Coimisiún na Scrúduithe Stáit

State Examinations Commission

Leaving Certificate 2025

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, 2025

Marking Scheme

Written Examination and Practical Examination

ENGINEERING –

Materials and Technology

HIGHER LEVEL

Introduction – written examination

In considering the marking scheme, the following should be noted.

1. The solutions presented are examples only. All other valid solutions are acceptable and are marked accordingly.

2. The detail required in any answer is determined by the context and the manner in which the question is asked, and by the number of marks assigned to the answer in the examination paper and, in any instance, therefore, may vary from year to year.

3. Bonus marks at the rate of 5% of the marks obtained will be given to a candidate who answers entirely through Irish and who obtains less than 75% of the total marks. In calculating the bonus to be applied decimals are always rounded down, not up e.g., 4.5 becomes 4; 4.9 becomes 4, etc. The bonus table given on the next page applies to candidates who answer entirely through Irish and who obtain more than 75% of the total marks.

4. The table below contains information about annotations used for marking throughout the exam paper.

Annotation	Meaning
	Blank page
	Page marked by examiner

Coimisiún na Scrúduithe Stáit

Marcanna Breise as ucht freagairt trí Ghaeilge

Léiríonn an tábla thíos an méid marcanna breise ba chóir a bhronnadh ar iarrthóirí a ghnóthaíonn níos mó ná 75% d'iomlán na marcanna.

N.B. Ba chóir marcanna de réir an ghnáthráta a bhronnadh ar iarrthóirí nach ngnóthaíonn níos mó ná 75% d'iomlán na marcanna don scrúdú. Ba chóir freisin an marc bónais sin **a shlánú síos**.

Tábla 300 @ 5%

Bain úsáid as an tábla seo i gcás na n-ábhar a bhfuil 300 marc san iomlán ag gabháil leo agus inarb é 10% gnáthráta an bhónais.

Bain úsáid as an ngnáthráta i gcás 187 marc agus faoina bhun sin. Os cionn an mharc sin, féach an tábla thíos.

Bunmharc	Marc Bónais
226	11
227 – 233	10
234 – 240	9
241 – 246	8
247 – 253	7
254 – 260	6

Bunmharc	Marc Bónais
261 – 266	5
267 – 273	4
274 – 280	3
281 – 286	2
287 – 293	1
294 – 300	0

LEAVING CERTIFICATE

ENGINEERING-MATERIALS AND TECHNOLOGY

(Higher Level – 300 marks)

Marking Scheme 2025

Answer **any six** questions.

Question 1 – 50 marks	**Question 2 – 50 marks**	**Question 3 – 50 marks**
Any ten @ 5 marks each.	Answer **all** parts of this question	Answer **all** parts of this question
(a) 3 + 2		
(b) 5	**(a)** **(i)** 5	**(a)** **(i)** 4
(c) 3 + 2	**(ii)** 3 + 2	**(ii)** 4
(d) 3 + 2	**(b)** **(i)** 5	**(iii)** 6
(e) **Any one** @ 5	**(ii)** 5	**(b)** **(i)** 10
(f) 3 + 2	**(c)** **(i)** 3 + 2	**(ii)** 2 + 2 + 2
(g) 5	**(ii)** 5	**(iii)** 4
(h) 3 + 2	**(d)** 10	**(c)** **(i)** 8
(i) 5	**(e)** **Any two** @ 5 + 5	**(ii)** 8
(j) 3 + 2		
(k) 5		
(l) 3 + 2		
(m) 3 + 2		

Question 4 – 50 marks	**Question 5 – 50 marks**	**Question 6 – 50 marks**
Answer **all** parts of this question	Answer **all** parts of this question	Answer **all** parts of this question
(a) **(i)** 4 + 4	**(a)** **(i)** 4	**(a)** **(i)** 10
(ii) 8	**(ii)** 2 + 2 + 2	**(ii)** 3 + 3
(b) **(i)** 2 + 2	**(iii)** 6	**(b)** **Any three** @ 6 + 6 + 6
(ii) 6	**(b)** **(i)** 8 + 1 + 1	**(c)** 16
(iii) 8	**(ii)** 4	***OR***
(c) **Any two** @ 8 + 8	**(iii)** 4	**(c)** **(i)** 4 + 4
	(c) **Any two** @ 8 + 8	**(ii)** 4 + 4

Question 7 – 50 marks	**Question 8 – 50 marks**	**Question 9 – 50 marks**
Answer **all** parts of this question	Answer **all** parts of this question	Answer **all** parts of this question
(a) **(i)** 2 + 2	**(a)** **(i)** 10	**(a)** **(i)** 10
(ii) 8	**(ii)** 3 + 3	**(ii)** 6
(iii) 2 + 2	**(b)** **Any three** @ 6 + 6 + 6	**(b)** **Any three** @ 6 + 6 + 6
(b) **Any three** @ 6 + 6 + 6	**(c)** **(i)** 8	**(c)** **(i)** 8
	(ii) 8	**(ii)** 8
(c) **(i)** 8	***OR***	***OR***
(ii) 8	**(c)** **(i)** 4 + 4	**(c)** **(i)** 4 + 4
	(ii) 8	**(ii)** 8

Marking Scheme

Note: The solutions presented are examples only.

All other valid solutions are acceptable and are marked accordingly.

Question 1 (50 Marks)

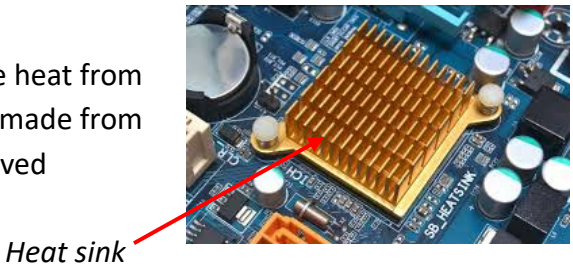
(a) Advantages of voice activated technology include:

- Voice-activated devices allow for quick and hands-free access to information and services, enabling users to complete tasks more efficiently.
- Improved accessibility for users with limited mobility or visual impairments, this technology can promote independence and empower individuals.
- Increased efficiency and productivity, users can accomplish various actions, such as setting reminders, scheduling appointments, or searching for information, simply by speaking a command.
- Overcoming language barriers for global accessibility.

3 + 2

(b) Function of a heatsink:

A heatsink provides a reservoir or pathway to remove heat from temperature sensitive components. They are usually made from metal (copper or aluminium) and will allow for improved performance and extended component life.



5

(c) Safety precautions to be observed when using cutting fluids:

- Avoid splashes on skin, wash immediately, use skin barrier cream.
- Wear eye protection.
- Remove spilt cutting fluids from floor to prevent slipping.
- Renew cutting fluid to prevent rancidity.
- Cutting fluids need to be filtered and cleaned.

3 + 2

(d) Reasons why cast iron is used to make kettlebells:

- Cast iron is easy to cast into intricate shapes, giving the kettlebell good ergonomics.
- Cast iron provides good stiffness and durability.
- Cast iron is a dense material, so when comparing two kettlebells of the same weight, the cast iron option will always be smaller and more compact.

3 + 2

(e) **(i) Michael Faraday**

English scientist who contributed to the study of electromagnetism and electrochemistry. His main discoveries include the principles underlying electromagnetic induction, diamagnetism and electrolysis – resulting in the development of the electric motor, generator and transformer. The Faraday cage is the basis for MRI machines.

(ii) Pierre Vernier

French mathematician and instrument inventor. He was the inventor and eponym of the vernier scale used in measuring devices.

(iii) Francis Beaufort

Irish hydrographer, naval officer, and creator of the Beaufort scale, which classifies the velocity and force of winds at sea. He was born in 1774, in Navan, County Meath.

Any one @ 5

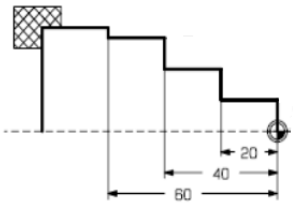
(f) **Benefits of the Deposit Return Scheme (DRS):**

- Reduces the amount of litter and waste ending up in landfill.
- Creates a cleaner more sustainable Ireland.
- Contributes to a circular economy by returning valuable materials and keeping them in the economy for as long as possible.
- This keeps the high-quality plastic in the loop, making it much easier to recycle into new products, meaning less need for new plastic bottles to be created.
- Recycles valuable metal (aluminium) which takes considerable energy to extract.

3 + 2

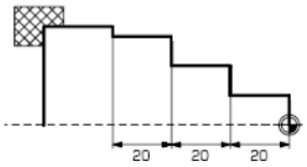
(g) **Absolute dimensioning:**

The tool coordinates are always referenced to a fixed point, usually the machine origin or a work offset.



Incremental dimensioning:

The tool coordinates are based on the previous position, and each move is a distance from the last point.



