# Coimisiún na Scrúduithe Stáit
# State Examinations Commission

## LEAVING CERTIFICATE EXAMINATION, 2022

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## ENGINEERING – MATERIALS AND TECHNOLOGY

(Higher level – 250 marks)

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**THURSDAY, 9 JUNE** **MORNING 9:30 – 12:30**

**INSTRUCTIONS**

**1.** Answer **any five** questions.

**2.** All questions carry equal marks.

**3.** All answers must be written in ink on the answer book supplied.

**4.** Diagrams should be drawn in pencil.

**5.** Squared paper is supplied for graphs, as required.

**6.** Please label and number carefully each question attempted.

**Question 1.** **(50 marks)**

Give **brief answers** to **any ten** of the following:


**(a)** Outline **two** health benefits of using $CO_2$ monitors in classrooms.

**(b)** Describe, with examples, the difference between amorphous structures and crystalline structures.

**(c)** Describe the difference between a *clearance fit* and an *interference fit* in engineering limits and fits.

**(d)** The single ratio gearbox motor shown opposite is suitable for model and light industrial applications and has a gear ratio of 100:1. Explain what is meant by 100:1 gear ratio motor.


**(e)** Describe, with the aid of a diagram, how a pulley may be securely attached to the output shaft of the gearbox motor shown.

**(f)** Discuss the contribution that **any one** of the following has made to technology:
**(i)** Nikola Tesla **(ii)** John McCarthy **(iii)** Alessandro Volta.


**(g)** Explain **two** environmental benefits of using hydrogen powered fuel cell vehicles in modern urban transportation.

**(h)** Explain the term *allotropy* in relation to iron.

**(i)** Describe **two** benefits of applying plastic powder coating to mild steel frames.

**(j)** Outline **one** method of reducing or eliminating the impact of any harmful fumes that may be created in the soldering of electronic circuits.

**(k)** Identify **two** reasons for the use of titanium in the manufacture of sport equipment, such as in modern golf clubs, as shown.

**(l)** Identify **one** advantage and **one** disadvantage of a gas shielded welding technique over a flux shielded welding technique.

**(m)** Photovoltaic power stations (solar farms) contain a large array of solar panels, as shown, that supply electricity to the power grid. Outline **one** advantage and **one** disadvantage of solar farms in Ireland.

**Question 2.** **(50 marks)**

Answer **all** of the following:

**(a)** Industry 4.0 (4th industrial revolution) is a fusion of leading-edge production techniques and smart systems that integrate with organisations and people. An essential element of industry 4.0 is Artificial Intelligence (AI) and Smart Manufacturing.


**(i)** Describe the term *Artificial Intelligence (AI)*.

**(ii)** Explain the basic difference between *machine learning* and *deep learning*.

**(b)** Artificial Intelligence can be broadly categorised in two forms. Describe the difference between:

- Artificial Narrow Intelligence (weak AI) and,
- Artificial General Intelligence (strong AI).

**(c)** Explain **any two** of the following terms in relation to artificial intelligence and smart manufacturing:

**(i)** Reactive machines;

**(ii)** Limited memory;

**(iii)** Theory of mind;

**(iv)** Self-awareness.

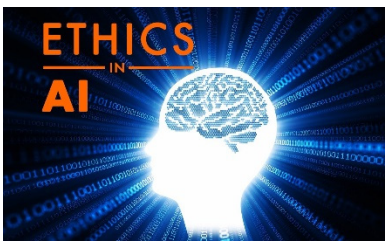
**(d)** Artificial intelligence offers a range of benefits in smart manufacturing processes. Explain **any two** of the following in relation to smart manufacturing:

**(i)** Predictive maintenance;

**(ii)** Supply chain management;

**(iii)** Quality control.

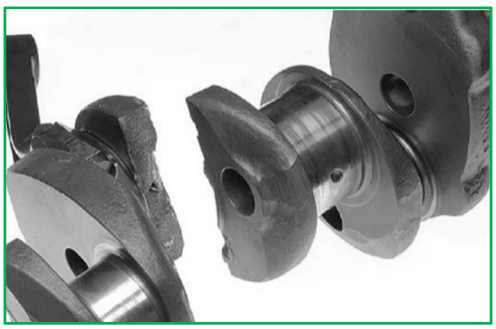
**(e)** Artificial intelligence provides both benefits and concerns for the business and manufacturing industries. Discuss **each** of the following in relation to artificial intelligence:




- Economic benefits;
- Ethical concerns.

**Question 3.** **(50 marks)**

**(a)** The engine crankshaft pictured opposite has failed due to metal fatigue.



**(i)** Explain the term *metal fatigue*.

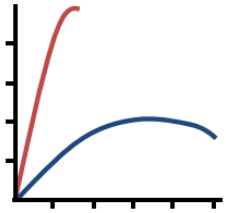
**(ii)** Outline **two** design considerations which will help minimise metal fatigue in the manufacture of crankshafts.

