UNIVERSITY OF GHANA

BSC. (ENG) MATERIALS SCIENCE & ENGINEERING

END OF FIRST SEMESTER EXAMINATIONS: 2015/2016

DEPARTMENT OF MATERIALS SCIENCE & ENGINEERING

MTEN 201: FUNDAMENTALS OF MATERIALS SCIENCE & ENGINEERING (3 CREDITS)

INSTRUCTIONS:

ANSWER ALL QUESTIONS IN (SECTION A) AND (SECTION B)

(Graph sheets are provided upon request)

TIME ALLOWED: TWO AND A HALF $(2\frac{1}{2})$ HOURS

SECTION A: OBJECTIVES

1. The smelting of a metal

(a) Raises the temperature above the melting point.

(b) Separates the metal from the ore.

(c) Deforms the metal into a shape.

(d) Cools the metal very rapidly from a high temperature.

2. What is the first known human-made material?

(a) Ceramic

(b) Bronze

(c) Flint arrowheads

(d) Copper

3. For a given element, which of the following has the greatest entropy?

(a) A perfect single crystal

(b) A polycrystal

(c) A liquid

(d) A vapor

4. Wrought iron is

(a) Heated and then rapidly quenched into water

(b) Packed in carbon to harden the iron

(c) Heated in carbon monoxide

(d) Deformed into shape

5. At a temperature below the melting temperature of the solid, if a mole of liquid changes to solid, the change in the Gibbs free energy is equal to:

(a) The negative of the heat of fusion.

(b) Zero.

(c) A negative value.

(d) A positive value

6. A microscope that can view the surface of insulators with atomic resolution is

(a) A scanning electron microscope

(b) A scanning tunneling microscope

(c) A light optical microscope

(d) An atomic force microscope

7. Which of the following is not a property of a ceramic such as alumina?

(a) A high melting temperature

(b) A high resistance to fracture

(c) It is a good insulator.

(d) It is inorganic.

8. Which of the following is not a property of a polymer?

(a) Large molecules with repeating units

(b) Can be either organic or inorganic

(c) A high density

(d) Good resistance to corrosion

9. The chassis of Formula 1 race cars is now made from

(a) High-strength steel

(b) High-strength aluminum

(c) High-strength polymers

(d) Graphite-fiber-reinforced epoxy

10. In the space shuttle, the areas exposed to the highest temperature are made of

(a) Graphite-fiber-reinforced carbon-carbon composite

(b) Silica tiles coated with silicon carbide

(c) Graphite-fiber-reinforced epoxy composite

(d) Alumina tiles

11. The highest-temperature aircraft gas-turbine blades are made from

(a) Tungsten

(b) Single crystals of nickel-based alloys

(c) Polycrystals of nickel-based alloys

(d) Alumina

12. Which of the following is not an appropriate use of OUHMWPE?

(a) Milk bottles

(b) Parachute lines

(c) Bow string

(d) Tug tow rope

13. A design project requires a TiNi wire to be shaped like the letter S at an operating temperature of 100°C. The selected TiNi atom arrangement starts to distort at a temperature of 90°C and the distortion is finished at a temperature of 60°C. The wire was drawn straight at a temperature of 500°C, and the wire supplied is straight. The wire is easily bent into the required S shape at room temperature. What will be the shape of the wire at the operating temperature of 100°C?

(a) S shaped

(b) C shaped

(c) Straight

(d) The shape is impossible to know.

14. A design requires a material that must have a high melting temperature, high stiffness, high compressive strength, low density, and low cost. Which of the following materials is most likely to best satisfy the design requirements?

(a) Alumina ceramic

(b) Carbon steel

(c) Polyethylene

(d) Graphite-reinforced-epoxy composite

15. A design requires a material to operate at normal atmospheric temperatures, be subjected to small applied forces, and have a low density and a low cost. Which of the following materials is most likely to best satisfy the design requirements?

(a) Alumina ceramic

(b) Carbon steel

(c) Polyethylene

(d) Graphite-reinforced-epoxy composite

[15 Marks]

SECTION B

(ANSWER ALL QUESTIONS)

1.

a. Define the terms lattice, unit cell, basis, and crystal structure

b. Calculate the atomic radius in cm for the following:

i. BCC metal with $a_0 = 0.3294$ nm; and

ii. FCC metal with $a_0 = 4.0862$ Å

c. Determine the indices for the directions in the cubic unit cell in **figure 1** below.

