. “reactor light” sunglasses
Magneto-rheostatic **Electro-rheostatic**	**Electro-rheostatic** (ER) and **magneto-rheostatic** (MR) materials are fluids that can undergo dramatic changes in their viscosity. They can change from a thick fluid to a solid in a fraction of a second when exposed to a magnetic (for MR materials) or electric (for ER materials) field, and the effect is reversed when the field is removed.	MR fluids are being developed for use in car shock absorbers, damping washing machine vibration, prosthetic limbs, exercise equipment and surface polishing of machine parts. ER fluids have mainly been developed for use in clutches and valves, as well as engine mounts designed to reduce noise and vibration in vehicle
Thermoelectricity	**Thermoelectricity** is, at its simplest, electricity produced directly from heat. It involves the joining of two dissimilar conductors that, when heated, produce a direct current. Thermoelectric circuits have been used in remote areas and space probes to power radio transmitters and receivers.	Nest was co-founded by former Apple engineers Fadell and Rogers in 2010 and now produces a range of household monitoring devices. The temperature monitors uses thermocouples to drive the electrical signal to provide the data. Nest products form part of the interface to create smart systems that are remotely driven through smartphone apps.

4.2a Metals and metallic alloys

Materials are classified into six basic groups based on their different properties. Typically hard and shiny with good electrical and thermal conductivity, metals are a very useful resource for the manufacturing industry. Most pure metals are either too soft, brittle or chemically reactive for practical use and so understanding how to manipulate these materials is vital to the success of any application.

Extracting metal from ore The Earth's crust contains metals and metal compounds such as gold, iron oxide and aluminium oxide, but when found in the Earth these are often mixed with other substances. To be useful, the metals have to be extracted from whatever they are mixed with.	A **metal ore** is a rock containing a metal, or a metal compound, in a high enough concentration to make it economic to extract the metal. The method used to extract metals from the ore in which they are found depends on their reactivity. For example, reactive metals such as aluminium are extracted by electrolysis, while a less-reactive metal such as iron may be extracted by reduction with carbon or carbon monoxide. Thus the method of extraction of a metal from its ore depends on the metal's position in the reactivity series:
Aluminium Extraction	Aluminium ore, most commonly bauxite, is plentiful and occurs mainly in tropical and sub-tropical areas. **Bauxite** is refined into aluminium oxide trihydrate (alumina) and then **electrolytically** reduced into metallic aluminium. 
Steel	**Blast Furnace using oxygen furnace** and the **electric arc furnace** contribute to high rates of steel reusability 

Grain size	Metals are crystalline structures comprised of individual grains. The grain size can vary and be determined by heat treatment, particularly how quickly a metal is cooled. Quick cooling results in small grains, slow cooling results in large grains. Grain size in metals can affect the **density, tensile strength and flexibility.** The smaller the grains in the metal the higher density the metal is. Higher density means a lower flexibility and sometime tensile strength. The tensile strength and flexibility will also depend on how the metal is tempered normally. The rate of cooling and the amount of impurities in the molten metal will affect its grain size: • Gradual cooling - a few crystals are formed - large grain size • Rapid cooling - many crystals formed - small grain size. • Reheating a solid metal / alloy allows the grain structure to re-align itself. • Directional cooling in a structure is achieved by selectively cooling one area of a solid. The effect of impurities (or additives) in a molten metal can induce a large number of fine grains that will give a stronger and harder metal. This addition must be carefully controlled as too many impurities may cause an accumulation at the grain boundaries, which will weaken the material.
Modifying physical properties by alloying, work hardening and tempering	**Alloying** is an **alloy** is a mixture of two elements, of which one is at least a metal - e.g. Carbon and Iron is Steel. Copper and Zinc (two metals) create Brass - Adding in different (materials to) metals to ultimately create a harder and strong metal. **Work hardening** or cold working, is the strengthening of a metal by plastic deformation. As the name suggests the **metal becomes harder after the process**. The metal is not heated at all. The process involves the metal passing through a set of rollers to reduce its thickness, (compressed) grains are deformed. The shape is changed, but the volume remains constant. The defects of these structures reduce the ability for crystals to move within the metal structure, becoming more resistant to more deformation as they recrystallize. Processes include - • rolling, • bending • shearing • drawing **Annealing** is a heat treatment that alters the physical and sometimes chemical properties of a material to increase its ductility and to make it more workable. It involves heating, maintaining a suitable temperature, and then cooling by slowly reducing the temperature over time. Annealing is **softening the metal after work hardening**. **Case Hardening** is hardening are processes in which the surface of the steel is heated to high temperatures (by direct application of a flame, or by induction heating) then cooled rapidly, generally using water; this creates a surface of martensite on the surface. **Improves hardness on the surface** or case of the material while keeping the inner core untouched and so still processes properties such as **flexibility and is still relatively soft.** **Tempering** is a process of heat treating, which is used to **increase the toughness** of metals containing iron. Tempering is usually performed after hardening, to reduce some of the excess hardness, and is done by heating the metal for a certain period of time, then allowed to cool in still air. Tempering is reducing brittleness after quenching.
Superalloys	**Design criteria for superalloys:** - Excellent mechanical strength and creep resistance at high temperatures - Corrosion and oxidation resistance **Creep Resistance:** - Creep is the gradual extension of a materials under constant force. Dependant on temp. and pressure. - Occurs as a result of thermal vibrations of the lattice. Can result in fracture of superalloy due to development of cavities in the material

	Oxidation Resistance: - Presence of other metals such as chromium ensure that a tight oxide film is formed on the surface - This restricts access of oxygen to the metal surface so that the rate of oxidation is heavily reduced. **Applications of Superalloys:** Nickel Based Alloy - Jet Engine Components (Turbine blades operate at high temperature and under extreme stress conditions. In operation they will glow red hot, however they must be creep resistant, fatigue and corrosion resistant.

Recovery and **disposal** of metals and metallic alloys	- car bodies and steel reinforcing recovered from concrete can be recycled into new steel
	- modern technologies are causing a significant problem
	    - 20 million to 50 million tonnes of e-waste
	- new recycling schemes directed specifically for e-waste
	    - example; Samsung Washing Machine where broken parts can be taken apart and replaced with a new one
	    - Aluminium recycling a huge advantage as extraction process is so expensive/damaging to environment therefore we should encourage alu recycling

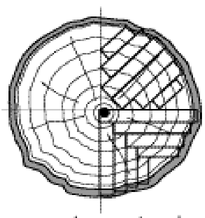
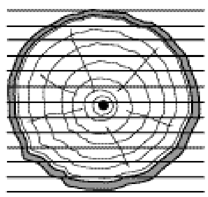
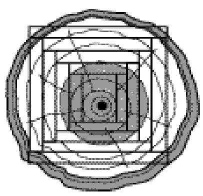
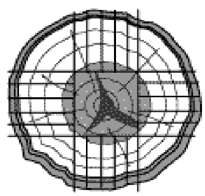
Notes:

Contexts where different metals and metallic alloys are used

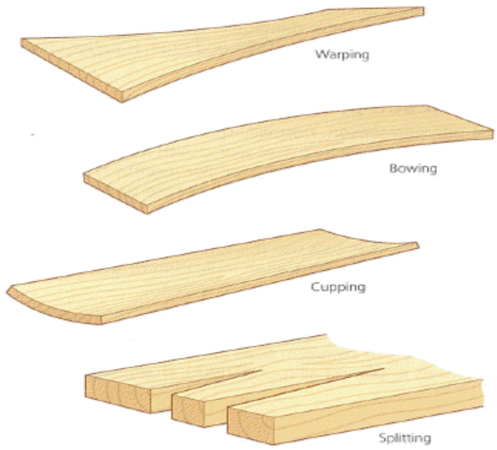
Classification and Type of Metal	Properties (pro's and con's)	Example of products
Ferrous metals: **Steel**	- Poor corrosion resistance - Tough - Ductile - Malleable - Good Tensile Strength - Can be recycled - Relatively Cheap	- Surgical tools - screw - nails - kitchen utensils - used in all purpose engineering
Ferrous metals: **Iron**	- very ductile - strong - malleable - Long lasting	- basic machinery - tools - building structures - manufacturing components of cars / automobiles
Ferrous metals: **Stainless Steel**	- high initial cost - difficult to fabricate - difficult to weld due to high carbon content?	- Pipes - cutlery - aircraft
Non Ferrous metals: **Aluminium**	- light weight - easily worked - Malleable and soft - Conducts heat and electricity - Corrosion resistant	- Aircraft manufacture - window frames and some kitchen ware
Non Ferrous metals: **Copper**	- conducts heat and electricity - Corrosion resistant - Tough, ductile	- Wiring - tubing - pipe work
Non Ferrous metals: **Tin**	- Soft - Corrosion resistant	- Tin cans
Non Ferrous metals: **Zinc**	- Layer of oxide, anti Corrosion - Easily worked with	- Makes brass - steel coating **(galvanising)** - tanks - anti rust
Non Ferrous metals: **Brass**	- Very corrosive - Tarnishes - Conducts electricity well	- Ornamental purposes - within electrical fittings

4.2b Timber

Timber is a major building material that is renewable and uses the Sun's energy to renew itself in a continuous cycle. While timber manufacture uses less energy and results in less air and water pollution than steel or concrete, consideration needs to be given to deforestation and the potential negative environmental impact the use of timber can have on communities and wildlife.

Characteristics of natural timber:	Natural timber is timber that is used directly from the tree after being **seasoned** (a controlled drying process). It is actually a type of composite material because it is made up of cellulose (wood fibres) held together with a natural adhesive (lignin). The tensile strength of timber is greater along the grain (fibre) than across the grain (matrix). Natural timber is classified into two main categories: **Softwood** and **Hardwood**. • Softwood comes from *coniferous* trees. These have needles that are kept year-round. • Hardwood comes from *deciduous* trees. These are broad leaved and often shed their leaves during winter, depending on the climate. The world's forests can be divided into **temperate** and **tropical**: • Temperate forests are in the regions between the tropics and the polar areas, mainly in the northern hemisphere. *Both hardwoods and softwoods grow in temperate forests.* Tropical forests are in the region between the 2 tropics. *Generally only hardwoods are found in these forests.*
Seasoning of Timber	Two types of seasoning- Artificial (Kiln) or Natural **1) Air Seasoning** Advantages : No expensive equipment needed, Small labour cost once stack is made, Environmentally friendly-uses little energy Disadvantages :Takes longer than Kiln seasoning, large area of space required for a lot of wood, it is notable to produce timber not dry enough for use in the dry, centrally heated air of modern buildings **2) Kiln Seasoning** Advantages: Insects are killed during this process, Require little stacking space, Moisture content of the timber may be brought to any desired level, It is dries quickly, It can be controlled, Achieve a lower moisture content, Defects associated with drying can be controlled Disadvantage: It is expensive , It gives a little weaker timber when compared to air seasoning, requires supervision by a skilled operator, uses a lot of energy
Conversion of timber	After a tree has been **felled/cut down** and taken to a sawmill, it is converted ready for **seasoning.** After the timber dries out, it is cut into smaller sections.  quartered conversion, showing 2 different cuts (radial boards)  through and through conversion. (tangential and some radial board  tangential cuts (heart is boxed)  boxed heart

Faults with **natural timber**

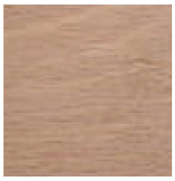
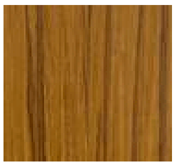
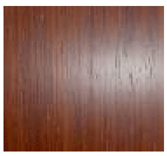


Natural woods are also subject to movements such as **splitting, cupping, warping** and **bowing.** All of these would make the wood **unusable.**

Woods can also form **knots** which are formed where branches grow from the main trunk or where the bud was formed. Knots will make the timber weaker, but it can be used from an aesthetic point of view.

