Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2021

Marking Scheme

ENGINEERING – Materials and Technology

Higher Level

Note to teachers and students on the use of published marking schemes

Marking schemes published by the State Examinations Commission are not intended to be standalone documents. They are an essential resource for examiners who receive training in the correct interpretation and application of the scheme. This training involves, among other things, marking samples of student work and discussing the marks awarded, so as to clarify the correct application of the scheme. The work of examiners is subsequently monitored by Advising Examiners to ensure consistent and accurate application of the marking scheme. This process is overseen by the Chief Examiner, usually assisted by a Chief Advising Examiner. The Chief Examiner is the final authority regarding whether or not the marking scheme has been correctly applied to any piece of candidate work.

Marking schemes are working documents. While a draft marking scheme is prepared in advance of the examination, the scheme is not finalised until examiners have applied it to candidates' work and the feedback from all examiners has been collated and considered in light of the full range of responses of candidates, the overall level of difficulty of the examination and the need to maintain consistency in standards from year to year. This published document contains the finalised scheme, as it was applied to all candidates' work.

In the case of marking schemes that include model solutions or answers, it should be noted that these are not intended to be exhaustive. Variations and alternatives may also be acceptable. Examiners must consider all answers on their merits, and will have consulted with their Advising Examiners when in doubt.

Future Marking Schemes

Assumptions about future marking schemes on the basis of past schemes should be avoided. While the underlying assessment principles remain the same, the details of the marking of a particular type of question may change in the context of the contribution of that question to the overall examination in a given year. The Chief Examiner in any given year has the responsibility to determine how best to ensure the fair and accurate assessment of candidates' work and to ensure consistency in the standard of the assessment from year to year. Accordingly, aspects of the structure, detail and application of the marking scheme for a particular examination are subject to change from one year to the next without notice.

LEAVING CERTIFICATE EXAMINATION

ENGINEERING - Materials and Technology

(Higher Level – 250 marks)

Written Examination Marking Scheme 2021

Answer any **FIVE** questions.

Question 1 – 50 marks
Any ten @ 5 marks each.

(a) 3 + 2
(b) 4 + 1
(c) **Any one** @ 5
(d) 5
(e) 3 + 2
(f) 5
(g) 3 + 2
(h) 3 + 2
(i) 5
(j) 3 + 2
(k) 5
(l) 3 + 2
(m) 3 + 2

Question 2 - 50 marks
Answer **all** of the following.

(a) (i) 5
(ii) 3 + 2

(b) (i) 4
(ii) 3
(iii) 3

(c) **Any one** @ 10

(d) (i) 2
(ii) 8

(e) **Any two** @ 5 + 5

Question 3 – 50 marks

(a) **Any two** @ 8 + 8

(b) (i) 10
(ii) 4
(iii) 4

(c) (i) 8
(ii) 8

Question 4 – 50 marks

(a) (i) 8
(ii) 4 + 4

(b) (i) 2 + 2 + 2 + 2
(ii) 4
(iii) 6

(c) **Any two** @ 8 + 8

Question 5 – 50 marks

(a) (i) 2 + 2 + 2
(ii) 6
(iii) 2 + 2

(b) (i) 10
(ii) 4
(iii) 4

(c) **Any two** @ 8 + 8

Question 6 – 50 marks

(a) **Any three** @ 6 + 6 + 6

(b) (i) 10
(ii) 2 + 2 + 2

(c) 16

OR

(c) (i) 4 + 4
(ii) 8

Question 7 – 50 marks

(a) (i) 2
(ii) 6
(iii) 4 + 4

(b) Any three @ 6 + 6 + 6

(c) (i) 8
(ii) 4 + 4

Question 8 – 50 marks

(a) (i) 2 + 2 + 2
(ii) 5 + 5

(b) Any three@ 6 + 6 + 6

(c) (i) 10
(ii) 6

OR

(c) (i) 8
(ii) 4 + 4

Question 9 – 50 marks

(a) (i) 8
(ii) 8

(b) **Any three**@ 6 + 6 + 6

(c) (i) 8
(ii) 8

OR

(c) (i) 8
(ii) 4 + 4

Sample Answers and Marking Scheme

Note: **The solutions presented are examples only.**

All other valid solutions are acceptable and are marked accordingly.

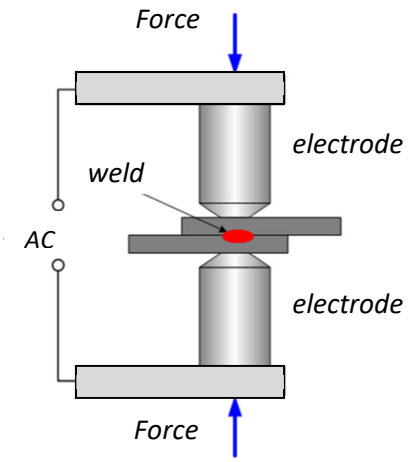
Question 1 **(50 Marks)**

(a) **Advantages of wireless headsets:**

- Portable/Wire free.
- Distance from connected source.
- Comfort.
- Audio quality.
- External noise reduction.

3 + 2

(b) **Resistance Spot Welding** is a welding process in which work pieces are welded due to a combination of a pressure applied to them and heat generated by a high electric current flowing through the contact area of the weld. Heat produced by the current is sufficient for local melting of the work piece at the contact point and formation of small weld pool called a 'nugget'. The molten metal then solidifies under pressure and joins the pieces. Time, pressure and current, required for the formation of a reliable joint, are determined by the dimensions of the electrodes and the work piece metal type. Typical applications include: car panels, electronics and battery manufacture.



4 + 1

(c) **(i)** **Ferdinand Porsche**

Ferdinand Porsche (1875 - 1951) was an Austrian-German automotive engineer and founder of the Porsche car company. He is best known for creating the first gasoline-electric hybrid vehicle (Lohner-Porsche), the Volkswagen Beetle, the Mercedes-Benz SS/SSK, several other important developments and Porsche automobiles.

(ii) **Hedy Lamarr**

Hedy Lamarr (1914 - 2000), was an Austrian-American actress, film producer, and inventor who co-invented an early version of frequency-hopping spread spectrum (a way of jumping around on radio frequencies in order to avoid a third party jamming your signal) and this was a precursor to today's Wi-Fi, GPS, and Bluetooth.

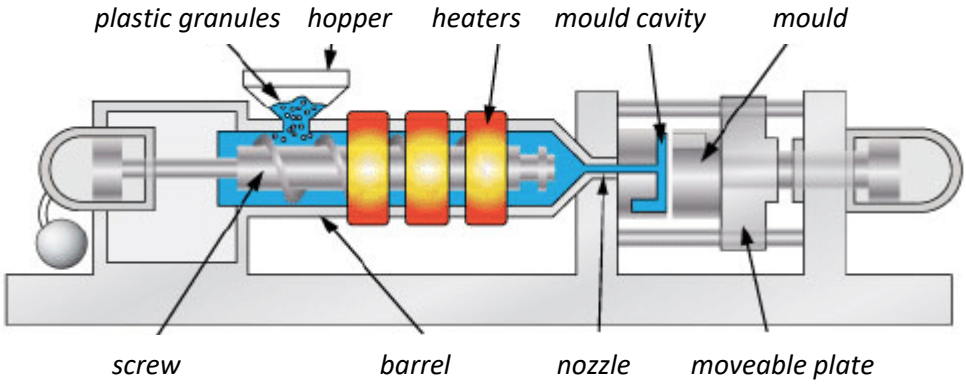
(iii) **Nicolaus Otto**

Nicolaus Otto (1832 - 1891) was a German engineer who successfully developed the compressed charge internal combustion engine (ICE) which ran on petrol and led to the modern internal combustion engine (4-stroke spark ignition) in which the ignition of the compressed fuel-air mixture is initiated by a timed spark.

Any one @ 5

(d) **Injection Moulding**

Pellets of thermoplastic polymer are fed into the barrel from the hopper.
The screw moves the polymer forward.
Heaters melt the polymer to liquid.
When there is enough liquid polymer, the ram will inject the polymer into the mould.



