TVET CURRICULUM DEVELOPMENT, ASSESSMENT AND CERTIFICATION COUNCIL (TVET CDACC)

Qualification Code	**:**	071606T4MCT
Qualification	**:**	Mechatronic Technician Level 6
Unit Code	**:**	ENG/OS/MC/CC/05/6/A
Unit of Competency	**:**	Apply material science principles

WRITTEN ASSESMENT

INSTRUCTIONS TO ASSESSOR:

1. The candidate has **TWO HOURS** to attempt all the questions.
2. Marks for each section are indicated in the brackets
3. The paper consists of **TWO** sections: **A** and **B.**
4. The candidate is required to attempt **ALL** questions from section **A** and **ANY THREE** questions from section **B.**
5. The candidate is provided with answer booklet for their responses.

NB: ***These only serves as a guide to expected responses.***

SECTION A: SHORT ANSWER QUESTIONS (40 MARKS)

1. Differentiate between atomic structure and crystal structure. [4 marks]
   - ✓ Atomic structure relates to the number of protons and neutrons in the nucleus of an atom, as well as the number and probability distributions of the constituent electrons.
   - ✓ On the other hand, crystal structure pertains to the arrangement of atoms in the crystalline solid material.
2. List **FOUR** situations in which casting is the preferred fabrication technique. [4 marks]
   - ✓ For large pieces and/or complicated shapes.
   - ✓ When mechanical strength is not an important consideration.
   - ✓ For alloys having low ductilities.
   - ✓ When it is the most economical fabrication technique.
3. Name **TWO** thermal properties of a liquid medium that will influence its quenching effectiveness. [2 marks]
   - ✓ thermal conductivity
   - ✓ heat capacity
4. Cite the **TWO** desirable characteristics of glasses. [2 marks]
   - ✓ optical transparency
   - ✓ ease of fabrication
5. List **FOUR** popular hardness testing techniques. [4 marks]
   - ✓ Rockwell
   - ✓ Knoop
   - ✓ Brinell
   - ✓ Vickers
6. Briefly describe the two techniques that are used for galvanic protection. [4 marks]
   - ✓ A sacrificial anode is electrically coupled to the metal piece to be protected, which anode is also situated in the corrosion environment. The sacrificial anode is a metal or alloy that is chemically more reactive in the particular environment. It (the anode) preferentially oxidizes, and, upon giving up electrons to the other metal, protects it from electrochemical corrosion.
   - ✓ An impressed current from an external dc power source provides excess electrons to the metallic structure to be protected.

7. State **THREE** advantages of cold working processes. [3 marks]

The disadvantages of cold working are:

- ✓ High deformation energy requirements.
- ✓ Large deformations must be accomplished in steps, which may be expensive.
- ✓ A loss of ductility.

8. State **THREE** criteria are upon which design safety factor is based. [3 marks]

- ✓ consequences of failure
- ✓ previous experience
- ✓ accuracy of measurement of mechanical forces and/or material properties
- ✓ economics.

9. Identify the **FIVE** different methods through which the purposes of heat treatment may be served. [5 marks]

- ✓ Annealing
- ✓ Normalizing
- ✓ Hardening
- ✓ Tempering
- ✓ Case hardening and surface hardening methods.

10. State **SIX** methods widely used for control and prevention of corrosion. [6 marks]

- ✓ Using high-purity metals and alloy additions (material selection)
- ✓ Proper design against corrosion
- ✓ Proper modification of corrosive environment
- ✓ Making use of protective coatings
- ✓ Making use of inhibitors
- ✓ Cathodic protection

11. Cite **THREE** reasons why engineering materials are tested by engineers. [3 marks]

- ✓ to check chemical composition
- ✓ to determine suitability of material for particular applications
- ✓ to assess numerically, the fundamental mechanical properties, e.g. ductility, malleability, toughness, etc.
- ✓ to determine the data such as stress values, to set up specification upon which engineer can base his design
- ✓ to determine surface and sub-surface defects in raw materials or processed parts.

SECTION B: EXTENDED ANSWER QUESTIONS (60 MARKS)

12.

i. Discuss **FIVE** mechanical properties of materials which are always considered in engineering works. [10 marks]

- ✓ Tensile Strength:
  - ✓ This enables the material to resist the application of a tensile force. To withstand the tensile force, the internal structure of the material provides the internal resistance.
- ✓ Hardness:
  - ✓ It is the degree of resistance to indentation or scratching, abrasion and wear. Alloying techniques and heat treatment help to achieve the same.
- ✓ Ductility:
  - ✓ This is the property of a metal by virtue of which it can be drawn into wires or elongated before rupture takes place. It depends upon the grain size of the metal crystals.
- ✓ Impact Strength:
  - ✓ It is the energy required per unit cross-sectional area to fracture a specimen, i.e., it is a measure of the response of a material to shock loading.
- ✓ Wear Resistance:
  - ✓ The ability of a material to resist friction wear under particular conditions, i.e. to maintain its physical dimensions when in sliding or rolling contact with a second member.
- ✓ Corrosion Resistance:
  - ✓ Those metals and alloys which can withstand the corrosive action of a medium, i.e. corrosion processes proceed in them at a relatively low rate are termed corrosion-resistant.
- ✓ Density:
  - ✓ This is an important factor of a material where weight and thus the mass is critical, i.e. aircraft components.