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(h) Anodising offers enhanced corrosion resistance, improved hardness and resistance to wear/abrasion.

Aluminium has good strength-to-weight ratio, it will not rust, can be formed into the shape easily, etc.

Anodising offers a wide range of colour options and finishes.

3 + 2

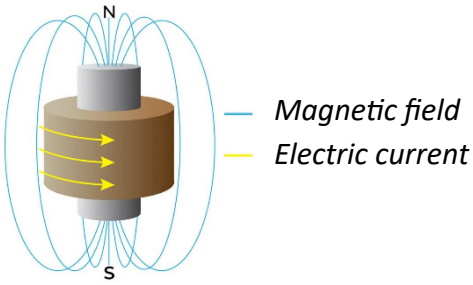
(i) **Factor of safety:** a component is designed to withstand a greater load than the expected operational load. It is commonly stated as a ratio, such as 5:1. This means that the carabiner can hold five times their Safe Work Load (SWL) before it will break.

5

(j) **Lathe processes used to manufacture the screw lock:**
Facing off, knurling, parting off, centre drilling/drilling, etc.

3 + 2

(k) **Operation of an electromagnet:**
An electromagnet is a type of magnet in which the magnetic field is produced by an electric current. Electromagnets usually consist of wire wound into a coil. A current through the wire creates a magnetic field which is concentrated in the hole in the centre of the coil. The magnetic field disappears when the current is turned off.



5

(l) **Benefits of pneumatic powered dentistry equipment:**
Using pneumatic systems to control dental equipment allows for smoother and gentler operation. Pneumatic systems are safer and more efficient to use. They also lower the risk of shock and hazardous fluid leakage.

3 + 2

(m) **Properties of stainless steel as a wire material in braces:**
Stainless steel wires are used in orthodontics because of their formability, biocompatibility and environmental stability, stiffness, resilience, etc.

3 + 2

Question 2 (50 Marks)

(a) **(i)** **Main properties of Hydrogen:**
Hydrogen is a chemical element represented by the symbol H on the periodic table and with an atomic number of 1 is the lightest of all the elements.
Hydrogen is the most abundant chemical substance making up around 75% of matter.
It is a colourless, odourless, tasteless, non-toxic and highly flammable gas.
Hydrogen normally exists as a molecule of two atoms (H_2) at room temperature and pressure. Hydrogen is found in compounds such as water (H_2O), ammonia (NH_3) and hydrocarbon fuels such as natural gas, coal, and oil.

5

(ii) The advantages of using hydrogen as a fuel source.

- Environmentally Friendly: When hydrogen is used in fuel cells, it produces water as a byproduct, eliminating greenhouse gas emissions and pollutants.
- Renewable source: Hydrogen can be produced from various renewable resources, such as water through electrolysis powered by renewable energy (e.g. solar, wind).
- Energy Efficiency: Hydrogen fuel cells are very efficient, converting chemical energy directly into electrical energy with efficiency rates of 40–60%, higher than conventional combustion engines.
- Hydrogen can be used as an energy storage medium, balancing intermittent renewable energy sources like wind and solar by storing excess energy for later use.
- Hydrogen can be used across various sectors, including transportation (fuel cell vehicles), industrial processes, and residential heating.

3 + 2

(b) (i) Steam Methane Reforming (SMR)

SMR is the most widely used industrial process for producing hydrogen. Methane (CH4) from natural gas and water (H2O) react to form carbon monoxide (CO) and hydrogen (H2).

- Reaction with Steam – methane reacts with steam to produce hydrogen (H_2) as well as CO and CO_2.
- Water-Gas Shift Reaction - Carbon monoxide reacts with additional steam to produce more hydrogen and carbon dioxide.
- Hydrogen Purification.

5

(ii) Data fossil fuel: coal, natural gas, biomass, domestic waste, etc. may be converted into hydrogen gas. Methane leaks in extraction and transportation are potent greenhouse gases.

Energy input: requires up to 1000°C temperature and high pressure.

Emissions: SMR will emit greenhouse gasses, CO2 and NOx emissions.

5

(c) (i) Research and Development (R&D) is important in hydrogen energy technology.

- Improving efficiency and performance.
- Reduction in costs as green technology is currently an expensive process.
- Could create a sustainable methodology for the future company development.
- Better storage, pipelines and transportation methods can be employed.
- Safety and reliability integrated into system design.

3 + 2

(ii) Data centres may use hydrogen to provide a sustainable and environmentally friendly power source. These centres require stable and uninterrupted energy making hydrogen a feasible alternative to other renewable sources. Can use high-cost hydrogen fuel cells and storage systems for efficient energy use.
Agriculture energy use is more variable and seasonal with energy demands higher at busy times. It tends to use hydrogen-powered machinery and systems (such as cleaning and irrigation) with the added benefit of ammonia use in fertilizers. On-site hydrogen production or refuelling station may be needed.

5

(d) Principle of operation of a hydrogen fuel cell:

A fuel cell is a device that generates electricity from the chemical energy of a fuel (hydrogen) and an oxidising agent (air) through an electrochemical reaction, not combustion. It consists of two electrodes, a negative electrode (anode) and a positive electrode (cathode) sandwiched around an electrolyte. A fuel, such as hydrogen, is fed to the anode, and air is fed to the cathode.
A catalyst at the anode separates the hydrogen fuel molecules into electrons and protons, which take different paths to the cathode.
As the fuel is consumed, the electrons create a flow of electricity which can be used to power electrical devices, while the protons migrate through the electrolyte to the cathode, where they unite with oxygen and the electrons to produce water and heat. Fuel cells operate similarly to batteries, but do not run down or need recharging, producing electricity and heat as long as fuel is supplied. As there are no moving parts, fuel cells operate silently and with extremely high reliability.

10

(e) (i) The production of green hydrogen.

Green hydrogen is hydrogen produced using renewable energy sources without emitting carbon dioxide (CO_2). The most common method for producing green hydrogen is electrolysis, which splits water (H_2O) into hydrogen (H_2) and oxygen (O_2) using electricity from renewable sources like solar, wind, or hydro power.

(ii) Energy storage.

Hydrogen can store energy for long periods, balancing supply and demand in renewable energy systems. It can be produced when renewable energy is abundant (e.g. solar or wind power) and stored for use when energy demand is high, making it an effective solution for stabilising energy grids and providing backup power.

(iii) Safety concerns.

Hydrogen is highly flammable and burns with a flame that is nearly invisible.
The storage of hydrogen under high pressure requires strong, lightweight tanks.
Hydrogen can make metals brittle increasing the likelihood of cracking and pipe failure.
Leaks are difficult to detect as hydrogen in colourless and odourless.

Any two @ 5 + 5

Question 3 (50 Marks)

(a) (i) Metal fatigue:

Metal fatigue is the initiation and propagation of cracks in a material due to cyclic loading (on/off loading). Once a fatigue crack has initiated, it grows a small amount with each loading cycle. The crack will continue to grow until it reaches a critical size and complete fracture of the structure.

4

(ii) Thermal creep is the slow, time-dependent deformation of metals under constant stress. It can be a significant issue for materials operating in high-performance systems, such as jet engines, that often reach extreme temperatures. Higher temperatures increase atomic movement, accelerating the creep deformation rate.

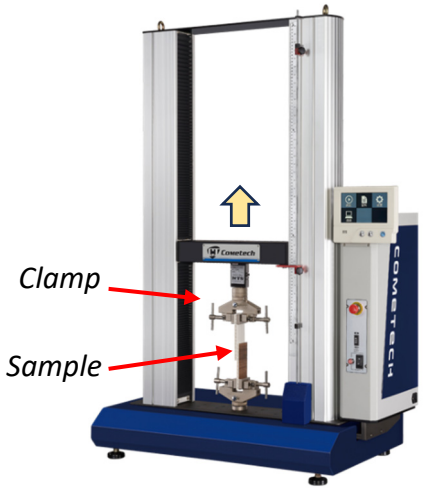
This can cause the blades to elongate, which can ultimately lead to the blade beginning to damage or pierce the turbine casing.

4

(iii) Tensile testing

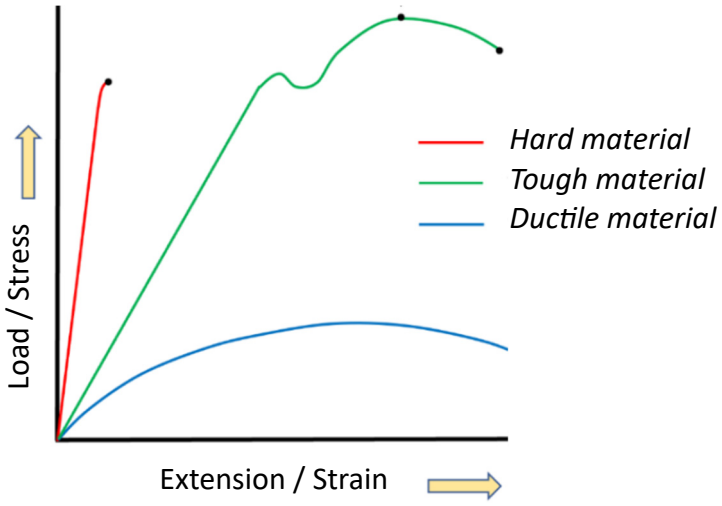
A standardised test specimen is placed in an extensometer machine where a measured tensile Load/Stress is applied.

