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NEW SCHEME

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Third Semester B.E. Degree Examination, July/August 2004

ME/IP/IM/MA/AU

Basic Thermodynamics

Time: 3 hrs.] [Max.Marks : 100

Note: 1. *Answer any FIVE full questions. Taking 2 from part A, 2 from Part B and 1 from Part C*
2. *Use of thermodynamic Data Hand Book Tables/Charts is permitted.*

PART-A

1. (a) Explain with examples the difference between a closed system, an open system and an isolated system. (6 Marks)

(b) State Zeroth law of thermodynamics and explain how this law is used to measure the temperature of a given system. (6 Marks)

(c) The readings t_A and t_B of two celsius thermometers, A and B agree at the ice point (0^0C) and the steam point (100^0C), but elsewhere are related by the equation $t_A = l + mt_B + nt_B^2$

Where l, m and n are constants. When both thermometers are immersed in a well stirred oil bath, A registers 51^0C, while B registers 50^0C.

i) Determine the reading on B when A reads 25^0C

ii) Which thermometer A or B is correct? (8 Marks)

2. (a) A simple magnetic substance is one involving only magnetic displacement work; i.e. a change in magnetisation of the substance in the presence of a magnetic field. For such a substance undergoing a quasistatic process at constant volume, the displacement work is given by

$$d_W = -C_o H dM$$

Where H = magnetic field intensity, M = magnetisation and C_o = a proportionality constant. For a first approximation, assume that magnetisation is proportional to the magnetic field divided by the temperature of the magnetic substance. Determine the workdone in an isothermal process when the magnetisation changes from M_1 to M_2.

What would be the workdone it temperature varies from T_1 to T_2 and the magnetic field intensity is constant. (8 Marks)

(b) An engine cylinder has a piston of area $0.12 m^2$ and contains gas at a pressure of 1.5 MPa. The gas expands according to a process which is represented by a straight line on a pressure volume diagram. The final pressure is 0.15 MPa. Calculate the work done by the gas on the piston if the piston stroke is 0.30 m. (8 Marks)

(c) Compare heat and Work. (4 Marks)

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3. (a) Starting from first law for a closed system undergoing a cyclic process obtain the first law equation for a closed system undergoing a non cyclic process and show that energy is a property of a system. (8 Marks)

(b) A nozzle is a device for increasing the velocity of a steadily flowing stream. At the inlet to a certain nozzle, the enthalpy of the fluid passing is 3000 kJ/kg and the velocity is 60 m/s. At the discharge end, the enthalpy is 2762 kJ/kg. The nozzle is horizontal and there is negligible heat loss from it.

i) Find the velocity at the exit section of the nozzle.

ii) If the inlet area is $0.1m^2$ and the specific volume at inlet is 0.187 m^3/kg find the mass flow rate.

iii) If the specific volume at the exit of the nozzle is $0.498m^3/kg$ find the diameter at the exit section of the nozzle. (12 Marks)

PART-B

4. (a) Show that, of all the reversed heat engines working between the same two constant but different temperature reservoirs, the reversible reversed heat engine will have the maximum coefficient of performance. (8 Marks)

(b) Demonstrate, using the second law, that free expansion is an irreversible process. (4 Marks)

(c) A reversible engine works between three thermal reservoirs A,B and C. The engine absorbs an equal amount of heat from the thermal reservoirs A and B kept at temperatures T_A and T_B respectively, and rejects heat to a thermal reservoir C kept at temperature T_C. The efficiency of this engine is α times the efficiency of a reversible engine which works between the two reservoirs A and C. Show that

$$\frac{T_A}{T_B} = (2\alpha - 1) + 2(1-\alpha)\frac{T_A}{T_C}$$ (8 Marks)

5. (a) State and prove Clasius inequality. (6 Marks)

(b) Show by invoking Kehin-Planck statement of second law that two reversible adiabatic paths cannot intersect each other. (4 Marks)

(c) Two Carnot engines A and B are connected in series between two thermal reservoirs maintained at 1000K and 100K respectively. Engine A receives 1680 kJ of heat from the high temperature reservoir and rejects heat to the Carnot engine B. Engine B takes in heat rejected by engine A and rejects heat to the low temperature reservoir. If engines A and B have equal thermal efficiencies, determine

i) the heat rejected by engine B

ii) the temperature at which heat is rejected by engine A

iii) Workdone by engine A and B, and

iv) If engines A and B deliver equal work.

find the efficiencies of engines A and B. (10 Marks)

6. (a) A rigid vessel contains 1 kg of wet steam at a pressure of 0.15 MPa. When the mixture is heated, the state passes through the critical point. Determine

i) The volume of the vessel

ii) Mass of liquid and of vapour initially in the vessel

iii) Temperature of the mixture when the pressure has risen to 3 MPa and

iv) The heat transfer required to produce the final state (iii). (12 Marks)

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(b) Steam at 10 bar and 200^0C undergoes a reversible adiabatic process to 1 bar in a turbine. Determine the final specific volume, the final temperature and the final specific entropy. If the mass flow rate of steam through the turbine is 2 kg/s determine the work output from the turbine. (8 Marks)

PART-C

(a) An ideal gas cycle consisting of three processes uses Argon (Molecular Weight = 40) as working substance. Process 1-2 is a reversible adiabatic process from $0.014m^3$ 700 kPa and 280^0C to $0.056m^3$. Process 2-3 is a reversible isothermal process. Process 3-1 is an isobaric process. Sketch the cycle on P-v and T-s diagrams and find

i) the work transfer in process 1-2

ii) work transfer in process 2-3 and

iii) network output from the cycle. Assume $\gamma = 1.67$

iv) Change in enthalpy for each process. (10 Marks)

(b) A gaseous mixture consists of 1 kg of oxygen and 2 kg of nitrogen at a pressure of 150 kPa and a temperatures of 20^0C. Determine

i) the gas constant of the mixture

ii) the molecular weight of the mixture

iii) Specific heats C_p and C_v of the mixture.

iv) the change in entropy of the mixture if the mixture is heated at constant volume to a temperature of 100^0C. (10 Marks)

(a) Write down the Vander Waal's equation of state. How is it different from the ideal gas equation of state? (6 Marks)

(b) Explain law of corresponding states. (4 Marks)

(c) Obtain expressions for the constants a,b and R in terms of critical properties for a Vander Waal gas. (10 Marks)

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NEW SCHEME

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Third Semester B.E. Degree Examination, January/February 2004

ME/IP/IM/MA/AU

Basic Thermodynamics

ne: 3 hrs.] [Max.Marks : 100

Note: 1. *Answer any FIVE full questions. taking 2 from part A, 2 from Part B and 1 from Part C*
2. *Use of thermodynamic charts and tables permitted.*

Part A

1. (a) Define mean free path and clarify the difference between microscopic and macroscopic approaches. (6 Marks)

(b) Define the following : i) Closed system ii) Open system
iii) Point function iv) Path function. (8 Marks)

(c) Distinguish between ;
i) Intensive and extensive properties
ii) Thermal equilibrium and mechanical equilibrium
iii) Adiabatic boundary and a dia-thermal boundary. (6 Marks)

2. (a) State Zeroth Law of thermodynamics and clarify whether you can extend it to mechanical chemical and electrical equilibria. (6 Marks)

(b) Clearly distinguish between heat and work in thermodynamics. (6 Marks)

(c) Classify the following as heat and work interactions. The system to be considered is shown underlined.
i) A honeybee sucking nector from a flower.
ii) Baking of Bread in an oven
iii) A person drawing money from his ATM cash counter.
iv) Rising of mercury column in a thermometer placed in the mouth of a patient. (4 Marks)

(d) A thermocouple with test junction at t^0C on a gas thermometer and cold junction at 0^0C gives output e m.f as per the following relation.

$$e = 0.20t - 5 \times 10^{-4}t^2, \ mV$$

where t is the temperature. The millivoltmeter is calibrated at ice and steam points. What temperature would this thermometer show when gas thermometer reads 70^0C. (4 Marks)

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3. (a) Give the precise statement of first law of thermodynamics as applied to a closed system undergoing a process, and hence prove that internal energy is a property. (6 Marks)

(b) Clearly write the steady flow energy equation for an open system and explain the terms involved. Given a chance, how would you modify the same to suit

i) Turbine ii) Steam nozzle iii) Evaporator. (6 Marks)

(c) Air flows steadily through a rotary compressor. At entry the air is 20^0C and 101kPa. At exit the same air is at 200^0C and 600 kPa. Assuming the flow to be adiabatic

i) evaluate the work done per unit mass of air if the velocities at inlet and exit are negligible.

ii) What would be the increase in work input if the velocities at inlet and exit are 50 m/s and 110 m/s. (8 Marks)

Part B

4. (a) Give precisely the Kelvin-Planck statement of 2nd law of thermodynamics and considering your own body as a heat engine explain how it is in conformity with the above law. (6 Marks)

(b) What do you understand by reversibility in thermodynamics? Explain the causes of irreversibility. (8 Marks)

(c) A reversible heat engine operates with two environments. In the first it draws 12000 kW from a source at 400^0C and in the second it draws 25000 kW from a source at 100^0C. In both the operations the engine rejects heat to a thermal sink at 20^0C. Determine the operation in which the engine delivers more power. (6 Marks)

