SOUTH EASTERN KENYA UNIVERSITY

UNIVERSITY EXAMINATIONS 2016/2017

FIRST SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE (PHYSICS) AND BACHELOR OF EDUCATION (SCIENCE)

SPH 408: PHYSICS OF MATERIALS

9TH DECEMBER, 2016 TIME: 1.30-3.30 P.M

INSTRUCTIONS TO CANDIDATES

- This paper consists of **FIVE (5)** questions.
- Answer question **ONE** and any other **TWO** questions.
- Question **ONE** carries 30 marks while the other **TWO** questions carry 20 marks each.
- The following constants may be necessary
  Molar gas constant, R = 8.3$Jmol^{-1}K^{-1}$
  Avogadro's constant NA = $6.0X10^{23}mol^{-1}$
  Planks constant, h=6.63x 10^{-34} Js

QUESTION ONE (COMPULSORY) (30 MARKS)

a) (i) Define surface tension (1mark)

(ii) Water in vertical glass tube rises to a height of 11.4 cm above the common level. The angle of contact is 20.5°. Given that the density of water is 1000kgm^{-3}, the radius of the tube is 0.72 mm and the gravitational acceleration strength g is 10Nkg^{-1}, determine the surface tension of water. (4marks)

b) An elastic string of cross sectional area 4 mm^2 requires a force of 2.8 N to increase its length by one tenth. If the original length of the string was 1 m, find:

i) The Young's modulus for the string (3marks)

ii) For the above extension, determine the energy stored in the string (3marks)

c) The latent heat of vaporization of water is $4.0 x 10^4 Jkg^{-1}$, at its boiling point, and each water molecule has on average, 10 near neighbors. Taking Avogadro's constant to be 6.0 $x10^{23}$ mol^{-1}, determine the binding energy of a pair of adjacent molecules of the water. (4marks)

d) A sample of glass has a crack of half-length 2 μm. the Young's modulus of the glass is 70 GNm^{-2} and the specific surface energy is 1 Jm^{-2}. Estimate using the Griffith criterion its fracture strength and compare it with its Young's modulus. (5marks)

e) Calculate the energy difference between the $n_x = n_y = n_z = 1$ level and the next higher energy level for free electrons in a solid cube of 10 mm x 10 mm x 10 mm. (6marks)

f) A steel tank contains hydrogen at a constant pressure of 10 atm, with a vacuum outside. The hydrogen concentration at the inner surface of the tank is equal to 10 kgm-3, the diffusion coefficient of hydrogen in steel at room temperature is 10^{-9} m^2 s^{-2}. Calculate the rate at which hydrogen escapes through the wall of the steel tank which has a thickness of 5 mm (4marks)

QUESTION TWO (20 MARKS)

a) Calculate the potential energy, in eV, per pair of atoms of a solid for which the latent heat of sublimation is $1.3x10^4 Jmol^{-1}$ and the number of neighbors per atom is 6. (4marks)

b) For a pair of atoms, sketch a graph showing how the potential energy per atom pair varies with the distance between the atoms and explain the shape of the graph (9marks)

On your graph show

i. The equilibrium separation, r_o, (1mark)

ii. The value of the energy calculated in (a) above (2marks)

c) For a pair molecules A and B at a distance, r, from each other, show that the force, F, acting between them is given by;

$$F = -\frac{dE}{dr}$$ (4marks)

QUESTION THREE (20MARKS)

a) An aluminium wire of length 0.35 m and radius 0.20 mm, is stretched by 1.40 mm. the young's modulus of aluminium is 7.0×10^{10}Pa. determine :

i. The strain in the wire (2marks)

ii. The stress in the wire (2marks)

iii. The cross sectional area of the wire (2marks)

iv. The tension in the wire (2marks)

b) Distinguish between shear modulus, G, and bulk modulus, K, giving their mathematical expressions (4marks)

c) With reference to rubber

i. Define elastic hysteresis (1mark)

ii. Sketch the hysteresis loop for rubber and briefly discuss the shape of the loop (7marks)

QUESTION FOUR (20MARKS)

a) When a material is subjected to cyclic loading, it may fail to function due to fatigue and eventually fracture. The material may undergo ductile fracture or brittle fracture.

i. Distinguish between ductile fracture and brittle fracture (2marks)

ii. The half length of cracks in a material in steel is 2μm. Taking the Young's modulus of steel as 200 GNm^{-2}, using Griffith theorem, estimate the brittle fracture strength at low temperatures if the true surface energy is 1.5 Jm^{-2}. The actual fracture strength is found to be 1200GNm^{-2}. Explain the difference if any between this and your result. (5marks)

b) i) Derive the kinetic energy E of free electrons as a function of their wave number k . (7marks)

ii) Calculate the conductivity of copper at 300 K. the collision time, τ, for electron scattering is $2x10^{-14}$s at this temperature. (6marks)

QUESTION FIVE (20MARKS)

a)

i. Define temperature gradient (1mark)

ii. A sheet of glass has an area of 2.0 m^2 and a thickness $8.0x10^{-3}$ m. the glass has a thermal conductivity of 0.80 $Wm^{-1}K^{-1}$. Calculate the rate of heat transfer through the glass when there is a temperature difference of 20 K between its faces. (4marks)

b) The equation of state for one mole of an ideal gas is pV = RT.

i. Write down the Van der Waals' equation for one mole of a real gas. (3marks)

ii. Explain the reasons for the modifications made (3marks)

iii. the following data refer to nitrogen gas:

Critical pressure = $3.4x10^6$ Pa

Critical volume = $9.0x10^{-5}$ m^3 mol^{-1}

Van der Waals' constant, a = $1.4x10^{-1}Pam^6mol^{-2}$

Van der Waals constant, b = $3.9x10^{-5}m^3mol^{-1}$

Use this information to calculate

I. the critical temperature of nitrogen. (5marks)

II. The temperature of an ideal gas with the same pressure and volume per mole as given in the data. (4marks)