KENYATTA UNIVERSITY

UNIVERSITY EXAMINATIONS 2011/2012

FIRST SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF EDUCATION (SCIENCE) BACHELOR OF SCIENCE, AND BACHELOR OF SCIENCE (TELECOMMUNICATION AND INFORMATION TECHNOLOGY)

SPH 203: THERMAL PHYSICS I

DATE: MONDAY, 5TH DECEMBER 2011 **TIME: 4.30 P.M. – 6.30 P.M.**

Instructions:

1. **Answer question one and any other two questions. Question one carries 30 marks while each of the other carries 20 marks**
2. **The following are constants that you may need.**
   - i) Universal gas constant $R = 8.314\ J\ mol^{-1}\ K^{-1}$
   - ii) Boltzmann's constant $k = 1.38 \times 10^{-23}\ J/K$
   - iii) Stefan-Boltzmann's constant $\sigma = 5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$
   - iv) Specific heat capacity of water = $4190\ Jkg^{-1}K^{-1}$
   - v) Specific heat capacity of ice = $2000\ Jkg^{-1}K^{-1}$
   - vi) Latent heat of fusion of ice $= 3.34 \times 10^{5} J/kg$
   - vii) Latent heat of vaporization of water = $2.256 \times 10^{6} J/K$
   - viii) Specific heat capacity of silver = $230\ Jkg^{-1}K^{-1}$
   - ix) Linear coefficient of expansion of steel = $1.2 \times 10^{-5}/K$
   - x) Young's modulus of copper = 3.5×10^{9} Pa
   - xi) Specific heat capacity of lead = $123\ Jkg^{-1}K^{-1}$
   - xii) Latent heat of fusion of lead = $2.45 \times 10^{4} J/kg$
   - xiii) Wien's constant $= 2.67 \times 10^{-3}$ mK
   - xiv) Atomic mass of silver $= 108\ g\ mol^{-1}$

Q1. a) What is meant by a thermometric property ? Give two examples of a thermometric properties [2marks]

b) Explain why the column of mercury first descends and then rises when a mercury in glass thermometer is put in a flame. [2marks]

c) Explain what is meant by the following terms as used in thermodynamics.
   - i) An isolated system
   - ii) A diathermal wall
   - iii) An adiabatic wall
   - iv) A quasi-static process
   - v) An isochoric process [5marks]

d) The specific heat of silver, measured at constant pressure is found to vary with Temperature between 50 K and 100 K by the empirical equation

$$C_p = 0.076T - 0.00026T^2 - 0.15$$

where C_p is in J/mol.K and T is the Kelvin temperature. Calculate the heat required to raise the temperature of 0.216 kg of silver from 50 K to 100 K. [5marks]

e) A metal rod that is 40 cm long expands by 0.1 cm when its temperature is Raised from 0° C to 100° C. A rod of different metal and of the same length expands by 0.05 cm for the same rise in temperature. A third rod, also 40 cm long is made of pieces of each of these two metals is places end to end and expands by 0.065 cm between 0°C to 100°C. Find the length of each portion of the composite rod. [5marks]

d) Show that the molar heat capacity C_v at constant volume and molar heat capacity C_p at constant pressure for an ideal gas are related by

$$C_p = C_v + R$$

where R is the universal gas constant. [5marks]

e) If Q is the heat input into a system, W is the work done, U_i and U_f the initial and final internal energies of the system and ΔU is the change in internal energy, copy the table and complete the missing quantities.

Process	Q (kJ)	W (jK)	U_i (kJ)	U_f (kJ)	ΔU (kJ)
a	12	6	81		
b	25	-8		-13	
c	-10			60	-18
d	-10	-6		-10	
e		25	58		16

[6marks]

Q2. a) i) What do you understand by an isotropic material ? [1 mark]

ii) I f α and β are coefficients of linear expansion and volume expansion respectively show that for an isotropic material, $\beta = 3\alpha$ [4marks]

b) A rod of initial length L_o and cross section area A has its ends rigidly fixed while the temperature is reduced by ΔT. Show that the tensile stress σ induced in the rod is given by

$$\sigma = Y\alpha\Delta T$$

where Y and α are the Young's modulus and the coefficient of linear expansion respectively. [4marks]

c) A copper wire 4 m long and 4 mm diameter was given the test below. A load was originally hung on the wire to keep it tight with position of the lower end of the wire against a scale reading 3.02 cm.

