Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2022

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, 2022

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 250 @ 5%

Bain úsáid as an tábla seo i gcás na n-ábhar a bhfuil 250 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
188 - 190	9
191 - 196	8
197 - 203	7
204 - 210	6
211 - 216	5

Bunmharc	Marc Bónais
217 - 223	4
224 - 230	3
231 - 236	2
237 - 243	1
244 - 250	0

LEAVING CERTIFICATE

ENGINEERING-MATERIALS AND TECHNOLOGY

(Higher Level – 250 marks)

Marking Scheme 2022

Answer **any five** questions.

Question 1 – 50 marks	
Any ten @ 5 marks each.	
(a)	3 + 2
(b)	5
(c)	5
(d)	5
(e)	5
(f)	**Any one** @ 5
(g)	3 + 2
(h)	5
(i)	3 + 2
(j)	5
(k)	3 + 2
(l)	3 + 2
(m)	3 + 2

Question 2 – 50 marks		
Answer **all** parts of this question		
(a)	**(i)** 5	
	(ii) 5	
(b)	10	
(c)	**Any two** @ 5 + 5	
(d)	**Any two** @ 5 + 5	
(e)	5 + 5	

Question 3 – 50 marks		
Answer **all** parts of this question		
(a)	**(i)**	4
	(ii)	4 + 4
	(iii)	4
(b)	**(i)**	10
	(ii)	4
	(iii)	2 + 2
(c)	**(i)**	8
	(ii)	4 + 4

Question 4 – 50 marks		
Answer **all** parts of this question		
(a)	**(i)**	4
	(ii)	4 + 4
	(iii)	2 + 2
(b)	**(i)**	2 + 4
	(ii)	2 + 4
	(iii)	6
(c)	**(i)**	8
	(ii)	4 + 4

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

Question 6 – 50 marks		
Answer (a) and (b) **and** either part of (c)		
(a)	**(i)**	10
	(ii)	3 + 3
(b)	**Any three** @ 6 + 6 + 6	
(c)	**(i)**	4 + 4
	(ii)	8
OR		
(c)	**(i)**	4 + 4
	(ii)	4 + 4

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

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

Question 9 – 50 marks		
Answer (a) and (b) **and** either part of (c)		
(a)	**(i)**	8
	(ii)	4 + 4
(b)	**Any three** @ 6 + 6 + 6	
(c)	**(i)**	8
	(ii)	4 + 4
OR		
(c)	**(i)**	8
	(ii)	4 + 4

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

Question 1 (50 Marks)

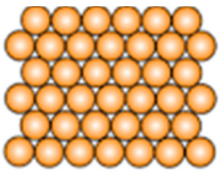
(a) **Health benefits of CO_2 monitors.**

- Creates awareness of air quality.
- Reduces the risk of Coronavirus transmission.
- Improved amounts of fresh air and oxygen circulating.
- Improved sleep quality.
- Increased cognitive function and boosts brain health.
- Boosts immune system.
- Reduces "sick building syndrome", etc.

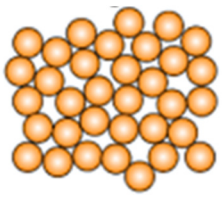
3 + 2

(b) Amorphous Structures - these structures have irregular and non-geometric patterns. e.g. Acrylic.

Crystalline Structures - these structures have regular, geometric and repeating molecular patterns e.g. BCC, FCC CPH.



Crystalline Structures



Amorphous Structures

5

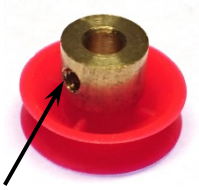
(c) **Clearance fit** is one in which two assembled parts are always free to move relative to each other in the assembly. In the clearance fit, the largest permitted shaft diameter is smaller than the diameter of the smallest hole. The difference between the size of the hole and the size of the shaft is defined as clearance.
Interference fit also known as a press fit, is a form of fastening between two tight fitting mating parts that produces a joint which is held together by friction after the parts are pushed together. In an interference fit, the smallest permitted shaft diameter is bigger than the largest diameter of the hole.

5

(d) The **100:1** ratio on this motor indicates that the output shaft is rotating 100 times slower than the input shaft. Therefore, if the input shaft is rotating at 2000rpm the output shaft is rotating at 20rpm. This is achieved by a series of gear reductions in a compound gear train.

5

(e) A pulley may be securely attached in a number of ways to the output shaft of the motor.
One such way is to use a pulley with a hub which can accommodate a grub screw. This grub screw will tighten against the flat part of the output shaft of the motor, holding it securely in place.



5

(f) **(i)** **Nikola Tesla**

Nikola Tesla (1856 – 1943) was a Serbian-American engineer and physicist made dozens of breakthroughs in the production, transmission and application of electric power.
He is best known for creating the first alternating current (AC) motor and developed AC generation and transmission technology.

(ii) **John McCarthy**

John McCarthy (1927 – 2011) was an American computer scientist and cognitive scientist. McCarthy was one of the founders of the discipline of artificial intelligence (AI). It was in the mid-1950s that McCarthy coined the term "Artificial Intelligence" which he would define as "the science and engineering of making intelligent machines".

(iii) **Alessandro Volta**

Alessandro Volta (1745 – 1827) was an Italian physicist, chemist, and pioneer of electricity and power who is credited as the inventor of the electric battery and the discoverer of methane. His invention of the electric battery provided the first source of continuous current.

Any one @ 5

(g) **Environmental benefits of hydrogen powered fuel cell vehicles:**

The biggest advantage to a hydrogen-powered fuel cell vehicle is that it only produces water and air, which are not harmful to the environment.
Driving hydrogen fuel-cell powered vehicles would eliminate greenhouse gases and help reduce air pollution.
Does not require large areas of land to produce hydrogen.

3 + 2

(h) Allotropy is the property of some chemical elements to exist in two or more different forms. Iron exists as a BCC structure up to approximately 910°C. Between 910°C and approximately 1390°C it exists as a FCC structure.

5

(i) **Benefits of powder coating steel frames:**

- Tougher, more durable coatings.
- Corrosion resistant.
- Consistent finish.
- No solvent disposal.
- Ease of application
- Quick process.

3 + 2

(j) Ensure adequate ventilation in the work area.
Use fume extraction system.
Do not breathe in fumes from the plume of smoke created by resin flux heating.
A risk assessment of the process and measures should be undertaken.

5

(k) Titanium is strong, long lasting and lightweight. Titanium is lighter than stainless steel and allows the designer to manufacturer a much larger club head that meets the weight specifications of a normal driver. Titanium does not corrode either.

3 + 2

(l)

Advantages of gas shielding	Disadvantages of gas shielding
• No slag on the weld. • Less toxic fumes produced.	• Difficult to use outdoors. • Cylinders need to be refilled.

3 + 2

(m)

Advantages of solar farms	Disadvantages of solar farms
• Renewable energy source. • Reduced electricity bills. • Diverse applications. • Low maintenance costs.	• Weather dependent. • Expensive to initially set-up. • Use up lots of space. • Solar energy is expensive to store.

