NCFE Engineering Knowledge Organiser

Southmoor Academy
ASPIRE · ACHIEVE · ENJOY

Name: ______________________________

Class: ______________________________

Teacher: ______________________________

Engineering Disciplines

You must know about different **Engineering disciplines** and the types of products produced by each of the disciplines.

Mechanical
Machinery, Hydraulics, gears and pulleys, mechanisms

Electrical and electronic
power station, household appliances, integrated circuits

Aerospace
aircraft, space vehicles, missiles

Communications
telephone, radio and fibre optic

Chemical
pharmaceuticals, fossil fuels, food and drinks

Civil
bridges, roads and railways

Automotive
cars, motorcycles and trains

Biomedical
prosthetics, medical devices and radiotherapy

Software
applications, systems and computer programming.

You must know how every product from each discipline on the list has solved problems and shaped the modern world.

Example: Bridges (Civil Engineering):

Problems solved: Bridges have allowed people and transport to cross over obstacles such as large bodies of water, roads and railways quickly and safely. Prior to a bridge being built people would either have to travel a long way around the obstacle,or make a potentially dangerous crossing. Both methods would be time consuming (slow) and possibly more hazardous or expensive.

They have shaped the modern world by making it easier and quicker to transport people and goods on foot, by road and by rail to places that might have been difficult to get to.

They have enabled people to work in places that they may not have been able to get to before. They have reduced the cost of goods by making them cheaper to transport. They have reduced journey times.Iincluding queuing and crossing, taking a ferry over a river might add 30 minutes travel time to a journey. The same crossing over a bridge may take less than a minute.

Furthermore, they have improved safety as people no longer have to make dangerous crossings (e.g. by boat at night or in bad weather or by crossing busy roads or railway lines).
Finally, travelling long distances around obstacles will use more fuel and release more CO_2, which is harmful to the environment, so bridges can have environmental benefits.

Likely to be an 8-10 mark question. Break it down into two sections:

Problems solved - Think about what the product actually does. Then explain what we can do now that we couldn't do easily before, because of the existence of the product in question.

How has it shaped the modern world? - List all of the possible benefits of the product. You must explain how or why each one is a benefit. Give examples where you can. For every point made, ask yourself 'so what?' then write your answer down after the point.

The Health and Safety Legislation Governing Engineering

Health and Safety in Engineering is important to ensure that every person is safe from harm or injury caused by accidents and hazards

Health and Safety at Work Act
- responsibilities of employers to their employees.
- responsibilities of employees at work.

Control of Substances Hazardous to Health (COSHH)
- chemicals
- fumes
- dust.

Manual Handling Operations Regulations
- Ensuring no-one lifts items that might injure them.
- Training and risk assessment of all manual handling tasks

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR)
- report forms (what information goes on them?)
- reportable incidents
- person responsible.

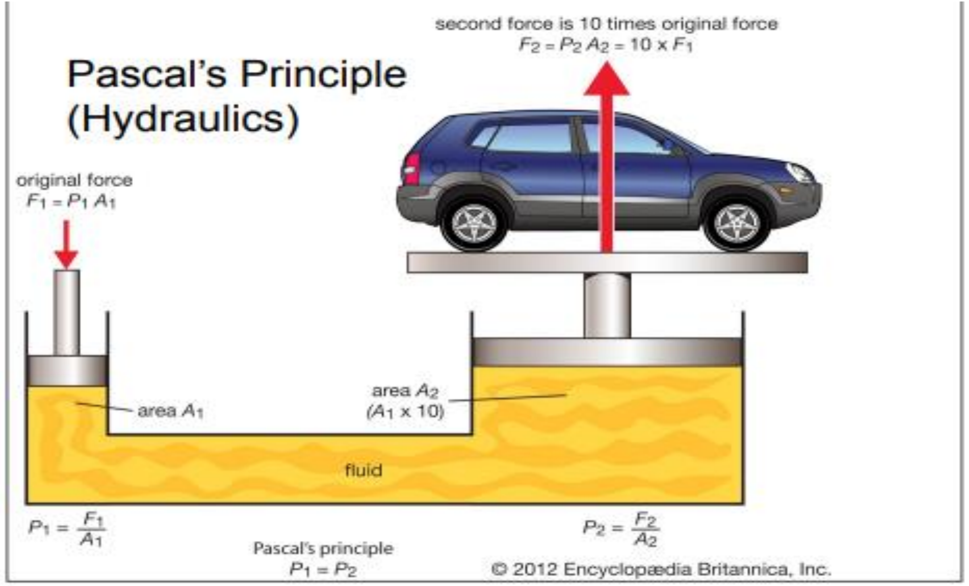
Personal Protective Equipment at Work Regulations

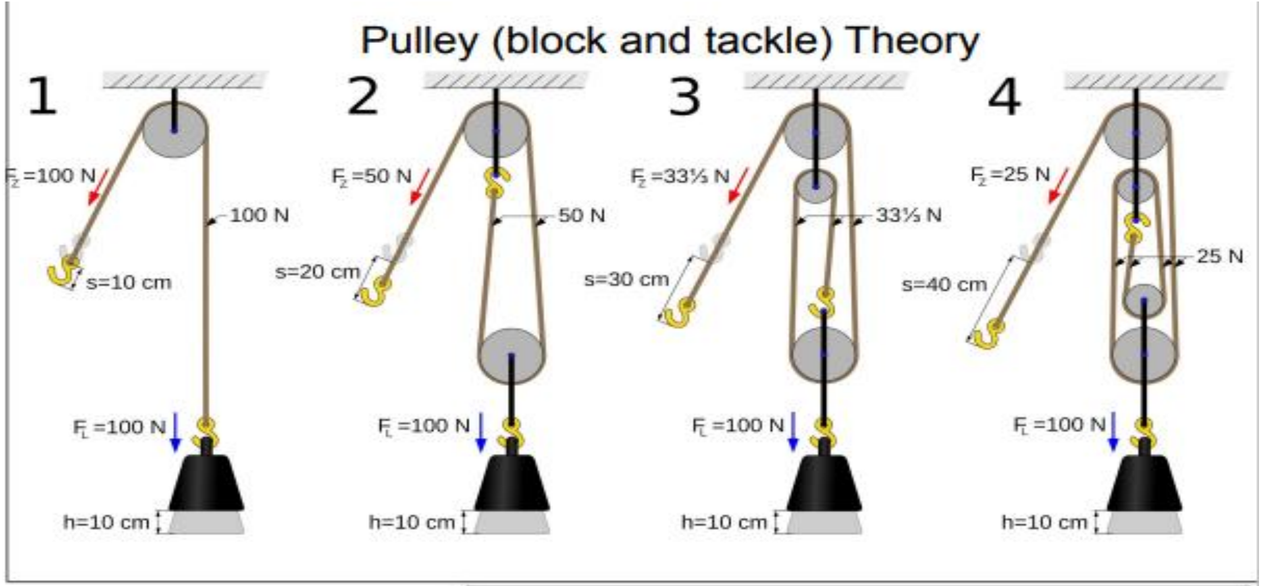
Eyes and ears - goggles, safety glasses, visors and ear protectors
Head and face – hard hats, helmets, bump caps
Respiratory – disposable filtering face-piece, full face respirators, breathing mask
Hand and arm – gloves, gauntlets, mitts, armlets
Clothing – disposable overalls, high visibility vest, aprons and boiler suits
Footwear – safety boots with protective toe caps, gaiters, spats.