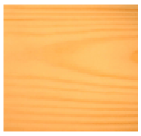
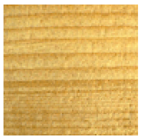
Characteristics of natural timber: **hardwood**

-Hardwood trees are mostly deciduous, and are characterised by their broad or large area leaves. hardwood trees also bear fruit, such as nuts, seeds or acorns, there name is often derived from the name of their fruits. They can 100 years to mature.
-Tropical hardwoods are not classified as deciduous but as *angiosperm*. but their timber has comparable mechanical properties of strength, hardness and durability. hardwood is mostly of a higher density and hardness than a softwood.
-Aesthetics of hardwoods is usually very appealing**.** This makes it very desirable and its often used in high-quality furniture. This also makes it very expensive.
-Hardwoods contain much more fibrous material than softwoods. The fibers are smaller and more compact, making it stronger and harder. In general, the greater the density of wood, the greater its mechanical strength.

Hardwood	Colour/texture	Uses
Beech - A straight-grained hardwood with a fine texture. Light in colour. Very hard so is ideal to be used where it is being bashed around and used often. Beech is also very easy to work with.		Used for furniture, children's toys, tool handles. Can be steam bent and laminates well.
Teak - A very durable oily wood which is golden brown in colour. Highly resistant to moisture as it contains natural oils.		A very durable oily wood which is golden brown in colour. Highly resistant to moisture and outdoor weather
Oak - A very strong wood which is light in colour. Open grain. Hard to work with. When treated it looks very classy and elegant.		A very strong wood which is light in colour. Open grain. Hard to work with. When treated it looks very classy and elegant.
Mahogany - An easy to work wood which is reddish brown in colour. This wood is very expensive. A hardwood.		An easy to work wood which is reddish brown in colour. This wood is very expensive.

Characteristics of natural timber: **softwood**

Softwoods

Softwood	Colour/Texture	Uses
Scots pine - A straight-grained softwood but knotty. Light in colour. Fairly strong but easy to work with.		Used for DIY and cheap quality furniture. Mainly used for constructional work and simple joinery.
Spruce - Creamy-white softwood with small hard knots. Not very durable.		Used for general indoor work, whitewood furniture used in bedrooms and kitchens.
European redwood - Quite strong, Lots of knots, durable when preserved.		Used for general woodwork, cupboards, shelves, roofs.

Softwoods come from **coniferous** trees which are evergreen, needle-leaved, cone-bearing trees, such as cedar, fir and pine.
Softwoods can often be harder than hardwood. Douglas Fir has a higher tensile and compressive strength than many hardwoods. Balsa wood, although technically a hardwood, is mechanical week, low tensile strength, low hardness and lacking in toughness.

Aesthetics : Softwoods such as pine are very resinous and at times this resin can leak out of the timber. Resin is really sticky and messy and will also come through painted surfaces (it makes a really bad stain).
Pine will change color if exposed to sunlight for long periods of time. Generally a pale yellow with brown streaks. Softwoods are also prone to decaying and warping, bowing, cupping and splitting.

Softwoods are usually made up of tube-like cells (similar to holding up a bunch of straws together). This would make the softwoods less dense and more prone to water damage. The timber absorbs water just like a sponge if the end grain is exposed.

Characteristics of **man-made timbers**	Man-made timbers are composite products that use wood lengths, fibres and veneers along with an adhesive binder and combined under heat and pressure to produce a product. Highlight characteristics include tensile strength,resistance to damp environments, longevity, aesthetic properties

MDF	Plywood	Chipboard/Particleboard
		
Smooth, even surface. Easily machined and painted or stained. Also available in water and fire resistant forms.	A very strong board which is constructed of layers of veneer which are glued at 90 degrees to each other.	Made from chips of wood glued together. Usually veneered or covered in plastic laminate.
Used mainly for furniture and interior panelling due to its easy machining qualities. Often veneered or painted.	A very strong board which is constructed of layers of veneer which are glued at 90 degrees to each other.	Made from chips of wood glued together. Usually veneered or covered in plastic laminate.

Advantages and **disadvantages** of man-made timbers

Advantages	Disadvantages
available in **large** flat sheets- 2440 x 1220mm so can be used for large pieces of furniture without having to join pieces together	sharp tools required when cutting manufactured boards, and tools and easily blunted
good **dimensional stability**- they don't warp as much as natural timber	difficult to join in comparison with traditional construction methods- you cannot cut traditional woodwork construction joints such as finger or dovetail joints
can be decorated in a number of ways, eg, with **veneers** or paint	thin sheets do not stay flat and will bow unless supported
sheets of plywood and MDF are flexible and easy to bend over formers for laminating	cutting and sanding some types of board generates hazardous dust particles
waste from wood production can be used to make MDF, chipboard and hardboard.	edges must be treated and covered to hide unsightly edges and to stop water getting in, a process called concealing edges; this also helps to create an appearance of a solid piece of timber.

Treating and **finishing timbers**	Timber treatments & finishes are used to protect, enhance and improve the mechanical properties. **Timber treatments-** are an additive preservative to improve the timber's resistance to attack and improve its durability is enhanced to a level which is suitable for the intended use. - **Wood destroying fungi -** resulted from moisture - **Wood destroying insects** - borers, white ants eg. Wood preserver, creosote, stain preservers **Timber finishes-** are applied to the surface of the timber and is usually carried out to achieve one or both of the the following reasons: - **Aesthetics**- to improve the materials natural beauty - **Function**- to protect it from environmental impact, heat, moisture Finished timber requires sanding with abrasive paper to close up the grain leaving smaller gaps. eg. varnish/estapol, finishing oil, wood wax Timber is **seasoned** as part of it preparation for commercial use. This process reduces the moisture content so that it becomes workable. The remaining moisture, albeit small, means that the wood never really stabilises and continues to swell and shrink, with humidity and temperature variations.
Recovery and **disposal** of timbers	**Reforestation** is the process of restoring tree cover to areas where woodlands or forest once existed. If this area never returns to its original state of vegetative cover the destructive process is called deforestation. In order to maintain a sustainable forest industry reforestation is necessary. **Wood recycling** is the process of turning waste timber into usable products. Recycling timber is a practice that was popularized in the early 1990s as issues such as deforestation and climate change prompted both timber suppliers and consumers to turn to a more sustainable timber source. **Recycling timber** is the environmentally friendliest form of timber production and is very common in countries such as the UK, Australia and New Zealand where supplies of old wooden structures are plentiful. Timber can be chipped down into wood chips which can be used to power homes or power plants. **Uses for recycled waste wood** include traditional feedstock for the panel board industry, which still accounts for the majority of recycled wood. Other uses include animal beddings, equestrian and landscaping surfaces, play areas and filter beds.

4.2c Glass

The rapid pace of technological discoveries is very evident in the manufacture and use of glass in electronic devices. Different properties have been presented in glass for aesthetic or safety considerations for many years but the future of glass seems to be interactivity alongside electronic systems. The structure of glass is not well understood, but as more is learned, its use is becoming increasingly prominent in building materials and structural applications.

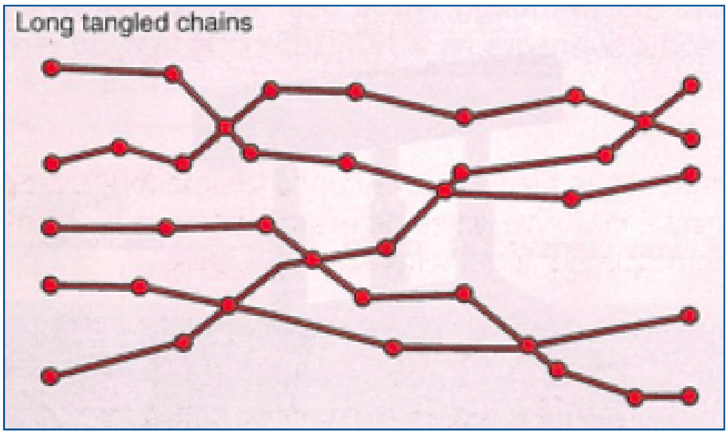
Characteristics of glass	Glass is a hard, brittle and typically transparent amorphous* solid made by rapidly cooling a fusion of sand, soda and lime. **amorphous-** Glass is an amorphous substance (a solid that is not crystalline) made primarily of silica fused at high temperatures with borates or phosphates. **transparency**- Ability to allow light to be transmitted with minimal scattering allowing a clear view through material. **chemically inert**- Lack of reactivity with other materials. **non-toxic**- Absence of toxic breakdown products/lack of reactivity. **brittle**- Breaks into numerous sharp shards. **biocompatibility**- The product ensures the continued health of a biological environment. **hardness**- Scratch resistance. **aesthetic appeal**- Favourable in terms of appearance. **electrical insulator**- Reduces transmission of electric charge. **cheap-** Abundance of material and high volume production in comparison to production cost.
Applications of glass	**Laminated Glass**- 2 thin sheets of glass with an interlayer of plastic in between. It is very strong bonds, retains shards of glass when cracked **e.g. iPhone glass cover,car windshield, architectural use, bullet proof windows** **Toughened** or **Tempered Glass**- Outer face of glass in compression, inner side of glass in tension, it shatters in small pieces and **used for furniture e.g. staircases/floors, architectural use** **Soda Glass-** Has poor thermal shock (shatters when hot water put in glass), expands quickly, cheap to produce and **used in drinking bottles** **Pyrex** slow expansion/contraction and **used for cooking, test tubes, thermometers, over doors** **Gorilla Glass** is a brand of specialized toughened glass developed and manufactured by Corning for use with mobile devices, designed to be thin, light and damage-resistant.
Recovery and disposal of glass	-Faulty and broken glass products are broken up (cullet) and reused by mixing with virgin materials to make a batch. This can save energy and also materials (virgin). -No degradation of glass quality in the process so it can be repeated several times. There is very little wastage during manufacture. -Glass is 100% recyclable and can be recycled endlessly without loss of purity or quality 

4.2d Plastics

Most plastics are produced from petrochemicals. Motivated by the finiteness of oil reserves and threat of global warming, bio-plastics are being developed. These plastics degrade upon exposure to sunlight, water or dampness, bacteria, enzymes, wind erosion and in some cases pest or insect attack, but in most cases this does not lead to full breakdown of the plastic. When selecting materials, designers must consider the moral, ethical and environmental implications of their decisions.

<table>
<tr>
<td>Raw materials for plastics</td>
<td>
<table>
<tr><th>Natural plastics</th><th>Semi synthetic plastics</th><th>Synthetic plastics</th></tr>
<tr>
<td>these are naturally occurring materials that can be said to be plastics because they can be shaped and moulded by heat. An example of this is amber, which is a form of fossilised pine tree resin and is often used in jewellery manufacture.</td>
<td>these are made from naturally occurring materials that have been modified or changed but mixing other materials with them. An example of this is cellulose acetate, which is a reaction of cellulose fibre and acetic acid and is used to make cinema film.</td>
<td>these are materials that are derived from breaking down, or 'cracking' carbon based materials, usually crude oil, coal or gas, so that their molecular structure changes. This is generally done in petrochemical refineries under heat and pressure, and is the first of the manufacturing processes that is required to produce most of our present day, commonly occurring plastics.</td>
</tr>
</table>
</td>
</tr>
<tr>
<td>Raw materials for plastics</td>
<td>Most modern plastics are derived from natural materials such as crude oil, coal and natural gas with crude oil remaining the most important raw material for their production.
Polymers are substances which are made up from many molecules which are formed into long chains. The differences in the way the chains bond cause the different properties in the different types of polymers.</td>
</tr>
<tr>
<td>Structure of thermoplastics</td>
<td>Thermoplastics are linear chain molecules, sometimes with side bonding of the molecules but with weak secondary bonds between the chains. Between the long chain molecules are secondary bonds which are weak forces of attraction between the molecules.

Thermoplastics can be heated and reformed. Their polymer chains do not form cross links. Thus, the chains can move freely each time the plastics are heated.



