Reg No.:_______________ Name:__________________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

Fourth Semester B.Tech Degree Examination July 2021 (2019 Scheme)

Course Code: MET202

Course Name: ENGINEERING THERMODYNAMICS

(Permitted to use Steam tables and Mollier charts)

Max. Marks: 100 Duration: 3 Hours

PART A

(Answer all questions; each question carries 3 marks) Marks

1		What do you mean by macroscopic and microscopic approaches in thermodynamics?	3
2		What do you mean by ideal gas temperature scale	3
3		Explain positive and negative heat and work interactions.	3
4		Which property of system increases when heat is transferred: (a) at constant volume, (b) at constant pressure? Give the expressions for these properties in terms of specific heats.	3
5		What are the causes of irreversibility of a process?	3
6		Give the Kelvin-Planck and Clausius' statements of second law of thermodynamics.	3
7		What is critical state? Explain the terms critical pressure, critical temperature and critical volume of water.	3
8		What is the fundamental property of gas with respect to the product pv? Differentiate Universal and characteristic gas constants.	3
9		What are reduced properties?	3
10		Why there is no temperature change when ideal gas is throttled?	3

PART B

(Answer one full question from each module, each question carries 14 marks)

Module -1

11	a)	Explain quasi static process with suitable sketches.	7
	b)	Describe about (i) system and control volume (ii) properties, state, path and process with respect to thermodynamics.	7
12	a)	Explain different types of temperature scales.	7
	b)	A new absolute temperature scale is proposed. On this scale the ice point of	7

water is 150^{o}S and the steam point is 300^{o}S. Determine the temperature in ^{o}C that corresponds to 100^{o}S and 400^{o}S respectively. What is the ratio of the size of the ^{o}S to the Kelvin? At what temperature both the Celsius and the new temperature scale reading would be the same?

Module -2

13 a) Explain first law of thermodynamics for a closed system undergoing change of state. Show that energy is a property of the system 7

b) A fluid is confined in a cylinder by spring-loaded, frictionless piston so that the pressure in the fluid is a linear function of the volume (p = a + bV). The internal energy of the fluid is given by the equation (U = 34 + 3.15 pV), where U in kj, p in kPa, and V in cubic metre. If the fluid changes from an initial state of 170 kPa, 0.03 m^3 to a final state of 400 kPa, 0.06 m^3, with no work other than that done on the piston. Find the direction and magnitude of the work and heat transfer. 7

14 a) Discuss the application of steady flow process in following engineering systems: (i) Nozzle and Diffuser (ii) Throttling device (iii) Turbine and Compressor 7

b) Air at a temperature of 15^{o}C passes through a heat exchanger at a velocity of 30 m/s where its temperature is raised to 800^{o}C. It then enters a turbine with the same velocity of 30 m/s and expands until the temperature falls to 650^{o}C. On leaving the turbine, the air is taken at a velocity of 60 m/s to a nozzle where it expands until the temperature has fallen to 500^{o}C. If the air flow rate is 2kg/s, calculate: 7

(a) The rate of heat transfer to the air in the heat exchanger,

(b) The power output from the turbine assuming no heat loss, and

(c) The velocity at exit from the nozzle, assuming no heat loss.

Take the enthalpy of air as $h=c_pt$; where c_p is the specific heat equal to 1.005 kJ/kg K and t is the temperature.

Module -3

15 a) Derive Clausius inequality and explain the criteria with respect to a cyclic process. 7

b) A heat pump working on the Carnot cycle takes in heat from a reservoir at 10^{o}C and delivers heat to a reservoir at 80^{o}C. The heat pump is driven by a reversible heat engine which takes in heat from a reservoir at 1000^{o}C and rejects heat to a 7 reservoir at 80^oC. The reversible heat engine also drives a machine that absorbs 50 kW. If the heat pump extracts 10 kJ/s from the 10^oC reservoir, determine

(a) The rate of heat supply from the 1000^oC source, and

(b) The rate of heat rejection to the 80^oC sink.

