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. Marks for each section are indicated in the brackets
2. The paper consists of **TWO** sections: **A** and **B.**
3. The candidate is required to attempt **ALL** questions from section **A** and **ANY THREE** questions from section **B.**

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

SECTION A: SHORT ANSWER QUESTIONS (40 MARKS)

1. Cite the difference between atomic mass and atomic weight. [2 Marks]
   - ✓ **Atomic mass is the mass of an individual atom,**
   - ✓ **whereas atomic weight is the average (weighted) of the atomic masses of an atom's naturally occurring isotopes.**
2. Figure 1 below is a unit cell for a hypothetical metal. Use it to answer the following questions. [2 Marks]

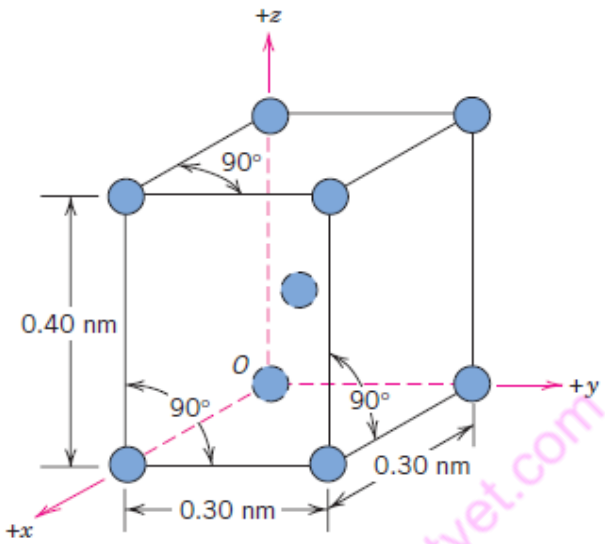

Figure 1

   i. Identify the crystal system this unit cell belongs to.
      - ✓ **tetragonal crystal system**

   ii. Name the crystal structure of the unit cell.
      - ✓ **body-centered tetragonal**

3. State **TWO** advantages of forming metals by extrusion as opposed to rolling. [2 Marks]
   - ✓ **Pieces having more complicated cross-sectional geometries may be formed.**
   - ✓ **Seamless tubing may be produced.**
4. Underline **THREE** sources of internal residual stresses in metal components. [3 Marks]
   - ✓ **Plastic deformation processes,**
   - ✓ **nonuniform cooling of a piece that was cooled from an elevated temperature, and**

- ✓ **a phase transformation in which parent and product phases have different densities.**

5. For thermoplastic polymers, state **FIVE** factors that favor brittle fracture. [5 Marks]
   - ✓ **a reduction in temperature,**
   - ✓ **an increase in strain rate,**
   - ✓ **the presence of a sharp notch,**
   - ✓ **increased specimen thickness, and**
   - ✓ **modifications of the polymer structure.**
6. Explain why chromium in stainless steels make them more corrosion resistant in many environments than plain carbon steels. [3 Marks]
   - ✓ **The chromium in stainless steels causes a very thin and highly adherent surface coating to form over the surface of the alloy,**
   - ✓ **which protects it from further corrosion.**
   - ✓ **For plain carbon steels, rust, instead of this adherent coating, forms.**
7. State **FOUR** simple-strain tests which can be used to ascertain the mechanical characteristics of metals. [4 Marks]
   - ✓ **Tensional test**
   - ✓ **Compression test**
   - ✓ **Torsional test**
   - ✓ **Shear test**
8. Give **TWO** reasons why metals are often tempered after hardening. [2 Marks]
   - ✓ **to remove stresses and**
   - ✓ **to improve their machinability**
9. Briefly explain the difference between oxidation and reduction electrochemical reactions. [4 Marks]
   - ✓ **Oxidation is the process by which an atom gives up an electron (or electrons) to become a cation.**
   - ✓ **Reduction is the process by which an atom acquires an extra electron (or electrons) and becomes an anion.**
10. Briefly explain three techniques that are utilized to strengthen concrete by reinforcement. [6 Marks]
    - ✓ **it is a relatively weak and brittle material**
    - ✓ **it experiences relatively large thermal expansions (contractions) with changes in temperature**