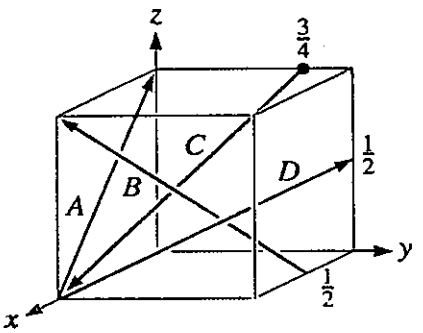

Figure 1. Directions in a cubic unit cell

[15 Marks]

2.

a. In determining the Apparent Porosity and Bulk Density of a ceramic roof tile, a Materials Engineer applied the Archimedes' principle and obtained the following results:

Weight of a test piece of the dry roof tile suspended in air = 58.8 g

Weight of soaked test piece of the roof tile in water = 33.0 g

Weight of soaked test piece of roof tile in air = 63.0 g

Calculate;

i. The Bulk Density of the roof tile

ii. The Apparent Porosity of the roof tile

If the specific gravity of the particles that make up the roof tiles is 3.0.

iii. Calculate the True Porosity of the roof tile

iv. What inference could you draw from the Apparent and True Porosity values?

[15 Marks]

3.

a. A 1.5-kg specimen of a 90 wt% Pb–10 wt% Sn alloy is heated to 250°C (480°F); at this temperature it is entirely an α-phase solid solution (**Figure 2**).The alloy is to be melted to the extent that 50% of the specimen is liquid, the remainder being the α -phase. This may be accomplished either by heating the alloy or changing its composition while holding the temperature constant.

i. To what temperature must the specimen be heated?

ii. How much tin must be added to the 1.5-kg specimen at 250°C to achieve this state?

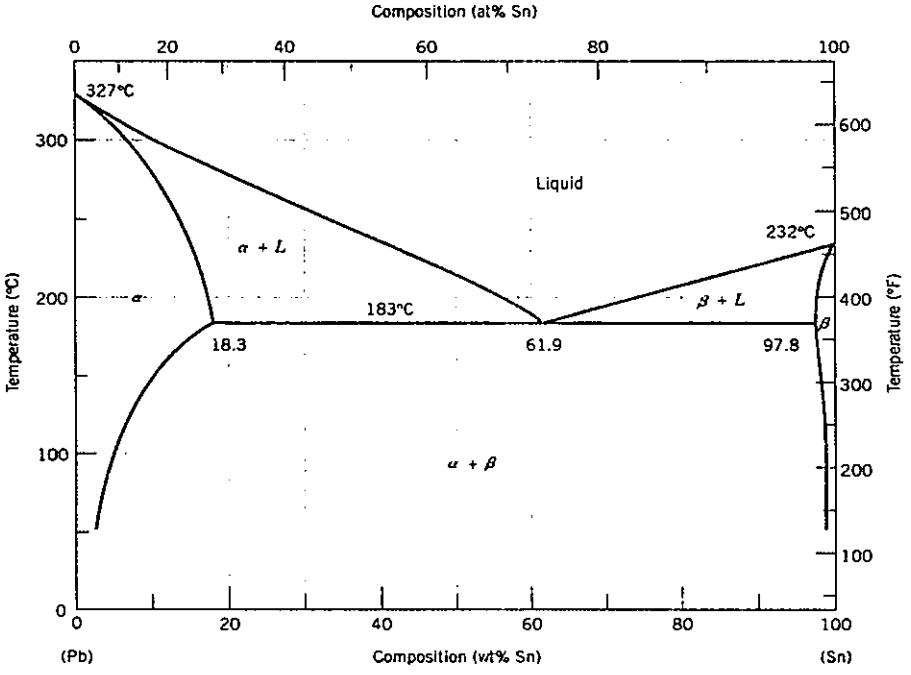

FIGURE 2 The lead–tin phase diagram

[15 Marks]

4.

a. What are 'composites'
b. Name the three basic categories of composite materials
c. Identify some of the characteristic properties of composite materials
d. What are the common forms of reinforcing phase in composite materials?
e. Briefly explain three techniques that are used to strengthen concrete by reinforcement.

[15 Marks]

5.

a. Define the following as applied to the mechanical properties of materials;
   i. Engineering stress and engineering strain
   ii. Modulus of elasticity
   iii. Plastic deformation
   iv. Elastic deformation
   v. Flexural strength
   vi. Flexural modulus

b. A bar of Al_2O_3 that is 0.625 cm thick, 1.25 cm wide, and 22.5 cm long is tested in a three-point bending apparatus with the supports located 15 cm apart. The deflection of the center of the bar is measured as a function of the applied load. The data are shown in table 1 below. Determine the flexural strength and flexural modulus.

Table 1: Three-point bending measurements

Force (N)	Deflection (cm)
64.5	0.00625
128.5	0.0125
193.0	0.01875
257.5	0.025
382.5	0.03725 (fracture)

[20 Marks]