UNIVERSITY OF GHANA

FACULTY OF ENGINEERING SCIENCE

BSc. (Eng) SECOND SEMESTER EXAMINATIONS 2012/2013

MTEN 204-THERMODYNAMICS OF MATERIALS (2 CREDITS)

TIME- 2HRS

ANSWER ALL QUESTIONS

1.

a) Briefly discuss the following terms associated with thermodynamics: **(6 marks)**
   (i) Internal energy,
   (ii) Black body,
   (iii)Thermal conductivity,
   (iv)specific heat capacity,
   (v) Latent heats of fusion
   (vi)Latent heats of vaporization.

b) Using appropriate equation, explain term Polytrophic Process. The exponent, n, in the polytrophic process equation may take on any value from $-\infty$ to $+\infty$ depending on the particular process; describe four (4) processes that may occur within the given conditions. **(8 marks)**

c) State and explain the three (3) laws of thermodynamics **(6 marks)**

d) A glass rod is heated and then blown by a glass blower. When it is at 185°C it is brought outside to cool. 3200 J of heat are transferred from the glass to the air, which is at 18°C. Find the change in entropy of the universe. **(5 marks)**

2.

a) Briefly describe with appropriate real life situations of the 3 main heat transfer processes. **(6 marks)**

b) Under nonstandard conditions, $\Delta G = \Delta G^{\circ} + RT\ln Q$, where Q is the reaction quotient and the gas constant R = 8.314 J/K. Calculate ΔG at 427°C for the reaction below if the P_{N2} = 33.0 atm, P_{H2}= 99.0 atm, and P_{NH3}= 2.0 atm:
   $\mathbf{N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)}$.
   Take the standard entropies S°, as:$NH_3(g)$=192.8 J/mol·K, $N_2(g)$ =191.5 J/mol·K, $H_2(g)$ =130.58 J/mol·K, and the standard enthalpies H° as; $NH_3(g)$=-46.19 J, $N_2(g)$ =0 J, $H_2(g)$ =0 J/mol·K. **(7 marks)**

c) State the energy balance law for a closed system. **(4 marks)**

d) An air tank with a volume of 20 m^3 is pressurized to 10 MPa. The tank eventually reaches room temperature of 25°C. If the air is allowed to escape with no heat transfer until P_f = 200

Examiner: Dr. David Dodoo-Arhin

kPa, determine the mass of air remaining in the tank and the final temperature of air in the tank. **(8 marks)**

3.

a) Air is contained in an insulated, rigid volume at 20°C and 200 kPa. A paddle wheel, inserted in the volume, does 720 kJ of work on the air. If the volume is $2m^3$, calculate the entropy increase assuming constant specific heats, a zero heat transfer and take the gas constant for air $R_{air} = 0.287$ kJ/kg. **(8 marks)**

b) Briefly explain the following terms: system, closed system and open system. **(6 marks)**

c) Given that the standard free energies of formation $\Delta G°_f$ of the following substances are

$CH_4(g) = -50.5$, $O_2(g) = 0.0$, $CO_2(g) = -394.4$, $H_2O(g) = -228.6$, $O_3(g) = 163.2$, calculate

$\Delta G°$ at 25°C for the reaction; $\mathbf{CH_{4(g)} + 8O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)} + 4\ O_{3(g)}}$ **(6 marks)**

d) A 2200-kg automobile traveling at 90 km/h (25 m/s) hits the rear of a stationary, 1000-kg automobile. After the collision, the large automobile slows to 50 km/h (13.89 m/s) and the smaller vehicle has a speed of 88 km/h (24.44 m/s). What has been the increase in internal energy, taking both vehicles as the system? **(5 marks)**

4.

a) Systems can be described from the macroscopic and microscopic points of view. Briefly discuss these 2 viewpoints. **(6 marks)**

b) Calculate $\Delta S°$ for the reaction;

$\mathbf{4NH_{3(g)} + 5O_{2(g)} \rightarrow 4NO_{(g)} + 6H_2O_{(l)}}$.

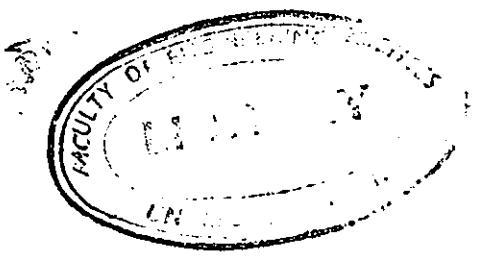
The standard entropies S°, are given as: $NH_3(g) = 192.8$ J/mol·K, $O_2(g) = 205.2$ J/mol·K, $NO(g) = 210.8$ J/mol·K, $H_2O(g) = 188.8$ J/mol·K **(6 marks)**

c) The reactions $\mathbf{SO_{2(g)} + ½\ O_{2(g)} \rightarrow SO_{3(g)}}$ has $\Delta H° = -98.9$ kJ and $\Delta S° = -94.0$ J/K at 25°C. Calculate $\Delta G°$ at 125°C and determine if the reaction is spontaneous. **(7 marks)**

d) Superman vaporizes an 1800 kg ice monster with his heat ray vision. The ice monster was at -20 °C. After being vaporized he is steam at 135 °C. How much energy did Superman expend? Take the following into consideration:

Substance	Specific Heat (in J / kg °C)
ice	2090
liquid water	4186
steam	1970

Also take for water: $L_f = 3.33 \times 10^5$ J/Kg; $L_v = 2.26 \times 10^6$ J/Kg **(6 marks)**



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7. If a system undergoes a change of state during which both heat transfer and work transfer are involved, the net energy transfer will be

A. stored or accumulated within the system.

B. ejected by the system.

C. released by the system as radiation

D. partially stored by the system

E. dissipated as sound energy

8. A heat engine typically uses energy provided in the form of heat to do work and then

A. releases all the energy as heat.

B. releases the energy as sound energy.

C. exhausts the heat which cannot be used to do work.

D. uses all the heat to do the work.

E. dissipates all the heat as light.

9. Calculate the heat required to raise the temperature of iron from 15°C to 220°C. The melting point of iron is 1535°C and the specific heat capacity of iron is 220 J/Kg K .

A. 4600 KJ

B. 1600 KJ

C. 45100 KJ

D. 45150 KJ

E. 1840 KJ

10. A closed system and its surroundings can interact in two (2) ways:

A. thermal transfer and light transfer

B. heat capacity and latent heat

C. work transfer and heat transfer

D. force exerted on the system

E. force exerted on the surrounding

SECTION B: Answer all questions (60 marks)

1.

a. A heat engine converts one sixth of the heat input into work. If the sink temperature is reduced by 62°C, the efficiency gets doubled. Find the source and the sink temperatures. ***8 marks***

b. When a system is taken from state ***a*** to state ***b*** as shown in Figure 1 below, along the path ***acb***, 84 KJ of heat flow into the system and the system does 32 KJ of work.

(i) How much will the heat that flows into the system along the path ***adb*** be, if the work done is 10.5 KJ? ***6 marks***

(ii) When the system is returned from ***b*** to ***a*** along the curved path, the work done on the system is 21 KJ. Does the system absorb or liberate heat, and how much of the heat is liberated or absorbed? ***6 marks***

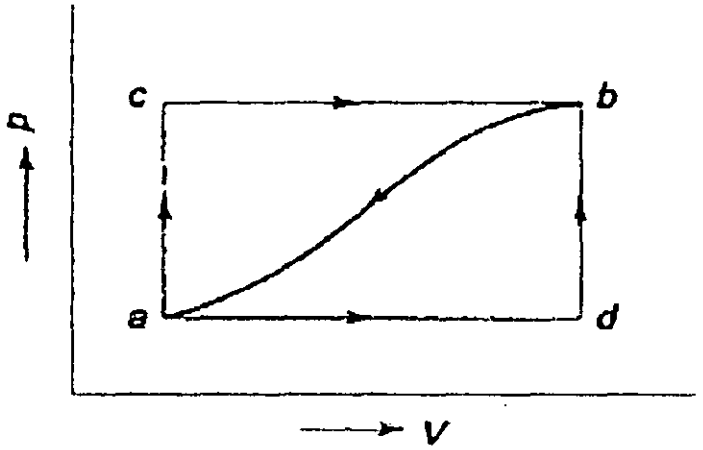

Figure 1

2.

a. In a cyclic heat engine shown in Figure 2 below, heat Q_1 is transferred to the system, work W_E is done by the system, work W_C is done upon the system and then the heat Q_2 is rejected from the system. For such a heat engine show that $Q_1 - Q_2 = W_E - W_C$. ***5 marks***

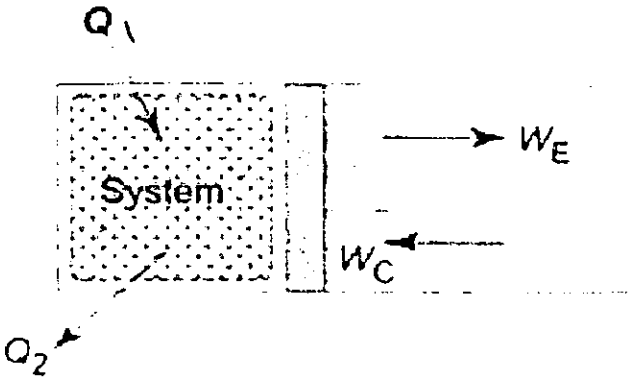

Figure 2

b. When the valve of an evacuated bottle is opened, atmospheric air rushes into it. If the atmospheric pressure is 101.325 kPa and 0.6 m^3 of air (measured at atmospheric conditions) enters into the bottles, calculate the work done by the air. ***5 marks***

c. Explain the statement; a cyclic heat engine can never be 100 % efficient. ***5 marks***

d. What is a "thermal energy reservoir"? Calculate the maximum efficiency of a heat engine operating between 120°C and 35°C. ***5 marks***

3.

a. Explain briefly the Kelvin-Planck and Clausius statements of the second law of thermodynamics. ***4 marks***

b. Define the terms specific heat and latent heat capacities. ***4 marks***

c. What would be the final temperature if a 2 kg piece of lead at 200°C is inserted in a container with 10 kg of water at 50°C? (The specific heat capacities of lead and water are c = 128 J / kg °C and 4186 J / kg °C respectively) **6 *marks***

d. A stationary mass of gas is compressed without friction from an initial state of 0.3 m^3 and 0.105 MPa to a final state of 0.105 m^3 and 0.105 MPa, the pressure remaining constant during the process. There is a transfer of 37.6 KJ of heat from the gas during the process. How much does the internal energy of gas change? ***6 marks***