3 + 2

Question 2 (50 Marks)

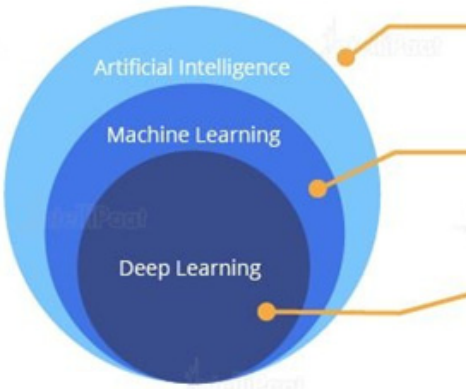
(a) (i) Artificial Intelligence

Artificial intelligence (AI) is a wide-ranging branch of computer science concerned with building smart machines capable of performing tasks that typically require human intelligence. Artificial Intelligence involves computers working in a way that simulates, mimics or augments human intelligence, and it is already part of your life. Airports use AI to route planes to the appropriate termini, banks use AI to search for suspicious activity on accounts.

5

(ii) **Machine learning** is the general term for when computers learn from data. It describes the intersect of computer science and statistics where algorithms are used to perform a specific task without being explicitly programmed; instead, they recognise patterns in the data and make predictions once new data arrives.

Deep learning algorithms can be regarded both as a sophisticated and mathematically complex evolution of machine learning algorithms. Deep learning describes algorithms that analyses data with a logic structure similar to how a human would draw conclusions.



Artificial Intelligence

Machine learning uses algorithms to learn from data and make informed decisions based on what it has learned.

Deep learning structures algorithms in layers to create an “artificial neural network” that can learn and make intelligent decisions on its own

5

(b) **Narrow artificial intelligence (weak AI)** is a specific type of artificial intelligence in which a learning algorithm is designed to perform a single task, and any knowledge gained from performing that task will not automatically be applied to other tasks.

Artificial general intelligence (strong AI) also known as artificial general intelligence (AGI) is a theoretical form of AI used to describe a certain mindset of AI development. Strong AI aims to create intelligent machines that are indistinguishable from the human mind. But just like a child, the AI machine would have to learn through input and experiences, constantly progressing and advancing its abilities over time.

10

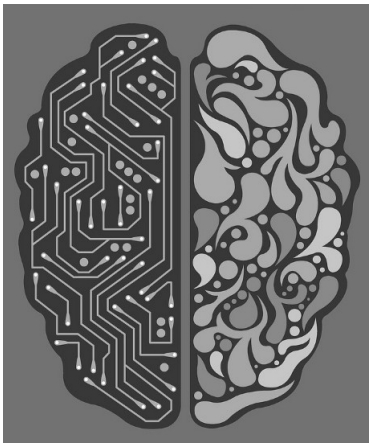
(c) (i) Reactive machines:

Reactive machines are basic in that they do not store "memories" or use past experiences to determine future actions. They simply perceive the world and react to it. IBM's Deep Blue, which defeated chess grandmaster Kasporov, is a reactive machine that sees the pieces on a chess board and reacts to them. It cannot refer to any of its prior experiences, and cannot improve with practice.

(ii) Limited memory:

Limited Memory machines can retain data for a short period of time. While they can use this data for a specific period of time, they cannot add it to a library of their experiences. Many self-driving cars use Limited Memory technology: they store data such as the recent speed of nearby cars, the distance of such cars, the speed limit, and other information that can help them navigate roads.

(iii) Theory of mind:



Psychology tells us that people have thoughts, emotions, memories, and mental models that drive their behaviour. Theory of Mind researchers hope to build computers that imitate our mental models, by forming representations about the world, and about other agents and entities in it. One goal of these researchers is to build computers that relate to humans and perceive human intelligence and how people's emotions are impacted by events and the environment. While plenty of computers use models, a computer with a "mind" does not yet exist.

(iv) Self-awareness:

Self-aware machines are the stuff of science fiction, though many AI enthusiasts believe them to be the ultimate goal of AI development. Even if a machine can operate as a person does, for example by preserving itself, predicting its own needs and demands, and relating to others as an equal, the question of whether a machines can become truly self-aware, or "conscious", is best left for philosophers.

Any two @ 5 + 5

(d) (i) Predictive maintenance:

Predictive maintenance utilises actual measured usage, operating conditions and equipment feedback to generate individualised predictions of impending issues.

Predictive maintenance has two primary objectives:

- Minimise the risk of failure: i.e. spot when something isn't working and implement a fix before a failure;
- Find existing relationships in data: i.e. examine available data, see where anomalies lie and predict parameters to change.

(ii) Supply chain management:

AI-lead supply chain optimisation software amplifies important decisions by using cognitive predictions and recommendations on optimal actions. This can help enhance overall supply chain performance. It also helps manufacturers with possible implications across various scenarios in terms of time, cost, and revenue.

(iii) Quality control:

The use of smart cameras and related AI-enabled software is helping manufacturers achieve improved quality inspection at speeds, latency, and costs beyond the capabilities of human inspectors.

Any two @ 5 + 5

(e) Economic benefits:

Artificial Intelligence (AI) has been around for quite some time now and AI is increasingly becoming a part of our day-to-day lives. The scope for innovation and development in AI is enormous and it will continue changing the world in diverse ways in the future. Benefits of AI include:

- Automation.
- Smart Decision Making.
- Enhanced Customer Experience.
- Medical Advances.
- Research and Data Analysis.
- Managing Repetitive Tasks, etc.

Ethical concerns:

In movies such as The Terminator, The Matrix, and many others, the movie industry placed into our shared imagination scenes demonstrating how more intelligent machines will take over the world and enslave or totally wipe humanity from existence. The potential for AIs to become more superior than any human intelligence paints a dark future for humanity. A robot vacuum is one thing, but ethical questions around AI in medicine, law enforcement, military defence, data privacy, quantum computing, and other areas are profound and important to consider.

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) Design considerations to prevent fatigue failure:

- Component size.
- Material choice.
- Avoid sharp corners – promote curved surfaces.
- Specific heat treatments where necessary.
- Environmental conditions.

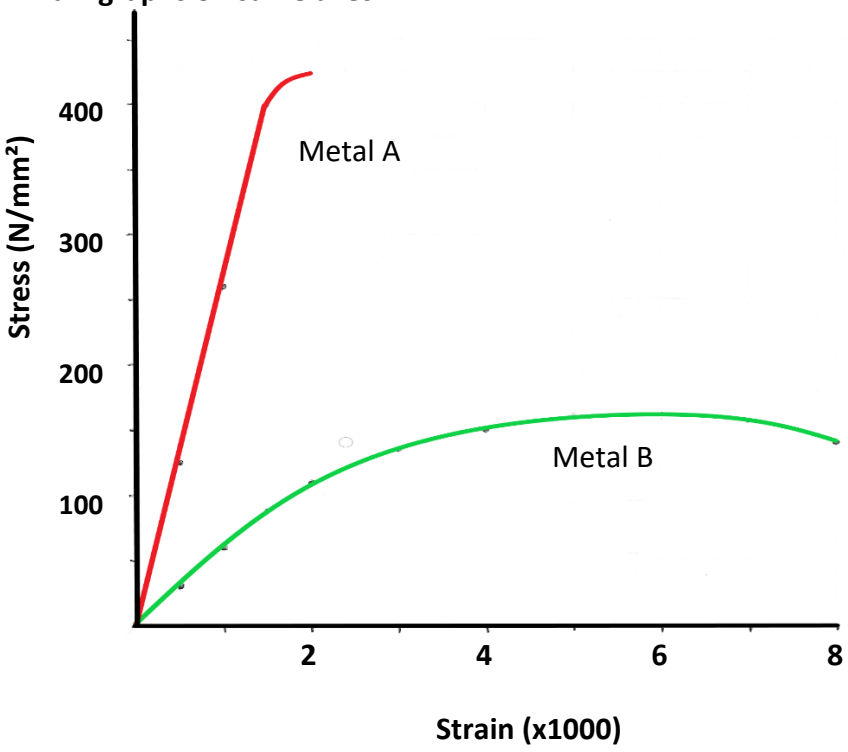
4 + 4

(iii) Quality control:

Quality control (QC) is a procedure or set of procedures intended to ensure that a manufactured product or performed service adheres to a defined set of quality criteria or meets the requirements of the client or customer. QC in engineering manufacture is crucial for standards to be maintained and adhered to.