**(iii)** Explain the importance of quality control (QC) in engineering manufacture.

**(b)** The results shown below were obtained from tensile tests on two metals, metal **A** and metal **B**.

| **Metal A** | **Stress (N/mm²)** | 125 | 260 | 400 | 425 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Metal B** | **Stress (N/mm²)** | 30 | 60 | 87 | 110 | 144 | 155 | 162 | 158 | 140 |
| **Metal A & B** | **Strain (x1000)** | 0.50 | 1.00 | 1.50 | 2.00 | 3.50 | 4.50 | 6.00 | 7.00 | 8.00 |

**(i)** Using the graph paper supplied, plot the stress-strain diagram for metal **A** and the stress-strain diagram for metal **B** on the same graph axes, as shown opposite.



**(ii)** With reference to metal **B**, describe with the aid of a diagram, the profile of the tensile test specimen when subjected to a load value of 158N/mm².

**(iii)** Calculate Young's modulus of elasticity for metal **A** and Young's modulus of elasticity for metal **B**.

**(c)** In magnetic particle non-destructive testing (NDT) a portable magnetic device is used, as shown, for detecting imperfections in ferromagnetic materials.

**(i)** Describe, with the aid of a suitable diagram(s), the process of magnetic particle testing.

**(ii)** Outline **two** benefits of using NDT, such as magnetic particle testing, in the gas and oil industries.

*magnetic particle test equipment*

**Question 4.** **(50 marks)**

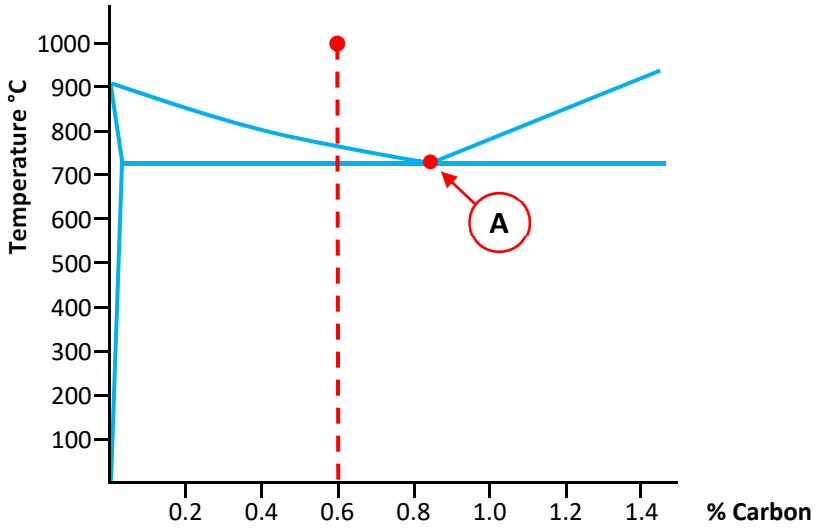
**(a)** The famous pedestrian Ha'penny Bridge which spans the river Liffey in Dublin is manufactured from a combination of cast iron and steel.

**(i)** Explain **one** difference between cast iron and steel.

**(ii)** Outline **two** reasons why cast iron was deemed suitable for the structure of the bridge.

**(iii)** Give **two** other applications of cast iron.

**(b)** A simplified portion of the iron-carbon equilibrium diagram is shown.

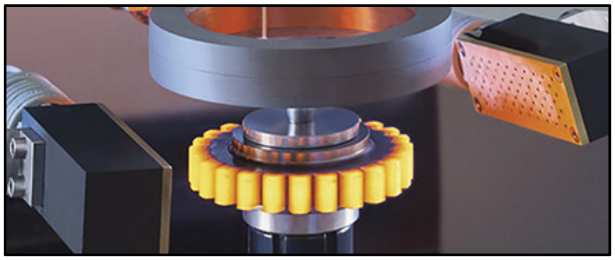



**(i)** Identify the point **A**, and describe the transformation which occurs at this point.

**(ii)** Identify and describe the heat treatment process which occurs when 0.6% carbon steel is cooled very slowly from 1000°C, as indicated on the diagram.

**(iii)** Describe **one** method of accurately measuring furnace temperature when heat treating steel.

**(c)** Induction hardening is a heat treatment technique that can be used to harden specific portions of gears to improve their mechanical properties.