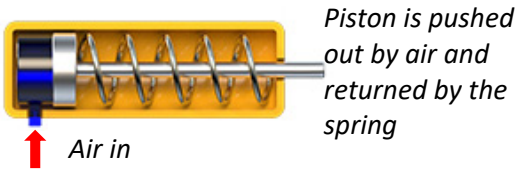
5

(e) Aluminium tubing has a high strength-to-weight ratio, it is lightweight, resists corrosion, extrudes well as aluminium is ductile, etc.

3 + 2

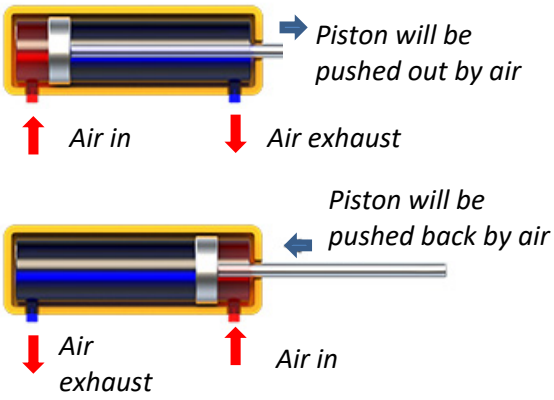
(f) **Single-acting pneumatic cylinder.**

A single-acting cylinder is one where the thrust or output force is developed in only one direction. The piston is returned by a fitted spring, or by some other external means such as a weight. They have a single port to allow compressed air to enter the cylinder to move the piston to the desired position.



Double-acting pneumatic cylinder.

In a double-acting pneumatic cylinder air pressure is applied alternately to the opposite ends of the piston. Double-acting cylinders have a port at each end and move the piston forward and back by alternating the port that receives the high-pressure air, necessary when a load must be moved in both directions such as opening and closing a gate.



5

(g) Automatic sanitisers dispense consistent quantities, they reduce waste, they ensure enough sanitiser will be dispensed, the automated sanitiser is a non-touch product, they are durable in operation as they are not pushed, etc.

3 + 2

(h) Drilling machines need to operate at different speeds due to:

- The diameter of the drill bit used
- The type of material being drilled
- Feed rate of the drill bit.

3 + 2

(i) Copper is annealed by heating the metal to a red colour (approx. 400°C) and then rapidly cooling it in water. Annealing copper makes it softer and less brittle, which allows you to bend it without breaking it. This malleability allows you to hammer and mould the copper into any shape you wish without cracking the metal.

5

(j) Advantages of selfie stick telescopic adjustment:

- Allows more control of phone for pictures
- Lightweight
- Easy to use
- Different lengths of adjustment are available for the selfie stick etc.

3 + 2

(k) A designer specifies the acceptable load a beam can withstand and multiplies this by the Factor of Safety (FoS) e.g. a beam made to withstand 10kN will be capable of withstanding 50kN when the FoS is 5.

5

(l) **Metals commonly used to protect steel from oxidation:**

- Zinc
- Chromium
- Copper
- Silver
- Gold

3 + 2

(m) Composite materials such as carbon fibre or fibre glass have a very high strength to weight ratio, they are impact resistant, they can be formed into intricate shapes, design features can be integrated into the kayak shape to make each unique and improve aerodynamic shape, they can be made in a range of colours, etc.

3 + 2

Question 2 (50 Marks)

(a) (i) Hybrid Vehicle Technology

Hybrid electric vehicles are powered by an internal combustion engine (ICE) and an electric motor, which uses energy stored in batteries. The battery can be charged through regenerative braking, plugged in to a charging point and by the internal combustion engine. The extra power provided by the electric motor can potentially allow for a smaller engine. Together, these features result in better fuel economy without sacrificing performance.

5

(ii) Benefits of hybrid vehicles in urban transport:

- Reduced emissions in atmosphere, urban transport creates a high volume of emissions from existing vehicles
- Reduced noise in cities
- Particularly efficient in short trips, which are a feature of urban transport
- Potential for self-driving vehicles with reduced workforce
- Regenerative braking energy can be employed efficiently, etc.

3 + 2

(b) (i) Full Hybrid:

The Full hybrid (FHEV) uses all the technologies described above and is the most fuel-efficient type of hybrid vehicle. It is also able to operate in series mode, parallel mode or all-electric mode. All-electric mode is self-explanatory and is typically used by FHEVs at low speed (for example up to around 50kph). Series mode also uses the electric motor to drive the wheels but the combustion engine is used at the same time as an on-board generator. Parallel mode uses the combustion engine and the electric motor together to drive the wheels.

Full hybrids have larger batteries and more powerful electric motors, which can power the vehicle for short distances and at low speeds. These vehicles cost more than mild hybrids but provide better fuel economy benefits.

4

(ii) Mild Hybrid:

A mild hybrid is limited to parallel mode, so can really be looked upon as having a battery and a helper motor. The electric motor is not powerful enough to drive the wheels at any significant speed without the assistance of the combustion engine.

Mild hybrids typically have stop-start and regenerative braking but are not capable of the MPG figures of a FHEV. Mild hybrids—also called micro hybrids—use a battery and electric motor to help power the vehicle and can allow the engine to shut off when the vehicle stops (such as at traffic lights or in stop-and-go traffic), further improving fuel economy. Mild hybrid systems cannot power the vehicle using electricity alone. These vehicles generally cost less than full hybrids but provide less fuel economy benefit than full hybrids.

3

(iii) Plug-in Hybrid

As the name implies, this type of hybrid can be plugged into an electric outlet to recharge their batteries, as well as being charged on the move.

Effectively, they are halfway between conventional hybrids and full electric vehicles. Although they have a conventional engine, they also have larger batteries than regular hybrids and can drive longer distances on electric power alone - up to 50 kilometres in some cases.

Typically, plug-in hybrids use all the technology of a FHEV but have a larger capacity battery which can be plugged into the mains to charge (for example, overnight). The range they can drive in all-electric mode is higher than the average FHEV.

3

(c) (i) Regenerative braking

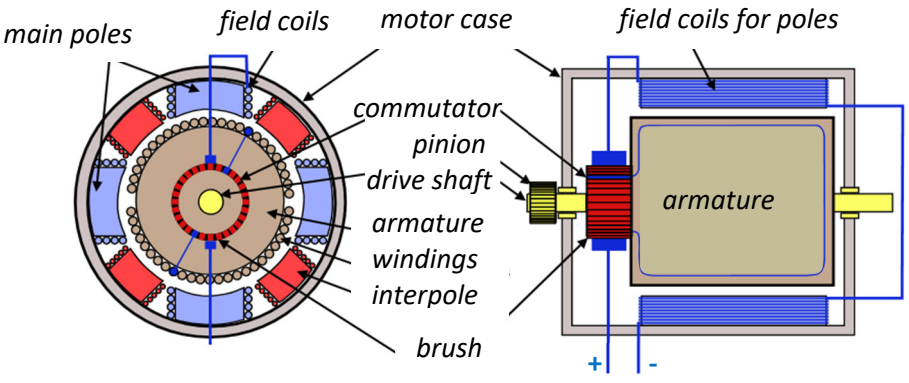
Braking friction in a petrol or diesel car works to slow the car down, generating heat and wearing away at the material on the pads and discs in the process. Regenerative braking is a way of taking the wasted energy from the process of slowing down a car and using it to recharge the car's batteries. On a normal car, braking simply wastes energy - but with regenerative braking, some of the energy is able to be reused.

The electric motor in a hybrid or electric car runs in two directions - one to drive the wheels and move the car and the other to recharge the battery. When you lift your foot off the accelerator pedal and onto the brake, the motor swaps directions and starts to put energy back into the battery.

(ii) Electric Traction Motors

Electric traction motors are more efficient than internal combustion engines (ICE), with high power-to-weight ratios providing torque over a wide speed range.

The traction motor consists of two parts, a rotating armature and a fixed field. The fixed field consists of tightly wound coils of wire fitted inside the motor case. The armature is another set of coils wound round a central shaft. It is connected to the field through "brushes" which are spring-loaded contacts pressing against an extension of the armature called the commutator. The commutator collects all the terminations of the armature coils and distributes them in a circular pattern to allow the correct sequence of current flow.