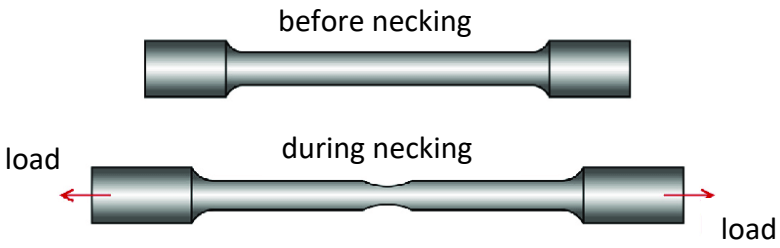
4

(b) (i) Draw graphs on same axes



10

(ii) At load value of 158N/mm², metal B will be in the "necking" phase of the tensile test. This is where the middle of the specimen is noticeably thinner than the rest of the specimen and with a little more stress the piece is going to fracture.



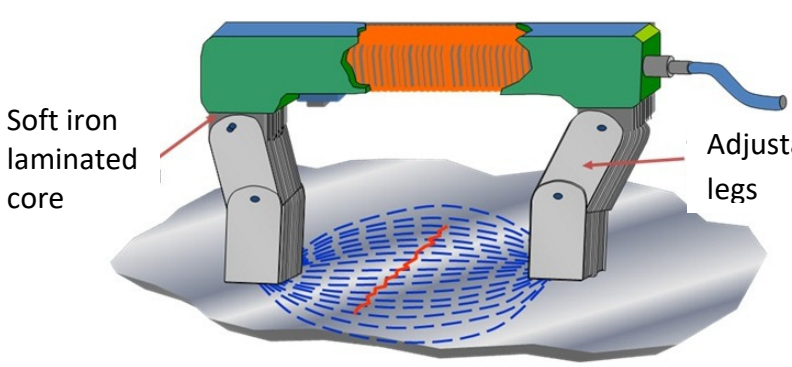
4

(iii) Young's Modulus of elasticity for metal A = 260 kN/mm²
Young's Modulus of elasticity for metal B = 60 kN/mm²

2 + 2

(c) (i) Magnetic particle testing:

In ferrous materials, cracks and cavities cause distortions in magnetic fields.
This technique involves passing a magnetic field through a ferro magnetic structure or component. Magnetic particles are applied to the magnetised component and any flaw will be shown by a distortion in the resultant magnetic field. Magnetic particle inspection produces strong results, enabling a thorough assessment of the materials and ensuring that safety standards are maintained.



8

(ii) Benefit of non-destructive testing (NDT) in gas and oil industries:

- Product will not be destroyed.
- Safe and clean NDT for the oil and gas industries.
- Speed – immediate results can be generated.
- Depth – thin and thick cross sections can be effectively tested.
- Portable – lightweight and portable to use in most situations.
- Accuracy – excellent at detecting large and small imperfections.

4 + 4

Question 4 (50 Marks)

(a) **(i)** Cast iron is an alloy of iron and carbon, just like steel, with the main difference being that cast iron has more carbon in it. Whereas steel requires a carbon content of no more than 2%, cast iron usually contains 2% to 3.5% carbon. The carbon content that gives cast iron a rough, slightly bumpy feel. Its higher carbon content makes cast iron more brittle than steel.

4

(ii) Cast iron is suitable for the construction of the bridge structure because of its ability to perform well in compression, resists corrosion, has high strength, is hard and tough. It casts well into the decorative shape of the bridge.

4 + 4

(iii) Cast iron can be used for frying pans, stoves, garden furniture, vices, etc.

2 + 2

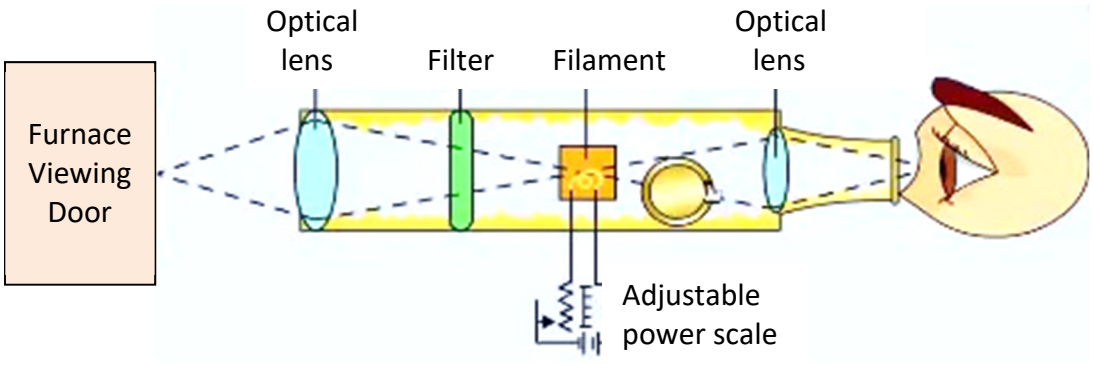
(b) **(i)** **A =** Eutectoid point.
This is where pearlite changes to austenite at 0.83% carbon content at 723°C. It is a solid to solid transformation.

2 + 4

(ii) The heat treatment process which occurs is annealing.
For annealing of 0.6% carbon content the steel is heated to 1000°C and soaked at this temperature until all of the workpiece is fully heated through.
The temperature of the furnace is gradually reduced so that the piece cools very slowly.
This causes the steel to become "soft", recrystallises the grains and makes the pieces more machineable and ductile.

2 + 4

(iii) 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 colour 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 can thus be taken.

Temperature too low Correct Temperature too high

6

(c) (i) Induction Hardening:

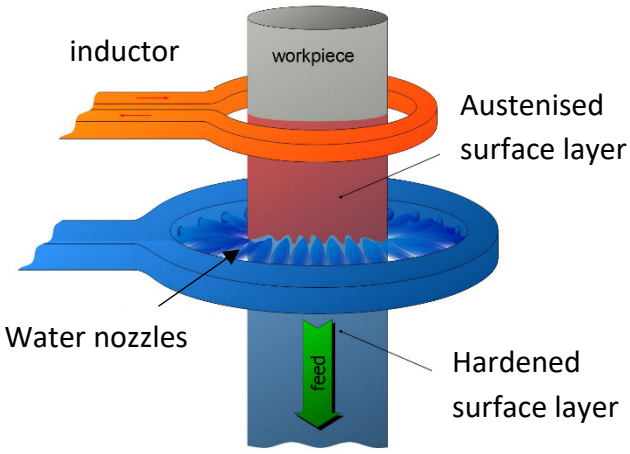
Induction hardening is a method of quickly and selectively hardening the surface of a metal part.