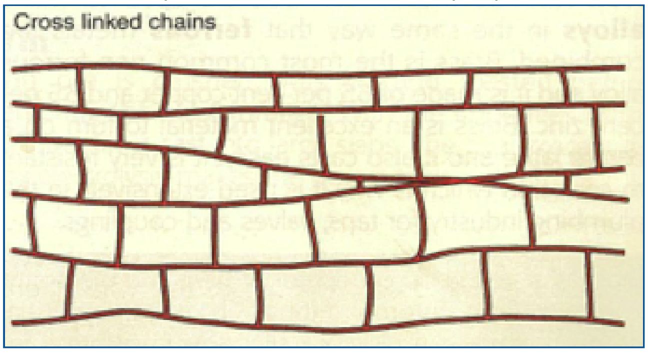
</td>
</tr>
</table>

Material	Properties	Applications
Polypropylene (PP)	Light, hard, tough, impact resistant, good chemical resistant, can be sterilised, good resistant to work fatigue	Used for medical and laboratory equipment, containers, chairs
Polyethylene (PE)	tough, resistant to chemicals, soft and flexible, good electrical insulator	
HIPS	Tough, high impact strength, rigid, good electrical insulator.	
ABS	High impact strength, tough, scratch-resistant, lightweight, durable, good resistance to chemicals, good electrical insulator	Kitchenware, GO Pro camera cases, Toys (Lego)
PET:	Chemical resistant, high impact resistance, tough, high tensile strength, durable, excellent water and moisture barrier	Plastic drinking bottles
PVC	Good chemical resistance, weather-resistant, lightweight, good electrical insulator, stiff, hard, tough, waterproof, durable	Pipes, Rainwater pipes and guttering, Window frames and fascias, Electrical cable insulation

Structure of **thermosetting plastics**

Thermosets are linear chain molecules but with **strong primary bonds between adjacent polymer chains (or cross links)**. This gives thermosets a rigid 3D structure.

On first heating, the polymer softens and can be moulded into shape under pressure. However, the heat triggers a chemical reaction in which the molecules become permanently locked together. As a result the polymer becomes permanently 'set' and cannot be softened again by heating. Examples of thermosetting plastics are polyurethane, urea formaldehyde, melamine resin and epoxy resin



Material	Properties	Applications
Polyurethane	strong electrical insulator (resistance) good tensile and compressive strength good thermal resistance can be fairly hard and tough can be easily bonded can be flexible and elastic	Wheels, foam, varnish, paint and glue

<table>
<tr><td></td><td>
<table>
<tr><td>Urea-formaldehyde</td><td>high tensile (tension) strength
high heat distortion temperatures
low water absorption
high surface hardness
weight/volume resistance</td><td>Tableware
Worktop laminates
Buttons
Electrical casings</td></tr>
<tr><td>Melamine resin</td><td>high electrical resistivity
very low thermal conductivity/ high heat resistance
hard/ solid
scratch resistant
stain resistant
available in a range of thicknesses and sizes</td><td>kitchen utensils plates, camping bowls (not microwave safe)kitchen utensils and plates, laminated benchtops</td></tr>
<tr><td>Epoxy resin</td><td>Tough
Chemical resistance (also water)
Fatigue and mechanical strength (Tensile strength and compressive strength)
Electrical insulation
Temperature resistant (maintains form and strength) (Though some are vulnerable to light)
Can be used on metal (The adhesive)</td><td>Construction of aircraft boats and cars, also are used in electrical circuits and general purpose adhesive and with glass reinforced plastics</td></tr>
</table>
</td></tr>
<tr><td>Temperature and recycling thermoplastics and thermoset plastics</td><td>-Thermoplastics soften when heated and harden and strengthen after cooling.
-Thermoplastics can be heated, shaped and cooled as often as necessary without causing a chemical change, while thermosetting plastics will burn when heated after the initial molding.
-Non-reversible effect of temperature on a thermoset contribute to it not being able to be recycled. Heating increases the number of permanent cross-links and so hardens the plastic, so therefore cannot be recycled</td></tr>
<tr><td>Recovery and disposal of plastics

Thermoplastics:
Heat, Reshape, Cool

Thermosetting
Plastics: Landfill, incinerate

Biodegradable
Plastics: Bury in the ground, landfill</td><td>Nearly all types of plastics can be recycled, however the extent to which they are recycled depends upon technical, economic and logistic factors. As a valuable and finite resource, the optimum recovery route for most plastic items at the ‘end-of-life’ is to be recycled, preferably back into a product that can then be recycled again and again and so on. The UK uses over 5 million tonnes of plastic each year of which an estimated 24% is currently being recovered or recycled.

Recycling: Turning waste into a new substance or product. Includes composting if it meets quality protocols.

Provides a sustainable source of raw materials to industry
Greatly reduces the environmental impact of plastic-rich products which give off harmful pollutants in manufacture and when incinerated
Minimises the amount of plastic being sent to the landfill sites
Avoids the consumption of the Earth’s oil stocks
Consumes less energy than producing new, virgin polymers
Encourages a sustainable lifestyle among children and young-adults

Bioplastics: To reduce the problems of disposing of plastics they can be designed to be biodegradable, known as bioplastics. These are plastics derived from renewable sources, such as vegetable fats and oils, corn starch, <u>pea</u> starch or microbiota.
Production of oil based plastics tends to require more fossil fuels and to produce more greenhouse gases than the production of biobased polymers (bioplastics).
Some, but not all, bioplastics are designed to biodegrade. Biodegradable bioplastics can break down in either anaerobic or aerobic environments, depending on how they are manufactured. Bioplastics can be composed of starches, cellulose, biopolymers, and a variety of other materials.</td></tr>
</table>

4.2e Textiles

The continuing evolution of the textiles industry provides a wide spread of applications from high performance technical textiles to the more traditional clothing market. More recent developments in this industry require designers to combine traditional textile science and new technologies leading to exciting applications in smart textiles, sportswear, aerospace and other potential areas.

<table>
<tr>
<td>Raw materials for textiles</td>
<td>Fibres can be classified as being from a natural or synthetic source. A fibre is an elongated hair like strand or continuous filament. The length exceeds more than 200 times the diameter.

-Wool, linen and cotton are short fibres. silk is a long continuous filament fibre.
-Fibres can be twisted using the spinning process and converted into yarn or fibres can be used in their raw form and manufactured to create felt.
-Consider absorbency, strength, elasticity and the effect of temperature

- manufactured from fibres, the origin can be subdivided into two section
  - natural (organic)
    - either a plant or animal origin
    - ex. cotton, linen, wool and silk
  - synthetic (man-made)
    - created by chemical processes
    - polymer-based from oil and coal, others are from glass, metal ceramic and carbon.</td>
</tr>
<tr>
<td>Properties of natural fibres</td>
<td>Properties of wool, cotton and silk and Design contexts in which different types of textiles are used
- originates from plants, animals and minerals
- are usually short fibres (staple fibres)
- can absorb moisture (ex. sweat from skin) therefore fabrics are ‘breathable.
- flammable, easy to dye, poor resilience, good conductor of electricity
- sources include cotton, wool, linen and silk

Fibres from Plants
- Cotton: Can be cool or warm to wear as fibres trap air, reducing convective heat loss. It is durable, creases easily, absorbent, dries slowly
- Linen: stiffer handle, dries quickly, durable, very absorbent

Fibres from Animals
- Wool: absorbent, dries slowly, warm to wear, not durable
- Silk: absorbent, durable, warm to wear, soft handle</td>
</tr>
<tr>
<td>Examples of natural fibres</td>
<td>
<table>
<tr><th>Natural Fibre</th><th>Origin</th><th>End uses</th></tr>
<tr><td>Wool
ANIMAL</td><td>Sheep fleece, goat, alpaca, camels</td><td>GOOD INSULATOR TRAPS AIR:
sweaters, blankets, socks, coats, tailored suits etc</td></tr>
<tr><td>Cotton
VEGETABLE</td><td>Cotton boll plant</td><td>HIGH ABSORBENCY:
nightwear, summer clothes, shirts, underwear, jeans, bedsheets, socks, towels, etc</td></tr>
<tr><td>Silk
ANIMAL</td><td>Silk cocoon.</td><td>HIGH LUSTRE:
evening dresses, nightwear, ties, cushions, wedding dresses etc</td></tr>
</table>
</td>
</tr>
</table>

<table>
<tr><td>Properties of synthetic fibres</td><td>

man made fibres (usually from chemical resources)
fibres produced are long and much smoother
most are thermoplastic and will soften and contract when exposed to heat.
have low affinity for moisture creating less ‘breathable’ fabrics.
sources include viscose, acrylic, nylon and polyester

</td></tr>
<tr><td>Examples of synthetic fibres</td><td>
<table>
<tr><th>Synthetic Fibre</th><th>End uses</th></tr>
<tr><td>Nylon</td><td>Rope, fishing filament, seatbelts, parachutes, luggage, conveyor belts, outerwear, tents.</td></tr>
<tr><td>Polyester (Dacron)</td><td>Outerwear, combined with other fibres to improve crease resistance, sportswear, hoses, sails, auto upholstery, carpets.</td></tr>
<tr><td>Lycra (Spandex)</td><td>Sportswear, combined with other fibres to improve stretch, disposable diaper, underwear.</td></tr>
</table>
</td></tr>
<tr><td>Conversion of fibres to yarns</td><td>

in the beginning, the strands are a tangle of loose fibres.
natural fibres, except silk, will be in different lengths to symbolise the maturity of growth.
natural fibres also require cleaning and refining, and some mixing in order to homogenise the batch
the fibres are then slightly twisted and thinned out in order to produce sufficient strength for handling
wrapping fibres around each other increases strength
the process is repeated, while lengthening the yarn.
the yarn that is formed is called a ‘single’ (single strand of yarn)

</td></tr>
<tr><td>Conversion of yarns into fabrics: weaving, knitting, lacemaking, and felting</td><td>
Weaving: undertaken on a machine called a loom with two distinct styles of thread which are interlaced together to form a fabric: warp and weft. Warp threads run lengthways on a piece of cloth and the weft runs across from side to side.

there are different kinds and ways to produce a weave; for example a thwill weave is by alternately passing under two and over one,
a smooth satin finish is achieved.

Knitting: process of forming fabrics by looping a single thread (by hand with slender wires or a machine provided with hooked needles)

made by making knots, however the destruction of one loop threatens the destruction of the entire web, unless the meshes are reunited (because of the interlocking nature of the yarn in knitted fabrics)
advantages include: fabric can stretch, low stress on the yarn, large number of stitch types are available

Lacemaking: lace-work is a stitched fabric patterned with holes, and is now commonly made from cotton.

it is made by hand with a needle (called needlepoint lace). by bobbins (along with a pins, pillow or a cushion, hence called ‘pillow lace’) or by a machine and is created by looping, plaiting one thread with another, without any backing material.
synthetic threads are often used for machine-manufactured lace and because of their high strength to weight circumstances, detailed and complex patterns are produced.

Felting: felt is made from animal fibres (sheep’s wool, rabbit fur), however today it can be made from man-made fibres (viscose)

felt-making process is dependent on the kinks in the fibres and the irregularities in the surface (to see if the fibres are able to interlock together) good wools, scales are perfect and numerous, while in inferior ones there are fewer serrations

</td></tr>
</table>

	(jagged edges) and are less perfect in structure - (from wool) progressively depositing layers of cleaned and combed fibers into a large tray, each 90 degrees from each other. - hot soapy water assists with lubrication and reduces friction and so the fibres can move and because entangles in the scales on the fibre surface. - they then bond to form a cloth. - (alternative) needle felting involves combining fibres using special felting needles.
Recovery and disposal of textiles	Many items of clothing are manufactured and produced in developing countries. Often working conditions that many people experience who do a repetitive, low skilled job. Other **ethical issues** connected to the production and manufacture of textiles are linked to environmental issues, chemical dyes, washing, finishes, use of pesticides to grow the crops and land usage for growing the crops and grazing for the animals. Development of new textiles and other related technologies needs to consider the sustainability issues such as recycling and disposal. • Wastage from textiles may be categorized as either pre- or post - consumer. Pre-consumer textile waste is mostly formed of materials that are generated as by-products of production processes. Post-consumer waste mentions to clothing or household textiles that is reused or recycled instead of being disposed. • Recycling involves the reprocessing of used materials (clothing, fabric scraps, etc) and waste from the manufacturing process. • Once all of the materials are collected, cleaned and sorted, recyclable textile may be processed; first mechanically where the fibres are separated before being re-spinned into yarn or chemically through repolymerizing fibres. to again spin into yarn. • With waste reduction, reuse and recycling results in: Lowering purchase prices, reducing use of virgin materials, reducing disposal costs and landfill, generating less air and water pollution, keeping materials out of the waste stream and preserving the 'embodied energy' used in manufacturing.