Any one @ 10

(d) **(i)** Parallel Hybrid

2

(ii) Parallel hybrids are the most common HEV design, they connect the engine and the electric motor to the wheels through mechanical coupling. Both the electric motor and the internal combustion engine drive the wheels directly.
These are the most common type of hybrid, and the Toyota Prius is the most widely known example. The vehicle's wheels can be powered in three different ways:

- either directly by the engine
- by the electric motor alone
- or by both power sources working together.

When pulling away, and at speeds up to 20kph, the Prius only uses the electric motor for power, making it very economical for stop-start city driving. The petrol engine cuts in as speed increases, and it is used most during hard acceleration. Whenever you decelerate or use the brakes, the regenerative braking system produces electricity and stores it in the battery for use later on. The battery is big enough so that the electric motor can power the vehicle for up to 2km.

8

(e) **(i)** **Vehicle ownership:**
People will still want to own a car and will buy a hybrid or electric one as a means to help the environment. The costs of hybrid vehicles can be prohibitive though. State grants and tax reliefs may assist people in buying hybrid vehicles. The total number of vehicles on the road is expected to fall by about half from its current level by 2050. With fewer private vehicles needing to be parked, vast areas of land currently wasted on parking will be available for other uses, such as housing.

(ii) **Environmental impact:**
Ultimately, hybrid cars can have immense power to reduce emissions and make the environment a better place if their drivers choose to make it so. Hybrid vehicles operate in a more fuel-efficient manner. There will also be a reduction in noise pollution as a result of the use of hybrid powered vehicles in urban settings.

(iii) **Vehicle maintenance:**
Hybrid vehicles can be expensive to maintain and service. Along with an internal combustion engine to service, battery packs and traction motors also need additional maintenance and service at regular intervals. Specialised mechanics capable of identifying issues with hybrid vehicles are needed also. Damage to hybrid vehicles, depending on the area of damage can lead to very expensive bills to make the car road worthy again.

Any two @ 5 + 5

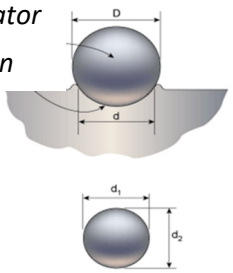
Question 3 (50 Marks)

(a) (i) Brinell hardness test:

- A hardened Steel or Tungsten Carbide ball indenter is used in this hardness test.
- The diameter of the ball may be Ø2.5mm, Ø 5mm or Ø 10mm.
- The loading force is in the range of 300N to 30kN.
- The indentation shape will be a circle and the diameter of this circle d_1 & d_2 is measured.
- Hardness Brinell (HB) number is calculated as follows; $HB = Load / d_1.d_2$
- The ball can deform when used on very hard materials.

ball indicator

impression



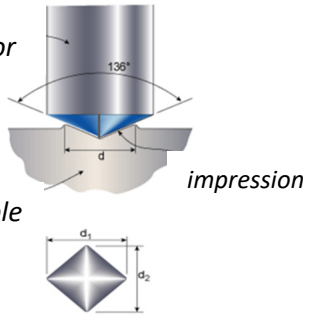
Vickers hardness test:

- A Diamond Square-based pyramid indenter is used in this hardness test.
- The angle of the indenter is 136˚.
- The length of the diagonals (d_1 and d_2) of the indentation are measured.
- Hardness Vickers (HV) number is calculated as follows; $HV = Load / d_1.d_2$
- The Vickers test is more accurate because it will mark a harder piece easier.
- Vickers and Brinell tests can be compared as they have similar hardness ranges.

square-based pyramidal indentor

impression

sample

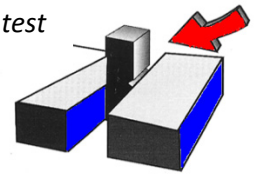


(ii) **Yield strength** is the maximum tensile load the material can withstand without being permanently stretched. In a tensile test, the 'straight line' part of the graph represents the elasticity of the material and where the straight line finishes is the yield point or strength. **Ultimate tensile strength** is the maximum tensile load the material can withstand before necking occurs and the material fails. It is represented by the highest part of the test graph. It can be calculated as follows: Max Load/C.S.A.

(iii) Izod impact test:

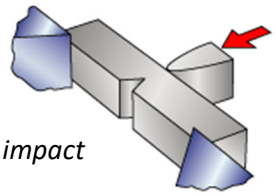
- 167 joules striking energy.
- Test specimen is vertical.
- Test piece is clamped at one end.
- Test piece notch is facing the pendulum.
- The distance the pendulum travels after breaking the piece will give the toughness value.

Izod impact test



Charpy Test:

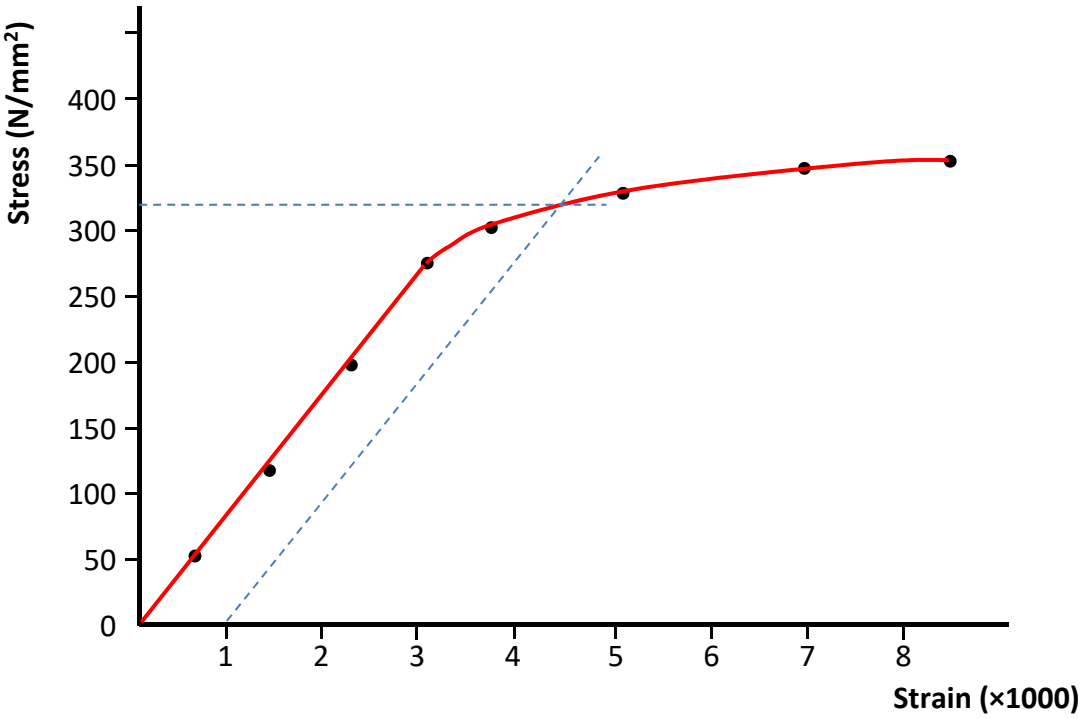
- 300 joules striking energy.
- Test specimen is horizontal.
- Test piece is clamped at both ends.
- Test piece notch is facing away from the pendulum.
- The distance the pendulum travels after breaking the piece will give the toughness value.



Charpy impact test

Any two @ 8 + 8

(b) **(ii)** Plot the graph.



10

(ii) 0.1% proof stress from graph - 325 N/mm²

4

(iii) Young's modulus = $\frac{\text{stress}}{\text{strain}} = \frac{260}{3.0} = 87$ N/mm²

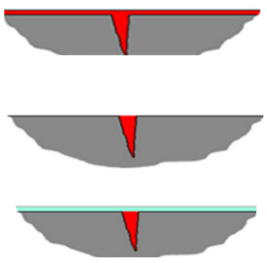
4

(c) **(i)** **Liquid penetrant testing:**

A coloured or fluorescent dye, when applied to a clean surface and allowed to dwell for 10 to 20 minutes, will be drawn into the flaw by capillary pressure.

The excess dye is then removed from the surface and a developer applied.