16 a) Explain the mixing of two fluids with respect to entropy principle. 7

b) Calculate decrease in available energy when 25 kg of water at 95^oC mix with 35kg of water at 35^oC, the pressure being taken as constant and the temperature of the surroundings being 15^oC (c_p of water = 4.2 kJ/kg K) 7

Module -4

17 a) Explain with P-V diagram, the different stages for a substance whose volume decreases on melting. 7

b) Steam at 0.8 MPa, 250^oC and flowing at the rate of 1kg/s passes into a pipe carrying wet steam at 0.8 MPa, 0.95 dry. After adiabatic mixing the flow rate is 2.3 kg/s. Determine the condition of steam after mixing and degree of superheat. 7

18 a) Explain Compressibility factor with respect to Virial expansions. 7

b) What are reasons for the deviation of the real gas behaviour from the ideal gas behaviour? With reference to van der Waals correction, explain the deviation of equation of state of a real substance from ideal gas. 7

Module -5

19 a) State and explain Dalton's law of partial pressures and Amagat's laws of additive volumes. 7

b) A mixture of ideal gases consists of 3kg of nitrogen and 5kg of carbon dioxide at a pressure of 300 kPa and a temperature of 20^oC. Find, 7

(a) The mole fraction of each component.

(b) The equivalent molecular weight of the mixture.

(c) The equivalent gas constant of the mixture.

(d) The partial pressure and the partial volumes.

20 a) Explain Joule-Kelvin effect with respect to significance of inversion curve. Show that for an ideal gas, Joule-Kelvin coefficient is zero 7

b) Derive Maxwell's equations 7

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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

Fourth Semester B.Tech Degree Examination June 2022 (2019 scheme)

Course Code: MET202

Course Name: ENGINEERING THERMODYNAMICS

Max. Marks: 100 Duration: 3 Hours

(Use of steam tables & Mollier chart and compressibility chart permitted)

PART A

(Answer all questions; each question carries 3 marks)

		Marks
1	Distinguish between thermodynamic system and control volume	3
2	Describe quasi static process undergone by a system with the help of neat sketches including the *pv* diagram.	3
3	Derive the equation for *pdv* work in a polytropic expansion process	3
4	State and explain the first law of thermodynamics for a closed system undergoing a cyclic process with the help of neat sketches	3
5	Distinguish between reversible and irreversible processes with the help of neat sketches.	3
6	Define a PMM2. Why is it impossible?	3
7	What are steam tables and saturation states? What for they are used?	3
8	Draw the T-s plot of a pure substance, and show various constant property lines on it.	3
9	Draw the isenthalpic curve and inversion curve in the *T-p* coordinates. Explain how these curves are obtained?	3
10	Derive the Clausius-Clapeyron equation from the first *T-ds* equation. What is the significance of this equation?	3

PART B

(Answer one full question from each module, each question carries 14 marks)

Module -1

11 a) Define the following terms associated with a thermodynamic system: 7

i. Properties.

ii. State

iii. Path

iv. Process

v. Cycle

vi. Intensive property (give at least one example)

vii. Extensive property (give at least one example)

b) What was the temperature measurement method used before 1954? Derive the equation used for temperature measurement in this method. 7

12 a) i) What do you mean by thermodynamic equilibrium of a system? What are the conditions required for a system to exist in thermodynamic equilibrium? Explain. 7

ii) Consider a system whose temperature is 18°C. Express this temperature in R, K, and °F.

b) i) The temperature t on a thermometric scale is defined in terms of a property K by the relation 7

$$t = a \ln K + b$$

where a and b are constants.

The values of K are found to be 1.83 and 6.78 at the ice point and the steam point, the temperatures of which are assigned the numbers 0 and 100 respectively. Determine the temperature corresponding to a reading of K equal to 2.42 on the thermometer.

ii) What is the working principle of a constant volume gas thermometer? Explain with neat sketches.