5. (a) Derive Claussius inequality and prove that entropy is a property. (10 Marks)

(b) Explain what is the common factor in the following processes

i) A mummy (a corpse) buried deep inside the pyramids of Egypt

ii) An allopathic medicine in an opaque glass bottle in the corner of your shelf, well past its expiry date

iii) In a perfectly insulated rigid container, an unstable uranium 235 decays to become lead. (4 Marks)

(c) A rigid tank contains air at 35^0C and is stirred by a paddle wheel which does 500 kJ of work on the air. During the stirring process, the temperature of air remains constant because of heat transfer to surroundings at 15^0C. Estimate the change in entropy of air in the tank and the change is entropy of the surroundings. (6 Marks)

6. (a) Briefly explain what is meant by

i) Available energy and ii) dead state with respect to a system. (5 Marks)

(b) Write a brief note on the law of degradation of energy. (5 Marks)

(c) A turbine expands air adiabatically from 6 bar $400^0 K$, $200 m/s$, to $1 bar$, $290^0 K$, $50 m/s$. Determine the actual work output and the maximum possible workout put for the above operating conditions. Also find the irreversibility of the process. Take surrounding atmosphere to be at 1 bar and $280 K$. (10 Marks)

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Part C

(a) Define the following :
i) Pure substance ii) Triple point iii) Critical point. (6 Marks)

(b) Briefly explain what you understand by two property rule. (4 Marks)

(c) Define dryness fraction and briefly explain how one could estimate the same using separating and throttling calorimeter. (6 Marks)

(d) A rigid container is filled with steam at 600 kPa and 200^0C. At what temperature the steam begins to condense when it is cooled? Determine the corresponding pressure. (4 Marks)

(a) Clearly distinguish between ideal and real gases. Mention any two equations of state you know off. (6 Marks)

(b) Write a note on compressibility factor. (4 Marks)

(c) State Dalton's Law of partial pressure and derive an expression for the gas constant of a mixture of ideal gases. (6 Marks)

(d) A gas mixture consists of 6 kmol of H_2 and 4 kmol of N_2. Determine the mass of each gas and the gas constant of the mixture. (4 Marks)

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NEW SCHEME

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USN [| | | | | | | | |]

Third Semester B.E. Degree Examination, January/February 2005

Mechanical Engineering

Basic Thermodynamics

Time: 3 hrs.] [Max.Marks : 100

Note: 1. *Answer any FIVE full questions.*
2. *Use of thermodynamic data hand book/charts permitted.*

1. (a) Compare microscopic and macroscopic description of matter. (4 Marks)

   (b) Explain mechanical, chemical and thermal equilibrium by means of examples. (6 Marks)

   (c) Sir Isaac Newton proposed a linear temperature scale wherein the ice point and the normal human body temperature were assumed as the two fixed points and assigned the temperatures of 0^0 and 12^0 respectively. If the temperature of the human body on the Fahrenheit scale is 98^0F, obtain the relation between the Newton's scale and the Fahrenheit scale. (10 Marks)

2. (a) What are the characteristics common between heat and work? (4 Marks)

   (b) An engine cylinder has a piston of area $0.12m^2$ and contains gas at a pressure of 1.5 MPa. The gas expands according to a process which is represented by a straight line on P-V diagram. The final pressure is 0.15 MPa. Determine the magnitude and direction of worktransfer if the piston stroke is 0.30m. (6 Marks)

   (c) A system of volume v contains a mass m of gas at pressure p and temperature T. These properties are related by the equation.

   $$\left[p + \frac{a}{v^2}\right] (v - b) = mRT$$

   Where a, b and R are constants obtain an expression for the displacement workdone when the system undergoes an isothermal process from volume V_1 to a final volume V_2. Calculate this work for the system which contains 10 kg of this gas expanding from $1m^3$ to $10m^3$ at a constant temperature of 293 K. Assume $a = 15.7 \times 10^4\ Nm^4$, $b = 1.07 \times 10^{-2} m^3$, $and\ R = 0.278\ kJ/kg\ K$. (10 Marks)

3. (a) Starting from first law equation for a closed system undergoing a non-cyclic process derive the equation for an open system under steady flow, steady state situation. List all the assumptions you have made. (12 Marks)

   (b) 1.5 kg of a gas undergoes a quasistatic process in which the pressure and specific volume are related by the equation $p = a + bv$, where a and b are constants. The initial and final pressures are 1000 kPa and 200 kPa respectively. The corresponding volumes are $0.2m^3$ and $1.2m^3$. The specific internal energy of the gas is given by the relation.

   $$u = 1.5pv - 35$$

   where u is in kJ/kg, p is in kPa and v is in $\frac{m^3}{kg}$. Find the magnitude and direction of the heat transfer and the maximum internal energy of the gas during the process. (8 Marks)

4. (a) Define a reversible heat engine. Show that of all the reversed heat engines working between any two constant but different temperature thermal reservoirs, the reversible reversed heat engine will have the maximum COP. (6 Marks)

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(b) A Carnot refrigerator consumes 200 W of power in summer when the ambient atmosphere is 40^0C. The rate of energy leak into the refrigerator is estimated at 20 W per degree Celsius temperature difference between the ambient atmosphere and the cold space of the refrigerator. If the refrigerator is continuously operated determine the temperature at which the cold space is maintained. (12 Marks)

5. (a) State and prove Clasius inequality. (6 Marks)

(b) In a certain reversible process the rate of heat transfer to the system per unit temperature rise is constant and equal to $2kJ/^0C$. If the system temperature changes from 27^0C to 127^0C. what is the increase in entropy of the system?

In a second process between the same end states, the temperature rise is accomplished by string accompanied by stirring addition half as great as in the above reversible process, what is the increase of entropy for this process? (6 Marks)

(c) A system maintained at constant volume is initially at temperature T_1 and a thermal reservoir at a low temperature T_0 is available. Show that the maximum work recoverable as the system is cooled to T_0 is given by

$$W_{max} = mC_v[(T_1 - T_0) - T_0 \, log_e(T_1/T_0)]$$

Where m = mass of the system and C_v = specific heat at constant volume of the system. (8 Marks)

6. (a) Define the following terms as applied to a pure substance. (12 Marks)

i) Triple point
ii) Critical point
iii) Subcooled liquid state
iv) Saturated liquid state
v) Wet vapour state
vi) Dry vapour state

(b) Stream at 1 MPa and 250^0C enters a nozzle with a velocity of 60 m/s and leaves the nozzle at 10 kPa. Assuming the flow process to be isentropic and the mass flow rate to be 1 kg/s determine.

i) the exit velocity
ii) the exit diameter. (8 Marks)

7. (a) Show that for a perfect gas undergoing a polytropic process according to the law pv^n=constant the change in entropy is given by

$$s_2 - s_1 = \frac{(n - \gamma)}{(\gamma - 1)(n - 1)} R \, log_e\left(\frac{T_2}{T_1}\right)$$

where γ =ratio of specific heats of the gas R = gas constant. (10 Marks)

(b) A gaseous mixture consists of 1 kg of oxygen and 2 kg of nitrogen is initially at a pressure of 150 kPa and a temperature of 20^0C. It is heated at constant pressure until its temperature reaches 100^0C. Determine :

i) Change in enthalpy
ii) Change in entropy and
iii) Change in internal energy (10 Marks)

8. (a) Explain the following :

i) Generalised compressibility chart
ii) Law of corresponding states
iii) Van der Waals equation of state. (12 Marks)

(b) The gas neon has a molecular weight of 20.183 and its critical temperature, pressure and volume are 44.5 k, 2.73 MPa and 0.0416 m^3/kg mol. Reading from a compressibility chart for a reduced pressure of 2 and a reduced temperature of 1.3, the compressibility factor is 0.7. What are the corresponding specific volume, pressure, temperature and reduced volume? (8 Marks)

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ME35

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NEW SCHEME

Third Semester B.E. Degree Examination, July 2006
Mechanical Engineering
Basic Thermodynamics

Time: 3 hrs.] [Max. Marks:100

Note: 1. *Answer any FIVE full questions.*
2. *Use of steam tables is permitted.*

1 a. Distinguish between,
i) System and control volume.
ii) State and state point.
iii) Intensive and extensive properties and
iv) Quasi-static process and cyclic process. **(12 Marks)**

b. State the Zeroth Law of Thermodynamics and briefly explain its significance. **(04 Marks)**

c. What are 'International Fixed Points'? What is their importance? **(04 Marks)**

2 a. State and explain Thermodynamic definition of work. **(05 Marks)**

b. Differentiate between the works obtained using i) $\int pdv$ and ii) pv, where 'p' is the pressure and 'v' is the specific volume. **(03 Marks)**

c. Derive an expression for the displacement work in a resisted polytropic process (pv^n = constant) **(06 Marks)**

d. Starting from a convenient common state point, on a $p-v$ diagram, show the four expansion processes for $n=0$, $n=1$, $n=\gamma$, (where γ is the ratio of specific heats) and $n=\infty$. What are each of these processes called? Indicate their names adjacent to the processes on the diagram. **(06 Marks)**

