

TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2083 Baishakh

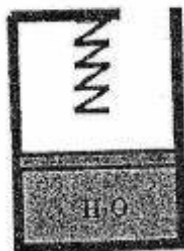
Exam.	Back		
	BE	Full Marks	80
	BCE, BME, BGE	Pass Marks	32
	I/I	Time	3 hrs.

Subject: - Fundamental of Thermodynamics and Heat Transfer (ME 402)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ Attempt All questions.
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- ✓ Necessary tables are attached herewith.
- ✓ Assume suitable data if necessary.



1. Differentiate state function and path function with relevant example. [4]
2. Derive an expression of work transfer in non-flow isothermal process with corresponding PV diagram. [4]
3. Explain the criteria of a pure substance. Define state postulate. [3+1]
4. Derive an expression of energy for adiabatic turbine and adiabatic nozzle. [3+3]
5. Show the equivalence of Kelvin Planck statement and Clausius statement using heat engine, refrigerator and heat pump. [2+4]
6. Derive an expression of efficiency of Brayton cycle in terms of pressure ratio. [6]
7. Define the properties: transmissivity, absorptivity, and reflectivity of a material. [2×3]
8. On a new scale N of temperature the freezing point of ice and boiling point of water are 100°N and 400°N respectively. Derive an expression to convert a temperature reading on °N scale to °C scale. Also determine the change in °N scale when the temperature of a system increases by 50°C. [6]
9. A piston cylinder arrangement shown in figure contains water initially at $P_1 = 101.3 \text{ kPa}$, $x_1 = 0.8$ and $V_1 = 0.010 \text{ m}^3$. When the system is heated, it encounters a linear spring ($k = 100 \text{ kN/m}$). At this state volume is 0.015 m^3 . The heating continues till its pressure is 200 kPa. If the diameter of the piston is 0.15 m, determine: [8]
 - a) The final temperature, and
 - b) The total work transfer.
 - c) Also sketch the process on $P - v$ diagram.



10. A piston cylinder device shown in figure contains water initially at $P_1 = 1 \text{ MPa}$ and $T_1 = 500^\circ\text{C}$. A pressure of 400 kPa is required to support the piston. There is a heat transfer from the device until its temperature drops to 30°C . Sketch the process on $P - v$ and $T - v$ diagrams and determine the total work and heat transfer. [8]



11. Air enters a gas turbine at 1 MPa and 1500 K and exits at 100 kPa . If its isentropic efficiency is 80% , determine the turbine exit temperature. [8]

12. The following data are given for a four stroke diesel engine: [8]

Cylinder bore	$= 14 \text{ cm}$
Stroke length	$= 25 \text{ cm}$
Clearance volume	$= 350 \text{ cm}^3$

Determine the air standard efficiency, if fuel injection takes place at constant pressure for 5% of the stroke.

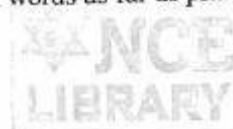
13. A 3 cm thick plate ($k = 50 \text{ W/mK}$) 50 cm by 70 cm is maintained at 300°C . Heat is lost from the plate surface by convection and radiation to the ambient air at 20°C . If the emissivity of the surface is 0.91 and the convective heat transfer coefficient is $25 \text{ W/m}^2 \text{K}$, determine the inside plate temperature. [Take $\sigma = 5.67 \times 10^{-8} \text{ W/m}^2 \text{K}^4$]. [6]

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1. Explain zeroth law of thermodynamics with its engineering application. [4]
2. Discuss the concept of stored and transient energy with their types for a closed system. [4]
3. Explain the necessity of property table and property charts of working substances in thermodynamics. [4]
4. Describe first law of thermodynamics for control mass with relevant energy and mass relations. Also discuss it while working in cyclic process. [4+2]
5. Derive an expression of performance measurement of heat engine, heat pump and refrigerator with relevant schematic diagram. [6]
6. Discuss vapor compression cycle used in refrigeration with major components with the help of P-h and T-s diagram. [6]
7. Determine expressions of overall heat transfer coefficient when a hollow cylinder is exposed to two convective medium with two different temperature conditions. [6]
8. A nitrogen cylinder having a volume of 15 m^3 initially contains 6 kg of nitrogen. Determine the specific volume of nitrogen in the cylinder initially. During certain process 4 kg of nitrogen is consumed, determine the final specific volume of nitrogen in the cylinder. Also plot the amount of nitrogen that has been consumed versus the specific volume of the remaining in the cylinder. [6]
9. A piston cylinder arrangement shown in figure contains 2 kg of water initially at a pressure of 200 kPa and a temperature of 50°C . Heat is added until the piston reaches the upper stops where the total volume is 1.5 m^3 . It takes a pressure of 600 kPa to lift the piston. Sketch the process on P-v and T-v diagrams and determine the final temperature and the work transfer. [8]



10. A gas undergoes a thermodynamic cycle consisting of the following three processes:

[8]

- Sketch the process on P-V and T-V diagrams.
- Calculate the net work for the cycle.
- Calculate the net heat for the cycle.
- Calculate the heat transfer for process 2-3.
- Calculate the heat transfer for process 3-1.
- Is this power cycle or a refrigeration cycle?

Process 1-2	constant volume, $V_1 = 0.08 \text{ m}^3$, $P_1 = 100 \text{ kPa}$, $U_2 - U_1 = 140 \text{ kJ}$
Process: 2-3	expansion with $PV = \text{constant}$, $U_3 = U_2$
Process: 3-1	constant pressure, $W_{31} = -56 \text{ kJ}$

11. Air enters a gas turbine at 1 MPa and 1500 K and exits at 100 kPa. If its isentropic efficiency is 80 %, determine the turbine exit temperature.

[8]

12. Air at the beginning of compression stroke in an ideal Diesel cycle is at 100 kPa and 295 K and the compression ratio is 20. Determine the maximum temperature during the cycle to have an efficiency of 65 %.

[8]

13. A thick-walled tube of stainless steel [$k = 19 \text{ W/m}^\circ\text{C}$] with 2 cm inside diameter and 4 cm outer diameter is covered with a 3 cm layer of asbestos insulation [$k = 0.2 \text{ W/m}^\circ\text{C}$]. If the inside wall temperature of the pipe is maintained at 600°C, calculate the heat loss per meter of length. Also calculate the tube-insulation interface temperature. Take outside temperature of the insulation as 100°C.

[6]

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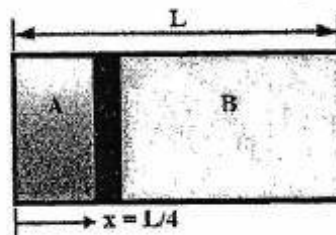
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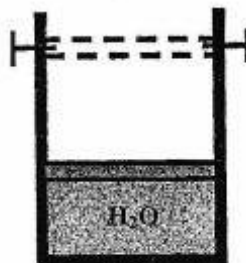
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1. Explain state, path and cycle in engineering thermodynamics with relevant example. [4]
2. Show the similarity and dissimilarities of heat and work transfer. [4]
3. Define critical point, ideal gas, quality and moisture content. [4]
4. Explain steady state work applications under control volume with relevant example. [6]
5. What is entropy? Derive an expression governing the change in entropy for incompressible substance under isentropic condition. [2+4]
6. Derive an expression of efficiency of diesel cycle in terms of compression ratio and cutoff ratio. [6]
7. Determine an expression of overall heat transfer coefficient when a plane slab is exposed to two convective medium with two different temperature conditions. [6]
8. A cylinder with a total volume of 0.5 m^3 has a movable piston as shown in figure. When the piston is at one fourth of the length, both sides have same specific volume of $4 \text{ m}^3/\text{kg}$. Determine the specific volumes of both sides when the piston is at middle of the cylinder. [6]



9. Water (2 kg) is contained within a piston-cylinder arrangement as shown in figure. The initial temperature is 105°C and there are equal masses of liquid and vapor initially. The system is heated to a position where the piston is locked, and then the system is cooled to the saturated vapor state at $T = 50^\circ\text{C}$. Draw the process on a P-v diagram, and evaluate the work done during the process. [8]



10. Air expands through an adiabatic turbine from 1,000 kPa, 1,000 K to 100 kPa, 400 K. The inlet velocity is 15 m/s whereas exit velocity is 150 m/s. The power output of the turbine is 3,600 kW. Determine the mass flow rate of air and the inlet and exit areas. [Take $R = 287 \text{ J/kgK}$ and $c_p = 1005 \text{ J/kgK}$]. [8]
11. A heat pump having a COP of 5 maintains a building at a temperature of 24°C by supplying heat at a rate of 72,000 kJ/h when the surroundings is at 0°C . The heat pump runs 12 hour in a day and the electricity costs Rs 11/kWh. [6+2]
- a) Determine the actual and minimum theoretical cost per day.
b) Compare the actual operating cost with the cost of direct electric resistance heating.
12. The following data are obtained for a four stroke petrol engine: [8]
- | | |
|------------------|-----------------------|
| Cylinder bore | = 14 cm |
| Stroke length | = 15 cm |
| Clearance volume | = 231 cm ³ |
- Determine:
- a) the ratio of clearance volume and swept volume,
b) the compression ratio, and
c) the thermal efficiency.
13. An exterior wall of a house consists of a 0.1m layer of common brick ($k=0.7\text{W/mC}$) followed by a 0.04 m layer of gypsum plaster ($k = 0.48\text{W/mK}$). What thickness of loosely packed rock wool ($k = 0.061\text{W/mK}$) should be added to reduce the heat loss through the wall by 65%? [6]

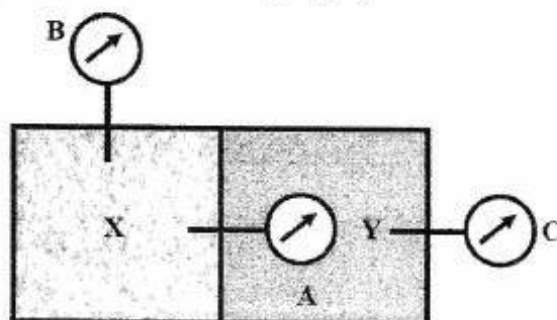
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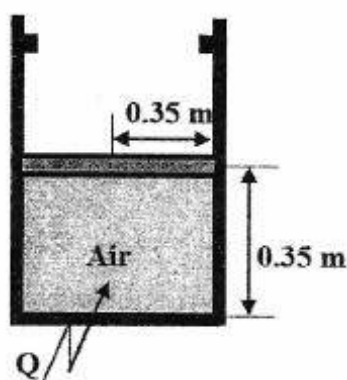
1. Define thermodynamic equilibrium. Explain the conditions required for thermodynamic equilibrium. [4]
2. Define energy and power. Explain how different forms of energies are classified in thermodynamics. [4]
3. Define the following terms: saturation pressure, saturated liquid, critical point and quality. [4]
4. Write down general mass conservation and energy conservation equations for a control volume. Also and reduce them for a control volume operating under steady state condition. [6]
5. Define entropy. Derive entropy relations for an ideal gas. [6]
6. List assumptions of an air standard analysis. Sketch P-v and T-s diagrams for Otto and Diesel cycle. [6]
7. Using thermal resistance derive an expression for outside overall heat transfer coefficient for composite cylinders consisting of two layers with convection on both sides. [6]
8. A large chamber is separated into two compartments which are maintained different pressures, as shown figure below. Pressure gauge A reads 180 kPa, and pressure gauge B reads 120 kPa. If the barometric pressure is 100 kPa, determine the absolute pressure existing in the compartments and the reading of gauge C. [6]



9. A piston cylinder device shown in figure below contains 2 kg of H_2O with an initial temperature and volume of $80^\circ C$ and 0.05 m^3 respectively. It requires a pressure of 400 kPa to lift the piston from the stops. The system is heated until its temperature reaches $250^\circ C$. Sketch the process on P-v and T-v diagrams and determine the total work transfer. [Refer attached table for the properties of steam] [8]



10. A piston cylinder device shown in figure below contains 3.06 kg of air initially at a temperature of $34^\circ C$. Heat is supplied to the system until it reaches to a final temperature of $950^\circ C$ and a final pressure of 5 MPa. Sketch the process on P-V and T-V diagrams and determine the total work transfer and total heat transfer. [Take $R = 287 \text{ J/kgK}$ and $c_v = 718 \text{ J/kgK}$] [8]



11. A heat pump has a coefficient of performance that is 80 % of the theoretical maximum. It maintains a hall at $20^\circ C$, which leaks energy 1 kW per degree temperature difference to the ambient. For a maximum of 1.5 kW power input, determine the minimum outside temperature for which the heat pump is sufficient. [8]
12. An ideal Brayton cycle has pressure ratio of 10. The temperature of air at compressor and turbine inlets are 300 K and 1200 K respectively. Determine its thermal efficiency and the mass flow rate of air required to produce net power output of 80 MW. [Take $\gamma = 1.4$, $c_p = 1005 \text{ J/kgK}$] [8]
13. A 2.5 cm thick plate ($k = 50 \text{ W/mK}$) 50 cm by 75 cm is maintained at $300^\circ C$. Heat is lost from the plate surface by convection and radiation to the ambient air at $20^\circ C$. If the emissivity of the surface is 0.9 and the convection heat transfer coefficient is $20 \text{ W/m}^2 K$, determine the inside plate temperature. [6]

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- Define thermodynamic property. Differentiate between intensive and extensive properties with examples. [4]
- Differentiate between heat and work. A gas in a piston-cylinder device is compressed, and as a result its temperature rises. Is this a heat or work interaction? [3+1]
- Define specific heat. Why a gas has two specific heats? Derive an expression for the specific heat of a gas at constant volume. [4]
- Define steady state work application. Write down the general mass and energy equation for a steady state process and reduce them for an adiabatic turbine. [1+2.5+2.5]
- Define isentropic process. Derive isentropic relations for an Ideal gas. [1+5]
- Define mean effective pressure (MEP) for an internal combustion engine. Draw P - V and T - S diagrams for an air standard Otto cycle. Also derive the thermal efficiency of this cycle as the function of compression ratio. [6]
- Derive an expression for the outside overall heat transfer coefficient of a composite cylinder consisting of three layers. [6]
- Air undergoes three processes in series to form a cycle
 Process 1-2: Compression with $PV^{1.3} = \text{constant}$, $P_1=100\text{kPa}$, $V_1=0.04\text{ m}^3$ to $V_2=0.02\text{ m}^3$
 Process 2-3: Constant Pressure process to $V_3=V_1$
 Process 3-1: Constant Volume
 Sketch the process on P - V diagram and determine the Total Work Transfer. [6]
- A closed, rigid container with a volume 0.2 m^3 initially contains a mixture of saturated liquid water and saturated water vapor at a pressure of 100 kPa with a quality of 50%. Heat is added, the pressure to the system until it reaches 200 kPa. Sketch the process on P - v and T - v diagram and determine [8]
 - The temperature of each state.
 - The mass of vapor present at each state
 - If the heating is continued, determine the pressure at which the container holds only saturated vapor.
- Air expands through an adiabatic turbine from 1000 kPa, 1000 K to 100kPa, 400 K. The inlet velocity is 10 m/sec whereas exit velocity is 100 m/sec. The power output of the turbine is 3600 kW. Determine the mass flow rate of air and inlet and exit area. Take $R = 287\text{ J/kgK}$ and $c_p = 1005\text{ J/kgK}$. [8]
- Block A ($m_A = 0.5\text{ kg}$, $c_A = 1\text{kJ/kgK}$) and Block B ($m_B = 1\text{ kg}$, $c_B = 0.5\text{kJ/kgK}$) which are initially at 100°C and 500°C respectively are brought in contact inside an isolated system. Determine the change in entropy when they reach to a final state of thermal equilibrium. [8]

12. An air standard diesel cycle has compression ratio of 18, and the heat transfer to the working fluid is 1800 kJ/kg. At the beginning of the compression process, the pressure is 0.1 MPa and temperature is 15°C. Determine [8]

- The maximum temperature.
- The cut off ratio.
- The thermal efficiency and
- The mean effective pressure of the cycle.

