Coimisiún na Scrúduithe Stáit

State Examinations Commission

Leaving Certificate 2023

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, 2023

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 5% gnáthráta an bhónais.

Bain úsáid as an ngnáthráta i gcás 225 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 2023

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 **(c)** 5 **(d)** 3 + 2 **(e)** 5 **(f)** **Any one** @ 5 **(g)** 3 + 2 **(h)** 3 + 2 **(i)** 3 + 2 **(j)** 3 + 2 **(k)** 3 + 2 **(l)** 5 **(m)** 3 + 2	**(a)** **(i)** 5 **(ii)** 3 + 2 **(b)** 4 + 3 + 3 **(c)** 10 **(d)** **Any two** @ 5 + 5 **(e)** **Any two** @ 5 + 5	**(a)** **(i)** 4 **(ii)** 8 **(iii)** 2 + 2 **(b)** **(i)** 10 **(ii)** 4 **(iii)** 4 **(c)** **(i)** 8 **(ii)** 8

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 (a) and (b) **and** either part of (c)
(a) **(i)** 8 **(ii)** 2 + 2 **(iii)** 4 **(b)** **(i)** 2 + 2 + 2 **(ii)** 3 + 3 **(iii)** 6 **(c)** **Any two** @ 8 + 8	**(a)** **(i)** 4 + 4 **(ii)** 4 **(iii)** 4 **(b)** **(i)** 9 + 3 **(ii)** 3 **(iii)** 3 **(c)** **Any two** @ 8 + 8	**(a)** **(i)** 10 **(ii)** 3 + 3 **(b)** **Any three** @ 6 + 6 + 6 **(c)** **(i)** 8 **(ii)** 4 + 4 **OR** **(c)** **(i)** 8 **(ii)** 4 + 4

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

Sample answers and Marking Scheme

Note: **The solutions presented are examples only.**
All other valid solutions are acceptable and are marked accordingly.

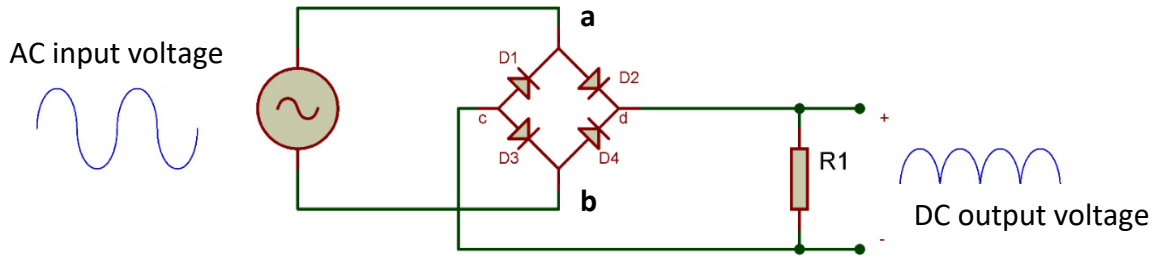
Question 1 (50 Marks)

(a)

Advantages of 'smart' glasses.	Disadvantages of 'smart' glasses.
• Hands-free operation • Can incorporate augmented reality (AR) capabilities • Can personalise information based on location, preferences or activity • Can gather information in 'real-time'	• Limited battery life • Privacy concerns with permissions of the capture of images • Screen limitations on visual clarity at this early stage of development • Cost and accessibility

3 + 2

(b) Bridge rectifier: Used to convert mains supply alternating current (AC) to the direct current (DC) needed for welding. The rectifier basically consists of Silicon diodes, which ensure the flow of current in one direction giving DC output. This is most commonly used with arc welding equipment.



The input AC signal is applied at terminals **a** and **b** with the output across the load resistor R1.

5

(c) In engineering drawing, the limits are the maximum and minimum dimensions of a component. This promotes mass production of component parts and can facilitate interchangeability and replacement of components.

5

(d) Flexibility is enhanced with foaming, low density yet keeps structural integrity, very good strength to weight ratio, will absorb impact and dissipate energy, chemical and water resistant, etc.

3 + 2

(e) **Metallic bond:**
Cations are bonded by a 'sea' of electrons giving metals that are usually malleable, ductile and conductive. The movement of the electrons promotes conductivity in the metal.

5

(f) **(i)** **Ivan Sutherland**

Ivan Sutherland (born 1938) is an American computer scientist and internet pioneer, widely regarded as a developer of computer graphics.

(ii) **Eileen Gray**

Irish-born architect and influential furniture designer, Eileen Gray was a pioneer of the modern Movement in Architecture since the 1920's with furniture designs in a range of materials. Her furniture is still in great demand with her Bibendum chair still in production.

(iii) **Dugald Clerk.**

Scottish engineer who designed the world's first successful two-stroke engine in 1878 and patented it in England in 1881.

Any one @ 5

(g) **Health benefits of using high efficiency particulate air (HEPA) purifiers:**

- HEPA purifiers are highly effective at capturing common allergens such as pollen, mould spores, pet and dust mites.
- Can filter airbourne particles such as dust, smoke, bacteria and some viruses.
- Enhanced respiratory health.

3 + 2

(h) **Benefits of using pneumatics over electrical power:**

- Can be employed in hazardous situations where electric spark might be a danger.
- Air can be stored and used when needed.
- Strong and precise action, non toxic.
- Range of applications in a production situation.
- Reduced chance of electrical shock.
- Can be easily programmed for a sequence of actions, etc.

3 + 2

(i) **Advantages of using anodised aluminium:**

- Enhanced corrosion resistance.
- Improved hardness and wear resistance.
- Anodising offers a wide range of colour options and finishes, making it a popular choice for decorative applications.
- The anodised layer acts as an insulator, preventing direct electrical contact with the aluminium substrate.
- Anodised aluminium is fully recyclable, allowing for the recovery and reuse of the material.

3 + 2

(j) The CNC lathe has a full cover machine guard, interlocking switching, simulation capabilities to test programmes and prevent accidents, emergency stop button, limit switching on carriage, etc.

3 + 2

(k) Charging is completed without trailing leads, phone connections are not subjected to wear, tidy storage, this unit charges multiple devices, etc.

3 + 2

(l) Creep is the slow deformation over time resulting from a constant force acting on the material. It occurs as a result of long-term exposure to high levels of stress that are below the yield strength of the material, the constant operation of a jet engine will create an environment for creep to be a potential source of failure.

5

(m) Set-up costs and maintenance are high, can create a hazard for shipping, weather conditions are variable, integrating wave energy into existing power grids can be complex, etc.

3 + 2

Question 2 (50 Marks)

(a) (i) Extended Reality (XR)

Extended Reality (XR) encompasses various immersive technologies including Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR). XR refers to the blending of the physical and virtual worlds, creating a spectrum of experiences that range from completely virtual environments to the augmentation of real-world environments with virtual elements.

5

(ii) Benefits of Extended Reality (XR)

- XR creates highly immersive and interactive experiences that captivates attention and engages the user.
- XR allows for realistic simulations of complex scenarios such as training simulations for high-risk professions like aviation and healthcare.
- This technology allows architects, engineers and designers to visualise and interact with 3D models and designs.
- Remote collaboration can be facilitated easily.

3 + 2

(b) (i) Virtual Reality (VR)

Virtual Reality refers to the use of computer-generated simulations to create a fully immersive digital environment that completely replaces the real world. Users wear VR headsets that typically consist of a display screen and motion sensors. These headsets block out the real world and present a virtual environment that users can see and hear.