3 a. State the First Law of Thermodynamics for a cyclic process. Write the steady state, steady flow energy equation based on unit time, identifying each term in the equation with its unit. **(06 Marks)**

b. A vertical cylinder of cross-sectional area 0.1 m^2, fitted with a leak-proof, frictionless, freely floating piston contains some air at a pressure of 1.2 bar. The air is agitated by a paddle wheel for 10 minutes. The shaft of the paddle wheel running at 250 rev/min with a torque of 0.5 Nm is driven by an external prime mover. During the same period an electrical resistor housed in the cylinder and connected to an external 24 volt battery draws a current of 0.45 amps to heat the air. In the said period find the distance, in cm, through which the piston rises, given that heat transfer from the air is 5.0 kJ and that the internal energy of air increases by 2.0 kJ. **(08 Marks)**

c. Air enters an adiabatic horizontal nozzle at 400°C with a velocity of 50 m/s. The inlet area is 240 cm^2. The temperature of air at the exit is 80°C. Given that the specific volume of air at the inlet and exit are respectively 0.2 m^3/kg and 1.02 m^3/kg, find the area of cross section of the nozzle at the exit. Assume that enthalpy of air is a function of temperature only and that c_p = 1.005 kJ/kg K. **(06 Marks)**

4 a. State the Kelvin-Planck and Clausius statements of the second law of thermodynamics and show that the violation of the former results in the violation of the latter statement. **(08 Marks)**

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4 b. What are the major factors that make a process irreversible? (04 Marks)

c. A direct heat engine operating between two reservoirs at 327°C and 27°C drives a refrigerator operating between 27°C and 13°C. The efficiency of the heat engine and the COP of the refrigerator are each 70% of their maximum values. The heat transferred to the direct heat engine is 500 kJ. The net heat rejected by the engine and the refrigerator to the reservoir at 27°C is 400 kJ. Find the net work output of the engine-refrigerator combination. Draw the schematic representation. (08 Marks)

5 a. Show that the change in entropy, $(S_2 - S_1)$, of a system undergoing an irreversible process between states 1 and 2 is related to $\int \delta Q / T$ by:

$$(S_2 - S_1) > \int_1^2 \delta Q / T$$

and thence show that entropy of the universe is increasing. (08 Marks)

b. Write the two 'Tds' relations and identify each term in these relations. (04 Marks)

c. A 5 kg copper block at a temperature of 200°C is dropped into an insulated tank containing 100 kg oil at a temperature of 30°C. Find the increase in entropy of the universe due to this process when copper block and the oil reach thermal equilibrium. Assume that the specific heats of copper and oil are respectively 0.4 kJ/kgK and 2.1 kj/KgK. (08 Marks)

6 a. Draw the $p - v$ diagram for water and show on it, i) the saturation liquid line, ii) the saturated vapor line, iii) the critical point, iv) an isotherm passing through sub-cooled liquid, mixture and superheated regions and v) constant dryness fraction lines. (05 Marks)

b. Steam at 1 bar and a dryness fraction of 0.523 is heated in a rigid vessel until it becomes saturated vapor. Calculate the heat transferred per kg steam. (08 Marks)

c. 2.5 kg steam at 10 bar and 400°C is cooled at constant pressure, in a heat exchanger, until it becomes saturated vapor. Find the available and unavailable parts of the energy from this steam. Assume the surroundings are at 27°C. (07 Marks)

7 a. Distinguish between Universal Gas Constant and Particular Gas Constant. (04 Marks)

b. When a kg ideal gas undergoes a resisted polytropic process according to pv^n =constant, show that the heat transfer during the process is given by:

$$Q = \left[(n-\gamma) \big/ (n-1) \right] c_v (T_2 - T_1)$$ (08 Marks)

c. 2 kg air (c_p = 1.005 kJ/kgK, c_v = 0.718 kJ/kgK) is compressed reversibly according to $pv^{1.3}$ = constant, from 1 bar, 37°C to 5 bar.
   i) Find the increase in internal energy.
   ii) Use the relation in 7 (b) and calculate the heat transfer.
   iii) Using the results in (i) and (ii) calculate the magnitude and direction of work.
   iv) Show the initial and final states and the process path on T-s diagram. (08 Marks)

8 a. Define mass fractions and mole fractions of the constituents of an ideal gas mixture. (04 Marks)

b. Find the gas constant and apparent molar mass of a mixture of 2 kg O_2 and 3 kg of N_2, given that universal gas constant is 8314.3 J/kmolK, molar masses of O_2 and N_2 are respectively 32 and 28. (04 Marks)

c. Write short notes on i) Van der Waal's equation of state, ii) Reduced properties and iii) Compressibility chart. (12 Marks)

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ME35

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NEW SCHEME

Third Semester B.E. Degree Examination, Dec. 06 / Jan. 07
Mechanical Engineering
Basic Thermodynamics

Time: 3 hrs.] [Max. Marks:100

Note : *1. Answer any FIVE full questions.*
2. Use steam tables is permitted.

1 a. Define open, closed and isolated system. Draw the boundaries of the following systems and label their type :
   i) A wind mill
   ii) Mixture of ice and water in a metal container.
   iii) Thermo flask filled with hot tea
   iv) Pressure cooker
   v) Storage cell producing electricity. **(10 Marks)**

b. Define zeroth law of thermodynamics, steam point and ice point. The temperature scale of a certain thermometer is given by the relation $t = a \ln(x) + b$ where 'a' and 'b' are constants and 'x' is the thermometric property of the fluid in the thermometer. If at the ice and steam point the thermometric property are found to be 1.5 and 7.5 respectively, what will be the temperature corresponding to the thermometric property 3.5? **(10 Marks)**

2 a. Define heat and thermodynamic definition of work. The initial pressure and volume of a mass of gas in a cylinder fitted with a moveable piston are P_1bar and V_1 m^3 respectively. Calculate the work done by the system when the gas expands reversibly to a volume V_2 m^3 during the following process :
   i) Isothermal process
   ii) Polytropic process. **(10 Marks)**

b. Define : i) Equilibrium state and ii) Quasistatic process.

A perfect gas is undergoing a process in which $T \propto V^{-\frac{2}{5}}$. Calculate the work done by the gas in going from state 1 in which pressure is 100 bar and volume is 4 m^3 to the state 2 in which volume is 2 m^3. Also calculate the final pressure. **(10 Marks)**

3 a. Define enthalpy and show that $h = U + PV$ with usual notations. A system contains 0.15 m^3 of air at a pressure of 3.8 bar and 150°C. It is expanded adiabatically till the pressure falls to 1 bar. The gas is then heated at a constant pressure till its enthalpy increases by 70 kJ. Determine the total work done. **(10 Marks)**

b. Define steady flow process with an example. A fluid flows through a steady flow system at the rate of 3 kg/sec. The inlet and outlet conditions are P_1 = 5 bar, V_1 = 150 m/s, U_1 = 2000 kJ/kg and P_2 = 1.2 bar, V_2 = 80 m/sec and U_2 = 1300 kJ/kg. The change in specific volume is from 0.4 m^3/kg to 1.1 m^3/kg. The fluid loses 25 kJ/kg heat during the process. Neglecting potential energy determine power out put of the system. **(10 Marks)**

4 a. Define the two statements of II law of thermodynamics. Show that violation of Clausius statement of second law of thermodynamics,violates the Kelvin-Planck statement of II law of thermodynamics. **(10 Marks)**

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b. Define heat engine and heat pump and show that $[COP]_{HP} = 1 + [COP]_R$, where HP stands for heat pump and R stands for refrigerator. The minimum power required to drive a heat pump which maintains a house 20^0C is 3 kW. If the outside temperature is 3^0C, estimate the amount of heat which the house loses per minute. **(10 Marks)**

5 a. Define inequality of Clausius and entropy of a system. Show that for an irreversible process $ds \geq \frac{dQ}{T}$. **(10 Marks)**

b. Define principle of increase of entropy. A heat engine is supplied with 278 kJ/s of heat at a constant fixed temperature of 283^0C and the heat rejections take place at 5^0C. The following results were reported.

i) 208 kJ/s of heat rejected
ii) 139 kJ/s of heat rejected
iii) 70 kJ/s of heat rejected.

