UGANDA MARTYRS UNIVERSITY

FACULTY OF SCIENCE

DEPARTMENT OF NATURAL SCIENCES

SEMESTER ONE EXAMINATIONS – 2023 / 2024

PAPER CODE	: PHY 1102
PAPER NAME	: HEAT AND THERMODYNAMICS
DURATION	: 3 Hours
YEAR OF STUDY	: TWO
DATE OF EXAM	: 13/12/2023
TIME OF EXAM	: 9:30am-12:30pm

INSTRUCTION (S) :

- ◊ Answer any ***FOUR*** questions.
- ◊ Begin each question you are answering on a fresh page.
- ◊ Read the additional instructions provided on the answer booklet.

Where necessary assume the following universal constants:

Planck's constant	$h = 6.63 \times 10^{-34}\ J\,s$
Boltzmann's constant	$K_B = 1.38 \times 10^{-23} JK^{-1}$
Mass of electron	$m_e = 9.11 \times 10^{-31}\ kg$
Electronic charge	$e = 1.60 \times 10^{-19}\ C$
Speed of light	$c = 3.0 \times 10^{8}\ ms^{-1}$
Avogadro's number	$NA = 6.02 \times 10^{23}\ mol^{-1}$
Universal gas constant	$R = 8.31\ JK^{-1}mol^{-1}$
Acceleration due to gravity	$g = 9.81 ms^{-2}$
1 standard atmosphere	$= 1.01 \times 10^{5} Nm^{-2}$
Radius of Earth	$R_e = 6.38 \times 10^{6}\ m$
Solar constant	$S = 1.37 \times 10^{3}\ Js^{-1}m^{-2}$
Universal constant	$G = 6.67 \times 10^{-11} Nm^{2}kg^{-2}$
Coulomb constant	$K = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^{9}$

Question one:

a. Explain the following:
   i. Open system
   ii. Isolated system.
   iii. Isochoric process.
   iv. Isobaric process.
   v. Quasi-static process

(2 marks each)

b. Differentiate between extensive and in-extensive properties of a system giving two examples of each. **(2 marks)**

c. Explain the followings;
   i. Thermodynamic coordinate.
   ii. Thermodynamic system.
   iii. Cyclic process.
   iv. Isobaric process.

(2 marks each)

Question two:

a. i. Name the three main methods of heat transfer and write the expression for the rate of heat transfer for each method. **(6 marks)**
   ii. A perfect blackbody has a temperature of 675^0 C. An identically shaped object whose emissivity is 0.800 emits the same radiant power as the blackbody. What is the Kelvin temperature of this second body? **(4 marks)**
   iii. The amount of radiant power produced by the sun is approximately 5.9×10^{26} W. assuming that the sun is a perfect blackbody sphere with a radius of 8.96×10^8 m, find its surface temperature. **(3 marks)**

b. Write the equation for work for the following systems;
   i. Film. **(2 marks)**
   ii. Wire. **(2 marks)**
   iii. Magnet. **(2 marks)**

c. State first law of thermodynamics. **(1 mark)**

Question three:

a. i. Draw the PV diagram for an Otto engine and describe all the processes in the cycle. **(8 marks)**
   ii. Show that the work done W by the ideal Stirling heat engine is,

$W = -nRTin\frac{V_2}{V_1}(T_H - T_C)$, where are V_2 and V_1 the two volumes at which the isochoric processes occur on the PV diagram and that $V_2 > V_1$ **(5 marks)**

b. i. Define entropy. **(1 mark)**

ii. How much heat is required for a reversible isothermal expansion of an ideal gas at 132 °C if the entropy of the gas increases by 46.0 J/K? **(4 marks)**

iii. State the second law of thermodynamics in relation to entropy. **(2 marks)**

Question four:

a. i) If there are 2 mole of gas kept at a constant temperature of 20^0C and if this gas is compressed from a volume of 4 m^3 to 2 m^3, calculate the work done on the gas. (R=8.31J/mol.K). **(3 marks)**

ii) Consider that 200 J of work is done on a system and 293.3 J is extracted from the system as heat. In the sense of the first law of thermodynamics, what is the value of ΔU? **(3 marks)**

b. Derive the corresponding equation of the first law of thermodynamics under the following processes;

i) Adiabatic process. **(2 marks)**

ii) Isochoric process. **(2 marks)**

iii) Cyclic process. **(2 marks)**

c. The equation of state of a gas is $PV = nRT\left(1 - \frac{B}{V}\right)$, where R is a constant and B is a function of temperature alone. Show that the work done by 1 mole of this gas during a quasi-static, isothermal expansion from initial volume V_i to final volume V_f is,

$$-R_f\left[in\frac{V_f}{V_i} + \left(\frac{B}{V_f} - \frac{B}{V_i}\right)\right]$$ **(8 marks)**

Question five

a. i) State the second law of thermodynamics according to Clausiu's Statement. **(2 marks)**

ii) A Carnot heat pump is used to heat a house to a temperature of 294 K. How much work must be done by the pump to deliver 3350 J of heat into the house when the outdoor temperature is 260 K. **(4 marks)**

iii) Draw the PV diagram of the Stirling-cycle refrigerator and describe all the processes. **(6 marks)**

b. i) A Carnot air conditioner uses 25, 500 J of electrical energy, and the temperatures indoors and outdoors are 27 °C and 39 °C respectively.

Calculate the amount of heat deposited outdoors. **(4 marks)**

ii) Find $C_P - C_V$ for a certain gas whose equation of state $(P + b)V = nRT$

(4 marks)

END