# Pandit Deendayal Petroleum University

# School of Technology

M.Sc. Course					SC 512T - Thermodynamics and Statistical Mechanics						
Teaching Scheme						Examination Scheme					
L	т	D	C	Hrs/Wook	Theory			Practical		Total	
		F			MS	ES	IA	LW	LE/Viva	Marks	
3	1	0	0	4	25	50	25			100	

#### **COURSE OBJECTIVES**

- **I** To explain the general laws of thermodynamics and their applications to pure and special systems.
- To demonstrates postulates of statistical mechanics and introduce students to quantum statistical mechanics, which is part of the foundation of several branches of physics and has many applications.
- It o enable students to understand the physics of phase transition and employ the concepts for applications.
- I To introduce with transport phenomenon and non-equilibrium systems.

#### UNIT 1: APPLICATION OF THERMODYNAMICS TO PURE SUBSTANCES AND SPECIAL SYSTEMS

Laws of thermodynamics and their consequences. Thermodynamic potentials, Maxwell's equation, TdS equation, Theory of heat capacity, Gruneisen's equation, Joule Kelvin effect, Surface film, Reversible cell, The piezoelectric effect, Dielectrics, Thermoelectric Phenomenon, and Paramagnetic Solids.

#### **UNIT 2: QUANTUM STATISTICAL MECHANICS**

Indistinguishable particles in quantum mechanics. Bosons and Fermions. Bose-Einstein statistics, ideal Bose gas, photons, Bose-Einstein condensation. Fermi-Dirac statistics, Fermi energy, ideal Fermi gas. Density operator, Quantum Liouville equation. Pure and mixed states.

#### UNIT 3: CRITICAL PHENOMENA AND PHASE TRANSITIONS

Phase transitions, Condition for phase equilibrium, First order phase transition, Clausius - Clayperon equation, Scaling hypothesis, The Critical exponent, Second order phase transition, Co - operative processes, Curie - Weiss theory of Magnetic transition, Ising Model, Ising Model in zeroth approximation, Exact solution of one dimensional Ising Model, Order parameters, Renormalization, Landau theory.

## UNIT 4 TRANSPORT PHENOMENON AND NON EQUILIBRIUM STATISTICAL MECHANICS

Scattering cross section, Effusion and Diffusion equation, Random walk and Brownian motion, Boltzmann equation, Linear response theory, Fokker-Planck and Langevin equations.

#### **COURSE OUTCOMES**

## After completion of this course students will be able to;

- CO1: State and express basic terms of Thermodynamics and statistical mechanics
- CO2: Apply foundation of thermodynamics to the several branches of physics and recognize its applications
- CO3: Appraise postulates of quantum statistical mechanics
- CO4: Recognize properties of quantum gases, other condensed matter systems in equilibrium
- CO5: Formulate and solve the problems of phase transitions

CO6: Review Transport Phenomenon and Non Equilibrium Statistical Mechanics

#### TEXT/REFERENCE BOOK

- 1. Thermodynamics: An Engineering Approach by Michael A. Boles and Yungus A. Cengel
- 2. Heat and Thermodynamics by Mark W. Zemansky
- 3. Fundamentals of Statistical Mechanics by B. B. Laud
- 4. Statistical Mechanics by Kerson Huang
- 5. Statistical Mechanics and Properties of Matter by E.S. Raja Gopal
- 6. Statistical Mechanics An Introduction by Evelyn Guha
- 7. Statistical Mechanics by R.K. Patharia
- 8. Funadamentals of Statistical Mechanics by F. Reif
- 9. Statistical Mechanics by R.K. Srivastava & J.Ashokm
- 10. Fundamentals of Statistical Mechanics by John D. Walecka
- 11. Landau and Lifshitz, Landau theory of phase transition Statistical Physics

#### **Course Delivery Methods**

# 15 Hrs.

15 Hrs.

# 15 Hrs.

# 15 Hrs.

## Max. 60 Hrs.

Lecture by use of boards/LCD projectors/OHP projectors	Yes
Tutorials/Assignments	Yes
Seminars	No
Mini projects/Projects	No
Laboratory experiments/teaching aids	No
Industrial/guest lectures	No
Industrial visits/in-plant training	No
Self- learning such as use of NPTEL materials and internets	Yes
Simulation	No

# Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

#### **Direct Assessment:**

	Assessment Tool	% Contribution during CO	Maximum Marks	Exam
		Assessment		Duration
Internal	Assignment	10 %	-	-
Assessment	Quiz	15%	-	-
Examiantion	Mid Semester Examination	25%	50	2 hours
	End Semester Examination	50%	100	3 hours

