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THE OPEN UNIVERSITY OF SRI LANKA

B.Sc. DEGREE PROGRAMME- 2010/2011

FINAL EXAMINATION 2011

PHU 2145- THERMODYNAMICS & RADIATION

DURATION: TWO HOURS (2HRS)

DATE: 08.07.2011 **TIME: 01. 30 p.m. – 03.30 p.m.**

ANSWER **FOUR** QUESTIONS ONLY.

Q1. (a) **(i)** State the first law of Thermodynamics.

(ii) Write down the mathematical formulation of it and explain the physical meaning of each term in the equation.

(iii) Convert the above expression to the differential form.

(b) The above law can be stated as "Energy is conserved and heat and work are both forms of energy". Justify the above statement.

(c) Is it always true that $dU = C_v dT$? Where C_v is the specific heat capacity at constant volume for a hydrostatic system.

(d) Assuming $U = C_v T$ for a gas find,

(i) The internal energy per unit mass

(ii) The internal energy per unit volume

(iii) One mole of an ideal monatomic gas is confined in a cylinder by a piston and is maintained at a constant temperature T_0, by thermal contact with a heat reservoir. The gas slowly expands from V_1 to V_2 while being held at the same temperature T_0. Why does the internal energy of the gas not change? Calculate the work done by the gas and the heat flow into the gas.

Q2. (a) Write the Kelvin-Plank statement and the Clausius statement of the second law of thermodynamics.

(b) What do you understand by ,

(i) Refrigerator

(ii) Heat Pump

(iii) Heat Reservoir

(c) Derive an expression for the coefficient of performance of a refrigerator.

(d) It is desired to maintain an auditorium at $25^0 C$ throughout the year. For this purpose, it is planned to use a reversible device as a refrigerator in summer and as a heat pump in winter. The rate of energy losses as heat from the roof and walls of the auditorium is estimated at $100kW$ pre degree Celsius difference between the inside and out side temperature. If the outside temperature is $0^0 C$ in winter and $41^0 C$ in summer, estimate the power required to operate the device in winter and summer.

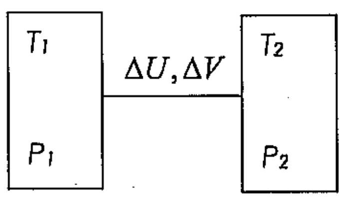
Q3. (a) Draw a Carnot cycle for a perfect gas filled in a piston cylinder in a P-V diagram and write down the processes that undergo in each step.

(b) State the Carnot's theorem and prove it for reversible heat engine with working capacity W, connected between hot and cold reservoirs.

(c) A large reservoir at temperature T_R is placed in thermal contact with a small system at temperature T_S. They both end up at the temperature of the reservoir, T_R. The heat capacity of the system is C. Show that the change in entropy of the universe, ΔS_{uni} is given by

$$\Delta S_{uni} = C\left[\ell n\left(\frac{T_R}{T_S}\right) + \frac{T_S}{T_R} - 1\right]$$

(d) Consider the two systems with pressure p_1 and p_2 and temperature T_1 and T_2. If internal energy ΔU is transferred from system 1 to system 2 and volume ΔV is transferred from system 1 to system 2 as shown in the diagram below, find the change of entropy. Show that equilibrium results, when $T_1 = T_2$ and $p_1 = p_2$.



Q4. (a) Explain what is meant by

(i) Macroscopic state.

(ii) Microscopic state

(iii) Thermodynamic probability used in statistical mechanics.

(b) Write down three types of statistics developed to differentiate assembly of particles with their respective rules.

(c) Consider an isolated system containing five (05) indistinguishable particles with a total energy of 12 units. There are four energy levels with energies 1,2,3 and 4 units, which are available to each of the particles. The degeneracies of these levels are 1, 2, 2 and 2 respectively. List the macroscopic states and microscopic states of the most probable macroscopic state for Bose- Einstein statistics.

Assume that the equation governing the microscopic states for a given macroscopic state is given by

$$W_k = \pi_{j=1} \frac{(g_j + N_j - 1)!}{(g_j - 1)!\, N_j!}$$

where W_k, N_j and g_j have their usual meanings.

Q5. (a) Define the following processes and draw them in a P-V diagram and label them clearly.

- Adiabatic process
- Isobaric process
- Isochoric process
- Isothermal process

Write down an expression for work done in each case.

(b) Derive the following general relations.

(i) $$\left(\frac{\partial T}{\partial V}\right)_U = \frac{-1}{C_V}\left[T\left(\frac{\partial P}{\partial T}\right)_V - P\right]$$

(ii) $$\left(\frac{\partial T}{\partial V}\right)_S = \frac{-1}{C_V} T\left(\frac{\partial P}{\partial T}\right)_V$$

(iii) $$\left(\frac{\partial T}{\partial P}\right)_U = \frac{1}{C_P}\left[T\left(\frac{\partial V}{\partial T}\right)_P - V\right]$$

In each case the quantity on the left hand side is the appropriate thing to consider for a particular type of expansion. State what type of expansion each refers to.

(c) Using the above relations, verify that for an ideal gas $\left(\frac{\partial T}{\partial V}\right)_U = 0$ and $\left(\frac{\partial T}{\partial P}\right)_U = 0$

Q6. **(a)** What do you understand by a black body?

(b) How do you define the absorptive power and emissive power of a radiative body?

Show that the emissive power of a black body at a given temperature is the ratio of emissive power to absorptive power of any body at the same temperature. Write down the laws that you have used in the proof.

(c) State the Stefan's Law for a black body.

(d) The temperature of the earth's surface is maintain by radiation from the sun. By making the approximation that the sun and the earth behave as black bodies, show that the ratio the earth's temperature to that of the sun is given by

$$\frac{T_{Earth}}{T_{Sun}} = \sqrt{\frac{R_{Sun}}{2D}}$$

where R_{sun} is the radius of the sun and Earth-Sun separation is D.