Understanding the effects of engineering achievements

Describing engineering developments

How have engineering developments impacted the following three areas:

Structural design – Development of bicycles

Developments in new lightweight materials have improved the efficiency of bicycles by reducing weight and increasing structural strength. The use of composite materials has allowed for improved streamlining. Further developments in tyre and gear technology have all impacted on the cycling world in both professional sports and daily use.

Mechanical design – Focus on theme parks

The engineering developments in theme parks have allowed the creations of far more immersive and challenging experiences for users. The integration of sophisticated mechanical animatronics combined with more mechanically advanced motions on rides and digital content have revolutionised theme parks.

Electronic design – Mobile phone technology

The developments in mobile phone technology are fast paced and evolve on a regular basis. The introduction of more connectivity to smart home devices, the inclusion of more control of our surrounding home environment, from geo tagging to camera and screen development, have revolutionised mobile phones and their use.

The effects of engineering developments

How has the impact on engineering products been impacted by:

Materials – New materials have impacted directly on engineered products in a variety of ways. Improved strength and reduced weight has had a dramatic impact, as has the development of new alloys and smart materials. Developments in plastics and textiles have also allowed for more diverse products and garments to be developed.

Smart technology – The growth in smart home integration has driven smart technology developers to focus on more integrated products and services. As more products incorporate Bluetooth and WiFi connectivity, the overall outcome is improved quality of living for people both at home and at work.

Electronic and microelectronic components – Continued miniaturisation of components has allowed electronic products to become smaller and faster with increased storage capacity, making devices more efficient and reliable. Improved screen technology and the way in which we interact with technology has changed considerably in recent years.

Considerations should be given to identify both the positive and negative aspects of the above developments when discussing the individual topics.

How environmental issues affect engineering

How engineering applications and products have an environmental impact.

Materials development – The improved use of sustainable materials and the way that recycling has improved has had a positive impact on the environment. The development of new plastic polymers is reducing the dependency on petroleum-based plastics.

Costs – The improvement of more efficient manufacturing techniques has helped to reduce the overall cost of producing some materials. Some raw material prices are volatile due to changing prices of oil and ores.

Transportation - The impact of the need to move products globally and the effect that emissions have on our environment.

Usage – The impact that end users have on products by the way that they are disposed of at the end of life. The different ways in which countries approach sustainability and recycling.

Disposal – How do different countries dispose of products when they fail or reach their obsolescence?

Recycling – What strategies are available for recycling products? Are these successful and are there any obvious failures?

Sustainability – What strategies exist for managing sustainable development of products and resources?

Understanding properties of engineering materials

Understanding materials, their properties, and their selections for specific purposes

Properties and classifications of materials

Ferrous metals contain iron and are magnetic. They are also prone to rust and need a protective finish to prevent corrosion.

- **Cast iron** is brittle if thin, can be cast in a mould, has strong compressive strength, good electrical and thermal conductivity, but has poor resistance to corrosion. It is used for products such as gates, manhole covers and drains.
- **High carbon steel** is also known as tool steel. It is hard and brittle and is less malleable than mild steel. It is an effective electrical and thermal conductor. Uses include tools, screwdrivers, and chisels.
- **Low carbon steel** is also known as mild steel and is ductile and tough, easy to shape, braze and weld. It is a good conductor of heat and electricity, but also corrodes easily. Commonly used for nuts and bolts, screws, bicycle frames and car parts.

Non-ferrous metals do not contain iron and are not magnetic. They do not rust.

- **Aluminium** is lightweight, malleable and strong. It is a good conductor of heat and electricity. It is used in drinks cans, cycle frames and saucepans.
- **Copper** is very malleable and an excellent conductor of electricity and heat, which makes it perfect for plumbing and central heating applications. It is orange/brown when polished but will oxidise to a green colour.

Differences between thermoforming and thermosetting polymers

Thermosetting polymers will strengthen when heated and cannot be re-moulded or heated after the initial forming. Thermoplastic can be reheated, remoulded without causing a chemical change.

Thermoforming polymers can be heated and shaped repeatedly and are readily recyclable.

- **Acrylic** is hard with good plasticity when heated, can be bent and folded easily but scratches and can be brittle. It is a popular material in the production of car headlights, protective visors and baths.
- **High density polythene** (HDPE) is a stiff and lightweight polymer that provides excellent chemical resistance. It has good plasticity when heated; it is perfect for buckets, bottles, pipes and washing up bowls.
- **Polyvinyl chloride** (PVC) is available in a range of colours as well as transparent. It can be used for vacuum forming.
- **Thermosetting polymers** are materials that are formed once and cannot be recycled. **Melamine formaldehyde** has excellent resistance to heat, moisture, scratching and staining, making it perfect for kitchen worktops and tableware.
- **Urea formaldehyde** is a hard, stiff polymer with excellent insulation properties, making it suitable for switches, plugs and electrical fittings.