4.2f Composites

Composites are an important material in an intensely competitive global market. New materials and technologies are being produced frequently for the design and rapid manufacture of high-quality composite products. Composites are replacing more traditional materials as they can be created with properties specifically designed for the intended application. Carbon fibre has played an important part in weight reduction for vehicles and aircraft.

Form: fibres/sheet/particles and matrix

Composite materials (also called **composition materials** or shortened to **composites**) are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter or less expensive when compared to traditional materials. One material acts as the matrix, which can be in the form of fibres, sheets or particles with the other as the bonding agent.

Advantages	Disadvantages
• high strength-to-weight ratio • high tensile strength • weave of the cloth can be chosen to maximise strength and stiffness of final component • can be woven in different patterns to create aesthetically pleasing surface patterns	• very expensive • requires specialist manufacturing facilities • weak when compressed, squashed, or subject to a high shock or impact • small air bubbles or imperfections of the matrix will cause weak spots and reduce the overall strength

Fibres/sheets/particles: textiles, glass, plastics and carbon

- Laminar

Consists of two or more layers of material bonded together usually with an adhesive to form a new composite material with improved properties

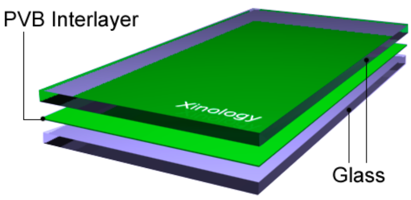
The most commonly recognized laminar material is plywood

Plywood

- ➔ Manufactured from an uneven number of plys
- ➔ Application where high quality, high strength, large sheet material is required
- ➔ It is resistant to cracking, breaking, shrinkage, twisting and warping
- ➔ Can be used as an engineering material for architecture or lightweight stressed skin applications (marine and aviation environments)

Laminated Glass

- ➔ Consists of a sandwich of two layers of glass and a polymer interlayer of Polyvinyl butyral (PVB) joined under heat and pressure in a furnace called an autoclave



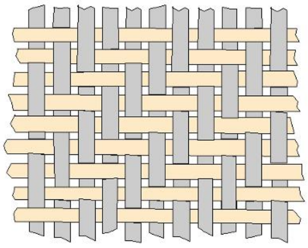
- ➔ When broken the PVB interlayer hold the pieces of glass together (safer) avoiding the release of otherwise dangerous shards of glass
- ➔ The fracture produces a pattern of radial and concentric cracks (spider-web mattern)
- ➔ used for car windscreens

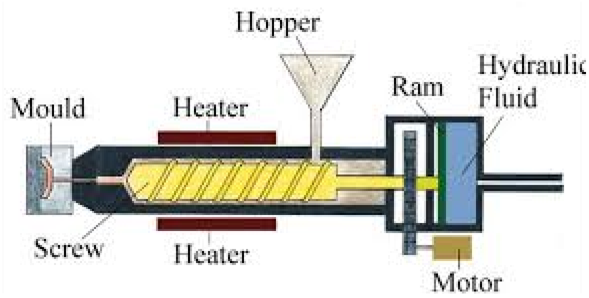
Laminar composites

- ➔ Laminates of different material joined together in a sandwich structure
- ➔ Consists of layer of thin or bidirectional fibres or metal sheet held apart by a lightweight core (foam or honey-comb style structure)
- Fibre-reinforced
- Particle reinforced

Process: weaving, moulding, pultrusion and lamination

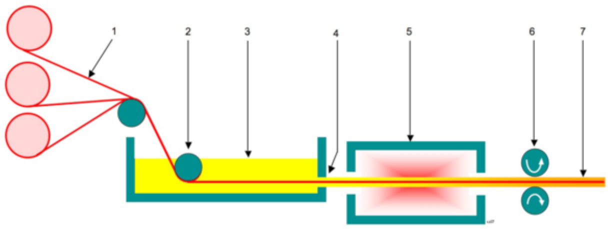
Weaving: to form (fabric or a fabric item) by interlacing long threads passing in one direction with others at a right angle to them.



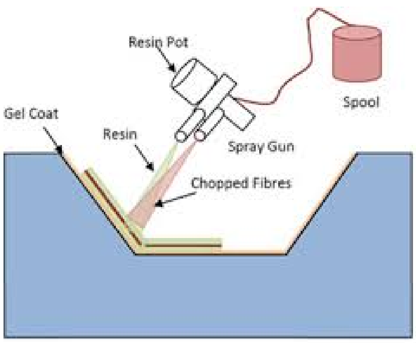


Moulding
Similar to injection moulding, using mix of materials. Or put under high pressure

Pultrusion is a continuous molding process whereby reinforcing fibers are saturated with a liquid polymer resin and then carefully formed and pulled through a heated die to form a part.



Lamination
One of the early materials that was used as part of a lamination process was called Formica. Formica originally consisted of layers of fabric bound together with resin; later, it was made with thick pieces of paper laminated with melamine. This tougher substance could resist heat and abrasion, while the paper opened up a wealth of possibilities for printing colours and patterns, which proved key to its success.



Spray-up
Spray-up is carried out on an open mould, where both the resin and reinforcements are sprayed directly onto the mould. The resin and glass may be applied separately or simultaneously "chopped" in a combined stream from a chopper gun. Workers roll out the spray-up to compact the laminate. Wood, foam or other core material may then be added, and a secondary spray-up layer embeds the core between the laminates (sandwich construction). The part is then cured, cooled and removed from the reusable mould.

<table>
<tr><td>Composition and structure of composites</td><td>Matrix: thermoplastics, thermosetting plastics, ceramics, metals</td></tr>
<tr><td>Design contexts in this composite materials is used

Types and how used</td><td>
<table>
<tr><td>Concrete: Sand, concrete, aggregate and water are mixed together, they form a fluid mass that is easily molded into shape. Over time, the cement forms a hard matrix which binds the rest of the ingredients together into a durable stone-like material with many uses</td><td>Construction (reinforced with Steel) to make strong</td></tr>
<tr><td>Engineered wood: is made by binding or fixing strands, particles of fibres, veneers of boards of wood together with adhesives or other fixing methods to create composite materials.</td><td>-Medium Density Fibreboard
-Particle or chipboard
-Plywood
-LVL- laminated veneered timer
-I joists or I beams</td></tr>
<tr><td>Plywood: is a sheet material manufactured from thin layers or "plies" of wood veneer that are glued together with adjacent layers having their wood grain rotated up to 90 degrees to one another.</td><td>It may be used for wall panelling, flooring and furniture.</td></tr>
<tr><td>Particleboard : also known as particleboard and chipboard, is an engineered wood product manufactured from wood chips,sawmill shavings, or even sawdust, and a synthetic resin or other suitable binder, which is pressed and extruded. Oriented strand board, also known as flakeboard, waferboard, or chipboard, is similar but uses machined wood flakes offering more strength.</td><td></td></tr>
<tr><td>Kevlar is a composite material similar to Carbon Fibre and is woven into a cloth which combined with Polyester resin can be moulded into a variety of complex shapes. It can also be woven into fabric cloth to protect the wearer almost like an indestructible net. Kevlar also has a high strength-to-weight ration and is five times stronger than steel.</td><td>Kevlar is used in a variety of applications because of its unique properties, including:
-body protection, such as bullet-proof vests Military helmet where lightweight properties, comfort and flexibility are important
-sports equipment, such as skis, helmets and racquets, where lightweight properties and strength are important
-sails for windsurfing, where the material has to withstand high speeds</td></tr>
<tr><td>Carbon reinforced plastic (GRP) is a composite material made from plastic and fine fibres of glass. It is also known as Fibreglass.The strands are combined with resin (polyester or epoxy resin) to make GRP. Fibreglass and resin on their own are weak but when combined create a good strength-to-weight ratio material. It is very versatile and can easily be moulded into 3D shapes.</td><td>• Boat hulls
• Canoes
• Car body panels
• Chemical storage tanks
• Train canopies</td></tr>
<tr><td>Laminated veneer lumber (LVL) is an engineered wood product that uses multiple layers of thin wood assembled with adhesives. It is typically used for headers, beams, rimboard, and edge-forming material.</td><td></td></tr>
</table>
</td></tr>
</table>

Advantages and disadvantages of composite materials	**Advantages** They are much stronger than the original material used. Laminated glass for example is much tougher, and shatters less -Corrosion and Chemical Resistance Composites are highly resistant to chemicals and will never rust or corrode -High cost of fabrication of composites is a critical issue **Disadvantages** They can not be recycled. Most composites are thermosetting and so it is hard to separate and recycle

Notes:

4.3 Scales of Production

The scale of production depends on the number of products required. Decisions on scale of production are influenced by the volume or quantities required, types of materials used to make the products and the type of product being manufactured. There are also considerations of staffing, resources and finance.

Scales of Production	**Description of why you would selecting an appropriate scale of production**	**Advantages**	**Disadvantages**
One-off	One - off production is where only one for a few specialist items are required. If a prototype is made then it usually part of the realisation of the product and so the next step after testing would be batch or volume production.	• Unique, high quality products are made • Workers are often motivated and take pride in their work	• Very labour intensive, so selling prices are usually higher • Production can take a long time and can be expensive as specialist tools are required • Economies of scale are not possible, often resulting in a more expensive product
Batch production	Limited volume production (a set number of items to be produced	• Since larger numbers are made, unit costs are lower • Offers the customer some variety and choice • Materials can be bought in bulk, so they are cheaper	• Workers are often less motivated because the work can be repetitive • Goods have to be stored until they are sold, which can be expensive
Mass	The production of large amounts of standardized products on production lines, permitting very high rates of production per worker.	• Labour Costs are usually lower/minimal • Materials can be purchased in large quantities so they are cheaper/provide excellent bargaining power • Large numbers of goods are produced	• Machinery is very expensive to buy and set up for production lines • Workers are not motivated • Not very flexible as a production line is difficult to adapt • Production process will have to stop when repairs are made
or **Continuous flow**	A production method used to manufacture, produce or process materials without interruption.		
Mass customization	A sophisticated CIM system that manufactures products to individual customer orders. The benefits of economy of scale are gained whether the order is for a single item or for thousands.	Mass customisation uses some of the techniques of mass production; for example, its output is based on a small number of platforms, core components that underlie the product. In the case of a watch, the internal mechanism is a platform to which can be added a wide variety of personalised options at later stages of production.	

Notes:

4.4 Manufacturing processes

Different manufacturing processes have been developed to innovate existing products and create new products. Designers sometimes engineer products in such away that they are easy to manufacture. Design for manufacture (DfM) exists in almost all engineering disciplines, but differs greatly depending on the manufacturing technologies used. This practice not only focuses on the design of a product's components, but also on quality control and assurance.

Process	Manufacturing techniques
Additive techniques	**Paper-based rapid prototyping** (Layers of paper cut and glued together to create a 3D shape) **Laminated object manufacture (LOM)** (Layers of material cut and glued together to create a 3D shape) **Stereolithography** (Solidification of powder using 3D printing)
Wasting/ subtractive techniques To **remove** material by **cutting**, **machining**, **turning** or **abrading**.	**Cutting** (Laser, Saws, Chiseling, Drilling) **Machining** (Router or Milling machine) **Turning** (Metal or Wood Lathe) **Abrading** (Sanding, Filing, Grinding)
Shaping techniques To **change the shape** of the material without wasting	**Moulding** (Injection moulding, extrusion) **Thermoforming** (Heating plastics and vacuum forming, or using a strip heater to heat and bend acrylic) **Laminating** (Flexi-plywood by gluing layers together over a former/shaped mould) **Casting** (Sand casting, Die casting- usually solid to liquid then cooled **Knitting** (textiles) **Weaving** (textiles)
Joining techniques	**Permanent**- e.g. Welding, Brazing, Soldering, Pop riveting, **Temporary** (non-permanent fastening) Fastening or joining materials mechanically through the use of screws, rivets, bolts, pins, clips, nails, press studs and snaps. The advantage of this technique is the ease for disassembly at the expense of permanent damage to the materials used eg. installing screws **Adhering- Gluing** once formed, cannot easily be separated **Fusing (welding)** Permanent process involving the heating of the surfaces such as metals and plastics. This process isn't recommended when considering design for disassembly.