ii. Describe **FIVE** major defects in a metal or an alloy that may be caused by faulty heat treatment. [10 marks]

- ✓ Overheating:
  - ✓ Prolonged heating of a metal or a alloy leads to the formation of very large actual grains. Such a structure has reduced ductility and toughness.
- ✓ Burning:
  - ✓ Heating a metal or an alloy near melting point for a longer duration may lead to burning. This leads to the formation of iron oxide inclusions along the grain boundaries. Burnt metal or alloy has a stoney fracture and such a metal or alloy is irremediable and such metals are rejected.
- ✓ Oxidation:
  - ✓ Sometimes a metal or alloy gets oxidized due to oxidizing atmosphere inside the furnace. It is usually characterized by a thick layer of scale on the surface of a metal or alloy.
- ✓ Decarburization:
  - ✓ Decarburization is the loss of carbon in the surface layers of metals or alloys. It is caused by the oxidizing furnace atmosphere.
- ✓ Cracks:
  - ✓ These occurs in quenching when the internal tensile stress exceeds the resistance of metal or alloy to separation. The tendency of a metal or alloy to crack formation increases with carbon content, hardening temperature and cooling rate in the temperature interval of martensite transformation. Cracks also increases with the hardenability of metal or alloy. Concentration of local stresses is another reason for the formation of cracks.
- ✓ Distortion and Warping:
  - ✓ This is consisting in changes in the size and shape of heat-treated work and is mainly due to thermal and structural stresses. Asymmetrical distortion of work is often called warping in heat-

treating practice. Usually, it is observed in case of overheating or non-uniform heating for hardening, when the work is quenched in the wrong position and when the cooling rate is too high in the temperature interval of martensite transformation.

13.

i. Plastic polymers are widely used in many applications. Discuss **FIVE** properties of plastic polymers that make them widely used. [10 marks]

- ✓ Plastics are light weight materials that is their densities and specific gravities are low.
- ✓ They have high resistance to chemical attack, i.e. corrosion.
- ✓ They have very good surface finish when obtained from the dies.
- ✓ They have high thermal and electrical insulation.
- ✓ As compared to metals their strength is low and also low elastic modulus value.
- ✓ As compared to metals, plastic have low softening and thermal degradation temperature.
- ✓ Plastics are poor to fair dimensional stability, particularly in moist conditions.
- ✓ Plastics are available in different colours as well as transparent form.
- ✓ With respect to metals, plastics have high coefficient of thermal expansion.
- ✓ These are unsuitable for high temperature applications.
- ✓ Plastics can be easily fabricated.

ii. Fracture can be classified as either brittle or ductile. Discuss **FIVE** comparisons of the two. [10 marks]

Ductile fracture	**Brittle fracture**
✓ Material fractures after plastic deformation and slow propagation of crack	✓ Materials fractures with very little or no plastic deformation, e.g. in a china clay, glass etc.

✓ Fractured surfaces are dull or fibrous in appearance	✓ Fractured surfaces are crystalline in appearance
✓ Percentage elongation is about 30% prior to fracture occurs	✓ Percentage elongation is about 0.5% or almost nil prior to fracture occurs
✓ There is reduction in cross-sectional area of the specimen	✓ There is virtually no change in the cross-sectional area
✓ Fracture takes place after necking with little sound	✓ Fracture occurs rapidly often accompanied by a loud noise

14. The atomic radius of an iron atom is $1.238 \times 10^{-10}\ m$. Iron crystallizes as BCC.

i. Define atomic packing factor (A.P.F); [1 mark]

✓ It can be defined as the ratio between the volume of the basic atoms of the unit cell (which represent the volume of all atoms in one-unit cell) to the volume of the unit cell itself.

ii. Calculate the lattice parameter of the unit cell, **a**; [3 marks]

For BCC unit cell;

✓ $a = \frac{4}{\sqrt{3}} r$

For iron, $r = 1.238 \times 10^{-10}$ m

Therefore;

✓ $a = \frac{4 \times 1.238 \times 10^{-10}}{\sqrt{3}}$

✓ $= \mathbf{2.861 \times 10^{-10}\ m}$

iii. How many atoms are contained within the BCC unit cell? Explain; [2 marks]

✓ There are 9 atoms

✓ 8 in the corners and 1 in the center of the cubic.

iv. Find the atomic packing factor. [6 marks]

✓ $r = \frac{\sqrt{3}}{4} a$

The volume of the atom can be calculated as follows:

✓ $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(\frac{\sqrt{3}}{4}a\right)^3$

The volume of the basic atoms in the unit cell can be calculated as follows:

✓ $V_b = 2\left[\frac{4}{3}\pi\left(\frac{\sqrt{3}}{4}a\right)^3\right]$

The volume of the unit cell is;