CA 1

ENGINEERING

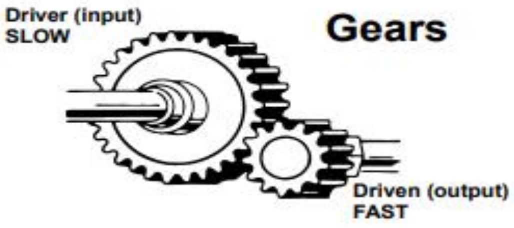
DISCIPLINES





CA 1

Gears



If the driver gear (input) is larger than the driven gear (output) then there will be an increase in speed.

The output gear will turn quicker than the input.
The trade off will be a reduction in turning force.

Useful in machines where high speed is needed but little resistance (food mixers).

In a car these gears are used for high speed driving where the car already has a lot of momentum as it is moving quickly.

If the driver gear (input) is smaller than the driven gear (output) then there will be an reduction in speed.

The output gear will turn slower than the input.
The benefit will be an increase in turning force.

Useful in machines where heavy loads need moving using a low powered motor (automatic garage door)

In a car these gears are used pulling away from a stopped position or driving up a hill. This is because the force required is high.

Gears can be used to change direction

When gears are placed next to each other they will change direction from clockwise to anti clockwise direction. An idler gear placed in the gear train will keep the direction of travel the same.

Rack and pinions can be used to change from rotary to linear movement.

Bevel gears can change the direction of travel through 90 degrees.

What do the COSHH symbols mean?

SI units of measurement
(and other accepted units)

Current – ampere
microamp
milliamp
amp
Kiloamp.

Luminous intensity – candela
microcandela
millicandela

Temperature – kelvin
kelvin
degrees Celsius (accepted for use within the SI).

Mass – kilogram
milligram
gram

Length – metre
micrometre
millimetre
centimetre
Kilometre.

Amount of substance – mole
nanomole
micromole
millimole

Time – second
microsecond
millisecond
minute (accepted for use within the SI)
hour (accepted for use within the SI).

Science and Mathematics in Engineering

Energy			
Value required	Formula	Written	Units
Efficiency	efficiency (%) =	(useful energy out ÷ total energy in) x 100	No unit. % value
Power	P = E ÷ t	power = energy ÷ time	Watt (W)
Work done	W = F x d	work done = force x distance	Joule (J)

Forces and Motion			
Value required	Formula	Written	Units
Speed	s = d ÷ t	speed = distance ÷ time	m/s
Acceleration	a = (v-u) ÷ t	acceleration = change in velocity ÷ time	m/s^2 or ms^{-2}
Force	F = m x a	force = mass x acceleration	Newton (N)
Moment of force	m = F x d	moment = force x perpendicular distance from pivot	Newton metre (Nm)
Weight	w = m x g	weight = mass x gravity	Newton (N)
Momentum	p = m x v	momentum = mass x velocity	Kg x m/s
Density	d = m ÷ v	density = mass ÷ volume	kg/m^3 or g/cm^3
Pressure	p = F ÷A	pressure = force ÷ area	Pascal (Pa)

CA 2

SCIENCE AND MATHS

CA 2

Geometric			
Value required	Formula	Written	Units
Area - square	L^2	length of side²	m^2 or cm^2 or mm^2
Area - rectangle	l x h	length of side 1 x length of side 2	m^2 or cm^2 or mm^2
Area - triangle	½ bxh	(length of base x height of triangle) ÷ 2	m^2 or cm^2 or mm^2
Area - circle	$\pi \times r^2$	π x radius²	m^2 or cm^2 or mm^2
Volume – cube cuboid	l x b x h	Length x breadth x height	m^3 or cm^3 or mm^3
Volume - pyramid	1/3 x Abase x height	(1/3) x (Area of base) x height of pyramid	m^3 or cm^3 or mm^3
Volume - cylinder	$\pi r^2 x h$	π x radius² x height of cylinder	m^3 or cm^3 or mm^3

Electricity			
Value required	Formula	Written	Units
Power	P = V x I	power = voltage x current	Watt (W)
Voltage	V = I x R	voltage = current x resistance	Volt (v)
Current	I = P ÷ V	current = power ÷ voltage	Amp (A)
Resistance	R = V ÷ I	resistance = voltage ÷ current	Ohm (Ω)

Properties of Engineering Materials

Chemical

- Heat of combustion - The amount of heat released when one mol of a material is burnt
- Toxicity - The degree to which a substance can harm humans or animals
- Oxidation state - The degree of electron loss (oxidation) of an atom in a chemical compound

Electrical and magnetic

- Conductivity - The ability of a material to allow electricity to flow through it
- Resistance - The ability of a material to prevent electricity from flowing through it.
- Magnetism - a force that can attract (pull closer) or repel (push away) objects that have a magnetic material like iron inside them

Mechanical

- Strength - The ability of a material to withstand a force without breaking (tensile or compressive)
- Hardness - The ability of a material to withstand scratching and indentation.
- Toughness - The ability of a material to withstand impacts without breaking
- Elasticity - The ability of a material to return to its original shape after an applied load has been removed
- Plasticity - The ability of a material to be easily shaped and moulded
- Ductility - The ability of a material to be stretched (drawn) out.
- Durability - The ability of a material to withstand wear, pressure or damage
- Malleability - The ability of a material to be hammered and pressed without breaking

Optical

- Reflectivity - The amount of light reflected by a material
- Photosensitivity - The amount to which a material reacts to receiving visible light

Thermal

- Flammability - The ability of a material to burn or ignite
- Thermal conductivity - The ability of a material to allow heat to flow through it
- Melting point - The temperature at which a solid material will change state to a liquid

Renewable	Advantages	Disadvantages
Wind	No fuel needed, no waste or greenhouse gases, can be used in remote areas or offshore to minimise impact.	Unreliable, unsightly effect on the landscape, can harm birds.
Solar	Low cost after initial outlay, no pollutants or waste, used on small or large scale in remote areas.	Expensive initial cost, unreliable, storage system needed.
Tidal	Low cost after initial outlay, no pollutants or waste, predictable.	Expensive initial cost, can damage habitats.
Biomass and biofuel	Readily available fuel, can use waste materials, low-cost process.	Air pollutants.