4.5 Production systems

The development of increasingly sophisticated production systems is transforming the way products are made. As a business grows in size and produces more units of output, then it will aim to experience falling average costs of production—economies of scale. The business is becoming more efficient in its use of inputs to produce a given level of output. Designers should incorporate internal and external economies of scale when considering different production methods and systems for manufacture.

Type	Description/Impact of different production systems on the workforce and environment	Advantages	Disadvantage
Craft production	This type of production makes a single, unique, product from start to finish. Labor intensive, highly skilled It is a small-scale production process centred on manual skills. eg. building ships, bridges, handmade crafts (furniture), tailored clothing	Locally based, allowing clients to converse directly with manufacture	This type of production is frequently slow May be required to have a variety of skills High cost.
Mechanized production	Volume production process involving machines controlled by humans.	Less labor intensive	
Automated production	Automated Production is the fasted way of mass producing goods and services. It is a volume production process involving machines controlled by computers. Pro's and con's of Automation include: -**Making complex decisions:** Automated systems can make decisions that are beyond the capacity of people to make. -**Speed of decision making.** Automated systems also can make decisions more quickly than people can. **-Routine, boring jobs.** Many people find repetitive, simple jobs, such as working on a factory assembly line, dull and degrading. They have difficulty maintaining the level of		
Assembly line production	Assembly line production is a volume production process where products and components are moved continuously along a conveyor. As the product goes from one workstation to another, components are added until the final product is assembled.		
Mass production	Mass production is the production of large amounts of standardized products on production lines, permitting very high rates of production per worker.		
Mass customization	Mass customization is a sophisticated CIM system that manufactures products to individual customer orders. The benefits of economy of scale are gained whether the order is for a single item or thousands.		
Computer numerical control (CNC)	CNC refers to the computer control of machines for the purpose of manufacturing complex parts in metals and other materials. Machines are controlled by a programme commonly called a "G code". Each code is assigned to a particular operation or process. The codes control X, Y and Z movement and feed speeds.		
Production system selection criteria	This is dependent on what type of production method that is selected for a product. Production system selection criteria include time, labour, skills and training, health and safety, cost, type of product, maintenance, impact on the environment and quality management E.g. Might be better to Injection mould a product case from 3 parts rather than 1 part as it might be easier and quicker to do final assembly.		

Design for manufacture (DfM)	Design for manufacture (DfM) means designers design specifically for optimum use of existing manufacturing capability. Designers need to consider designing products so they can be easily and efficiently manufactured with minimal impact on the environment. Design for Manufacture can be a constraint on the design brief. Design for Manufacture involves Design for Process, Design for Materials and Design for Assembly/Disassembly. There are four aspects of DfM.
	Design for materials: designing in relation to materials during processing. The selection of materials is an important consideration for a designer. It can affect environmental at each stage of the Product Cycle, from pre-production to disposal. For example, the choice of a thermoplastic may mean an impact on the environment through the extraction of oil, however thermoplastics are highly recyclable meaning less of an impact at the disposal stage, providing they are recycled and not sent to landfill or incinerated. Minimising the amount of materials and using non-toxic or biodegradable alternatives can also reduce the impact on the environment.
	Design for process: designing to enable the product to be manufactured using a specific manufacturing process, for example, injection moulding . When designing or redesigning products, designers should consider how the manufacture of parts and components can be achieved efficiently and with minimal waste. For example injection moulding is an extremely energy efficient process with minimal waste produced.
	Design for assembly: designing taking account of assembly at various levels, for example, component to component, components into sub-assemblies and sub-assemblies into complete products
	Design for disassembly: designing a product so that when it becomes obsolete it can easily and economically be taken apart, the components reused or repaired, and the materials repurposed or recycle. By minimising components, assembly can be made to be quicker and more efficient. In addition, using standard components can decrease manufacturing time. More and more designers are considering how their designs can be disassembled. This means that different materials can be separated for recycling or to make repair or reconditioning easier resulting in less products being sent to landfill.

Notes:

4.6 Robots in automated production

The development of increasingly sophisticated robotic manufacturing systems is transforming the way products are made. Designers should consider the benefits of increased efficiency and consistency when using robots in production and be able to explore the latest advances in technology to ensure the optimum manufacturing process is used. However, a good designer will also understand their responsibility to consider the moral and ethical issues surrounding increased use of automation, and the historical impact of lost jobs.

Primary characteristics of robots	A robot is defined as an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications. The introduction of robots to an assembly line has had a major impact on the labour force, often making skilled workers redundant in favour of a technician who can maintain and equip a large number of robots.	
Work envelope	The 3D space a robot can operate within, considering **clearance** and **reach.** These distances are determined by the length of a robot's arm and the design of its axes. Each axis contributes its own range of motion. A robot can only perform within the confines of this work envelope. Still, many of the robots are designed with considerable flexibility. Some have the ability to reach behind themselves. Gantry robots defy traditional constraints of work envelopes. They move along track systems to create large work spaces.	
Load Capacity	Within this context, the weight a robot can manipulate	
	Advantages of using robotic systems in production	**Disadvantages of using robotic systems in production**
Single-task robots	-Reduces chance of error -Learnability for the operator	-Expensive relative to the outcome -Long process as little can be done with only single task robots
Multi-task robots	-Manufacture is sped up, more efficiency and -Inputs and outputs can be varied	-Increased chance of error
Teams of robots	-Increased efficiency and versatility -Need to hold parts in place while performing other tasks e.g. welding -Production line processes – require teams of robots to perform different tasks at different stages. Robots exhibit varying degrees of autonomy (ability to work independently, without human input. Some robots are programmed to faithfully carry out specific actions over and over again (repetitive actions) without variation and with a high degree of accuracy. These actions are determined by programmed routines that specify the direction, acceleration, velocity, deceleration and distance of a series of coordinated motions.	Other robots are much more flexible as to the orientation of the object on which they are operating or even the task that has to be performed on the object itself, which the robot may even need to identify. For example, for more precise guidance, robots often contain machine vision sub-systems acting as their "eyes", linked to powerful computers or controllers. Artificial intelligence or what passes for it, is becoming an increasingly important factor in the modern industrial robot.
Machine to machine (M2M)	(M2M) refers to wired and wireless communication between similar devices. In product restocking, for example, a vending machine can message the distributor when a particular item is running low. M2M communication is an important aspect of warehouse management, remote control, robotics, traffic control, logistic services, supply chain management, fleet management and telemedicine. It forms the basis for a concept known as the Internet of Things (IoT).	

	Key components of an M2M system include sensors, a Wi-Fi or cellular communications link and autonomic computing software programmed to help a networked device interpret data and make decisions
First generation robots	First-generation robots are a simple mechanical arm that has the ability to make precise motions at high speed. They need **constant supervision by a human operator**. The operation of these machines must be constantly supervised, because if they get out of alignment and are allowed to keep working, the result can be a series of bad production units.
Second generation robots	Second-generation robots are equipped with sensors that can provide information about their surroundings. They can synchronize with each other and do not require constant supervision by a human; however, they are controlled by an external control unit. Second-generation robots can stay synchronized with each other, without having to be overseen constantly by a human operator. Of course, periodic checking is needed with any machine, because things can always go wrong; the more complex the system, the more ways it can malfunction.
Third generation robots	Third-generation robots are autonomous and can operate largely without supervision from a human. They have their own central control unit. Swarms of smaller autonomous robots also fit in this category. There are some situations in which autonomous robots do not perform efficiently. In these cases, a fleet of simple insect robots, all under the control of one central computer, can be used. These machines work like ants in an anthill, or like bees in a hive. While the individual machines lack artificial intelligence (AI), the group as a whole is intelligent.

Notes:

Topic 5
Innovation + Design

5.1 Invention

The protection of a novel idea of how to solve a problem is a major factor in commercial design. Invention by lone inventors or in collaborative, creative teams is at the forefront of design. Designers must not only be creative and innovative, but also understand the concepts that will make a new product viable. A designer must use imagination and be firmly grounded in factual and procedural knowledge while remembering the needs and limitations of the end user.

Define an **Invention**	Invention is the process of discovering a principle which allows a technical advance in a particular field that results in a novel/new product.
Drivers for Invention/Motivation for Invention	Drivers for invention include personal motivation to express creativity/for personal interest, scientific or technical curiosity, constructive discontent, desire to make money, desire to help others. A few of the many reasons that drive invention are listed below • a personal motivation to invent in order to express one's creativity or personal interest • scientific and/or technical curiosity • constructive discontent with an existing invention/design • desire to make money • desire to help others.
The Lone Inventor What are the advantages and disadvantages of being a lone inventor	**The lone inventor** is an individual working outside or inside an organization who is committed to the invention of a novel product and often becomes isolated because he or she is engrossed with ideas that imply change and are resisted by others. Individuals with a goal of the complete invention of a new and somewhat revolutionary product. • Have ideas that are completely new and different. • May not comprehend or give sufficient care to the marketing and sales of their product. • Are usually isolated, and have no backing towards their design. • Are having a harder time to push forward their designs, especially in a market where large investments are required for success. • Their ideas, because of how different they are are often resisted by other employees and workers.
Intellectual Property (IP)	A legal term for intangible property such as "creations of the mind" such as inventions and designs that are used in a commercial setting. Intellectual property is protected by law.
What are the **benefits of IP**	Benefits of IP include differentiating a business from competitors, selling or licensing to provide revenue streams, offering customers something new and different, marketing/branding, its value as an asset. The benefits of intellectual property include: • differentiating a business from competitors • allowing sale or licensing, providing an important revenue stream • offering customers something new and different • marketing/branding • establishing a valuable asset that can be used as security for loans.
What are **effective strategies for protecting IP**	**Patents**: "An agreement from a government office to give someone the right to make or sell a new invention for a certain number of years".
	Trademarks: A trademark is a recognisable sign, design or expression which distinguishes products or services of a particular trader from the similar products or services of other traders.
	Copyright: Copyright is a legal right created by the law of a country, that grants the creator of an original work exclusive rights to its use and distribution, usually for a limited

	time, with the intention of enabling the creator (e.g. the photographer of a photograph or the author of a book) to receive compensation for their intellectual effort.
Patent pending	An indication that an application for a patent has been applied for but has not yet been processed. The marking serves to notify those copying the invention that they may be liable for damages (including back-dated royalties), once a patent is issued.
First to market	When a company or a person has or think they have a innovative idea or product, therefore will rush to have it on the market before anyone else. Some innovators decide not to protect their IP as an alternative strategies to ensure success by allowing them to get first to market rather than spend money on patents or waste time.
Shelved technologies- Reasons why some patented inventions are shelved	Technology that is shelved for various reasons. Sometimes shelved technologies will be rediscovered or taken off the shelf.