The developer assists in drawing the dye back out to the surface by giving good visual contrast.

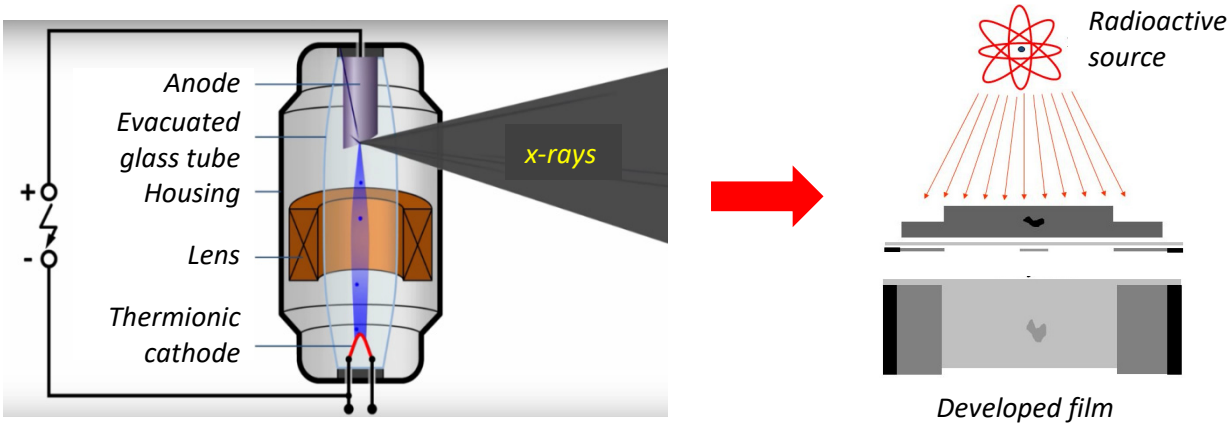


After a time, usually a minimum of 10 minutes, the surfaces are visually inspected. White light is used for red dyes, ultra-violet light for fluorescent dyes.

8

(ii) X-Ray non-destructive testing:

X-ray radiation penetrates materials and produces an internal photographic image of the test piece. Electrons are released by heating the cathode to high temperature. A high DC voltage speeds up the electrons, which are aimed at the anode. The electrons penetrate the anode and the energy is given off as X-rays. The anode reflects the X-rays to the test piece and an image plate is used to capture the internal image. Any flaw or cavity in the test piece will appear dark on the image plate as the radiation will not be absorbed by the flaw. Proper shielding is necessary when using x-ray equipment as a safety precaution. Internal cavities in welded joins can be determined by this NDT method.

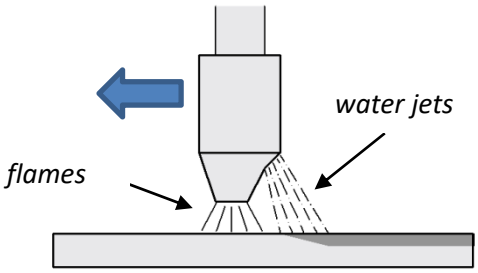


8

Question 4 (50 Marks)

(a) (i) **Flame hardening**

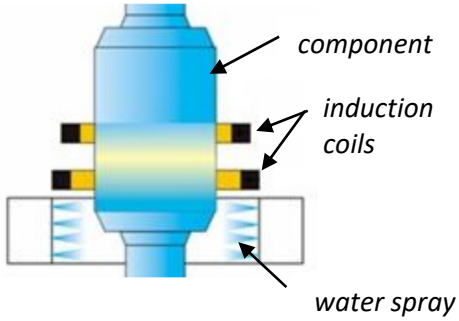
The surface of the steel object is heated to 850˚C with an oxy-acetylene flame and quenched quickly. This creates a hard outside layer as the heated austenite structure changes to martensite.
The depth of hardening depends on the rate of heating.



OR

Induction hardening

A coil carries high frequency currents which are induced on the surface of the component causing a rapid rise in temperature. This allows a change to austenite in the surface layers of the component. Water jets then cool the steel, transforming the austenite to martensite. This leaves the outer surface hard while the inner core is tough. The frequency of the current determines the depth of heating and the depth of hardening.



8

(ii) **Benefits of surface hardening:**

- Hard outer shell while softer tougher inner core.
- Warping or distortion, due to rapid cooling of the whole piece is avoided.
- Improved wear resistance.
- Short processing time (fewer steps involved).
- Cost-effective.

4 + 4

(b) (i) **A** = Austenite
B = Austenite and Cementite
C = Ferrite and Pearlite
D = Pearlite and Cementite

2 + 2 + 2 + 2

(ii) The microstructure present at 0.83% carbon content, up to 723°C, is called pearlite. Pearlite is a layered structure with alternate layers of ferrite and cementite. It has a "mother of pearl" sheen when fractured.

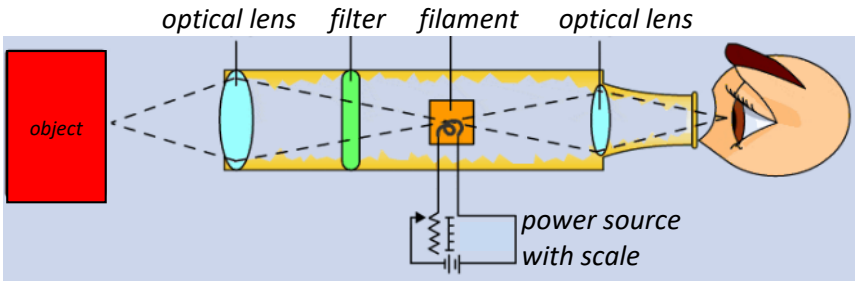
4

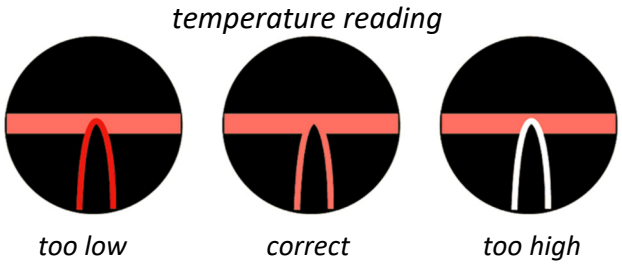
(iii) Point "X" is the eutectic point. This is where the liquid steel turns into solid steel without going through a pasty stage. It occurs at approx. 1140°C and 4.3% carbon content.

6

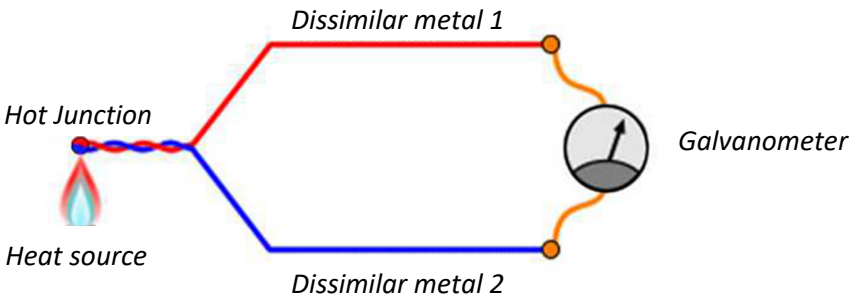
(c) (i) Optical pyrometer

The optical pyrometer method compares the intensity of light from the filament of a lamp with the colour from the furnace. Current flow from the lamp can be adjusted, using a variable resistor, to match the light from the furnace. There are three possible results with the optical pyrometer: filament too bright, filament not bright enough and filament matching the furnace colour. When the filament seems to 'disappear', the temperature of the filament matches that of the furnace and a reading can thus be taken.





The **thermocouple pyrometer** works on the principle that different metals conduct heat at different speeds. Two dissimilar metals usually, nickel-aluminium and nickel-chromium, are joined together with a galvanometer placed at the cold junction. A rise in temperature at the hot junction produces an electrical current which is recorded by the galvanometer. This galvanometer is calibrated to read in degrees of temperature rather than indicating electrical units.