(ii) Augmented Reality (AR)

Augmented Reality overlays digital content onto the real world, enhancing the user's perception and interaction with their physical surroundings. AR is experienced through devices like smartphones, tablets, smart glasses or headsets equipped with cameras and sensors. These devices capture the real-world environment and overlay virtual objects, information or graphics onto it, which users can see and interact with in real-time.

(iii) Mixed Reality (MR)

Mixed Reality combines elements of both VR and AR, allowing users to interact with virtual objects that are seamlessly integrated into the real world. Users wear headsets or glasses that combine the capabilities of VR (computer-generated simulations) and AR (overlaying virtual objects onto the real world). These devices use sensors and cameras to track the user's position and enable real-time interactions with the virtual objects.

4 + 3 + 3

(c) Extended Reality (XR) immersive technology has the potential to provide learners of the future with more engaging and effective learning experiences.

- XR allows students to visualise abstract or complex concepts in a more tangible and immersive manner, this can facilitate deeper comprehension and retention of knowledge.
- This enables interactive and hands-on learning experiences. Students can actively engage with virtual objects, conduct experiments, manipulate simulations and solve problems in a virtual environment. This experiential learning approach fosters critical thinking, problem-solving skills and collaboration among students.
- XR technology can transport students to different locations and eras without leaving the classroom.
- It allows for personalised learning experiences tailored to individual student needs. Virtual environments can adapt to the student's pace, level of understanding and learning style.
- Simulation training can develop skills.
- XR can enhance speed of learning and focus on learning styles that suit the learner.

10

(d) (i) Gaming and entertainment:

Extended reality (XR) is transforming gaming and entertainment by providing immersive experiences that blend the virtual and real worlds. With virtual reality (VR), players can be fully immersed in realistic virtual environments, interacting with objects and characters. Augmented reality (AR) overlays digital content onto the real world, enabling interactive gaming experiences in our physical surroundings. Mixed reality (MR) combines virtual and physical elements, creating seamless and interactive experiences. These XR technologies also extend to location-based entertainment, live streaming and gamified experiences, enriching the way we play games and consume entertainment content.

(ii) Vehicle design and development:

Extended reality (XR) is changing vehicle design and development by providing immersive and efficient tools for engineers and designers. Through virtual reality (VR), designers can create and evaluate vehicle prototypes in realistic virtual environments, allowing for quicker designs and cost savings. Augmented reality (AR) enables engineers to overlay digital information onto physical vehicles, aiding in assembly, maintenance and troubleshooting processes.

(iii) Surgical applications and physiotherapy:

Surgeons can use virtual reality (VR) to plan complex procedures, visualise patient-specific anatomy and practice surgical techniques in a realistic virtual environment, leading to improved precision and reduced risks. In physiotherapy, augmented reality (AR) can assist therapists by guiding exercises, tracking progress and enhancing rehabilitation processes.

(iv) Real estate property viewing:

With virtual reality (VR), potential buyers can explore realistic 3D virtual tours of properties from anywhere, saving time and travel costs. Augmented reality (AR) allows users to overlay digital information, such as furniture placement or renovation possibilities, onto real-world spaces, enabling them to visualise and customise properties before making purchasing decisions.

Any two @ 5 + 5

(e) (i) Privacy:

XR devices like virtual reality (VR) headsets and augmented reality (AR) glasses often capture and collect personal data, raising concerns about data privacy and security. XR experiences may involve the collection and processing of sensitive user information, such as biometric data, location data and behavioural patterns, these may lead to privacy breaches or unauthorised access. There is a risk of increased surveillance and the potential for invasion of personal space and privacy in both public and private settings.

(ii) Social engagement:

Prolonged use of XR devices, such as virtual reality (VR) headsets, may isolate individuals from their physical surroundings and limit face-to-face interactions, potentially leading to a decrease in social connections. The immersive nature of XR experiences can make it challenging to maintain a healthy balance between virtual and real-world relationships resulting in a loss of social skills and decreased empathy. The potential for anonymity in XR environments may lead to online harassment, bullying or other negative social behaviours.

(iii) Implementation costs:

The initial investment required for high-quality XR devices, such as VR headsets or AR glasses, can be prohibitive for individuals with limited financial resources. The development and implementation of XR applications often involve specialised expertise and resources, leading to extra expenses. Maintaining and updating XR hardware and software can also have ongoing costs, making it a barrier for widespread adoption and accessibility.

Any two @ 5 + 5

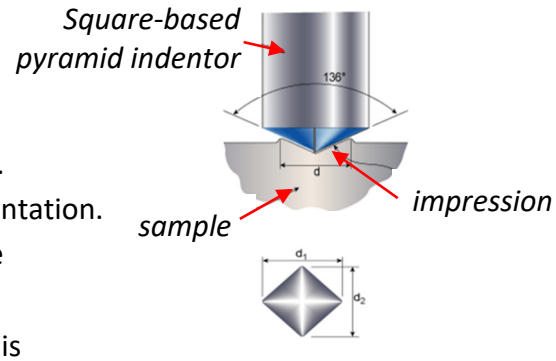
Question 3 (50 Marks)

(a) (i) Material hardness:

Hardness can be described as the ability of a material to resist denting and scratching.

4

(ii) Vickers hardness test:



A hard metal point, called an indenter, is pressed into the surface of the material being tested with a measured force.
Softer materials will produce a deeper indentation.
The test piece is considerably thicker than the indentation.
The test material is placed on a table, which can be adjusted for height.

- 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 provides accurate results on a full range of test pieces.

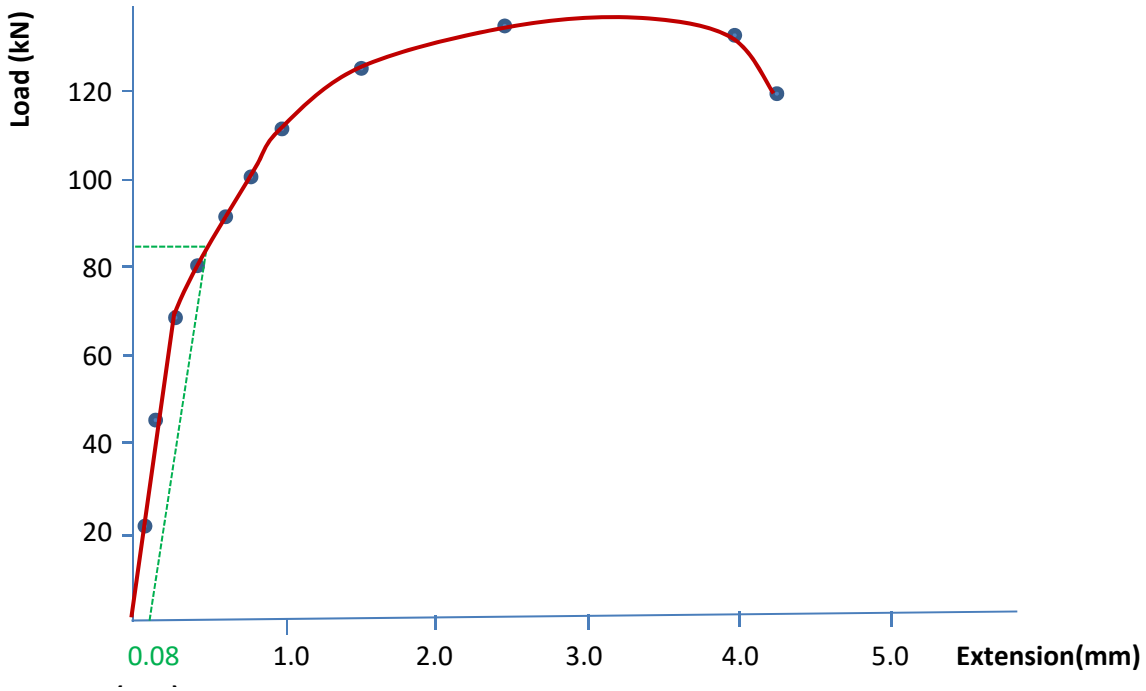
8

(iii) **Advantages:** Stainless steel gives an attractive shiny finish, it will maintain a hygienic surface, is hard wearing, etc.