- ✓ **it may crack when exposed to freeze-thaw cycles.**

11. Cite **FOUR** factors that determine the fabrication technique to use in forming polymeric materials. [4 Marks]
    - ✓ **whether the polymer is thermoplastic or thermosetting**
    - ✓ **if thermoplastic, the softening temperature**
    - ✓ **atmospheric stability**
    - ✓ **the geometry and size of the finished product.**
12. State **THREE** advantages of cold working. [3 Marks]

    The advantages of cold working are:
    - ✓ **A high-quality surface finish.**
    - ✓ **The mechanical properties may be varied.**
    - ✓ **Close dimensional tolerances.**

SECTION B: EXTENDED ANSWER QUESTIONS (60 MARKS)

13. Some of the more common steels are classified according to alloy concentration. List the **FOUR** classifications of steels, and, for each, describe **TWO** properties and cite **TWO** typical applications. [20 Marks]

- ✓ **Low Carbon Steels**

  Properties:

  - ✓ **nonresponsive to heat treatments;**
  - ✓ **relatively soft and weak;**
  - ✓ **machinable and**
  - ✓ **weldable.**

  Typical applications:

  - ✓ **automobile bodies,**
  - ✓ **structural shapes,**
  - ✓ **pipelines,**
  - ✓ **buildings,**
  - ✓ **bridges, and**
  - ✓ **tin cans.**

- ✓ **Medium Carbon Steels**

  Properties:

  - ✓ **heat treatable,**
  - ✓ **relatively large combinations of mechanical characteristics.**

  Typical applications:

  - ✓ **railway wheels and tracks,**
  - ✓ **gears,**
  - ✓ **crankshafts, and**
  - ✓ **machine parts.**

- ✓ **High Carbon Steels**

  Properties:

  - ✓ **hard,**
  - ✓ **strong, and**
  - ✓ **relatively brittle.**

  Typical applications:

  - ✓ **chisels,**

- ✓ **hammers,**
- ✓ **knives, and**
- ✓ **hacksaw blades.**

✓ **High Alloy Steels (Stainless and Tool)**

Properties:

- ✓ **hard and wear resistant;**
- ✓ **resistant to corrosion in a large variety of environments.**

Typical applications:

- ✓ **cutting tools,**
- ✓ **drills,**
- ✓ **cutlery,**
- ✓ **food processing, and**
- ✓ **surgical tools.**

14.

a) Discuss the three primary requirements for polymeric materials utilized in the packaging of food products and drinks? [9 Marks]

- ✓ **sufficient strength, to include tensile, tear, and impact strengths;**
- ✓ **barrier protection--that is, being resistant to permeation by oxygen, water vapor, and carbon dioxide; and**
- ✓ **being nonreactive with the food/drink contents--such reactions can compromise the integrity of the packaging material, or they can produce toxic by-products.**

b) For each of the features below, name two materials that can offer it [6 Marks]

i. High tensile strengths **-poly (ethylene terephthalate) (PET or PETE) and oriented polypropylene (OPP)**

ii. High tear strengths **-linear low-density polyethylene (LLDPE) and low-density polyethylene (LDPE) have high tear strengths,**

iii. High impact strengths **-PET and poly (vinyl chloride) (PVC).**

c) What is the role played by aesthetics in packaging [2 Marks]

The aesthetics of packaging polymers are also important in the marketing of food and drink products.

- ✓ **Some will be colored, many are adorned with printing, others need to be transparent and clear,**
- ✓ **and many need to be resistant to scuffing.**

d) Identify three polymers with specific applications [3 Marks]

- ✓ **PET(E) for soda pop containers;**
- ✓ **PVC for beer containers;**
- ✓ **LDPE and HDPE films for packaging bread and bakery products.**

15.

a) Discuss **FIVE** principal kinds of heat treatment performed on steel.