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.

Examples of where this process is used include the slide-ways on the center lathe and gears.



8

(ii) Safety hazards associated with induction hardening:

- High temperatures associated with the heating process – wear PPE.
- Electrical Alternating current supplying the coil can cause an electrical hazard.
- Spitting of the water on impacting the heated surface could lead to burning.
- Fumes could lead to dangerous gas levels in the work area.

4 + 4

Question 5 (50 Marks)

(a) (i) Dendritic growth:

As a metal reaches its cooling point small particles cool first. Solidification takes place in a pattern. This pattern is called Dendritic Growth and looks like the branches of a tree. Each small particle grows to form a crystal or grain. Crystals grow together to form a solid. This process is known as dendritic growth from Greek word "dendron" for treelike.

8

(ii) Substitute Defect

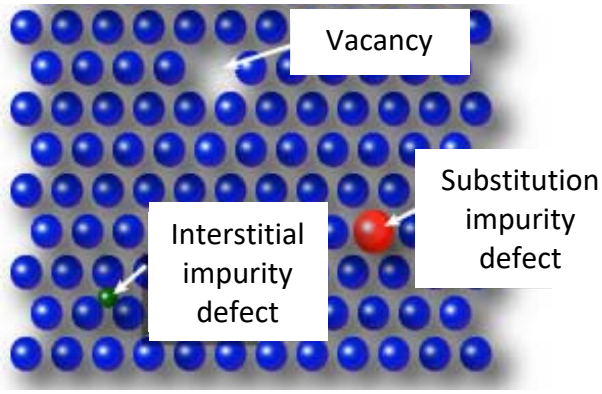
This is where foreign atoms replace the parent atoms.

Vacancy Defect

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

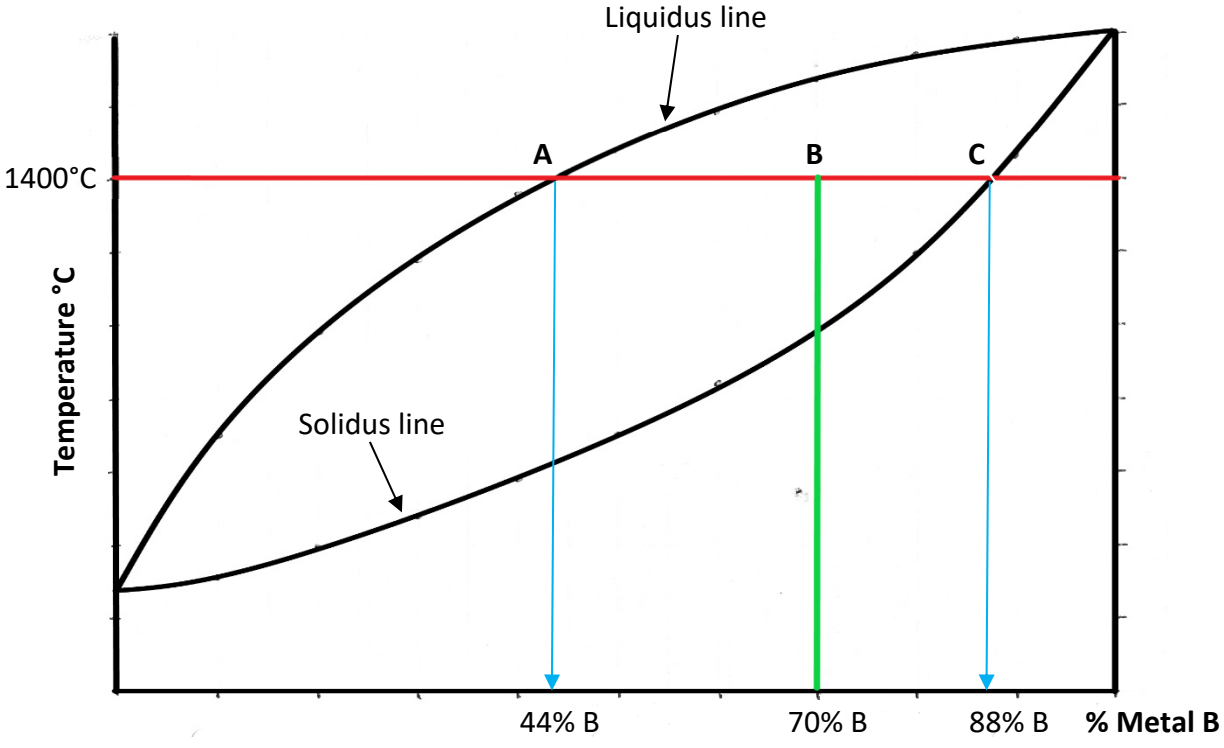
Interstitial Defect

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



4 + 4

(b) (i)



10

(ii) Ratio of Liquid to solid = $\frac{|AB|}{|BC|} = \frac{70 - 44}{88 - 70} = \frac{26}{18}$

4

(iii) A - 1120°C
B - 1500°C

2 + 2

(c) **(i)** **The impact of dislocation in crystal structures.**

- Dislocations can move as far as grain boundaries under a shear stress. Fine grained metals are stronger, stiffer and harder than coarse grained metals.
- Dislocations promote material malleability. The motion of dislocations allows slip deformation to occur.
- Heat treatments can impact on dislocation density caused by cold working.

(ii) **The possible corrosive effects of the environment on metal objects.**

- Ferrous metals (e.g. steel) may rust. This may cause early failure of steel products.
- An oxide layer can form on some metals such as aluminium giving a dull colour.
- Other metals may tarnish due to corrosion e,g. copper can turn a green colour.
- The presence of water (especially acidic water) can initiate electrochemical reactions in some metals e.g. stainless steel or zinc are impacted by seawater.

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(iii) **The refining of aluminium in Ireland.**

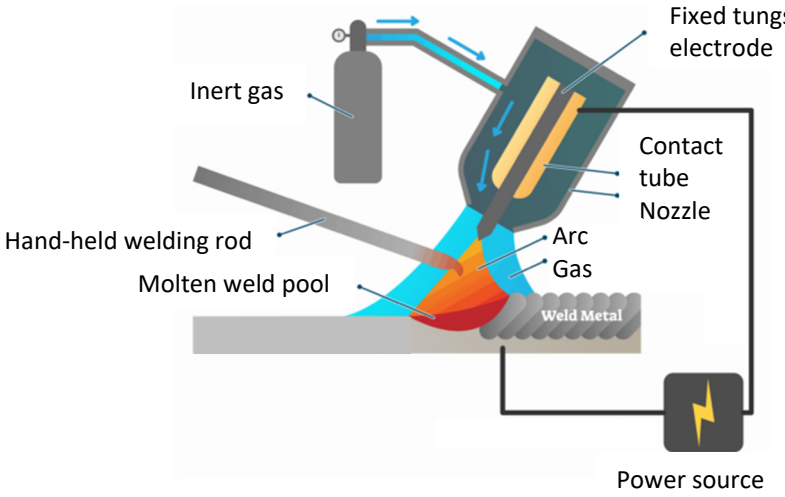
Rusal Aughinish Alumina is the largest alumina refinery in Europe. In this refinery bauxite is refined into alumina.