Characteristics of Engineering Materials

Aesthetics

- Colour - the property possessed by an object of producing different sensations on the eye as a result of the way it reflects or emits light
- Surface texture - The roughness and variations of the surface of a material
- Finish effect - The effect on a material's surface created by adding a finish (e.g. paint, lacquer or plastic coating)

Environmental impact

- Extraction of raw material - How much energy used and environmental harm caused by extracting raw materials such as oil or metal ores.
- Fossil fuels - The use of fossil fuels as a form of energy releases CO2 which contributes to global warming
- Sustainability - how much we can sustain (keep going) the earth's resources by carefully managing their use.

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Extraction of raw materials	
Timber: Forestry	• Cutting down trees causes huge areas of forest disappear. Hardwoods are particularly slow growing and cannot be easily replaced in a lifetime. • If forests are destroyed through logging or burning, carbon dioxide (a climate-changing greenhouse gas) is released into the atmosphere. • Deforestation also impacts water cycles since trees absorb water through the roots. A lack of trees can cause flooding or areas of extreme dryness. • Deforestation also reduces wildlife habitats and biodiversity.
Forest Stewardship Council	• FSC forests are managed with consideration for people, wildlife and the environment. • Logo is found on wooden and paper products. • To make sure more trees are replanted than are cut down so we don't run out. Shows that… • As trees are chopped down, they are replaced. • Parts of the forest are untouched to protect animals and plants. • Once a section of the forest has been cut down, it is left for 20 years so the trees can re-grow. • Local workers run the forest, get a fair wage and safe conditions.
Metals: Mining and drilling	• The environmental impact of mining and drilling includes loss of habitat for wildlife caused by the clearance of land, noise, and light pollution. • Water run off can also create ponds of concentrated chemicals and pollute water and soils.
Polymer: Oil extraction	• Synthetic plastics dominate the plastic processing industry because they are easy to process. The shortage of oil reserves worldwide has led to the adoption of bioplastics extracted from animal wastage and waste biomass. • Raw materials from crude oil, natural gas, and sometimes coal need to be extracted for the polymerisation process. • Drilling for oil, both on land and at sea, is disruptive to the environment and can destroy natural habitats. Additionally, oil spills have a devastating effect on the environment: they ruin habitats, destroy food sources, and poison living organisms
Gas: Fracking	• Fracking is the process of extracting gas from shale. It involves drilling down into the earth and forcing water, sand and chemicals into the rock to release the gas. • It can cause mini earth quakes. It could damage the environment. The chemicals used may contaminate drinking water. • There could be enough gas in the UK alone to last for decades.

Life-cycle assessment stage	Plastic	Metal
Material extraction	Plastic is extracted using oil rigs, a lot of energy is needed. Animal habitats can be destroyed and potential oil spills	Metal is mined. This create sink holes, can damage water suppls
Manufacturing and packaging	Processed, then moulded. Each stage uses energy. Packaged in cardboard. Formed at 160°C (Polypropylene).	Processed, then formed. Each stage uses energy. Packaged in cardboard and or plastic. Formed at 1400°C.
Product use and reuse	Energy and chemicals used to wash and reuse product Strong so reusable Life expectancy a couple of years.	Energy and chemicals used to wash and reuse product. Strong and durable so reusable. Life expectancy 5-10 years.
End of life disposal	Recyclable – Requires energy. Not biodegradable Take up space in landfill unless recycled.	Recyclable – Requires high amount of energy because of its high melting point. Not biodegradable Take up space in landfill unless recycled.

CA4

- Carbon Footprint- A carbon footprint is the amount of carbon dioxide and other greenhouse gases released into the atmosphere due to the activities of humans. A carbon footprint can be based on the activities of an individual, business, or country.
- Direct emissions- are created by individuals and companies and their influence on the environment such as fossil-fuel combustion in manufacturing, heating, and transportation; these emissions are controllable.
- Indirect emissions- are emissions that are consequences of the activities of individuals or companies, but occur at sources owned or controlled by another entity, such as the carbon produced by the country in which a person lives and emissions required to produce the electricity associated with goods and services consumed.
- Carbon footprint offsetting- consists of neutralising the carbon footprint, or amount of CO2 emissions emitted by an individual, company, organisation, product or service.

The 6R's	
Refuse	Don't accept a product at all if you don't need it or if its environmentally or socially unsustainable, do not use materials if it is not environmentally friendly
Rethink	Change your views on current lifestyles and the way we design and make
Reduce	Minimise the amount of materials and energy used during the whole of a products life cycle
Reuse	Take an existing products that's become waste and use the material or parts for another purpose, without processing it
Repair	When a product breaks down or doesn't function properly, fix it
Recycle	Take an existing product that has become waste and re-process the material for use in a new product

CA 4

Thermosetting - Once heated and moulded, thermoset plastics cannot be reheated and remoulded.

Names	Properties	Uses
Urea formaldehyde (UF)	Stiff, hard strong, brittle, good electrical insulator.	Electrical fittings, handles and control knobs, adhesives.
Epoxy resin (ER)	Good electrical insulator, hard, brittle unless reinforced, chemical resistant.	Casting and encapsulation, adhesives, bonding of other materials.
Polyester resin (PR)	Stiff, hard, brittle unless laminated, good electrical insulator, chemical resistant.	Casting and encapsulation, bonding of other materials.

Thermoplastic- These plastics can be re-heated and re-shaped in various ways.

Names	Properties	Uses
Acrylic (Perspex or PMMA)	Hard, rigid, good surface finish, liable to crack, do not bend.	Display signs, clock faces, fake finger nails, car headlights.
Polypropylene (PP)	Very strong, scratch resistant, lightweight, expensive.	Chair seats, mobile phones, toys.
High-impact polystyrene (HIPS)	Clear, rigid, brittle and moderately strong.	Buckets, bowls, appliances components

Elastomer- Elastomers have the ability to deform and then return to their original shape almost instantly.

Names	Properties	Uses
Rubber	Tough, water repellent, chemical and abrasion resistant.	Footwear, tyres, cookware.
Neoprene	Temperature insulator, chemical resistant, high tensile strength.	Wetsuits, hoses, orthopaedics.
Silicone	Elastic, thermal insulator, water repellent.	Sealants, adhesives, lubricant.

Manufactured Boards- Manufacture boards are timber sheets produced by gluing wood layers or wood fibres together. Manufactured boards are often made use of waste wood materials. They are not expensive so are often used instead of real woods

Names	Properties	Uses
Chipboard	Made from compressed wood chips. Strength varies with density. Absorbent to water. Strong and easy to work with.	Floorboards, veneered worktops, and self-assembly furniture
Medium-density fibreboard (MDF)	Higher density than chipboard. Strong and cheap.	Flat-pack furniture and kitchen furniture.
Plywood	Layers of wood bonded together with grains at right angles. Very strong and durable. Can be turned into curved shapes.	Flooring and furniture.

Ferrous Alloys- Contain iron. Almost all are magnetic. Little resistance to corrosion and prone to rust. Good electrical and thermal conductivity/ conductor

Name	Composition	Properties	Uses
Mild steel	Carbon 0.1 - 0.3% Iron. 99.9 - 99.7%	Tough. High tensile strength Good electrical and thermal conductivity. Rusts very easily.	Most common metal used in school workshops. Used in a lot of products.
Cast iron	Carbon 2 - 6% Iron. 98 - 94%	Strong but brittle. High compressive strength.	Castings, utility access covers, engines, pans.
Stainless steel	Iron, nickel and chromium	Tough. Resistant to rust and stains.	Cutlery, medical instruments.