Module -2

13 a) i) Give an account of various forms of energy that may be stored in a system. Write the first law equation for a system undergoing change of state accounting all forms of above energies. 7

ii) Assume that a battery is connected to an external electrical load in a closed circuit for a period of time so that the battery is discharged as a result of the electric current flow. Apply first law of thermodynamics for this case, assuming no dissipation of energy into heat.

b) A turbine operates under steady flow conditions, receiving steam at the following state: Pressure 1.2 MPa, temperature 188°C, enthalpy 2785 kJ/kg, velocity 33.3 m/s and elevation 3 m. The steam leaves the turbine at the following state: Pressure 20 kPa, enthalpy 2512 kJ/kg, velocity 100 m/s and elevation 0 m. Heat is lost to 7 the surroundings at the rate of 0.29 kJ/s. If the rate of steam flow through the turbine is 0.42 kg/s, what is the power output of the turbine in kW?

14 a) Derive the general energy equation for a variable flow process using control volume technique. What happens to this equation for a steady flow? 7

b) i) 1.5 kg of liquid having a constant specific heat of 2.5 kJ/kgK is stirred in a well-insulated chamber causing the temperature rise by 15°C. Find ΔE and W for the process. 7

If the same liquid is stirred in a conducting chamber, the temperature of the liquid is increased to 15°C, and the heat transfer from the liquid to the surroundings was 1.7 kJ. Find ΔE and W for the process

ii) The properties of a certain fluid are related as follows:

$$\boldsymbol{u = 196 + 0.718\,t}$$

$$\boldsymbol{pv = 0.287\,(t + 273)}$$

where *u* is the specific internal energy (kJ/kg), *t* is in °C, *p* is pressure (kN/m^2) and *v* is the specific volume (m^3/kg). For this fluid, find c_v and c_p.

Module -3

15 a) With the help of neat sketches, prove that Kelvin Planck and Clausius statements of second law are equivalent. (Both the proofs are required) 7

b) Prove the inequality of Clausius for defining the reversibility condition for a cycle. Write also the criterion for reversible cycle, irreversible cycle and impossible cycle 7

16 a) A fluid undergoes a reversible adiabatic compression from 0.5 MPa, 0.2 m^3 to 0.05 m^3 according to the law, $pv^{1.3}$=constant. Determine the change in enthalpy, internal energy, entropy, heat transfer and the work transfer during the process. 7

b) With neat sketches, explain the concept of construction of absolute thermodynamic temperature scale between the ice point and the steam point. 7

Module -4

17 a) Explain the *p-v* diagram of a pure substance other than water with the help of neat sketches. Write the critical pressure, critical temperature, and critical volume of water? 7

b) Steam initially at 0.3 MPa, 250°C is cooled at constant volume. Determine the following: 7

(a) At what temperature will the steam become saturated vapor?

(b) What is the quality at 80°C?
(c) What is the heat transferred per kg of steam in cooling from 250°C to 80°C?

18 a) i) What are Virial equations of state? 7

ii) Define compressibility factor.

Also derive the relation between Virial expansion coefficients B' and B, C' and C, and D' and D for a real gas

b) Derive the equation of law of corresponding states from Vander Waals equation of state? What is the significance of this expression? Explain. 7

Module -5

19 a) i) State and derive Dalton's law of partial pressures and Amagat's law of partial volumes for an ideal gas mixture. 7

ii) Derive the expression for partial pressure of component gas in terms of mole fraction

b) A vessel is divided into three compartments (a), (b), (c) by two partitions. Part (a) contains oxygen and has a volume of 0.1 m^3, Part (b) has a volume of 0.2 m^3 and contains nitrogen, while part (c) is 0.05 m^3 and holds CO_2. All three parts are at a pressure of 2 bar and a temperature of 13°C. When the partitions are removed and the gases mix, determine the change in entropy of each constituent, the final pressure in the vessel and the partial pressure of each gas. The vessel may be taken as being completely isolated from its surroundings. 7

20 a) Two vessels, A and B, both containing nitrogen, are connected by a valve which is opened to allow the contents to mix and achieve an equilibrium temperature of 27°C. Before mixing, the details of gases in the two vessels are as given below: 7