[Take $\gamma = 1.4$, $R = 287 \text{ J/kgK}$ and $C_p = 1005 \text{ J/kgK}$]

13. A 140 mm diameter pipe carrying steam is covered by a layer of insulation ($k = 0.5 \text{ W/mK}$) of 30mm thick. Later, an extra layer of another insulation ($k = 1 \text{ W/mK}$) having a thickness 20mm is added. If the surrounding temperature remains constant and heat transfer coefficient for both insulating layers is $10 \text{ W/m}^2\text{K}$, determine the percentage change in heat transfer rate due to extra insulation. [6]

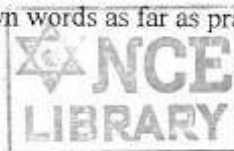
Properties of Saturated Water - Temperature Table

P	T	v_f	v_{fg}	v_g	u_f	u_{fg}	u_g	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g
kPa	°C	m^3/kg	m^3/kg	m^3/kg	kJ/kg	kJ/kg	kJ/kg	kJ/kg	kJ/kg	kJ/kg	kJ/kg.K	kJ/kg.K	kJ/kg.K
50	81.339	0.001030	3.2398	3.2408	340.49	2142.8	2483.3	340.54	2304.8	2645.3	1.0912	6.5016	7.5928
60	85.949	0.001033	2.7314	2.7324	359.84	2129.2	2489.0	359.90	2293.1	2653.0	1.1454	6.3856	7.5310
70	89.956	0.001036	2.3644	2.3654	376.68	2117.3	2494.0	376.75	2282.9	2659.6	1.1920	6.2869	7.4789
80	93.511	0.001038	2.0866	2.0876	391.63	2106.7	2498.3	391.71	2273.6	2665.3	1.2330	6.2009	7.4339
90	96.713	0.001041	1.8688	1.8698	405.11	2097.1	2502.2	405.20	2265.3	2670.5	1.2696	6.1247	7.3943
100	99.632	0.001043	1.6933	1.6943	417.41	2088.3	2505.7	417.51	2257.6	2675.1	1.3027	6.0562	7.3589
101.32	100.00	0.001043	1.6727	1.6737	418.96	2087.1	2506.1	419.06	2256.6	2675.7	1.3069	6.0476	7.3545
125	105.99	0.001048	1.3742	1.3752	444.25	2068.9	2513.2	444.38	2240.7	2685.1	1.3741	5.9100	7.2841
150	111.38	0.001053	1.1584	1.1595	467.02	2052.4	2519.4	467.18	2226.2	2693.4	1.4338	5.7894	7.2232
175	116.07	0.001057	1.0027	1.0038	486.89	2037.8	2524.7	487.08	2213.3	2700.4	1.4851	5.6866	7.1717
200	120.24	0.001060	0.8848	0.8859	504.59	2024.8	2529.4	504.80	2201.7	2706.5	1.5304	5.5968	7.1272
225	124.01	0.001064	0.7923	0.7934	520.59	2012.9	2533.5	520.83	2191.2	2712.0	1.5708	5.5172	7.0880
250	127.44	0.001067	0.7177	0.7188	535.22	2001.9	2537.1	535.49	2181.3	2716.8	1.6075	5.4454	7.0529

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1. What is the difference between gauge pressure and absolute pressure? Define atmospheric pressure, gauge pressure and absolute pressure and show them on a common pressure scale. [2+2]
2. Define total energy. Differentiate between stored and transient energies with examples. [1+3]
3. Define degree of superheat and quality. Derive an expression for specific volume of a two-phase mixture in terms of quality. [4]
4. Define steady state flow application. Write down general mass and energy equations for a steady state process and reduce them for an adiabatic nozzle. [1+2.5+2.5]
5. Define a reversible heat transfer reservoir and a reversible work transfer reservoir. Derive the expressions for the entropy change for a reversible heat transfer process and a reversible work transfer process. [6]
6. Sketch the components of a Rankine cycle. Explain its working principle with corresponding process on P - v and T - s diagrams. [6]
7. Explain the following terms: emissivity, thermal conductivity, black body, gray body, thermal resistance free convection and forced convection. [6]
8. Steam is supplied to a turbine at a gauge pressure of 20 bar. After expansion in the turbine the steam passes to a condenser at a constant vacuum gauge pressure of 250 mm of mercury. If barometer reads 750 mm of mercury, determine [6]
 - i) the absolute pressure of the steam at inlet of turbine and
 - ii) the absolute pressure of the steam at inlet of condenser in kPa.

(Take density of mercury, $\rho = 13600 \text{ kg/m}^3$ and $g = 9.81 \text{ m/s}^2$).
9. Steam is contained in a closed rigid container. Initially, the pressure and temperature of the steam are 1500 kPa and 250°C, respectively. The temperature drops as a result of heat transfer to the surroundings. Determine the pressure at which condensation first occurs, in bar, and the fraction of the total mass that has been condensed when the temperature reaches 100°C. What percentage of the volume is occupied by saturated liquid at the final state? Sketch P - v and T - v diagrams. [8]
10. A gas is held in a cylinder behind a piston undergoes a cycle composed of three process:

Process 1 - 2: an adiabatic compression process. For this process $W_{1-2} = -58 \text{ kJ}$.

Process 2 - 3: an expansion during which heat is added and work is done on the piston. $Q_{2-3} = 253 \text{ kJ}$, and $W_{2-3} = 95 \text{ kJ}$.

Process 3 - 1: a cooling of the gas while the piston is stationary to bring the gas to its initial state.

Sketch the cycle on P - v diagram.

Determine the net heat transfer and heat transfer of process 3 - 1. Determine its network and confirm whether it is a power cycle or a refrigeration cycle. [8]

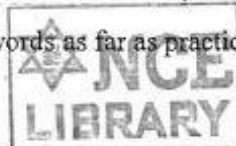
11. A cold storage is to be maintained at -5°C while the surroundings are at 35°C . The heat leakage from the surroundings into the cold storage is estimated to be 29 kW. The actual COP of the refrigeration plant is one third of an ideal plant working between the same temperatures. Calculate [8]
- The power required to drive the ideal plant
 - The power required to drive the actual plant.
12. Air enters the compressor of an ideal air-standard Brayton cycle at 100 kPa, 290 K, with a volumetric flow rate of $4 \text{ m}^3/\text{s}$. The compressor pressure ratio is 10. The maximum temperature during cycle is 1500 K. Determine. [8]
- The thermal efficiency of the cycle.
 - The back work ratio.
 - The net power developed, in kW.
 - The efficiency of Carnot cycle working between same temperature limit.
- Take $\rho = 287 \text{ J/kg.K}$ and $c_p = 1005 \text{ J/kg.K}$.
13. A reactor's wall 320 mm thick is made up of an inner layer of fire brick ($k = 0.84 \text{ W/mK}$) covered with a layer of insulation ($k = 0.16 \text{ W/mK}$). The reactor operates at a temperature of 1325°C at the atmospheric temperature of 25°C . Calculate [6]
- The thickness of brick and insulation.
 - Heat loss per unit area presuming that the insulating material has a maximum temperature of 1200°C .

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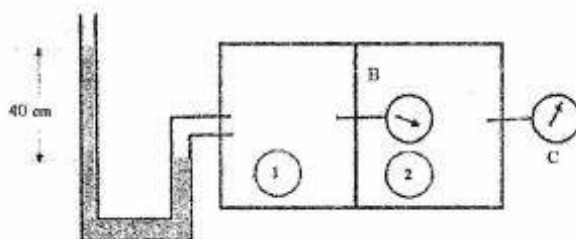
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1. Define thermodynamic process. Sketch P-V, T-V and P-T diagrams for an ideal gas undergoing expansion in the piston-cylinder arrangement without any stops, until the final volume is doubled of the initial volume. [4]
2. Define work transfer. Derive the expression for heat and work for adiabatic process. [4]
3. What is an equation of state? Derive an expression for equation of state of an ideal gas. [4]
4. Write down the statement of first law of thermodynamics for an isolated system. Derive the expressions for mass flow rates at the inlet and outlet of a control volume. [6]
5. Define isentropic process. Derive isentropic relations for an ideal gas. [6]
6. Sketch an air standard diesel cycle on P - V and T - S diagrams and derive an expression for its efficiency in terms of compression ratio and cut-off ratio. [6]
7. Derive an expression with appropriate diagram for conduction heat transfer through a composite cylinder consisting of three layers of different materials. [6]
8. A large chamber is separated into two compartments which are maintained at different pressures, as shown in figure below. The local barometer reads 740 mm of Hg and pressure gauge B reads 30 kPa vacuum pressures. The U-tube manometer connected to compartment 1 contains mercury and its reading is 40 cm of Hg. Determine the absolute pressure in each compartment and reading of pressure gauge C. [Take $p_{Hg} = 13600 \text{ kg/m}^3$, $g = 9.81 \text{ m/s}^2$] [6]



9. A piston cylinder device shown in figure below contains 2 kg of water with an initial temperature and volume of 80°C and 0.05m³. It requires a pressure of 400 kPa to lift the piston from the stops. The system is heated until its temperature reaches 250°C. Sketch the process on P-v diagram and determine the total work transfer. [8]



10. An ideal gas undergoes a thermodynamic cycle consisting of the following three processes in series.

[8]

Process 1-2: constant volume, $V_1 = 0.1 \text{ m}^3$, $P_1 = 100 \text{ kPa}$, $U_2 - U_1 = 150 \text{ kJ}$

Process 2-3: expansion with $PV = \text{constant}$

Process 3-1: constant pressure, $W_{31} = -60 \text{ kJ}$

- Sketch the process on P-V and T-V diagram.
 - Calculate network for the cycle.
 - Calculate net heat for the cycle.
 - Calculate the heat transfer for the process 1-2.
 - Calculate heat transfer for the process 2-3.
 - Calculate the heat transfer for the process 3-1.
 - Is this power cycle or a refrigerator cycle?
11. It is desired to maintain an auditorium hall at 25°C throughout the year. For this it is planned to use a reversible air conditioning unit which can be used as a refrigerator in summer and a heat pump in winter. The outside temperature in summer is 45°C and in winter it falls down to 3°C . The heat loss through walls, roof, windows and doors is estimated as 50 kW . Determine minimum theoretical power required to operate the air conditioning unit in summer and in winter.
12. An ideal Brayton cycle has a pressure ratio of 8. The air temperatures at the compressor and turbine inlets are 300 K and 1300 K respectively. Determine:
- The air temperatures at the exits of the compressor and turbine,
 - The back work ratio, and
 - The thermal efficiency of the cycle.

[8]

[Take $\gamma = 1.4$ and $c_p = 1005 \text{ kJ/kgK}$]

13. The hot combustion gas of a furnace is separated from the ambient air by a brick wall of 0.2 m thick with thermal conductivity of 1.5 W/mK and surface emissivity of 0.85 . Under steady state conditions, an inner surface temperature of brick wall is measured to be 850°C . The ambient air temperature is 20°C and the convection heat transfer coefficient between the surface and air is $20 \text{ W/m}^2\text{K}$. What is the brick outside surface temperature? [$\sigma = 5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4$]

[6]

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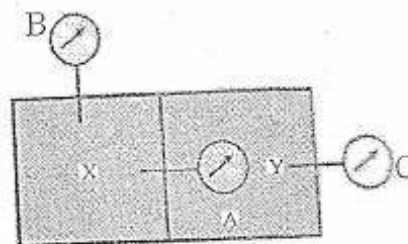
Exam.	Regular		
Level	BE	Full Marks	80
Programme	BCE, BME, BGE	Pass Marks	32
Year / Part	I / I	Time	3 hrs.

Subject: - Fundamental of Thermodynamics and Heat Transfer (ME 402)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ Attempt All questions.
- ✓ The figures in the margin indicate Full Marks.
- ✓ Necessary tables are attached herewith.
- ✓ Assume suitable data if necessary.
- ✓ For air take $C_p = 1005 \text{ J/kgK}$ and $C_v = 718 \text{ J/kgK}$.



1. How will you find out whether a given variable is a thermodynamic property? How are those properties classified? Give examples. [4]
2. Define transient energy with its salient features. Differentiate between molecular potential energy and macroscopic potential energy of a system. [4]
3. Show how saturation curve is formed on P-v diagram by sketching constant temperature process lines. Sketch saturation curve and show all important points, lines and regions. [4]
4. State first law of thermodynamics for a power cycle and a refrigeration cycle. Write down general mass and energy conservation equations for a control volume and reduce them for a steady state process. [2+4]
5. Define entropy. State and explain second law of thermodynamics for an isolated system. [1+5]
6. Derive an expression for compression ratio for an internal combustion engine in terms of cylinder dimensions. Also explain how the thermal efficiency of an air standard otto cycle can be increased with respect to the cylinder dimensions. [6]
7. Derive expressions for overall heat transfer coefficients for a composite cylinder consisting of two layers and subjected to convection medium on outside of the composite cylinder only. [6]
8. A large chamber is separated into two compartments which are maintained at different pressure, as shown in figure below. Pressure gauge A reads 200kPa and pressure gauge B reads 120 kPa. If the barometric pressure is 100 kPa, determine the absolute pressure existing in the compartments and reading of gauge C. [6]



9. Water (1 kg) at 0.2 MPa is initially enclosed within a volume of 0.1 m^3 and the piston rest on stops as shown in figure below. The piston will move when the pressure is 1 MPa. A total heat transfer of 2500 kJ is added to the water. Determine the total work done and draw the P-V and T-V diagram. [8]



10. Air at 100 kPa and 130°C enters an adiabatic diffuser at a rate of 1.5 kg/s and leaves at a pressure of 150 kPa. The velocity of the air is decreased from 250 m/s to 50 m/s as it passes through the diffuser. Determine the exit temperature of the air and exit area of the diffuser. [8]
11. A cold storage is to be maintained at -5°C while the surroundings are at 40°C . The heat leakage from the surroundings into the cold storage is estimated to be 1.35 kW per degree temperature difference. The actual COP of the refrigeration plant is 75% of an ideal plant working between the same temperatures. Find the power required to drive the plant. [8]
12. A steam power plant works on Rankine cycle that operates between boiler pressure of 1.6 MPa and condenser pressure of 600 kPa. Steam leaves the boiler as saturated vapor. The mass flow rate of the steam is 40 kg/s . Determine: [8]
- the pump work and turbine work of the cycle, in kW,
 - the heat transferred to boiler
 - the efficiency of the cycle
 - the efficiency of Carnot cycle working between same temperature limit
13. A hot room wall has made of 40 cm of brick on the outside, 12 cm of plastic foam and finally 2 cm of the fire clay on the inside. The inside and outside temperatures are 590°C and 220°C respectively. If inside and outside heat transfer coefficients are $56 \text{ W/m}^2\text{K}$ and $6 \text{ W/m}^2\text{K}$ and thermal conductivities of brick, foam and fire clay are 0.98 W/mK , 0.02 W/mK and 0.09 W/mK respectively. Determine: [6]
- rate of heat loss from the hot room if the total wall area is 100 m^2 and
 - the temperature at the interface

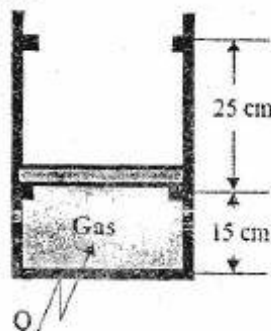
TRIBHUVAN UNIVERSITY
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Examination Control Division
2078 Bharda

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BCE, BGE	BME, Pass Marks	32
Year / Part	I / I	Time	3 hrs.