Classify which of the results report a reversible cycle, irreversible cycle or impossible cycle. **(10 Marks)**

6 a. Define critical temperature and pressure. Draw a neat sketch of temperature-volume diagram for water showing liquid and vapour phases. Mark all the salient points on the diagram. **(10 Marks)**

b. Define dryness fraction. Determine the dryness fraction of the steam sample which is tested in a separating and throttling calorimeter and the following data were obtained:

i) Pressure of steam sample = 15 bar
ii) Pressure of steam at exit = 1 bar
iii) Temperature of steam at exit = 150^0C
iv) Water collected from separating calorimeter = 0.2 kg/min
v) Discharge collected at exit = 10 kg/min. **(10 Marks)**

7 a. Define mass fraction and mole fraction. A gas mixture consists of 0.5 kg of carbon monoxide and 1 kg of CO_2. Determine :

i) Mass fraction of each component
ii) Mole fraction of each component
iii) The average molar mass and
iv) The gas constant of the mixture. **(10 Marks)**

b. Define the term ideal gases and real gases. One kg of air at a pressure of 8 bar and temperature 100^0C undergoes a reversible polytropic process following the law $PV^{1.2}$ = constant. If the final pressure is 1.8 bar determine

i) Final specific volume, temperature and increase in entropy
ii) Work done and heat transfer. **(10 Marks)**

8 a. Write short notes on :

i) Vander Waals equation of state
ii) Law of corresponding states. **(12 Marks)**

b. Show that entropy of an ideal gas is given by the equation

$S_2 - S_1 = C_p \ln\left(\frac{V_2}{V_1}\right) + C_v \ln\left(\frac{P_2}{P_1}\right)$ starting from the general property relations

$T.ds = du + pdv$ and $T.ds = dh - vdp$. **(08 Marks)**

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MODEL QUESTION PAPER 2

Sub : - Basic Thermodynamics
Subcode : - ME33
Time : - 3 hours. Max Marks : - 100

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Note: - 1) Answer 5 full questions, taking 2 from Part A, 2 from Part B & 1 from Part C.
2) All questions carry equal marks.
3) Use of Thermodynamics Data book/charts/tables permitted.

Part A

Q1. a. Explain with examples the difference between a closed system, an open system and an isolated system.

b. Define thermometric property and list the various thermometric properties used to measure the temperature of a given system.

c. Describe a constant volume gas thermometer and explain how this thermometer is used to measure the temperature of a given system.
Why a constant volume gas thermometer is preferred to a constant pressure gas thermometer?

Q2. a. What are the characteristics common between work and heat?

b. What is mean effective pressure? How is it measured?

c. Consider the rectangular face-surface water, piston-cylinder system shown in Fig.Q2 c.

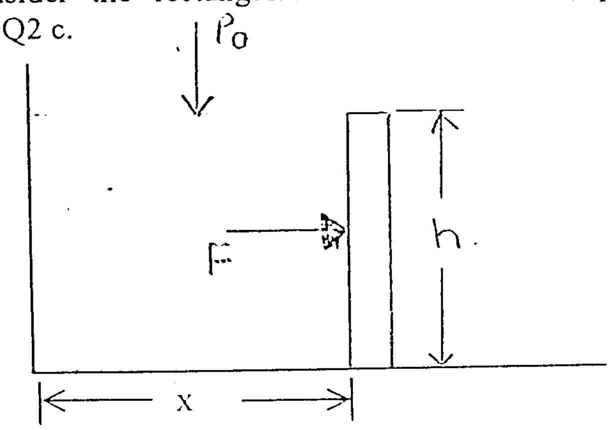

Fig: Q2.c; Figure for Question 2 c.

The width of the chamber is 'b' (normal to paper), and the atmospheric pressure is Po. The force exerted by water on the piston is given by

$$F = \left(p_o + \frac{rh}{2}\right) hb$$

where r is the specific weight of water. Obtain an expression for the displacement work done when the chamber length is slowly increased from X_1 to X_2. Express your answer in terms of Po, b, h_1, h_2, X_1, X_2 and r. Sketch the system before and after the process.

Q3. a. Starting from the first law equation for a closed system (control mass) undergoing a non-cyclic process, derive the steady state steadily flow energy equation for an open system (control volume).

b. In a water cooling tower air enters at a height of 1m above the ground level with a velocity of 20m/s and leaves the tower at a height of 7m above the ground level with a velocity of 30m/s. Water enters the tower at a height of 8m above the ground level with a velocity of 3m/s and leaves the tower at a height of 0.8m with a velocity of 1m/s. Water temperatures at inlet and exit are 80°c and 50°c respectively, while the inlet and exit temperatures of air are 30°c and 70°c respectively. The cooling tower is well insulated and a fan of 2.25KW drives the air through the cooling tower. Determine the mass flow rate of air required if the mass flow rate of water is 1.5Kg/s. Assume that for air Cp=1.005KJ/kg-k and for water Cp=4.187KJ/kg-k.

Part B

Q4. a. Show that heat transfer through a finite temperature difference is an irreversible process.

b. Which is more effective way of increasing the thermal efficiency of a Carnot Engine? Increasing the source temperature, keeping the sink temperature constant or decreasing the sink temperature and keeping the source temperature constant.

c. Two reversible refrigerators are connected in series. The first one removes heat from a cold resorvoir at temperature T_L and discharges at 10°c. The second refrigerator absorbs heat from the first at 10°c, and in turn discharges heat to the ambient at 25°c. If the cop for both the refrigerators are same, what is the value of T_L? If we want the same work input to both the refrigerators what should be the value of the T_L?

Q5. a. Show that the entropy of an isolated system always increases.

b. A system maintained at constant volume is initially at temperature T_1 and a heat resorvoir at a low temperature T_0 is available. Show that the maximum work recoverable as the system is cooled to T_0 is given by

$$W_{max} = Cv\left((T_1 - T_0) - T_0 \log e\left(\frac{T_1}{T_0}\right)\right)$$

c. In a certain reversible process the rate of heat transfer to the system per unit temperature rise is constant and is given by

$$\frac{dq}{dT} = 2KJ/°c$$

If the system temperature changes from 27°c to 127°c, what is the change in entropy of the system?

If in a second process between the same end states, the temperature rise is accomplished by stirring accompanied by a heat addition half as much as in the first process, what would be the change in entropy of the system?

Q6. a. Define a pure substance and state the two property rule for a pure substance.

b. Explain how the quality of steam is determined by using a throttling calorimeter. What should be the condition of steam after throttling if one has to use throttling calorimeter for finding the quality of steam?

c. The following observations were recorded in an experiment with a combined separating throttling calorimeter.

Pressure in the steam Mains = 15bar; Mass of water drained from the separator 0.55Kg; Mass steam condensed in the throttling calorimeter = 4.20 Kg; Pressure

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of steam after throttling = 5mm of mercury (gauge); Barometer reading=760mm of mercury; Temperature of steam after throttling=120°c .

Determine the dryness faction of the steam sample.

Part C

a. An ideal cycle using an ideal gas as the working substance consists of three reversible processes in the following sequences:
   i. constant volume pressure rise;
   ii. isentropic expansion to 'r' times the initial volume, and
   iii. constant pressure decrease in volume so that the gas comes back to its initial state.

   Sketch the cycle on p-v and T-S diagrams. Show that the thermal efficiency of the cycle is given by

$$\eta_{cycle} = \frac{r^{\gamma} - 1 - r(r-1)}{r^{\gamma} - 1}$$

b. A mixture of ideal gases consists of 3Kg. of N_2 and 5 Kg. of co_2 at 300 Kpa and 20°c. Find
   i. mole fraction of each constituent,
   ii. molecular weight and gas constant for the mixture,
   iii. the partial pressures of each constituent
   iv. volume and density of the mixture.

5. a. Write Van der Waal's equation of state. How dies it differ from ideal gas equation of state? What is force of Cohesion? What is co-volume?

b. What is law of corresponding states?

c. Obtain expressions for the constants 'a', 'b' and 'R' in terms of the critical properties for a Van der Waal gas.

MODEL QUESTION PAPER 1

Sub : - Basic Thermodynamics
Subcode : - ME33
Time : - 3 hours. Max Marks-100

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Note: - 1) Answer any 5 full questions, taking two from PART A, two from PART B and one from PART C.
2) Use of Thermodynamics Data book/charts/tables permitted.
3) Answer any five full questions.

Part A

1. a. Explain the following by means of examples: 08
   i) Mechanical equilibrium,
   ii) Chemical equilibrium,
   iii) Thermal equilibrium and
   iv) Thermometric property.

b. Differentiate between an adiabatic boundary and a dia-thermal boundary. 04

c. In 1703 Sir Issac Newton proposed a linear temperature scale for which he chose the ice point and the human body temperature as the two fixed points and assigned numerical values of 0° and 100° respectively. If the human body temperature in centigrade scale is 36°c, obtain the relation between the Newton's scale and the centigrade scale. 08

2. a. What is thermodynamic definition of work? Explain how this definition is more general than the mechanics definition of work. 06

b. Work and heat are said to be in exact differentials; explain. 04

c. A system of volume V contains a mass m of gas at pressure P and temperature T. The pressure, the volume and the temperature of the gas are related by the equation 10

$$\left(P + \frac{a}{V^2}\right)(V - b) = mRT$$

Where a, b and R are constants. Obtain an expression for the displacement work when the system is undergoing an isothermal process from V_1 to V_2. Calculate the displacement work if m=10Kg, T=293 K and the gas expands from $1m^3$ to $10m^3$ at atmospheric pressure. Assume that a = 15.7 X $10Nm^4$, b =1.07 X $10^{-2}m^3$ and R= 0.278 KJ/kg-K.

