MACHAKOS UNIVERSITY

University Examinations 2019/2020Academic year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

SECOND YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE APPLIED PHYSICS AND TECHNOLOGY

BACHELOR OF SCIENCE TELECOMMUNICATION

BACHELOR OF SCIENCE MATHEMATICS

BACHELOR OF EDUCATION SCIENCE

SPH 203: THERMAL PHYSICS 1

DATE: 2/12/2019 **TIME: 2.00-4.00 PM**

INSTRUCTIONS TO CANDIDATES

1. Answer question No 1 and any other two questions.
2. Question No 1 carries 30 marks while the other two carry 20 marks each.
3. Use of sketches and brief illustrations where necessary
4. Read the instructions on the booklet keenly and adhere to them.

The following constants may be useful;

Universal gas constant R = 8.314 J/mol.K or 0.0821L.atm/mol.k

Wein constant for a black body $b = 2.9 \times 10^{-3}$ m.K

Stefans-Boltzman constant $\sigma = 5.67\times10^{-8}$ W/m^2.K^4

Avogadro constant = 6.023×10^{23}

Boltzmann constant $k_B = 1.38 \times 10^{23}$J/K

Black body emissivity conctant $\varepsilon = 1$

Specific heat capacity of water = 4200 J/kgK

Specific heat capacity of lead = 128 J/Kg^{o}C

QUESTION ONE (30 MARKS)

a) Define the term system in thermal dynamics (1 mark)

b) In a quasi-static isothermal expansion or compression of an ideal gas,

Show that $W = -RT \ln \frac{V_f}{V_i}$ (2 marks)

c) An ideal gas occupies a volume of 100 cm3 at 20°C and 100 Pa. Find the number of molecules of the gas in the container. (2 marks)

d) i State the Wein's displacement law (1 mark)

ii The sun's surface has a temperature of approximately 5800K. If treated like a black body determine the peak intensity wavelength λ_{max} and the total radiation power per unit area (2 marks)

e) Distinguish between the following thermodynamic processes (2 marks)

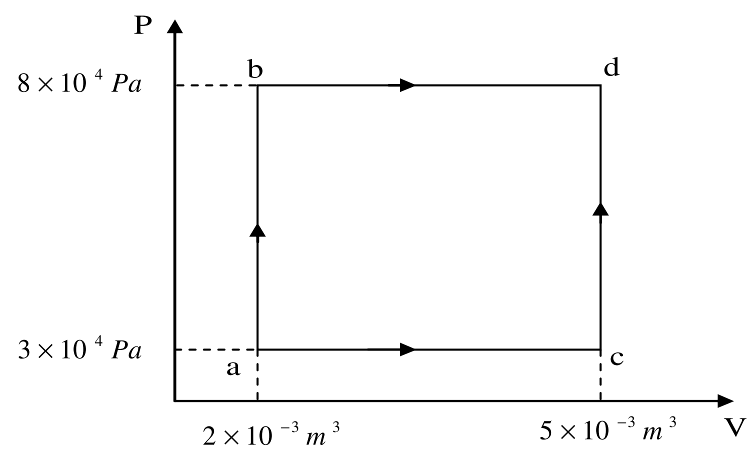
i. Adiabatic and isothermal processes

ii. Isochoric and isobaric processes

f) Give two assumptions made by the kinetic theory of gases. (2 marks)

g) The diagram in figure 1 shows PV diagram of a system taken through a series of states.

Fig 1



In process ab 300J of heat are added to the system while in bd 1200 J are added. Find

i. Internal energy change in process abd (3 marks)

ii. Heat added in process acd (2 marks)

h) An aluminum sphere of radius 10 mm is at 100°C. Determine its new volume at 0.0°C if the coefficient of linear expansion of the material is 2.4×10^{-5} °C^{-1} (3 marks)

i) i Define the term specific heat capacity (1 mark)

ii 1 kg of a material was heated to 200°c then dropped into a beaker containing 0.04 kg of water initially at 20°c. The final temperature of the mixture was 80°c. Find the specific heat capacity of the material (3 marks)

j) Calculate the work done when an ideal gas at 273K and pressure of $101325 Nm^{-2}$ expands isothermally from $0.056m^3$ to $0.28m^3$ (3 marks)

k) Sketch a pressure versus temperature diagram of pure water (2 marks)

l) State one way through which an adiabatic process can be achieved (1 mark)

QUESTION TWO (20 MARKS)

a) i Define the term isothermal compressibility (K) (1 mark)

ii A mass of mercury at atmospheric pressure and temperature of 0^oC is kept at constant volume. If the temperature is increased to 10^oC, what will be the final pressure? Take $\beta = 1.81 \times 10^{-4} K^{-1}$ and $K = 3.82 \times 10^{-11} Pa^{-1}$ of mercury (4 marks)

b) An approximate equation of state of a real gas at moderate pressure putting into account the molecular sizes is given as $P(V-b) = RT$ An approximate equation of state of a real gas at moderate pressure putting into account the molecular sizes is given as $P(V-b) = RT$ where ***b*** is a constant. Show that Isothermal compressibility and volume expansivity can be given