Subject: - Fundamental of Thermodynamics and Heat Transfer (ME 402)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ Attempt All questions.
- ✓ The figures in the margin indicate Full Marks.
- ✓ Necessary tables are attached herewith.
- ✓ Assume suitable data if necessary.

1. Define a thermodynamic property and thermodynamic state. List two important features of a thermodynamic property. [4]
2. Define work transfer and heat transfer with examples. Also derive a mathematical expression of displacement work for an ideal gas undergoing an adiabatic process. [4]
3. Explain how saturation curve is formed on T-V diagram. [4]
4. Define unsteady state work applications. Derive general mass and energy conservation equations for an open system undergoing a process in which a fluid is being supplied into a piston cylinder device through a valve. [6]
5. Define refrigerator and its COP. Explain how first law and second law of thermodynamics can be applied to analyze the performance of the refrigerator. [6]
6. Derive an expression of thermal efficiency of an ideal Rankine cycle. Sketch P-V and T-S diagrams of the cycle. [6]
7. Define thermal resistance. Write the expression of thermal resistance for plane wall, hollow cylinder and convective layer. Differentiate between free and forced convection with examples. [6]
8. A piston cylinder arrangement as shown in figure below contains gas initially at $P_1 = P_{atm} = 100 \text{ kPa}$ and $T_1 = 20^\circ \text{C}$. The cross sectional area of the piston is 0.01 m^2 and has a mass of 50 kg and is initially resting on the bottom stops. Heat is added to the system until it touches the upper stops. [6]
 - a) Sketch the process on P-V and T-V diagrams.
 - b) Determine the total work transfer.



9. A rigid container with a volume of 0.2 m^3 is initially filled with steam at 200 kPa , 200°C . It is cooled to 100°C . [8]
- At what temperature and pressure does a phase change start to occur?
 - What is the final pressure?
 - What mass fraction of the water is liquid in the final state?
 - Sketch the process on P-V and T-V diagrams.
- [Refer attached table for the properties of steam]
10. Air enters the turbine at 1 MPa and 327°C with a velocity of 100 m/s and exits at 100 kPa and 27°C with low velocity. Heat loss from the turbine surface is 1200 kJ/min and power output of the turbine is 240 kW . For an inlet area of turbine 800 cm^2 , determine the velocity and volumetric flow rate of air at turbine exit. [Take $R = 287 \text{ J/kgK}$ and $C_p = 1005 \text{ J/kgK}$] [8]
11. Air enters a gas turbine at 1 MPa and 1500 K and exists at 100 kPa . If its isentropic efficiency is 80% , determine the turbine exit temperature. (Take $\gamma = 1.4$ and $C_p = 1005 \text{ J/kgK}$) [8]
12. An ideal Otto cycle has a compression ratio of 8. At the beginning of the compression process, air is at pressure 95 kPa and temperature 27°C , and 750 kJ/kg of heat is transferred to air during the heat addition process. Determine:
- pressure and temperature at the end of the heat addition process,
 - the net work output per kg of air and
 - the thermal efficiency of the cycle. [Take $R = 287 \text{ J/kgK}$ and $C_v = 718 \text{ J/kgK}$] [8]
13. The walls of furnace $4 \text{ m} \times 3 \text{ m}$ are constructed from a inner fire brick ($k = 0.4 \text{ W/mK}$) wall 30 cm thick, a layer of ceramic blanket insulation ($k = 0.2 \text{ W/mK}$) 10 cm thick and steel protective layer ($k = 50 \text{ W/mK}$) 4 mm thick. The inside temperature of the fire brick layer was measured as 500°C and the temperature of the outside of the insulation as 50°C . Determine:
- The rate of heat loss through the wall.
 - The temperature at the interface between fire brick layer and insulation layer, and
 - The temperature at the outside surface of the steel layer.
- [6]

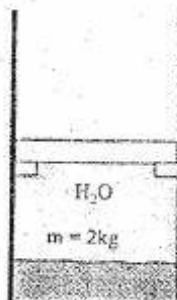
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Exam.	Back		
Level	BE	Full Marks	80
Programme	BCE, BME, BGE	Pass Marks	32
Year / Part	I / I	Time	3 hrs.

Subject: - Fundamental of Thermodynamics and Heat Transfer (ME 402)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ Attempt All questions.
- ✓ The figures in the margin indicate Full Marks.
- ✓ Necessary Tables are attached herewith.
- ✓ Assume suitable data if necessary.
- ✓ Take $C_p = 1005 \text{ J/kgK}$, $R = 287 \text{ J/kgK}$, $\gamma = 1.4$ for air.

1. Explain how you would find out whether a given variable is a thermodynamic property or not. Also differentiate between state function and path function with examples. [4]
2. Define Polytropic process and polytropic index. Find the value of polytropic index for isochoric reduction. [2+2]
3. Define the following terms: [4×1]
 - a) Saturation pressure
 - b) Superheated vapor
 - c) Critical point
 - d) Degree of super heat
4. Explain first law of thermodynamics for a control mass undergoing cyclic process. Write down statements of first law for power cycle and refrigeration cycle. [6]
5. Explain second law of thermodynamics for a control mass with necessary derivations. [6]
6. Explain the working principle of Vapour compression Refrigeration cycle with corresponding processes on P-h and T-S diagram. [6]
7. Derive an expression for radial steady state heat transfer through a composite cylinder with two different materials with a convective layer on the inside only. [6]
8. At the inlet and exhaust of a turbine the absolute steam pressure are 5000kPa and 5.0 cm of Hg, respectively. Barometric pressure is 76cm of Hg. Calculate the gauge pressure for the entering steam and the vacuum gauge pressure for the exhaust steam. [Take $\rho_{\text{Hg}} = 13600 \text{ kg/m}^3$ and $g = 9.81 \text{ m/s}^2$] [6]
9. A piston cylinder device shown in figure below contains 2kg of water with an initial temperature and volume of 80°C and 0.05 m^3 . It requires a pressure of 400kPa to lift the piston from the stops. The system is heated until its temperature reaches 250°C . Sketch the process on P-V diagram and determine the total work transfer. [8]



10. Air at 90kPa, 27°C and 220m/s enters a diffuser at a rate of 4 kg/s and leaves at 42°C. The exit area of the diffuser is 450cm². The air is estimated to lose heat at a rate of 25kJ/s during this process. Determine:
- a) the inlet area of the diffuser
 - b) the exit velocity and
 - c) the exit pressure of the air.
- [8]
11. An air conditioning unit having a COP 65% of the theoretical maximum maintains a house at a temperature of 17°C by cooling it against the surrounding temperature. The house gains energy at a rate of 0.6kW per degree temperature difference. For a maximum work input of 1.8kW, determine the maximum surrounding temperature for which it provides sufficient cooling.
- [8]
12. The following data relate to an air standard Diesel cycle. The pressure and temperature at the end of suction stroke are 100kPa and 30°C respectively. Maximum temperature during the cycle is 1800°C and compression ratio is 16. Determine:
- a) the percentage of stroke at which cut-off takes place
 - b) the temperature at the end of expansion stroke, and
 - c) thermal efficiency.
- [8]
13. A 100mm diameter pipe carrying steam is covered by a layer of insulation ($k=0.06\text{W/mK}$) having a thickness of 50mm. The heat transfer coefficient between the outer surface of insulation and the ambient air is 20W/m²K. Determine the required thickness of another insulating layer ($k=0.1\text{ W/mK}$) that must be added to reduce the heat transfer by 40% assuming that the heat transfer coefficient remains the same.
- [6]

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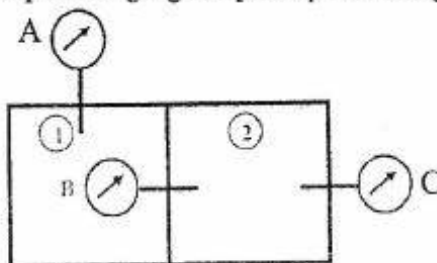
Exam.	Regular		
Level	BE	Full Marks	80
Programme	BCE, BME, BGE	Pass Marks	32
Year / Part	I / I	Time	3 hrs.

Subject: - Fundamental of Thermodynamics and Heat Transfer (ME 402)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ Attempt All questions.
- ✓ The figures in the margin indicate Full Marks.
- ✓ Necessary tables are attached herewith.
- ✓ Assume suitable data if necessary.



1. State and explain equality of temperature. [4]
2. Derive a general expression for the displacement work transfer for a piston cylinder device. Also reduce it for an ideal gas undergoing isothermal process. [4]
3. Define quality and write why it is necessary. Derive an expression for specific volume of a two phase mixture in terms of quality. [4]
4. Write the general mass and energy equation for a control volume operating under unsteady state condition. Derive the mass conservation and energy conservation equation for a process in which gas is supplied to piston cylinder device through a valve and it can produce some work by displacing the piston. [6]
5. Define an isentropic process. Also derive isentropic relations for an ideal gas. [6]
6. Sketch an ideal Otto cycle on P-V and T-S diagrams. Also derive an expression for its efficiency in terms of compression ratio. [6]
7. Derive an expression for steady state heat transfer through a composite cylinder consisting of three layers. [6]
8. Three pressure gauges are connected to a container consisting of two compartments as shown in figure below. If the local barometer reads 760mm of Hg and pressure gauges A and B read 250kPa and 150kPa respectively, determine the absolute pressure in each compartment and reading of pressure gauge C. [Take $\rho=13600 \text{ kg/m}^3$ and $g=9.81 \text{ m/s}^2$]. [6]



9. A closed rigid container of volume 0.5 m^3 is placed on a plate. Initially the container holds two phase mixture of saturated liquid water and saturated water vapor at initial pressure $P_1=100 \text{ kPa}$ with a quality of 50%. After heating, the pressure in the container is $P_2=150 \text{ kPa}$. Draw the P-V and T-V diagrams of the heating process and determine:
 - a) the temperature at each state.
 - b) the mass of the vapor present at each state.
 [Refer the attached table for properties of water] [8]

10. An adiabatic diffuser has air entering at 100kPa, 300K with a velocity of 200m/s. The inlet cross sectional area of the diffuser is 100mm². At the exit, the area is 860 mm² and velocity is 20m/s. Determine the exit temperature and pressure of the air. [Take $c_p=1005$ J/kgK, $R=287$ J/kgK] [8]
11. 2 kg of water at 100°C is mixed with 4kg of water at 20°C in an isolated system. Calculate the neat change in entropy due to the mixing process. [Take specific heat of water, $c=4.18$ kJ/K] [8]
12. Air is used as the working fluid in a simple ideal Brayton cycle that has a pressure ratio of 12, a compressor inlet temperature of 300K, and a turbine inlet temperature of 1000K. Determine the required mass flow rate of air for a net power output of 90MW. Also calculate thermal efficiency of the cycle. [Take $c_p=1005$ J/kgK, $R=287$ J/kgK, $\gamma=1.4$] [8]
13. An exterior wall of a house consists of 10cm of common brick ($K=0.8$ W/mK) followed by a 4cm layer of gypsum plaster ($K=0.5$ W/mK). What thickness of rock wool insulation ($k=0.065$ W/mK) should be added to reduce the heat transfer though the wall by 50%? [6]

Properties of Saturated Water-Pressure Table

P kPa	T °C	v_f m ³ /kg	v_{fg} m ³ /kg	v_g m ³ /kg	u_f kJ/kg	u_{fg} kJ/kg	u_g kJ/kg	h_f kJ/kg	h_{fg} kJ/kg	h_g kJ/kg	s_f kJ/kg.K	s_{fg} kJ/kg.K	s_g kJ/kg.K
100	99.632	0.001043	1.6933	1.6943	417.41	2088.3	2505.7	417.51	2257.6	2675.1	1.3027	6.0562	7.3589
101.32	100.00	0.001043	1.6727	1.6737	418.96	2087.1	2506.1	419.06	2256.6	2675.7	1.3069	6.0476	7.3545
125	105.99	0.001048	1.3742	1.3752	444.25	2068.9	2513.2	444.38	2240.7	2685.1	1.3741	5.9100	7.2841
150	111.38	0.001053	1.1584	1.1595	467.02	2052.4	2519.4	467.18	2226.2	2693.4	1.4338	5.7894	7.2232
175	116.07	0.001057	1.0027	1.0038	486.89	2037.8	2524.7	487.08	2213.3	2700.4	1.4851	5.6866	7.1717
200	120.24	0.001060	0.8848	0.8859	504.59	2024.8	2529.4	504.80	2201.7	2706.5	1.5304	5.5968	7.1272

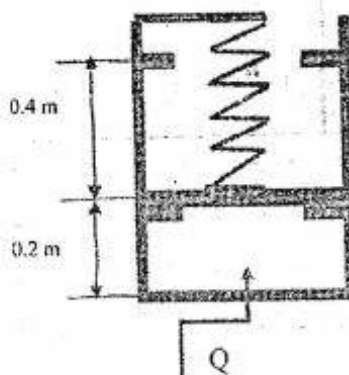
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2076 Ashwin

Exam.	Back		
Level	BE	Full Marks	80
Programme	BME, BCE, BGE	Pass Marks	32
Year / Part	I / I	Time	3 hrs.