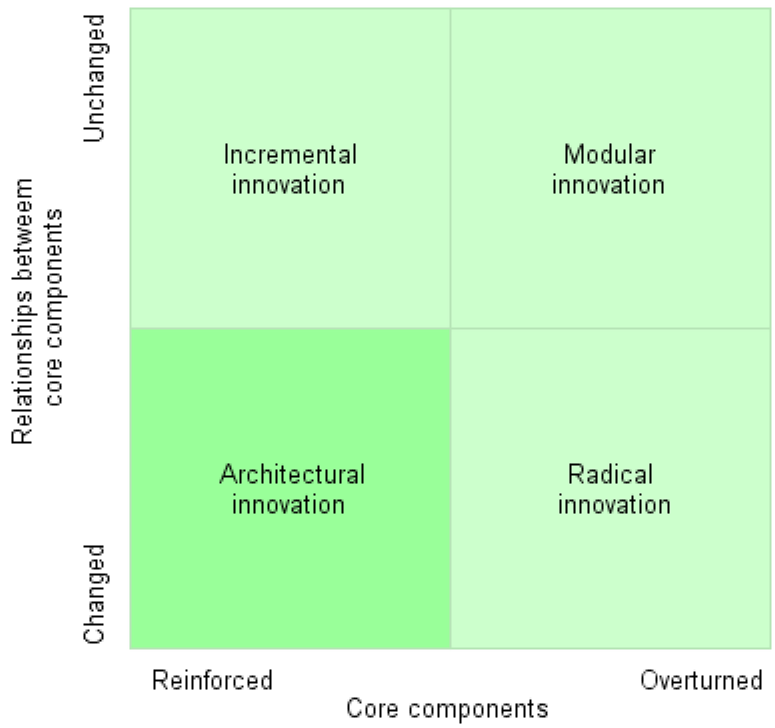
Notes:

5.2 Innovation

There are many different types of innovation. Designers will be successful in the marketplace when they solve long-standing problems, improve on existing solutions or find a "product gap". The constant evaluation and redevelopment of products is key, with unbiased analysis of consumers and commercial opportunities.

Define an **Innovation**	The business of putting an invention in the marketplace and making it a success.
Reasons why **inventions become innovations**	Few inventions become successful innovations due to the following reasons: • **Marketability-** Low product demand or not readily saleable • **Financial support-** There is little monetary backing from the organisation or an outsider. The invention would need more sponsors to financially aid the product. • **Marketing-** Is the process of getting products from the producer or vendor to the consumer or buyer, which includes advertising, shipping, storing, and selling. Poor marketing strategies or wrong target markets. Invention would need to be advertised as a product the public would want. • **The need for the invention-** Examples include alternative energy resources to combat our insatiable need for oil however if oil prices are low or there is a ready supply of oil then the alternative energy invention will not take hold. • **Price-** Affordable, cost effectiveness or value for money … therefore it may be too expensive to purchase, or to manufacture and the consumer may not see it worth its cost compared to its use.Keep in mind, the product's price needs to be equivalent to the income of the specific age group that would buy the majority of the product. • **Resistance to change-** People and organisations can be resistant and reluctant to change, feeling comfort and security in the familiar thus resist new ideas/products. • **Aversion to risk-** "Risk aversion is a concept in economics, finance, and psychology related to the behaviour of consumers and investors under uncertainty".
Sustaining Innovation	Innovative ideas that are constantly updated in order to maintain their success. A new or improved product that meets the needs of consumers and sustains manufacturers. 
Disruptive Innovation	 A product or type of technology that challenges existing companies to ignore or embrace technical change. Examples include the iPod which changed the way we managed and listened to music. Mobile phones so we were no longer restricted to landlines.

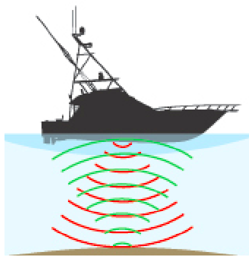
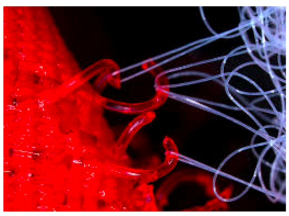
Process Innovation	An improvement in the organization and/or method of manufacture that often leads to reduced costs or benefits to consumers. Example is in the automobile industry such as Ford with the introduction of assembly line production and Toyota with lean manufacturing. 
Architectural Innovation	 The technology of the components stays the same, but the configuration of the components is changed to produce a new design. Putting existing components together in novel ways. Examples include: electric cars, Sony Walkman
Modular Innovation	 The basic configuration stays the same, but one or more key components are changed. Example include a new type of switch/button on a toaster. Also known as **incremental design**
Configurational Innovation	  Modifying arrangements of components to improve performance, usability and function (buttons, interface, dials, better heating element, 4 slots rather than 2, etc).
Radical Innovation	 Changing the paradigm of the market that the new product is produced in: invention of smartphones changed the phone industry. It is similar to diffusion but the difference is that a radical innovation might not be successful as it might not be accepted into the marketplace e.g. Sinclair C5 electric car Radical could include new materials, manufacturing, etc.

	
Innovation strategies for markets: **Diffusion** and **suppression**	**Diffusion**: is a process where a market will accept a new idea or product. The rate it accepts the new idea or product can be increased by several factors. • Examples of widely diffused products include the, light bulb, refrigerator (100%), ATM cards, Music CD's (now mp4 format). • Once widely accepted they often become dominant designs. **Suppression**: is a process where a new idea or adoption of a product by the market is actively slowed. This may be due to difficulties competing with a dominant design, ambiguity over patent ownership, competing companies actively petitioning against a new product it perceives as threatening, or the natural resistance to an unfamiliar concept.

Notes:

5.3 Strategies for innovation

Designers have a range of strategies for innovation. Companies encourage advancements in technology and services, usually by investing in research and development (R&D) activities. Even though the R&D may be carried out by a range of different experts from varied fields of research, the development process is often based on common principles and strategies to identify the direction of development. This methodology structures the R&D of new technologies and services.

Act of insight	Often referred to as the "eureka moment", a sudden image of a potential solution is formed in the mind, usually after a period of thinking about a problem. Such as Newton watching an apple fall and gaining insight in gravitation forces.
Adaptation	 A solution to a problem in one field is adapted for solving a problem in another field. The principle of how a hovercraft works was adapted the hover lawn mower.
Technology transfer	Technological advances that form the basis of new designs may be applied to the development of different types of products/systems, for example, laser technology. Laser transferred into surgery or audio or data CDs
Analogy	 **An idea from one context is used to stimulate ideas for solving a problem in another context.** Sonar modelled on how bats navigate and used now in ships to check depth or placement of fish.
Chance	 **An unexpected discovery leads to a new idea.** Velcro was developed when a chap walking with his dog found lots of seed pods stuck to his socks and dog. He looked under the microscope and made his discovery of the pods having many little hooks
Technology push	**Scientific research leads to advances in technology that underpin new ideas.** This is where the driving force for a new design emerges from a technological development. The Sony walkman is an example. • Innovation is created, then appropriate applications are sought to fit the innovation • Did the market ask "please give me an iPod with download store" or a camera phone? Most likely not; so this would be a technology push  © Chappatte – www.globecartoon.com – "Here comes the iPad"

Market pull	A new idea is needed as a result of **demand** from the marketplace. The car market which has separate sectors for the supermini, family cars, mini-vans, executive cars, sports cars, SUV, and so on. “Market” Pull approaches: • Implemented on platforms • Platforms are open ended and can evolve based on changing needs • Has low market related risk because application is known • Has low technology related risk because solution is not known • When the market asks for better safety features in a car then this would be market pull.

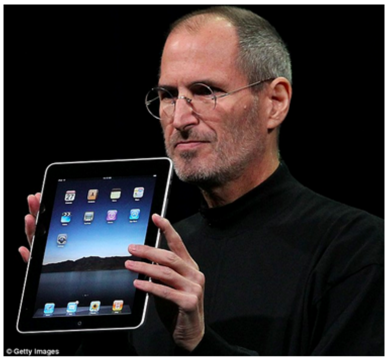
Notes:

5.4 Strategies for innovation

There are three key roles in invention and innovation, which can be shared by one or more people. Collaborative generation of knowledge and high efficiency information flow allow for diversity, increased resilience, reliability and stability within an organization. Through participatory research, stakeholders can make full use of the resulting innovation and invention, by transferring findings relevant to the sector in which they are positioned. A designer's increased awareness through shared industry knowledge enhances profitability and policy.

<table>
<tr>
<td>The Lone Inventor</td>
<td>The lone inventor is an individual working outside or inside an organization who is committed to the invention of a novel product and often becomes isolated because he or she is engrossed with ideas that imply change and are resisted by others.
Lone inventors are:

Individuals with a goal of the complete invention of a new and somewhat revolutionary product.
Have ideas that are completely new and different.
May not comprehend or give sufficient care to the marketing and sales of their product.
Are usually isolated, and have no backing towards their design.
Are having a harder time to push forward their designs, especially in a market where large investments are required for success.
Their ideas, because of how different they are are often resisted by other employees and workers.
</td>
</tr>
<tr>
<td>The Product Champion</td>
<td>An influential individual, usually working within an organization, who develops enthusiasm for a particular idea or invention and "champions" it within the organization.



Steve Jobs

Profile of a Product Champion

Has business experience in the domain
Can speak intelligently about the issues
Acts as a good facilitator
Works and plays well with others
Accepts responsibility for the product
Defends the team's ability to produce the product
Is willing to make hard decisions about scope
Treats the team as knowledgeable professionals
Sets reasonable performance expectations
Communicates with the team, the customer, management, sales, and marketing
Has a willingness to learn—from everyone
Doesn't trust everyone; does trust the right people
</td>
</tr>
<tr>
<td>The Entrepreneur</td>
<td>An influential individual who can take an invention to market, often by financing the development, production and diffusion of a product into the marketplace. Profile of an Entrepreneur

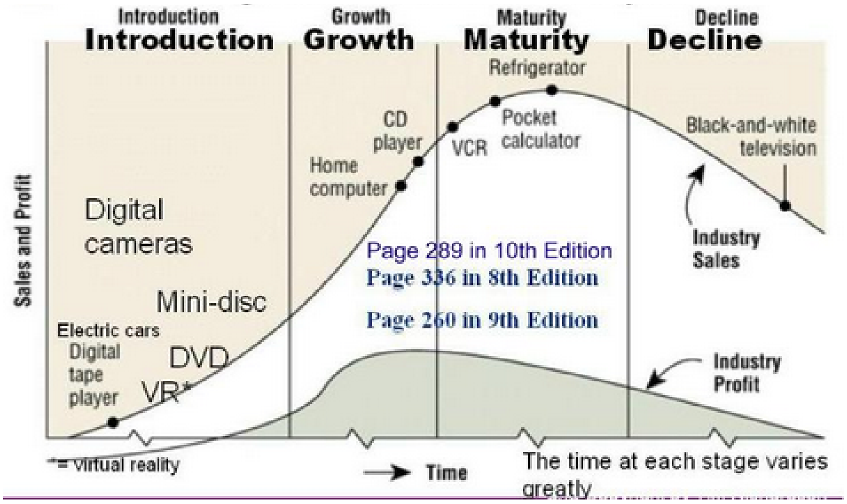
Business acumen
Self-control
Self -confidence
Sense of urgency
Comprehensive Awareness
Realism
Conceptual Ability
Status Requirements
Interpersonal Relationships
Emotional Stability
</td>
</tr>
</table>

Roles of the product champion and entrepreneur in the innovation of products and systems	Sometimes an inventor may have developed skills or profiles of a product champion and/or entrepreneur. James Dyson and Thomas Edison are two examples. Edison (later it was discovered that Swan invented the light bulb) used profits from his earlier inventions to bring the light bulb to market. James Dyson is an example of an inventor, product champion and/or entrepreneur. He invented the cyclone technology for suction. At first no-one was interested in this radical design so he 'championed' his product until he found a Japanese company would would take it on. Later he would use the profits to further improvements and novel products. He build an understanding of business.
Comparison between Lone Inventor and Product champion	The lone inventor may lack the business acumen to push the invention through to innovation. The product champion is often a forceful personality with much influence in a company. He or she is more astute at being able to push the idea forward through the various business channels and is often able to consider the merits of the invention more objectively. Inventors often take the role of product champion and/or entrepreneur because … • Their product or idea is novel • Too novel or 'out there' for a company to take a risk on • Can't find a backer or company to produce it • The inventor will have to 'champion' their product to different companies
The advantages and disadvantages of multidisciplinary approach to innovation	Effective design draws from multiple areas of expertise, and this expertise can be utilized at different stages of product development. Most products are now extremely complex and rely on expertise from various disciplines. Most designs are developed by multidisciplinary teams. • Modern Products such as smart-phones, printer/scanners are very complex. • Requires knowledge from many disciplines. • It would be unlikely that a lone inventor would have the expertise in all the disciplines. • Most modern day designs are developed in multidisciplinary teams

Notes:

5.5 Product life cycle

There are several key stages in the product life cycle. Designers need to consider the whole product cycle of potential products, services and systems throughout the design cycle and beyond. Products may have an impact not only on the direct consumer but also on society at large and the environment.