Disadvantages: Stainless steel is not an environmentally friendly material compared to other countertop materials as it is challenging to produce and fabricate, gives a 'cold' feel to a kitchen, etc.

2 + 2

(b) (i) Draw load-extension graph



10

(ii) **U.T.S.** = $\frac{\text{Max. Load}}{\text{C.S.A.}}$ = $\frac{135}{\pi . (8^2)}$ = **0.67 kN/mm²**

4

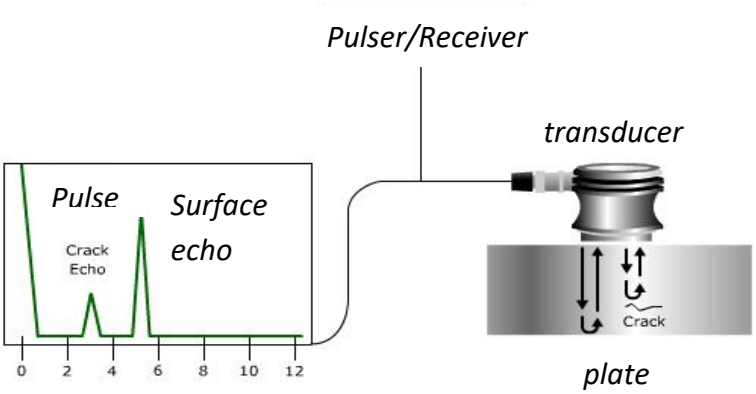
(iii) From the graph: **84 kN**

0.1% proof stress = $\frac{84}{\text{C.S.A}}$ = **0.42 kN/mm²**

4

(c) (i) Ultrasonic non-destructive testing:

A quartz crystal is used to generate high frequency vibrations and passed over the material to be tested. If the material has internal defects, vibrations will be reflected quicker back to the receiver and displayed on a screen. It is used to test thick components such as castings and forgings for defects. It is quick and has the ability to probe deeply without damaging the piece. Ultrasonic wave generation and use is safe for humans, therefore no extra safety precautions need to be taken.



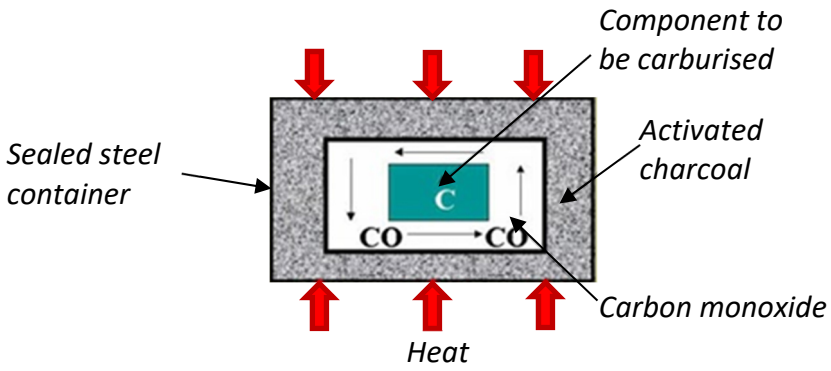
8

(ii) **Macroscopic** 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

Question 4 (50 Marks)

(a) **(i)** *Suggested answer other solutions accepted*
Pack Method Carburising



The piece is packed in a box with a carbon rich material such as charcoal and placed in a furnace at 920˚C (above UCT). This allows the carbon to diffuse into the piece.
The longer the component is in the furnace the greater the depth of penetration of carbon.
The result is a very hard coarse outer shell.
Grain refining is necessary to prevent cracking and this is done by putting the piece into a bath of molten salt at 780˚C for half an hour and then quenching it in water.

8

(ii) **Reasons for case hardening the chuck arbour:**

- 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.

2 + 2

(iii) Case hardening gives a hard, abrasion resistant outer surface yet has reduced brittleness due to the softer inner core, it is less likely to break on impact compared to a fully hardened product, etc.

4

(b) **(i)** **A =** Liquidus line
B = Solidus line
C = Eutectoid line / Lower Critical Temperature (LCT) line

2 + 2 + 2

(ii) **D =** At the eutectoid point, during the cooling process, the single-phase austenite (γ) transforms into a mixture of two distinct phases: ferrite (α) and cementite (Fe_3C). This transformation is known as the eutectoid transformation. It is a crucial process that affects the microstructure and properties of the steel.
E = This is a single-phase liquid of 4.3% carbon at the eutectic temperature 1147 ^oC which converts into solid austenite and cementite.

3 + 3

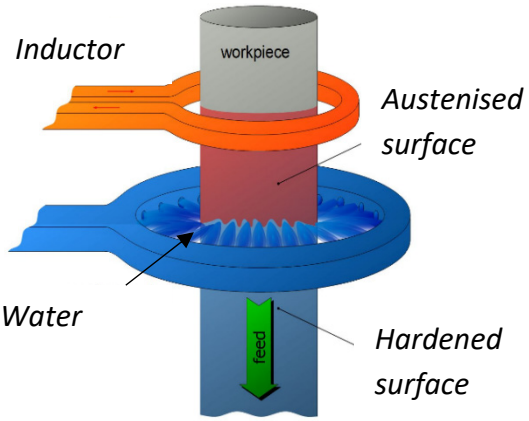
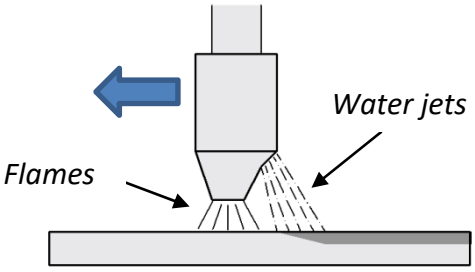
(iii) Austenite is a high-temperature phase with an FCC crystal structure, forming above the critical temperature and dissolving higher carbon contents (in excess of 0.76% carbon). Pearlite is a BCC microstructure that forms during the eutectoid transformation of austenite and consists of alternating layers of ferrite and cementite. It forms at temperatures below the eutectoid temperature of 723 ^oC with a carbon content around the eutectoid composition.

6

(c) **(i)** **Annealing**: The primary purpose of annealing is to relieve internal stresses, improve ductility and refine the grain structure of the metal. It is used to make the metal more malleable and reduce brittleness. The slow cooling rate will make a metal softer. Annealing is often employed to prepare the metal for further processing, such as machining or forming operations.
Normalising aims to refine the grain structure and produces a finer and more uniform microstructure compared to annealing. It will enhance mechanical properties and improve

the strength and toughness of the metal. It is typically used to achieve uniformity and consistent properties throughout the metal, making it suitable for applications where strength and toughness are crucial.