Subject: - Fundamental of Thermodynamics and Heat Transfer (ME 402)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ Attempt All questions.
- ✓ The figures in the margin indicate Full Marks.
- ✓ Steam tables are attached herewith.
- ✓ Assume suitable data if necessary.

1. Differentiate between the microscopic and macroscopic view point in thermodynamic with examples. [4]
2. Differentiate between the stored energy and transient energy with examples. [4]
3. Define pure substance. Explain how saturation curve is formed on T-v diagram. [6]
4. Write down general energy equation for a heat exchanger, condenser, compressor, evaporator and throttling valve. [6]
5. Derive an expression for control mass formulation of second law of thermodynamics. [7]
6. Sketch the cycle on P-v and T-s diagrams for an ideal Diesel cycle and derive an expression for its efficiency in terms of compression ratio and cut-off ratio. [6]
7. Differentiate between steady state and unsteady state heat transfer. Derive an expression for steady state heat transfer through a composite cylinder consisting of two different materials. [6]
8. A piston cylinder arrangement with two set of stops is restrained by a linear spring ($k=12 \text{ kN/m}$) as shown in figure below. The initial pressure of the gas is 500 kPa and the pressure required to lift the piston is 1000 kPa. Cross sectional area of the piston is 0.05 m^2 . Heat is supplied to the gas until its pressure reaches 6000 kPa. Sketch the process on P-V diagram and determine the total work transfer. [8]



9. A closed rigid container with a volume of 0.2 m^3 , initially contains a mixture of saturated liquid water and saturated water vapour at a pressure of 100 kPa with a quality of 40%. Heat is added to the system until its pressure reaches 200 kPa. sketch the process on P-v and T-v diagram and determine,
 - a) The temperature at each state.
 - b) The mass of vapour present at each state.
 - c) If the heating is continued, determine the pressure at which the container holds only saturated vapour.

10. Steam enters a nozzle operating at steady state with $P_1 = 10$ bar, $T_1 = 400^\circ\text{C}$ and velocity of 10 m/s. The steam flows through the horizontal adiabatic nozzle. At the exit, $P_2 = 1.5$ bar and the velocity of 1075 m/s. The mass flow rate is 2 kg/s. Determine the exit area of the nozzle. [6]
11. 4kg of water at 25°C is mixed with 1 kg of ice at 0°C in an isolated system. Calculate the change entropy due to mixing process. [Take latent heat of ice $L = 336$ kJ/kg, specific heat of water $C = 4.18$ kJ/kg.k]. [6]
12. An ideal Brayton cycle has a pressure ratio of 12. The pressure and temperature at the compressor inlet are 100 kPa and 27°C respectively. The maximum temperature during the cycle 1200°C . If the mass flow rate is 8 kg/s, determine the power output and efficiency of the cycle. [Take $C_p = 1.005$ kJ/kg.k, $\gamma = 1.4$] [7]
13. A square plate heater ($10\text{ cm} \times 10\text{ cm}$) is inserted between two slabs having the same cross sectional areas. The left slab is 100 mm thick ($k = 50\text{ W/mK}$) and the right slab is 50 mm thick ($k = 0.25\text{ W/mK}$). The heat transfer coefficients for left and right slab outer surface are $250\text{ W/m}^2\text{K}$ and $50\text{ W/m}^2\text{K}$ respectively. The ambient air temperature is 25°C . If the rating of the heater is 1 kW, determine,
a) Temperature at the heater surface
b) Outer surface temperature of each slab [7]

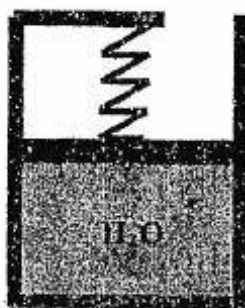
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Exam.	Regular / Back		
Level	BE	Full Marks	80
Programme	BCE, BME, BGE	Pass Marks	32
Year / Part	I / I	Time	3 hrs.

Subject: - Fundamental of Thermodynamics and Heat Transfer (ME 402)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ Attempt All questions.
- ✓ The figures in the margin indicate Full Marks.
- ✓ Steam tables are attached herewith.
- ✓ Assume suitable data if necessary.

1. State and explain zeroth law of thermodynamics. Write down its application. [4]
2. Derive an expression for displacement of work transfer. [5]
3. Define the term saturation curve for two phase mixture, Quality and moisture content. [6]
4. Derive general energy conservation equation for control volume. [6]
5. Define reversible and irreversible process with reference to entropy. [3]
6. Sketch otto cycle on P-v and T-s diagram. Derive expression for its efficiency to relate to compression ratio. [6]
7. Explain mode of heat transfer with their types and specific differences with them. [6]
8. During operation of a lift, it can be subjected to a maximum gauge pressure of 500 kPa. If it is designed to lift a mass upto 900 kg, what should be diameter of piston-cylinder? [6]
9. A piston cylinder device with a linear spring initially contains water at a pressure of 4 MPa and 500°C with the initial volume being 0.1 m³, as shown in figure below. If the piston is at the bottom, the system pressure is 300 kPa. The system now cools until the pressure reaches 1000 kPa. Sketch the process on P-v diagram and determine [8]
 - a) the mass of H₂O
 - b) the final temperature and volume, and
 - c) the total work transfer



10. Air expands through an adiabatic turbine from 1100 kPa, 1000 K to 100 kPa, 100 K. The inlet velocity is 10 m/s and exit velocity is 100 m/s. The power output of turbine is 3600 kW. Determine mass flow rate of air and inlet and exit areas. [Take $r = 287 \text{ J/KgK}$, $C_p = 1005 \text{ J/KgK}$] [8]
11. Steam enters into a turbine at 2 MPa, 400°C with a velocity 200 m/sec and saturated vapour exits from turbine at 100 kPa with velocity 80 m/s. The power output of turbine is 800 kW, when mass flow rate is 1.5 kg/sec. Turbine rejects heat to surrounding at 300K. Determine rate at which entropy is generated within the turbine. [8]

{ $h_1 = 3247.5 \text{ kJ/kg}$, $s_1 = 7.1269 \text{ kJ/kg}$ }
12. An air standard diesel cycle has a compression ratio of 22 and expansion ratio of 11. Determine its cut off ratio and the efficiency. [6]
13. A hollow cylinder with inner and outer diameter of 8 cm and 12 cm respectively has an inner surface temperature of 200°C and the outer surface temperature of 50°C. If the thermal conductivity of the cylinder material is 60 W/mK, determine heat transfer from the unit length of the pipe. Also determine the temperature at the surface at a radial distance of 5 cm from the axis of the cylinder.

Exam.	BE	Back	
Level	BE	Full Marks	80
Programme	BCE, BME, BGE	Pass Marks	32
Year / Part	1 / 1	Time	3 hrs.

Subject: - Fundamentals of Thermodynamics and Heat Transfer (ME402)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ Attempt All questions.
- ✓ The figures in the margin indicate Full Marks.
- ✓ Necessary tables are attached herewith.
- ✓ Assume suitable data if necessary.

1. Define thermodynamic property. Explain intensive and extensive property with examples. [4]
2. Define polytropic process. Sketch polytropic processes with $n = 0, 1, \gamma$ and ∞ on a common P-V diagram. Derive an expression for work transfer for a polytropic process. [4]
3. Derive an expression for the specific volume of a two phase mixture in term of quality. Which takes more energy to vaporize 1 kg of saturated liquid water at 100°C or 120°C? Why? [4]
4. Define a cyclic process. Derive first-law of thermodynamics for a control mass undergoing a cyclic process. Also write down the statements for a power cycle and refrigeration cycle. [6]
5. Define heat engine, heat pump and refrigerator. Explain how first and second law are applied to determine performance of heat engine. [6]
6. Explain the working principle of a Brayton cycle. Sketch the cycle on p-v and T-s diagrams and explain the variation of its efficiency with pressure ratio. [6]
7. Derive the overall heat transfer coefficient for composite for plane wall consisting of two layers with convection on both sides. [6]
8. A piston-cylinder device contains 0.05 m³ of a gas initially at 200 kPa. At this state, a linear spring that has a spring constant of 150 kN/m is touching the piston but exerting no force on it. Now heat is transferred to the gas, causing the piston to rise and to compress the spring until the volume inside the cylinder doubles. If the cross-sectional area of the piston is 0.25 m², determine: [6]
 - i) The final pressure inside the cylinder
 - ii) The total work done by the gas
9. A piston cylinder device shown in figure below contain 2 kg of H₂O with an initial temperature and volume of 80°C and 0.05 m³ respectively. It requires a pressure of 400 kPa to lift the piston from the stops. The system is heated until its temperature reaches 250°C. Sketch the process on P-v and T-v diagrams and determine the total work transfer. [8]



10. Air flows at a rate of 1.2 kg/s through a compressor, entering at 100 kPa, 25°C, with a velocity of 60 m/s and leaving at 500 kPa, 150°C, with a velocity of 120 m/s. Heat lost by the compressor to the surrounding is estimated to be 20 kJ/kg. Calculate the power required to drive the compressor and diameters to inlet and exhaust pipes. [8]
[Take $R = 287 \text{ J/kgK}$ and $c_p = 1005 \text{ J/kgK}$]
11. Five kg of water at 30°C is mixed with 1 Kg of ice at 0°C. Assuming the process of mixing is adiabatic, find the change in entropy. Latent heat of ice = 336 kJ/kg, C_p for water = 4.2 kJ/kgK. [8]
12. In a Rankine cycle steam leaves the boiler and enters the turbine at 4 MPa, 400°C. The condenser pressure is 10 kPa. Determine the cycle efficiency. [8]
13. A steel pipe having an outer diameter of 4 cm is maintained at a temperature of 80°C in a room where the ambient temperature is 25°C. The emissivity of the surface is 0.8 and the convection heat transfer coefficient between the surface and air is 10 W/m²K. Determine the total heat loss from the unit length of the pipe. [Take $\sigma = 5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4$] [6]

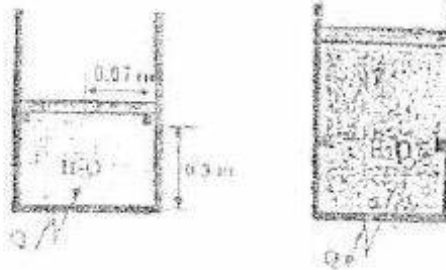
Exam.	Back		
Level	BE	Full Marks	80
Programme	BCE, BME, BGE	Pass Marks	32
Year / Part	1 / I	Time	3 hrs.

Subject: - Fundamental of Thermodynamics and Heat Transfer (ME402)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ Attempt All questions.
- ✓ The figures in the margin indicate Full Marks.
- ✓ Necessary figures and tables are attached herewith.
- ✓ Assume suitable data if necessary.

1. Define thermodynamic equilibrium. Explain reversible and irreversible processes with reference nature of intermediate states. [4]
2. Define internal energy, potential energy, kinetic energy and total energy of a thermodynamic system. Also differentiate between microscopic potential energy and macroscopic potential energy. [4]
3. Define saturation pressure, saturation temperature and critical point. Write down the effect of pressure on
 - a) Specific volume of a saturated liquid (V_l)
 - b) Specific volume of a saturated vapor (V_g)
 - c) Change in specific volume due to evaporation (V_{lg})
 [4]
4. State and explain conservation of energy for a control volume. [6]
5. Differentiate between thermal and mechanical irreversibilities. Explain why most of the real processes are irreversible. Also explain how they can be assumed to be reversible. [6]
6. Explain with the help of neat diagrams the various processes of any Rankine cycle and derive an expression for its efficiency. [6]
7. Derive an expression with appropriate diagram for conduction heat transfer through a composite cylinder tube consisting of three layers of different materials. [6]
8. A piston cylinder has a diameter of 0.1 m. With an outside atmospheric pressure of 100 kPa, determine the piston mass that will create an inside pressure of 500 kPa. What would be the new pressure if the piston mass is halves. [Take $g = 9.81 \text{ m/s}^2$] [6]
9. Steam is contained in a closed rigid container. Initially, the pressure and temperature of the steam are 1500 kPa and 250°C, respectively. The temperature drops as a result of heat transfer to the surroundings. Determine the pressure at which condensation first occurs and the fraction of the total mass that gas been condensed when the temperature reaches 100°C. What percentage of the volume is occupied by saturated liquid at the final state? [8]
10. A piston cylinder devices shown in figure below contains water initially at 105°C with quality 10%. Heat is added to the system until it becomes saturated vapor. It takes pressure of 1000 kPa to lift the piston from the stops. Sketch the P-v, T-v diagram and determine: [8]
 - a) The mass of water in system
 - b) The total work transfer

c) The total heat transfer [Refer the attached table for properties of water]



11. 2 kg water at 100°C is mixed with 4 kg of water at 20°C in an isolated system. Calculate the net change in entropy due to the mixing process. [Take specific heat of water $c = 4.18 \text{ kJ/K}$] [8]
12. An ideal Brayton cycle has pressure ratio of 10. The temperature of air at compressor and turbine inlets are 300K and 1200K respectively. Determine its thermal efficiency and mass flow rate of air required to produce net power output of 80MW . [Take $C_p = 1005 \text{ J/Kg.K}$, $\gamma = 1.4$] [8]
13. A 200 mm diameter 50 m long pipe carrying steam is covered with 40 mm thick of high temperature insulation ($k = 0.1 \text{ W/m}$) and 30 mm thick of low temperature insulation ($k = 0.05 \text{ W/m}$). The inner and outer surfaces of the insulating layer are at 400°C and 40°C respectively. Determine:
 - a) The rate of heat loss from the pipe,
 - b) The temperature at the interface of two insulating layer.

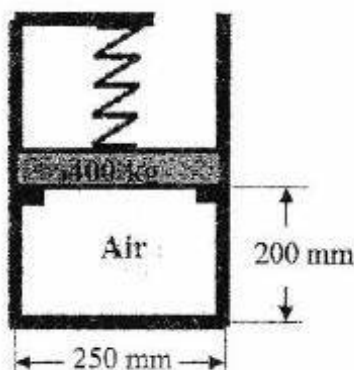
[6]

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BCE, BME, BGE	Pass Marks	32
Year / Part	1 / I	Time	3 hrs.