Non- Ferrous Metals- Do not contain iron. Are not magnetic. Usually more resistant to corrosion.

Name	Colour	Properties	Uses
Aluminium	Light grey	Ductile, soft, malleable. Very light. Good conductor of heat.	Window frames, aircraft, kitchen ware, bike frames.
Copper	Reddish brown	Ductile, can be beaten into shape, can be polished. Conducts electricity and heat.	Electrical wiring, tubing, kettles, bowls, pipes.
Lead	Bluish grey	Soft, heavy, ductile. Good conductor of electricity	Batteries, roofing materials.

Non- Ferrous Alloys - Mixtures either of different metals or of a metal and small quantities of other substances. Require a protective finish.

Name	Composition	Properties	Uses
Bronze	88 % copper and 12% tin.	Brittle, highly ductile, casts well. Corrosion-resistant	Sculpture, musical instruments, medals, and industrial application.
Brass	65% copper and 35% zinc	Hard, ductile, casts well, conduces heat.	Parts for electrical fittings, ornaments.
Silver solder	Mainly silver but alloyed with copper.	Ductile, malleable, solders, resists corrosion.	Jewellery, solder, ornaments.
Solder	60% tin, 39% lead, and 1% other alloys.	Melting range in 270–350°C, good electrical conductivity, good mechanical properties.	Used for soldering. Especially useful in electronics and plumbing.

CA 4

Softwood-Softwoods come from coniferous trees which have needles instead of leaves. They do not lose their leaves in winter. They are ever green.			
Names	Properties	Colours	Uses
Pine	A straight-grained softwood but knotty. Fairly strong but easy to work with. Cheap and Tough.	Light	Furniture, constructional work and simple joinery.
Spruce	Small hard knots. Not very durable, tough.	Creamy-white	Furniture used in bedrooms and kitchens.
Cedar	Fine even texture. Lightweight, stiff and stable.	Pale yellow	Furniture, boat building, veneers, and model making.

Hardwood- come from deciduous or broad-leafed trees. They lose their leaves in the winter. They grow slower than softwoods so they are more expensive.			
Names	Properties	Colours	Uses
Beech	A straight-grained hardwood with a fine texture. Tough.	Light pink.	Furniture, toys, tool handles.
Oak	Durable and strong wood. Open grain.	Light brown.	Furniture, boats, beams used in buildings, veneers.
Ash	Flexible, tough, shock-resisting density.	Pale.	Sports equipment, staircases, furniture.
Sycamore	Strong, durable. Interlocked grain	Pale, sometimes darker reddish brown.	Veneer, pallets/crates, flooring.
Balsa	Soft, durable. Straight grain. Easy to work with	Pale.	Model building, breakable furniture on film sets.

A composite material combines two or more types of materials. The properties of each material in the composite complement each other and produce a material with improved properties. E.G Stronger material. A composite material takes the form of fibres, sheets or particles in a matrix (glue).

Particle-based composites are made with small particles of material by mixing smaller particles of sand with larger particles of cement and aggregate.		
Name	Components	Uses
Concrete	Cement, sand and aggregate.	Buildings, street furniture.
Reinforced concrete	Concrete and steel.	Construction on a large scale, such as bridges, dams, piers, tall buildings and stadiums.
Glass fibre reinforced concrete	Glass fibre and concrete.	Street furniture, urban features.

Ceramics are made of a variety of materials, but usually silicate minerals as clay, feldspar, quartz, and talc. When heated, these materials become hard and brittle. The properties of ceramics include:

•Hardness. Wear-resistance. Brittleness. Heat resistance (refractory). Thermal and electrical insulation. Non-magnetic. Chemically stable.

Cement	Cement is a material made by heating limestone with clay in a kiln. Cement is mainly used as a binder in concrete, which is a basic material for all types of construction, including housing, roads, schools, hospitals, and dams, as well as for decorative applications.
Bricks	Bricks are produced by mixing clay with water, shaping and forming the bricks, then drying and firing them. Bricks are widespread building materials for walls, chimneys, fireplaces, and more. Bricks are hard, strong under compression, but brittle.
Glass	Glass is a rigid material formed by heating a mix of sand and metallic oxides, which influence the glass properties and its colour. It is brittle and can break if handled carelessly.
Diamond	Diamond is the hardest material available in nature. It has many applications such as industrial abrasives, cutting tools, abrasion-resistant coatings, and, most famously, in jewellery.
Pottery	Pottery is clay that is modelled, dried, and fired, usually with a glaze or finish, into a decorative object. Clay is a natural product that has decomposed from rock within the earth's crust for millions of years. Pottery must be fired to a temperature high enough to mature the clay, meaning that the high temperature hardens the piece to enable it to hold water. Ceramics are heat resistant so they can reach a high temperature without breaking. Clay ceramics are often coated with a glaze (made from glass), which hardens on heating to form a hard, smooth, opaque, and waterproof layer (which makes them non-porous).

Fibre-based composites are reinforced with fibres by mixing resin or concrete with fibres of glass or carbon.			
Names	Components	Propeties	Uses
Glass reinforced plastic (GRP)	Glass fibres and resin.	Strong and light material	Boats, instrument cases.
Carbon fibre reinforced polymer (CFRP)	Carbon fibre and resin.	VERY Strong, has the best weight to strength ratio.	Formula 1 car bodies, crash helmets, sports equipment.

Natural fibre composite are composite materials in which the reinforcing fibres are derived from renewable and carbon dioxide neutral resources such as wood or plants.

The applications of natural fibres are growing in many sectors such as automobiles, furniture, packing and construction.

Tools and Equipment

CA 5

TOOLS

EQUIPMENT

MACHINES

Image	Name and description
	Scriber – used to mark out metals
	Steel Rule for measuring
	Engineers Square – used to measure right angles
	Marking gauge for marking straight lines in wood
	Dividers and Callipers – for measuring and marking out

Image	Name and description
	Hacksaw – For cutting metals
	Junior Hacksaw – Small / light metal cutting
	Tenon saw – cutting straight lines in wood
	Coping saw – Cutting curves and intricate shapes

	Tin snips – for cutting sheet metal
	Pliers – for gripping work
	Hammer – for striking objects e.g. a centre punch or nail.
	Files – for removing materials and making work smooth
	Jigsaw – for cutting shapes in sheet material

Angle Grinder – For grinding and cutting metal	Cordless drill – portable way of drilling holes	Pillar drill – bench or floor mounted method of drilling holes	Scroll Saw – For cutting curves and intricate shapes in thin materials
			

Router – For creating cuts, grooves and profiles in wood	Centre lathe – for making round and cylindrical items from metals	Milling Machine – for cutting steps, grooves and straight edges in metal	Laser cutter – for cutting and engraving materials
			

Drilling

- Cordless drills can be used on construction sites because they use a battery, they are portable and light enough to carry around.
- Pillar drills are fixed machines used in workshops, they can apply force, be used on a range of materials, and are good for creating holes in harder materials (such as mild steel). The distance between the drill bit and the bed can be very large, which means there is space for bigger materials.
- Bench drills have a smaller distance from the drill bit to the table and are fixed to a bench. This means there is less space for large workpieces.
- Bench drills and pillar drills are used to create holes in hard materials, so work-holding devices, such as a G-clamp or machine vice should be used to stop work falling onto the machine operator's foot.