$K = \frac{RT}{P(RT + Pb)}$ and $\beta = \frac{R}{RT + Pb}$ (4 marks)

c) A 2000 cm^3 aluminum container is filled with water at 0^oC and then heated to 90^oc. If the coefficient of linear expansion of aluminum is 24×10^{-6} $^oC^{-1}$ and the coefficient of volume expansion of water is 6.3×10^{-4} $^oc^{-1}$ determine the volume of the spilled water (4 marks)

d) A 4 litre sample of H_2 gas at 15 atm and $25^0 C$ is allowed to expand to a final pressure of 1 atm. Calculate heat, work, change in internal energy and change in enthalpy if the gas expands

i. Isothermally and reversibly (4 marks)

ii. Isothermally and irreversibly (3 marks)

QUESTION THREE (20 MARKS)

a) Given the equation of state of an ideal gas as $PV = RT$, show that $\beta = \frac{1}{T}$ and $K = \frac{1}{P}$ where symbols have their usual meanings (4 marks)

b) A 5.0 gm bullet travelling at 300 m/s is stopped by a large tree. If half of the kinetic energy of the bullet is transformed into internal energy and remain with the bullet while the other half is tranmitted to the tree, what is the increase in temperature of the bullet. (5 marks)

c) Show that at the same temperature change internal energy change in isochoric and isobaric processes is the same (4 marks)

d) i) State the Newton's law of cooling (1 mark)

ii) a 20 mm diameter copper wire is used to carry heated water, the external surface of the pipe is subjected to a convective heat transfer coefficient of h= 6 W/m^2.K. The surface temperature is 80^{o}C while the surrounding is at 20 ^{o}C Find

i. Heat loss by convection per meter of the pipe (3 marks)

ii. Heat loss by radiation assuming it behaves like a blackbody (3 marks)

QUESTION FOUR (20 MARKS)

a) Define the term volume expansivity in thermodynamics (1 mark)

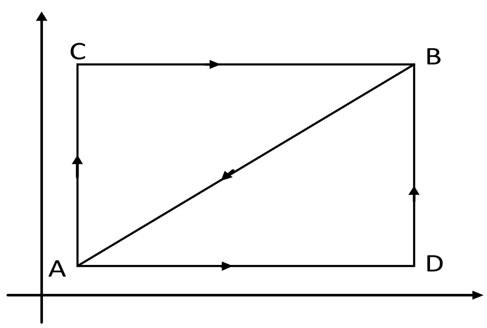
b) Given that α is the coefficient of linear expansivity and β is the coefficient of volume expansivity, show that $\beta = 3\alpha$. (4 marks)

c) i) State the Stefan-Boltzmann law of radiation (1 mark)

ii) A man is deciding on what to dress on. The surrounding is at a temperature of 10^{o}C while his body is at normal temperature. Calculate the net heat loss by radiation from his body in one hour. (Take his surface area to be 2.0 m^2 while $\varepsilon = 0.85$) (4 marks)

d) Consider the PV diagram in figure 2. When a system is taken from state A to B, along path ACB, 80 kJ of heat flow into the system and it does 30 kJ of work.

Fig 2



i. How much heat will flow into the system along the path ADB if the work done by it along this path is 10 kJ. (2 marks)

ii. If the system is returned from B to A along a straight path, calculate the amount of work and direction of heat interactions. (NB: the work done on the system is negative) Along path BA; (2 marks)

iii. If $U_A = 10kJ$, find U_B (2 marks)

iv. If $U_D = 24kJ$, find the heat flow for AD (2 marks)

v. Determine the heat flow in process DB. (2 marks)

QUESTION FIVE (20 MARKS)

a) i) Show that the work done in an adiabatic expansion of an ideal gas is given by

$W = \frac{nR}{\gamma - 1}(T_1 - T_2)$ where $\gamma = \frac{C_P}{C_V}$ (3 marks)

ii A typical room contains 2500 moles of air. Find the change in internal energy of this air when the room is cooled from 297K to 287K at constant pressure of 0.5 atmospheres. (Take air like an ideal gas and $\gamma = 1.4$) (4 marks)

b) A tank used for filling helium balloons has a volume of 0.3 m^3 and contains 2.0 mol of helium gas at 20.0°C. Assuming that the helium behaves like an ideal gas,

i. What is the total translational kinetic energy of the molecules of the gas? (3 marks)

ii. What is the average kinetic energy per molecule? (2 marks)

iii. Using the fact that the molar mass of helium is 0.004 kg/mol, determine the rms speed of the atoms at 20.0°C (2 marks)

c) In an experiment 1.35 moles of a gas is heated at constant pressure starting at 11^0C. Calculate the heat that must be added to the gas to double its volume if the gas is

i. Diatomic (3 marks)

ii. Monoatomic (3 marks)