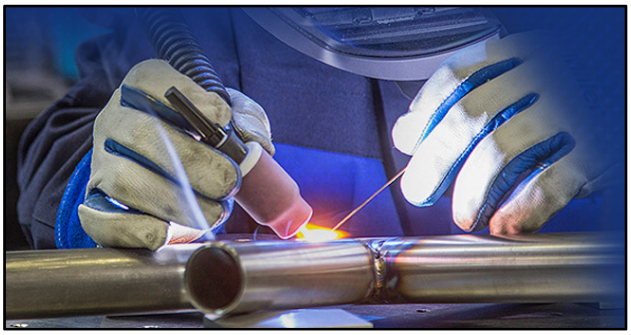
Any two @ 8 + 8

Question 6 (50 Marks)

(a) (i) TIG Welding:

An arc is formed between the non-consumable tungsten electrode and the metal being welded. The inert gas shielded arc is used to flux the joint, argon or helium are typically used to prevent oxygen getting to the joint area. A filler metal (welding rod) is added manually to the weld pool when necessary. A high frequency generator provides a path for the welding current. Both AC and DC power can be used in TIG welding techniques. TIG welding is a highly skilled welding process and is generally a manual operation.





10

(ii) Reasons for TIG welding aluminium:

- TIG welding offers more precision.
- Uses a cleaner process, fewer fumes and less smoke when TIG welding.
- Low deposition rates.
- Greater control of heat produced by the welder.
- TIG welding allows you to choose the precise amperage for your work.
- The cost of a TIG welder is comparable to the other methods.

3 + 3

(b) (i) Function of the Electrode Coating:

- The gas produced by burning prevents oxidation.
- The flux helps the weld to form.
- There are slag forming elements in the flux and these will facilitate the formation of the slag.
- Alloying elements if needed can be added as part of the flux coating.

(ii) Safety hazards associated with resistance spot welding:

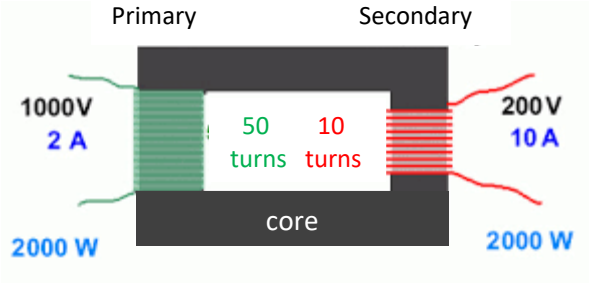
- Electrical shock – connected to high voltage.
- Can cause fire or explosion beside flammable materials.
- Flying sparks from the spot welding process.
- Fumes and gases from the welding technique.
- Hot parts as electrodes and the material will generate high heat.
- Moving parts/arms can be a cause of injury.

(iii) Step-down Transformer:

A transformer can either step down or step up the voltage in a circuit.

In a step-down transformer, the voltage at the output line (secondary coil) is directly proportional to the voltage at the input line (primary coil).

If the primary coil consists of 50 turns and carries 1000 volts and a secondary coil consists of 10 turns, the secondary voltage is then 200 volts (5 times less).



(iv) Function of consumable bare wire electrode:

- Gets used up in the welding process.
- Fill the weld area to increase the strength of the weld.
- Generates an arc to facilitate the welding process.
- Will be used with either a granulated flux or a gas shield in the welding process.

Any three @ 6 + 6 + 6

(c) (i) Slag is a residue of the flux coating in MMA welding, it may become trapped in the weld when adjacent weld beads are deposited with inadequate overlap resulting in a void or impurities trapped in the weld. Slag inclusions result from faulty welding technique or improper access to the joint.

Most defects encountered in welding are due to an improper welding procedure.

A major cause of weld cracking is when internal stresses exceed the strength of the weld metal or base metal. Cracking also results from the shrinkage that occurs as the weld metal cools.

4 + 4

(ii) Cracks will weaken the weld strength, often to the point of failure when stresses are applied. Spatter can be in indication of improper welding technique, this may impact on weld strength. Spatter gives an unappealing finish. Grinding is commonly used to remove spatter which adds additional work.

8

OR

(c) (i) **Automatic charging zones:** There are 2 systems which AMR's operate in, opportunity charging and autonomous charging.

Opportunity Charging: Because AMRs drive over charging areas on their own, there's no human intervention required, leaving workers to focus on more important matters. The robots don't interrupt themselves to recharge either, only driving over charging contact poles during necessary movement and between tasks.

Autonomous charging: Here, each robot stops working to charge its battery to full power (like your phone on an adaptor). The AMR works continuously until the battery falls below a defined threshold (i.e. 20%), then drives and docks itself to a charging station. After the complete charging cycle, the robot returns to the floor ready to work.

24-hour remote monitoring:

AMR's are connected remotely so they can be monitored from a distance by operatives while in use. This allows operatives and service engineers to plan shut downs and services of the AMR's at specific times and dates. It also facilitates mapping of the AMR's routes and journeys and editing of these routs too.

4 + 4

(ii) **Benefits of AMR's in warehouse operations:**

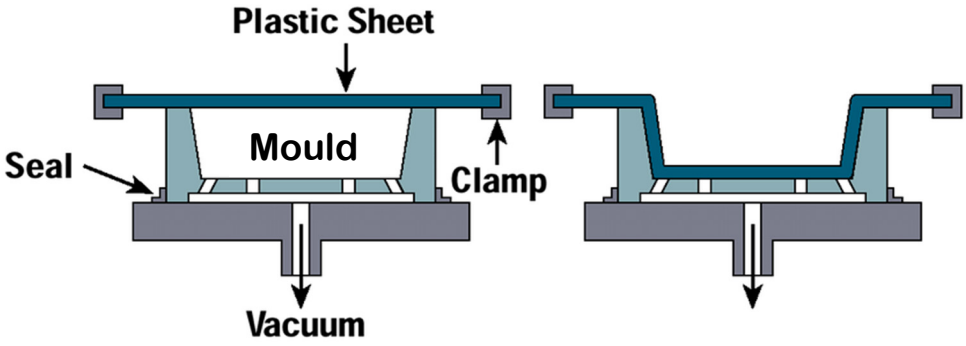
- Faster order fulfilment.
- Greater order accuracy.
- Reduced damages.
- Improved labour productivity.
- Better customer service levels.

4 + 4

Question 7 (50 Marks)

(a) (i) Vacuum forming:

A thermoplastic sheet is clamped in a frame and heat is applied until the sheet begins to sag. At this stage, the mould is lifted up into the plastic sheet and vacuum pressure is applied. This causes the plastic sheet to pull against the mold and form the final shape. After cooling, the mould is lowered and the plastic part is removed from the frame. Excess material is trimmed away.



8

(ii) Properties of expanded polystyrene:

- Dissipates shock.
- Lightweight.
- Thermal insulation. EPS has very low thermal conductivity.
- Moisture resistance.
- Durability.
- Environmental safety.

2 + 2

(iii) Suggested plastic is nylon. Nylon is strong, wear resistant and can be made into woven and flexible straps.

2 + 2

(b) (i) A catalyst is used to speed up or slow down a chemical reaction. In the addition polymerisation process, a catalyst is introduced to the monomers to instigate the chemical reaction of joining the monomers together.

