NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

FACULTY OF HEALTH, NATURAL RESOURCES AND APPLIED SCIENCES

SCHOOL OF HEALTH AND APPLIED SCIENCES

DEPARTMENT OF BIOLOGY, CHEMISTRY AND PHYSICS

QUALIFICATION: BACHELOR OF SCIENCE (MAJOR AND MINOR)	
QUALIFICATION CODE: 07BOSC	**LEVEL:** 6
COURSE CODE: TPH601S	**COURSE NAME**: THERMAL PHYSICS
SESSION: JUNE 2023	**PAPER:** THEORY
DURATION: 3 HOURS	**MARKS:** 100

FIRST OPPORTUNITY EXAMINATION PAPER	
EXAMINER(S)	DR VAINO INDONGO
MODERATOR:	PROF SYLVANUS ONJEFU

INSTRUCTIONS	
1.	Write all your answers in the answer booklet provided.
2.	Read the whole question before answering.
3.	Begin each question on a new page.
4.	The list of constants and useful formulae are on the last page of this paper.

PERMISSIBLE MATERIALS

1. Non-Programmable Scientific Calculator

THIS PAPER CONSISTS OF 5 PAGES

(INCLUDING THIS FRONT PAGE)

QUESTION 1 **(20)**

1.1 Briefly explain of the following thermodynamic terms:

(i) Environment (2)

(ii) Universe (2)

(iii) Isobaric process (2)

(iv) Temperature (2)

1.2 State the zeroth law of thermodynamics. (2)

1.3 A male student in a physics class takes two cups of water at 303 K and mixes them with one cup of water at 278 K (each mass of water weighs 50 g). Set the equation $Q_{total} = 0$ and calculate the likely temperature of the mixture? Show your work/steps. (6)

1.4 A brass rod is 0.70 m long at 40°C. Find the increase in length of this rod at 70°C. (Hint: $\alpha = 1.90 \times 10^{-5}/°C$) (4)

QUESTION 2 **(20)**

2.1 A steam in cylindrical glass of height h = 100 mm covered with a piston of mass 3500 g and has a cross sectional area of 450 cm^2. Determine the:

(i) pressure that is exerted by this piston on the gas in the chamber, as shown in Figure 1. Assume gravitational acceleration 'g' to be 9.81 m/s^2. (4)

(ii) work done when the same cylinder is heated afterwards at a constant pressure of 1 atm and its initial volume changes from V_o to $5V_o$. (4)

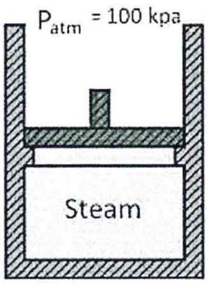

Fig. 1

2.2 An amount of heat Q was added to a substance (ice block) of mass 500 g at a temperature of – 40°C and is converted to steam at a temperature of 140°C (Fig 2). The specific heats, c, of ice, water and steam are 2060 J/kg.°C, 4180 J/kg.°C and 1870 J/kg.°C, respectively. The latent heats of fusion and vaporizations are 336 kJ/kg and 225 kJ/kg, respectively. Determine:

(a) heat energy required to turn ice into water. (3)

(b) heat energy required to change the temperature of ice from – 40°C to 0°C. (3)

(c) total heat energy required to change the temperature of a substance between 0°C to 120°C. (6)

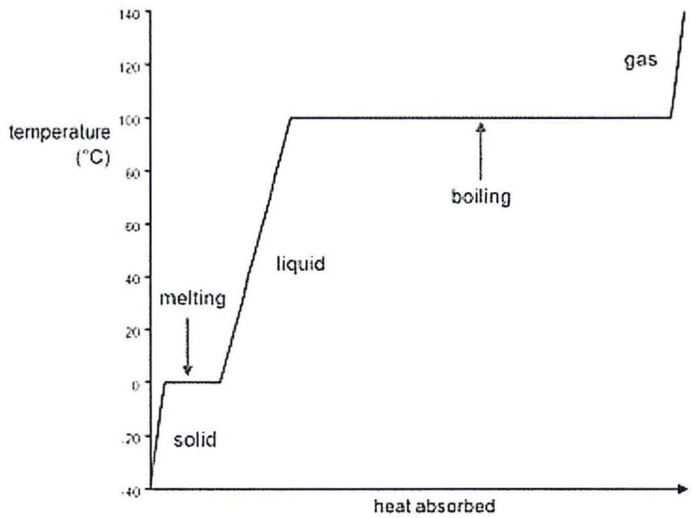

Fig. 2

QUESTION 3 **(20)**

3.1 An ideal gas undergoes an *isothermal* (constant-temperature) compression at temperature T, with its volume changing from V_1 to V_2.

(i) Prove that the work done during this process is given by an expression

$W = nRTln\frac{P_1}{P_2}$. (6)

(ii) Is the work done positive or negative? Give reasons. (2)

3.2 A temperature of 120 moles of monoatomic ideal gas with a ratio $\gamma = 1.600$ confined in a cylinder was increased from 273.15 K to 292.15 K at a uniform atmospheric pressure (*1 atm*). The cylinder was covered with a piston and the volume increases by 4.28×10^{-2} cm^3. Calculate the amount of heat transferred. (5)

3.3 Use the relationships for specific heats, Cv and Cp as well as ideal gas constant R to prove that $TV^{\gamma-1}$is constant under an adiabatic condition. (7)

QUESTION 4 **(20)**

4.1 Define entropy and state the second law of thermodynamics. (3)

4.2 A gasoline truck engine takes in 35 kJ of heat and delivers 13.5 kJ of mechanical work per cycle. The heat is obtained by burning gasoline with heat of combustion $l_c = 5 \times 10^4$ J/g. Calculate;

(a) the thermal efficiency of this engine? (3)

(b) heat discarded per cycle (3)

(c) If the engine goes through 8 cycles per second, what is its power output in kW and hp? Hint: 1 hp = 746W (4)

(d) How much gasoline is burned in each cycle in kg? (4)

4.3 Suppose an engine absorbs 1000 J of heat at 383.15 K and expels 713 J at 273.15 K per cycle. Determine the total entropy of the system in one cycle. (3)

QUESTION 5 **(20)**

5.1 Show that internal energy (U) is a thermodynamic potential which is a function of entropy and volume. (4)

5.2 Derive the differential form of Gibb's free energy/function from $G = U + pV - TS$. (6)

5.3 (i) The speeds of five molecules of a gas are 24k, 25k, 26k, 23k, 30k all in ms^{-1}, where k is equal to the number of molecules. Evaluate the rms speed. (7)

(ii) Detemine average kinetic energy of a gas at a temperature 27°C. (3)

END

Useful equations and constants:

$$\langle K.E. \rangle = \frac{1}{2}mv_{rms}^2 = \frac{1}{2}m\frac{3k_BT}{m} = \frac{3}{2}k_BT$$

$$v_{rms} = \sqrt{\frac{3PV}{Nm}} = \sqrt{\frac{3Nk_BT}{Nm}} = \sqrt{\frac{3k_BT}{m}}$$

The ideal gas law $PV = Nk_BT$

Boltzman's constant: $k_B = 1.38 \times 10^{-23}\ JK^{-1}$,

Avogadro's number: $N_A = 6.022 \times 10^{23}\ mol^{-1}$

Mean free path: $\lambda = \frac{k_BT}{\sqrt{2}d^2P}$

1 atm = 1.01×10^5 Pa

Maxwell-Boltzmann Distribution: $f(V) = 4\pi\left[\frac{m}{2\pi k_BT}\right]^{\frac{3}{2}} v^2 e^{-mv^2/2k_BT}$