(ii) **Grey cast iron** is named after its grey fractured surface, which occurs because the graphitic flakes deflect a passing crack and initiate countless new cracks as the material breaks. Grey cast iron results from slow cooling and/or high carbon equivalent. The carbon exists as flakes of graphite. It has a grey appearance when fractured and it is the most commonly used cast iron. Grey cast iron has poor tensile strength and shock resistance but has good compressive strength. It is soft and machinable.

White cast iron is named after its white surface when fractured, due to its carbide impurities which allow cracks to pass straight through. White cast iron results from fast cooling and/or low carbon equivalent. The carbon is tied up as cementite. It has a white shiny appearance when fractured and it is used in the impellers of slurry pumps, shell liners and lifter bars in ball mills and in the balls and rings in coal pulverisers. It is hard, brittle and generally not machinable.

(iii) **The upper critical temperature (UCT)** in the iron carbon phase diagram is the "V" shaped line boundary above which solid solution austenite exists. Its "V" point is at 0.83% carbon content called the eutectoid point.
The lower critical temperature (LCT) is the horizontal line at 723°C. The LCT is the temperature of the austenite-to-pearlite eutectoid transformation. Below this temperature austenite does not exist and the steel has a layered microstructure.

Any two @ 8 + 8

Question 5 (50 Marks)

(a) (i) **Structure A:** Body-Centred Cubic (BCC) Structure.
Structure B: Face-Centred Cubic (FCC) Structure.
Structure C: Close-Packed Hexagonal (CPH) Structure.

2 + 2 + 2

(ii) The face-centered cubic unit cell has atoms at each of the eight corners of a cube, plus one atom in the centre of each of the cubes faces giving a total of 14 atoms while the body-centered cubic unit cell has atoms at each of the eight corners of a cube, plus one atom in the centre of the cube giving a total of 9 atoms. The more atoms in the structure the more ductile the material is as the atoms slip across each other easier.

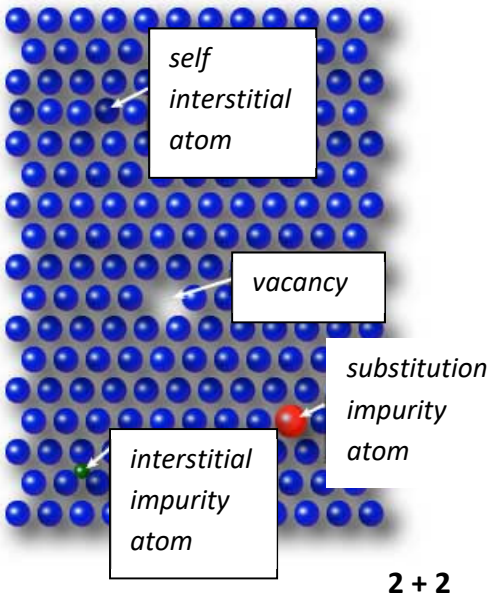
6

(iii) **Crystal point defects:**

Substitute Defect
This is where foreign atoms replace the parent atoms.

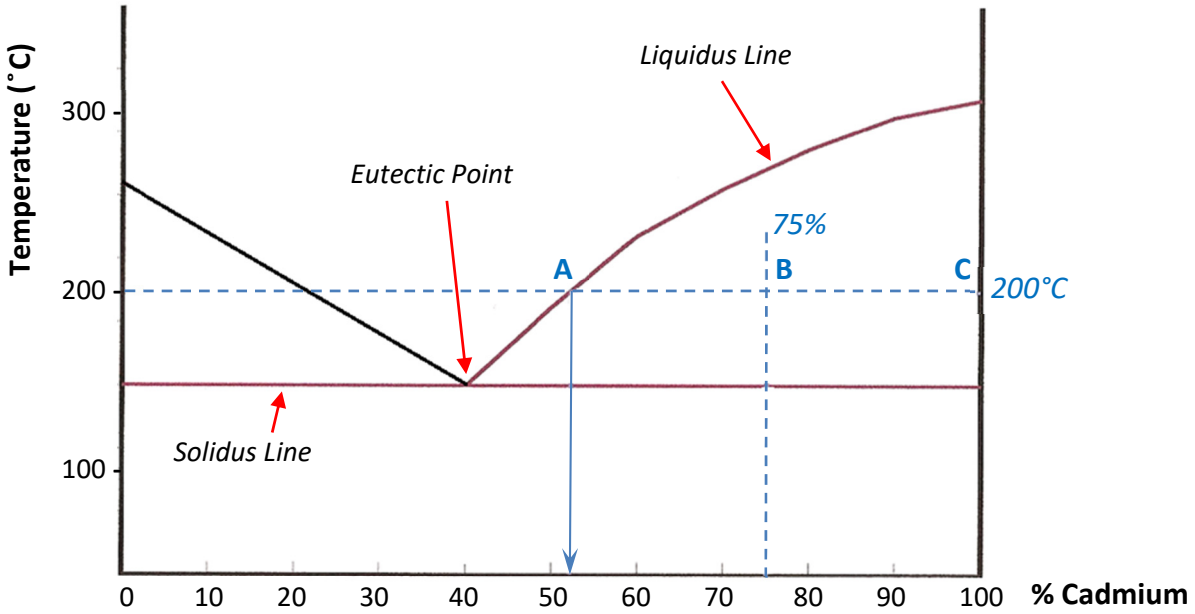
Vacancy Defect
This is where there is an atom missing from the lattice.

Interstitial Defect
This is where foreign atoms fit in between the parent atoms.



2 + 2

(b) (i)

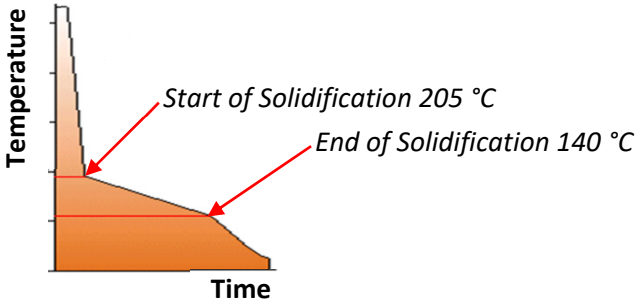


Graph 7
Labels 1 + 1 + 1

(ii) Ratio of Liquid to solid $= \frac{|AB|}{|BC|} = \frac{75 - 52}{100 - 75} = \frac{23}{25}$

4

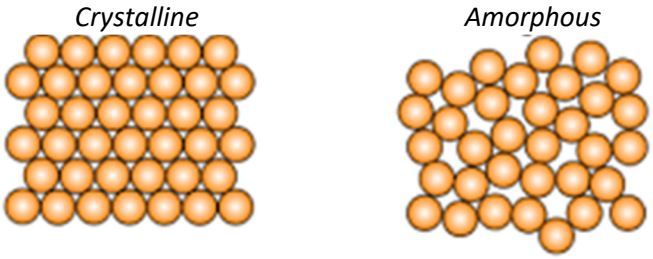
(iii) As the 20% alloy cools, it begins to solidify at 205°C and becomes a solid alloy at 140°C



4

(c) **(i)** In a **Solid Solution alloy**, the two metals are completely soluble in each other in all three states. The solid solution can be substitutional or interstitial in nature.
In a **Partial Solubility alloy** the two metals are completely soluble in the liquid phase. Both metals are also soluble in each other (in a solid state) to a limited degree. This is denoted by the Solvus Lines.

(ii) **Crystalline Structures** - these structures have regular, geometric and repeating molecular patterns i.e. BCC, FCC CPH.
Amorphous Structures - these structures have irregular and non-geometric patterns.



(iii) **Eutectic transformation** is where the metal goes from a liquid state to a solid state without going through a pasty stage.
Eutectoid transformation is a solid to solid transformation of a metal such as steel at 0.83% carbon at 723°C.

Any two @ 8 + 8

Question 6 (50 Marks)

(a) (i) Electro-slag welding:

- A highly productive, single-pass welding process for thick metals up to 300 mm
- Effectively used for vertical welding with the use of copper 'shoes'
- Can be automated
- Safe and clean, with no arc flash and low weld splatter and low distortion

(ii) Safety features integrated into oxy-acetylene welding:

- Low pressure acetylene and high-pressure oxygen cylinders and lines are colour-coded
- Acetylene is stored in acetone to prevent explosion
- Regulators are fitted with different threads to prevent interchange
- Flashback arrestors are used

(iii) The earth clamp is a tool that, via the earth cable, ensures the electrical circuit is closed between the welding power source and the piece to be welded.