The resultant extension is plotted on a Load/Extension or Stress/Strain diagram where the tensile strength of the material can be assessed.



Typical graphs represent tensile tests for a variety of materials are shown.

- Very hard and brittle (red), high stress with only a limited degree of elasticity before failure. Results in a brittle fracture.
- Tough material (green), elastic and plastic deformation, necking and failure. Results in a ductile fracture.
- Very Ductile material (blue), a lot of plastic deformation under load before failure.



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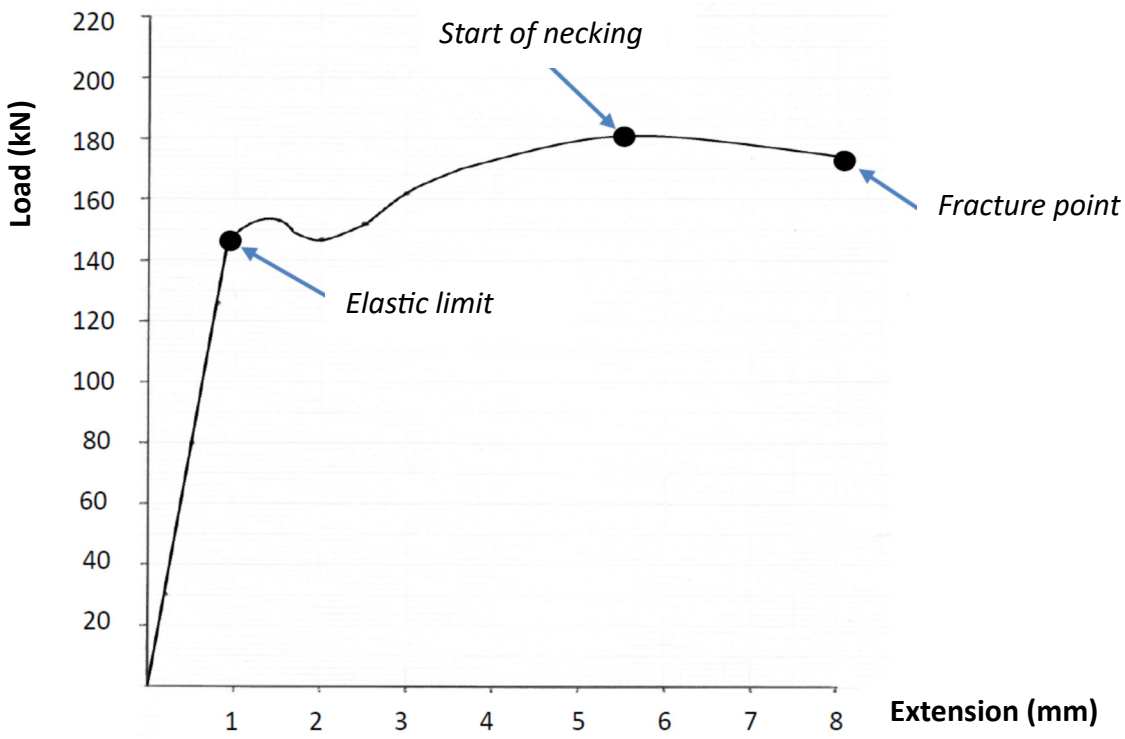
(b) (i) Load-extension graph:



10

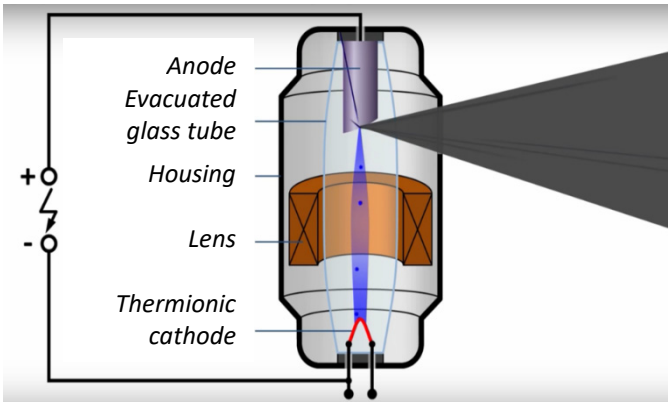
(ii) On graph **2 + 2 + 2**

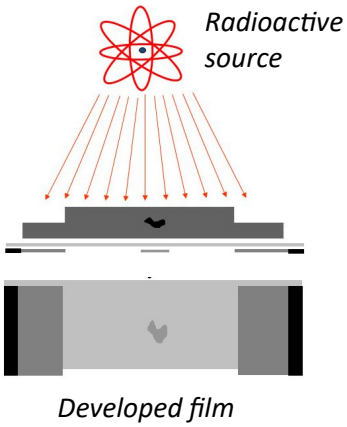
(iii) Ultimate tensile strength = $\frac{\text{Max Load}}{\text{C.S.A}} = \frac{181\text{kN}}{113.1\ \text{mm}^2} = 1.6\ \text{kN/mm}^2$ **4**

(c) (i) Metal *macroscopic* examination is a visual inspection process. Physical manufacturing defects can be detected by eye or low powered magnifying glass.
Microscopic examination of metals allows for more detailed examination of grain size and some impurities. An optical microscope is used for this type of inspection.

8

(ii) Radiography (X-ray) NDT
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 jet engine turbine blades can be determined by this NDT method.





8

Question 4 (50 Marks)

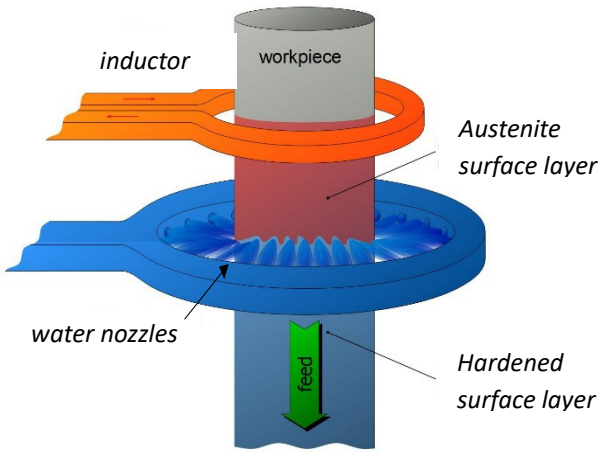
(a) (i) Ploughing conditions often cause excessive wear of agricultural machine parts. Surface hardening of the plough points will increase the hardness of the outer surface while the core remains relatively soft. This results in the plough point having an increased resistance to both fatigue failure and abrasive wear.

4 + 4

(ii) Induction Hardening:

Induction hardening is a method of quickly and selectively hardening the surface of a metal part. A copper coil carrying a significant level of alternating current is placed near (not touching) the part.

The workpiece is heated by a high frequency electric current passing through the copper coil to a high temperature (austenite zone) and then quenched with jets of water. The quenched metal undergoes a martensitic transformation, increasing the hardness of the outer surface while keeping the inner core tough.



8

(b) (i) **A** = Upper Critical Temperature Line (UCT) – ferrite starts to form.

B = Lower Critical Temperature Line (LCT) - Austenite and cementite to pearlite and cementite transformation, magnetic transformation temperature.

2 + 2

(ii) Point **C** is called the eutectoid point. At this point solid austenite changes to solid pearlite at approximately 723°C at 0.83% carbon.

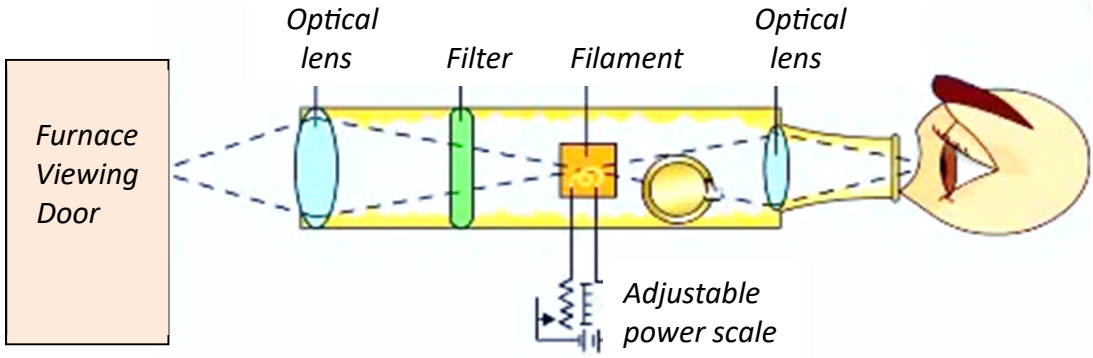
6

(iii) Annealing 1.2% carbon steel: For 1.2% steel the piece is heated 25˚C-50˚C above the LCT (approx. 800°C). It is then soaked at this temperature allowing the whole of the piece to be at the same temperature. It is then allowed to cool gradually in the furnace by reducing the temperature. During full annealing new grains are formed and this is called recrystallisation and this makes the metal soft, improves ductility, refines the grain size and removes internal stresses.