(ii) When two or more different monomers are added together, their result is called as copolymer and the process is called copolymerisation. It is similar to the process of metal alloying.

Examples of copolymers include:

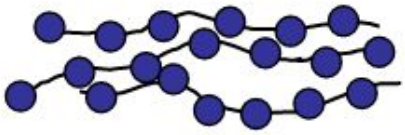
- Acrylonitrile butadiene styrene (ABS),
- Nitrile rubber,
- Styrene-acrylonitrile,
- Styrene-isoprene-styrene (SIS),
- Ethylene-vinyl acetate.

(iii) Additives include colour pigments, plasticisers to improve flexibility, flame retardants, light and heat stabilizers and lubricants to make moulding effective.

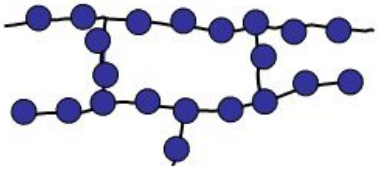
(iv) **Benefits of polymer recycling on the environment:**

- Reduces pollution across ecosystems.
- Requires less energy and helps conserve natural resources.
- Saves fast-depleting landfill space.
- Eases the demand on fossil fuel consumption.
- Promotes a sustainable lifestyle.

(v) Linear structures are associated with thermoplastics and addition polymerisation. The polymer chain structures are not linked together.



Cross-linked structures are associated with thermosetting polymers and condensation polymerisation. The polymer chains structures are linked together.



Any three @ 6 + 6 + 6

(c) **(i)** Glass is brittle so has low impact resistance, it is very transparent and is a hard material. Polycarbonate has excellent impact resistance, it is transparent and is reasonably hard when compared to other polymers but soft when compared to most resistant materials.

10

(ii) **Polymer lamination:**
Thin layers of materials bonded together. High strength plastics can be produced by layers of other polymer, fibres, paper or cloth coated with resin being bonded together. Heat and pressure are applied.

6

Question 8 (50 Marks)

(a) **(i)** Water, soluble oils, mineral oils, straight oils, synthetic fluids, semi-synthetic fluids, etc

4 + 4

(ii) Rancidity is caused by bacteria and other microscopic organisms that grew and multiply within the cutting fluid resulting in poor odour and the presence of unpleasant and hazardous bacteria. **4**

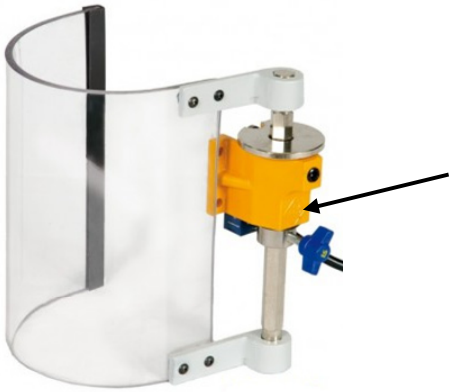
(iii) **Advantages of using cutting fluids in machining:**

- Extending tool life.
- Making metal cutting more efficient.
- Cooling the cutting tool and the workpiece.
- Reducing friction.
- Removing metal particles from cutting area.
- Protecting the workpiece and the machine tool from corrosion.

2 + 2

(b) **(i)** The 3-jaw self-centring lathe chuck allows workpieces to be centred and held with high precision. It will quickly and easily hold round materials.
4-jaw independent lathe chucks can hold square, round, and irregular-shaped workpieces. The 4-jaw independent lathe chucks can offer stronger grip on round stock. These chucks can turn work off-centre.

(ii) An interlocking chuck guard is a safety device which kills the power going to the machine when the guard is in the open position. A micro switch is connected to the hinge point of the guard, and when the guard is opened, the micro switch will break the circuit and stop the machine from operating. Interlocking guards are common on centre lathes, pillar drilling machines, bandsaw machines, milling machines in the Engineering room.



Pillar drilling machine interlocking guard

Centre lathe interlocking guard

(iii) The spindle speed(N) of a lathe is determined by the formula:

$$N = S \times 1000/\pi \times D$$

where "D" is the diameter of the drill bit. As the diameter of the drill bit increases the spindle speed of the lathe will reduce. Therefore, the larger the drill bit the slower the spindle speed of the lathe.

(iv) **Benefits of step cone drill:**

- Don't have to constantly change drill bits to increase the size of the hole.
- Excellent for drilling large holes in sheet material.
- Safer technique for drilling larger hole in sheet material.
- Shorter length and easy to manoeuvre.
- Deburring ability.
- Smooth hole finish.

(v) **Importance of electrical isolating switches in engineering rooms:**

An isolation switch is fundamental when working with electrical circuits, as they are used to ensure the circuit is safe and de-energised which allows maintenance work to take place. Also referred to as main switches, these devices separate the circuit from the main power source and dispels any trapped charges.
An isolation switch is a manually operated mechanical switch which electrically isolates a circuit from the main power.

Any three @ 6 + 6 + 6

(c) **(i)** **Safety features integrated into the design of a modern horizontal bandsaw:**

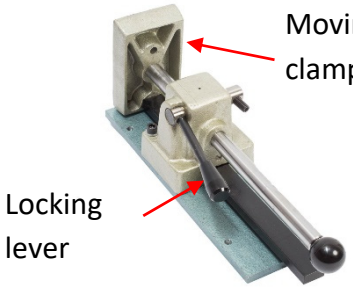
- The blade is guarded for most of its length.
- Sturdy bed construction to absorb vibrations.
- Switches are located at a safe distance from the moving blade.
- Secure clamping device to grip materials.
- Automatic stopping action at the end of cutting cycle.
- Machine can be bolted to the floor.

2 + 2 + 2

(ii) **Clamping on horizontal bandsaw.**

A traditional machine vice can be used with a horizontal bandsaw saw. A variety of clamping devices, including quick release and hydraulic clamps, can also be used as the workpiece usually needs to be held securely.

Suggested description

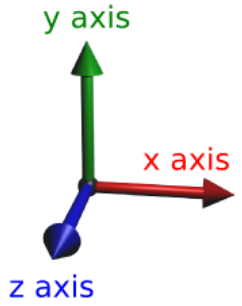


The device shown has a moveable clamp that runs on a guide rail. This is pushed on to the material to be clamped and then locked in place. A cam operated locking lever tightens on to the material.
This type of vise is particularly useful for tubular materials as the gripping strength can be gauged to avoid crushing the material.

10

OR

(c) **(i)** **3-axis CNC machining:**
Machines that work in three dimension such as milling machines, 3-D printers etc. operate in three axes to generate the workpiece. The x-axis and y-axis represent the first two dimensions; the z-axis, the third dimension. In a graphic image, the x and y denote width and height; the z denotes depth.