(ii)

Induction Hardening	**Flame Hardening**
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. 	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. 

(iii) 18/10 stainless steel is used in applications including kitchenware, cutlery and food processing equipment. The numbers 18 and 10 refer to the percentages of chromium (Cr) and nickel (Ni) present in the alloy.
Chromium (18%) provides corrosion resistance, durability and oxidation resistance.
Nickel (10%) enhances the corrosion resistance of the stainless steel, improves its ductility and toughness, and also contributes to its aesthetic appeal.

Any two @ 8 + 8

Question 5 (50 Marks)

(a) (i) **A = Vacancy Defect**
This is where there is an atom missing from the lattice.

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

4 + 4

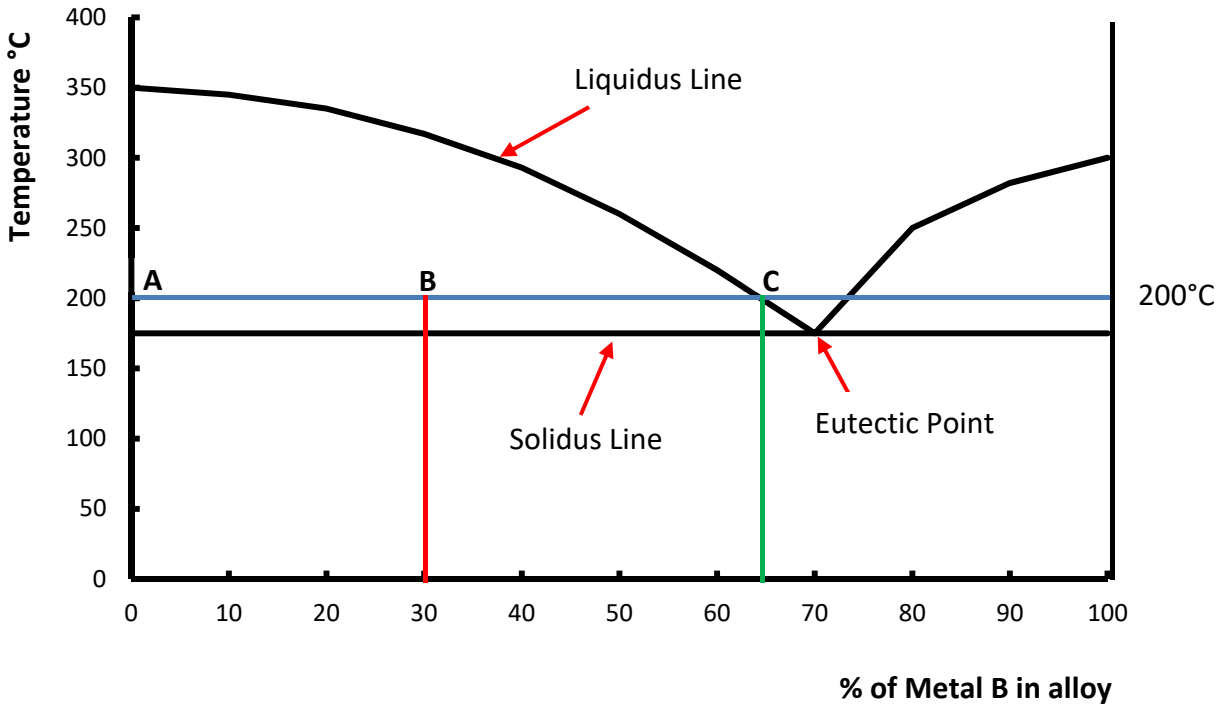
(ii) Interstitial defects can increase the hardness and strength of a metal as dislocations can be more difficult to move. Ductility is reduced and brittleness can be increased. Interstitial defects may reduce electrical and thermal conductivity with disruption of the regular patterns of atoms.

4

(iii) Substitutional defect.

4

(b) (i) **Draw the thermal equilibrium diagram**



Draw equilibrium diagram **9**
Identify liquidus, solidus lines and eutectic point **3**

(ii) Ratio of the phases at 200 °C = $\frac{|AB|}{|BC|} = \frac{30}{35}$

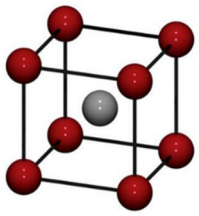
3

(iii) The metal transforms from a liquid to a solid at 175˚C without going through a pasty phase.

3

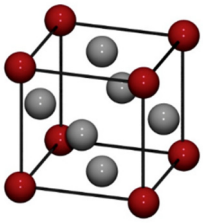
(c) **(i)** **BCC Structure**

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.

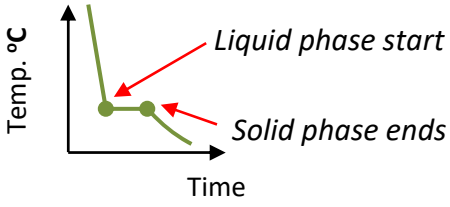


FCC Structure

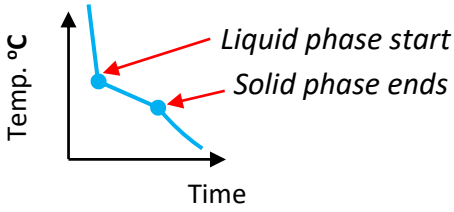
The face-centred cubic unit cell has atoms at each of the eight corners of a cube with one atom in the centre of each of the cube faces (total of 14 atoms). FCC metals tend to be soft and ductile over a range of temperatures. Examples include gamma iron, aluminium, nickel, silver, copper and gold.



(ii) When the temperature of a cooling molten metal alloy is plotted against time, a cooling curve is formed.



Cooling curve for a pure metal.



Cooling curve for an alloy.

(iii) 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, copper-nickel and iron-chromium are examples.