Subject: - Fundamentals of Thermodynamics and Heat Transfer (ME402)

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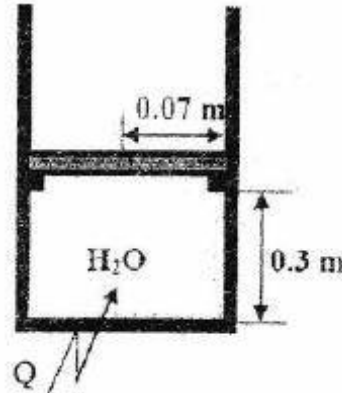
1. State and explain Zeroth law of thermodynamics. Also write down its application. [4]
2. Compare heat and work with suitable examples. Prove that work is a path function. [4]
3. Define pure substance. Explain why quality is necessary to define the state of a two phase mixture. [4]
4. Differentiate between steady state work applications and steady state flow applications. Write down the function of turbine and nozzle. Derive governing equations for them when they operate under steady state condition. [6]
5. State second law of thermodynamics for an isolated system and define entropy generation. Differentiate between reversible and irreversible processes with reference to entropy. [6]
6. Explain the working of simple vapor compression refrigeration cycle with corresponding process in P-h and T-s diagram. [6]
7. Derive an expression for steady state heat transfer through a composite cylinder consisting three different materials. [6]
8. Air (0.01 kg) is contained in a piston cylinder device restrained by a linear spring ($k = 500 \text{ kN/m}$) as shown in figure below. Spring initially touches the piston but exerts no force on it. Determine the temperature at which piston leaves the stops when heat is supplied to the system. [Take $R = 287 \text{ J/kg} \cdot \text{K}$, $P_{\text{atm}} = 100 \text{ kPa}$ and $g = 9.81 \text{ m/s}^2$] [6]



9. A piston cylinder device shown in figure below contains water initially at a pressure of 125 kPa with a quality of 50%. Heat is added to the system until it reaches to a final temperature of 800°C. It takes a pressure of 600 kPa to lift the piston from the stops. Sketch the process on P-V and T-V diagrams and determine:

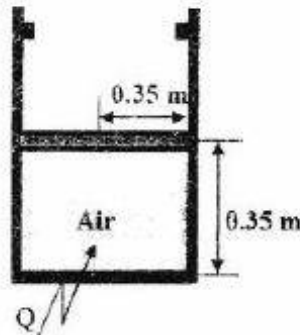
[8]

- The mass of H_2O in the system and
- The total work transfer



10. A piston cylinder device shown in figure below contains 3.06 kg of air initially at a temperature of 34°C. Heat is supplied to the system until it reached to a final temperature of 950°C and a final pressure of 5 MPa. Sketch the process on P-V and T-V diagrams and determine the total work transfer and total heat transfer. [Take $R = 287 \text{ J/kgK}$ and $c_v = 718 \text{ J/kgK}$]

[8]



11. A piston cylinder device shown in figure below contains 1.5 kg of water initially at 100 kPa with 10% of quality. The mass of the piston is such that a pressure of 400 kPa is required to lift the piston. Heat is added to the system from a source at 500°C until its temperature reaches 400°C. Sketch the process on p-V and T-V diagrams and determine the total entropy generation during the process.

[8]



P.T.O

12. The compression ratio of an air standard Otto cycle is 8. At the beginning of the compression process, the pressure and temperature of air are 100 kPa and 20°C respectively. The heat added per kg of air during the cycle is 2000 kJ/kg. Determine:

[8]

- i) The pressure and temperature at the end of each process of the cycle
- ii) The thermal efficiency
- iii) The mean effective pressure

[Take $R = 287 \text{ J/kg}\cdot\text{K}$ and $c_v = 718 \text{ J/kg}\cdot\text{K}$]

13. A gas turbine blade is modeled as a flat plate. The thermal conductivity of the blade material is $15 \text{ W/m}\cdot\text{K}$ and its thickness is 1.5 mm . The upper surface of the blade is exposed to hot gases at 1000°C and the lower surface is cooled by air bled from the compressor. The heat transfer coefficients at the upper and lower surfaces of the blade are $2500 \text{ W/m}^2\cdot\text{K}$ and $1500 \text{ W/m}^2\cdot\text{K}$ respectively. Under steady state conditions, the temperature at the upper surface of the blade is measured as 850°C , determine the temperature of the coolant air.

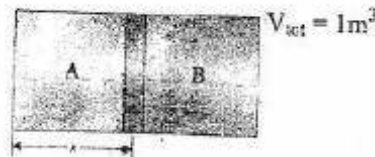
[6]

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BCE, BME, BGE	Pass Marks	32
Year / Part	I / I	Time	3 hrs.

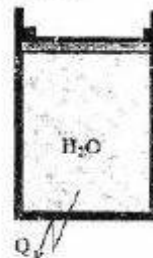
Subject: - Fundamental of Thermodynamics and Heat Transfer (ME402)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ Attempt All questions.
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1. Define macroscopic and microscopic viewpoint as applied to the study of thermodynamics. Also list their features. [4]
2. Define stored energy and transient energy. Also list their features. [4]
3. Define quality. Explain why it is necessary to define the state of two phase mixture. Also derive an expression for specific volume of a two-phase mixture. [4]
4. Differentiate between steady state and unsteady state control volume. Derive mass and energy conservation equation for a process in which gas is being supplied to a rigid cylinder. [6]
5. Write down the similarities and differences between heat pump and refrigerator. Explain how first and second laws can be applied to analyze the performance of a heat pump. [6]
6. Sketch ideal Vapour compression refrigeration cycle and explain the processes on P-h and t-s diagram. Also write an expression for theoretical COP of the cycle used as heat pump. [6]
7. Differentiate between free and forced convection with examples. Write down the expressions for thermal resistance for a plane wall, a hollow cylinder and convective layer of fluid. [6]
8. The device shown in figure below has a free moving piston between the two chambers. The initial total volumes of A and B are equal with $v_A = 100 \text{ m}^3/\text{kg}$ and $v_B = 50 \text{ m}^3/\text{kg}$. If the piston is moved so that x is one-fourth of the entire length, determine the final specific volumes of chambers A and B. [6]



9. A piston cylinder arrangement shown in figure below contains 1 kg of water initially at a pressure of 1 MPa and a temperature of 500°C . The water is cooled until it is completely converted into saturated liquid. It requires a pressure of 400 kPa to support the piston. Sketch the process on P-v and T-v diagrams and determine the total work transfer. (Refer the attached table for the properties of water) [8]



10. Steam at 0.4 MPa and 200°C enters into an adiabatic nozzle with a velocity of 50 m/s and leaves the nozzle at 0.1 MPa and with a velocity of 75 m/s. Determine [8]
- The exit temperature of the steam.
 - The ratio of inlet diameter to the exit diameter. (Refer the attached table for the properties of steam)
11. Work output of an ideal engine is 4 times the heat rejected by it. Determine its efficiency. If the sink temperature increases by 300°C, its efficiency reduces to 60%. Determine its source and sink temperatures. [8]
12. An air standard Otto cycle has a compression ratio of 10. At the beginning of the compression stroke, the pressure and temperature are 100 kPa and 20°C respectively. The peak temperature during the cycle is 2000 K. Determine,
- The pressure and temperature at the end of each process of the cycle
 - The thermal efficiency (Take $C_v = 718 \text{ J/kgK}$, $\gamma = 1.4$) [8]
13. A thick walled tube of stainless steel ($k = 19 \text{ W/m}^\circ\text{C}$) with 2 cm inside diameter and 4 cm outer diameter is covered with a 3 cm layer of asbestos insulation ($k = 0.2 \text{ W/m}^\circ\text{C}$). If the inside and outside wall temperature of the pipe is maintained at 600°C and 100°C. Calculate the heat loss per meter of length. Also calculate the tube-insulation interface temperature. [6]

Exam.	New Back (2066 & Later Batch)		
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1. Define thermodynamic property. Differentiate between state function and path function with examples. [4]
2. Define total energy. Differentiate between stored energy and transient energy with examples. [4]
3. Define quality and write why it is necessary. Sketch saturation curve on P-V diagram and also show constant quality lines. [4]
4. Differentiate between steady state work application and unsteady state flow applications. Derive mass conservation and energy conservation equations for a process in which gas contained in a rigid cylinder is being consumed during cooking. [6]
5. Define Entropy. Derive an expression for change in Entropy for reversible heat transfer and reversible work transfer process. [6]
6. Differentiate between gas and vapor cycles. Sketch P-V and T-S diagrams and layout for Brayton and Rankine cycle. [6]
7. Write down expressions for thermal resistance for a plane wall and a convective fluid layer. Use them to derive overall heat transfer coefficient for a plane subjected convection on both sides. [6]
8. An oxygen cylinder having a volume of 10 m^3 initially contains 5 kg of oxygen. Determine the specific volume of oxygen in the cylinder initially. During certain process 3 kg of oxygen is consumed. Determine the final specific volume of oxygen in the cylinder. Also sketch the amount of oxygen that has been consumed versus the specific volume of the remaining in the cylinder. [6]
9. A piston cylinder device shown in Figure P.9 contains 2 kg of water initially at a pressure of 500 kPa with a quality of 20 %. The water is heated until it becomes a saturated vapor. The volume of the system when the piston is at the upper stops is 0.4 m^3 . Sketch the process on P-v and T-v diagrams and determine: [8]
 - (a) the final pressure, and
 - (b) the total work transfer. [Refer the attached tables for the properties of steam]



Figure P.9

10. Air enters a nozzle steadily at 300 kPa, 127°C and with a velocity of 40 m/s and leaves at 100 kPa and with a velocity of 300 m/s. The heat loss from the nozzle surface is 20 kJ/kg of the air. The inlet area of the nozzle is 100 cm². Determine: [8]
- (a) the exit temperature of the air, and
(b) the exit area of the nozzle. [Take $R = 287 \text{ J/kgK}$ and $c_p = 1005 \text{ J/kgK}$]
11. A Carnot engine operates between two reservoirs at temperature T_L and T_H . The work output of the engine is 0.6 times the heat rejected. The difference in temperature between the sources and the sink is 200°C. Calculate the thermal efficiency, source temperature and the sink temperature. [8]
12. An ideal gas turbine cycle has a pressure ratio of 10. The minimum and maximum temperatures are 300 K and 1500 K respectively. Determine: [8]
- i) The net work per kg of air
ii) The thermal efficiency of the cycle and
iii) Compare both of these for a cycle with ideal compressor and turbine.
[Take $\gamma = 1.4$ and $c_p = 1005 \text{ J/kg.k}$]
13. A steel pipe having an outside diameter of 2 cm is to be covered with two layers of insulation, each having a thickness of 1 cm. The average conductivity of one material is 5 times that of the other. Assuming that the inner and outer surface temperature of the composite insulation are fixed, calculate by what percentage the heat transfer will be reduced when the better insulating material is nearer to the pipe than it is away from the pipe. [6]

TABLE 1.1 Properties of SATURATED WATER – Pressure Table

P kPa	T °C	v_f m ³ /kg	v_g m ³ /kg	v_{fg} m ³ /kg	u_f kJ/kg	u_g kJ/kg	u_{fg} kJ/kg	h_f kJ/kg	h_g kJ/kg	h_{fg} kJ/kg	s_f kJ/kg.K	s_g kJ/kg.K	s_{fg} kJ/kg.K
400	143.64	0.001084	0.4614	0.4625	604.47	1949.0	2553.5	604.91	2133.6	2738.5	1.7770	5.1191	6.8961
425	145.83	0.001085	0.4557	0.4578	605.81	1942.2	2555.5	606.27	2126.9	2741.3	1.7796	5.1062	6.8858
450	148.04	0.001087	0.4499	0.4486	607.16	1934.7	2557.6	607.67	2120.3	2742.7	1.7821	5.0936	6.8757
475	150.24	0.001090	0.4441	0.4451	608.56	1927.3	2559.4	609.17	2113.7	2744.5	1.7845	5.0811	6.8656
500	152.43	0.001093	0.4383	0.4379	609.96	1920.4	2561.2	610.73	2107.2	2746.6	1.7869	5.0687	6.8557
550	156.09	0.001097	0.4315	0.4316	613.48	1908.9	2561.9	613.68	2100.6	2748.9	1.7917	5.0517	6.8464
600	158.86	0.001101	0.4145	0.4156	620.05	1897.3	2567.3	620.71	2086.0	2756.7	1.9315	4.8286	6.7601
650	162.02	0.001104	0.2915	0.2926	683.71	1886.2	2569.9	684.42	2075.8	2760.2	1.9631	4.7699	6.7330
700	164.98	0.001108	0.2717	0.2728	696.58	1875.8	2572.4	697.35	2066.0	2763.3	1.9925	4.7154	6.7079
750	167.79	0.001111	0.2544	0.2555	708.76	1865.8	2574.6	709.59	2056.6	2766.2	2.0203	4.6642	6.6845
800	170.44	0.001115	0.2393	0.2404	720.33	1856.3	2576.6	721.23	2047.7	2768.9	2.0464	4.6161	6.6625
850	172.97	0.001119	0.2258	0.2279	731.17	1847.4	2578.3	732.17	2039.1	2771.5	2.0712	4.5707	6.6419
900	175.39	0.001123	0.2138	0.2149	741.29	1839.0	2579.7	742.39	2030.7	2773.7	2.0948	4.5277	6.6229
950	177.70	0.001127	0.2030	0.2041	750.72	1831.3	2580.7	752.80	2022.5	2775.7	2.1177	4.4867	6.6056
1000	179.92	0.001131	0.1933	0.1944	759.59	1824.3	2581.3	762.43	2014.5	2777.7	2.1398	4.4474	6.5899
1100	184.13	0.001143	0.1763	0.1775	780.14	1810.7	2580.0	781.38	2002.8	2784.2	2.1791	4.3716	6.5527

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1. Explain different types of thermodynamic systems with examples. [4]
2. Differentiate between heat transfer and work transfer. Derive the mathematical expression for work transfer for an ideal gas undergoing isothermal process. [4]
3. Define quality and moisture content. Derive an expression for specific volume of a two phase mixture in terms of quality. [4]
4. Differentiate between steady state work applications and steady state flow applications with examples. Also write the functions and governing equations for an adiabatic turbine and adiabatic nozzle. [6]
5. Define heat engine and heat pump. Explain how first law and second law of thermodynamics can be applied to analyze the performance of a heat pump. [6]
6. Sketch an ideal otto cycle on P-v and T-s diagram. Derive the expression for compression ratio in terms of cylinder dimension. [6]
7. Derive an expression for overall heat transfer coefficient for a hollow cylinder subjected to convection medium on both sides. [6]
8. Three pressure gauges are connected to a container consisting of two compartments as shown in figure below. If the local barometer reads 760 mm of Hg and pressure gauges A and B read 250 kPa and 150 kPa respectively. Determine the absolute pressure in each compartment and reading of pressure gauge C. [Take $\rho_{Hg} = 13600 \text{ kg/m}^3$ and $g = 9.81 \text{ m/s}^2$] [6]

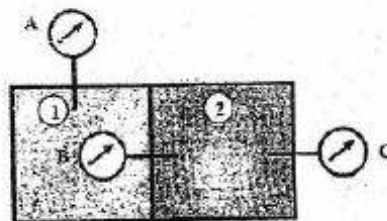


Figure P1

9. A rigid vessel having a volume of 0.4 m^3 contains 2.0 kg of liquid water and water vapor mixture in equilibrium at a pressure of 250 kPa . Calculate: [8]
 - i) The volume and mass of liquid
 - ii) The volume and mass of vapour
 - iii) Temperature
 - iv) Enthalpy
 - v) If it is heated until its pressure reached to 350 kPa , what will be its quality?