3. a. A system consisting of 2Kg.of a pure substance has a specific internal energy of 16 KJ/kg. The system is moving with a velocity of 120 m/s at an elevation of 1500 m above sea level. Determine the total energy of the system relative to an observer at rest at sea level. The system undergoes a process to a final specific internal energy of 20 KJ/kg, a final velocity of 215 m/s and a final elevation of 300 m. If the work done on the system during the process is 2200Nm, determine the magnitude and direction of the heat transfer during the process. 10

b. The internal energy of air is given by 10

$$u = u_o + 0.718\, t$$

where u is in KJ/kg, u_o is any arbitrary value of u at 0°c. Also for air, Pv = 0.287 (t + 273), where P is in kPa and V is in m^3/kg.

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A mass of this air is stirred by a paddle wheel in an insulated constant volume tank. The velocities due to stirring make a negligible contribution to the internal energy of air. Air flows out through a small valve in the tank at a rate controlled to keep the temperature in the tank constant. At a certain instant of time the conditions of air in the tank are as follows:
Tank volume=0.12m^3; pressure=1Mpa; temperature=150°c; power wheel=0.1KW.

Find the rate of flow of air out of the tank at this instant.

Part B

Q4. a. Give the Kelvin–Planck statement and Clausius statement of second law and sh that the two statements are equivalent.

b. A reversible engine operates between temperatures T_1 and $T(T_1 > T)$. The er rejected from this engine is received by a second reversible engine at the s. temperature T. The second engine rejects heat at temperature T_2 ($T_2 < T$).

i) Show that T is the arithmetic mean of T_1 and T_2 if both the en produce the same amount of work and
ii) Show that T is the geometric mean of T_1 and t_2 if both the engines h the same thermal efficiency.

Q5. a. What is the criteria on which you can decide whether a given thermodynamic is reversible, irreversible, or impossible?

b. How do you determine the change in entropy for any irreversible process betwee any two given end states.

c. 10 grams of water at 20°c is converted into ice at $^-$10°c in a constant pressure process. Assuming Cp for water as 4.2 KJ/kg-k and that of ice as half this value, and taking the latent heat of fusion of ice at 0°c as 335 J/g, calculate the change in entropy of the system during the process.

Q6. a. Draw the T–P diagram for water showing all the necessary details. Explain with the help of this diagram how ice skating is possible.

b. Show that the specific enthalpy of a wet vapour is given by

$$h = h_f + xh_{fg}$$

where h_f is the enthalpy of saturated liquid, h_{fg} is the enthalpy of vapourisation both evaluated at the mixture pressure and x is the quality of the wet vapour.

c. Steam at 10 bar and 200°c undergoes a reversible polytropic process to 1 bar according to the law $Pr^{1.15}$ = constant. Determine the final specific volume, the final temperature and the heat transfer for the process.

Part C

Q7. a. Show that for a reversible adiabatic process executed by an ideal gas, the following relations hold good:

(i) Pv^{γ} = constant (ii) $TV^{\gamma-1}$ = constant and (iii) $TP^{(1-\gamma)/\gamma}$ =constant.

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b. Two vessels, A and B both containing nitrogen are connected by a valve which is opened to allow the contents to mix and achieve an equilibrium temperature of 27°c. Before mixing, the following information is known about the gases in the two vessels. 12

Vessel A	Vessel B
P = 1.5 MPa	P = 0.6 MPa
T = 50°c	t = 20°c
N = 0.5 Kg mol	n = 2.5 Kg mol

Calculate the final equilibrium pressure and the amount of heat transferred to the surroundings. Assume r = 1.4.

Q8. a. Explain compressibility chart and generalised compressibility chart. 08

b. Assume that 20Kg of steam is required at a pressure of 600 bar and a temperature of 750°c in order to conduct an experiment. A heavy duty tank of 140 liter capacity is available for the purpose. Predict if this is adequate storage capacity using: 12

a. ideal gas theory;
b. the compressibility factor chart,
c. the Van der Waal's equation of state with a= 5.454 $(\text{liter})^2 - \text{atm}/(\text{g mol})^2$; b= 0.03042 liter/g mol for steam;
d. the Mollier chart.

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06ME33

Third Semester B.E. Degree Examination, Dec. 07 / Jan. 08
Basic Thermodynamics

Time: 3 hrs. Max. Marks:100

Note : ***1. Answer any FIVE full questions.***
2. Use of thermodynamics data handbook permitted.

1 a. Distinguish between:
i) Open system and closed system
ii) Macroscopic and microscopic approaches
iii) Point function and path function
iv) Intensive and extensive properties
v) Diathermic and adiabatic walls. **(10 Marks)**

b. State the concept of temperature and equality of temperature. Two Celsius thermometers 'A' and 'B' agree at ice point and steam point and the related equation is $t_A = L + Mt_B + Nt_B^2$, where L, M and N are constants. When both thermometers are immersed in fluid, 'A' registers 26^0C while 'B' registers 25^0C. Determine the reading of 'A' when 'B' reads 37.4^0C. **(10 Marks)**

2 a. Starting from a common state point, draw the following processes on the P-V plane and write expression for the work in each case:
i) Isochoric process ii) Isobaric process iii) Isothermal process iv) Isentropic process v) Polytropic process. **(10 Marks)**

b. Distinguish between heat and work in thermodynamics. **(04 Marks)**

c. A cylinder contains 1 kg of a certain fluid at an initial pressure of 20 bar. The fluid is allowed to expand reversibly behind a piston according to law pV^2 = constant until the volume is doubled. The fluid is then cooled reversibly at constant pressure until the piston regains its original position; heat is then supplied reversibly with the piston firmly locked in position until the pressure rises to the original value of 20 bar. Calculate the net work done by the fluid, for an initial volume of 0.05 m^3. **(06 Marks)**

3 a. Show that energy is a property of the system. Define the specific heats at constant volume and constant pressure. **(10 Marks)**

b. Define steady flow process. A piston and cylinder machine contains a fluid system, which passes through a complete cycle of four processes. During a cycle, the sum of all heat transfer is –170 kJ. The system completes 100 cycles per min. Complete the following table showing the method for each item, and compute the net rate of work output in kW.

Process	Q (kJ/min)	W (kJ/min)	ΔE (kJ/min)
a – b	0	2,170	-
b – c	21,000	0	-
c – d	-2,100	-	-36,600
d – a	-	-	-

(10 Marks)

4 a. Define the thermal efficiency of a heat engine cycle. Can be this 100%? **(02 Marks)**

b. Describe the working of a carnot cycle and show $\eta_{th} = 1 - \frac{T_2}{T_1}$. **(08 Marks)**

c. A reversible heat engine operates between two reservoirs at temperature of 600^0C and 40^0C. The engine drives a reversible refrigerator, which operates between reservoirs at temperatures of 40^0C and -20^0C. The heat transfer to the heat engine is 2000 kJ and the net work output of the combined engine refrigerator plant is 360 kJ.

i) Evaluate the heat transfer to the refrigerant and the net heat transfer to the reservoir at 40^0C.

ii) Reconsider (i) given that the efficiency of the heat engine and the COP of the refrigerator are each 40% of their maximum possible values. **(10 Marks)**

5 a. State and prove Clausius theorem. **(08 Marks)**

b. What do you understand by the entropy principle? **(02 Marks)**

c. Air at 20^0C and 1.05 bar occupies 0.025 m^3. The air is heated at constant volume until the pressure is 4.5 bar, and then cooled at constant pressure back to original temperature. Calculate:

i) The net heat flow from the air ii) The net entropy change.

Sketch the process on T-S diagram. **(10 Marks)**

6 a. Explain the concept of available and unavailable energy. When does the system become dead? **(06 Marks)**

b. Write a brief note on the law of degradation of energy. **(04 Marks)**

c. 8 kg of air at 650 K and 5.5 bar pressure is enclosed in a closed system. If the atmosphere temperature and pressure are 300 K and 1 bar respectively, determine;

i) The availability if the system goes through the ideal work producing process

ii) The availability and effectiveness if the air is cooled at constant pressure to atmospheric pressure without bringing it to complete dead state. Take C_V = 0.718 kJ/kgK; C_P = 1.005 kJ/kgK. **(10 Marks)**

7 a. Define the following:

i) Pure substance ii) Triple point iii) Critical point. **(06 Marks)**

b. With a neat sketch explain the measurement of dryness fraction of steam by using "Throttling calorimeter". **(08 Marks)**

c. Determine the amount of heat, which should be supplied to 2 kg of water at 25^0C to convert it into steam at 5 bar and 0.9 dry. **(06 Marks)**

8 a. Distinguish between real gas and ideal gas. **(04 Marks)**

b. Starting from the relation Tds = du + pdv, show that for an ideal gas undergoing a reversible adiabatic process, the law for the process is given by $Tv^{\gamma-1}$ = a constant. **(08 Marks)**

c. A mass of 0.25 kg of an ideal gas has a pressure of 300 kPa, a temperature of 80^0C, and a volume of 0.07 m^3. The gas undergoes an irreversible adiabatic process to a final pressure of 300 kPa and final volume of 0.10 m^3, during which the work done on the gas is 25 kJ. Evaluate the C_P and C_V of the gas and the increase in entropy of the gas. **(08 Marks)**

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06ME33

Third Semester B.E. Degree Examination, June / July 08
Basic Thermodynamics

Time: 3 hrs. Max. Marks:100

Note : ***1. Answer any FIVE full questions choosing at least TWO questions from Part A and Two questions from Part B.***
2. Use of Thermodynamic Data Hand Book is allowed.