CA 5

Image	Name and description
	Pop Rivet Gun – for securing pop rivets into holes in sheet metal
	Screwdrivers – Various heads – for tightening and loosening screws
	Spanners – Open, Ring and Adjustable – for tightening and loosening nuts and bolts

	Hot Glue Gun – for quickly gluing materials together
	Soldering iron – used to join electronic components to circuit boards
	Nail Gun – Used to rapidly insert nails into wood
	Machine Screws – for screwing into a tapped hole or securing items by screwing into a nut.

Risk Assessment

A **risk assessment** is a careful examination of what, in your work, could cause harm to people, so that you can weigh up whether you have enough precautions or whether you should do more. ... It includes all the **risks** identified in the **risk assessment** and the measures needed to control those **risks**.

The aim of the **risk assessment** process is to evaluate hazards, then remove that **hazard** or minimize the level of its **risk** by adding control measures, as necessary. By doing so, you have created a **safer and healthier workplace.**

Machine Guards

The purpose of **machine guarding** is to protect the **machine** operator and other employees in the work area from hazards created during the **machine's** normal operation. This would include hazards of concern such as: ingoing nip points, rotating parts, reciprocating, transversing, and/or flying chips & sparks.
Machine guards help prevent injury.

Name and description	Image
Pop Rivet Gun – for securing pop rivets into holes in sheet metal	
Screwdrivers – Various heads – for tightening and loosening screws	
Spanners – Open, Ring and Adjustable – for tightening and loosening nuts and bolts	
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Soldering iron – used to join electronic components to circuit boards	
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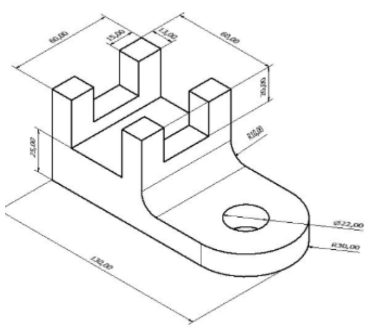
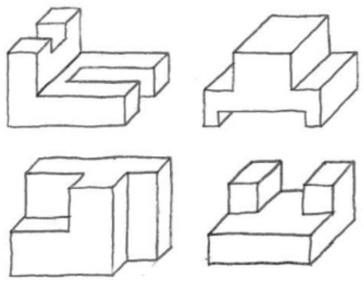
Machine Screws – for screwing into a tapped hole or securing items by screwing into a nut.	

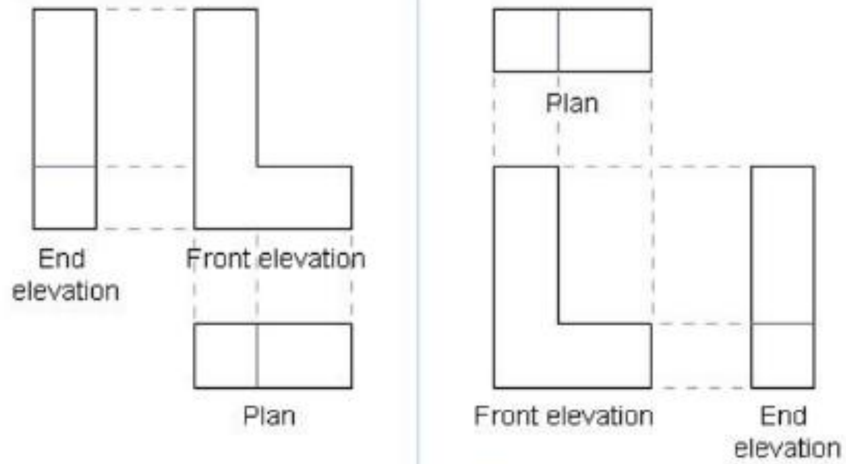
CA 3/ CA6 ENGINEERING DRAWINGS

3D drawings:

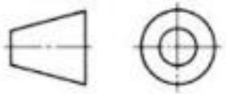



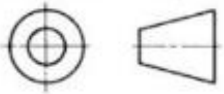
Isometric **Oblique**

2D drawings:



First Angle Projection **Third Angle Projection**

Projection	Symbol
First angle	

Projection	Symbol
Third angle	

When drawing at school you have always used 3rd Angle Projection

British Standards and International Standards

British Standards are set by the BSI Group. They were the world's first national standards body, and still remain global leaders in this field.
A standard is an agreed way of doing something, in this case a technical drawing. They provide a framework for all businesses to follow, so there is a standard way of working recognised by all.
The current British Standard for technical drawings is BS8888.
This standard is related to the layout of technical drawings.

- the various ways to indicate dimension
- the way tolerance is identified
- the way surface finish is identified
- systems for adding
  - annotation
  - symbols
  - abbreviations.

The basic principles allow technical drawings to be easily interpreted by people with limited engineering knowledge. Benefits include:

- Efficiency and Effectiveness
- Fewer Errors

Linetypes

- Visible - outlines and edges that exist
- Hidden - outlines and edges that exist but can't be seen (are hidden)
- Centre - line of symmetry
- Construction - used to help build a drawing and line up views
- Dimensions - used to show measurements between two points

Title Blocks on Engineering Drawings - may contain the following information

Date of Production:	**Author:**	
System of Measurement:	**Title:**	
Scale:		
Projection:	**Drawing Number:**	**Sheet Number:**
	Material:	**Surface Finish:**

Systems of measurement

Metric

Units include:
mm, cm, m, km
Grams (g), mg,
Litres (l), millilitres (ml)

Used in most of the world for measuring (except USA).

Used in the UK since around 1970

Sizes are all based on the decimal system - e.g. 3.25mm, 150.75 etc.
Easy to calculate as all in base 10

Thread forms are M3, M4, M5 etc.
M stands for metric, the number is the thread diameter.

Remember - Metric = mm

Imperial

Units include:
Miles, feet, inches.
Pounds and Ounces
Pints, fl oz

Only really used in the USA

System still used when dealing with 'legacy' (old) equipment.

Sizes are often given as fractions - e.g. 3¼, 6⅞ etc.

Lots of different thread forms e.g. UNF, Whitworth, UNC, BSF

Remember - Imperial = inches

- To convert millimetres to inches, divide by 25.4.
- To convert inches to millimetre, multiply by 25.4.