[Refer the attached table for properties of water]

10. Air enters a compressor operating at steady state at 100 kPa, 300 K and leaves at 1000 kPa, 400 K. The volumetric flow rate of air at the exit is 1.5 m³/min. The work consumed by the compressor is 250 kJ per kg of air. Neglecting the effects of potential and kinetic energy, determine the heat transfer rate, in kW. [Take $R = 287 \text{ J/kgK}$ and $C_p = 1005 \text{ J/kgK}$]

[8]

11. A heat pump heats a house in the winter and then reverses to cool it in the summer. The room temperature should be 22°C in the winter and 26°C in the summer. Heat transfer through the walls and ceilings is estimated to be 3000 kJ/h per degree temperature difference between the inside and outside.

[8]

- Determine the power required to run it in the winter which when the outside temperature decrease to 0°C.
- If the unit is run by the same power as calculate in (i) throughout the year, determine the maximum outside summer temperature for which the house can be maintained at 26°C

12. Air enters the compressor of an ideal Brayton cycle at 100 kPa, 290 K with a volumetric flow rate of 4 m³/s. The pressure ratio for cycle is 10 and the maximum temperature during the cycle is 1500 K. Determine:

[8]

- The thermal efficiency of the cycle
- The fraction of work output that is consumed by the compressor and
- The net power output

[Take $C_p = 1005 \text{ J/kg.K}$, $\gamma = 1.4$]

13. A 2 m long steel plate ($k = 50 \text{ W/mK}$) is well insulated on its sides, while its left section is maintained at 120°C and the right section is exposed to ambient air at 40°C. Under steady state conditions, a thermocouple inserted at the middle of the plate gives a temperature of 100°C. Determine the value of convection heat transfer coefficient for convection heat transfer between the right section of the plate and air.

[6]

Properties of SATURATED WATER - Pressure Table

P [*] kPa	T °C	v _f m ³ /kg	v _g m ³ /kg	v _{fg} m ³ /kg	u _f kJ/kg	u _g kJ/kg	u _{fg} kJ/kg	h _f kJ/kg	h _g kJ/kg	h _{fg} kJ/kg	s _f kJ/kg.K	s _g kJ/kg.K	s _{fg} kJ/kg.K
25	64.980	0.001020	6.2038	6.2048	271.97	2190.3	2462.3	271.99	2345.4	2617.4	0.8933	6.9365	7.8298
30	69.114	0.001022	5.2288	5.2298	289.27	2178.4	2467.7	289.30	2335.3	2624.6	0.9441	6.8231	7.7672
35	72.700	0.001024	4.5252	4.5262	304.28	2168.0	2472.3	304.32	2326.4	2630.7	0.9878	6.7266	7.7144
40	75.877	0.001026	3.9930	3.9940	317.59	2158.8	2476.4	317.64	2318.5	2636.1	1.0261	6.6427	7.6688
45	78.736	0.001028	3.5789	3.5799	329.58	2150.3	2480.0	329.62	2311.3	2640.9	1.0603	6.5684	7.6287
50	81.339	0.001030	3.2398	3.2408	340.49	2142.8	2483.3	340.54	2304.8	2645.3	1.0912	6.5016	7.5928
55	83.699	0.001033	2.9714	2.9724	350.84	2135.2	2486.0	350.90	2298.1	2653.0	1.1193	6.4385	7.5610
60	85.956	0.001035	2.7714	2.7724	359.84	2129.2	2489.0	359.90	2293.1	2659.6	1.1450	6.3855	7.5310
65	88.096	0.001036	2.6444	2.6454	367.68	2124.3	2494.0	367.75	2288.7	2665.6	1.1686	6.3389	7.5029
70	89.956	0.001038	2.5866	2.5876	374.63	2119.7	2498.3	374.71	2284.6	2669.3	1.1903	6.2969	7.4789
75	91.581	0.001041	1.8688	1.8698	405.11	2097.1	2502.2	405.20	2265.3	2670.5	1.2696	6.1247	7.3943
80	96.713	0.001043	1.6933	1.6943	417.41	2088.3	2505.7	417.51	2257.6	2675.1	1.3027	6.0562	7.3589
90	99.632	0.001043	1.6727	1.6737	418.96	2087.1	2506.1	419.06	2256.6	2675.7	1.3069	6.0476	7.3545
100	100.00	0.001043	1.6727	1.6737	418.96	2087.1	2506.1	419.06	2256.6	2675.7	1.3069	6.0476	7.3545
101.32	100.00	0.001043	1.6727	1.6737	418.96	2087.1	2506.1	419.06	2256.6	2675.7	1.3069	6.0476	7.3545
125	105.99	0.001048	1.3742	1.3752	444.25	2068.9	2513.2	444.38	2240.7	2685.1	1.3741	5.9100	7.2841
150	111.38	0.001053	1.1584	1.1595	467.02	2052.4	2519.4	467.18	2226.2	2693.4	1.4338	5.7894	7.2232
175	116.07	0.001057	1.0027	1.0038	486.89	2037.8	2524.7	487.08	2213.3	2700.4	1.4851	5.6866	7.1717
200	120.24	0.001060	0.8848	0.8859	504.59	2024.8	2529.4	504.80	2201.7	2706.5	1.5304	5.5968	7.1272
225	124.01	0.001064	0.7923	0.7934	520.39	2012.9	2533.3	520.83	2191.2	2712.0	1.5708	5.5172	7.0880
250	127.44	0.001067	0.7177	0.7188	535.22	2001.9	2537.1	535.49	2181.3	2716.8	1.6075	5.4454	7.0529
275	130.61	0.001070	0.6553	0.6564	548.93	1991.8	2540.5	549.02	2172.3	2721.3	1.6413	5.3800	7.0211
300	133.56	0.001073	0.6048	0.6059	561.29	1982.2	2543.5	561.61	2163.7	2725.3	1.6721	5.3200	6.9921
325	136.31	0.001076	0.5609	0.5620	573.04	1973.3	2546.3	573.39	2155.6	2729.0	1.7009	5.2645	6.9654
350	138.89	0.001079	0.5232	0.5243	584.10	1964.8	2548.9	584.48	2147.9	2732.4	1.7278	5.2129	6.9407
375	141.33	0.001081	0.4903	0.4914	594.56	1956.7	2551.3	594.96	2140.6	2735.6	1.7531	5.1646	6.9177

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BCE, BME, BGE	Pass Marks	32
Year / Part	I / I	Time	3 hrs.

Subject: - Fundamental of Thermodynamics and Heat Transfer (ME402)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ Attempt All questions.
- ✓ The figures in the margin indicate Full Marks.
- ✓ Necessary tables are attached herewith.
- ✓ Assume suitable data if necessary.

1. Sketch P-V, T-V and P-T diagrams for an ideal gas undergoing
 - i) Constant volume cooling process
 - ii) Constant temperature heat rejection process[4]
2. Differentiate between heat transfer and work transfer. Derive the mathematical expression for work transfer for an isobaric process. [4]
3. Define pure substance. State two property rules and give examples. [4]
4. Write down general mass conservation and energy conservation equations for a control volume. Also reduce them for a control volume operating under unsteady state condition. [6]
5. Define refrigerator and its COP. Explain how first law and second law of thermodynamics can be applied to analyze the performance of the refrigerator. [2+4]
6. Differentiate between power cycle and refrigeration cycle. Sketch P-V and T-S diagram for ideal otto and ideal diesel cycles. Also write down the expressions for their efficiencies. [6]
7. Write down the expression for thermal resistance for a hollow cylinder and connective fluid layer. Use them to derive overall heat transfer coefficient for a hollow cylinder subjected to convection of both sides. [6]
8. A piston-cylinder device shown in **Figure P.8** contains 0.05 m^3 of a gas initially at 200 kPa. At this state, a linear spring that has a spring constant of 150 kN/m is touching the piston but exerting no force on it. Now heat is transferred to the gas, causing the piston to rise and to compress the spring until the volume inside the cylinder triples. If the cross-sectional area of the piston is 0.25 m^2 , determine the final pressure inside the cylinder. [6]



Figure P.8

9. A rigid container with a volume of 0.170 m^3 is initially filled with steam at 200 kPa , 300°C . It is cooled to 90°C . [8]
- At what temperature does a phase change start to occur?
 - What is the final pressure?
 - What mass fraction of the water is liquid in the final state? [Refer the attached tables for the properties of steam]

10. Nitrogen (5 kg) is contained in a piston cylinder device shown in Figure P.10 initially at a pressure of 800 kPa and a temperature of 127°C . There is a heat transfer to the system until the temperature reaches to 527°C . It takes a pressure of 1500 kPa to lift the piston. Sketch the process on $P - V$ and $T - V$ diagrams and determine the total work and heat transfer in the process. [Take $R = 297 \text{ J/kgK}$ and $c_v = 743 \text{ J/kgK}$] [8]



Figure P.10

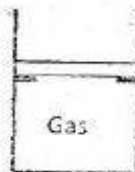
- A heat pump having a COP of 5 maintains a building at a temperature of 24°C by supplying heat at a rate of 72000 KJ/h when the surrounding is at 0°C . The heat pump runs 12 hrs in a day and the electricity costs Rs 10/Kwh. [8]
 - Determine the actual and minimum theoretical cost per day.
 - Compare the actual operating cost with the cost of direct electric resistance heating.
- The pressure and temperature at the end of suction stroke are 100 kPa and 27°C respectively. Maximum temperature during the cycle is 1600°C and the compression ratio is 16. Determine: [8]
 - The percentage of stroke at which cut-off takes place
 - The temperature at the end of the expansion stroke and
 - The thermal efficiency [Take $\gamma = 1.4$ and $R = 287 \text{ J/kg.K}$]
- The heat flux at the surface of an electrical heater is 3500 W/m^2 . The heater surface temperature is 120°C when it is cooled by air at 50°C . What is the average convective heat transfer coefficient? What will be the heater temperature be if the power is reduced so that heat flux is 2500 W/m^2 ? [6]

Exam.	New Batch 2066 & Later Batch		
Level	BE	Full Marks	80
Programme	BCE, BME, BGE	Pass Marks	32
Year / Part	1 / 1	Time	3 hrs.

Subject: - Fundamental of Thermodynamics and Heat Transfer (ME402)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ Attempt All questions.
- ✓ The figures in the margin indicate Full Marks.
- ✓ Necessary figures are attached herewith.
- ✓ Assume suitable data if necessary.

1. Differentiate between the microscopic and macroscopic view point in thermodynamics with example. [4]
2. Define energy and power. Differentiate between stored and transient energy with examples. [4]
3. Define moisture content and critical point. Derive an expression for specific volume of a two phase (liquid and vapor) mixture in terms of quality. [4]
4. Differentiate between steady state work application and steady state flow application. Write down mass and energy conservation equation of steady state process. Reduce them for a nozzle and a condenser. [6]
5. Explain entropy. Derive the relations for entropy for an ideal gas and an incompressible substance. [6]
6. Sketch Rankine cycle on P-v and T-s diagram using dry saturated steam and obtain an expression for the Rankine cycle efficiency. [6]
7. Define thermal resistance. Derive an expression for heat transfer through composite plane wall of three different layers of different materials using electric analogues approach. [6]
8. A piston cylinder arrangement shown in figure below has cross sectional area of 0.01 m^2 and a piston mass of 80 kg . If the atmospheric pressure is 1 bar , what should be the gas pressure to lift the piston? If 50 kg mass is added above the piston, what would be the new pressure? [6]



9. A piston cylinder device with a linear spring initially contains water at a pressure of 4 MPa and 500°C with the initial volume being 0.1 m^3 , as shown in figure below. The system now cools until the pressure reaches 1000 kPa . If the piston is at the bottom, the system pressure is 300 kPa . Sketch the process on P-v diagram and determine the mass of H_2O , the final temperature and volume and the total work transfer. [Refer the attached table for properties of steam] [8]



10. A perfect gas flows through a nozzle where it expands in a reversible adiabatic manner. The inlet conditions are 22 bar, 500°C and 36 m/s at the exit the pressure is 2 bar. Determine the exit velocity and exit area if the flow rate is 4 kg/s. Take $R = 190 \text{ J/Kg K}$ and $\gamma = 1.35$. [1]

11. A house is to be maintained at 25°C in summer as well as winter. For this purpose, it is proposed to use a reversible device as a refrigerator in summer and a heat pump in winter. The ambient temperature is 40°C in summer and 3°C in winter. The energy losses as heat from the roof and the walls are estimated as 5 kW per degree Celsius temperature between the room and the ambient conditions. Calculate the power required to operate the device in summer and winter. [8]

12. At the beginning of a compression stroke of an air standard Diesel cycle having a compression ratio of 16 the temperature is 300 K and the pressure is 1000 kPa, if the cut off ratio for the cycle is 2 Determine: [8]

a) The pressure and temperature at the end of each process of the cycle.

b) The thermal efficiency and

c) The mean effective pressure

Take $R = 287 \text{ J/kg K}$ and $\gamma = 1.4$

13. A gas turbine blade is modeled as a flat plate. the thermal conductivity of the blade material is 15 W/mK and its thickness is 1.5 mm. The upper surface of the blade is exposed to hot gases at 1000°C and the lower surface is cooled by air bled of the compressor. The heat transfer coefficients at upper and lower surfaces of the blade are 2500 W/m²K and 1500 W/m²K respectively. Under steady state conditions, the temperature at upper surface of the blade is measured as 850°C, determine the temperature of the coolant air. [6]

TABLE 1 Properties of SATURATED WATER - Pressure Table

P	T	v_f	v_g	v_{fg}	u_f	u_g	u_{fg}
kPa	°C	m ³ /kg	m ³ /kg	m ³ /kg	kJ/kg	kJ/kg	kJ/kg
0.01	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
0.05	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
0.1	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
0.5	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
1	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
5	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
10	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
20	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
30	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
40	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
50	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
60	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
70	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
80	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
90	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
100	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
150	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
200	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
300	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
400	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
500	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
600	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
700	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
800	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
900	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
1000	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
1500	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
2000	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
3000	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
4000	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
5000	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
6000	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
7000	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
8000	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
9000	0.01	0.001000	206.136	206.135	0.01	209.91	209.90
10000	0.01	0.001000	206.136	206.135	0.01	209.91	209.90

TABLE 2 Properties of SUPERHEATED STEAM

P	T	v	u	h	s
kPa	°C	m ³ /kg	kJ/kg	kJ/kg	kJ/kg·K
4000	(230.39)	(0.09977)	(2601.3)	(2800.6)	(6.0689)
	300	0.05382	2724.4	2959.7	6.3598
	350	0.06644	2826.1	3091.8	6.5811
	400	0.07340	2919.3	3213.4	6.7628
	450	0.08002	3010.3	3330.4	6.9364

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BCE, BME, BGE	Pass Marks	32
Year / Part	1 / 1	Time	3 hrs.