PART – A

1 a. Differentiate between the following with suitable examples. i) System and control volume ii) Intensive and extensive properties iii) Path and point functions. **(06 Marks)**

b. Define the following : i) Thermodynamic state ii) Quasistatic process iii) Cyclic and Non – cyclic processes. **(08 Marks)**

c. The resistance of the windings in a certain motor is found to be 80 ohm at room temperature (25^0C). When operating at full load, under steady state conditions, the motor is switched off and the resistance of the windings immediately measured again, is found to be 930 ohms. The windings are made of copper whose resistance at temperature t^0C is given by $R_t = R_o\,[1 + 0.00393t]$, when R_o is the resistance at 0^0C. Find the temperature attained by the coil during full load. **(06 Marks)**

2 a. Show that the work and heat are path functions. **(05 Marks)**

b. A system undergoes a process in which the pressure and volume are related by an equation of the form PV^n = a constant. Derive an expression for displacement work during this process. **(05 Marks)**

c. A fluid at 0.7 bar occupying $0.09m^3$ is compressed reversibly to a pressure of 3.5 bar according to a law PV^n = constant. The fluid is then heated reversibly at constant volume until the pressure is 4 bar; the specific volume is then $0.5m^3$/kg. A reversible expansion according to a law PV^2 = constant, restores the fluid to its initial state. Sketch the cycle on a P-V diagram and calculate. i) the mass of fluid present ii) the value of 'n' in the first process iii) the net work of the cycle. **(10 Marks)**

3 a. State the first law of Thermodynamics as applied to a cycle and prove that for a non – flow process, it leads to the energy equation of the form ${}_1Q_2 - {}_1W_2 = U_2 - U_1$. **(06 Marks)**

b. A gas undergoes a thermodynamic cycle consisting of the following processes:
i) Process 1 – 2 : Constant pressure, P = 1.4 bar, $V_1 = 0.028m^3$, ${}_1W_2 = 10.5$ kJ.
ii) Process 2 – 3 : Compression with PV = constant, $U_3 = U_2$.
iii) Process 3 – 1 : Constant volume, $(U_1 - U_3) = -26.4$ kJ.
There are no significant changes in KE and PE.
1) Sketch the cycle on a P-V diagram 2) Calculate the network for the cycle in KJ.
3) Calculate the heat transfer for process 1-2. 4) Show that $\sum_{cycle} Q = \sum_{cycle} W$. **(06 Marks)**

c. A turbine operating under steady – flow conditions receives steam at the following state : Pressure = 13.8 bar, Specific volume = $0.143m^3$/kg, Specific internal energy = 2590 kJ/kg, Velocity = 30m/sec. The state of the steam leaving the turbine is as follows :
Pressure = 0.35 bar, Specific volume = $4.37m^3$/kg, Specific internal energy = 2360 kJ/kg, Velocity = 90m/sec. Heat is rejected to the surroundings at the rate of 0.25 kW and the rate of steam flow through the turbine is 0.38 kg/sec. Calculate the power developed by the turbine. **(08 Marks)**

4 a. Represent the Carnot Heat Engine cycle on a P – V diagram and explain briefly. (06 Marks)
b. State and prove Carnot's theorem. (06 Marks)
c. Two reversible heat engines A and B are arranged in series, A rejecting heat to B through and intermediate reservoir. Engine 'A' receives 200kJ at a temperature of 421^0C from a hot source, while Engine 'B' is in communication with a cold sink at a temperature of 4.4^0C. If the work output of A is twice that of B, find i) the intermediate temp between A and B. ii) the efficiency of each engine and iii) the heat rejected to the cold sink. (08 Marks)

PART – B

5 a. With usual notations, state and prove Clausius inequality. (06 Marks)
b. Show that entropy is a property. (06 Marks)
c. A heat engine receives reversibly 420 kJ/cycle of heat from a source at 327^0C and rejects heat reversibly to sink at 27^0C. There are no other heat transfers. For each of the three hypothetical amounts of heat rejected in (i), (ii) and (iii), given below, compute the cyc... integral of $\frac{\delta Q}{T}$. From these results, show which case is reversible, which is irreversible and which is impossible. i) 210 kJ / cycle is rejected ii) 105 kJ / cycle rejected iii) 315 kJ / cycle rejected. (08 Marks)

6 a. Explain the term availability and derive expression for availability for a non – flow steady – flow processes with usual notations. (12 Marks)
b. A system at 500K receives 7200 kJ/min from a source at 1000K. The temperature of atmosphere is 300K. Assuming that the temperature of the system and source remain constant during heat transfer, find out i) The net change of entropy during heat transfer ii) The decrease in available energy after heat transfer. (08 Marks)

7 a. Define 'Quality of Steam'. Explain any one method for determining the quality of steam with a sketch. (06 Marks)
b. Draw enthalpy and entropy diagram for water and indicate the following on the same. i) Saturated liquid line ii) Saturated Vapour line iii) Critical point iv) Const... pressure line v) Constant temp line vi) Constant Quality lines. (06 Mark...
c. A vessel of volume $0.04 m^3$ contains a mixture of saturated water and saturated steam at a temperature of 250^0C. The mass of the liquid present is 9kg. Find the pressure, the mass, the specific volume, the enthalpy, the entropy and the internal energy. (08 Marks)

8 a. With usual notations, for a ideal gas undergoing a reversible adiabatic process, the law of the process is given by $TV^{\gamma-1} = C$. (06 Marks)
b. Show that the entropy change of an ideal gas is given by the equation of the form $S_2 - S_1 = C_p \ ln \frac{V_2}{V_1} + C_V \ ln \frac{P_2}{P_1}$. (06 Marks)
c. 0.5 kg of air is compressed reversibly and adiabatically from 80 kPa, 60^0C to 0.4 Mpa and is then expanded at constant pressure to the original volume. Sketch these processes on the P-V and T-S planes. Compute the heat transfer and work transfer for the whole path. (08 Marks)

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06ME33

Third Semester B.E. Degree Examination, Dec.08/Jan.09
Basic Thermodynamics

Time: 3 hrs.

Max. Marks:100

Note: ***Answer any FIVE full questions choosing at least two questions from each part.***

Part A

1 a. Mention the characteristics of a thermodynamic property. **(04 Marks)**
b. Explain thermodynamic equilibrium. **(08 Marks)**
c. The temperature t on a certain Celsius thermometric scale is given by means of a property through a relation $t = a \ln P + b$ where a and b are constants and P is the property of the fluid. If, at the ice point and steam points the values of P are found to be 4 and 20 respectively, what will be temperature reading corresponding to a reading of $P = 16$? **(08 Marks)**

2 As an engineering student suggest the most economical process when it is desired to compress one mole of air ($\gamma = 1.4$) from an initial state of 300 K and 1 bar to a final state of 300 K and 10 bar from among the following processes:
a. Isothermal compression.
b. Cooling at constant pressure followed by heating at constant volume.
c. Adiabatic compression followed by cooling at constant volume and
d. Heating at constant volume followed by cooling at constant pressure.
Take the value of R = 8.314 J/mol K. **(20 Marks)**

3 a. State the important consequences of the first law of thermodynamics and show that perpetual motion machine of the first kind is impossible. **(08 Marks)**
b. In a thermal power plant operating in a steady state an adiabatic steam turbine receives 1 kg/s of superheated steam at 3 MPa and 400°C. The steam enters the turbine with a velocity of 10 m/s at an elevation of 10 m above the ground level. The steam leaves the turbine at 0.1 bar with 10% moisture content. The velocity of steam at exit is 3 times that at inlet and the exit is at an elevation of 40% of inlet. Show that it is safe to ignore the changes in kinetic energy and potential energy.
Given : P = 3 MPa and t = 400°C; h = 3232.5 kJ/kg; P = 0.1 bar;
$h_f = 191.83$ kJ/kg ; $h_g = 2584.8$ kJ/kg **(12 Marks)**

4 a. Show that of all heat engines working between two given thermal reservoirs, the Carnot engine is the most efficient one. **(08 Marks)**
b. It is proposed to produce 1000 kg of ice per hour from liquid water at 0°C in summer when the ambient atmospheric temperature is 37°C. It is planned to use a heat engine to operate the refrigeration plant. Hot water at 70°C, produced by solar heating acts as a source to the heat engine which uses atmosphere as the sink. Calculate i) the power required by the refrigeration plant ii) the ratio of the energy extracted from freezing water to that absorbed by heat engine and iii) the rate of rejection of heat by both the devices. Take enthalpy of fusion of water at 0°C as 333.43 kJ/kg. **(12 Marks)**

Part B

5 a. Apply the Clausius inequality for a system undergoing an irreversible cyclic change and show that the entropy change of the system is given by $ds \geq \frac{\delta Q}{T}$ (06 Marks)

b. Two identical blocks of mass m are at temperatures T_1 and T_2 and act as source and sink for the operation of a heat engine. Determine the maximum amount of work that can be obtained if the specific heat of the blocks is C in both cases. (06 Marks)

c. An inventor claims to have designed a heat engine, which absorbs 260 kJ of energy as heat from a reservoir at 52°C and delivers 72 kJ of work. His claim includes that the engine rejects 100 kJ and 88 kJ of energy to the reservoirs at 27°C and 2°C respectively. Verify the claim. How is the temperature of the source to be altered in accordance with the verification, if necessary? (08 Marks)