8

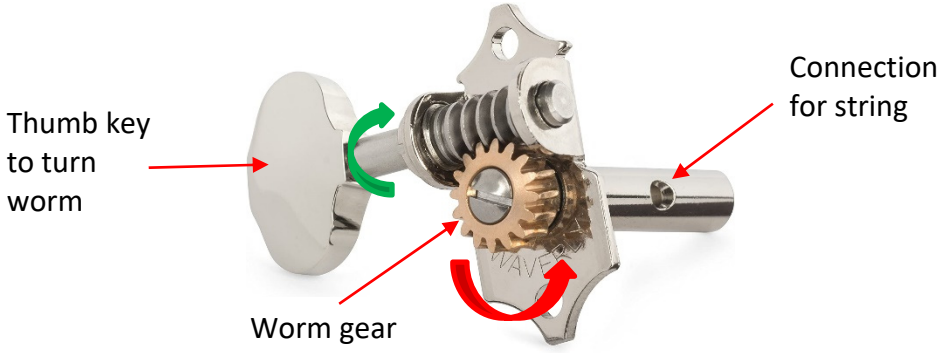
(ii) **CNC simulation tools** are mathematical applications designed to predict the behaviour, performance and outcome of programmed manufacturing processes. They provide the means for testing and verifying the CNC program, usually written in G-code, before the instructions are sent to the machine.
From verifying code integrity to preventing any issues that could damage physical components, CNC simulation tools can provide insights into how the whole process can be optimised.

Tool offsets: Programming on a CNC machine is done with reference to the centre point of the cutter. Tool offsets are the set of values that move the centre point of the cutter to the correct position for cutting a work piece using a specific tool.

4 + 4

Question 9 (50 Marks)

(a) **(i)** As the thumb key is turned the worm is rotated. This in turn rotates the worm gear and as the string is attached to the worm gear the string will be tightened or loosened depending on the direction of rotation of the worm.



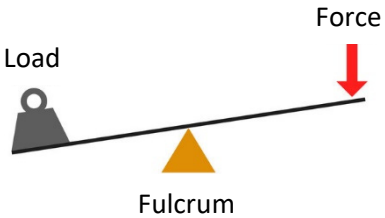
8

(ii) Advantages of worm and worm gear mechanism for stringed instruments:

- Worm drives offer a high speed reduction thus one turn of the worm will result in a limited turn of the worm gear.
- Setting the correct pitch of the string is much easier to attain.
- Once set, the worm gear cannot turn the worm so the string will not "slip" backwards due to the tension on it.

4 + 4

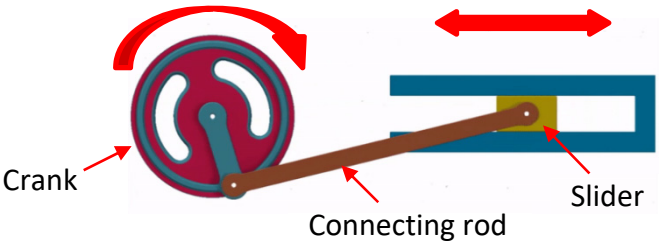
(b) **(i)** **Fulcrum.**
The fulcrum is the point on which the lever pivots. When a force is applied to one end of the lever with a load at the other end, the load will move upward.
The position of the fulcrum will determine the lifting power of a lever as well as the class or type of lever.



(ii) A car battery will convert chemical energy to electrical energy.

(iii) Bevel gears are most often used to transmit power at a right angle. The axes of the two bevel gear shafts intersect and the tooth-bearing faces of the gears themselves are conically shaped. Bevel gears are most often mounted on shafts that are 90 degrees apart.

(iv) A **crank and slider** mechanism converts rotating motion at the crank to reciprocating motion of a slider via the connecting rod.



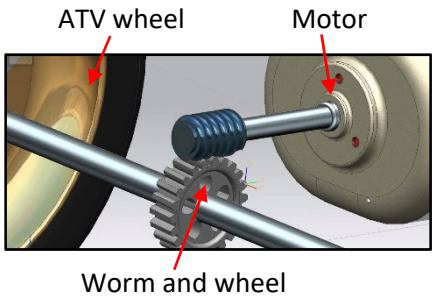
(v) Spur gears are the most common type of gear. They have straight teeth that are produced parallel to the axis of the gear.
Helical Gears have teeth that are set on an angle to the gear axis. Since the teeth engage more gradually, they have a smoother and quieter operation than spur gears.


Spur gear


Helical gear

(Any three) 6 + 6 + 6

(c) **(i)** The use of a worm and worm wheel mechanism would provide a drive mechanism for the ATV. The drive motor is attached to the worm and the worm wheel and shaft is connected to the drive tracks on both sides. This also provides for speed reduction and increased torque. A variable resistor can be added to the circuit to vary the speed of the motor and in turn the output shaft.



8

(c) (ii) Benefits of lifeguard® roll bar

- It could save a life and prevent major injury.
- It can also help protect the quad as well as the rider if the quad rolls - being flexible, the Lifeguard absorbs a lot of impact.
- Easy to attach and made to fit most makes and models.

4 + 4

OR

(c) (i) Wireless charging is based on inductive charging, whereby power is created by passing an electrical current through two coils to create an electromagnetic field.
When the receiving magnetic plate on the mobile device comes into contact with the transmitter - or at least within the specified range - the magnetic field generates an electrical current within the device.
This current is then converted into direct current (DC), which in turn charges the built-in battery.

8

(ii) Advantages of wireless charging:

- Less cords to worry about.
- Universal compatibility.
- Safer connections.
- Won't overheat your phone.

Disadvantages of wireless charging:

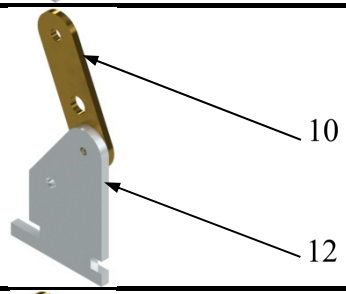
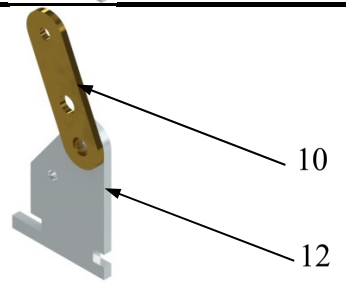
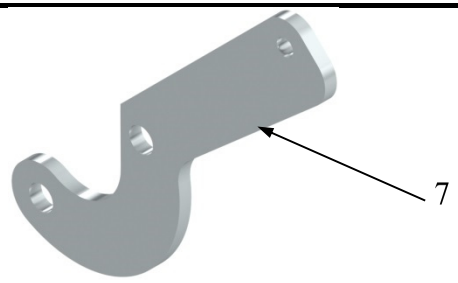
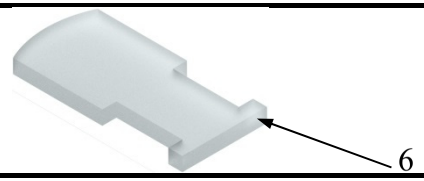
- You aren't able to use your phone.
- It takes longer to charge your phone.
- You have to pay closer attention to your phone.
- Wireless charging pads cost more than cable chargers.

