SOUTH EASTERN KENYA UNIVERSITY

UNIVERSITY EXAMINATIONS 2016/2017

FIRST SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE IN (PHYSICS/ELECTRONICS/GEOLOGY/METEOROLOGY) AND BACHELOR OF EDUCATION (SCIENCE)

SPH 203: STRUCTURE AND PROPERTIES OF MATTER

8^{TH} 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 $N_A = 6.0X10^{23}mol^{-1}$

  Young's modulus of steel = 2.0 x 10^{11} Pa,

  Linear expansivity of steel = 1.6 x $10^{-7o}C^{-1}$

  Volume of unit all for aluminium Vu= 8.99 X $10^{-29}m^3$

QUESTION ONE (COMPULSORY) (30MARKS)

a) (i) Differentiate surface tension and free surface energy (2marks)

(ii) A soap bubble was slowly enlarged from a radius of 6 cm to a radius of 9 cm. the amount of work necessary for the enlargement was 20×10^{-4} Joules. Calculate the surface tension of the soap bubble (3marks)

b) (i) Bernoulli's equation states the consequences of the principle that work done on a fluid as it flows from one place to another is equal to the change in its mechanical energy. State the four conditions under which this principle is valid (4marks)

(ii) A horizontal pipe of cross sectional area 15 cm^2 carries water from one place to another. At the second point, the pressure difference is observed to be 200 Nm^{-2}. Determine the volume flux. (5marks)

C) A 20 m length of continuous steel railway line of cross sectional area 8.0×10^{-3} m^2 is welded into place after heating to a uniform temperature of 40^oC. Taking Young's modulus for steel to be 2.0×10^{11} Pa, its linear expansivity to be $12 \times 10^{-6} K^{-1}$, its density to be $7800 kgm^{-3}$ and its specific capacity to be 500 $Jkg^{-1}K^{-1}$, calculate, for normal operating conditions at 15^oC;

i. The tensile strain (2marks)
ii. The tensile stress (3marks)
iii. The elastic strain energy in the rail (3marks)

d) A mole of an ideal gas at 300 K is subjected to a pressure of 10^5Pa and its volume is 0.0025 m^3. Calculate:

i. The molar gas constant R (2marks)

ii. The Boltzmann constant k (2marks)

iii. The average translational kinetic energy of a molecule of the gas

($N_A = 6.0 \times 10^{23}$ $mole^{-1}$) (4 marks)

QUESTION TWO (20MARKS)

a)

i. Define a polymer. (1mark)

ii. Distinguish between a thermosetting and thermoplastic polymers giving an example in each case (3marks)

iii. For ionic crystals, show that the main contribution to the binding energy of ionic crystals is electrostatic and is given by the Madelung energy expressed by

$$U_{R_0} = -\frac{9}{10}\left[N_0 \frac{Q^2}{4\pi\varepsilon_0 R_0}\alpha\right]$$ (10marks)

b) i. Differentiate between density and parking fraction as used in crystal structure (2marks)

ii. Calculate the parking fraction for the Body Centered Cubic (BCC) crystal structure of sodium. Take lattice parameter ‘a’ as 4.22Å (4marks)

QUESTION THREE (20MARKS)

a) Aluminium has a density of $2699kgm^{-3}$ and its atomic weight is 26.97

i. determine how many moles of aluminium are contained in 1 m^3 of the solid (3marks)

ii. calculate the number of atoms contained in $1m^3$ (2marks)

iii. determine the length of the unit cube for this FCC metal (5marks)

iv. calculate the atomic radius of aluminium atom (3marks)

v. determine the weight of a single atom of aluminium (2marks)

(b) Consider a clean narrow tube of internal radius R held vertically and lowered into water. Show that the surface tension is given by

$$\gamma = \frac{R\rho g}{2\cos\theta}\left(h + \frac{R}{3}\right)$$ (5marks)

(c) A steel rod of length 0.60m and cross sectional area 2.5x 10^{-5} m^2 at 100^oC is clamped so that when it cools it is unable to contract. Find the tension in the rod when it has cooled to 20^oC. (5marks)

QUESTION FOUR (20 MARKS)

a)

i. Derive Poiseuille's formula $V = \frac{\pi P a^4}{8\eta L}$ for a fluid through a narrow tube (Symbols have their usual meaning) (10marks)

ii. State the assumptions made in the above derivation (2marks)

b) An empty vessel which is open at the top has a horizontal capillary tube of length 20 cm and internal radius 1.0 mm protruding from one of its side walls immediately above the base. Water flows into the vessel at a constant rate of 1.5 cm^3s^{-1}. Determine the depth at which the water level will stop rising. Assume the flow is steady, the coefficient of viscosity for water = $1.0x10^{-3}Nsm^{-2}$, density of water = $1.0x10^3kgm^{-3}$ and acceleration due to gravity = 10 ms^{-1} (8marks)

QUESTION FIVE (20MARKS)

a) Air is contained in a cylinder by a frictionless gas-tight piston. Find the work done by the gas as it expands from a volume of 0.015 m^3 to a volume of 0.027 m^3 at a constant pressure of $2.0x10^5$ Pa. (5marks)

b) Find the final pressure if, starting from the same initial conditions as in (a), and expanding by the same amount, the change occurs

   i. Isothermally

   ii. Adiabatically (γ for air = 1.40) (5marks)

c) A steel pressure vessel of volume 2.2×10^{-2} m^3 contains 4.0×10^{-2} kg of a gas at a pressure of 1.0×10^{5} Pa and temperature 300 K. An explosion suddenly releases 6.48×10^{4} J of energy, which raises the pressure instantaneously to 1.0×10^{6}Pa. assuming no loss of heat to the vessel and ideal gas behavior, calculate:

   i. The maximum temperature attained (3marks)

   ii. The two principal specific heat capacities of the gas (4marks)

   iii. Determine the velocity of sound in this gas at a temperature of 300 K(3marks)