6 a. Explain Availability. (05 Marks)

b. What is the availability function for a non-flow process? (05 Marks)

c. Explain second law efficiency. (05 Marks)

d. In a thermal power plant, superheated steam at 50 bar and 400°C enters an adiabatic turbine and leaves as wet steam of quality 0.9 at 1 bar to the atmosphere at 30°C. Calculate the second law of efficiency of the turbine.
Take for steam at 50 bar and 400°C
$h_1 = 3198.3$ kJ/kg and $S_1 = 6.6508$ kJ/kg K
and at 0.1 bar
$h_f = 191.83$ kJ/kg and $h_g = 2584.8$ kJ/kg
$S_f = 0.6493$ kJ/kg K and $S_g = 8.1511$ kJ/kg K (05 Marks)

7 a. Define : i) Isothermal compressibility ii) Isentropic compressibility and iii) Coefficient of volume expansion. (06 Marks)

b. Explain the terms: i) Saturated liquid ii) Saturated power iii) Saturation temperature iv) Saturation pressure. (08 Marks)

c. Sketch and explain the PT diagram for water. (06 Marks)

8 a. Derive Vander Waal's constants in terms of critical properties. (12 Marks)

b. Define compressibility factor and explain its significance. (03 Marks)

c. A cylinder of 0.01 m^3 volume is filled with 0.727 kg of n-octane (C_8H_{18}) at 427.85 K. Assuming that n-octane obeys the Vander Waal's equation of state calculate the pressure of the gas in the cylinder. Take the constants a and b as 3.789 Pa $(m^3/mol)^2$ and 2.37×10^{-4} m^3/mol respectively. (05 Marks)

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Third Semester B.E. Degree Examination, June-July 2009
Basic Thermodynamics

Time: 3 hrs. Max. Marks:100

Note: ***1. Answer any FIVE full questions, selecting at least Two full questions from each part.***
2. Use of steam Table, Mollier chart is allowed.

PART – A

1 a. Distinguish between
i) Macroscopic and Microscopic approach of study.
ii) Intensive and Extensive properties.
iii) Closed, Open and Isolated systems. **(07 Marks)**

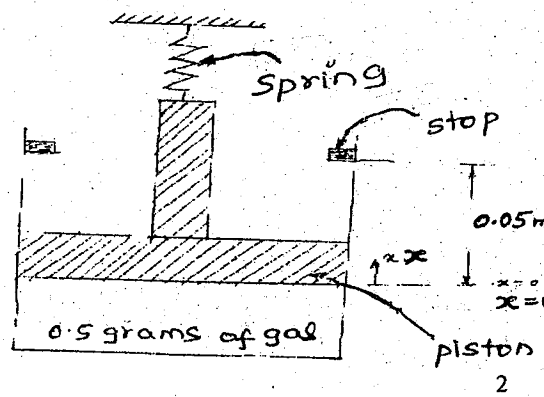
b. What you mean by Thermodynamic equilibrium' of a system. **(05 Marks)**

c. A thermometer is calibrated at '0' degree mark with boiling point of carbon Tetrachloride and 100 degree mark with melting point of lead, when used to measure temperature, the device indicates 16 degrees. Carbon tetrachloride boils at 76.75°C and lead melts at 327°C. Convert reading of device to the equivalent reading on Celsius scale. **(08 Marks)**

2 a. State Thermodynamics definition of work. How it is superior to mechanics definition of work? List different forms of work. **(07 Marks)**

b. Derive expression for displacement work in a polytropic process. **(05 Marks)**

c. A cylinder piston assembly contains 0.5 grams of gas, as shown in Fig.Q2(c). Initially, the piston face at x = 0 sping exerts no force on piston. As a result of heat transfer, the gas expands, raising the piston until it hits the stops. At this point the piston location is x = 0.05m, and heat transfer stops. The force exerted by the spring varies linearly with 'x' according to the equation F = kx, where k is the spring constant = 10,000 N/m. Take mass of piston = 10 kg, area of piston = 0.0078 m^2, atmospheric pressure = 1.0 bar and specific internal energy at initial and final states as 214 KJ/kg and 337 KJ/kg respectively. Determine initial pressure, work done and heat transfer in the process. **(08 Marks)**



3 a. For Isothermal non flow and steady flow processes show that $\int_1^2 P.dv = -\int_1^2 vdp$ also state the assumptions. **(07 Marks)**

b. Show that internal energy is a property. **(05 Marks)**

c. The working fluid, in a steady flow process flows at a rate of 220 kg/min. The fluid rejects 100 KJ/s of heat passing through the system. The conditions of the fluid at inlet and outlet are given as velocity = 220 m/s, P_1 = 6.0 bar, u_1 = 2000 KJ/kg, v_1 = 0.36 m^3/kg and velocity = 140 m/s, P_2 = 1.2 bar, u_2 = 1400 KJ/kg, v_2 = 1.3 m^3/kg. The suffix '1' indicates condition at inlet and 2 at outlet. Determine the power capacity of the system in MW. **(08 Marks)**

4 a. Give Kelvin – Plank and clausius statements of second law of thermodynamics and show that they are equivalent. (10 Marks)

b. A reversible heat engine operates between two reservoirs at temperatures of 600^0C and 40^0C. The engine drives a reversible refrigerator, which operates between 40^0C and -20^0C. The heat transfer to the engine is 2000 KJ and network output from combined engine and refrigerator system is 360 KJ. Calculate heat transfer to the refrigerator and net heat transfer to the reservoir at 40^0C. (10 Marks)

PART – B

5 a. State and prove Clausius Inequality. (07 Marks)

b. Explain principle of increase of entropy of universe. (05 Marks)

c. 1.2 m^3 of air is heated reversibly at constant pressure from 300 K to 600 K and is then cooled reversibly at constant volume back to initial temperature. If the initial pressure is 1 bar, calculate net heat flow and overall change in entropy. Also represent the processes on T-S diagram. Take C_p = 1.005 KJ/kgk and R = 0.287 KJ/kgk. (08 Marks)

6 a. Explain Available, Unavailable energies. When does the system becomes dead? (06 Marks)

b. Derive expression for availability in a non-flow system. (06 Marks)

c. 2 kg of air at 5 bar, 80^0C expands adiabatically in a closed system until its volume is doubled and its temperature becomes equal to that of surrounding which is at 1 bar and 5^0C. Determine : i) Maximum work, ii) Change in availability and iii) Irreversibility. (08 Marks)

7 a. Define the following with respect to steam formation.

i) Sub-cooled liquid
ii) Dryness fraction
iii) Latent heat of vaporization
iv) Degree of super heat. (06 Marks)

b. Describe with neat sketch working of separating and throttling calorimeter. (06 Marks)

c. Steam initially at a pressure of 15 bar and 0.95 dry expands isentropically to 7.5 bar and then throttled until it becomes just dry and saturated. Determine per kg of steam:
i) Change in internal energy; ii) change in enthalpy and iii) Change in entropy. (08 Marks)

8 a. Explain van-der-waals equation. (06 Marks)

b. Write a short note on compressibility chart (04 Marks)

c. In an engine cylinder a gas has volumetric analysis of 13% CO_2, 12.5% O_2, and 74.5% N_2. The temperature at the beginning of expansion is 950^0C. Gas mixture expands reversibly through a volume ration of 8:1 according to the law $Pv^{1.2} = C$. Calculate per kg of mixture i) Work done; ii) Heat transfer and iii) Change in entropy. Take C_p for constituent gases CO_2, O_2 and N_2 are 1.235, 1.008 and 1.172 KJ/kgk respectively. (10 Marks)

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06ME33

Third Semester B.E. Degree Examination, Dec.09/Jan.10
Basic Thermodynamics

Time: 3 hrs. Max. Marks:100

Note: ***1. Answer any FIVE full questions, selecting at least TWO questions from each part.***
2. Use of Thermodynamics Charts and Tables is permitted.

