MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY

(MMUST)

UNIVERSITY EXAMINATIONS

2021/2022 ACADEMIC YEAR

FOURTH YEAR SECOND SEMESTER MAIN EXAMINATIONS

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN PHYSICS AND BACHELOR OF EDUCATION SCIENCE

COURSE CODE: SPH 415

COURSE TITLE: THERMODYNAMICS

DATE: TUESDAY 19TH APRIL, 2022 TIME: 12:00 PM – 2:00 PM

INSTRUCTIONS TO CANDIDATES

Answer question ONE and any TWO of the remaining
Symbols used bear the usual meaning.

MMUST observes ZERO tolerance to examination cheating

USEFUL CONSTANTS

Gas constant $R = 8.313 Jmol^{-1}K^{-1} = 8.3 \times 10^7 ergs/K$

Boltzmann constant $\kappa = 1.38 \times 10^{-38} JK^{-1}$

Planck constant $h = 6.63 \times 10^{-34} Js$

$\mu_B = 9.27 \times 10^{-24} J/T$ $\quad 1J = 1.0 \times 10^7 erg$

1 calorie = 4.18 joules

$\gamma = 1.4$ for diatomic gas

One atmosphere (1 atm) = 1.013×10^5 N/m^2

Latent heat of fusion of water = 3.34×10^5 J kg^{-1}

Latent heat of vaporization of water = 2.256×10^6 J kg^{-1}

Latent heat of fusion of ice = 80 cal/g

Specific heat capacity of water = 4190 J (kg °C)$^{-1}$

QUESTION ONE (30 MARKS)

a. Define the following terms:

i. Process **(1 mark)**

ii. Isolated system **(1 mark)**

iii. Reversible process **(1 mark)**

iv. Thermodynamic equilibrium **(1 mark)**

b. State the first law of thermodynamics for a cyclic process **(2 marks)**

c. Using the zeroth law of thermodynamics, explain how a glass tube thermometer works. **(3 marks)**

d. Show that for a reversible work done isothermally the total work can be expressed as

$$W = RTIn \frac{v_2}{v_1}$$

(3 marks)

e. A fluid of volume 0.05 m^3 is contained behind a piston at a pressure of 1.0×10^6N/m^2. After a reversible expansion of constant pressure, the final volume is 0.2m^3. Calculate the work done by the fluid. **(3 marks)**

f. Express the first law of thermodynamics in terms of specific heat capacity at constant volume. **(2 marks)**

g. With the aid of a diagram, show that the thermal efficiency of a heat engine is given by $\eta = 1 - \frac{Q_2}{Q_1}$ **(4 marks)**

h. An Engine absorbs heat at 227°C and rejects at 27°C. Determine its efficiency. **(2 marks)**

i. 1 *gm* of 0_2 is compressed adiabatically at Normal Temperature and Pressure (N.T.P) to half its volume. What is the work done against the substance? Take γ for $O_2 = 1.33$. **(3 marks)**

j. One mole of gas at $127\ ^{\circ}C$ expands isothermally till its volume is doubled. Find the work done and heat absorbed. **(4 marks)**

QUESTION TWO (20 MARKS)

a. Show that the equation for a reversible adiabatic change is given by $PV^{\gamma} = constant$ *(Poisson's law)* where $\gamma = \frac{C_p}{C_v}$ is an ideal gas constant. **(10 marks)**

b. A refrigerator is working between 200 K and 300 K at 60% efficiency regarding the use of power $(\varepsilon \neq \beta)$. The power supply used to run the refrigerator is 400 V and the current through the refrigerator is 0.25 A. Calculate the number of KWH spend to run the refrigerator for one full day. **(5 marks)**

c. At Atmospheric pressure $1.00\ g$ of water, having a volume of $1.00\ cm^3$, becomes $1671\ cm^3$ of steam when boiled. The heat of vaporization of water is 539 cal/g at atmospheric pressure. Calculate the work done by the system in such an expansion and the increase in internal energy of the system. **(5 marks)**

QUESTION THREE (20 MARKS)

a.

i. Define C_p and C_v **(2 marks)**

ii. Derive the Mayer's relation from any two state variables such as $U = f(V,T)$ **(10 marks)**

b. A reversible engine works between two temperatures whose difference is 100°C. If it absorbs 746 Joule of heat from the source and give 546 to the sink, calculate the temperatures of source and sink. **(4 marks)**

c. A Carnots Engine take 1000 k calories of heat from a source at 627°C and rejects to the sink some heat at 27°C. Express the mechanical work done by the engine in kilowatt hours and also in electron volts given that $1eV = 1.6 \times 10^{-19}\ J$. **(4 marks)**

QUESTION FOUR (20 MARKS)

a. Ten grams of water at 20°C are converted into ice at 0°C at constant atmospheric pressure. Calculate the entropy change. **(7 marks)**

b. Derive two Maxwell's thermodynamic relations from the thermodynamic potentials. **(6 marks)**

c. Using Maxwell's relations, show that $pv = RT$ **(7 marks)**

QUESTION FIVE (20 MARKS)

a. Show that the coefficient of performance of a refrigerator is given by: **(5 marks)**

$$\beta = \frac{1-\varepsilon}{\varepsilon}$$

b. With the aid of diagram, explain the processes that take place in a Four-Stroke Otto-cycle and show that its efficiency is given by $\therefore \eta = 1 - \left(\frac{V_2}{V_1}\right)^{\gamma-1} = 1 - \frac{1}{r_c{}^{\gamma-1}}$ where r_c is the compression ratio. **(15 marks)**