(iv) Benefits of formation of slag:

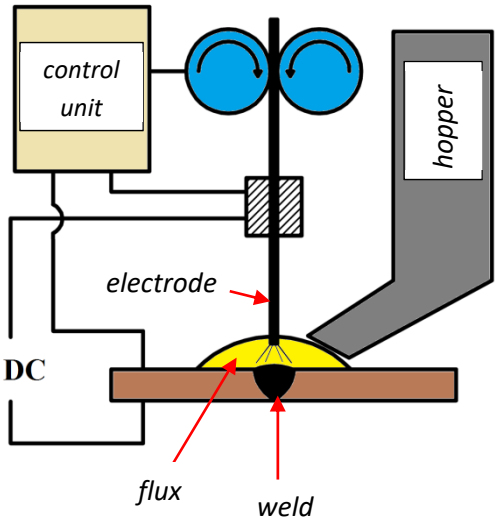
- Allows the weld to cool slower, this improves weld quality
- Provides a protective layer on the newly formed weld
- Prevents oxidation of weld
- Helps form the weld pool

Any three @ 6 + 6 + 6

(b) (i) Submerged Arc Welding:

In submerged arc welding, a bare wire electrode is used. It is fed automatically from a spool and generates an electric arc to heat the metal. The flux, in powder form, is fed from a hopper to completely cover the joint and the tip of the electrode. The arc creates the heat to melt the joint, flux and electrode. A slag is formed to provide a protective coating for the weld. The excess flux powder can be collected and used again. Submerged arc welding is a fully automated process.

Applications: used for large-scale straight-line welds such as steel reinforcing beams, shipbuilding and bridge construction.



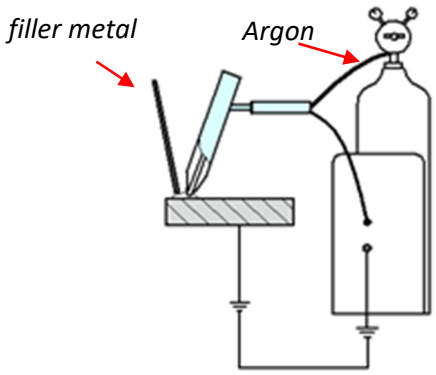
10

(ii) Safety precautions to be observed when operating a welding unit:

- Wear a welding mask to prevent "arc-eye" and facial burning.
- Wear heavy gloves to prevent hands from being burned.
- Have a ventilation system in place to deal with the toxic fumes.
- Have all electrical units earthed and connections properly insulated.

2 + 2 + 2

(c) **Electrode type:** Tungsten Inert Gas (TIG) welding uses a non-consumable electrode with a filler rod.
Operation: An arc is formed between the non-consumable electrode and the metal being welded. The inert gas shielded arc is used to flux the joint. A filler metal is added manually to the weld pool when necessary. A high frequency generator provides a path for the welding current.
Preventing oxidation: The inert gas such as Argon is often used to prevent oxygen getting to the joint area.
Applications: TIG is commonly used to weld aluminium components and stainless-steel pipes.



16

OR

(c) **(i)** **Degrees of freedom:** A description of the number of axes the robot arm can move. A single joint will provide one degree of freedom. To provide a variety of degrees of freedom, different robotic joints can be used such as rotary or linear joints.

Machine vision: Machine vision is the use of a camera or multiple cameras to inspect and analyse objects and movements automatically, usually in an industrial or production environment. After a process is performed the camera is triggered to capture, analyse and process the action.

4 + 4

(ii) **Stepper motors in control of robotic arms provide:**

- Incremental movement and allow for precision control of movement
- Reliability of operation
- Good power output to give torque required for operation
- Stepper motors are driven by control circuits

8

Question 7 (50 Marks)

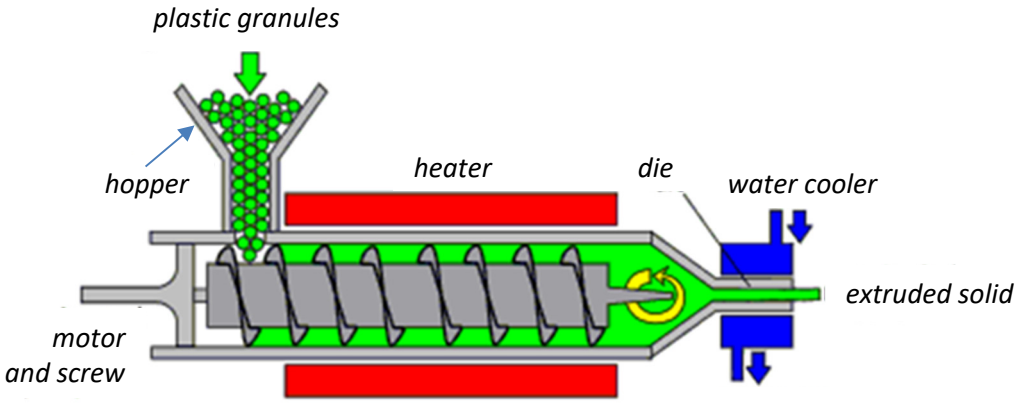
(a) (i) Bioplastic:

Bioplastics are plastic materials produced from renewable biomass sources, such as vegetable fats and oils, corn starch, straw, woodchips, sawdust, recycled food waste, etc. Bioplastic can be made from agricultural by-products and also from used plastic bottles and other containers using micro-organisms. Bioplastics are biodegradable materials that come from renewable sources and can be used to reduce the problem of plastic waste that is contaminating the environment.

2

(ii) Extrusion:

- Granulated thermoplastic polymer is fed into the barrel from the hopper.
- The screw moves the polymer forward.
- Heaters melt the polymer to liquid.
- As the screw continues to rotate, the polymer is pushed out through the die to give the required shape.



6

(iii) Reasons for using Polyactic acid (PLA):

- PLA is ideal for 3D prints where aesthetics are important
- Due to its lower printing temperature, it is easier to print with and therefore better suited for parts with fine details
- It is not prone to warping
- PLA is not costly
- It can be recycled and is biodegradable

4 + 4

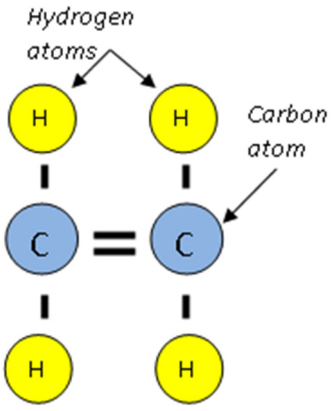
(b) (i) Most **natural rubber** is produced from a softwood tree native to Brazil, though several other species of trees and shrubs are sources of rubber as well. Natural rubber has a high tensile strength and is resistant to fatigue from wear such as chipping, cutting or tearing. Natural rubber has only moderate resistance to damage from exposure to heat, light and

the ozone in the air. Natural rubber also has tack, which means it can adhere to itself as well as other materials. It adheres particularly well to steel cord, which makes it an excellent material for use in tyres.
Synthetic rubber is produced artificially from polymers in different varieties to mimic the different properties of natural rubber. Synthetic rubber offers better resistance to abrasion than natural rubber, as well as superior resistance to heat and the effects of ageing. Many types of synthetic rubber are flame-resistant, so it can be used as insulation for electrical devices. It also remains flexible at low temperatures and is resistant to grease and oil.

(ii) **Plastic pultrusion** is similar to extrusion and is associated mainly with thermosetting polymers. In the standard pultrusion process the reinforcement materials like fibres are impregnated with resin, possibly followed by a separate preforming system, and pulled through a heated stationary die where the resin undergoes polymerisation. The impregnation is either done by pulling the reinforcement through a bath or by injecting the resin into an injection chamber which typically is connected to the die.
Many resin types may be used in pultrusion including polyester, polyurethane, vinylester and epoxy. Resin provides the resistance to the environment, (i.e., the corrosion resistance, the UV resistance, the impact resistance, etc.) and the glass provides strength, in addition to safety from fire.