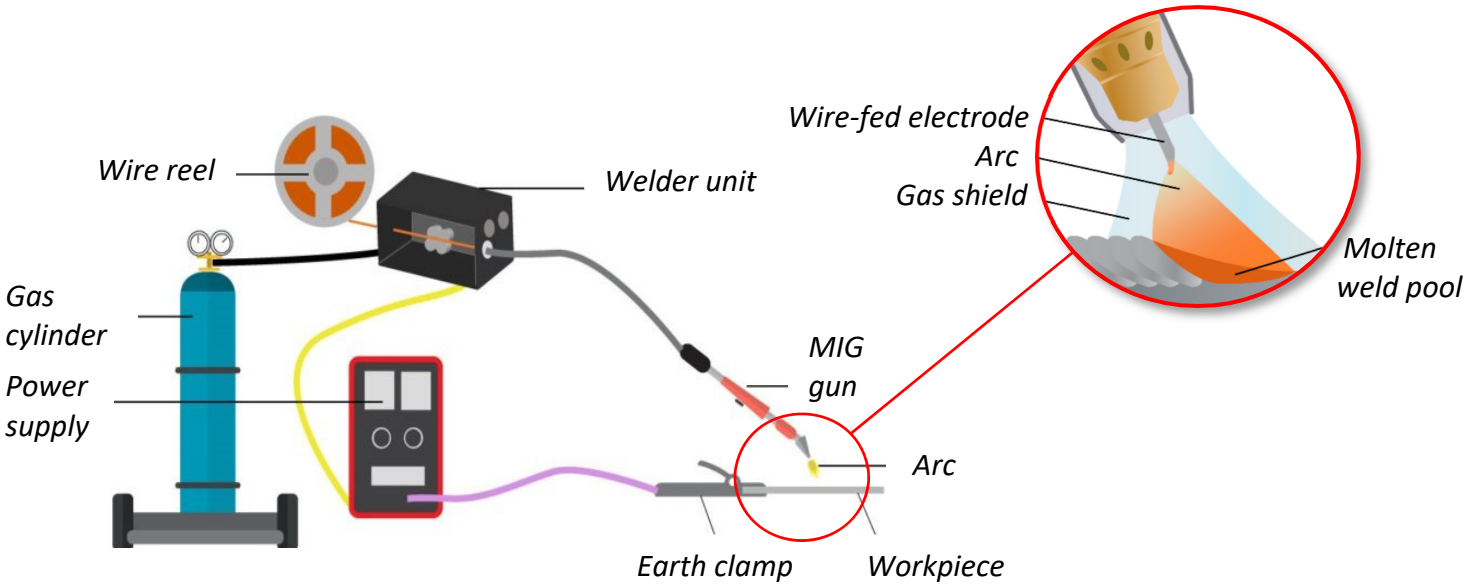
In a **Partial Solubility alloy**, the two metals are completely soluble in the liquid phase. Both metals are also soluble in each other (in a solid state) to a limited degree. This is denoted by the solvus lines.

Any two @ 8 + 8

Question 6 (50 Marks)

(a) (i) MIG Welding

MIG Welding is a semi-automatic process. A consumable bare wire electrode is fed continuously into the weld pool area through the welding torch. An inert gas, such as Argon, creates a protective shield around the weld pool giving a fluxing action. The feed rate and flow rate of the gas are set by the operator. This allows the operator to guide the torch along the weld once the arc is generated between the electrode and the work. MIG welding does not produce a slag on the weld.



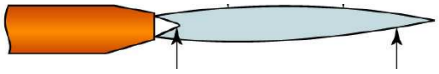
10

(ii) Reasons for MIG welding:

- MIG will weld thin sheet steel without burning holes in the metal. Most classic cars are made from sheet steel.
- MIG can be used for a variety of metals and thicknesses.
- It is relatively easy to use.
- MIG gives a clean weld with minimal spatter.

3 + 3

(b) (i) Neutral flame:



- A balanced proportion of oxygen and acetylene.
- Maximum combustion as all carbon from the acetylene is used.
- Has a working temperature of up to 3300°C.
- The most extensively used flame for oxy-acetylene welding.

(ii) MIG, TIG, resistance welding, Submerged Arc welding, Electro-slag welding, etc. are suitable for automated welding.

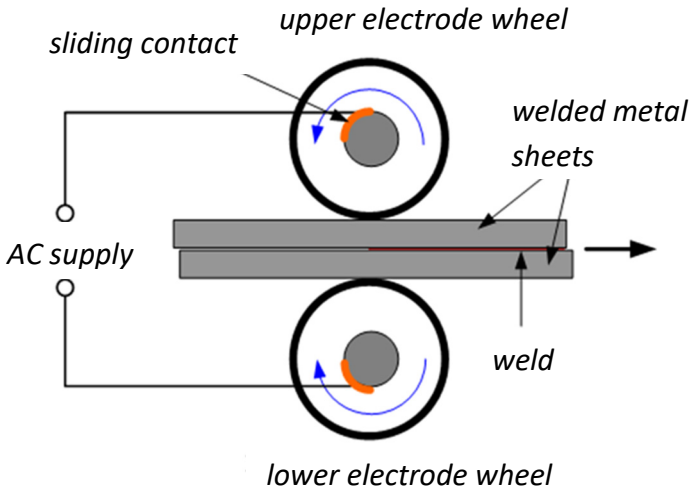
(iii) The weld can be protected from oxidation and potential weaknesses in SAW, fumes are reduced, arc is not visible, reduced fire and heat hazards, etc.

(iv) Multi-runs produce a superior quality weld which is more refined than a single run weld. Multi-run welds have a post heating effect on the previous weld which will improve its quality.

(v) The primary function of a pressure regulator is to control the pressure of the gases being supplied to the welding torch. Regulators prevent gas pressure from exceeding safe limits and give precise control of the gas flow rate.

Any three @ 6 + 6 + 6

(c) **(i)** **Resistance seam welding:**



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.
Used when continuous weld is required e.g. fuel tanks, drums, domestic radiators.

8

(ii) Advantages for using seam welding: the weld is designed to be leak-proof with a continuous seam of weld, it welds quickly with only localised heating which minimises warp on thin metal sheets used in fuel tanks, etc.

4 + 4

OR

(c) (i) **Visual SLAM** relies on cameras and visual information for simultaneous localisation and mapping, it relies on visual features and can struggle in low-light or featureless environments.
Laser SLAM utilises laser range finders or LiDAR sensors which give precise distance measurements, it is robust and precise in a variety of environmental conditions.

8

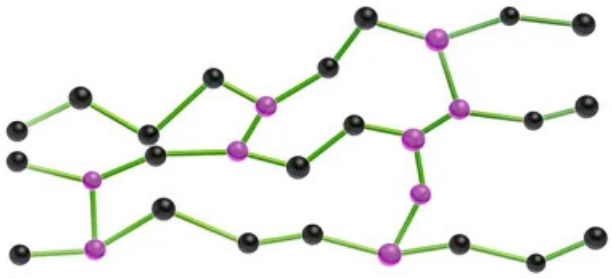
(ii) **Difficulties associated with the use of delivery robots:**

- A high degree of programming is necessary.
- Some customers will not accept robots for this role, it creates a less personal environment.
- Initial investment is high. It is a doubt if there is any real saving as they must be monitored by staff.

4 + 4

Question 7 (50 Marks)

(a) (i) A group of polymers consisting of linear chains that are coiled, entangled and are subject to minimal cross-linking. This irregular internal structure and bonding arrangement allows these materials to be very elastic at room temperature.



8

(ii) **Properties of polyurethane elastomers for running shoe soles:**

- Soft, deformable and flexible.
- Elastic at room temperature.
- Resilience to return to shape when forces of tension, torsion or compression are removed.
- Low permeability to air, gases, water and steam.
- Recyclability.
- Good electrical and thermal insulation.

2 + 2

(iii) Window seals, belts, gaskets, hoses, pipes, etc.

2 + 2

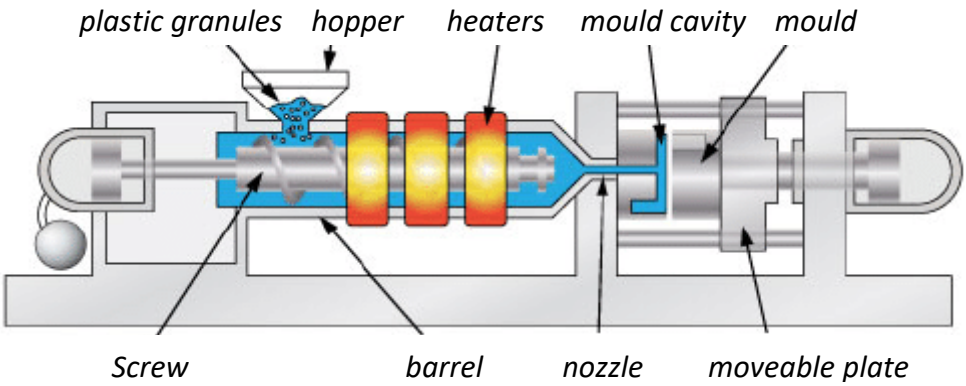
(b) **(i)** When two or more different monomers are added together, their result is called a copolymer and the process is called copolymerisation. It is similar to the process of metal alloying. Examples of copolymers include Acrylonitrile butadiene styrene (ABS), Nitrile rubber and Ethylene-vinyl acetate.