Subject: - Fundamentals of Thermodynamics and Heat Transfer (ME402)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ Attempt All questions.
- ✓ The figures in the margin indicate Full Marks.
- ✓ Necessary tables are attached herewith.
- ✓ Assume suitable data if necessary.

1. State and explain zeroth law of thermodynamics. Write down its application. [4]
2. Differentiate between stored energy and transient energy with examples. [4]
3. Define saturation pressure and saturation temperature. Explain why quality is necessary for a liquid vapor mixture. [4]
4. Derive general mass conservation and energy conservation equations for a control volume. [6]
5. Define entropy and isentropic process. Derive detail mathematical expression for entropy relation for an ideal gas in terms of pressure and temperature. [6]
6. Sketch the Rankines cycle on p-v and T-s diagrams and derive an expression for its efficiency. [6]
7. Derive the expression for overall heat transfer coefficient for composite plane wall consisting of two layers and subjected convective medium on both sides. [6]
8. At the inlet and exhaust of a turbine the absolute steam pressure are 6000 kPa and 4.0 cm of Hg, respectively. Barometric pressure is 75 cm of Hg. Calculate the guage pressure for the entering steam and the vacuum gauge pressure for the exhaust steam. ($\rho_{Hg} = 13600 \text{ kg/m}^3$ and $g = 9.81 \text{ m/s}^2$) [6]
9. A piston cylinder arrangement shown in figure below contains water initially at $P_1 = 100 \text{ kPa}$, $x_1 = 0.8$ and $V_1 = 0.01 \text{ m}^3$. When the system is heated, it encounters a linear spring ($k = 100 \text{ kN/m}$). At this state volume is 0.015 m^3 . The heating continues till its pressure is 200 kPa. If the diameter of the piston is 0.15 m, determine: [8]
 - a) The final temperature and
 - b) The total work transfer



10. Air enters into a turbine at 2 MPa, 400°C and with a velocity of 200 m/s and exits from the turbine at 100 kPa and 100°C with a velocity of 80 m/s. The power output of the turbine is 800 kW when the mass flow rate of air is 4.5 kg/s. Determine the rate of heat loss from the turbine surface, inlet and exit diameters. [Take $C_p = 1005 \text{ J/kg}$, k and $R = 287 \text{ J/kg.h}$] [8]

11. A piston cylinder device shown in figure below contains 1.5 kg. of water initially at 100 kPa with 10% of quality. The mass of the piston is such that a pressure of 400 kPa is required to lift the piston. Heat is added to the system from a source at 500°C until its temperature reaches 400°C. Determine the total entropy generation during the process. [8]



12. A power plant operating on an ideal Brayton cycle delivers a power output of 80 MW. The minimum and maximum temperatures during cycle are 300 K and 1500 K respectively. The pressure at the inlet and exit are 100 kPa and 1400 kPa respectively: [8]
- Determine the thermal efficiency of the cycle
 - Determine the power output from the turbine and
 - What fraction of the turbine power output is required to drive the compressor? [Take $C_p = 1005 \text{ J/kg.k}$, $\gamma = 1.4$]
13. A 40 m long steel pipe ($k = 50 \text{ W/mK}$) having an inside diameter 80 mm and outside diameter 120 mm is covered with two layers of insulation. The layer in contact with pipe is 30 mm thick asbestos ($k = 0.15 \text{ W/mK}$) and the layer next to it is 20 mm thick magnesia ($k = 0.1 \text{ W/mK}$). The heat transfer coefficients for the inside and outside surfaces are $240 \text{ W/m}^2\text{K}$ and $10 \text{ W/m}^2\text{K}$ respectively. If the temperature of the steam inside the pipe is 400°C and the ambient air temperature is 25°C. Determine: [6]
- The inside overall heat transfer coefficient U_i ,
 - The outside overall heat transfer coefficient U_o ,
 - The heat transfer rate using U_i and
 - The heat transfer rate using U_o



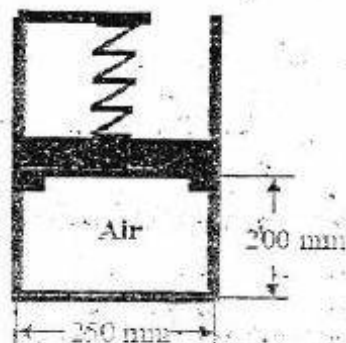
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Examination Control Division
2070 Ashad

Exam.	New Back (2066 & Later Batch)		
Level	BE	Full Marks	80
Programme	BCE, BME, BGE	Pass Marks	32
Year / Part	I / I	Time	3 hrs.

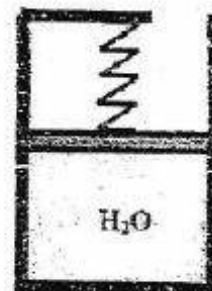
Subject: - Fundamental of Thermodynamics and Heat Transfer (ME402)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ Attempt All questions.
- ✓ The figures in the margin indicate Full Marks.
- ✓ Necessary figures are attached herewith.
- ✓ Assume suitable data if necessary.

1. State and explain equality of temperature. Also state zeroth law of thermodynamics. [4]
2. Derive an expression for work transfer for any process on a piston cylinder device. Reduce it to get the expression for work transfer during a polytropic process. [4]
3. Define pure substance. State and explain "state postulate". [4]
4. Differentiate between steady state work applications and steady state flow applications. Write down the functions of a thermal turbine and nozzle. Also derive governing equations for them when they operate under steady state condition. [6]
5. State the entropy change statement for a control volume and derive an expression for its entropy generation. [6]
6. Sketch an ideal Otto cycle on P-v and T-s diagrams. Also derive an expression for its efficiency in terms compression ratio. [6]
7. Derive the expression for overall heat transfer coefficient for a composite plane wall consisting of two layers and subjected to convective medium on both sides. [6]
8. Air (0.01 kg) is contained in a piston cylinder device restrained by a linear spring ($k = 500 \text{ kN/m}$) as shown in figure below. Spring initially touches the piston but exerts no forces on it. Heat is added to the system until the piston is displaced upward by 80 mm. Determine: [6]
 - a) The temperature at which piston leaves the stops and
 - b) The final pressure. [Take $R = 287 \text{ J/kg} \cdot \text{K}$, $p_{\text{atm}} = 100 \text{ kPa}$ and $g = 9.81 \text{ m/s}^2$]



9. A piston cylinder device with a linear spring initially contains H_2O at 1000 kPa and 500°C with the initial volume being 0.1 m^3 , as in figure. The piston is at pressure is 300 kPa. Sketch the process on P-v diagram and determine the final temperature and volume and the total work transfer. [Ref: properties of steam]



10. Air flows at rate of 1.2 kg/s through a compressor, entering at velocity of 60 m/s and leaving at 500 kPa , 150°C , with a velocity of 10 m/s . The heat transfer from the compressor to the surrounding is estimated to be 20 kJ/kg of air. Determine the work required to drive the compressor and diameters of inlet and outlet. [Take $R = 287 \text{ J/kgK}$ and $c_p = 1005 \text{ J/kgK}$].
11. A rigid vessel consists of 0.4 kg of hydrogen initially at 200°C . It is then transferred to the system from a reservoir at 600 K until its temperature is 400 K . Determine the heat transfer, the change in entropy of hydrogen and the entropy produced. [Take $c_v = 10.183 \text{ J/kgK}$].
12. An ideal gas turbine cycle produces 15 MW of power output. The compression inlet are 100 kPa and 17°C . The pressure ratio for the cycle is 10 . The heat added per kg of air per cycle is 900 kJ/kg . Determine: (a) Efficiency, (b) Maximum temperature during the cycle and (c) Mass flow rate of air. [Take $c_p = 1005 \text{ J/kgK}$].
13. A furnace wall 300 mm thick is made up of an inner layer of fire brick covered with a layer of insulation ($k = 0.2 \text{ W/mK}$). The inner surface is at 1300°C and the outer surface is at 30°C . Under steady state condition the interface temperature is measured to be 1100°C . Determine:
- Heat loss per unit area of the wall and
 - The thickness of each layer



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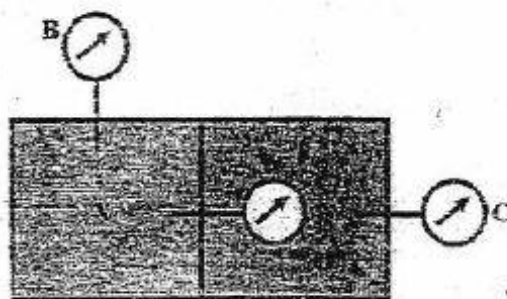
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Exam.	Regular		
Level	BE	Full Marks	80
Programme	BCE, BME, BGE	Pass Marks	32
Year / Part	I / I	Time	3 hrs.

Subject: - Fundamental of Thermodynamics and Heat Transfer (ME402)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ Attempt All questions.
- ✓ The figures in the margin indicate Full Marks.
- ✓ Necessary tables are attached herewith.
- ✓ Assume suitable data if necessary.

1. Explain the difference between path function and point function with example. [4]
2. Define heat transfer and work transfer. Also mention similarities and differences between heat and work. [4]
3. Define pure substance. Explain why property tables and charts are necessary. [4]
4. Differentiate between steady state and unsteady state analysis. Write down general mass conservation and energy conservation equation for a steady state process and reduce them for an adiabatic turbine. [6]
5. Define isentropic process. Derive isentropic relations for an ideal gas and an incompressible substance. [6]
6. Sketch the cycle on P-v and T-s diagrams and derive an expression for its efficiency in terms of compression ratio and cut-off ratio. [6]
7. Derive expressions for inside and outside overall heat transfer co-efficient for a hollow cylinder subjected to convection medium on both sides. [6]
8. A large chamber is separated into two compartments which are maintained different pressures as shown in figure below. Pressure gauge A reads 200 kPa and pressure gauge B reads 150 kPa. If the atmospheric pressure is 100 kPa, determine the absolute pressure existing in the compartments and the reading of gauge C. [6]



9. A rigid container with a volume of 0.170 m^3 is initially filled with steam at 200 kPa, 300°C . It is cooled to 90°C . [8]
 - a) At what temperature does a phase change start to occur?
 - b) What is the final pressure?
 - c) What mass fraction of the water is liquid in the final state?Also, sketch the process on P-v and T-v diagrams. [Refer the attached table for properties of steam]

0. Air flows at a rate of 1.2 kg/s through a compressor, entering at 100 kPa , 25°C , with a velocity of 60 m/s and leaving at 500 kPa , 150°C , with a velocity of 120 m/s . Heat loss from the compressor to the surrounding is estimated to be 20 kJ/kg . Calculate the power required to drive the compressor and diameter of inlet and exhaust pipes. [Take $R = 287 \text{ J/kgK}$ and $c_p = 1005 \text{ J/kgK}$]
1. An air condition unit having COP 50% of the theoretical maximum maintains a house temperature of 20°C by cooling it against the surrounding temperature. The house gains energy at a rate of 0.8 kW per degree temperature difference. For a maximum work input of 1.8 kW , determine the maximum surrounding temperature for which it provides sufficient cooling.
2. The compression ratio of an air standard Otto cycle is 8. At the beginning of compression process, the pressure and temperature of air are 100 kPa and 20°C respectively. The heat added per kg air during the cycle is 2000 kJ/kg . Determine pressure and temperature at the end of each process of the cycle, the thermal efficiency and the mean effective pressure. [Take $R = 287 \text{ J/kg.k}$ and $\gamma = 1.4$]
3. A steel pipe having an outside diameter of 2 cm is to be covered with two layers of insulations, each having a thickness of 1 cm . The average conductivity of one material is 5 times that of the other. Assuming that the inner and outer surface temperature of composite insulation are fixed, calculate by what percentage the heat transfer will be reduced when the better insulating material is nearer to the pipe than it is away from the pipe.



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INSTITUTE OF ENGINEERING

Examination Control Division-

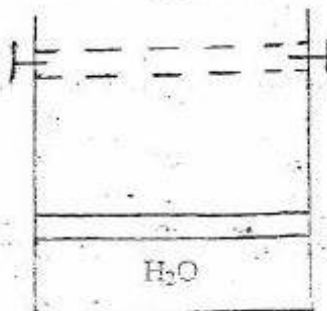
2069 Ashad

Exam.	New Back (2066 & Later Batch)		
Level	BE	Full Marks	80
Programme	BCE, BME	Pass Marks	32
Year / Part	I / I	Time	3 hrs.

Subject: - Fundamental of Thermodynamics and Heat Transfer (ME 402)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ Attempt All questions.
- ✓ The figures in the margin indicate Full Marks.
- ✓ Necessary Tables are attached herewith.
- ✓ Assume suitable data if necessary.

1. Define these terms: (a) Quasi-equilibrium process (b) An open system (c) Thermodynamic equilibrium (d) Intensive property. [4]
2. Define stored and transient energies with examples. [2+2]
3. Define the terms saturated vapor, superheated vapor and critical point. Also derive an expression for specific volume of a two phase mixture in terms of quality. [3+3]
4. Derive unsteady state energy equation for an open system. Apply this equation to derive governing equations for the discharge of a gas from a cylinder. [6]
5. State and explain Kelvin-Planck and Clausius statement of second law of thermodynamics. Also prove their equivalence. [8]
6. Sketch the Brayton cycle on P-V and T-s diagrams and derive an expression for its efficiency in terms of pressure ratio. [6]
7. Derive an expression for inside overall heat transfer coefficient for a hollow cylinder subjected to convection on both sides. [6]
8. A cylinder with a frictionless piston contains 0.1m^3 of gas at 200KPa pressure. The piston is connected to a coil spring, which exerts a force proportional to displacement from its equilibrium position. The gas is heated until the volume is doubled at which pressure is 500KPa. Determine the work done by the gas. Take atmospheric pressure equal to 100KPa. [4]
9. A piston cylinder arrangement shown in figure below contains 0.5kg of water initially at a pressure of 400KPa with a quality of 50%. The system is heated to a position where the piston is locked, and then cooled till it becomes a saturated vapor at a temperature of 60°C . Sketch the process on P-v and T-v diagrams and determine total work transfer. [8]



10. Steam enters a turbine operating at steady state with a mass flow rate of 4600 kg/h . The turbine develops a power output of 1000 kW . At the inlet, the pressure is 6000 kPa , the temperature is 400°C , and the velocity is 10 m/s . At the exit, the pressure is 100 kPa , the quality is 0.9 , and the velocity is 50 m/s . Calculate the rate of heat transfer between the turbine and surroundings in kW ? (Refer the attached table for properties of steam). [8]
11. A heat engine working on Carnot cycle converts one-fifth of the heat input into work. When the temperature of the sink is reduced by 80°C , the efficiency gets doubled. Make calculations for the temperature of source and sink. [6]
12. Determine the efficiency of an ideal Rankine cycle operating between boiler pressure of 1.6 MPa and condenser pressure of 6 kPa . Steam leaves the boiler as saturated vapor. [8]
13. An exterior wall of a house may be approximated by a 10 cm layer of common brick [$k=0.7 \text{ W/m}^\circ\text{C}$] followed by a layer of a 3.8 cm layer of cement plaster [$k=0.48 \text{ W/m}^\circ\text{C}$]. What thickness of loosely packed rock-wool insulation [$k=0.065 \text{ W/m}^\circ\text{C}$] should be added reduce the heat loss (or gain) through the wall by 80 percent? [6]