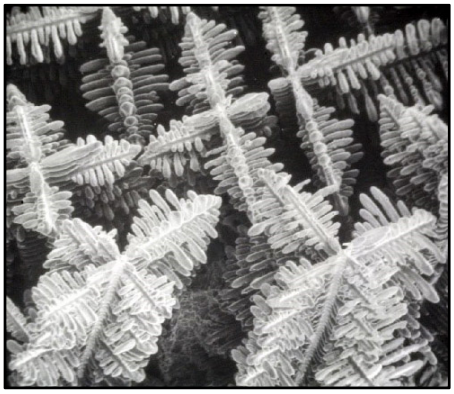


**(i)** Describe, with the aid of a diagram, the heating and cooling process used in induction hardening.

**(ii)** Outline **two** safety hazards associated with the induction hardening process.

**Question 5.** **(50 marks)**

**(a)** A microscopic image of the metal solidification process, dendritic growth, is shown.



**(i)** Describe, with the aid of diagrams, the process of dendritic growth.

**(ii)** Describe, with the aid of a diagram, **any two** crystal point defects which may occur during the solidification process.

**(b)** The table shows the solidification temperatures for various alloys of metal **A** and metal **B**.

| **% of metal B in the alloy** | **0** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Start of solidification (°C)** | 1120 | 1225 | 1295 | 1345 | 1390 | 1420 | 1445 | 1468 | 1485 | 1495 | 1500 |
| **End of solidification (°C)** | 1120 | 1128 | 1150 | 1170 | 1195 | 1225 | 1260 | 1295 | 1350 | 1420 | 1500 |

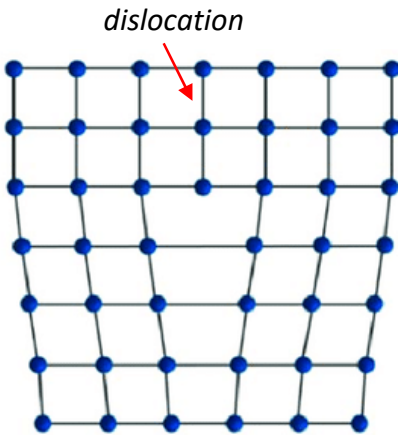
Using the graph paper supplied:

**(i)** Draw the equilibrium diagram according to the given data and label the liquidus and solidus lines.

**(ii)** For the alloy containing **70%** metal **B**, determine from the diagram the ratio of the phases at **1400 °C**.

**(iii)** State the melting point of metal **A and** the melting point of metal **B** in this alloy.

**(c)** Select **any two** from **(i)**, **(ii)** or **(iii)** below and explain:




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

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

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

**Question 6.** **(50 marks)**

**(a)** The chassis of electric scooters is often constructed from lightweight industrial grade aluminium. Tungsten inert gas (TIG) welding may be used to fabricate the chassis.

**(i)** Describe, with the aid of a diagram, the process of TIG welding.

**(ii)** Explain **two** reasons for using TIG welding in fabricating industrial grade aluminum.

**(b)** Answer **any three** of the following:

**(i)** Outline **three** functions of the electrode coating in manual metal arc welding.

**(ii)** Explain **two** safety hazards associated with resistance spot welding.

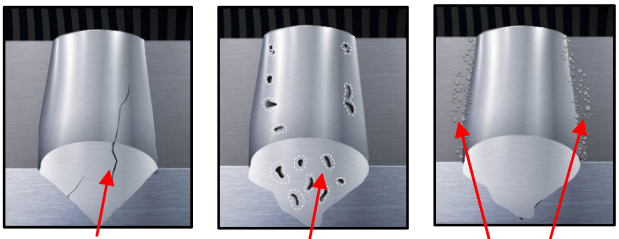
**(iii)** Describe the principles of operation of a step-down transformer in welding.

**(iv)** Outline the function of a *consumable bare wire electrode*.

**(c)** Welding defects include cracking, slag inclusions and spatter.

**(i)** Outline how weld cracks **and** slag inclusions may form on a weld.

**(ii)** Describe the effects of either cracks **or** spatter on weld strength and finish.

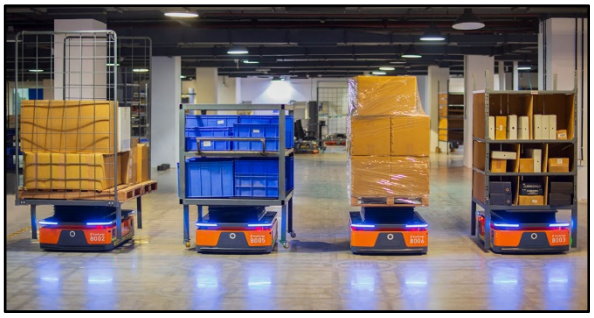



**OR**

**(c)** An autonomous mobile robot (AMR) is a vehicle that uses on-board sensors and processors to autonomously move materials without the need for physical guides or markers.

**(i)** Explain the following terms in relation to the autonomous mobile robots (AMR):

- Automatic charging zones;
- 24-hour remote monitoring.