4

(ii) **Injection Moulding:**

- Granulated thermoplastic polymer is 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.

Injection Moulding Machine



10

(iii) A selection of plasticisers makes the polymer flexible, easier to mould and non-toxic. Pigments give the plastic hull its tinted colour.

2 + 2

(c) **(i)** Thermoplastics can generally be recycled, remoulded and used again. Polythene, acrylic and PVC are examples of thermoplastics.
Thermoset plastics are configured to be permanently moulded as they will not breakdown nor recycle effectively. Epoxy resins and polyurethanes are examples.

(ii) **Collect:** The plastic materials are gathered through municipal and industrial collection.
Sort: Different plastic materials are sorted by different polymer types.
Shred: The plastic materials are cut into small pieces, making them uniform and easier to process.

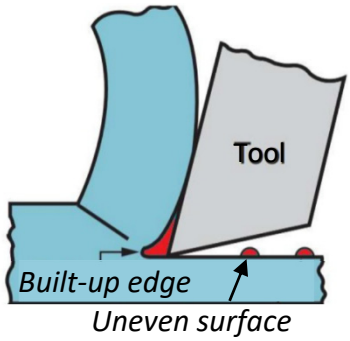
Wash: the plastic pieces are cleaned.
Fabricate: plastic pieces can be formed into beads and then used for remoulding.

(iii) Used to produce fencing panels as plastic wood, containers, insulation, waterproof membrane sheets, etc.

Any two @ 8 + 8

Question 8 (50 Marks)

(a) **(i)** **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 which is caused by incorrect machine speeds for the metal, machine feed rate, cutting fluids, etc. 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.



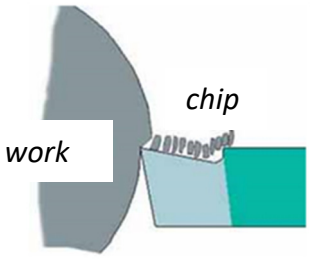
8

(ii) **Methods of preventing a built-up edge**

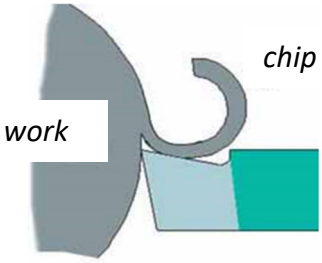
- Use of cutting fluids.
- Select correct cutting speed for the metal.
- Use appropriate machine speeds.
- Ensure good condition of the cutting tools in terms of geometry and sharpness.

2 + 2

(iii) **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 in poor surface finish and excessive wear on tools.



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.



2 + 2

(b) (i) Tapping a blind hole

- The component is turned to size.
- The component is drilled with the tapping hole size, ensure that the hole depth is measured using the lathe tailstock.
- The hole is tapped while ensuring that the chips are periodically emptied during tapping. This ensures that the chips do not clog up the hole. A taper tap is used first with a plug tap used to finish the thread to the bottom of the blind hole.

(ii) Safety precautions when using a milling machine:

- Keep work area clean to prevent machine grabbing tools or objects.
- Ensure workpieces are secured in place before operating the machine.
- Do not attempt to remove chips when the machine is running.
- Ensure all guards are clean and operating properly.
- Use appropriate speeds and feeds for the milling operation.
- Use suitable PPE.

(iii) The milling machine table can move in the X, Y and Z axes. This can be used to produce a variety of profiles. The drilling machine will drill holes effectively.

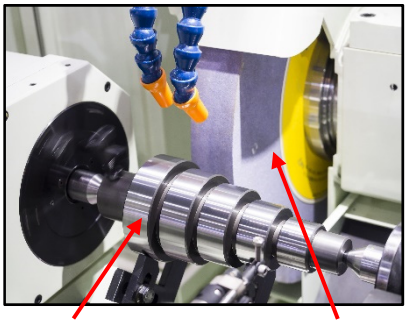
(iv) Additive manufacture, such as 3D printing does not waste material as products are precisely built layer by layer. Subtractive methods, such as using cutting and grinding machines, generate chips, swarf and waste material while fabricating objects.
Complex design can be produced quickly using additive methods compared to slower machining of complicated shapes.
Additive methods can be redesigned quickly, this is particularly effective for prototyping.
Manufacturing can be on-demand for additive techniques, this minimises storage.

(v) Use of tungsten carbide cutting tips:

- Tungsten carbide tools will retain their cutting edge at high temperatures more effectively than high speed steel (HSS).
- Experienced operators will ensure long tool life.
- Tools are not sharpened which is time consuming and dependent on the skill of the operator for effectiveness, inserts are replaced.
- Inserts can have a number of cutting edges integrated into their design.

Any three @ 6 + 6 + 6

(c) (i) **Cylindrical grinding:** This is used to produce cylindrical objects. The workpiece is held in a chuck, or between centres, and set to rotate. Then a grinding wheel, when brought into contact with the workpiece, will produce a smooth accurate cylinder. Long workpieces can be ground as the table can reciprocate and the wheel head can move towards the workpiece. Tapered work can also be carried out.



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(ii) Cylindrical grinding produces a high-quality finish on round workpieces.
It is a very accurate manufacturing process.
High quality parts are produced by precision grinding.
It is often used on very hard materials.

4 + 4

OR

(c) (i) CAD – computer aided drawing/ computer aided drafting uses programmes to design, edit and draw products on a computer.
CAM – computer aided manufacture will take CAD drawings and produce machined components using computer driven machines such as laser cutters.

8

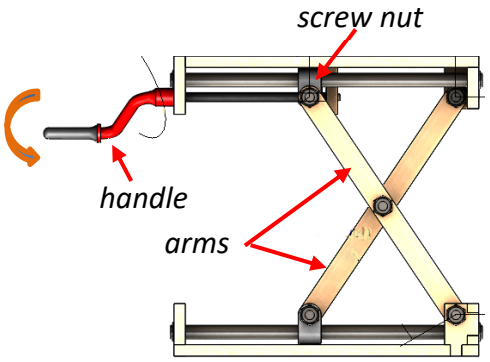
(ii) Integrated safety features in CNC laser cutting machines:

- Full cover screen to protect operators from the hazards of laser cutting.
- Sensors will detect if there is potential for materials to be destroyed by heat.
- Emergency stop buttons and fume extraction systems are integrated.
- Laser beams are protected from the operator and can be shut off.
- Interlocking guards will ensure safe operation of the machine.

