KABARAK UNIVERSITY

UNIVERSITY EXAMINATIONS

2009/2010 ACADEMIC YEAR

FOR THE DEGREE OF BACHELOR OF EDUCATION SCIENCE

COURSE CODE: **PHYS 121**

COURSE TITLE: **HEAT AND THERMODYNAMICS**

STREAM: **SESSION II**

DAY: **MONDAY**

TIME: **9.00 – 11.00 A.M.**

DATE: **30/11/2009**

INSTRUCTIONS:

ANSWER QUESTION **ONE** AND ANY OTHER **TWO** QUESTIONS.
QUESTION ONE CARRIES 30 MARKS AND THE OTHERS 20 MARKS EACH.
THE FOLLOWING CONSTANTS AND RELATION MAY BE USEFUL.

Volume expansion coefficient $\beta = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$

Universal gas constant R=8.314$Jmol^{-1}(C^o)^{-1}$
Boltzmann constant k=$1.38x10^{-23}$J/K
Stafan's constant σ = $5.67x10^{-8}J/s.m^2.K^4$
One atmosphere = $1.01x10^5$ Nm^{-2}
Specific heat capacity of water=4186J/kg.^{o}C
One kilo calorie = 4186J

PLEASE TURN OVER

Q1. (a) Define the following (i) Isothermal process (1mark)

(ii) Thermal equilibrium. (1 mark)

(iii) Isochoric process. (1 mark)

(b) (i) State the Zeroth law of thermodynamics. (1 marks)

(ii) Convert the temperature of a normal body which is 98.6^{o}F in to its Celcius scale equivalent. (2 marks)

(c) (i) Write the equation of state of an ideal gas. (1 mark)

(ii) The change in pressure of a gas can be expressed as $dP = \frac{\beta}{\kappa} d\theta - \frac{1}{\kappa V} dV$, where β is the volume expansivity and κ is the isothermal compressibility. Show that the pressure change P_i to P_f corresponding to a small temperature change T_i to T_f at constant volume is $P_f - P_i = \frac{\beta}{\kappa}\int_{T_i}^{T_f} d\theta$. (2 marks)

(iii) Hence, given that a mass of mercury at standard atmospheric pressure and temperature of 0^{o}C is kept at constant volume and the temperature is raised to 10^{o}C, find the final pressure if β=1.81x10^{-6}K^{-1} and κ=3.82x10^{-11}Pa^{-1} for mercury. (3 marks)

(d) Ice at 0^{o}C is placed in a Styrofoam cup containing 0.32kg of tea at 27^{o}C. The specific heat capacity of tea is virtually the same as that of water. After the ice and tea reach an equilibrium temperature, some ice still remains. Neglecting the specific heat capacity of the cup and any heat losses to the surroundings, determine that mass of the ice that has melted. Latent heat of fussion of ice is 33.5x10^{4}J/kg.

(2 marks)

(e) (i) Using a schematic diagram, describe the operations of I. a heat engine. (2 marks)

II. a refrigerator. (2 marks)

(ii) The efficiency of an engine is $Efficiency(\%) = 100\left(1 - \frac{1}{\left(\frac{V_1}{V_2}\right)^{\gamma-1}}\right)$. Find the efficiency of an engine whose compression ratio is 10 and γ=1.4. (2 marks)

(f) (i) One kilogram of ice at 0^{o}C is melted and converted to water at 0^{o}C. Compute its change in entropy, given that the latent heat of fusion of water is 334880J/kg. (2 marks)

(ii) Sketch a T-S diagram and starting with the Claussiss inequality, derive the expression for the law of increase of entropy. (3 marks)

(iii) Explain which processes the equality, greater than or less than signs stand for. (3 marks)

(iv) State the third law of thermodynamics. (1 mark)

(v) Define an isentropic process. (1 mark)

TOTAL MARKS=30

Q2 (a) (i) Define the triple point of water. (1 mark)

(ii) A gas thermometer has a pressure of 1.60×10^4Pa at the triple point of water and a pressure of 2.5×10^4Pa at some unknown temperature T. Find the value of T. (2 marks)

(b) Cold water at a temperature of 15^oC enters a heater, and the resulting hot water has a temperature of 61^oC. A person uses 120kg of hot water in taking a shower. Find the number of (i) Joules and (2 marks)

(ii) kilocalories needed to heat the water (1½ marks)

(iii) Assuming that the power supply company charges 5 Kenya shillings per kilowatt.hour for electrical energy, determine the cost of heating the water. (1½ marks)

(c) (i) Write the Stefan-Boltzmann law for blackbody radiation. (1 marks)

(ii) A perfectly blackbody whose total surface area is $1.5m^2$ and has a surface temperature of 30^oC is placed in a surrounding whose temperature is 20^oC. Calculate the net rate of (heat) loss from the body by radiation. (3 marks)