Assessment Components	CO1	CO2	CO3	CO4	CO5	CO6
Mid Sem Examination Marks	YES	YES	Yes	NO	NO	NO
End Sem Examination Marks	YES	YES	YES	YES	YES	YES
Assignment	YES	YES	YES	YES	YES	YES

# Indirect Assessment :

1. Student Feedback on Faculty

2. Student Feedback on Course Outcome

# Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Programme Outcome					
course outcome	PO1	PO2	PO3	PO4	PO5	
CO1: State and express basic terms of Thermodynamics and statistical mechanics	н	н	м	L	М	
CO2: Apply foundation of thermodynamics to the several branches of physics and recognize its applications	L	н	н	М	М	
CO3: Appraise postulates of quantum statistical mechanics	М	н	н	L	М	
CO4: Recognize properties of quantum gases, other condensed matter systems in equilibrium	м	н	н	L	М	
CO5: Formulate and solve the problems of phase transitions	н	М	н	М	L	
CO6: Review Transport Phenomenon and Non Equilibrium Statistical Mechanics	н	Н	м	м	L	

# Lecture wise Lesson planning Details:

Week No.	Lect. No.	Unit No.	Topics To be covered	CO Mapped	Remarks by Faculty
	1		Laws of thermodynamics and their consequences	CO1, CO2	
1	2		Thermodynamic potentials, Maxwell's equation	CO1, CO2	
1	3		TdS equations	CO1, CO2	
	4		Tutorial	CO1, CO2	
	5		Theory of heat capacity	CO1, CO2	
2	6		Gruneisen's equation	CO1, CO2	
2	7	1	Joule Kelvin effect,	CO1, CO2	
	8		Tutorial	CO1, CO2	
	9		Joule Kelvin effect,	CO1, CO2	
2	10		Surface film	CO1, CO2	
5	11		Reversible cell	CO1, CO2	
	12		Tutorial	CO1, CO2	
4	13		The piezoelectric effect, Dielectrics	CO1, CO2	

