JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE AND TECHNOLOGY

SCHOOL OF BIOLOGICAL AND PHYSICAL SCIENCES

UNIVERSITY EXAMINATION FOR THE DEGREE OF BACHELOR OF EDUCATION (SCIENCE)

3RD YEAR 1ST SEMESTER 2018/2019 ACADEMIC YEAR

MAIN

REGULAR

COURSE CODE: SPH 302

COURSE TITLE: THERMODYNAMICS

EXAM VENUE: **STREAM: EDUCATION**

DATE: **EXAM SESSION:**

TIME: 2:00 HRS

Instructions:

1. **Answer question 1 (Compulsory) and ANY other 2 questions.**
2. **Candidates are advised not to write on the question paper.**
3. **Candidates must hand in their answer booklets to the invigilator while in the examination room.**

Useful constants

Latent heat of fusion of water $= 334 kJkg^{-1}$

Latent heat of vaporization of water $= 2256 kJkg^{-1}$

SECTION A

QUESTION 1(30 MARKS)

(a) State the first law of thermodynamics hence explain the concept of positivity and negativity of work within this law. **(2 marks)**

(b) State any **TWO** conditions that determine the occurrence of an adiabatic process. **(1 mark)**

(c) A system containing $+14.7kJ$ of heat undergoes an adiabatic free expansion. Determine the change in the system's internal energy. **(2 marks)**

(d) Show that the work done by an ideal gas during isothermal process is given by

$W = nRT \ln\left(\frac{V_f}{V_i}\right)$ where the symbols have their usual meanings. **(4 marks)**

(e) Define a reversible thermodynamic process and state any four factors that cause a process to become irreversible. **(3 marks)**

(f) (i) State **the main** difference between entropy and energy. **(1 mark)**

(ii) $20g$ of ice at precisely $0°C$ melts to liquid water without change in temperature. Calculate the change in entropy during the process. **(3 marks)**

(g) (i) Distinguish between a heat engine and a Carnot engine. **(1 mark)**

(ii) Compute the maximum possible efficiency of a heat engine operating between the temperature limits $100°C$ and $400°C$. **(2 marks)**

(h) Explain the significance of a TS diagram in thermodynamics. **(1 mark)**

(i) Starting with the Gibbs free energy, obtain the expressions for entropy, volume and the chemical potential **(3 marks)**

(j) Using the differential of enthalpy in the form $dH = TdS + VdP,$ determine the resulting Maxwell's thermodynamic relations. **(2 marks)**

(k) State the importance of Clausius-Clapeyron equation. **(1 mark)**

(l) Determine the physical consequences of the third law of thermodynamics in the following phenomena.

(i) A system subjected to work by hydrostatic pressure such that;

$$\left(\frac{\partial S}{\partial P}\right)_T = -\left(\frac{\partial V}{\partial T}\right)_P = -V\beta_P$$ where β_P is the isobaric cubic expansivity. **(1 mark)**

(ii) A system subjected to surface energy with a surface tension, σ given by

$$\left(\frac{\partial \vec{S}}{\partial \vec{A}}\right)_T = -\frac{d\sigma}{dT}$$ **(1 mark)**

(m) $1mol$ of an ideal gas has a temperature of $310K$ and volume $12l$. The gas is allowed to expand

adiabatically to a volume $19l$. Determine the final temperature $(\gamma = 1.4)$. **(2 marks)**

SECTION B

Answer any TWO questions in this section

QUESTION 2 (20 MARKS)

(a) $1kg$ of liquid water at $100°C$ is converted to steam at $100°C$ by boiling at standard atmospheric pressure $(1.01\times10^5 Pa)$. The volume of the water changes from an initial value of $0.001\ m^3$ as liquid to $1.671\ m^3$ as steam. Calculate the change in the system's internal energy during the process. **(4 marks)**

(b) Show that the molar specific heat at constant pressure is greater than the molar specific heat at constant volume by an amount equal to the universal gas constant, R. **(6 marks)**

(c) Two identical copper blocks L and R each of mass $1.5kg$ are at initial temperature of $60°C$ and $20°C$ respectively. The blocks are in a thermally insulated box and are separated by an insulating shutter. When the shutter is lifted, the blocks eventually come to the equilibrium $T_f = 40°C$. Given that the specific heat capacity of copper is $386 Jkg^{-1}K^{-1}$.determine the net entropy change of the two-block system during this irreversible process. **(10 marks)**

QUESTION 3 (20 MARKS)

(a) (i) Write down the Clausius statement of the second law of thermodynamics. **(1 mark)**

(ii) Suppose $1.0 mol$ of nitrogen gas is confined to the left side of an insulated container whose right hand side is a vacuum. If a stop cork separating the two sides is opened and the volume of the gas doubles, what is the entropy change of the gas for this irreversible process? Treat the gas as ideal ($R = 8.31 J / mol.K$) **(7 marks)**

(b) Derive the thermal efficiency of a Carnot engine in the form $\eta = 1 - \frac{Q_L}{Q_H}$ where the symbols have their usual meanings. **(3 marks)**

(c) A Carnot engine operates between the temperatures $850K$ and $300K$. The engine performs

$1200J$ of work each cycle which takes 0.25 seconds. Determine:

(i) The average power of the engine. **(2 marks)**

(ii) The energy extracted as heat from the high temperature reservoir every cycle. **(5 marks)**

(iii) The energy delivered as heat to the low temperature reservoir. **(2 marks)**

QUESTION 4 (20 MARKS)

(a) Determine the Maxwell's thermodynamic relations using the differential form of Internal energy, Helmholtz free energy and Gibbs free energy respectively **(6 marks)**

(b) Water at $100°C$ under one atmospheric pressure has entropy $S = 0.31 cal g^{-1} K^{-1}$ while that of steam under the same conditions is $1.76 cal g^{-1} K^{-1}$.

(i) Determine the heat of vapourization. **(4 marks)**

(ii) If the enthalpy of steam is $640 cal g^{-1}$, calculate the enthalpy of water under the same conditions. **(5 marks)**

(iii) Calculate the Gibbs free energy of water under the same conditions. **(5 marks)**

QUESTION 5 (20 MARKS)

(a) State the third law of thermodynamics. **(1 mark)**

(b) By taking the example of a system in two phases α and β, show that the condition for equilibrium between the phases is the existence of equality in their specific Gibbs functions.

(9 marks)

(c) Prove that during an adiabatic process of an ideal gas, the relation between temperature and volume is $TV^{\gamma-1} = constant$ where $\gamma = \frac{c_p}{c_v}$ is the specific heat ratio. **(10 marks)**