(d) (i) With the help of a diagram, Show that the work done by a gas expanding in a piston of area A from volume V_1 to V_2 is $W = \int_{V_1}^{V_2} PdV$, where P is the pressure of the gas. (2 marks)

(ii) A piston cylinder device initially contains $0.6m^3$ of air at 100kpa and 80^oC. The air is now compressed to $0.2m^3$ in such a way that the temperature inside the cylinder remains constant. Determine the work done during this process. (3 marks)

(e) If the relation between the pressure and volume of an adiabatic process is $P_1V_1^{\gamma} = P_2V_2^{\gamma}$, show that the work done in the process is $W = \dfrac{P_2V_2 - P_1V_1}{1-\gamma}$. (3 marks)

TOTAL MARKS=20

Q3 (a) (i) State and prove both Avogandro's and Dalton's laws. (2½, 2½ marks)

(ii) the first law of thermodynamics. (1 mark)

(iii) From the first law of thermodynamics and given that h=u+pv, show that change in entropy of an ideal gas can be written as

$dS = C_{v,av.} \ln\left(\dfrac{T_2}{T_1}\right) + R\ln\left(\dfrac{V_2}{V_1}\right)$,where the symbols have their usual meanings. (4 marks)

(b) Starting with the fisrt law of thermodynamics, show that the specific heat capacity at constant pressure C_p and the specific heat capacity at constant volume C_v are related by the equation, C_p-C_v=R, where R is the universal gas constant.(4 marks)

(c) Using the result of part (b) above, show that for an adiabatic process,

PV^{γ}=constant, where $\gamma=C_p/C_v$. (6 marks)

TOTAL MARKS=20

Q4. (a) Distinguish between the three forms of heat transfer. (3 marks)

(b) Give the difference between forced and natural convection. (2 marks)

(c) A metal rod 200cm long is heated from 68°F to 140°F. It has a radius of 3.5mm and coefficient of thermal conductivity $385 JS^{-1}m^{-1}(C^{o})^{-1}$. Calculate:-

(i) The temperature gradient giving its correct SI units. (2 marks)

(ii) The rate of heat flow in the metal rod. (2 marks)

(d) (i) Consider the kinetic theory of a gas with N particles contained in a cuboid of length L. With the help of a well labeled diagram, show that the average of the square of the velocity of the gas particles is $\overline{V}^2 = \left(\frac{3kT}{m}\right)$ where m is the mass of a gas particle (molecule/atom), and the other symbols have their usual meanings. (5½ marks)

(ii) Calculate the average translational kinetic energy of gas molecules at 35°C. (2 marks)

(iii) If the gas in part (ii) above is composed of electrons whose mass is $m_e=9.1 \times 10^{-31}$kg, calculate the value of $\overline{V}$ at 1000°C. (2½ marks)

(e) Write down an expression for the enthalpy of gas. (1 mark)

TOTAL MARKS=20

Q5. (a) (i) With the help of a well-labeled diagram, show that the thermal efficiency of a heat engine is $Efficiency = 1 - \frac{Q_C}{Q_H}$, where Q_C is heat for the cold reservoir while Q_H is the heat of the hot reservoir. (3½ marks)

(ii) Hence, find the efficiency of a heat engine operating between two reservoirs at 293K and 373K. (1½ marks)

(b) State the second law of thermodynamics. (1 mark)

(c) (i) Show that the change in the internal energy and enthalpy of an ideal gas during a process from state 1 to state 2 is $\Delta U=C_{v.av}(T_2-T_1)$ KJ/Kg and $\Delta h=C_{p.av}(T_2-T_1)$ KJ/Kg respectively. (1, 1 marks)

(ii) Argon gas is compressed from an initial state of 1000kpa and 17°C to a final state of 600kpa and 57°C. Given that $S_2 - S_1 = C_{p.av} \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}$ kJ/kg.K, determine the entropy change during this compression process by using average specific heats, $C_{p,av}$=10.394kJ/kg.K, R=0.297kJ/kg.K. (3 marks)

(d) (i) Starting with the expression Tds=dU+PdV, show that the entropy change of solids and liquids which are essentially incompressible is $S_2 - S_1 = C_{av} \ln \frac{T_2}{T_1}$. (3 marks)

(ii) A 50kg block of copper at 1000K is thrown into a large lake that is at a temperature of 295K. The copper block eventually reaches thermal equilibrium with the lake water. Assuming an average specific heat capacity of 0.5kJ/kg.K for copper, determine:-

I. The entropy change of the copper block (2 marks)

II. The entropy change of the lake water (2 marks)

III. The total entropy change for this process. (2 marks)

TOTAL MARKS=20