4 + 4

Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate Engineering Practical Marking Scheme 2022 Day 1

Subjective Marking 1 - 20 17 - 20 Excellent 13 - 16 Very Good 9 - 12 Good 5 – 8 Poor 1 - 4 Very Poor

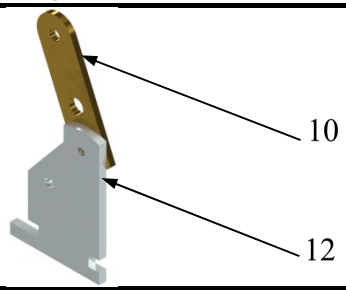
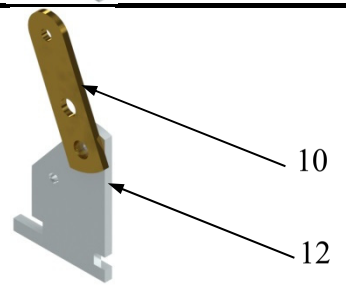
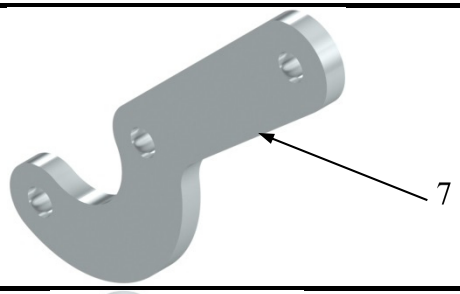
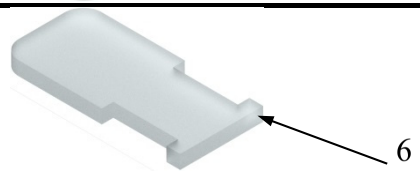
Section	Part Number	Pictorial Sketch / Description	Concept		Mark	Mark
1	**All Parts of Test-piece**		**Assembly** **Function** **Finish** **Subjective Mark 1 – 20**		**20**	**20**
2	**Parts 10 and 12 Left**		**Part 10 Left** 8 Marks	Marking Out, Ø5.5 and Ø8 mm Holes	**4**	**20**
				External Profile	**4**	
			Part 12 Left 12 Marks	Marking Out, M5 and Ø5.5 mm Holes	**4**	
				6 mm x 6 mm Slots	**4**	
				External Profile	**4**	
3	**Parts 10 and 12 Right**		**Part 10 Right** 8 Marks	Marking Out, Ø5.5 and Ø8 mm Holes	**4**	**20**
				External Profile	**4**	
			Part 12 Right 12 Marks	Marking Out, M5 & Ø5.5 mm Holes	**4**	
				6 mm × 6 mm Slots	**4**	
				External Profile	**4**	
4	**Part 7**		**Part 7** 20 Marks	Marking Out, Ø5.5 and Ø8 mm Holes	**4**	**20**
				Handle Profile	**4**	
				Internal 15 mm Radius	**4**	
				External 35 mm Radius	**4**	
				10 mm Radii	**4**	
5	**Part 6**		**Part 6** 20 Marks	Marking Out	**4**	**20**
				Radius Profile	**4**	
				28 mm Rectangular Slots	**12**	

100 Marks (× 1.5 = 150 Total)

Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate Engineering Practical Marking Scheme 2022 Day 2

Subjective Marking 1 - 20 17 - 20 Excellent 13 - 16 Very Good 9 - 12 Good 5 – 8 Poor 1 - 4 Very Poor

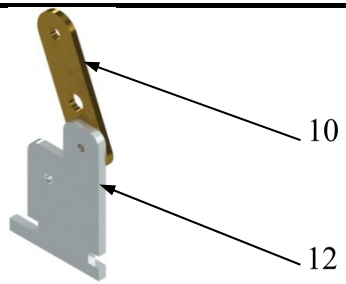
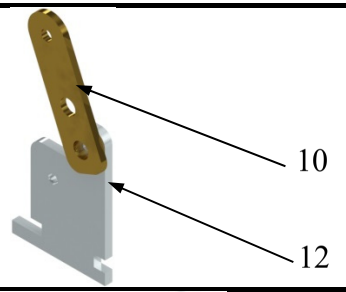
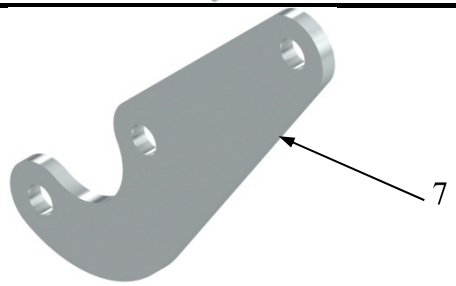
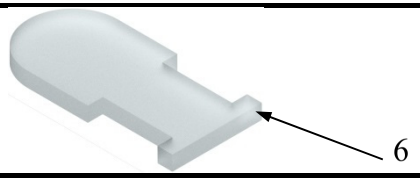
Section	Part Number	Pictorial Sketch / Description	Concept		Mark	Mark
1	**All Parts of Test-piece**		**Assembly** **Function** **Finish** **Subjective Mark 1 – 20**		**20**	**20**
2	**Parts 10 and 12 Left**		**Part 10 Left** 8 Marks	Marking Out, Ø5.5 and Ø8 mm Holes	**4**	**20**
				External Profile	**4**	
			Part 12 Left 12 Marks	Marking Out, M5 and Ø5.5 mm Holes	**4**	
				6 mm x 6 mm Slots	**4**	
				External Profile	**4**	
3	**Parts 10 and 12 Right**		**Part 10 Right** 8 Marks	Marking Out, Ø5.5 and Ø8 mm Holes	**4**	**20**
				External Profile	**4**	
			Part 12 Right 12 Marks	Marking Out, M5 & Ø5.5 mm Holes	**4**	
				6 mm × 6 mm Slots	**4**	
				External Profile	**4**	
4	**Part 7**		**Part 7** 20 Marks	Marking Out, Ø5.5 and Ø8 mm Holes	**4**	**20**
				Handle Profile	**4**	
				Internal 15 mm Radius	**4**	
				External 35 mm Radius	**4**	
				10 mm Radii	**4**	
5	**Part 6**		**Part 6** 20 Marks	Marking Out	**4**	**20**
				Radius Profile	**4**	
				28 mm Rectangular Slots	**12**	

100 Marks (× 1.5 = 150 Total)

Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate Engineering Practical Marking Scheme 2022 Day 3

Subjective Marking 1 - 20 17 - 20 Excellent 13 - 16 Very Good 9 - 12 Good 5 – 8 Poor 1 - 4 Very Poor

Section	Part Number	Pictorial Sketch / Description	Concept		Mark	Mark
1	**All Parts of Test-piece**		**Assembly** **Function** **Finish** **Subjective Mark 1 – 20**		**20**	**20**
2	**Parts 10 and 12 Left**		**Part 10 Left** 8 Marks	Marking Out, Ø5.5 and Ø8 mm Holes	**4**	**20**
				External Profile	**4**	
			Part 12 Left 12 Marks	Marking Out, M5 and Ø5.5 mm Holes	**4**	
				6 mm x 6 mm Slots	**4**	
				External Profile	**4**	
3	**Parts 10 and 12 Right**		**Part 10 Right** 8 Marks	Marking Out, Ø5.5 and Ø8 mm Holes	**4**	**20**
				External Profile	**4**	
			Part 12 Right 12 Marks	Marking Out, M5 & Ø5.5 mm Holes	**4**	
				6 mm × 6 mm Slots	**4**	
				External Profile	**4**	
4	**Part 7**		**Part 7** 20 Marks	Marking Out, Ø5.5 and Ø8 mm Holes	**4**	**20**
				Handle Profile	**4**	
				Internal 15 mm Radius	**4**	
				External 35 mm Radius	**4**	
				10 mm Radii	**4**	
5	**Part 6**		**Part 6** 20 Marks	Marking Out	**4**	**20**
				Radius Profile	**4**	
				28 mm Rectangular Slots	**12**	

100 Marks (× 1.5 = 150 Total)

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