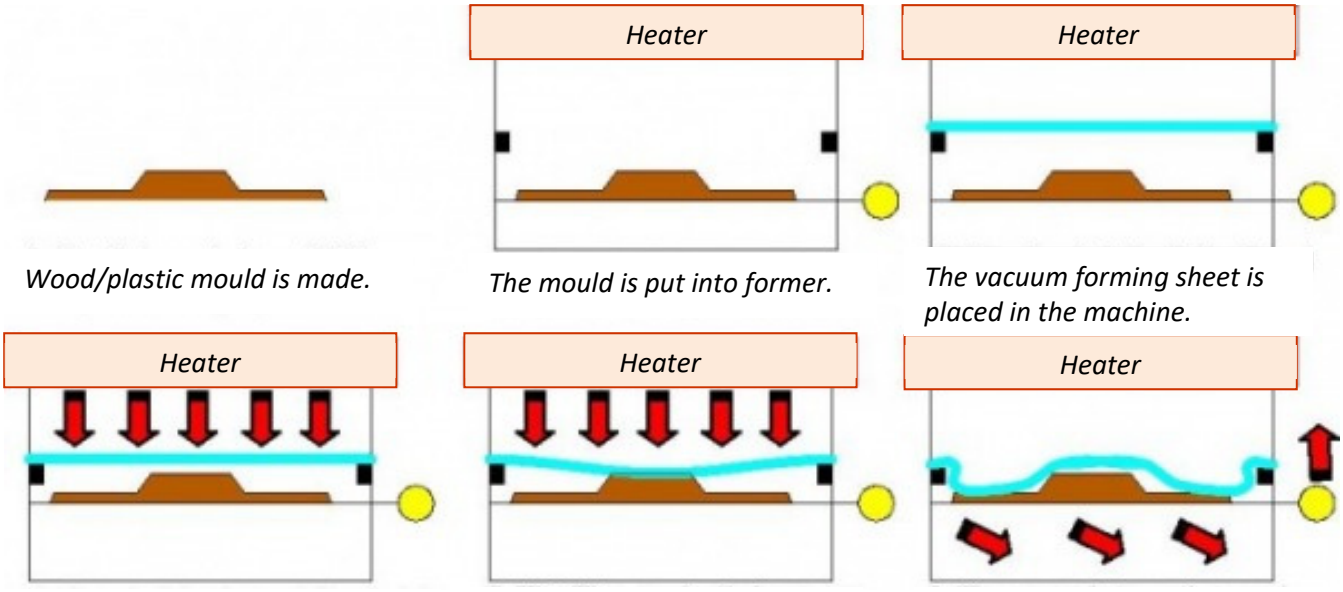
(iii) Products are produced from non-renewable sources.
The synthesis of petroleum products also uses large amounts of energy.
Some chemical by-products may also be hazardous.
Petroleum products are likely to be long-life, presenting a challenge for disposal at end-of-life.

(iv) The ethylene monomer (or mer) consists of hydrogen and carbon atoms as shown in the diagram.
There is a strong and a weak bond between the carbon atoms. This monomer polymerises to form polyethylene by addition polymerisation.



Ethylene monomer

(v) Vacuum forming:



Wood/plastic mould is made.

The mould is put into former.

The vacuum forming sheet is placed in the machine.

Heater is turned on and warms the plastic sheet.

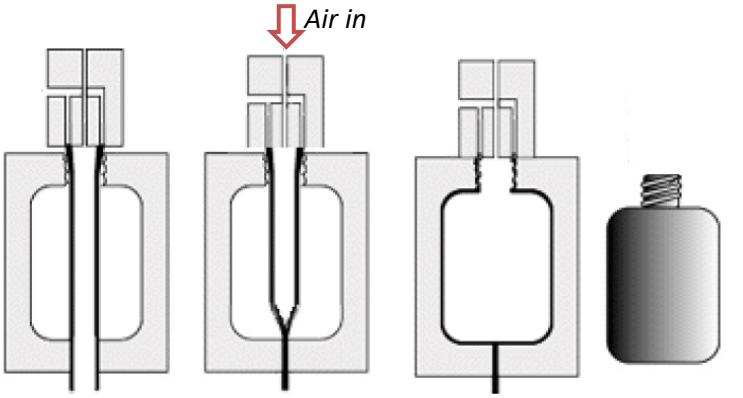
The thermoplastic sheet becomes flexible when heated.

The pump removes the air and draws the plastic sheet onto the mould.

(Any three) 6 + 6 + 6

(c) (i) Blow moulding:

1. An extruded plastic parison is clamped in the blow moulder.
2. Air is blown into the heated chamber.
3. The pliable plastic takes the shape of the mould.
4. The finished product is removed.



1. Parison *2. Clamping* *3. Moulding* *4. Finished bottle*

8

(ii) **Stabilisers** are added to prolong the useful life of a polymer formulation by protecting it from thermal and light-assisted oxidation.

A selection of **plasticisers** make the polymer flexible, easier to mould and non-toxic.

Pigments give the plastic bottle its tinted colour.

4 + 4

Question 8 (50 Marks)

(a) (i) **Safety hazards using the centre lathe:**

- Rotating workpieces at high speed - chuck guards need to be used.
- Metals can get hot - use cutting fluids if needed, ensure lathe cutting tools are in good condition.
- Cutting metal swarf is sharp – do not allow to build up and dispose of carefully.
- Rotating shafts can catch loose clothing – ensure guards are in place.
- Inexperienced users need supervision.

2 + 2 + 2

(ii) Polycarbonate is transparent, screens can be replaced easily, polycarbonate is tough and will not shatter if struck by loose metals, etc.

5 + 5

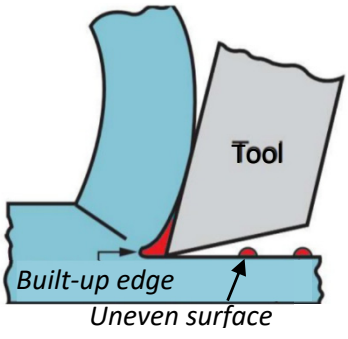
(b) (i) **Clearance hole** is a hole through an object which is large enough to enable threads of a screw or bolt to pass through but not the head of the screw or bolt.
A **tapping size hole** is drilled to allow threads to be cut on the inside of the hole.

(ii) **Safety Features** integrated into horizontal bandsaw:

- Blade is covered by guard
- Sturdy construction which can be bolted on to ground
- Feed rate can be regulated
- Has a cutting fluid reservoir integrated into the machine
- Cut-off switch prevents machine from cutting into bed

(iii) Cutting fluids will keep the material and cutting tools cool, this prevents heat build up and improves cutting action.
Tool life is extended.
Most cutting fluids have some lubricating action to make cutting more efficient.

(iv) **Built-up edge:** In single point cutting of metals, a built-up edge is an accumulation of material against the rake face which adheres to the tool tip. The cutting tool is separated from the chip by the built-up edge.
As the built-up edge enlarges, the cutting edge will not cut effectively as the tool cutting angles are compromised. The surface finish will deteriorate and machining will not be smooth. The machine is likely to be subjected to excess vibration.

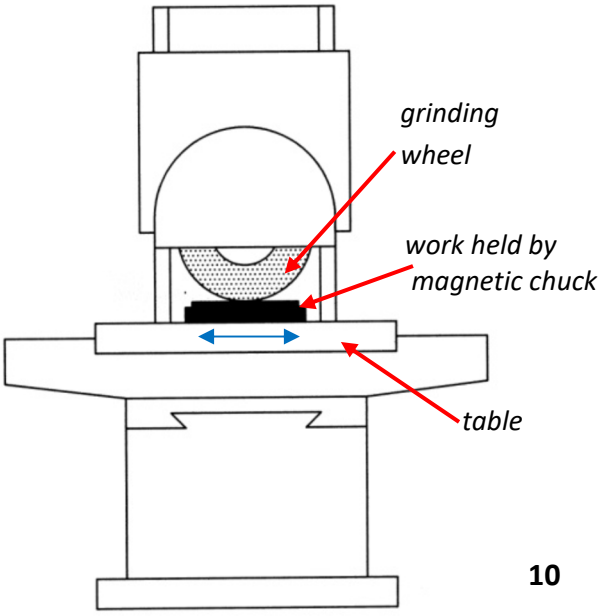


(v) In the grinding process, wheel dressing is used to restore the cutting surface of any irregularities. Grinding wheels are designed to have a self-dressing action in which grains should break free and expose sharp edges. Wheel dressing will renew a sharp cutting face and correct irregularities such as wheel concentricity, loaded and glazed wheels.
The process can remove any undulations from the wheel.

