MACHAKOS UNIVERSITY COLLEGE

(A Constituent College of Kenyatta University)
University Examinations for 2015/2016

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF BUILDING AND CIVIL ENGINEERING

FIRST SEMESTER EXAMINATION FOR DEGREE IN BACHELOR OF SCIENCE IN CIVIL ENGINEERING

ECV 101: MATERIAL SCIENCE

Date: 3/12/2015 **Time: 2:00 – 4:00 PM**

INSTRUCTIONS:

- ***This paper comprises five questions***
- ***Question one is compulsory and carries 30 marks***
- ***All other questions carry 20 marks each***
- ***Answer question one and any other two questions*** ***TOTAL: 70 MARKS***

QUESTION ONE (30 MARKS)

a) Define the following terms
   i) Electron affinity
   ii) Electronegativity
   iii) Ionization energy (6 marks)

b) Mg has an atomic number Z = 12. What is the electronic configuration for a magnesium ion with a plus two (+2) charge: (3 marks)

c) Briefly explain what you understand by the following terms
   i) Atoms
   ii) Elements
   iii) Isotopes (6 marks)

d) Indicate the material class for each of the following materials
   i) Quartz
   ii) Bone china
   iii) Aluminum
   iv) Plywood
   v) Fiberglass

vi) Diamond
vii) Zip lock
viii) Polyvinyl Chloride
ix) Paper Clip
x) Concrete
xi) Plywood
xii) Zinc (3 marks)

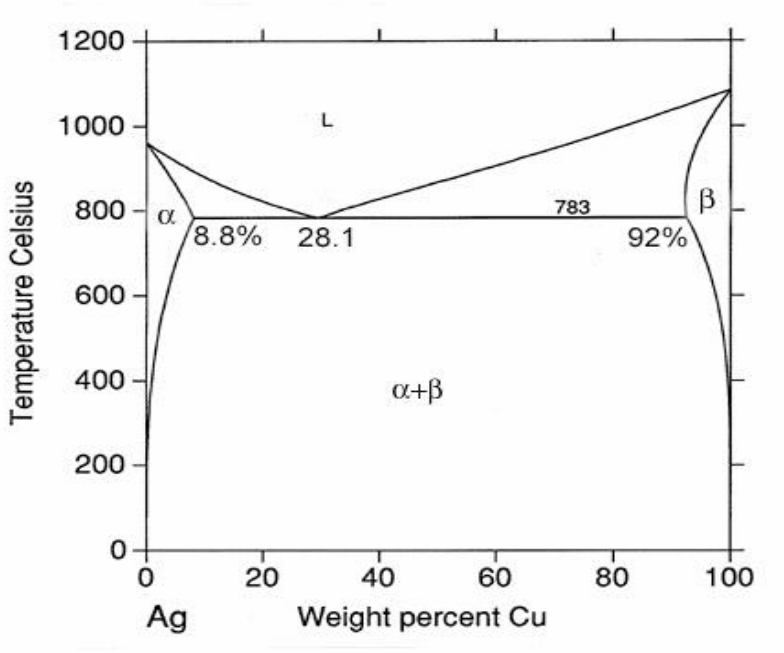
e) Which kinds of bonding are present in the case of graphite? Draw schematically the graphite structure and explain which material properties are a consequence of this structure. (6 marks)

f) A three-point bending test was conducted on an Al_2O_3 specimen having a circular cross section of radius 3.5mm. The specimen fractured at a load of 950N when the support point separation distance was 50mm. Another test is to be performed on a specimen of this same material, but having a square cross section of 12mm length on each edge. At what load would you expect this specimen to fracture if the distance between the support points is 40mm? (6 marks)

QUESTION TWO (20 MARKS)

Phase Diagrams and Strengthening of Metal Alloys (20 marks)

Shown below is the Ag-Cu phase diagram



a) State the main characteristics (structure, composition) of the phases that are labeled by α and β.
b) State the eutectic temperature and concentration.
c) Sterling silver, an alloy containing approximately 92.5 wt.% silver, is held for some time at a temperature in the α phase field, and then rapidly quenched to room temperature. What microstructure is likely? By what mechanisms is the quenched alloy strengthened?
d) Sterling silver can be heat treated to produce β particles in a matrix of α. However, little strengthening occurs, compared to, for example, the strengthening effect of Fe_3C particles in BCC iron. Why is there a difference?

QUESTION THREE (20 MARKS)

Tensile Test and Plastic Deformation (20 marks)

A copper rod is deformed using a uniaxial tensile force of 16,000 N. Deformation continues until sufficient strain hardening has occurred such that the applied force is too small to allow further deformation. After deformation, the rod has a diameter of 0.01 m and a length of 1.5 m. Assume that copper follows the Strain hardening law $\sigma = K\varepsilon^n$ with K = 310 MPa, and n = 0.54. **In the following, do not forget to state the units.**

a) Briefly explain why many ductile materials exhibit an increase in yield stress with plastic deformation when deformed at room temperature.
b) Calculate the true stress that caused the deformation.
c) Calculate the true strain after deformation.
d) Calculate the initial length of the rod before deformation began.
e) Suggest a way to further deform the rod using the same applied force.

QUESTION FOUR (20 MARKS)

Brittle Fracture

A thick plate of Al_2O_3 (alumina) contains an embedded elliptical crack (geometry factor = 1) and is broken in uniform tension (mode I loading). The fracture stress was 12 MPa and the critical crack size ($2c$) was 60 mm. The Young's modulus of Al_2O_3 is 400 GPa.

(a) Determine the fracture toughness. **Do not forget to state the units.**
(b) Determine the fracture surface energy. **Do not forget to state the units.**

(c) Explain, qualitatively, why is alumina brittle?

(d) Explain why it is not good engineering practice to use the maximum tensile stress when designing mechanically reliable parts made of ceramics such as alumina.

QUESTION FIVE (20 marks)

a) Draw the monomer and polymer chain of ethylene. By which properties are the mechanical properties of polymer materials determined? (6 marks)

b) Which material would you choose for (a) a crank shaft of an internal combustion engine, (b) a helicopter rotor blade and (c) a complex housing of a cheap DVD player? Give reasons for your decision. Which engineering activities are required to ensure a safe in-service operation? (10 marks)

c) Order the following materials by (a) their modulus of elasticity, (b) their costs and (c) the ease to recycle them: low carbon steel, Al_2O_3, pure gold. (5 marks)