Scale

An Engineering drawing is nearly always drawn to **scale.**

A drawing that shows a real object with accurate sizes reduced or enlarged by a certain amount is called a scale drawing.

If a drawing is drawn **ACTUAL** size, the scale is 1:1. This means that one unit on the page represents one unit in 'real life'.

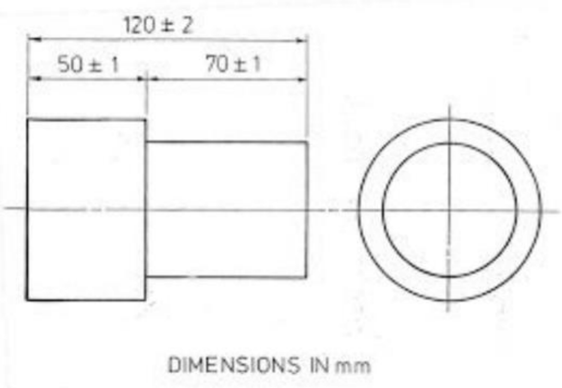
If a drawing is drawn **HALF** the actual size of the object, the scale is 1:2. This means that one unit on the page is equal to two units in real life.

If a drawing is drawn **DOUBLE** the actual size of the object, the scale is 2:1. This means that two units are used on the drawing to represent one unit in real life.

Scale is important because of the following reasons:

1. If an object is very small, the drawing may need to be enlarged (scaled up) so we can see all of the detail - E.g. electronics components
2. If an object is very big, it will need to be reduced (scaled down) so it fits on the drawing paper - E.g. Cars, buildings etc.
3. We can take measurements off drawings so it is important to know they are accurate and what scale they are drawn at.

Tolerances



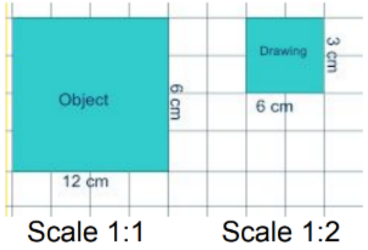
For the dimensions shown on this drawing		
Dimension	Min	Max
120mm	118mm	122mm
50mm	49mm	51mm
70mm	69mm	71mm

Tolerances show the maximum and minimum permissible sizes of the finished part.

CA 3/ CA6

Annotations

- The annotation on your picture or diagram could be used to show key detail, sizes and materials and much more.
- The annotations could help you out as a reference for explaining your design ideas.
- A design engineer can send their sketches to the client, so they may not always be there. The annotations need to be very clear and explain the design idea.



•General: There will be slight variation in size when making components. Creating products to an exact measurement is expensive. Using a smaller tolerance means that production will be cheaper. Products will work and be safe.

•Specific: A specific or close tolerance is used for specific parts of a design where the size may be more critical. They are used for safety reasons, so parts fit, so they are accurate, so they function correctly and used for location and fit.

CA 7

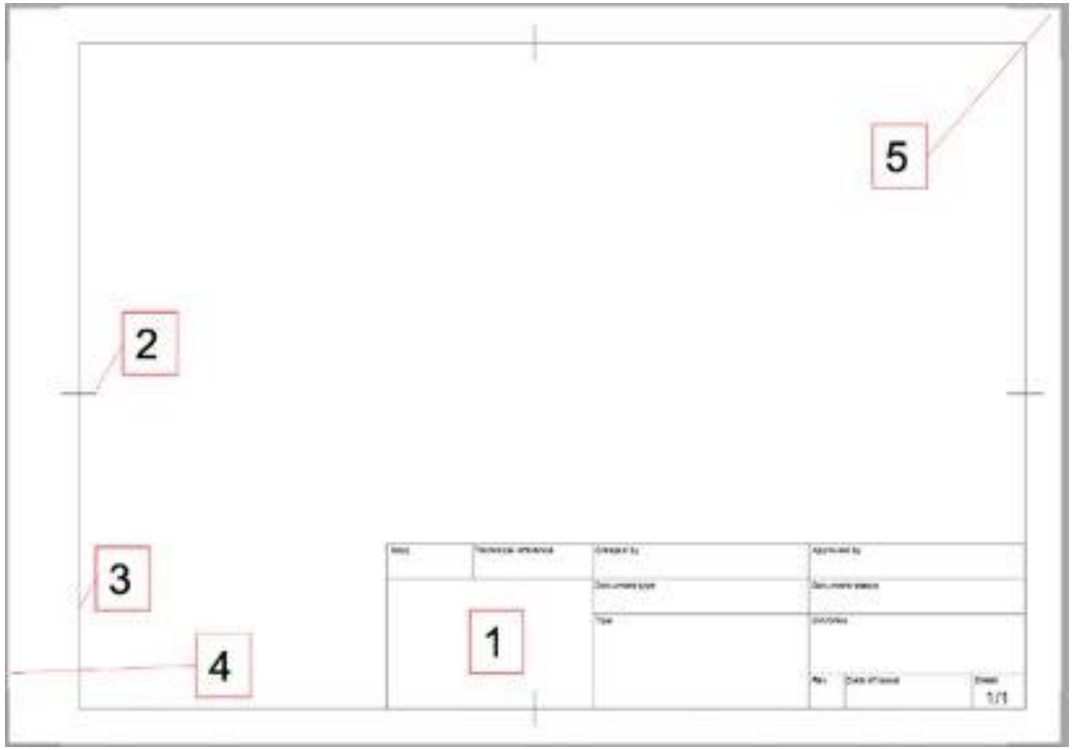
CAD ENGINEERING DRAWINGS

CAD (Computer Aided Design
CAD allows users to develop and modify their designs. They can also simulate how different materials will look or perform in a particular design.

Advantages of CAD	Disadvantages of CAD
• Ideas can be developed quickly. • Drawings can be drawn quickly and changed easily. • Designs can be viewed from different angles and with different materials. • Ideas can be tested and modified before manufacturing starts.	• Set-up is expensive. • Users need to be skilled and trained. • Technology is always changing, and users need additional training. • Some updates and new software are expensive.

Finite element modelling (FEM)	FEM provides a numerical solution to a complex problem, which allows for some level of error. Usually, it is used when a math equation is too complex. FEM can be used, for example, to assess the structural mechanics of different parts of a bridge under different loads and environmental conditions or the deformation of a vehicle from collision.
Finite element analysis (FEA)	Finite element analysis (FEA) is a computerised method for predicting how a product reacts to real-world forces, vibration, heat, fluid flow and other physical effects.
Fluid dynamics	Fluid dynamics is a practical application of finite element modelling software by engineers. Computers are used to perform the calculations required to simulate the free flow of fluids (liquid or gases) and their interaction with surfaces. Fluid dynamics are used to simulate, for example, how airplane wings would perform,

1. Title block.-Title blocks record all important information necessary for engineering drawings.
2. Centring mark.-centring marks should be provided on all drawings to facilitate their positioning when reproduced.
3. Frame.-limits the drawing space of the drawing sheet
4. Edge- a border should be used to demarcate the edge of the drawing region.
5. Trimming mark.- trimming marks may be added at the edge of the drawing within the border to facilitate trimming of the paper. Trimming marks should be placed at four corners.