Key stages of the product life cycle: launch, growth, maturity, decline. Including examples of products at different stages of the product life cycle including those new to the market and classic designs	1. **Launch**: There are slow sales and little profit as the product is launched on the market. 2. **Growth**: The market gradually accepts the product, so diffusion starts and sales expand. 3. **Maturity**: Sales peak but remain steady, so maximum profit is achieved. 4. **Decline**: Market saturation is reached and sales start to reduce as well as profit.  *Product Life Cycle with Products*
Obsolescence: planned, style (fashion), functional, technological	Obsolescence affects the product life cycle. **Planned**: A product becomes outdated as a conscious act either to ensure a continuing market or to ensure that safety factors and new technologies can be incorporated into later versions of the product. **Style (fashion)**: Fashions and trends change over time, which can result in a product no longer being desirable. However, as evidenced by the concept of retro styling and the cyclic nature of fashion, products can become desirable again. **Functional**: Over time, products wear out and break down. If parts are no longer available, the product can no longer work in the way it originally did. Also, if a service vital to its functioning is no longer available, it can become obsolete. **Technological**: When a new technology supersedes an existing technology, the existing technology quickly falls out of use and is no longer incorporated into new products. Consumers instead opt for the newer, more efficient technology in their products.
Length of the product life cycle considering the effect of technical development and consumer trends	-Length of the product life cycle considering the effect of technical development -Length of the product life cycle considering the effect of consumer trends including fashion
Product versioning/generations	A business practice in which a company produces different models of the same product, and then charges different prices for each model. Product Versioning is offering a range of products based on a core or initial product market segments. A company can maintain a pioneering strategy and consistent revenue flow by introducing new versions or generations of a product to a market. Apple uses this strategy effectively, creating multiple versions and generations of their iPod®, iPhone® and iPad® products.

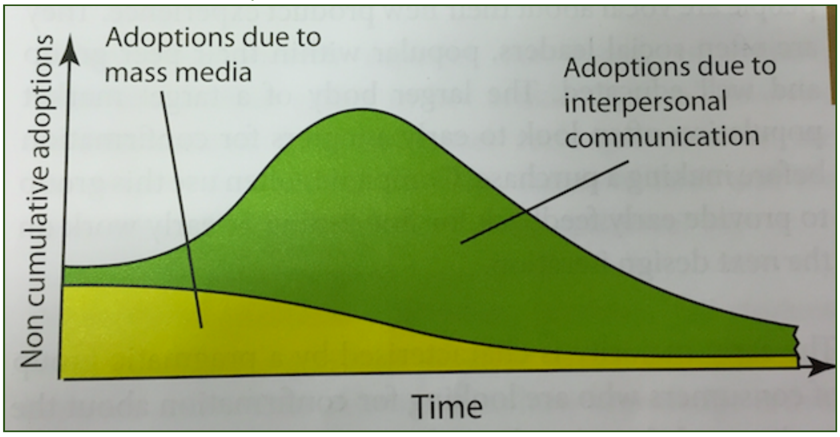
Advantages and disadvantages for a company of introducing new versions and generations of a product	Advantages and disadvantages for a company of introducing new versions and generations of a product • Improved consumer choice: consumers can choose the version thats suits them. • Improved consumer choice: can choose a budget level such as Quicken tax software • Maximise profits for the company hopefully through increased sales.

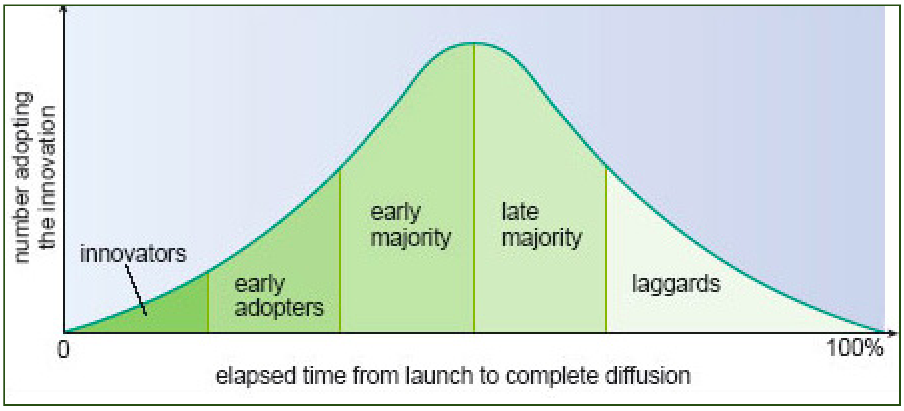
Notes:

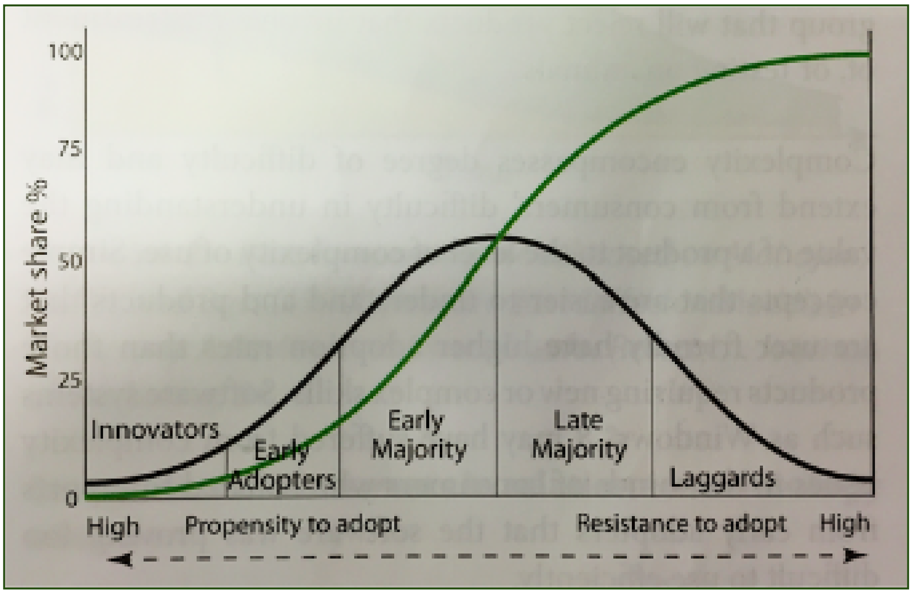
5.6 Rogers' characteristics of innovation and consumers

Innovations take time to diffuse into a target audience. Rogers' four main elements that influence the spread of new ideas (innovation, communication channels, time and a social system) rely heavily on human capital. The ideas must be widely accepted in order to be self sustainable. Designers must consider various cultures and communities to predict how, why and at what rate new ideas and technology will be adopted.

<table>
<tr><td>The impact of Rogers' five characteristics on consumer adoption of an innovation</td><td>Five characteristics identified by Rogers that impact on consumer adoption of an innovation: Relative advantage; Compatibility; Complexity; Observability; Trialability:

1. Innovation/Relative advantage – is the "the degree to which the innovation is perceived as better than the idea it supersedes. Relative advantage refers to the extent to which the innovation is more productive, efficient, costs less, or improves in some other manner upon existing practices".
2. Compatibility – is 'the degree to which the innovation is perceived as being consistent with existing values, past experiences, and needs of potential adopters. An innovation must be considered socially acceptable to be implemented. And some innovations require much time and discussion before they become socially acceptable'.
3. Complexity (simplicity) – is "the degree to which the innovation is perceived as difficult to understand and use".
4. Observability – is "the degree to which the results of the innovation are visible to others. The chances of adoption are greater if folks can easily observe relative advantages of the new technology. In fact, after some adopt, observability can improve the diffusion effect, a critical component of technology transfer".
5. Trialability – is "the degree to which the innovation may be experimented with on a limited basis. Innovations are easier to adopt if they can be tried out in part, on a temporary basis, or easily dispensed with after trial".</td></tr>
<tr><td>Social roots of consumerism</td><td>Issues for companies in the global marketplace when attempting to satisfy consumer needs in relation to lifestyle, values and identity.
Consumerism is concerned with protecting customers from all organisations where there is an exchange relationship. The roots of consumerism can be traced through: disillusionment with the system; the performance gap; the consumer information gap; antagonism toward advertising; impersonal and unresponsive marketing institutions; intrusions of privacy; declining living standards; special problems of the disadvantaged; different views of the marketplace.

</td></tr>
<tr><td>The influence of social media on the diffusion of innovation</td><td>Consumers can influence diffusion of innovation. When considering the influence of social media in rallying support for boycotting of some products/systems, students can explore the concepts behind organizations such as Kickstarter, Sellaband, Seedrs and CrowdCube, which act as crowd-funding platforms for creative products and projects. They can also examine the role of social networks such as Facebook®, LinkedIn® and Twitter® as methods of raising brand awareness.</td></tr>
</table>

<table>
<tr>
<td>The influence of trends and the media on consumer choice</td>
<td>You will need to consider how consumer choices are influenced by trends and the media, including advertising through magazines, television, radio, sponsorship and outdoor advertising; product placement through film and television; product endorsement; and so on.</td>
</tr>
<tr>
<td>Categories of consumers include innovators, early adopters, early majority, late majority, laggards</td>
<td>




This in relation to how adopt consumers technology:

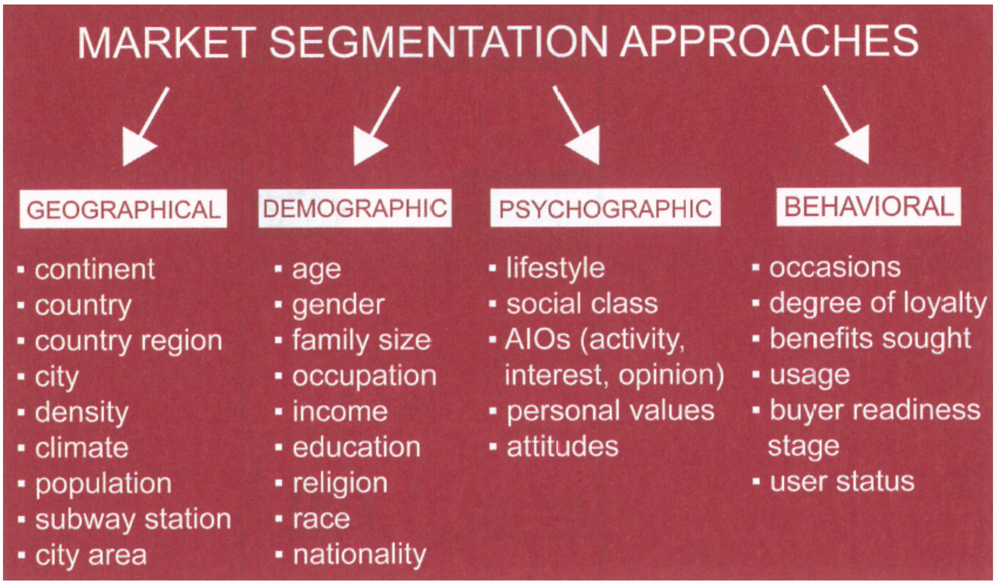
Innovators (risk takers) – are the first individuals to adopt an innovation. They are willing to take risks.
Early adopters (hedgers) – are the second fastest category to adopt an innovation.
Early majority (waiters) – the third group, tends to take more time to consider adopting new innovations and is inclined to draw from feedback from early adopters before taking the risk of purchasing new products/systems.
Late majority (skeptics) – adopts the innovation after it has been established in the marketplace and is seldom willing to take risks with new innovation.
Laggards (slow pokes) – are the last to adopt an innovation. They tend to prefer traditions and are unwilling to take risks.