4 + 4

Question 9 (50 Marks)

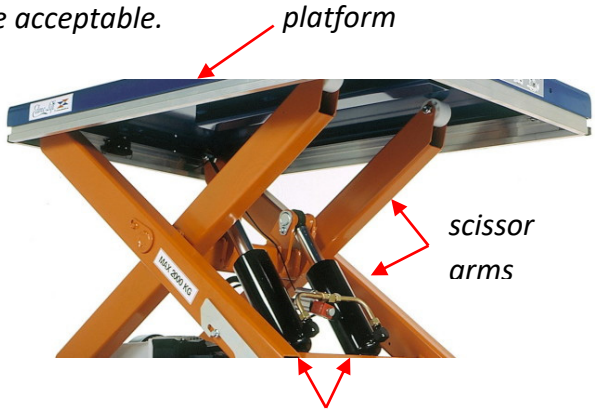
(a) **(i)** As the handle is rotated, the screw turns in the nut driving the arms to push closer. The platform will then raise with each rotation of the screw. To lower the platform the handle is turned in the opposite direction. This principle is also used in a scissors jack for a car.



8

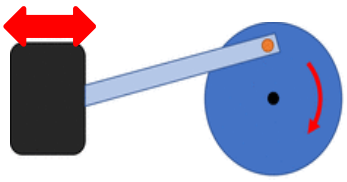
(ii) *Suggested solution - other viable solutions are acceptable.*

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.

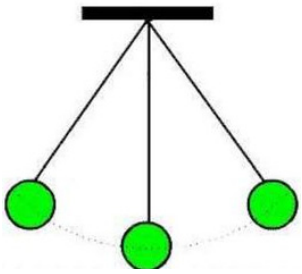


8

(b) **(i)** Reciprocating motion is a repetitive back-and-forth linear movement. It is found in a wide range of mechanisms including internal combustion engines.
Oscillating motion refers to the repetitive back-and-forth or to-and-fro movement of an object or a system about a central point or axis. An example is the pendulum of a clock or metronome.



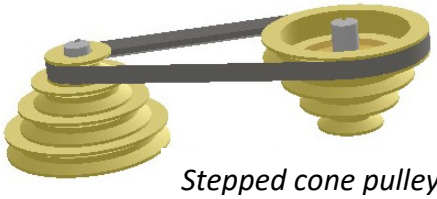
Reciprocating motion



Oscillating motion

(ii) Tension force in chair cables.
Centripetal and centrifugal forces of chairs swinging in a circle.
Gravity allows the ride to return to the ground.

(iii) A stepped cone pulley mechanism allows for various speeds of a machine. If the belt is on the smallest driving pulley, then it will have to be on the largest driven pulley and this gives a slow speed. If the belt is on the largest driving pulley, then it will have to be on the smallest driven pulley and this gives a fast speed.

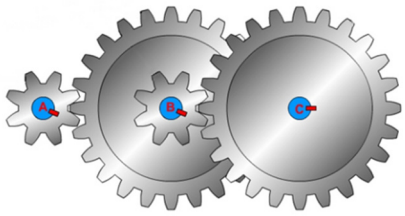


Stepped cone pulleys

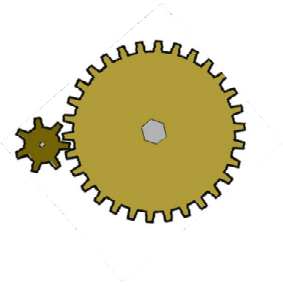
(iv) **Advantages of timing belt over a timing chain:**

- The timing belt provides a quieter drive.
- No lubrication required.
- It is easier to replace a belt.
- Smoother in operation.

(v) A compound gear train can achieve a large reduction or large increase in gear ratio using gear sizes that are not excessively big.
A simple gear train needs to have small gears driving large gears to achieve a significant reduction in speed. This impacts on the torque of the system.
Compound gears commonly use only two gear wheel sizes to achieve speed reduction, a series of these can be connected together.



Compound gear reduction 9:1

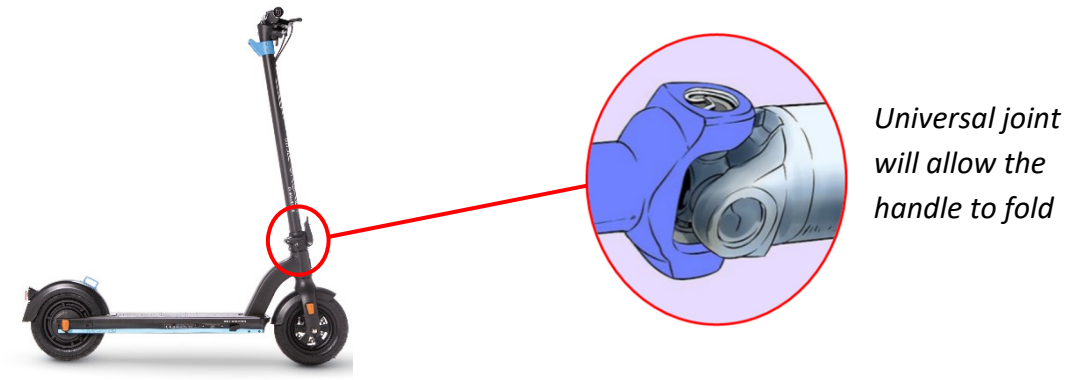


Simple gear reduction 3:1

(Any three) 6 + 6 + 6

(c) **(i)** *Suggested solution:*

The use of a universal joint inserted in the stem of the handle will allow the handle to fold.
A locking mechanism is required to keep the handle in the desired position.



Universal joint will allow the handle to fold

8

(ii) It will make storage and security of the scooter more practical.
It allows the scooter handle to be adjusted for each individual.
The scooter can be folded to travel on public transport making the product more environmentally friendly.

4 + 4

OR

(c) **(i)** Reduced electricity from the national grid is required.
LED lights use less electricity than traditional bulbs.
LED lights do not require as much maintenance or replacement.
It allows new attractive designs to be introduced.

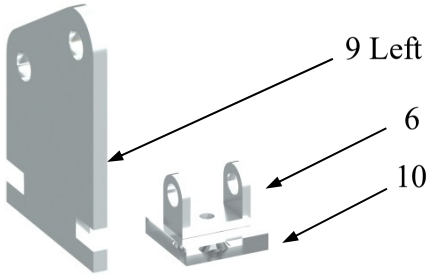
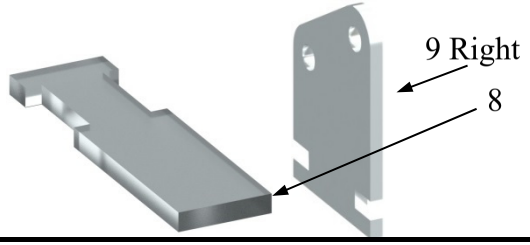
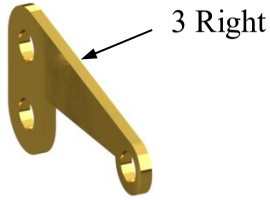
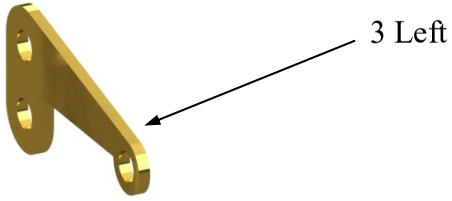
4 + 4

(ii) Solar energy is generated during daylight hours, stored in batteries and then lights are switched on at night.