CA 7

Computer Aided Manufacturing (CAM) uses software and computer-controlled machinery to automate a manufacturing process.	
One off	This is when only one product is made at a time. One-off products often require high level of skills. One-off products are often highly specialised, custom built . They are normally expensive, because of the amount of skill required and the time taken to make them. Various CAD software programmes draw up virtual 3D models of designs for simulations and testing on screen. No unnecessary manufacture is needed, and expenses are reduced.
Batch	This is when small quantities are made, from a few hundreds to a few thousands, depending on the type of product. Batch production normally uses machine tools, and costs less to make products than with one-off manufacturing, because relatively small volumes are produced. Batch production often has flexible systems and responds to demand from consumer quickly. Batch production uses some industrial methods and makes good use of CAD/CAM because of the relatively fast and repetitive process.
Mass	This is usually carried out on an assembly line by machines and robots. Machinery and automated systems are expensive. The cost of setting up a production line is very high, so large quantities of a product need to be produced to recuperate the initial investment. CAD engineering programmes can be used to produce detailed manufacturing diagrams to be used by equipment on the production lines. CAM equipment has high tolerance levels and is extremely accurate and reliable.

3D printing- 3D printing is the creation of three-dimensional solid objects from a digital file. The process uses additive processes and creates an object by layering layers of material until the object is created.

Advantages	Disadvantages
• Different industries now incorporate 3D printing into their processes and take advantage of the technology's capabilities. • 3D printing gives the ability to print complex shapes and interlocking parts and to design and produce differently shaped objects without the need for specialised tools. • 3D printing provides companies with a greater degree of flexibility in production and helps to reduce production time, waste, errors, and costs. Designs can also be verified through creating a 3D prototype before going ahead with production.	• 3D printing has several disadvantages. The major downsides of 3D printing lie in the areas of cost, energy requirement, scale, speed, and accuracy of the operations. • 3D printing can also be used for counterfeiting, illegal activities, and the production of dangerous weapons, as there is no regulation or control for purchasing 3D printers. • 3D printing is also a disruptive technology that makes several jobs (especially manufacturing jobs) obsolete.

CNC- (Computer numerical control) is a computer code that control machine tools. It is commonly used in manufacturing for machining metal and plastic parts.	
Laser cutting	Laser cutters work with a computer code (G-code) that starts as a line drawing of a part to be cut, this is converted into a series of co-ordinates, the arm of the laser cutter moves as if the co-ordinates are being drawn onto the bed. Laser cutters can be used to cut wood, polymers, card, paper, and metals, including mild steel, stainless steel, or aluminium. Laser cutters are often used for one-off or batch production because the process is too slow for mass production.
Router	The CNC routing process uses a computer to control the movement of a cutter, allowing for precise, complex shapes in materials like composites and rigid polymers. Routing can be used to produce items such as door carvings, interior and exterior decorations, wood panels, sign boards, wooden frames, mouldings, and musical instruments.
Lathe	Computer numerical control (CNC) turning is a subtractive machining process where a cutting tool is placed against a spinning piece to take material off. This is usually done with a CNC lathe or turning centre which cuts the material including wood, metal, and plastic.

- Hazard

Something that has the ability to harm you or other people

- Risk

The likelihood that a particular hazard will actually cause harm and how serious that harm would be

- Control measure

A precaution that is put in place to minimise or eliminate risk

Why do we complete risk assessments?	Before starting any activity, a risk assessment should be taken. Risk assessments are performed to bring dangers to attention so that we can limit the risk of accidents happening.
Why are risk assessments important?	• Meet legal requirements • Prioritize hazards and control measures • Prevent injuries or illnesses • Decide if existing control measures are working correctly and if anything, else should be put in place • Identifying who is at risk
When should risk assessments be completed?	New risk assessments should be: Before new processes or activates are introduced Before changes to certain activities New equipment

Consequences of failing to carry out risk assessments

- Increased risk of accidents
- Heath and Safety investigations
- Enforcement action
- Emotional trauma
- Project delays
- Financial consequences
- Losing customers

Hazard	Risk	Rating (L,M,H) Likelihood of happening Consequences	Additional Action Required (Action by whom and completion data)

Risk assessments include:

- Include the risk
- Rate its severity (L,M, H) Likelihood of happening (L, M, H) and Consequences
- Additional Action Required (Action by whom and completion data)

Risk Ratings:

- Low- Little of no impact to a person or the company
- Medium- An activity that has a risk that could cause an impact but not a serious one
- High- Could cause life changing damage to a person or cause reputational damage to the company

Emergency Cut Off	The emergency push button is to stop the machinery quickly when there is a risk of injury or the workflow requires stopping. If a employee get into difficulties on a machine, or they see someone else having problems, only then should the emergency stop button be pushed. Theses can also be located around the factory and workshops.
Isolation buttons	There will be a number of isolation buttons in a factory or in your school workshop. They can be located on machines or on the wall. These should be sign posted. They are red on a yellow background. Machines should be isolated and be able to be turned on by undoing the padlock and key. This prevents accidents. Circuits can be isolated when completing electrical work, this is for safety and stops the flow of electricity to a certain point. This will mean no one will be electrocuted.
PPE	PPE Act- This regulation was set up in 1992 under the health and safety act. These regulations place a duty on every employer to ensure that suitable personal protective equipment is provided to employers who may be exposed to a risk to their health and safety while at work.
Guards	Guards on machines can be adjusted into different positions. They can also be used to prevent saw dust or swaf. With modern pillar drills, if the front guard is not locked into position then the machine will not work. This is a safety feature.
Safety zones	A safety zone can either be painted or taped onto the floor. The zone exists when the machine is being used and it means that no one else should not entre the area. In factories the safe zone can show where people can walk when machinery or vehicles are moving around the warehouse. They can label one way traffic or speed limits.
Extraction and ventilation	Workshop extraction systems are very important for creating a pollution-free environment that is clean, safe and healthy. Extractors filter out particles in the air. This prevents people from breathing in toxic materials that could lung problems, such as breathing problems and cancer. Examples include extraction of sawdust off disc sanders, toxic fumes from spray painting and toxic fumes off laser cutting. Extraction units should be tested every 14 months under LEV testing to ensure they are safe. (Local exhaust Ventilation)