Added load in (N)	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0
Scale reading in (cm)	3.02	3.07	3.12	3.17	3.22	3.27	3.32	4.27

i) Plot a graph of load against extension [3marks]
ii) Determine the Young's modulus of copper [3marks]

d) A 5 g lead bullet traveling at 300 ms^{-1} strikes a flat steel plate and stops. If lead has a melting point of 327° C and assuming that all thermal energy generated by the impact remains with the bullet, determine whether the bullet melts ? [5marks]

Q3. a) i) State Zeroth law of thermodynamics [1mark]

ii) Write down the mathematical statement of the first law of thermodynamics. [1mark]

b) Show that for an ideal gas undergoing an adiabatic process,

$TV^{\gamma-1}$ = constant

where $\gamma = C_p / C_v$ and C_p and C_v are specific molar heat at constant pressure and volume respectively. [5marks]

b) A cylinder with a piston contains 0.50 moles of oxygen at 5.0×10^5 Pa at 300 K. and can treated as an ideal gas. The gas is first expanded at constant pressure to twice its original volume. It is then compressed isothermally back to its original volume, and finally it is cooled at a constant volume to its original pressure.

i) Show the series of processes on a pV diagram. [2marks]
ii) Compute the temperature during the isothermal process [3marks]
iii) Compute the maximum pressure. [2marks]
iv) Calculate the work done by the gas, and its change in internal energy during the initial expansion [3marks]
v) Calculate the heat added and the internal energy change during the final cooling. [3marks]

Q4. a) How much heat would you require to heat 50 g of ice from -10° C to Complete evaporation at 100° C at normal atmospheric pressure ? [5marks]

b) The equation for a fixed mass of an ideal gas at absolute temperature T, pressure P and volume V is given by PV = mRT, where R is the gas constant. Show that:

$$\left(\frac{\partial P}{\partial V}\right)_T \left(\frac{\partial V}{\partial T}\right)_P \left(\frac{\partial T}{\partial P}\right)_V = -1$$ [5marks]

c) i) What do we mean by a black body ? [1mark]

ii) On the same axes, sketch curves showing the variation with frequency of the energy radiated from a black body at temperatures 1000 K and 5000 K. [2marks]

iii) Write down the mathematical statement of Wien's displacement law and define the parameters used. [2marks]

d) To a good approximation, the sun is a black body. If the surface temperature of the sun is 5900 K, calculate,

i) the peak intensity wavelength [2marks]

ii) total radiated power per unit area [3marks]

Q5. a) Write down the dimensions of thermal conductivity. [2marks]

b) Consider a well insulated copper rod of length 0.3 m and cross section area of 2 cm^2 . If one end is kept at a temperature of $T_H = 200^\circ C$ and the other end is at $T_L = 20^\circ C$ and a steady state temperature is attained find,

i) the temperature gradient [1mark]

ii) the rate of heat transfer by conduction [3marks]

iii) the temperature at 10 cm from the lower temperature end [2marks]

iii) Two slabs of thermal conductor are placed between a reservoir at high Temperature T_H and a low temperature T_L as shown in the Fig. 5.1 The slabs Have a cross sectional area A m^2 and a thickness L m.

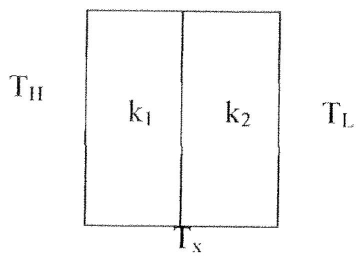

Fig.5.1

Derive the expression for

i) the temperature T_x of the interface between the conductors [5marks]

ii) the rate at which heat is conducted into the lower temperature reservoir [4marks]

iii) Generalize your expression for rate of heat conducted for N slabs of different thermal conductivities combined in series [2marks]