</td>
</tr>
</table>

Notes:

5.7 Innovation, design and marketing specifications

Successful innovations typically start with detailed design and marketing specifications. Designers must establish clear parameters for a marketing specification in order to create unique and creative solutions to a problem. Designers need to collect valid and useful data from the target market and audience throughout the design cycle to ensure the specification includes certain essential components.

Target markets	When determining the target market, market sectors and segments need to be identified.
Target audiences	It is important to differentiate between the target market and the target audience. When determining the target audience, characteristics of the users should be established.
How a target audience is used to establish the characteristics of users	Who is most likely to buy this product given its benefits? How can the organization tap into the buying power of these consumers? Where is the target market most likely to find out about the product? Answering these questions helps you to position your product in the correct marketing and distribution channels.
Market analysis	An appraisal of economic viability of the proposed design from a market perspective, taking into account fixed and variable costs and pricing, is important. It is typically a summary about potential users and the market. 
User need	A marketing specification should identify the essential requirements that the product must satisfy in relation to market and user need.
Competition	A thorough analysis of competing designs is required to establish the market need. Every product you take to market, even ones that are new inventions or improvements on old products, face competition. This is because customers buy products for many different reasons. Some are interested in the innovation of new products, others care more about price point and clever marketing schemes. Your competition will capitalize on these buyer preferences and seek to edge out your product from the market. Identifying the competition in your marketing specification helps the organization to clarify how it can edge out and respond to the competition.
Research methods A thorough analysis of competing designs is required to establish the market need.	**Literature search** Usually performed using authoritative sources such as: academic journals, books, theses, consumer magazines, government agency and industry publications **User trial** A trial where members of the community who will use the product are observed using the product. This usually happens in a lab environment and participants have set tasks to perform under controlled conditions.

	User research The questioning of users about their experience using a product. Usually as a questionnaire or focus group. **Expert appraisal** Where an expert (chosen on the basis of their knowledge or experience) is asked to give their opinion. **Performance test** Where the product is tested and data is collected- crash test dummy
Design specifications	All of the requirements, constraints and considerations must be specific, feasible and measurable. A list of requirements, constraints and considerations that a yet-to-be-designed product must fulfil. The design specification must be developed from the design brief and research and requirements would include: • aesthetic requirements • cost constraints • customer requirements • environmental requirements • size constraints • safety considerations • performance requirements and constraints • materials requirements • manufacturing requirements

Notes:

Topic 6
Classic Design

6.1 Characteristics of classic design

A classic design has a timeless quality, which is recognized and remains fashionable. A classic design is not simply defined by how well it functions or its impact. Classic designs can be recognized as from their design movement/era. Yet, originality, whether it is evolutionary or revolutionary, seems to be the trait that makes a product "timeless".

Design Classic	A product that serves as a standard of its time, that has been manufactured industrially and has timeless appeal. It serves as a standard of its time, despite the year in which it was designed, is still up to date and remains relevant to future generations and in this way has a lasting impact on society. The design resists the vagaries of taste and fashion and once established as a "classic" it gradually acquires further value. Design classics are iconic products and characterised by simplicity, balance, is still up to date and usually innovative in their use of material. Often they unite technological advances with beautiful design, for example, Apple products such as the iPod, the Coca-Cola bottle and soft drink cans. Classic designs can emerge from any sector of the market. To ensure sustained success over an extended period of time, design classics must not only address functional and aesthetic requirements but also an **emotional connection** with the user/owner. Examples: Fender Telecaster, Eames Lounge chair and Ottoman, Porsche 911
Image	 Within the context of classic design, image relates to the instantly recognizable aesthetics of a particular product. For example, the shape of a Coca-Cola bottle, or the shape of a Volkswagen Beetle motor car. The classic design is instantly recognizable and provokes emotional reactions. Often referred to as "iconic", the longevity of classic designs suggests quality and the continued demand for such products is not dependent on heavy marketing or advertising, although this often takes place to reinforce the status and remind new generations of consumers of the intrinsic value of the classic design. The design is often widely imitated, usually with cheaper versions, so this reinforces the status of the original design and its "pioneering" concept.
Status and culture	Classic design defies obsolescence and transcends its original function. Classic designs are often **recognised** across culture and hold iconic status The iconic status of classic design is often attributed to them being breakthrough products, products that set new standards or new meanings.
Status	 Products considered as classic designs often increase in value and can project a certain status as they become more desirable. The ownership of a classic design can increase the perceived status of an individual. E.g. Status of wearing a Rolex Watch

Culture	 In the context of classic design, culture plays an important part. They often reflect cultural influences and mark transition points within a particular culture. The culture of concern may be national, religious or a sub-culture, such as a particular youth culture or movement. E.g. British culture: red letterbox, red double-decker bus, union jack flag and colours,
Obsolescence	A product that is obsolete is no longer produced or used or out of date. The role of mass production has contributed to a product reaching classic design status. Some products are considered to be classic design based on the quality of execution, enduring qualities and restraint. This is the stage in a product life cycle where the product is no longer needed even though it functions as well as it did when first manufactured. Classic designs tend to transcend obsolescence and become desired objects long after they have ceased to be manufactured.
Planned obsolescence	When a product is deliberately designed to have a specific product cycle. This is usually a shortened life span. The product is designed to last long enough to develop a customer's lasting need. The product is also designed to convince the customer that the product is a quality product, even though it eventually needs replacing. In this way, when the product fails, the customer will want to buy another, a up to date version. Obsolescence can be determined by fashion, technology, materials, construction techniques. The classic design may no longer be needed as a functional object or it may become technologically obsolete. However, it may still sell very small numbers although it may no longer be viable to produce it commercially. In such circumstances the resale value of existing products increases enormously as the number of products available lessens over time. Such products become very collectable and have investment value, for example, classic cars. Other products may not intrinsically be worth much money but are valuable to certain owners or collectors, such as toys that have been used and are in poor condition.
Mass production	For many centuries prior to the Industrial Revolution, "classic" evoked thoughts of artistry and craft skills, for example, classical architecture and furniture. The advent of mass production and "designing for the masses" often meant a reduction in quality of products and poor design. However, once mass production techniques became more established some designers embraced the opportunities offered by the new techniques and materials as a way of providing people with well-designed products at an affordable price due to the cost-effectiveness of production. No longer was classic design the preserve of the elite in society. Mass production involves the bulk manufacture of products that have little or no customisation. The setup costs for mass production are high because it usually involves extensive mechanisation and automation. The total cost per unit is lower though as less labour is required and materials can be sourced in larger quantities for less. The constant presence of a product in a changing context leads to classic design status Example: VW Beetle 21 million sold (1941-2003)

Ubiquitous/ omnipresence	A classic design often has a constant presence, or **omnipresence**, in a rapidly changing context. When an object becomes part of our everyday lives, we become very familiar and comfortable with it's presence and style. The product becomes part of our life and we start to attach emotions, feelings and experiences to the product. The product becomes embedded in our life. Therefore the demand for the product continues even when new products with better function enter the market. This continued demand for the product when newer alternatives are available afford the product classic design status. This makes a classic designs often dominant in the marketplace and difficult to change.
Dominant design	The design contains those implicit features of a product that are recognized as essential by a majority of manufacturers and purchasers. When classic design is dominant in the market-place it can be difficult to change. Apart from the functional or particular feature that is so appealing to the user, emotional issues can impact. Users are often reluctant to change, they are happy with the product and **can not** see any advantage in 'up-grading' or changing to a later model. Users can become emotionally attached to the classic design, can cannot believe that any other product is better, or in fact simply do not want to change from their reliable, and cherished possession.

Notes:

6.2 Classic design, function and form

For a design to become a classic design, the form can transcend the function. Classic design holds "form follows function" as a fundamental principle, but this is not always evident in practice. Some products are so well designed with function as their primary goal, that their use is intuitive. As designers develop new technologies, the lines between the form and function of a product continue to blur.

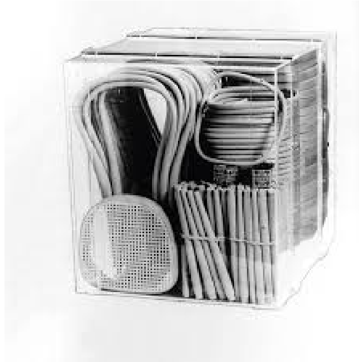
Form	Also considered as the three-dimensional space that a product takes up, in the context of classic design, form relates to the **shape of a product and the aesthetic qualities** that the shape gives.
Function	Products can be considered classic designs based on how well they **fulfil the task** that they have been designed for.
Form versus **function**	This is the meaning that the result of design should derive directly from its purpose. Sometimes there is tension between form and function when developing new products based on a classic design. When considering form, it can also be dictated by other functions such as design for manufacture techniques, for example, design for disassembly.
Bauhaus School	The Bauhaus School (literally meaning 'building house' in German) was founded in 1919 by Walter Gropius in Weimar, then the capital of post WWI Germany. In this era of change and disillusionment, the movement sought to embrace 20th century machine culture in a way that allowed basic necessities like buildings, furniture, and design, to be completed in a utilitarian but effective way. With **their theory of form follows function**, the school emphasized a strong understanding of basic design, especially the principles of composition, color theory, and craftsmanship, in a wide array of disciplines.
Retro-styling	Retro styling uses the form and decoration of classic designs from a particular period of time and/or style. Retro styling builds on the classic image but can often involve the use of new technology. Retro-styling a new product needs to respect and understand the original form and underlying structure before making changes. Designers need to however be respectful of the original designer's' intent. Retro-design often mimic a product or past experience to evoke feelings of nostalgia. Modern retro products may also use an old format to meet a new demand. E.g. Sony XDR-S16DBP digital clock radio For the Mini Cooper it was important to keep the car small, playful and cute. A whole generation had grown up with the original Mini, and it's retro styled remake needed to capture the same emotion to appeal to this generation a second time around.
Conflict and **compromise**	Comparison of retro-styled products with the original production models in relation to form and function. The balance between function and form is often a difficult area for the designer. If a product is purely functional, it may be lacking in appeal to consumers, no matter how good it is at completing its job. Often we are drawn to products that have been developed with form as the primary consideration. The human psyche appreciates beauty. The aesthetics of a product are embedded in its form- and often we can be drawn or attracted to it because of its inherent beauty- perhaps over-looking its functional attributes. The Starck designed Salif juicer, a classic design, has a high aesthetic value, its form is celebrated yet its function is poor. The MT49 teapot by Marianne Brandt is completely stripped of the decoration popular in 1924 - presenting as a purely functional product.
Practical function	The practical function of an object or space is determined by the rational - the logical or well reasoned approach to its design. Decisions by the designer or user will determined by the objects usability and reliability.

Psychological function	The psychological function of an object or space is determined by the **emotional responses**. These are the 'needs and wants' driven by fads, fashion and technological trends. Decisions by the designer or the user will evoke psychological responses- personal identity, the narrative of 'me' and relate to the desirability of the object or space.
Practical function **versus** psychological function	Some products have either practical function or psychological function has the determining factor in the design. When practical function forms the designers primary goal the interaction with the object can become intuitive. Intuitive design will have a number of redeeming features: affordance, expectation, efficiency, responsiveness, responsiveness, forgiveness, explorability, emotional security. A product can transcend the its practical function to meeting the psychological needs of the user by evoking emotions- aesthetically pleasing objects appear to the user to be more effective, by virtue of their sensual appeal. This is due to the affinity the user feels for an object that appeals to them, due to the formation of an emotional connection with the object.

Notes:

Examples of Classic Design Products

^Anglepoise 1227 Lamp



^Thonet's No14 Bistro Chair

^Philippe Starck's Juicy Salif Citrus Juicer

^Eames ottoman chair

^Fender Telecaster

^Marianne brandt tea pot

^Mini Classic

^Sony XDR-S16DBP digital clock radio