8

Coimisiún na Scrúduithe Stáit
State Examinations Commission

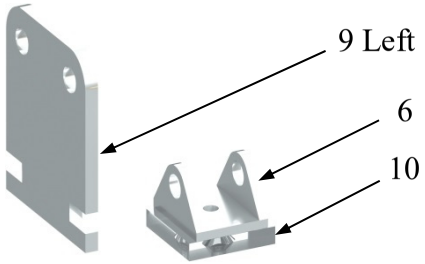
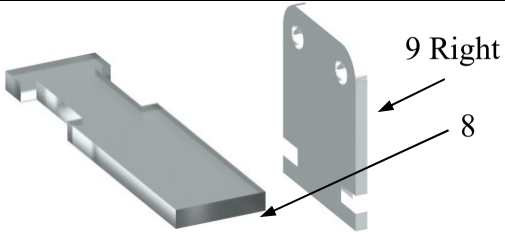
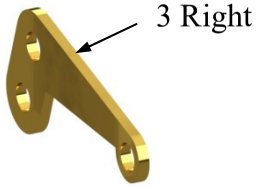
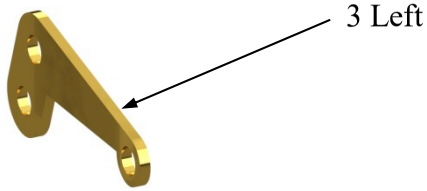
2023 Leaving Certificate Engineering Practical - Marking Scheme Day 1

Section	Part Number	Pictorial Sketch / Description	Concept		Mark	Mark
1	**All Parts of Test-piece**		**Assembly (5)** **Function (10)** **Finish (5)**		**20**	**20**
2	**Parts 6, 9 Left and 10**		**Part 6** 8 Marks	Marking Out, Ø5 and Ø8 mm Holes	**4**	**20**
				External Profile	**4**	
			Part 9 Left 10 Marks	Marking Out, Ø8 mm Holes	**4**	
				6 mm x 10 mm Slots & External Profile	**6**	
			Part 10 2 Marks	Marking Out, Ø5 CSK Hole	**2**	
3	**Parts 8 and 9 Right**		**Part 8** 10 Marks	Marking Out, Length 65 mm	**2**	**20**
				5 mm x 30 mm Slots	**8**	
			Part 9 Right 10 Marks	Marking Out, Ø8 Holes	**4**	
				6 mm x 10 mm Slots & External Profile	**6**	
4	**Part 3 Right**		**Part 3 Right** 20 Marks	Marking Out, Ø8 mm Holes	**4**	**20**
				7 mm Radius	**4**	
				10 mm Radii	**6**	
				Straight Profiles	**6**	
5	**Part 3 Left**		**Part 3 Left** 20 Marks	Marking Out, Ø8 mm Holes	**4**	**20**
				7 mm Radii	**4**	
				10 mm Radii	**6**	
				Straight Profiles	**6**	

100 Marks (× 1.5 = 150 Total)

Coimisiún na Scrúduithe Stáit
State Examinations Commission

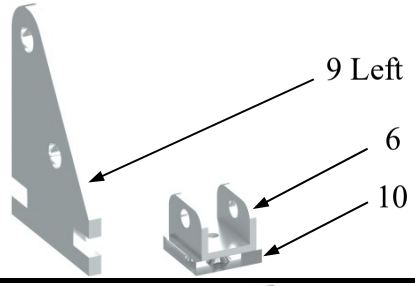
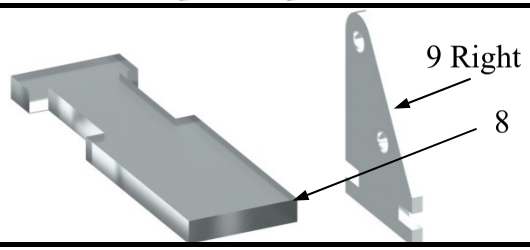
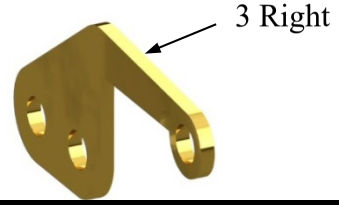
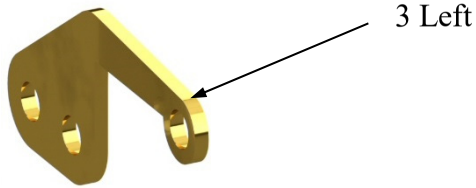
2023 Leaving Certificate Engineering Practical - Marking Scheme Day 2

Section	Part Number	Pictorial Sketch / Description	Concept		Mark	Mark
1	**All Parts of Test-piece**		**Assembly (5)** **Function (10)** **Finish (5)**		**20**	**20**
2	**Parts 6, 9 Left and 10**		**Part 6** 8 Marks	Marking Out, Ø5 and Ø8 mm Holes	**4**	**20**
				External Profile	**4**	
			Part 9 Left 10 Marks	Marking Out, Ø8 mm Holes	**4**	
				6 mm x 10 mm Slots & External Profile	**6**	
			Part 10 2 Marks	Marking Out, Ø5 CSK Hole	**2**	
3	**Parts 8 and 9 Right**		**Part 8** 10 Marks	Marking Out, Length 65 mm	**2**	**20**
				5 mm x 30 mm Slots	**8**	
			Part 9 Right 10 Marks	Marking Out, Ø8 Holes	**4**	
				6 mm x 10 mm Slots & External Profile	**6**	
4	**Part 3 Right**		**Part 3 Right** 20 Marks	Marking Out, Ø8 mm Holes	**4**	**20**
				7 mm Radius	**4**	
				10 mm Radii	**6**	
				Straight Profiles	**6**	
5	**Part 3 Left**		**Part 3 Left** 20 Marks	Marking Out, Ø8 mm Holes	**4**	**20**
				7 mm Radii	**4**	
				10 mm Radii	**6**	
				Straight Profiles	**6**	

100 Marks (× 1.5 = 150 Total)

Coimisiún na Scrúduithe Stáit
State Examinations Commission

2023 Leaving Certificate Engineering Practical - Marking Scheme Day 3

Section	Part Number	Pictorial Sketch / Description	Concept		Mark	Mark
1	**All Parts of Test-piece**		**Assembly (5)** **Function (10)** **Finish (5)**		**20**	**20**
2	**Parts 6, 9 Left and 10**		**Part 6** 8 Marks	Marking Out, Ø5 and Ø8 mm Holes	**4**	**20**
				External Profile	**4**	
			Part 9 Left 10 Marks	Marking Out, Ø8 mm Holes	**4**	
				6 mm x 10 mm Slots & External Profile	**6**	
			Part 10 2 Marks	Marking Out, Ø5 CSK Hole	**2**	
3	**Parts 8 and 9 Right**		**Part 8** 10 Marks	Marking Out, Length 55 mm	**2**	**20**
				5 mm x 30 mm Slots	**8**	
			Part 9 Right 10 Marks	Marking Out, Ø8 Holes	**4**	
				6 mm x 10 mm Slots & External Profile	**6**	
4	**Part 3 Right**		**Part 3 Right** 20 Marks	Marking Out, Ø8 mm Holes	**4**	**20**
				7 mm Radius	**4**	
				10 mm Radii	**6**	
				Straight Profiles	**6**	
5	**Part 3 Left**		**Part 3 Left** 20 Marks	Marking Out, Ø8 mm Holes	**4**	**20**
				7 mm Radii	**4**	
				10 mm Radii	**6**	
				Straight Profiles	**6**	

100 Marks (× 1.5 = 150 Total)