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

PART – A

1 a. Distinguish between:
i) Microscopic and macroscopic approaches of thermodynamics
ii) Intensive and extensive properties. **(06 Marks)**

b. Explain mechanical, chemical and thermal equilibrium. **(06 Marks)**

c. State zeroth law of thermodynamics. The emf, in millivolts in a thermocouple with the test junction at t°C on gas thermometer scale and reference junction at ice point is given by $e = 0.0367t + 1.33 \times 10^{-4}t^2$. The millivolt meter is calibrated at ice point and steam points. What will this thermometer read in a place where the gas thermometer reads 50°C? **(08 Marks)**

2 a. Define thermodynamic work and heat. **(04 Marks)**

b. Derive an expression for displacement work for polytropic process. **(06 Marks)**

c. A cylinder contains one kg of fluid at an initial pressure of 20 bar. The fluid is allowed to expand reversibly behind a piston according to law $PV^2 = C$ untill the volume is doubled. The fluid is then cooled reversibly at constant pressure untill the piston regains its original position, heat is then supplied reversibly with the piston firmly locked in this position untill the pressure rises to the original value of 20 bar. Calculate the net work done by the fluid for an initial volume of $0.05m^3$. **(10 Marks)**

3 a. State : i) I law of thermodynamics as applied to a closed system
ii) Two-property rule. **(04Marks)**

b. A fluid system undergoes a non-flow frictionless process following the pressure – volume relation as $P = \frac{5}{V} + 1.5$, where P is in bar and V is in m^3. During the process volume changes from $0.15m^3$ to $0.05m^3$ and the system rejects 45 kJ of heat. Determine: i) Change in internal energy ; ii) Change in enthalpy. **(08 Marks)**

c. A fluid flows steadily through a rotary device. For a kg of fluid, the heat transfer out of the device is 25 kJ. The fluid properties at the entry are 5 bar, 50 m/s and 0.78 m^3/kg. The corresponding properties at the exit are 1 bar, 100 m/s and 0.97m^3/kg. The inlet is 5m above the exit and the internal energy at the entry is greater than that of exit by 119 kJ. Find the out put work. **(08 Marks)**

4 a. Represent schematically heat engine, heat pump, and refrigerator. Give their performance. **(06 Marks)**

b. Prove that Kelvin Planck and Claussius statements of second law of thermodynamic are equivalent. **(07 Marks)**

c. A heat engine is used to drive a heat pump. The heat transfers from the heat engine and the heat pump are used to heat the water circulating through a radiator of a building. If the COP of the heat pump is 4 and the efficiency of the heat engine is 0.3, how much heat is transferred to the radiator water for every kJ heat transferred to the heat engine? **(07 Marks)**

PART – B

5 a. State and prove "Clausius inequality". (06 Marks)
b. Define entropy and prove that it is a property of the system. (06 Marks)
c. Obtain an expression for entropy change of a closed system when it undergoes a polytropic process. (08 Marks)

6 a. Define :
i) Available energy
ii) Availability
iii) Effectiveness. (06 Marks)
b. Obtain an equation for maximum work available in a non – flow system. (06 Marks)
c. A system at 500 K receives 7200 kJ/min from a source at 1000 K. The temperature of atmosphere is 300 K. Assuming that the temperatures of system and source remain constant during heat transfer, find out
i) The entropy produced during heat transfer.
ii) The decrease in available energy after heat transfer. (08 Marks)

7 a. Write a neat P – T diagram for a pure substance and define : i) Tripple point ; ii) Critical point. (06 Marks)
b. Define :
i) Sensible heat of water
ii) Latent heat and
iii) Dryness fraction. (06 Marks)
c. The following data were obtained in a test on a combined separating and throttling calorimeter.
Pressure of steam sample = 15 bar
Pressure of steam at exit = 1 bar
Temperature of steam at exit = 150°C
Discharge from separating calorimeter = 0.5 kg/min
Discharge from throttling calorimeter = 10 kg/min. Determine the dryness fraction of the sample of steam. (08 Marks)

8 a. Write a short note on Vander Wall's equation. (05 Marks)
b. Explain reduced properties and compressibility chart. (05 Marks)
c. A vessel of capacity $3m^3$ contains 1 kg mole of N_2 At 90°C
i) Calculate pressure and specific volume of gas
ii) If the ratio of specific heats are 1.4, obtain cp and cv
iii) Subsequently, the gas cools to the atmospheric temperature of 20°C; evaluate the final pressure of gas.
iv) Evaluate the increase in specific internal energy, the increase in specific enthalpy, increase in specific entropy and heat transfer. (10 Marks)

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06ME33

Third Semester B.E. Degree Examination, May/June 2010
Basic Thermodynamics

Time: 3 hrs. Max. Marks:100

Note: ***1. Answer any FIVE full questions, selecting at least TWO questions from each part.***
2. Use of thermodynamics data handbook is permitted.

PART – A

1 a. What are intensive, extensive and specific extensive properties? Give examples of each. **(06 Marks)**

b. What is a quasistatic process? What is its characteristic feature? **(04 Marks)**

c. A thermometer is calibrated with ice and steam points as fixed points referred to as 0°C and 100°C respectively. The equation used to establish the scale is $t = a\log_e x + b$

i) Determine the constants 'a' and 'b' in terms of ice point (x_I) and stam point (x_S).

ii) Show that $t^{\circ}C = 100\dfrac{\log_e\left(\dfrac{x}{x_I}\right)}{\log_e\left(\dfrac{x_S}{x_I}\right)}$ **(08 Marks)**

d. Define thermodynamic equilibrium. **(02 Marks)**

2 a. Does heat transfer inevitably cause a temperature rise? What is the other cause for rise in temperature? **(05 Marks)**

b. Define thermodynamic work. Briefly explain, what is displacement work. **(07 Marks)**

c. A mass of gas is compressed in a quasistatic process from 80 Kpa; 0.1 m^3 to 0.4 MPa, 0.03 m^3. Assuming that the pressure and volume are related by PV^n = constant, find the work interaction during the process. Is it a work producing system or work absorbing system? **(08 Marks)**

3 a. State and explain the first law of thermodynamics for a closed system undergoing a cycle. What is PMM1? **(07 Marks)**

b. During one cycle, the working fluid in an engine engages in two work interactions: 15 kJ to the fluid and 44 kJ from the fluid. There are three heat interactions, two of which are known: 75 kJ to the fluid and 40 kJ from the fluid. Evaluate the magnitude and direction of the third heat transfer. **(04 Marks)**

c. At the inlet to a certain nozzle, the enthalpy of the fluid passing is 3000 kJ/kg and the velocity is 60 m/s. At the discharge end, the enthalpy is 2762 $\frac{kJ}{kg}$. The nozzle is horizontal and there is negligible heat loss from it.

i) Find the velocity at the exit from the nozzle.

ii) If the inlet area is 0.1 m^2 and specific volume at inlet is 0.187 m^3/kg, find the mass flow rate.

iii) If the specific volume at the nozzle exit is 0.498 m^3/kg, find the exit area of the nozzle. **(09 Marks)**

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

4 a. Establish the equivalence of Kelvin – Planck and Clausius statements of second law of thermodynamics. **(08 Marks)**

b. A source 'X' can supply energy at a rate of 11000 kJ/minute at 320°C. A second source 'Y' can supply energy at a rate of 110000 kJ/minute at 60°C. Which source 'X' or 'Y' would you choose, to supply energy to an ideal reversible engine, that is to produce a large amount of power, if the temperature of surroundings is 4°C? **(08 Marks)**

c. What do you understand by a reversible and an irreversible process? What are the causes of irreversibility of a process? **(04 Marks)**

PART – B

5 a. Define entropy. Show that entropy is a property of the system. **(08 Marks)**

b. Define the terms, available and unavailable energy. **(02 Marks)**

c. One kg of ice at -5°C is exposed to the atmosphere, which is at 20°C. The ice melts and comes into thermal equilibrium with the atmosphere. Determine the entropy increase of the universe. Take Cp of ice = $2.093\frac{kJ}{kgK}$ and latent of fusion of ice = 334 kJ/kg. **(10 Marks)**

6 a. 25 kg of water at 95°C is mixed with 35 kg of water at 35°C, the pressure being taken as constant and temperature of the surroundings being 15°C. Calculate decrease in available energy of the system. **(10 Marks)**

b. Define the terms : i) Useful work ; ii) Reversible work ; iii) Irreversibility. **(06 Marks)**

c. Define first law efficiency and second law efficiency. How these efficiencies can be improved? **(04 Marks)**

7 a. What do you understand by the term "degree of superheat" of steam? Show that dryness fraction of a sample of steam measured using combined separating and throttling calorimeter is given by $X = X_1 X_2$, where,

X = Dryness fraction of steam in steam main

X_1 = Dryness fraction of steam as measured by using separating calorimeter.

X_2 = Dryness fraction of steam as measured using throttling calorimeter. **(10 Marks)**

b. A pressure cooker contains 1.5 kg of steam at 5 bar and 0.9 dryness when the gas was switched off. Determine the quantity of heat rejected by the pressure cooker when the pressure in the cooker falls to 1 bar. **(10 Marks)**

8 a. Under what conditions the behaviour of a real gas approaches closely that of an ideal gas? Write van der waal's equation for a real gas. **(06 Marks)**

b. A gas at a pressure of 1.4 MN/m^2 and 360°C is expanded adiabatically to a pressure of $100\ \frac{kN}{m^2}$. The gas is then heated at constant volume until it attains 360°C when its pressure is found to be 220 kN/m^2. Finally it is compressed isothermally to the original pressure of $1.4\ \frac{MN}{m^2}$. Sketch the process on P-V and T-S diagrams. For 0.23 kg of gas, evaluate the following : work transfer, heat transfer, change in internal energy and change in entropy during each process. Assume the following data for the gas:

$C_p = 1.005$ kJ/kg K

$C_v = 0.718$ kJ/kg K

$R = 0.287$ kJ/kg K

$\gamma = 1.4$

(14 Marks)

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