Smart and composite materials

Smart materials can display a physical change due to external stimuli.

A smart material is a category of materials that react to a change in temperature or light, for example.

- **Photochromic pigments** or film are used to change colour in ultraviolet (UV) light. This is used in spectacles that automatically darken as the sunlight gets brighter. It is useful in office blocks windows to dim sunlight.
- **Thermochromic pigments** are useful when used in baby products like spoons, bottles and bath toys. This allows the product to change colour to indicate temperature.
- **Shape memory alloys** are materials that change their shape when heated. Spectacle frames and dental braces made from Nitinol can be returned to their original shape.

Composite materials are relatively new and have specific working properties and performance characteristics.

- **Carbon fibre** has high stiffness and tensile strength, with low weight. Carbon fibre is created by bonding carbon atoms together in crystals. It is then woven into fabric and combined with other materials to form a composite.
- **Kevlar** is a heat resistant and strong synthetic fibre with the ability to stop bullets and knives form penetrating it. Kevlar is often described as being five times stronger than steel.

Properties and testing materials

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Understanding the physical properties of materials

Understanding that materials can be defined by a range of properties, for example:

- **tensile strength** – the ability of a material to resist stretching or breaking when pulled
- **compressive strength** – a materials ability to withstand loads without changing its shape
- **hardness** – this is a materials ability to resist changing shape when impacted by another object
- **toughness** – the ability of a material to absorb energy (impacts) before it starts to deform (change shape)
- **malleability** – the materials ability to be repeatedly hammered, pressed, bent or rolled into thin sheets
- **ductility** – the ability of a material to be drawn or plastically deformed without breaking
- **conductivity** – a measure of how well the material conducts heat or electricity
- **corrosive resistance** – how well the material can withstand damage caused by chemicals or oxidisation
- **elasticity** – the ability of a material to limit distorting and return to its original shape and size
- **environmental degradation** - how the physical environment is degraded, damaged or compromised through a range of situations such as air pollution, water contamination etc.

Physical properties required for specific products (examples)

Mobile phones

- **compressive strength** to resist weight put on the phone casing
- **corrosive resistance** to limit damage to the phone casing from chemicals such as hairspray, sun cream or other daily exposures.

Security alarm

- **compressive strength** in its casing to avoid deformation from high winds
- **hardness** to avoid possible vandalism or attempts to gain access to the circuit.

Bicycles

- **ductility** to allow the tubular forms of the frame to be created (drawn)
- **toughness** to absorb impact, for example when children drop bikes on the floor or during a crash in a race
- **compressive and tensile strength** to absorb the shifting weight of the cyclist on the bike.

Children's play area

- **toughness** to absorb impact when children climb frames and obstacles
- **elasticity** when children climb ladders and ropes or walk across suspended bridges
- **compressive strength** to withstand loads of several children standing in a small area or climbing on frames
- **tensile strength** when children hang or swing on sections of the play area.

How materials are tested to determine their physical properties

Testing is undertaken in engineering to determine the physical properties of materials.

Destructive testing will test the material, part or product until it breaks or is destroyed. Non-destructive testing is used to evaluate the property of the material without causing it damage.

Tensile testing - the material or part is clamped in two locations, usually on opposite ends, and increasing pulling force is applied in opposing directions to measure stretching.

Hardness testing - this is tested by indenting the material with a known hard material such as diamond. The force used to create this is measured to determine hardness.

Toughness testing – this is undertaken by allowing a pendulum with a mass on the base to strike the side of the material or part. The extent to which the shape bends (deflects) dictates its level of toughness.

Malleability testing is done by applying a stamping action (pressing) on the material to see how much the malleable material will flatten without breaking.

Ductility testing is performed in a similar manner to tensile strength testing, where the material is drawn apart.

Conductivity testing is done by passing an electrical current through the metal material and measuring its resistance.

Elasticity is another stretching test but measures a material's ability to be stretched without permanent deformation.

Preparation, forming joining and finishing of materials

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Describing engineering processes

Understanding the application of engineering processes including:

- **Marking** includes applying a marking out medium such as engineer's blue to the material and using a scriber to mark lines for cutting or forming. Dividers and calipers may also be used for marking out. Common tools also used would be engineers square and a steel rule.
- **Cutting** can occur using a hand tool like a hacksaw, sheers or snips saw or fretsaw, or using machinery such as a metal bandsaw.
- **Finishing** applications can include oil bluing, lacquer applications, paint, dip coating etc.
- **Shaping** can involve the removal of materials using saws, files or grinding equipment. It is usually applied to change the form/ shape of stock material.
- **Drilling** is a process whereby a hole is required in a material. Drilling can be done using a hand drill, or drill press/pillar drill, and use a variety of different drill types.
- **Milling** uses a milling machine to cut accurate features such as; open slots, steps and enclosed slots. It can also be used to face off edges and produce holes.
- **Brazing** typically involves a brazing hearth to braze metals together to form a permanent joint. The brazing hearth can also be used to heat treat metals by annealing, normalizing, tempering or hardening a range of metals.
- **Turning** uses a machine called a lathe that can be used to turn a piece of metal to create differently shaped round pieces. It can also be used to create threads and to apply different knurled finishes, as well as to apply chamfers or rebates to material.
- **Joining** metals can be done permanently using welding, brazing, epoxy resin adhesives and soldering. Temporary methods include nuts and bolts, hinges, screws and rivets.
- **Soldering** is used to heat join softer metals such as silver in jewelry (silver solder) or to attach electronic components to printed circuit boards.
- **Forming** is a process used to change the shape of the material, for example by bending, compressing or extruding. Additional tools such as vices and clamps are often used in this process. Heat is often used to assist forming processes.
- **Preparing** materials includes cutting materials to rough sizes (slightly larger than required) from stock material (the material as purchased from the supplier). Preparation can also consider ensuring that all of the tools and equipment identified in the planning stages is available and ready to use. This can also include undertaking appropriate risk assessment measures to ensure safe working practice is undertaken.

Risk assessments and safe working practices

Risk assessments are performed prior to manufacture to ensure that operations can be undertaken safely.

They can include the following:

Identifying potential hazards

- Visual inspection of the workplace to ensure that no obstructions or hazards are present.
- Visual inspection of equipment, which includes guards and safety features.
- Checking of tools to ensure there are no defects or missing parts.

Undertaking a risk assessment

Risk assessments aim to identify potential risks based on the work which will be undertaken during manufacture. The risk assessment will classify the risk according to severity of harm. Once the areas are identified, the likelihood and the control measures are put into place to reduce and minimize the risks from becoming potential accidents to the machinist or operator.

Personal protective equipment (PPE)

The risk assessment document should also identify appropriate PPE, which should be used for key equipment and processes. For example:

- ear defenders
- safety goggles
- protective aprons
- heat resistant gloves
- face shields.

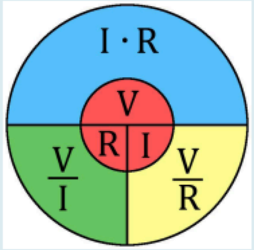
Solving engineering problems

Describing engineering processes

Engineering often involves the need to understand calculations and apply mathematical techniques. These include:

Formulae

- **Ohm's Law** is used to calculate resistance, current and voltage. A typical application may be to calculate the correct value of resistor in an LED circuit.



Mechanical advantage

- When using mechanisms, you can calculate the mechanical advantage (MA) of the system using the formula:

(MA) = Load/Effort

Velocity ratio

- Calculating the velocity ratio (VR) of a mechanism requires the information of the distances moved by the load and the distances moved by the effort.

$$\text{VR} = \frac{\text{Distance moved by effort}}{\text{Distance moved by load}}$$

Calculations

- Calculations for mechanisms formula above should include an understanding of application on gears, levers and pulleys.

Areas and volumes

- Calculating areas of engineered parts where subtractions or additions of materials are made by:
  - calculating volumes of cylinders
  - calculating volumes of shapes
  - working out areas of objects.

Estimating costs and materials

- Using a range of sourced costs to calculate the cost of material needed to manufacture a part or component in the engineering outcome.

Scale

- Being able to apply and understand scale factors when reading or producing an engineering drawing is a vital skill. Scales are shown as ratios, for example 2:1 or 1:5.

Units

- Using metric and imperial units for measurements and calculating costs such as:
  - **millimetres** and metres – used in giving sizes on engineering drawings and during manufacture of products
  - **pounds** and pence – used for estimating and working out costs of materials etc
  - **time** in hours, minutes and seconds – used in planning stages for manufacture.

Graphs

- A range of graphs can be applied in planning the manufacture or other relevant areas.

Technical details in engineering drawings

Engineering drawings may be made up of several different parts to the drawing. All elements of an engineering drawing must conform to a standard convention.

Orthographic views

- These are the views of a product or part, which appear on engineering drawings. Typical views are Plan View, End View and Front View.

Hidden detail

- Hidden detail lines are used to show surfaces that are not directly visible. All surfaces must be shown in all views. If an edge or surface is blocked from view by another feature, it is drawn using a hidden detail line.

Section view

- A sectional view or a section looks inside an object. Sections are used to clarify the interior construction of a part that cannot be clearly described by hidden lines in exterior views.

Isometric views

- Isometric projection is a method for visually representing three-dimensional objects in two dimensions in technical and engineering drawings.