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1. Write features of a thermodynamic property. Also differentiate between state function and path function with examples. [4]
2. Differentiate between heat and work. [4]
3. Define compressed liquid, degree of superheat, moisture content and saturated vapor. [4]
4. Define cyclic process State and explain first law of thermodynamics for a control mass undergoing a cyclic process. [6]
5. Explain the directional feature of the natural process with any one example. State the second of thermodynamics for an isolated system. Also explain the entropy generation. [6]
6. Sketch P-v and T-s diagram for a Brayton cycle. Also derive an expression for its efficiency in terms of pressure ratio. [6]
7. Derive expressions for inside overall heat transfer coefficient and outside overall heat transfer coefficient for a hollow tube subjected to convection medium on its both inner and outer surface. [6]
8. The Piston of a vertical Piston cylinder device containing as gas has a Mass of 50 kg and cross sectional area of 0.02m^2 . [6]
 - i) Determine the pressure inside the cylinder.
 - ii) During some process heat is lost by the gas to the surroundings and it's volume decreases to $\frac{3}{4}$ th of the initial volume, determine it's final pressure. [Take $P_{\text{atm}} = 100 \text{ KPa}$ and $g = 9.81 \text{ M/s}^2$]
9. A piston cylinder device shown in figure P.9 contains 0.2 Kg of a mixture of saturated liquid water and saturated water vapor at a temperature of 50°C and a volume of 0.03m^3 . The mass of the piston resting on the stops is 50 Kg and the cross sectional area of the piston is 12.2625 cm^2 . The atmospheric pressure is 100 kPa. Heat is transferred until it becomes saturated vapor. Sketch the process on P-v and T-v diagrams and determine: [8]
 - i) The final pressure, and
 - ii) The total work transfer. [Take $g = 9.8 \text{ ms}^{-2}$] [Refer attached table for the properties of steam]



Figure P.9

10. Air flows at a rate of 1.2 kg/s through a turbine entering at 500 kPa , 150°C ; with a velocity of 120 m/s and leaving at 100 kPa , 25°C ; with velocity of 60 m/s . Heat lost by the turbine to the surrounding is found to be 20 kJ/kg . Calculate the power developed by the turbine and diameter of inlet and exhaust pipes. [Take $R = 287 \text{ J/kg}\cdot\text{K}$, and $C_p = 1005 \text{ J/kg}\cdot\text{K}$] [8]
11. A heat Pump having COP of 5 maintains a building at a temperature of 24°C by supplying heat at a rate of 72000 kJ/h , when the surroundings is at 0°C . The heat Pumps run 12 hours in a day and the electricity costs Rs $10/\text{kWh}$. [8]
- i) Determine the actual and minimum theoretical cost per day.
 - ii) Compare the actual operating cost with the cost of direct electric resistance heating.
12. Steam at 2 MPa , 350°C is expanded in a steam turbine working on a Rankine cycle to 8 kPa . Determine the net work per kg of steam and the cycle efficiency assuming ideal processes. What will be the difference in efficiency if pump work is neglected? [Refer attached table for the properties of steam] [8]
13. A gas turbine blade is modeled as a flat plate. The thermal conductivity of the blade material is $15 \text{ W/m}\cdot\text{K}$ and its thickness is 1.5 mm . The upper surface of the blade is exposed to hot gases at 1000°C and the lower surface is cooled by air bled of the compressor. The heat transfer coefficients at the upper and lower surfaces of the blade are $2500 \text{ W/m}^2\cdot\text{K}$ and $1500 \text{ W/m}^2\cdot\text{K}$ respectively. Under steady state conditions, the temperature, at the upper surface of the blade is measured as 850°C ; determine the temperature of the coolant air. [6]

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Year / Part	1 / 1	Time	3 hrs

Subject: - Fundamentals of Thermodynamics and Heat Transfer

- ✓ Candidates are required to give their answers in their own words as far as practicable.
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1. Highlight assumptions of air standard cycle. Derive the thermal efficiency of two stroke Spark Ignition (SI) Engine. [4]
2. Define a polytropic process. Sketch polytropic processes with $n = 0, 1, 1.4$ and ∞ on a common P-V diagram. Derive an expression for work transfer for a polytropic process. [6]
3. Draw saturation curve of water using isobar lines. Differentiate between compressed liquid and saturated liquid as well as saturated vapor and superheated vapor. [6]
4. Derive general energy equation for an open system and modify it for steady state, steady flow operation. [6]
5. Define isentropic process. Derive isentropic relations for an ideal gas. [6]
6. Derive the relationship between rate of heat transfer and thermal resistance for a composite wall having three layers. [6]
7. Derive an expression for overall heat transfer coefficient for a composite plane wall consisting of three layers with convection on both sides. [6]
8. A gas is contained in a piston cylinder device at 101.325 KPa, 200°C and 0.425 m³ as shown in figure below. At this state, a linear spring with a spring constant of 219 kN/m is touching the piston but exerts no force on it. The cross sectional area of the piston is 0.279 m². Heat is transferred to the gas, causing it to expand until it's volume doubles. Determine: [5]
 - a) The final pressure
 - b) The ratio of fraction of work done against the spring and total work done
 - c) The total heat transfer during the process
 - d) Also, show the process on a P-V and T-V diagrams. (Take $R = 287 \text{ J/kgK}$ and $C_v = 718 \text{ J/kgK}$)



9. The mass rate of flow into a turbine is 1.5 kg/s , and the heat transfer from the turbine is 8.5 kW . The following data are known for the steam entering and leaving the turbine.

[8]

	Inlet Conditions	Exit Conditions
Pressure	2.0 MPa	0.1 MPa
Temperature	350°C	
Quality		100%
Velocity	50 m/s	100 m/s
Elevation above reference plane	6 m	3 m

Determine the power output of the turbine and exit area of outlet pipe. [Refer the attached table for properties of steam]

10. Two kg of water at 90°C is mixed with three kg of water at 10°C in an isolated system. Calculate the change of entropy due to the mixing process. [C_p for water = 4.18 kJ/kgK].

[6]

11. Air enters the compressor of an ideal air standard Brayton cycle at 100 kPa , 300 K , with a volumetric flow rate of $5 \text{ m}^3/\text{s}$. The compressor pressure ratio is 10. The turbine inlet temperature is 1400 K . Determine:

[11]

- The thermal efficiency of the cycle.
- The net power developed in kW.

12. A steel pipe having an outside diameter of 2 cm is to be covered with two layers of insulation, each having a thickness of 1 cm . The average conductivity of one insulation is 5 times that of the other. Assuming that the inner and outer surface temperatures of the composite insulation are fixed, calculate by what percentage the heat transfer will be reduced when the better insulating material is next to the pipe than it is away from the pipe.

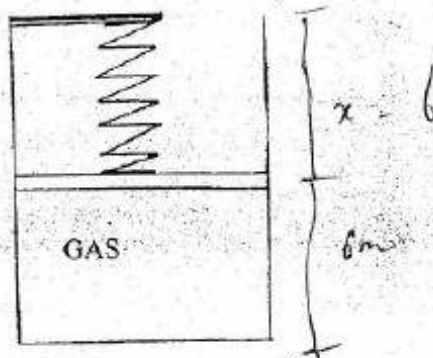
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Year / Part	1 / I	Time	3 hrs.

Subject: - Fundamental of Thermodynamics and Heat Transfer (ME 402)

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- ① Differentiate between the microscopic and macroscopic view point in thermodynamics with suitable examples. [4]
2. Define internal energy. Derive an expression for displacement work transfer for a polytropic process. [4]
3. State two property rule for a state. Explain the importance of graphical and tabular data presentation. [5]
4. Derive a general expression for energy conservation for a control volume and reduce it for steady state condition. [6]
5. Differentiate between heat engine and refrigerator. Also explain the factors used for their performance evaluation. [6]
6. Explain the working principle of the Rankine cycle with the corresponding process on P-V and T-S diagrams. [6]
7. a) Derive an expression for steady state heat transfer through a composite cylinder consisting of two different materials. [4]
b) Define terms black body and gray body. [2]
8. A piston cylinder arrangement loaded with a linear spring as shown in figure below has cross sectional area of 0.01 m^2 , contains gas piston mass of 80 kg . Initially spring touches the piston but exerts no pressure on it. Heat is supplied to the system until its volume doubles. Determine the final pressure. [Take $g = 9.81 \text{ m/s}^2$, outside atmospheric pressure = 100 kPa , spring const, $k = 50 \text{ kN/m}$, initial volume = 0.06 m^3 of gas] [6]

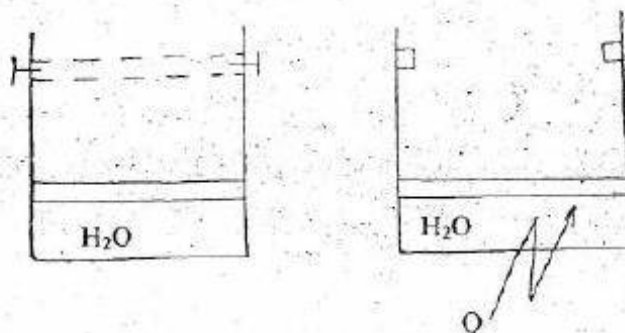


9. A vessel having a volume of 0.4m^3 contains 2.0 kg of liquid water and water vapor mixture in equilibrium at a pressure of 250kPa . Calculate: [7]

- The volume and mass of liquid
- The volume and mass of vapor
- Temperature
- Enthalpy

(Refer the attached table for properties of steam)

10. A piston cylinder device shown in figure below contains 2kg of water initially at saturated liquid state of 1MPa . There is heat transfer to the system until it hits the stops at which time its volume is 0.3m^3 . There is further heat transfer to the device until water is completely vaporized. Sketch the process on P - v and T - v (pressure - specific volume) diagrams and determine total work and heat transfer. [8]



11. Steam enters into a turbine at a rate of 2kg/s with $P_1 = 2\text{MPa}$, $T_1 = 600^\circ\text{C}$ and exits at $P_2 = 9\text{kPa}$. Find: [8]

- Power output if the turbine is isentropic
- Power output if isentropic efficiency of turbine is 80% and
- Outlet enthalpy of steam from the real turbine

12. At the beginning of the compression process of an air standard Otto cycle, $P_1 = 100\text{kPa}$, $T_1 = 290\text{K}$, $V_1 = 400\text{cm}^3$. The maximum temperature in the cycle is 2200K and the compression ratio is 8 . Determine: [8]

- The heat addition, in kJ
- The network, in kJ
- The thermal efficiency
- The mean effective pressure

[Take $R = 287\text{ J/kgK}$, $C_v = 718\text{ J/kgK}$]

13. A 3cm thick $50\text{cm} \times 75\text{cm}$ plate ($K = 50\text{W/mK}$) has inner surface temperature of 310°C . Heat is lost from the plate surface by convection and radiation to ambient air at 20°C . If the emissivity of the surface is 0.85 and convection heat transfer coefficient is $20\text{W/m}^2\text{K}$, determine outer surface temperature of the plate. [6]

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	Level	BE	Full Marks 80
Programme	BEL	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Fundamental of Thermodynamics and Heat

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- ✓ Attempt *All* questions.
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1. List out and explain the three types of thermodynamic system. Derive an expression for work done during an isothermal process. [6]
2. Write down steady flow energy equation (SFEE) with necessary assumptions. Reduce it for nozzle, adiabatic pump and throttling valve. [4]
3. Define entropy. Derive the expressions for change of entropy for an ideal gas by combining first and second laws of thermodynamics. [6]
4. What are the major two differences between Otto cycle and Diesel cycle? Draw P-v and T-s diagrams for the Dual cycle. Write down the expression for an efficiency of Dual cycle and conditions when Dual cycle tends to Diesel cycle and Otto cycle. [6]
5. Derive an expression for radial heat flow through three layer composite cylinders. [6]
6. What is brake nozzle? Differentiate between impulse turbine and reaction turbine. [6]
7. Write short notes: (any four) [2×4]
 - a) Surface tension
 - b) Buoyant force
 - c) Path line
 - d) Statement and assumptions of Bernoulli's equation
 - e) Lift force and drag force
8. Air is contained in a vertical cylinder fitted with a frictionless piston and a set of stops as shown in figure below. The cross-sectional area of the piston is 0.05m^2 . At initial condition, piston is in upper stops with pressure and temperature inside the cylinder are 0.3 MPa and 731°C respectively. Air is cooled as a result of heat transfer to the surroundings. The piston starts to move down at pressure 0.21 MPa. The cooling process continues until the temperature reaches 70°C . [8]
 - a) Draw P-V diagram for the process.
 - b) Find the temperature of the air inside the cylinder when the piston reaches the lower stops.
 - c) Calculate the heat transfer during the process. (For air $R = 287\text{ J/kg K}$, $C_p = 1004\text{ J/kg K}$, $C_v = 717\text{ J/kg K}$)



9. A rigid container with a volume of 0.170 m^3 is initially filled with steam at 200 kPa and 350°C . It is cooled to 90°C . [2]

- a) At what temperature does a phase change starts to occur?
- b) What is the final pressure?
- c) What mass fraction of the water is liquid in the final state?

Also sketch the process on $P-v$ and $T-v$ diagrams. [Refer the attached table for properties of steam]

10. An adiabatic diffuser has air entering at 100 kPa , 300 K , with a velocity of 200 m/s . The inlet cross sectional area of the diffuser is 100 mm^2 . At the exit, the area is 850 mm^2 , and the exit velocity is 20 m/s . Determine the exit temperature and pressure of the air. [Take $C_p = 1005\text{ J/kg K}$, $R = 287\text{ J/kg K}$]. [8]

11. Steam at 700 kPa with a quality of 0.96 , is throttled down to 350 kPa . Calculate the change of entropy per unit mass of steam. [Refer the attached table for properties of steam.] [6]

12. Air enters the compressor of an ideal air standard Brayton cycle at 100 kPa , 300 K , with a volumetric flow rate of $5\text{ m}^3/\text{s}$. The compressor pressure ratio is 4 . The turbine inlet temperature is 1400 K . Determine: [8]

- a) The thermal efficiency of the cycle
- b) The net power developed, in kW . [Take $R = 287\text{ J/kg K}$, $c_p = 1005\text{ J/kg K}$, $\gamma = 1.4$]

13. The inside surface of an insulating layer is at 270°C , and the outside surface is dissipating heat by convection in to air at 20°C . The insulation layer is 4 cm thick and has thermal conductivity of 1.2 W/m.K . What is the minimum value of the heat transfer coefficient at the outside surface if the outside temperature is not to exceed 70°C ? [6]