8

(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 then be established.

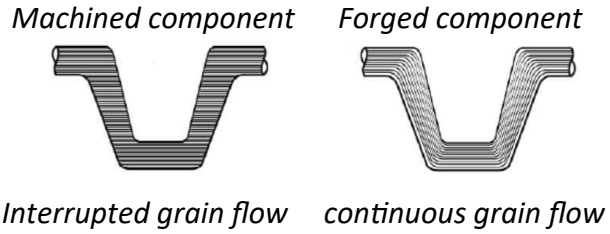
Temperature too low *Correct* *Temperature too high*

(ii) Three quenching media:

Oil, water, brine, air cooling, furnace cooling, lime, etc.

(iii) Benefits of forged metal components:

- Superior mechanical properties due to continuous grain flow.
- Toughness; forged components have higher toughness values.
- Less brittle than castings.



Any two @ 8 + 8

Question 5 (50 Marks)

(a) (i) Allotrope

The ability of some chemical elements to exist in two or more forms is known as allotropy, e.g. steel can exist in a BBC structure at low temperatures and FCC at 910°C and BCC at 1400°C.

4

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

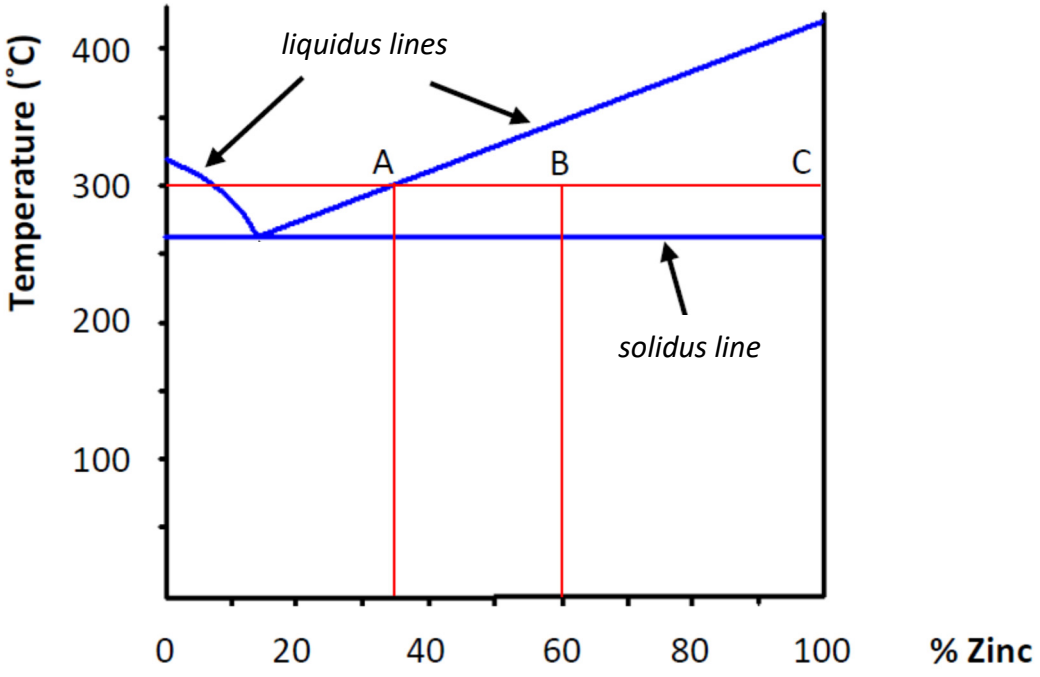
2 + 2 + 2

(iii) The body-centred cubic unit cell has atoms at each of the eight corners of a cube, plus one atom in the centre of the cube (total of 9 atoms). BCC metals tend to be strong and brittle. Examples include alpha iron, vanadium and chromium.

The face-centred cubic unit cell has atoms at each of the eight corners of a cube with one atom in the centre of each of the cube faces (total of 14 atoms). FCC metals tend to be soft and ductile over a range of temperatures. Examples include gamma iron, aluminium, nickel, silver, copper and gold.

6

(b) (i) Draw the thermal equilibrium diagram and label



8 + 1 + 1

(ii) Ratio of the phases at 300°C for 60% Zinc:

A = 34

B = 60

C = 100

|AB|/|BC| = 26/40

4

(iii) Eutectic point. Here the alloy changes straight from a liquid to a solid without going through the pasty phase.

4

(c) (i) Metal recycling process:

1. *Collection*: The first step in metal recycling is the collection of all metal products, through waste collection, the deposit return scheme and scrap metal recycling facilities.
2. *Sorting*: Metals are separated from other materials; plastic is stripped from wires and metal pieces are removed from items. Then, with the use of magnets, ferrous metals and non-ferrous metals are separated. After that, the metals are sorted by type.
3. *Shred*: Scrap metal processing plants first crush the metal in hydraulic compactors so it can be handled on conveyor belts easier. Hammer mills then shred the metal into smaller pieces. Shredding the metal makes the melting process easier because, when the pieces are smaller, it creates a larger surface-to-volume ratio.

4. *Melting*: The shredded metal is now melted in a furnace. Each metal has a specially designed furnace depending on its properties. The melted metals are purified by electrolysis.
5. *Solidifying*: While in a molten state, chemicals are added to the melted metal to create desired properties. They are then poured into moulds to from ingots and allowed to solidify.
6. *Rolling*: The solid ingots are then sent to mills where they are rolled into sheets and then bought by manufacturers to make into new products.
7. *Manufacture*: The rolled sheets of metal are further processed and manufactured into various items such as car parts and new drink cans.

(ii) Benefits of upcycling metal components:

- **Environmental Impact**: Upcycling reduces waste by diverting metal from landfills, minimising the environmental burden of mining and manufacturing new materials. This contributes to a lower carbon footprint and conserves natural resources.
- **Economic Advantages**: Upcycling can be cost-effective, allowing businesses and individuals to save on material costs. It can also create new economic opportunities through the sale of upcycled products.
- **Resource Efficiency**: Utilising existing materials reduces the demand for new resources, promoting a circular economy where materials are continuously reused and repurposed.
- **Creativity and Innovation**: Upcycling encourages creative thinking, enabling designers and artisans to develop unique products that stand out in the market. This can lead to innovative solutions and new design trends.

(iii) Aluminium electrometallurgy: The electrometallurgy of aluminium begins by crushing bauxite ore into smaller particles before placing them into an electrolytic cell. The cell is filled with an ionic solution known as an electrolyte. An electrical current is then passed through the cell, transferring positively charged ions from the electrolyte to the aluminium ore, resulting in pure aluminium being deposited on the cathode. The cathode can then be removed from the cell and melted down to produce aluminium ingots that can be sold to manufacturers for further processing.

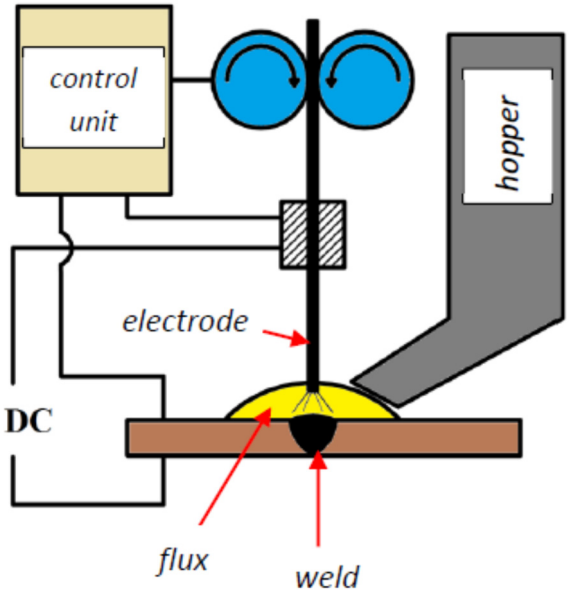
Any two @ 8 + 8

Question 6 (50 Marks)

(a) (i) SAW 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.