Vessel A	Vessel B
p = 1.5 MPa	p = 0.6 MPa
t = 50°C	t = 20°C
Contents = 0.5 kg mol	Contents = 2.5 kg

Calculate the final equilibrium pressure and the amount of heat transferred to the surroundings. Take γ =1.4

b) Derive the *TdS* equations for a pure substance undergoing an infinitesimal reversible process. 7

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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

Fourth Semester B.Tech Degree Supplementary Examination June 2023 (2019 scheme)

Course Code: MET202

Course Name: ENGINEERING THERMODYNAMICS

Max. Marks: 100 Duration: 3 Hours

Use of steam tables, Mollier diagram and compressibility charts are permitted

PART A

(Answer all questions; each question carries 3 marks)

		Marks
1	Differentiate between macroscopic and microscopic analyses in thermodynamics. How does the concept of continuum relate to the above?	3
2	What is a thermocouple? How does it work? State the thermometric property used in thermocouples.	3
3	How does flow work differ from displacement work?	3
4	A gas enclosed in a cylinder piston assembly expands from 2 m^3 to 4 m^3. The pressure volume correlation is given by $p = V^2 + \frac{6}{V}$, where p is in bar. Determine the work done by the system, considering the process as non-flow and reversible.	3
5	Describe the limitations of first law of thermodynamics, with the help of suitable example.	3
6	An inventor claims that he invented a cyclic heat engine that can produce work continuously by receiving heat from a higher temperature reservoir, and without leaving any heat to the lower temperature reservoir. Is his claim correct or not? Justify your answer.	3
7	What are compressed liquid, superheated vapour, and quality of vapour?	3
8	Write a short note on Mollier diagram.	3
9	State Dalton's law of partial pressure. How is the partial pressure of a component in a gaseous mixture related to the mole fraction of that component?	3
10	Show, with the help of appropriate property relation, that the saturation pressure of a liquid increases with temperature, in a phase change process from liquid to vapour.	3

PART B

(Answer one full question from each module, each question carries 14 marks)

Module -1

11	a)	Differentiate between thermodynamic system and control volume with the help of at least one example for each. What is meant by thermodynamic equilibrium of a system? Give a brief description on the conditions to be satisfied for a system to be in thermodynamic equilibrium.	8
	b)	With the help of an example, describe the concept of a quasi-static process. Illustrate - isobaric, isothermal, and adiabatic processes on p-v plot within the same diagram.	6
12	a)	State Zeroth law of thermodynamics. What is its significance? Describe Celsius scale and its corresponding absolute scale. Which is the fixed point used in the measurement of temperature in Celsius scale? Show the mathematical relation connecting the absolute temperature and the thermometric property, in terms of the fixed point.	8
	b)	The temperature 't' on a thermometric scale is defined in terms of property K by the relation $t = a ln K + b$, where a and b are constants. The values of K are found to be 1.52 and 8.79 at the ice point and steam point, the temperatures of which are assigned the numbers 0^0C and 100^0C respectively. Determine the value of K at 25^0C and 50^0C?	6

Module -2

13	a)	State first law of thermodynamics for a cycle, and for a closed system undergoing a change of state. Explain the terms in the above relationships. What is a PMM1? Is a PMM1 possible?	7
	b)	A stationary mass of gas is compressed without friction from an initial state of 0.3 m^3 and 0.105 MPa to a final state of 0.15 m^3 and 0.105 MPa, the pressure remaining constant during the process. There is a transfer of heat 37.6 kJ from the gas during the process. How much does the internal energy of the gas change?	7
14	a)	Derive Steady flow energy equation (for one inlet and one outlet stream each), and from it deduce an expression for the work done by a steam turbine, with proper simplifications.	7

b) Air at 110 K and 101.32 kPa is passing through a converging nozzle and leaves at 300 K. Determine the velocity of air at nozzle outlet. The nozzle is laid horizontal. The inlet velocity of air is 10 m/s. Write the assumptions made. 7