15Paramagnetic SolidsCO1, CO217TutorialCO1, CO218Bosna and FermionsCO3, CO420Bosna and FermionsCO3, CO420Control and Control		14		Thermoelectric Phenomenon	CO1, CO2	
16     Tutorial     C01, C02       18     Indistinguishable partices in quantum mechanics     C03, C04       19     Bosons and Fermions     C03, C04       19     Bose-Einstein statistics     C03, C04       21     Bose-Einstein statistics     C03, C04       22     2     Fermi-Dira statistics     C03, C04       24     Bose-Einstein condensation     C03, C04       24     Fermi energy     C03, C04       25     Fermi energy     C03, C04       26     Itermi para     C03, C04       27     Density operator     C03, C04       28     Quantum Liouville equation.     C03, C04       30     Pure and mixed states     C03, C04       31     Tutorial     C03, C04       32     Fermi energy     C03, C04       33     Tutorial     C03, C04       34     So     Pure and mixed states       35     Second order phase transition.     C01, C05       36     Curie - Weiss theory of Magnetic transition.     C01, C05       36     Curie - Weiss theory o		15		Paramagnetic Solids	CO1, CO2	
17 18Indistinguishable particles in quantum mechanicsCO3, CO41919Bose-Einstein statisticsCO3, CO42020TutorialCO3, CO42122Fermi-Dirac statisticsCO3, CO42224Fermi-Dirac statisticsCO3, CO42325Fermi-Dirac statisticsCO3, CO42425Fermi energyCO3, CO4257CO3, CO4CO4, CO426TutorialCO3, CO42728Fermi energyCO3, CO4287CO3, CO4CO4, CO4317CO3, CO4CO3, CO432Pure and mixed statesCO3, CO431Phase transitions, First order phase transitionCO3, CO433Condition for phase equilibrium, Clausius - Clayperon equationCO3, CO436Curie - Weiss theory of Magnetic transitionCO536Curie - Weiss theory of Magnetic transitionCO5373Curie - Weiss theory of Magnetic transitionCO538Second order phase transitionCO3, CO51039Landau theoryCO539Sattering cross sectionCO640TutorialCO51142Sattering cross sectionCO612Filsion and Diffusion equationCO613Filsion and Diffusion equationCO614TutorialCO615Filsion and Diffusion equationCO616Sattering cross section <td></td> <td>16</td> <td></td> <td>Tutorial</td> <td>CO1, CO2</td> <td></td>		16		Tutorial	CO1, CO2	
18     Bosons and Fermions     CO3, CO4       19     Bose-Einstein statistics     CO3, CO4       20     Tutorial     CO3, CO4       21     Bose-Einstein condensation     CO3, CO4       22     2     Fermi-Dira statistics     CO3, CO4       23     2     Fermi-Dira statistics     CO3, CO4       24     Fermi-Dira statistics     CO3, CO4       25     Fermi energy     CO3, CO4       26     Tetorial     CO3, CO4       27     Density operator     CO3, CO4       28     Outoral mixed states     CO3, CO4       30     Pure and mixed states     CO3, CO4       31     Pure and mixed states     CO3, CO4       31     Forma traitions, First order phase transition     CO3, CO4       33     Condition for phase equilbrium, Clausius - Clayperon equation     CO1, CO5       35     Second order phase transition, Co- operative processes,     CO1, CO5       36     Sing Model     CO3, CO4       37     Second order phase transition, Co- operative processes,     CO1, CO5       38     Sing Mo	-	17	-	Indistinguishable particles in quantum mechanics	CO3, CO4	
319800-Einstein statisticsCO3, CO4621TutorialCO3, CO47222Fermi-Dirac statisticsCO3, CO472525Fermi-Dirac statisticsCO3, CO4726TutorialCO3, CO4726Fermi-Dirac statisticsCO3, CO4829Fermi-Dirac statisticsCO3, CO430Pure and mixed statesCO3, CO4931Pure and mixed statesCO3, CO431726TutorialCO3, CO4337Condition for phase transition, CO3, CO4Pure and mixed states337Scaling hypothesis, First order phase transitionCO3, CO4938Condition for phase quilibrium, Clausus - ClayperonCO1, CO536Scaling hypothesis, The critical exponent,CO53738Curie - Weiss theory of Magnetic transitionCO3, CO41043Co1, CO5Scaling hypothesis, The critical exponent,CO51142Landau theoryCO544Cod for of an emensional Ising ModelCO3, CO51142Scattering cross sectionCO643Scattering cross sectionCO614Scattering cross sectionCO6151Random walk and Brownian motionCO6161TutorialCO617TutorialCO6180Rohoma and pervine quationsCO619Ferker-Planck and Langevin equationsCO6 <td>18</td> <td>Bosons and Fermions</td> <td>CO3, CO4</td> <td></td>		18		Bosons and Fermions	CO3, CO4	
20 Tutorial CO3, CO4   1 Ideal Bose gas, Photons CO3, CO4   23 2 Fermi-Dirac statistics CO3, CO4   24 Tutorial CO3, CO4   25 Fermi-Dirac statistics CO3, CO4   26 Ideal Fermi gas CO3, CO4   27 Z Ideal Fermi gas CO3, CO4   28 Tutorial CO3, CO4   29 Quantum liouville equation. CO3, CO4   30 Pure and mixed states CO3, CO4   31 Phase transitions, First order phase transition CO3, CO4   33 Phase transition, CO-operative co3, CO4 Condition for phase equilibrium, Clausus - Clayperon equation   34 Scaling hypothesis, The Critical exponent, cos CO5   35 Scaling hypothesis, The Critical exponent, cos CO5   36 Scaling hypothesis, The Critical exponent, cos CO5   36 Scaling hypothesis, The Critical exponent, cos CO5   36 Scaling hypothesis, The Critical exponent, cos CO5   37 S Curie - Weiss theory of Magnetic transition CO5   38 Sing Model CO3, CO5   39 Ising Model CO3, CO5   41 Cordition for edimensional lsing Model CO3,	5	19		Bose-Einstein statistics	CO3, CO4	