10

(ii) Reasons for SAW welding of wind turbine tower:

Submerged arc welding (SAW) is a suitable welding technique for the rolled steel segment as SAW is an automated process used for long uninterrupted welding. The SAW process is efficient, allowing for deep weld penetration and high deposition rates and is frequently used in heavy structural construction.

3 + 3

(b) (i) Steps in the preparation of a joint for welding:

- Clean the surfaces to be welded by removing dirt, grease, oil and rust. Use a wire brush, grinder or chemical cleaner.
- Ensure there are no sharp edges or burrs on the metal pieces by grinding or filing them down.
- Ensure the metal pieces are correctly aligned and close fitting, for thicker materials, bevel the edges using a grinder or cutting tool.
- Ensure that the angles and alignment are accurate and secure the workpieces using clamps, jigs, or fixtures.
- Some metals, like high-carbon steel or thick materials, may require preheating to prevent cracking. Use a torch or heating element to bring the metal to the desired temperature.

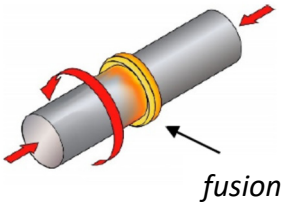
(ii) Functions of the electrode coating include:

- To generate a shield of carbon dioxide gas to protect welded joints from contamination by oxygen and nitrogen in the air.
- To form a slag coating which protects the weld from oxidation and ensures a slow cooling rate for the weld, this prevents cracks and brittleness.
- Facilitates the striking action of the arc between the work and electrode.

(iii) Storage of acetylene gas:

Acetylene is safely stored in colour coded cylinders that contain a porous material soaked with a solvent like acetone. This method keeps the gas dissolved at low pressures, reducing the risk of explosion. The cylinders are stored upright in cool, well-ventilated areas, with safety features like pressure relief devices to further ensure safe storage.

(iv) **Friction welding** is a solid-state fusion process that produces full contact, high quality joints. By rotating one work piece at high-speed relative to another, a compressive axial force is applied. This generates sufficient temperature to cause the interface to plasticise and fuse.

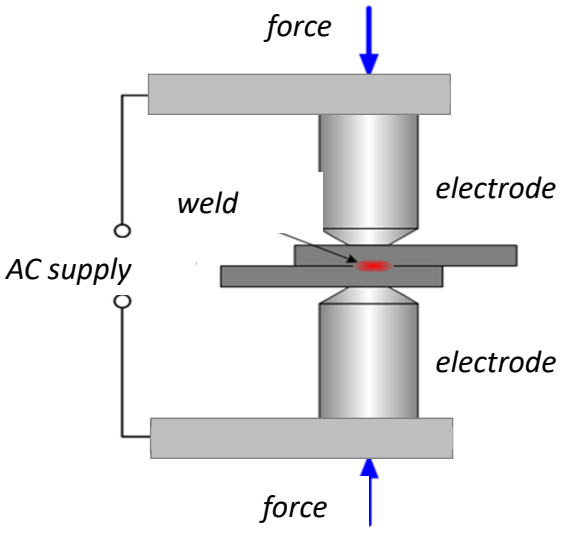


(v) **Distortion** during welding is a common issue caused by the uneven expansion and contraction of the metal as it is heated and cooled. The welded component fails to maintain its original shape and may result in shrinkage, angular movement or buckling and other defects that compromise the integrity and appearance of the welded structure.

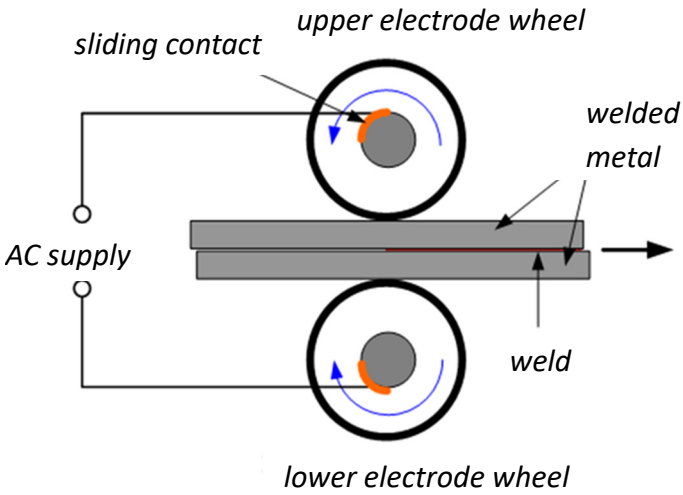
Any three @ 6 + 6 + 6

(c)

Resistance spot welding



Resistance seam welding



Electrode shape:

The electrode is in the shape of a round bar with tapered ends where it contacts the material.

The electrodes are disc shapes as they need to rotate during the process

Welding procedure:

The components to be joined are placed between the electrodes and then pressed together. A nugget weld is achieved as current is passed through the electrodes generating a large heat between the metals. It is very effectively used to join sheet metal together and is recognised by the distinctive circular mark left at the site of the weld.	A form of resistance welding that uses copper roller electrodes to provide a continuous run of overlapping welds as the current is activated at set intervals. One of the electrodes may be driven by an electric motor. The workpiece is moved between the rollers and pulses of current are supplied. Each pulse is set to last long enough to produce a weld.

Safety considerations:

Electrical equipment needs to be maintained. Localised spots of weld will be hot after welding, metal must be handled with care. Proper ventilation.	Process tends to be more automated allowing sheet metal to move through the machine. Risk of pinch hazard keep hands and clothing protected. A strip of hot metal is created while welding.

Applications:

Used in the automotive industry for body panel assembly.	Used when continuous tight weld is required e.g. fuel tanks, drums, domestic radiators.

16

OR

(c) (i) Benefits of using artificial intelligence (AI) to visually inspect welds for defects:

Using artificial intelligence (AI) to visually inspect welds for defects offers several advantages, including enhanced accuracy and efficiency.

- AI systems can be trained to recognise subtle defects that might be missed by human inspectors, such as tiny cracks, porosity or undercuts. Machine learning algorithms can analyse images of welds with high precision, ensuring that even the smallest inconsistencies are detected.
- Consistency: Unlike human inspectors, who may experience fatigue or variability in judgment, AI systems provide consistent evaluations every time. This reduces the likelihood of errors or overlooked defects, leading to higher quality welds and fewer failures in the final product.
- AI can analyse images or video of welds in real-time, significantly speeding up the inspection process compared to manual methods. This allows for quicker identification of defects and reduces the time needed for quality control.
- AI-powered inspection systems can operate continuously without breaks, making them ideal for high-volume production environments, increasing overall productivity and reducing bottlenecks in the manufacturing process.

4 + 4

(ii) Advantages of using Virtual Reality (VR) headsets during welder training:

- VR provides a risk-free environment where trainees can practice welding techniques without exposure to real-world hazards like burns, fumes or electrical shock. This allows learners to build confidence and refine their skills without the fear of injury.
- VR can replicate a wide range of welding scenarios, materials and conditions, providing immersive and realistic experiences. Trainees can practice different types of welds, positions, and techniques, receiving immediate feedback on their performance. This accelerates skill development and improves the overall quality of training.
- Traditional welding training requires significant amounts of consumables, including metal, electrodes, gas and energy. VR training eliminates these costs, as no physical materials are consumed during practice sessions. This leads to substantial savings over time.
- VR training can be easily scaled to accommodate multiple trainees simultaneously without the need for multiple physical setups. Additionally, it allows for repeated practice without wear and tear on equipment and trainees can practice anytime and anywhere, increasing flexibility and accessibility.

4 + 4

Question 7 (50 Marks)

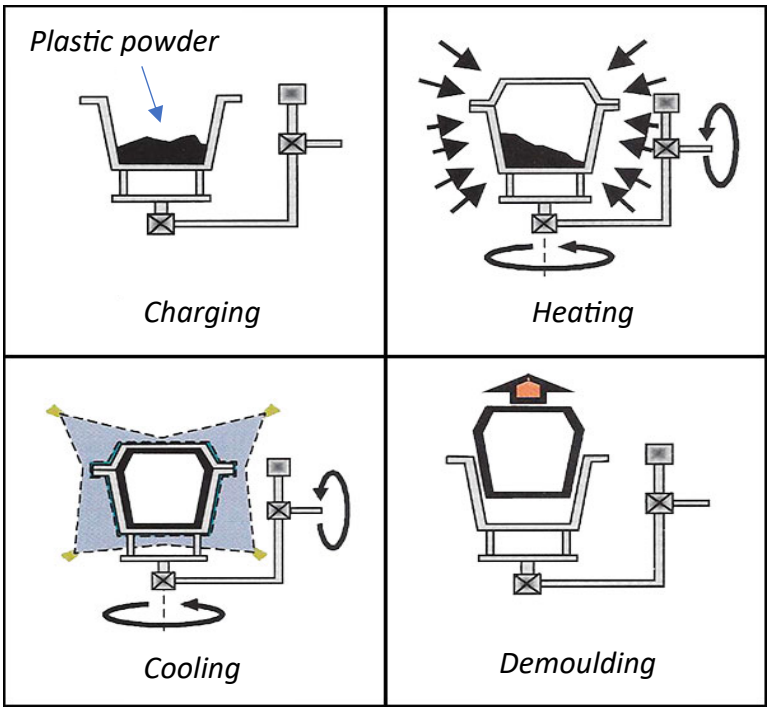
(a) (i) Reasons for the hollow design of the barriers:

- Hollow plastic barriers are much lighter than solid barriers, making them easier to transport, install and reposition. This is particularly important for temporary setups, such as during road construction or events, where barriers need to be frequently moved or adjusted.
- Hollow barriers can be filled with water or sand once they are in position. This filling provides the necessary weight and stability to resist impacts and remain in place under various conditions. When the job is done, the filling can be drained, returning the barrier to its lightweight state for easy removal.
- Using hollow plastic reduces the amount of raw material required to manufacture each barrier, making them more cost-effective to produce compared to solid barriers.
- In the event of a collision, hollow plastic barriers, especially when filled with water, can absorb and dissipate some of the impact energy, reducing the severity of damage to vehicles and minimising the risk of injury to occupants. This makes them safer compared to solid, rigid barriers.

2 + 2

(ii) Rotational Moulding

Rotational Moulding involves a heated hollow mould which is filled with a charge of thermoplastic material. The charge is heated and softened and then slowly rotated (usually around two perpendicular axes) causing the softened material to disperse and stick to the walls of the mould. In order to maintain even thickness throughout the part, the mould continues to rotate at all times during the heating phase. Products that can be manufactured using rotational moulding include storage tanks, toys, bins and refuse containers, footballs, helmets and canoes.



8

(iii) High-density polyethylene (HDPE) suitability for the manufacture of the barriers:

- Does not absorb water.
- HDPE will not decay.
- HDPE maintains its colour for the life of the barrier.
- HDPE only loses 10% of its strength over its lifetime, thus making it ultimately ideal for outdoor use.

2 + 2

(b) (i) Reasons for the use of carbon composite materials in the manufacture of body panels for the aircraft:

- Carbon composites offer a superior strength-to-weight ratio and are significantly lighter than traditional materials like aluminium or steel. This weight reduction is critical for eVTOL aircraft, as it enhances energy efficiency, increases range and improves overall performance by allowing for higher payloads and longer flight durations.
- Unlike metals, carbon composites are resistant to corrosion, which reduces maintenance costs and extends the lifespan of the aircraft.

- The ability to mould carbon composites into complex shapes allows for innovative and streamlined designs that improve aerodynamic efficiency, contributing to better flight performance and reduced drag.
- The acoustic properties of carbon composites can help minimise noise levels, contributing to quieter operations, which is particularly important for urban air mobility solutions.

(ii) **Elastic memory** in thermoplastics is the ability of the polymer to return to its original state from a deformed state. If a thermoplastic has been bent to a specific shape, when reheated it will return to its original shape.
Elasticity is displayed when a load is applied to a polymer to cause the object to change shape. When the load is removed, the polymer will return to its original shape.

(iii) A **catalyst** accelerates the chemical reaction by initiating or facilitating the polymerisation process without being consumed in the reaction.
An **inhibitor** slows down or temporarily halts the addition polymerisation process. It does this by reacting with free radicals or other reactive species that are essential for the polymerisation to proceed.

(iv) Foaming agents create a porous structure in the polymer, significantly reducing its density and weight. This results in a lightweight, porous product with variety of beneficial properties:
- The cellular structure formed by foaming agents enhances thermal and acoustic insulation properties.
- By expanding the volume of the polymer, foaming agents reduce the amount of raw material needed, leading to cost savings in production. This also contributes to environmental sustainability by lowering material consumption.
- Foamed polymers often exhibit greater flexibility and cushioning properties, which are beneficial in products like foam cushions, mattresses and protective packaging.

(v) **Reasons why Polyurethane is used to manufacture skateboard wheels:**
- Polyurethane is durable and resistant to wear, making it ideal for skateboard wheels that endure constant friction and impact with various surfaces. This ensures that the wheels have a long lifespan.
- Polyurethane has excellent shock-absorbing properties, which helps to cushion the rider from impacts and vibrations when skating over rough terrain or landing tricks.
- Polyurethane's hardness can be precisely controlled during manufacturing, allowing for the production of skateboard wheels with different durometers (a measure of hardness). Softer wheels offer better grip and a smoother ride, ideal for cruising or rough surfaces, while harder wheels provide faster speeds and are better suited for tricks and smooth surfaces like skateparks.

Any three @ 6 + 6 + 6

(c) (i) **Negative effects of plastic waste on marine life:**

- Marine animals mistake plastic for food, leading to blocked digestive systems and death.
- Animals can become entangled in plastic debris.
- Plastic waste damages coral reefs, smothers marine habitats and disrupts nesting sites, leading to ecosystem imbalances.
- Microplastics from degraded plastics are ingested by marine life and then enter the food chain.
- Declines in marine life affect fishing industries and tourism, leading to financial losses for coastal communities.

8

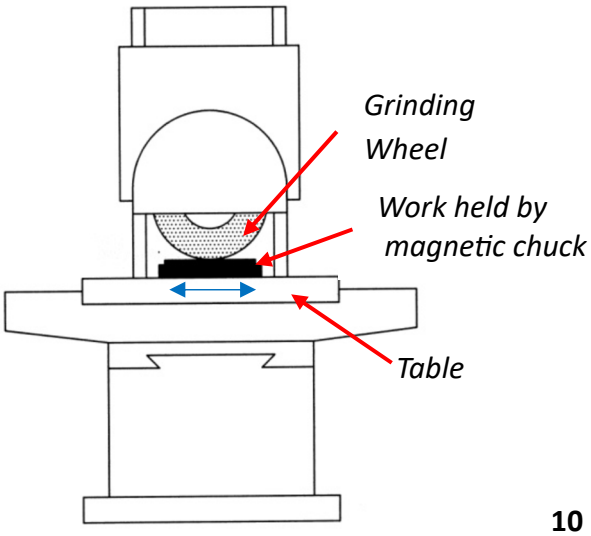
(ii) **Thermoplastics** can be recycled relatively easily. They can be melted and reshaped multiple times without significantly altering their chemical structure or properties.
The recycling process for thermoplastics typically involves collecting, sorting, cleaning, shredding, and then melting the plastic before remoulding it into new products. Examples include polyethylene (PE), polypropylene (PP) and polyvinyl chloride (PVC).

Thermosetting plastics are much harder to recycle. Once they have been cured and set into a rigid form, they cannot be remelted or reshaped due to their cross-linked chemical structure. This makes traditional recycling methods like melting and remoulding ineffective.
Recycling thermosetting plastics usually involves grinding them into small particles that can be used as fillers or in composite materials, rather than being reformed into new plastic products.

8

Question 8 (50 Marks)

(a) (i) Precision surface grinding is 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.



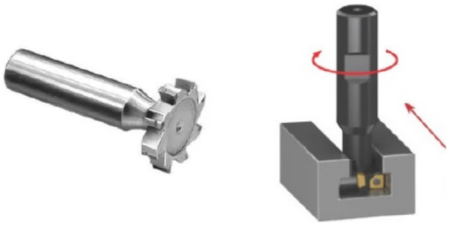
10

(ii) Safety hazards associated with using a grinding machine:

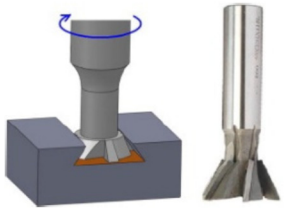
- The grinding process generates sparks, metal fragments and abrasive particles that can fly off at high speeds. These can cause injuries to the eyes and skin.
- The grinding wheel can break or shatter if it is damaged, improperly mounted, or used at excessive speeds. This can result in serious injuries from high-speed projectiles.
- The workpiece may become loose and dislodge if appropriate clamping is not applied.

3 + 3

(b) (i) T-slot cutters have a T shaped profile and are generally used for creating inverted T-slots on machine tables and beds when fitted to a milling machine. A dovetail cutter will machine an angled profile suitable for dovetail joints.



Tee slot cutter



Dovetail cutter

(ii) Advantages of using tungsten carbide insert tips:

- Tungsten carbide tools will retain their cutting edge at high temperatures more effectively than HSS.
- Long life and cost effective.
- Easily replaced, do not require sharpening.

(iii) Methods used to prolong tool life:

- Use cutting fluids when machining.
- Choose suitable cutting tools for each machining process.
- Run the machine at the correct speed to prevent heat build-up.
- Ensure that the machine is in good condition and not prone to excessive vibration.
- Use the correct cutting speed and cutting feed for the material.