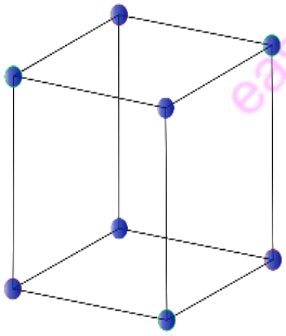
✓ $V_u = a^3$

✓ $A.P.F = \frac{V_b}{V_u} = \frac{2\left[\frac{4}{3}\pi\left(\frac{\sqrt{3}}{4}a\right)^3\right]}{a^3}$

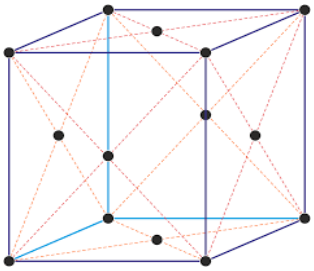
✓ $= \mathbf{0.68}$

b. There are several types of patterns in which metallic atoms can arrange themselves on solidification. With the aid of sketches, explain four most common such patterns.
[8 marks]

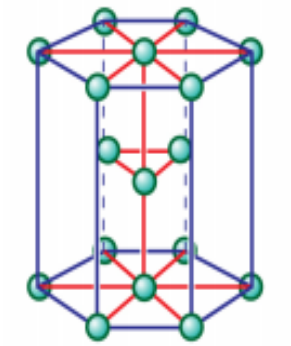
✓ Simple cubic
✓



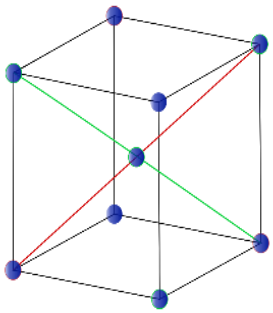
✓ Face centred cubic
✓



✓ Hexagonal closed packed
✓



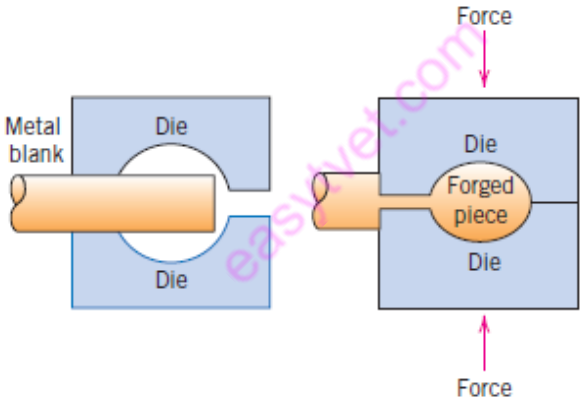
✓ Body centred cubic
✓



15. With the aid of neat and labelled diagrams, discuss the **FOUR** forming operations.

[20 marks]

- ✓ **Forging**
  - ✓ Forging is mechanically working or deforming a single piece of a normally hot metal;
  - ✓ this may be accomplished by the application of successive blows or by continuous squeezing.
  - ✓ Forgings are classified as either closed or open die.
  - ✓ For closed die, a force is brought to bear on two or more die halves having the finished shape such that the metal is deformed in the cavity between them.
  - ✓ For open die, two dies having simple geometric shapes (e.g., parallel flat, semicircular) are employed, normally on large workpieces.
  - ✓



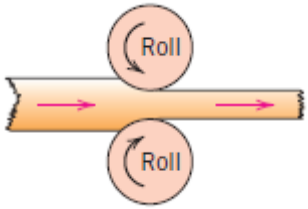
Forged articles have outstanding grain structures and the best combination of mechanical properties.

Wrenches, automotive crankshafts, and piston connecting rods are typical articles formed using this technique.

- ✓ **Rolling**
  - ✓ Rolling, the most widely used deformation process, consists of passing a piece of metal between two rolls;
  - ✓ a reduction in thickness results from compressive stresses exerted by the rolls.

Cold rolling may be used in the production of sheet, strip, and foil with a high-quality surface finish. Circular shapes as well as I-beams and railroad rails are fabricated using grooved rolls.

✓

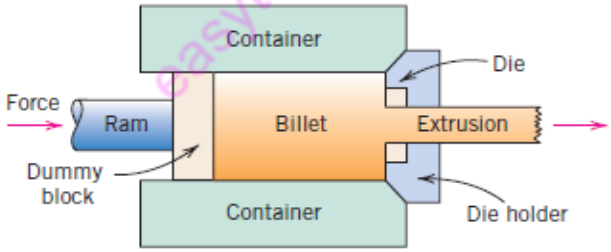


✓ **Extrusion**

- ✓ For extrusion, a bar of metal is forced through a die orifice by a compressive force that is applied to a ram;
- ✓ the extruded piece that emerges has the desired shape and a reduced cross-sectional area.

  Extrusion products include rods and tubing that have rather complicated cross-sectional geometries; seamless tubing may also be extruded.

✓



✓ **Drawing**

- ✓ Drawing is the pulling of a metal piece through a die having a tapered bore by means of a tensile force that is applied on the exit side.
- ✓ A reduction in cross section results, with a corresponding increase in length.
- ✓ The total drawing operation may consist of a number of dies in a series sequence.

  Rod, wire, and tubing products are commonly fabricated in this way.

✓