1     1		20		Tutorial	CO3, CO4	
6     22     2     Bose-Einstein condensation     CO3, CO4       24		21	1	Ideal Bose gas, Photons	CO3, CO4	
b     23     2     Fermi-Dirac statistics     CO3, CO4       24     Tutorial     CO3, CO4       25     Fermi energy     CO3, CO4       26     ideal Fermi aga     CO3, CO4       27     Z8     Fermi energy     CO3, CO4       28     7     Z6     Ideal Fermi gas     CO3, CO4       28     29     Quantum licoville equation.     CO3, CO4       30     Pure and mixed states     CO3, CO4       31     Phase transitions, First order phase transition     CO3, CO4       32     Tutorial     CO3, CO4       33     Pure and mixed states     CO3, CO4       33     Condition for phase equilibrium, Clausius - Clayperon equation     CO1, CO5       33     Scaling hypothesis, The Critical exponent, processes, processes, To Tutorial     CO3, CO5       10     38     Ising Model     CO3, CO5       39     Ising Model in zeroth approximation     CO3, CO5       11     42     Curie - Weiss theory of Magnetic transition     CO3, CO5       12     43     Ising Model in zeroth approximation     CO3, CO5 </td <td></td> <td>22</td> <td>1</td> <td>Bose-Einstein condensation</td> <td>CO3, CO4</td> <td></td>		22	1	Bose-Einstein condensation	CO3, CO4	
24     Tutorial     CO3, CO4       7     26     Fermi energy     CO3, CO4       27     26     ideal Fermi gas     CO3, CO4       28     Tutorial     CO3, CO4       28     Quantum Liouville equation.     CO3, CO4       30     Pure and mixed states     CO3, CO4       31     Guantum Liouville equation.     CO3, CO4       32     Tutorial     CO3, CO4       33     Phase transitions, First order phase transition     CO3, CO4       32     Tutorial     CO3, CO4       33     Second order phase transition, Clasus - Clayperon equation     CO1, CO5       36     Scaling hyoothesis, The Critical exponent, CO3, CO5     CO3, CO5       37     3     Curie - Weiss theory of Magnetic transition     CO3, CO5       38     Tutorial     CO1, CO5     Second order phase transition     CO3, CO5       39     Gurie - Weiss theory of Magnetic transition     CO3, CO5     CO3, CO5       40     Tutorial     CO3, CO5     CO3, CO5       41     Co3     Co3     CO3     CO3     CO5 <td>6</td> <td>23</td> <td>2</td> <td>Fermi-Dirac statistics</td> <td>CO3. CO4</td> <td></td>	6	23	2	Fermi-Dirac statistics	CO3. CO4	
25     Fermi energy     CO3, CO4       27     Density operator     CO3, CO4       28     Tutorial     CO3, CO4       30     Pues and mixed states     CO3, CO4       31     Phase transitions, First order phase transition     CO3, CO4       31     Phase transitions, First order phase transition     CO3, CO4       32     Tutorial     CO3, CO4       33     Phase transitions, First order phase transition     CO3, CO4       33     Scaling hypothesis, The Critical exponent, equation     CO1, CO5       36     Scaling hypothesis, The Critical exponent, eprocesses,     CO1, CO5       37     Curie - Weiss theory of Magnetic transition     CO3       38     Curie - Weiss theory of Magnetic transition     CO3, CO5       40     Tutorial     CO3, CO5       41     Curie - Weiss theory of Magnetic transition     CO3, CO5       41     Curie - Weiss theory of Magnetic transition     CO3, CO5       43     Tutorial     CO5       44     Tutorial     CO5       50     Scaling fryothesin equation     CO6       51		24		Tutorial	CO3, CO4	
7     26 27 27 28     ideal Fermi gas     C03, C04       28     Tutorial     C03, C04       28     Tutorial     C03, C04       29     Quantum Lioville equation.     C03, C04       30     Pure and mixed states     C03, C04       31     Pure and mixed states     C03, C04       32     Tutorial     C03, C04       31     Phase transitions, First order phase transition     C03, C04       32     Tutorial     C03, C04       33     Scaling hypothesis, The Critical exponent, Scaling hypothesis, The Critical exponent, equation     C01, C05       35     Scaling hypothesis, The Critical exponent, Scaling Model     C03, C05       36     Tutorial     C01, C05       37     3     Curie - Weiss theory of Magnetic transition     C05       38     Scaling Model     C03, C05     Scaling Model       40     Tutorial     C03, C05     Scaling Model       41     Exact solution of one dimensional Ising Model     C03, C05       42     Order parameters, Renormalization     C05       44     Tutorial     C05 </td <td></td> <td>25</td> <td></td> <td>Fermi energy</td> <td>CO3. CO4</td> <td></td>		25		Fermi energy	CO3. CO4	