(iv) Benefits of laser measuring systems in CNC machining:

High Precision and Accuracy - Laser measuring systems provide extremely accurate and precise measurements, allowing CNC machines to produce parts with tight tolerances. This precision is critical for industries requiring exact specifications, such as aerospace, automotive and medical devices.

Non-Contact Measurement - Laser systems measure without physically touching the workpiece, reducing the risk of damage to delicate or complex surfaces. This non-invasive approach helps maintain the integrity of both the tool and the part being machined, ensuring consistent quality.

Increased Efficiency - Laser measuring systems enable real-time measurements and feedback during the machining process, allowing for immediate adjustments. This reduces downtime, minimises errors and increases overall production efficiency.

(v) Rancidity of the cutting fluid is caused by bacteria and other microscopic organisms growing and eventually causing bad odours to form. Most cutting fluids contain bactericides that control growth of bacteria and make fluids more resistant to rancidity. Other ways of preventing rancidity include continuous filtering of the cutting fluid to keep it clean, by keeping the fluid at proper strength and out of direct sunlight.

Any three @ 6 + 6 + 6

(c) (i) **Continuous chips** are formed during metal machining in long ribbons without breakage. This chip formation is characterised by high cutting speeds and minimum friction between tool face and metal on ductile materials such as mild steel and aluminium.

Discontinuous chips are small segments produced by metal cutting processes. These chips usually fracture without deformation and are associated with brittle materials such as brass, bronze and cast iron. Discontinuous chips produce effective cutting conditions for brittle materials but may have a tearing action on ductile materials resulting on poor surface finish and excessive wear on tools.

8

(ii) **Built-up edge (BUE)** is common in machining, particularly in lathe work, where material being cut adheres to the cutting tool, forming a small deposit or "edge" on the tool's tip. This occurs when the pressure and temperature at the cutting zone cause workpiece material to weld to the cutting tool.
BUE impacts safety as it increases the risk of tool failure and machine stress, potentially leading to accidents if the tool breaks or the workpiece is ejected.
BUE can negatively affect the surface finish of the workpiece, it can leave behind rough or irregular surfaces, resulting in a poor finish with increased roughness. BUE can lead to inaccuracies in the dimensions of the machined part.

8

OR

(c) (i) Stepper motors, as used in control of robotic CNC milling technology, provide incremental movement and allow for precision control of movement. They have good reliability of operation and good power output to give torque required for operation. Stepper motors are driven by control circuits.

Feedback sensors are used in robotic CNC milling machines to continuously monitor and measure the output value of the system and compare the output value with the desired value. If the value of the output and input are not equal, then an adjustment is made.

4 + 4

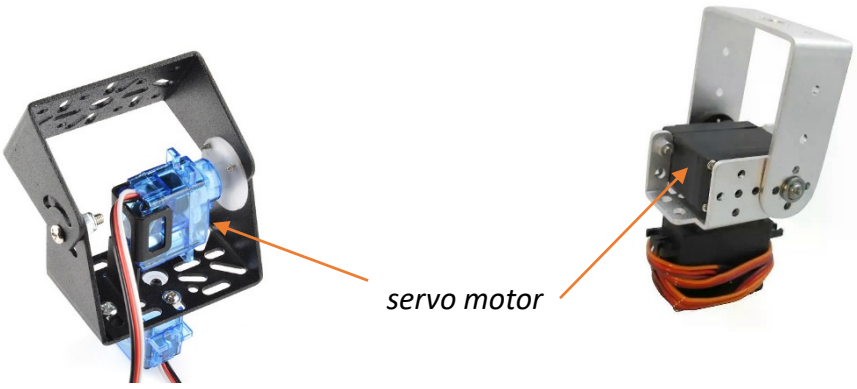
(ii) Subtractive manufacturing is a term for various controlled machining and material removal processes that start with solid blocks, bars, rods of plastic, metal or other materials that are shaped by removing material through cutting, boring, drilling and grinding. In CNC milling, these processes are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

8

Question 9 (50 Marks)

(a) (i) Mechanism to tilt the camera unit:

Suggested solution – other valid solutions accepted
Precise tilt control of the camera's position can be achieved using servomotors, which are often used in conjunction with a control unit to execute the tilt movements.



Mechanism to rotate the camera unit:
High-precision motors paired with a belt drive system are used to achieve precise positioning and variable speed rotation.
The motor is attached to the top smaller pulley and the camera shaft is attached to the larger pulley.
A DPDT switch can be used to ensure the motor rotates in both forward and reverse.

10

(ii) Remote control robots can be used for the following:

- To inspect pipelines, storage tanks, etc. in hazardous environments.
- Underwater inspections for ships and submerged structures.
- Search and rescue operations to locate survivors in disaster zones and unstable buildings.
- Monitor crop health and support systems remotely.
- Performing surveillance and military operations.
- Remote healthcare for patients and equipment.

6

(b) (i) Operation of bevel gears:
Bevel gears have a conical shape and are used to transmit rotational power through shafts that are typically at an angle of 90° to each other. They are typically used for motor transmission differential drives.

(ii) Benefits of using thermostatic control in home heating systems:
Thermostats allow you to control the temperature of each room individually, rather heating the entire floor or entire property at the same time.
This reduces energy wastage and excessive heat use, resulting in financial savings. Smart thermostats allow the user to control their heating system remotely.

(iii) Mechanism name: Ratchet and pawl
Suitable uses include ratchet strap, winch mechanism on trailer, fishing reel, ratchet spanner, turnstile, etc.

(iv) A single acting cylinder is a pneumatic output device that requires compressed air to make the piston move. If the air is removed the piston will return because of the spring.

No compressed air

Force of air moves ram

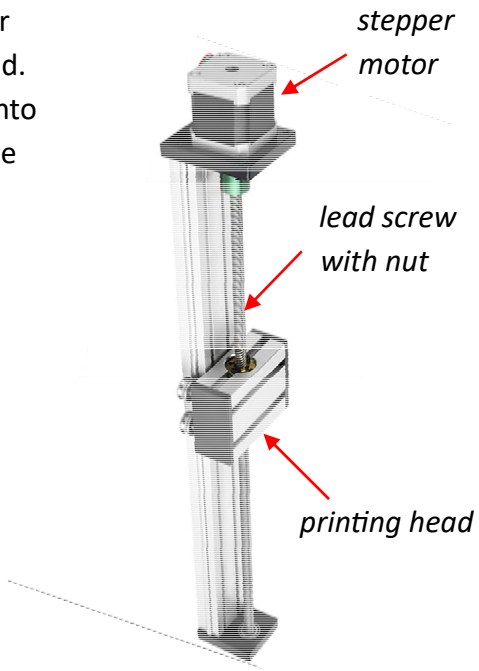
Compressed air applied

(v) A capacitor is an electronic component that stores and releases electrical energy.
It consists of two conductive plates separated by an insulating material (dielectric). When a voltage is applied, electrons accumulate on one plate, creating a negative charge, while the other plate becomes positively charged. This creates an electric field between the plates, storing energy.
When the circuit allows current to flow, the capacitor discharges, releasing the stored energy. Capacitors are used for energy storage, filtering and timing applications in electrical and electronic circuits.

Any three @ 6 + 6 + 6

(c) (i) A leadscrew mechanism would be suitable for controlling the movement of the printing head. The leadscrew will translate turning motion into linear motion. The pitch or lead is the distance the nut travels along the screw for every complete revolution. A stepper motor will rotate the leadscrew precisely to ensure that the printing head will raise and lower the correct distance.

Suggested solution - other viable solutions are acceptable.



8

(ii) Function of the limit switch:

Limit switches are used to detect the presence or absence of an object. The limit switch in the 3D printer is used to define the limit of travel of the printing head. As the printing head reaches its lowest position it engages the limit switch and prevents it from travelling too far and causing damage to the machine.

8

OR

(c) (i) The benefits of the solar carport:

- Energy Generation
  Solar carports are equipped with solar panels on their roofs, allowing them to generate renewable energy from sunlight. This energy can be used to power nearby buildings, charge electric vehicles or be fed back into the grid, reducing energy costs and dependence on fossil fuels.
- Vehicle Protection
  Solar carports provide shade and protection for vehicles parked underneath. This helps protect cars from weather elements like rain, snow and UV rays, which can prolong the life of the vehicle's paint and interior while keeping the car cooler in hot weather.

4 + 4

(ii) Solar energy is harnessed by solar panels or photovoltaic (PV) cells that are installed on the roof of the carport. The captured sunlight is converted from direct current (DC) to alternating current (AC) and either used immediately or stored in batteries.