CA 8

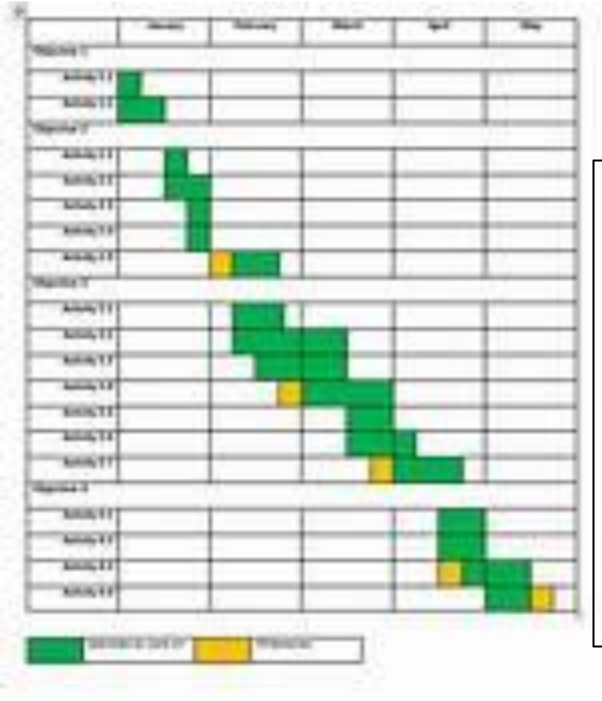
PRODUTION

PLANING

CA 8

Flow charts

Start/End	Arrows	Input/Output	Process	Decision
An oval shape to represent the start or the end of the process/system. It should contain the word 'Start' or 'End'	The arrow is a line that connects each shape together. It shows the relationship between the shapes	A parallelogram is used to represent the input/output. This represents information entering the system or product.	A rectangle represents a process or a step.	A diamond indicates a decision. This will often have multiple arrows from it. Lines could represent different decisions emerging



Gantt Charts

Gantt charts have the task on the vertical axis and the time frame on the horizontal axis. The horizontal time frame, could be months, weeks, days or in a school project a lesson. Boxes are then shaded to show how long the task takes.

Production plan

A production plan is a document that sets out the crucial information about each of the different stages of production. This helps to ensure that the given product along with its components can be made to the same standards. Your production plan needs to show how a product is made. A person should be able to understand and follow your production plan. An engineering plan should be accompanied with an engineering drawing.

Stage	Operations/ process	Materials	Tools/ Equipment	Health and Safety	Action	Quality Control

Outsourcing

Some companies may not have all the skills or equipment required for specialist tasks . Commissioning another company to do this work is known as outsourcing.

Supply Chain

- A supply chain is a networked system of organisations, activities, information, and resources that are designed to source, produce, and transport goods from their point of origin to their destination.
- In a supply chain materials and components can be ordered and delivered.
- If the supply chain breaks down or it cannot provide the materials or deliver them on time, then the manufacturing will stop.

Considering a good supply chain

Manufacturers should consider the supply chain when developing a new engineering product or component to ensure

- They can meet demand (how much the company need)
- The materials and components are available
- They can work out costs to make the product
- They have the correct delivery times and dates, to meet their deadlines

Benefits of timescales and time plans

- Increased productivity- When you have a plan, you are able to work more efficiently and get more done in less time as you are more focused as you have goals to achieve.
- Improved job satisfaction- When you are able to complete tasks, you will feel a sense of satisfaction
- Less stress- When you have a time plan, you will be less likely to feel overwhelmed or stressed. This is because you will know what needs to be done and when

CA 9

APPLIED PROCESSING SKILLS

Failing to clean materials

- Metal stock usually comes covered in grease to reduce oxidisation and corrosion. Grease can make the material slippery and difficult to handle, it can also make it hard to mark out accurately.
- When ferrous metals are stored in cold, damp warehouses or workshops, they can be prone to corrosion over time, iron oxide can form as dark orange layers or a fine powder on the surface of steel.
- Marking out can be inaccurate if a material's surface is uneven and unclean.

Safe use of solvents

Solvents are dangerous chemicals. Engineers need to be aware of the risks and control measures when using them.

Solvents are:

- Flammable – So should be stored in a heatproof cabinet, away from direct sunlight and naked flames.
- Irritants – So engineers should ensure that their skin is covered with gloves and overalls.
- Harmful – So should not enter eyes or mouth, be consumed or breathed into the lungs. They should be clearly labelled as they can have the same appearance as water.

Preparing materials for marking out

- De-burring stock with a file to remove sharp edges should take place before marking out, to reduce the risk of injury to the engineer.
- Metals cannot be marked accurately with a pen or pencil, because the lines wipe away. To mark out accurately, engineer's blue can be used to dye the surface, this makes marking out "scratches" easier to see.

Joining of Materials

Bolting-

Nuts and bolts are usually found holding together more than one piece of material. Bolts can be removed to allow maintenance of parts to take place, but they can also work loose and fall off unexpectedly.

Riveting-

- Snap rivets have a tail that can be pulled using a rivet gun. This gun squeezes the rivet head against the material and automatically snaps off the tail.
- Cold rivets are compressed using force, using either an electric or hydraulic rivet gun.
- Hot rivets, often seen in bridge construction, are large so need to be heated before being formed.

Adhesives-

- Polyvinyl acetate (PVA) can be used on softwood, hardwood, and manufactured boards.
- Contact adhesive can join dissimilar materials and needs to be applied to both surfaces and air dried for ten minutes before joining.
- Epoxy resin can join lots of different materials but can be difficult to work with.

Preparation and use of saws

Before using a saw, engineers should consider the following:

- The condition of the saw: missing teeth and damaged guards.
- The shape of the cut (straight, curved, or intricate) shown on the engineering drawing.
- The material that can be cut (wood, metal, plastic).
- The thickness/density of the material and the force required.
- The scale of production (how many cuts/products need to be made).
- The location: in a workshop or on a work site.

Casting

- **Die casting** uses dies made from tool steel, they take a long time and a lot of skill to produce but are useful when making tens of thousands of products or more.
- **Investment casting** requires a wax pattern made by a combination of machine and hand moulding. They are coated in a ceramic shell, then the wax is melted away and a shell with many cavities is formed. Batches of identical parts are possible.
- **Sand casting** is best for smaller quantities of products, as packing sand around a pattern is time consuming.

Soldering can be summarised as:

- Soldering uses molten metal to join gaps between copper pipes.
- Soldering uses melted metal to join pieces of metal.
- Joining electrical components with melted metal.
- A joining process that turns metal from solid, to molten and back to solid.

- Soft soldering - PCBs (printed circuit boards) use soldering so that the joint will conduct electricity around the circuit. The temperature of the process must be low, so that sensitive components do not get damaged.
- Hard soldering (brazing) - Copper pipes require soldering as the process allows a small amount of molten metal to flow around a joint, sealing the gaps. This is very important for gas pipes and keeping homeowners safe from gas leaks.

Bending Materials

- A press brake forces sheet metal into a V shaped groove, to create a fold.
- Pressing can create very complex shapes at the same time as stamping (cutting) out the final shape.
- Tubes must be formed around a jig, or the tube collapses and the strength is lost.
- Blacksmiths use a forge, anvils, hammers and heat; the force bends into mild steel.

Finishing is the term used to describe preparing and applying a surface coating to a material.

Finishes are applied for several reasons, including:

- Improving the appearance.
- Protecting from corrosion.
- Improving wear resistance.
- Reducing friction.
- Increasing the life span of the product.