[10 Marks]

The principal kinds of heat treatment are:

- ✓ **Annealing**
  - ✓ **A material is exposed to an elevated temperature for an extended time period and then slowly cooled.**
- ✓ **Normalising**
  - ✓ **Heating and soaking in this process is same as in the full annealing but part is allowed to cool in air so that cooling rate is much faster.**
- ✓ **Hardening**
  - ✓ **It is a kind of heat treatment which forms a non-equilibrium structure in an alloy. To form a non-equilibrium structure in an alloy, it is heated above the temperature of the phase transformation in the solid state and then cooled (chilled) quickly**
- ✓ **Tempering & Aging**
  - ✓ **Tempering and ageing are the kinds of heat treatment which are applied to hardened alloys. Tempering releases the stresses and reduces the brittleness.**
- ✓ **Case hardening & Surface hardening**
  - ✓ **A number of components require only a hard surface to resist wear and tear and a tough core to resist shock loads instead of complete component being made hard.**

b) Figure 2 shows the tensile engineering stress–strain behaviour for a steel alloy. Use the graph to interpret the following;

i. The modulus of elasticity [4 Marks]

- ✓ **The elastic modulus is just the slope of the initial linear portion of the curve; or, from the inset**

✓ $E = \frac{\sigma_2 - \sigma_1}{\varepsilon 2 - \varepsilon 1}$

✓ $= \frac{(200-0)MPa}{0.0010-0}$

✓ $= 200 \times 10^3\ MPa = 200\ GPa$

ii. The proportional limit [2 Marks]

✓ **The proportional limit is the stress level at which linearity of the stress-strain curve ends,**

✓ **which is approximately 300 MPa**

iii. The yield strength at a strain offset of 0.002 [2 Marks]

✓ **The 0.002 strain offset line intersects the stress-strain curve at**

✓ **approximately 400 MPa**

iv. The tensile strength [2 Marks]