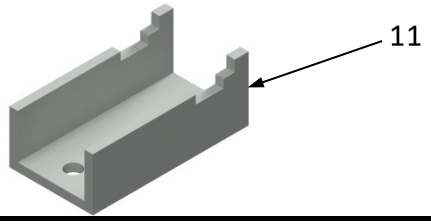
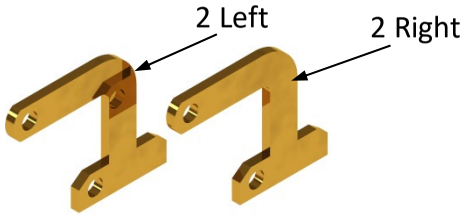
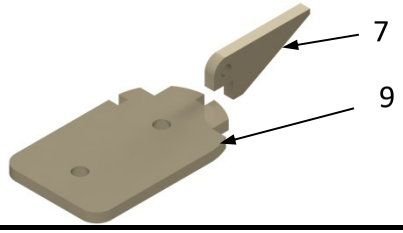
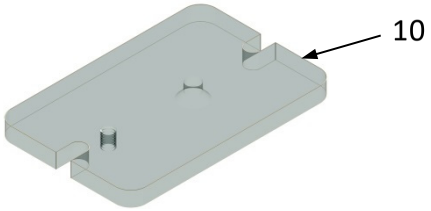
The energy is then supplied to an electric vehicle (EV) through a charging station, where it recharges the vehicle’s battery.

In some cases, EVs can also use integrated solar panels for direct energy generation, although this is usually supplementary. This process enables the use of clean, renewable energy to power electric vehicles, reducing reliance on fossil fuels and lowering carbon emissions.

8

Coimisiún na Scrúduithe Stáit
State Examinations Commission

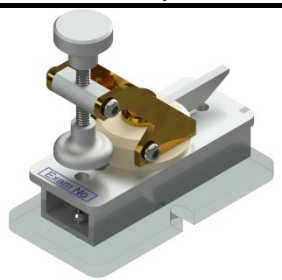
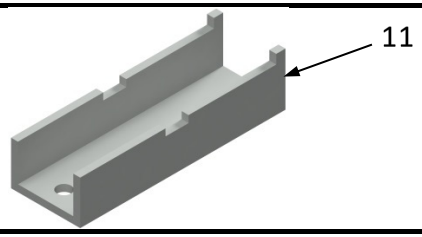
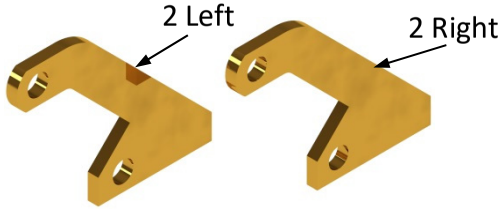
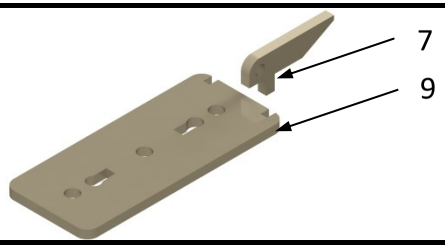
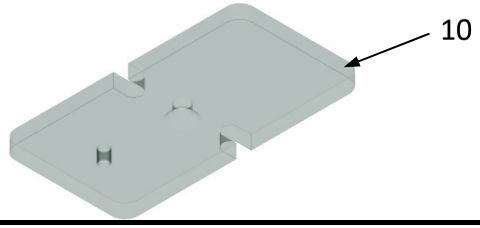
Day 1 – Leaving Certificate – Engineering – Practical Examination – Marking Scheme - 2025

Section	Part Number	Pictorial Sketch / Description	Concept		Mark	Mark
1	All Parts of Test-piece		Assembly – 5 Function – 10 Finish – 5		20	20
2	Part 11		Part 11 - 20 Marks	Marking Out	5	20
				10 mm × 3 mm Slots	5	
				Length, Ø5.5 mm Holes	5	
				Top Profile	5	
3	Parts 2		Part 2 Left - 10 Marks	Marking Out, Ø5.5 mm Holes	5	20
				External Profile	5	
			Part 2 Right - 10 Marks	Marking Out, Ø5.5 mm Holes	5	
				External Profile	5	
4	Parts 7 and 9		Part 7 - 5 Marks	Marking Out, Ø4.2 mm Hole, External Profile	5	20
			Part 9 - 15 Marks	Marking Out, Ø5.5 mm Holes	5	
				4mm Locking Slots	5	
				External Profile and Recess × 2	5	
5	Part 10		Part 10 - 20 Marks	Marking Out	5	20
				Drill and Tap M5, Drill and CSK Ø5.5 mm	5	
				Length and R6 mm Radii	5	
				6mm Slots	5	

100 Marks (× 1.5 = 150 Total)

Coimisiún na Scrúduithe Stáit
State Examinations Commission

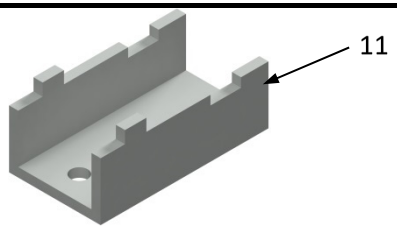
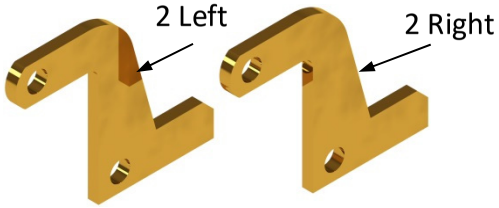
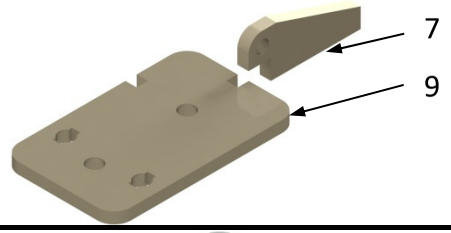
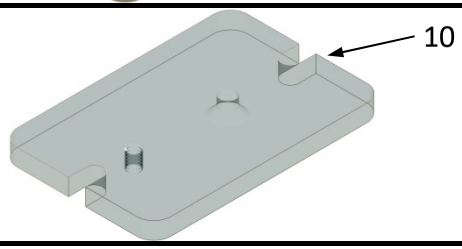
Day 2 – Leaving Certificate – Engineering – Practical Examination – Marking Scheme - 2025

Section	Part Number	Pictorial Sketch / Description	Concept		Mark	Mark
1	All Parts of Test-piece		Assembly – 5 Function – 10 Finish – 5		20	20
2	Part 11		Part 11 - 20 Marks	Marking Out	5	20
				10 mm × 3 mm Slots	5	
				Length, Ø6 mm Holes	5	
				Top Profile	5	
3	Parts 2		Part 2 Left - 10 Marks	Marking Out, Ø5.5 mm Holes	5	20
				External Profile	5	
			Part 2 Right - 10 Marks	Marking Out, Ø5.5 mm Holes	5	
				External Profile	5	
4	Parts 7 and 9		Part 7 - 5 Marks	Marking Out, Ø4.2 mm Hole, External Profile	5	20
			Part 9 - 15 Marks	Marking Out, Ø5.5 mm Holes	5	
				4mm Locking Slots	5	
				External Profile and 3 mm Recess × 2	5	
5	Part 10		Part 10 - 20 Marks	Marking Out	5	20
				Drill and Tap M5, Drill and CSK Ø5.5 mm	5	
				Length and R6 mm Radii	5	
				6mm Slots	5	

100 Marks (× 1.5 = 150 Total)

Coimisiún na Scrúduithe Stáit
State Examinations Commission

Day 3 – Leaving Certificate – Engineering – Practical Examination – Marking Scheme - 2025

Section	Part Number	Pictorial Sketch / Description	Concept		Mark	Mark
1	All Parts of Test-piece		Assembly – 5 Function – 10 Finish – 5		20	20
2	Part 11		Part 11 - 20 Marks	Marking Out	5	20
				10 mm × 3 mm Slots	5	
				Length, Ø5.5 mm Holes	5	
				Top Profile	5	
3	Parts 2		Part 2 Left -10 Marks	Marking Out, Ø5.5 mm Holes	5	20
				External Profile	5	
			Part 2 Right -10 Marks	Marking Out, Ø5.5 mm Holes	5	
				External Profile	5	
4	Parts 7 and 9		Part 7 - 5 Marks	Marking Out, Ø4.2 mm Hole, External Profile	5	20
			Part 9 - 15 Marks	Marking Out, Ø5.5 mm Holes	5	
				4mm Locking Slots	5	
				External Profile & Internal 3 mm Recess × 2	5	
5	Part 10		Part 10 - 20 Marks	Marking Out	5	20
				Drill and Tap M5, Drill and CSK Ø5.5 mm	5	
				Length and R6 mm Radii	5	
				6mm Slots	5	

100 Marks (× 1.5 = 150 Total)

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