7     27     Density operator     C03, C04       28     Tutorial     C03, C04       29     Quantum Liouville equation.     C03, C04       30     Pure and mixed states     C03, C04       31     Phase transitions, First order phase transition     C03, C04       32     Tutorial     C03, C04       32     Tutorial     C03, C04       32     First order phase transition     C03, C04       33     Condition for phase equilibrium, Clausius - Clayperon equation     C01, C05       36     Scaling hypothesis, The Critical exponent,     C05       36     Curie - Weiss theory of Magnetic transition     C03, C05       37     Second order phase transition     C03, C05       38     Curie - Weiss theory of Magnetic transition     C03, C05       39     Ising Model     C03, C05     Ising Model       40     Tutorial     C03, C05       41     Exact solution of one dimensional Ising Model     C03, C05       41     Exact solution of one dimensional Ising Model     C03, C05       42     Gradau theory     C05		26		ideal Fermi gas	CO3. CO4	
1     28     Tutorial     CO3, CO4       29     Quantum Liouville equation.     CO3, CO4       30     Pure and mixed states     CO3, CO4       31     Phase transitions, First order phase transition     CO3, CO4       32     Tutorial     CO3, CO4       32     Tutorial     CO3, CO4       33     Phase transitions, First order phase transition     CO3, CO4       34     Scaling hypothesis, The Critical exponent, equation     CO1, CO5       36     Scaling hypothesis, The Critical exponent, processes,     CO1, CO5       37     3     Curie - Weiss theory of Magnetic transition     CO3, CO5       38     Ising Model     CO3, CO5       40     Tutorial     CO3, CO5       41     Exact solution of one dimensional Ising Model     CO3, CO5       41     Exact solution of one dimensional Ising Model     CO3, CO5       43     Landau theory     CO5       44     Tutorial     CO6       45     Landau theory     CO5       46     Scattering cross section     CO6       51     Fifusion an	7	27		Density operator		
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934Scaling hypothesis, The Critical exponent, processes, TutorialCOS3636Second order phase transition, Co - operative processes, TutorialCO1, COS3738Curie - Weiss theory of Magnetic transitionCOS3940CO3, COS40Sing ModelCO3, COS40TutorialCO3, COS4142CO3, COS43Corie - weiss theory of magnetic transitionCO3, COS44TutorialCO3, COS44Corder parameters, RenormalizationCOS44Corder parameters, RenormalizationCOS44CuroialCOS44Scattering cross sectionCO647Scattering cross sectionCO648TutorialCO651SinEffusion and Diffusion equationCO651Scattering cross sectionCO651Scattering cross sectionCO651Scattering cross sectionCO652Handom walk and Brownian motionCO654Boltzmann equationCO655Boltzmann equationCO656TutorialCO657Linear response theoryCO658Fokker-Planck and Langevin equationsCO658Fokker-Planck and Langevin equationsCO658Fokker-Planck and Langevin equationsCO658Fokker-Planck and Langevin equationsCO659Fokker-Planck and Langevin equationsCO6		33		Condition for phase equilibrium, Clausius - Clayperon equation	CO1, CO5	
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37373Curie - Weiss theory of Magnetic transitionCO53839Ising ModelCO3, CO54040TutorialCO3, CO54142CO3, CO543Corder parameters, RenormalizationCO544CO5Cos44CosCos44CosCos44CosCos44CosCos44CosCos44CosCos44CosCos44CosCos44CosCos44CosCos44CosCos44CosCos44CosCos44CosCos44CosCos45Cardering cross sectionCo647Scattering cross sectionCo648Effusion and Diffusion equationCo651SoEffusion and Diffusion equationCo652CosTutorialCo653SoSoltzmann equationCo654Boltzmann equationCo6Co656CutorialCo658SoFokker-Planck and Langevin equationsCO650Fokker-Planck and Langevin equationsCO656Fokker-Planck and Langevin equationsCO657Linear response theoryCO658Fokker-Planck and Langevin equationsCO650Fokker-Planck and Langevin equations<		36		Tutorial	CO1, CO5	
38     38     Ising Model     CO3, CO5       39     40     Ising Model in zeroth approximation     CO3, CO5       40     Tutorial     CO3, CO5     CO3, CO5       11     42     CO3, CO5     CO3, CO5       44     CO4     CO5       44     Tutorial     CO5       44     Tutorial     CO5       44     Scattering cross section     CO6       47     Scattering cross section     CO6       48     Tutorial     CO6       50     Scattering cross section     CO6       51     Scattering cross section     CO6       52     Random walk and Brownian motion     CO6       51     Random walk and Brownian motion     CO6       56     Tutorial     CO6       56     Scattering response theory     CO6       58     Fokk		37	3	Curie - Weiss theory of Magnetic transition	CO5	
1039 40Ising Model in zeroth approximationCO3, CO51140TutorialCO3, CO51142Order parameters, RenormalizationCO543Landau theoryCO544TutorialCO545Landau theoryCO546Scattering cross sectionCO647Scattering cross sectionCO648TutorialCO648TutorialCO650S1Effusion and Diffusion equationCO651S2Fandom walk and Brownian motionCO652S4Boltzmann equationCO656TutorialCO657Linear response theoryCO658Fokker-Planck and Langevin equationsCO6Fokker-Planck and Langevin equationsCO6Fokker-Planck and Langevin equationsCO6	10	38		Ising Model	CO3, CO5	
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4142114243		40		Tutorial	CO3, CO5	
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