✓ **The tensile strength (the maximum on the curve) is**

✓ **approximately 515 MPa**

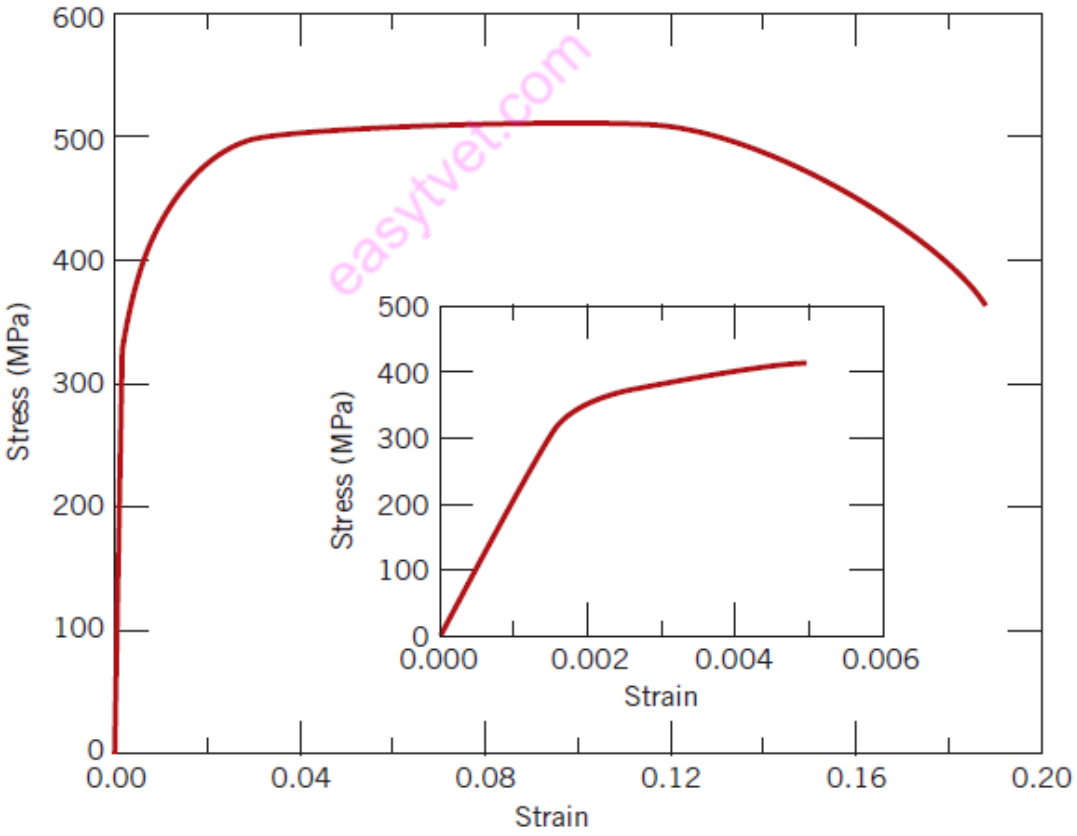

Figure 2

16. It is convenient to classify corrosion according to the manner in which it is manifest.

i. Outline **FIVE** forms of metallic corrosion. [5 Marks]

✓ **Uniform** ✓ **Galvanic**

- ✓ **Crevice**
- ✓ **Pitting**
- ✓ **Intergranular**
- ✓ **selective leaching**
- ✓ **erosion-corrosion**
- ✓ **stress corrosion.**

ii. Describe the conditions under which the corrosion name in (i) above occurs. [5 Marks]

Uniform

- ✓ **occurs with equivalent intensity over the entire exposed surface and often leaves behind a scale or deposit. In a microscopic sense, the oxidation and reduction reactions occur randomly over the surface.**

Galvanic

- ✓ **occurs when two metals or alloys having different compositions are electrically coupled while exposed to an electrolyte.**

Crevice

- ✓ **occur as a consequence of concentration differences of ions or dissolved gases in the electrolyte solution, and between two regions of the same metal piece**

Pitting

- ✓ **form of very localized corrosion attack in which small pits or holes form. They ordinarily penetrate from the top of a horizontal surface downward in a nearly vertical direction.**

Intergranular

- ✓ **occurs preferentially along grain boundaries for some alloys and in specific environments. The net result is that a macroscopic specimen disintegrates along its grain boundaries.**

selective leaching

- ✓ **found in solid solution alloys and occurs when one element or constituent is preferentially removed as a consequence of corrosion processes.**

erosion-corrosion

- ✓ **arises from the combined action of chemical attack and mechanical abrasion or wear as a consequence of fluid motion.**

stress corrosion.

- ✓ **results from the combined action of an applied tensile stress and a corrosive environment; both influences are necessary.**

iii. Explain **FIVE** general techniques of corrosion prevention. [10 Marks]

- ✓ **Material selection**

- ✓ **Perhaps the most common and easiest way of preventing corrosion is through the judicious selection of materials once the corrosion environment has been characterized. Standard corrosion references are helpful in this respect.**

- ✓ **Environmental alteration**
  - ✓ **Changing the character of the environment, if possible, may also significantly influence corrosion. Inhibitors are substances that, when added in relatively low concentrations to the environment, decrease its corrosiveness.**
- ✓ **Design**
  - ✓ **Especially with regard to galvanic and crevice corrosion and erosion–corrosion. The design should allow for complete drainage in the case of a shutdown, and easy washing. Because dissolved oxygen may enhance the corrosivity of many solutions, the design should, if possible, include provision for the exclusion of air.**
- ✓ **Coatings**
  - ✓ **Physical barriers to corrosion are applied on surfaces in the form of films and coatings. The coating must be virtually nonreactive in the corrosive environment and resistant to mechanical damage that exposes the bare metal to the corrosive environment.**
- ✓ **Cathodic protection.**
  - ✓ **Cathodic protection simply involves supplying, from an external source, electrons to the metal to be protected, making it a cathode; the preceding reaction is thus forced in the reverse (or reduction) direction.**
  - ✓ **One cathodic protection technique employs a galvanic couple: the metal to be protected is electrically connected to another metal that is more reactive in the particular environment**