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: JULY 2023	**PAPER:** THEORY
DURATION: 3 HOURS	**MARKS:** 100

SECOND OPPORTUNITY/SUPPLEMENTARY EXAMINATION PAPER	
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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.	A list of constants and useful formulae are shown on that las page of this paper.

PERMISSIBLE MATERIALS

1. Non-Programmable Scientific Calculator

THIS PAPER CONSISTS OF 4 PAGES

(INCLUDING THIS FRONT PAGE)

QUESTION 1 **(20)**

1.1 Briefly, explain the following thermodynamic terms:

(i) Internal energy (2)

(ii) Boundary wall (2)

(iii) Open system (2)

(iv) Isochoric process (2)

(v) The triple point of water (2)

1.2 Use the following information in the table below to calculate the unknown temperature T (in Kelvin). (4)

Temperature (°C)	**Height of mercury (Hg)**
100	8.1 cm
T	6.5 cm
0	2.1 cm

1.3 Suppose that the gas tank in your car is completely filled when the temperature is 7°C. How many gallons will spill out of the 150-gallon steel tank when the temperature rises to 35°C? (6)

QUESTION 2 **(25)**

2.1 Draw and label correctly a P-V diagram of three isotherms of temperatures $T_1 = 200$ K, $T_2 = 260$ K and $T_3 = 230$ K. Illustrate an adiabatic curve on the same diagram, cutting through all isotherms. (5)

2.2 Convert the following temperatures into Fahrenheit readings:

2.2.1 263.15 K (3)

2.2.2 101°C (2)

2.4 The compression ratio of a petrol engine is 20.0 to 1; that is, air in a cylinder is compressed adiabatically to $\frac{1}{20.0}$ of its initial volume.

(a) If the initial pressure is $1.01 \times 10^5 Pa$ and the initial temperature is 20°C, find the final pressure and the temperature after adiabatic compression. (6)

(b) How much work does the gas do during the compression if the initial volume of the cylinder is $1.00\ L = 1.00 \times 10^{-3} m^3$. Use the values $C_v = 20.8\ J/mol.K$ and $\gamma = 1.400$ for air. (5)

(c) Hence, find the change in internal energy of the air. (4)

QUESTION 3 **(30)**

3.1 Calculate the entropy change of 150 moles of an ideal gas which undergoes a free expansion from V_1 to $8V_1$ under a constant temperature. R = 8.314 J/mol.K (6)

3.2 Suppose 0.400 mol of an ideal diatomic gas [γ = 1.400] undergoes a Carnot cycle between 227°C and 37°C, starting at $p_a = 25.0 \times 10^5 Pa$ at point *A* in the *pV*-diagram of Figure 1. The volume triples during the isothermal expansion step *A-B*.

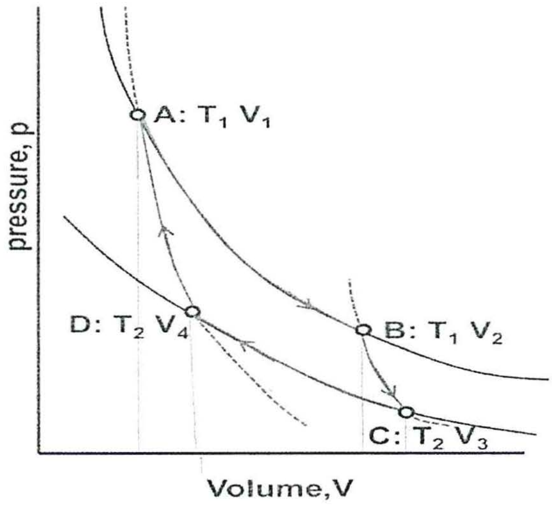

Fig. 1

(a) Find the pressure and volume at points *A*, *B*, *C*, and *D*. (14)
(b) Find *Q*, *W*, and *U* for each step and for the entire cycle. (8)
(c) Find the efficiency directly from the results of part (b). (2)

QUESTION 4 **(25)**

4.1 A gasoline engine takes in 1.42×10^4 J of heat and delivers 3300 J of work in every cycle. The heat was obtained by burning gasoline with heat combustion of 4.60×10^4 J/g.

(i) What is the thermal efficiency of the gasoline engine? (3)

(ii) How much heat is discarded to the environment in each cycle? (3)

(iii) What mass of fuel is burned per cycle? (3)

(iv) If the engine goes through 70.0 cycles per second, what is the power output of the engine in kW? (3)

4.2 Derive the Maxwell Relation from Helmholtz Free energy, F = U – TS. (7)

4.3 The speeds of 9 molecules of a gas are 24*n*, 20*n*, 25*n*, 21*n*, 23*n*, 30*n*, 29*n*, 19*n* and 27*n* all in ms^{-1}, such that *n* is equal to the number of molecules. Evaluate the rms speed. (6)

END

Useful equations and constants:

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

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

The ideal gas law $PV = Nk_BT$

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

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