Module -3

15 a) With the help of schematic diagrams describe cyclic heat engine, cyclic heat pump and cyclic refrigerator. How they differ purpose wise? Define the performance parameters of the above three machines. 7

b) Two reversible heat engines operate in series between two end temperatures 600K and 300K via an intermediate thermal reservoir. Both the engines develop the same power. Determine the temperature of the intermediate thermal reservoir. 7

16 a) Give the statement of third law of thermodynamics and explain it. 7

Will a reversible and adiabatic process surely be isentropic? Justify your answer. Comment on the reverse statement; that is, Will an isentropic process surely be reversible and adiabatic? Justify your answer.

b) A heat engine is embedded between two temperature reservoirs 500 K and 300 K. In three different cycles which it rejects 210 kW, 180 kW and 150 kW, while receiving heat at the rate of 300 kW in each case. 7

Justify in which case the engine runs reversibility and irreversibility. Also look for the impossible.

Module -4

17 a) Explain the terms - critical state, critical pressure, critical temperature, and critical volume. Show the critical state point on any suitable phase change diagram. Differentiate between sensible heat and latent heat. 7

b) A steam at 2 MPa has a specific volume of 0.09 m^3/kg. Determine the dryness fraction of the steam. Also calculate the specific enthalpy and specific entropy. Use steam table for the above calculations. 7

18 a) Give descriptions on the following. 7

Virial expansions, Law of corresponding states and generalised compressibility chart.

b) Determine the specific volume of nitrogen at 100 atm and 300 K. For nitrogen 7

P_c=3390 kPa

T_c= 126.2 K

Module -5

19 a) State and prove Dalton's law of partial pressures. Obtain the relationships for the characteristic gas constant and molecular weight of a gas mixture from their component characteristics. 7

b) A vessel divided into two chambers by a partition wall contains oxygen gas in either chamber 7

Chamber -1	Chamber –II
P= 1500 kPa	P= 600kPa
T= 323 K	T= 292K
Mass of oxygen = 0.5 mol	Mass of oxygen =2.5 kg

Determine the final equilibrium pressure?

Take γ=1.4

Assume oxygen behaves ideally throughout the process?

20 a) What is a throttling process? Give a description on Joule Thomson coefficient with its significance. What would be the value of Joule Thompson coefficient for ideal gas and how would it adversely influence the refrigeration effect in a throttling process? 6

b) Derive Maxwell relations, beginning from the appropriate combined first and second laws. 8

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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

B.Tech Degree S4 (R, S) / S2 (PT) (R, S) Examination June 2023 (2019 scheme)

Course Code: MET202

Course Name: ENGINEERING THERMODYNAMICS

Max. Marks: 100 Duration: 3 Hours

Use of steam tables, Mollier chart and compressibility chart are permitted

PART A

(Answer all questions; each question carries 3 marks) Marks

1		State the three conditions to be satisfied for a system to be in thermodynamic equilibrium.	3
2		Give the definition and a brief description of the term thermodynamic property of a system. Give the classification of property with exactly one example for each.	3
3		What is a steady flow process?	3
4		Describe the limitations of first law of thermodynamics, with the help of an example case.	3
5		A cyclic heat engine operates between a source temperature of 700^0C and a sink temperature of 28^0C. What is the least rate of heat rejection per KW net output of the engine?	3
6		Why does free expansion have zero work transfer?	3
7		What is the difference between critical point and triple point?	3
8		Give a description on the law of corresponding states.	3
9		Write the ideal gas equation for *n* moles of a gas. Explain each term used in the equation with proper units in SI. How the characteristic gas equation can be obtained from this equation?	3
10		Define Joule-Thomson coefficient. Prove that Joule-Thomson coefficient is zero for an ideal gas.	3

PART B

(Answer one full question from each module, each question carries 14 marks)

Module -1

11	a)	What are meant by a thermometric property and a thermometric substance? Enlist any four types of thermometers with the thermometric substance and thermometric property used in them.	6

b) Explain the working of constant volume gas thermometer. Explain how a constant volume gas thermometer can be used to measure the correct value of steam point. 8