**(ii)** Outline **two** benefits of autonomous mobile robots (AMR) in warehouse operations.

**Question 7.** **(50 marks)**

**(a)** Bicycle helmets are manufactured from a range of thermoplastic polymers. The shell is generally manufactured from polyethylene terephthalate (PET) and the liner from expanded polystyrene (ESP).


**(i)** Describe, with the aid of a diagram, a suitable thermoplastic manufacturing process for the polyethylene terephthalate (PET) shell.

**(ii)** Give **two** properties of expanded polystyrene (ESP) which make it suitable for use in the helmet liner.

**(iii)** Select a suitable polymer for the manufacture of the chin straps on the bicycle helmet. Justify your selection.

**(b)** Answer **any three** of the following:

**(i)** Outline the function of a *catalyst* in the addition polymerisation process.

**(ii)** Explain, with an example, the term *copolymerisation*.

**(iii)** Name **any two** polymer additives which are used in the production of mobile phone covers.

**(iv)** Outline **two** environmental benefits of promoting widespread recycling of mobile phone covers.

**(v)** Describe, with the aid of a diagram(s), the main differences between linear and cross-linked chains in polymers.

**(c)** A range of plastic materials and glass are often used in the manufacture of mobile phone protective screens. Screen protectors may be laminated and tempered.


**(i)** Compare glass and polycarbonate as suitable materials in the production of mobile phone screen protectors, making reference to:

- impact resistance
- transparency
- hardness.

**(ii)** Describe the process of polymer *lamination*.

**Question 8.** **(50 marks)**

**(a)** Cutting fluids are used in a range of engineering machines.

**(i)** Name **two** types of cutting fluid.

**(ii)** Explain cutting fluid *rancidity*.

**(iii)** Outline **two** reasons for using cutting fluids in machining operations.

**(b)** Answer **any three** of the following:

**(i)** Outline, with examples, the difference between a 3-jaw self-centring lathe chuck and a 4-jaw independent lathe chuck.

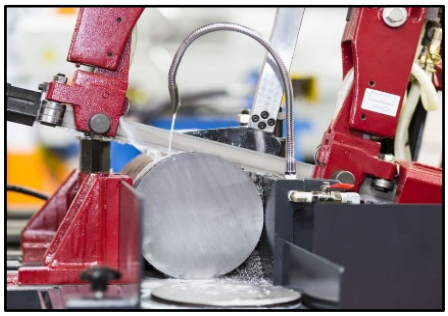
**(ii)** Describe the term *interlocking guard* in relation to engineering machines.

**(iii)** Explain how the size of a drill bit affects the spindle speed of a lathe.

**(iv)** Identify **two** benefits of using a step cone drill bit as shown.

**(v)** Describe the importance of electrical isolating switches in the engineering room.

**(c)** Horizontal bandsaws are often used to cut metals efficiently in modern engineering rooms.



**(i)** Outline **three** safety features integrated into the design of a modern horizontal bandsaw.

**(ii)** Describe, with the aid of diagram(s), a method of securely clamping metals in a horizontal bandsaw.

**OR**

**(c)** Computer Numerical Control (CNC) machining is a manufacturing process in which pre-programmed computer software controls the movement of tools and equipment.

**(i)** Explain, with the aid of a diagram, the term *3-axis CNC machining*.

**(ii)** Describe the following CNC terms:

- Simulation;
- Tool offsets.

**Question 9.** **(50 marks)**

**(a)** A worm and worm gear mechanism is often used in stringed musical instruments, such as cellos and guitars, to tension the strings to their correct pitch.

**(i)** Describe, with the aid of a diagram, the operation of the worm and worm gear in the tensioning of the strings.

**(ii)** Discuss **two** advantages of using this mechanism in the musical instrument shown.

**(b)** Answer **any three** of the following:

**(i)** Outline the function of the *fulcrum* in relation to levers.

**(ii)** Describe an energy conversion that takes place in a car battery.

**(iii)** Describe, with the aid of a diagram, the operation of a bevel gear system.

**(iv)** Explain **one** method of converting rotary motion to reciprocating motion.

**(v)** Distinguish between spur gears and helical gears.

**(c)** The all-terrain vehicle (ATV) shown opposite, features a variable speed rear wheel drive transmission and a *LifeGuard®* safety roll bar.


**(i)** Describe, with the aid of a diagram, a suitable variable speed drive mechanism for the ATV.

**(ii)** Identify **two** benefits of using a *LifeGuard®* safety roll bar on an ATV.

**OR**

**(c)** "*Qi*" is the wireless charging standard widely adopted by the largest and most well-known technology manufacturers in the world.

**(i)** Describe the basic principles of wireless charging.

**(ii)** Outline **one** advantage and **one** disadvantage of wireless charging electronic devices.

Leaving Certificate – Higher Level

# Engineering – *Materials and Technology*

Thursday 9 June
Morning 9:30 – 12:30