(Any three) 6 + 6 + 6

(c) **(i)** **Precision surface grinding:**

A metal cutting process in which flat and extremely smooth surfaces are produced. The grinding wheel rotates and the workpiece, usually held in a magnetic chuck, is fed to and from continuously. At the end of each stroke, the table is moved across the wheel by a small amount. The grinding wheel can be lowered to take a new cut.



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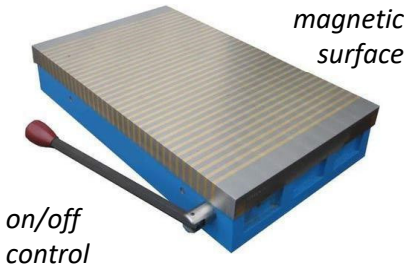
(ii) **Magnetic chuck**

Used for holding ferromagnetic workpieces, a magnetic chuck consists of an accurately centred permanent magnet face. Electromagnets or permanent magnets are brought into contact with fixed ferrous plates, or pole pieces, contained within a housing. These pole pieces are usually flush with the housing surface. The part (workpiece) to be held forms the closing of the magnetic loop or path, onto those fixed plates, providing a secure anchor for the workpiece.



There are two basic types of magnetic chucks now available (electromagnetic and permanent), but they come in a variety of sizes, shapes and modifications to suit many different applications. Electromagnetic chucks are charged by an electrical current while permanent-type magnetic chucks are based on permanent magnets. Both types can be turned on and off.

6

OR

(c) **(i)** **Subtractive manufacturing** is a term for various controlled machining and material removal processes that start with solid blocks, bars, rods of plastic, metal, or other materials that are shaped by removing material through cutting, boring, drilling, and grinding. In CNC milling, these processes are controlled by programmes devised to produce complex shapes.

8

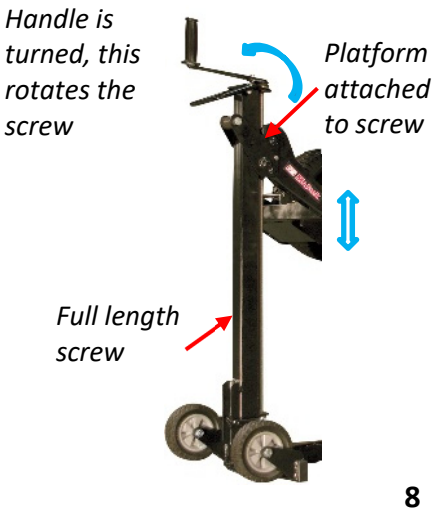
(ii) **Automatic tool change (ATC)** selects and changes machine tools as part of the machining process, this expands the tool carrying capacity of the machine. ATC changes the tool very quickly, reducing the non-productive time.

Tool offsets are the set of values that move the centre point of the cutter to the correct position for cutting a work piece using a specific tool. This accounts for variation in tool geometry (diameter, length, etc.) and ensures precise cutting.

4 + 4

Question 9 (50 Marks)

(a) **(i)** As the leadscrew handle is rotated, the screw rotates causing the platform to raise and lower.
The platform is attached with a fixed threaded nut which follows the threaded leadscrew until the handle stops turning.



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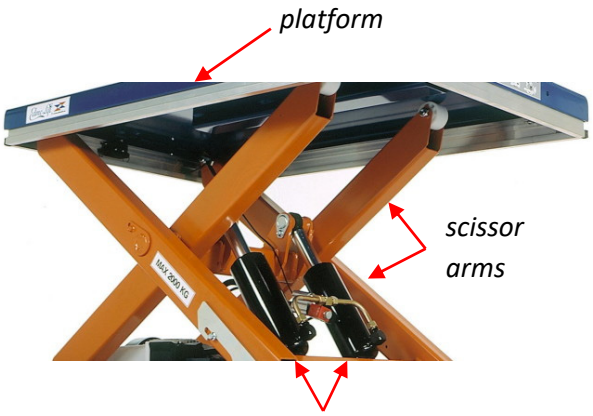
(ii) *Suggested solution - other viable solutions are acceptable.*



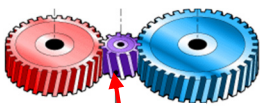
This lift table design incorporates hydraulic cylinders and an electrically powered pump to actuate the scissor lifting mechanism. As the cylinder extends, the scissor arm is pushed upwards raising the platform.

8

(b) **(i)** Grease is more viscous than oil. Grease can lubricate and protect moving parts from corrosion, it has the ability to seal some parts. It exhibits less leakage than oil and will stay in place longer.

(ii) The toggle mechanism has a strong clamping action, it is used to clamp sheets into a vacuum former.

(iii) Idler gears are used to change the direction of a gear train, it can also ensure that driver and driven gears rotate in the same direction.


idler gear

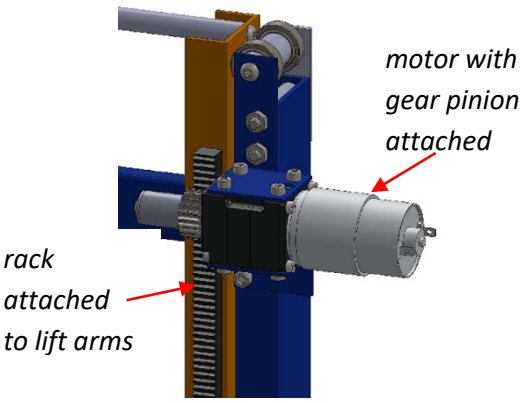
(iv) The gear drive mechanism should be securely housed.
Gear wheels need to be securely attached to drive shafts due to high speeds.

(v) A **universal joint** is a mechanical device that allows one or more rotating shafts to be linked together, allowing the transmission of torque and/or rotary motion. It also allows for transmission of power between two points that are not in line with each other.

(Any three) 6 + 6 + 6

(c) **(i)** The use of a rack and pinion mechanism would provide a drive mechanism for the platform to be raised and lowered.

A worm-wheel could also be used with the gear pinion to prevent the mechanism slipping, the motor would have to drive all movement.



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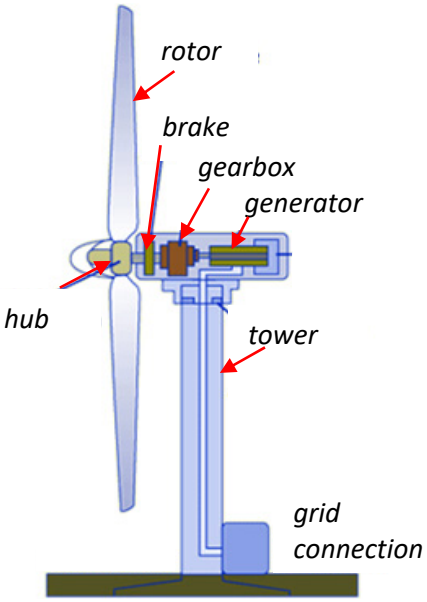
(ii) The forklift shown can lift long loads safely. Loads can be manoeuvred with minimal need to change direction. The design of the forklift gives a wide range of user visibility.

8

OR

(c) **(i)** Wind turbines convert the energy in wind to electricity by rotating propeller-like blades around a rotor. The rotor turns the drive shaft, which turns an electric generator.



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(ii) **Advantages of** offshore wind energy: provides renewable energy; does not consume water; provides a domestic energy source; creates jobs; and does not emit environmental pollutants or greenhouse gases.
Disadvantages of offshore wind energy: can be expensive to build and maintain; hard to reach locations; susceptible to damage from very high-speed winds during storms, which is expensive to repair.

4 + 4

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