12 a) Explain the concept of continuum in thermodynamics. How will you define density as a macroscopic property using this concept. 6

b) A temperature scale of certain thermometer is given by the relation $t = a \ln p + b$ where a and b are constants and p is the thermometric property of the fluid in the thermometer. If at the ice point and steam point, the thermometric properties are found to be 1.5 and 7.5 respectively, what will be the temperature corresponding to the thermometric property of 3.5 on Celsius scale? 8

Module -2

13 a) A three-process cycle operating with nitrogen as the working fluid has constant temperature compression at 30^0C with initial pressure 100 kPa. Then the gas undergoes a constant volume heating and then polytropic expansion with 1.35 as index of expansion. The isothermal compression requires -67 kJ/kg of work. Determine 10

1. Pressure, volume, and temperature around the cycle
2. Heat in and out
3. Net work

For Nitrogen gas $c_v = 0.7431$ kJ/kgK

b) Explain the first law of thermodynamics as referred to closed systems undergoing a cyclic change. 4

14 a) A compressor receives carbon dioxide gas at 140 kPa with a specific volume of 0.37 m^3/kg and compresses it to a temperature of 325 K. The work per unit mass for compression is 80 kJ/kg. The gas enters through a 15 cm diameter line with a velocity of 10 m/s and leaves with a velocity of 25 m/s. Determine the heat transfer in kW. Take c_p of CO_2 as 0.846 kJ/kgK. 10

b) Derive an expression for work done in an adiabatic process. 4

Module -3

15 a) Two reversible heat engines operating in series are giving equal amount of work. The total work is 50 kJ. If the reservoirs are 1000 K and 250 K, find the intermediate temperature and the efficiency of each engine. Also, find the heat extracted from the source. 10

	b)	Determine the temperature ratio $\left(\frac{T_2}{T_1}\right)$ (where T_2 = source temperature and T_1 = sink temperature) for a Carnot refrigerator whose COP is 5. If the cycle is used as heat pump, find the COP for heating cycle.	4
16	a)	Define the term 'Entropy'. Derive an expression for change of entropy for an isothermal process.	7
	b)	5 kg of air at 550 K and 4 bar is enclosed in a closed vessel. Determine the availability of the system if the surrounding pressure and temperature are 1 bar and 290 K respectively.	7

Module -4

17	a)	A rigid closed tank of volume 3 m^3 Contains 5 kg of wet steam at a pressure of 200 kPa. The tank is heated until the steam becomes dry saturated. Determine final pressure and heat transfer to the tank.	9
	b)	Consider the cases of vaporisation of saturated liquid to a saturated vapour at pressure of 100 kPa and 500 kPa. Which case requires more energy? Explain with enthalpy – temperature plots.	5
18	a)	Explain the significance of Vander walls equation and its limitations	6
	b)	A 5 m^3 tank contains 1.0 kmol of an ideal gas at 400 kPa with a molar weight of 31 kg/kmol. i. Determine the gas temperature. ii. Gas is removed from the tank, temperature remaining constant, until the pressure decreases to 100 kPa. What mass of gas was removed?	8

Module -5

19	a)	Give the statement of Amagat's Law of partial volume for analysis of gas mixtures. Clearly define the terms used in the statements. Write the mathematical equation.	5
	b)	The products of combustion from a diesel engine have the following molal analysis: CO_2 = 10.2%, CO = 0.4%, H_2O = 14.3%, O_2 = 1.9% and N_2 = 73.2%. Determine the mass fraction of each component. What is the molar mass of the mixture?	9
20	a)	Derive energy equation in the form $du = c_v dT + \left\{T\left(\frac{\partial p}{\partial T}\right)_v - p\right\}dv$	8
	b)	A gas obeys *p(v-b) = RT*, where *b* is a positive constant. Find the expression for its Joule-Thomson coefficient. Can this gas be cooled effectively by throttling?	6

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