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**According to New Revised Credit System Syllabus**

Second Year Degree Course In  
MECHANICAL, MECHANICAL SANDWICH &  
AUTOMOBILE ENGINEERING (Sem - I)

# THERMODYNAMICS



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Dr. S. N. SAPALI  
Dr. S. V. DINGARE  
Dr. S. S. KORE  
S. S. GHORPADE

**A TEXT BOOK OF**

# **THERMODYNAMICS**

**FOR  
SEMESTER - I**

**SECOND YEAR DEGREE COURSE IN MECHANICAL,  
MECHANICAL SANDWICH & AUTOMOBILE ENGINEERING**

**Strictly According to New Revised Credit System Syllabus  
of Savitribai Phule Pune University**

**(w.e.f June 2016)**

**Dr. S. N. SAPALI**

B.E., M.E. (Mech.) Ph.D. (IIT Kharagpur)  
Professor & Head, Mech. Engg. Deptt.  
College of Engineering (COEP),  
Pune.

**Dr. S. V. DINGARE**

B.E., M.E., Ph.D (Mech.)  
Professor, Mech. Engg. Deptt.  
MIT College of Engineering,  
Kothrud Pune.

**Dr. S. S. KORE**

B.E., M.E., Ph.D (Mech.)  
Associate Professor & Head  
Mech. Engg. Deptt.  
Sinhgad Academy of Engineering,  
Kondhwa (Bk), Pune.

**Dr. S. S. GHORPADE**

B.E., M.E. (Mech.)  
Assistant Professor,  
Mech. Engg. Deptt.  
Sinhgad Academy of Engineering,  
Kondhwa (Bk), Pune.

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1311, Kasbapeth, Pune – 411011.

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Phone (020) 24577245

Email : niralipune@pragationline.com

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Email : bharatsavla@yahoo.com

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## PREFACE TO THE SECOND EDITION

We are glad and excited to announce that the First Edition of this book received an overwhelming response from the engineering student community, compelling us to release its **Second Edition** within a very short period of time.

This thoroughly revised **Second Edition** has been updated with additional matter, many solved problems, including solutions to Numerous Exercises and University Question Papers (December 2013 to May 2017) for practice.

Special care has been taken to maintain high degree of accuracy in the theory and numericals throughout the book.

We take this opportunity to express our sincere thanks to Dineshbhai Furia of Nirali Prakashan, a reputed pioneer in the publication field. Our special thanks to Jignesh Furia for their effective cooperation and great care in bringing out this revised edition. We also appreciate the efforts of M. P. Munde and the entire staff of Engineering Books Deptt. of Nirali Prakashan namely Mrs. Deepali Lachake (Co-ordinator) for bringing this book to the students in a timely manner.

We sincerely hope that this "**Second Edition**" will also be warmly received by all concerned as in the past.

Valuable suggestions from our esteemed readers to improve the book are most welcome and highly appreciated.

**Pune**

**Authors**

## PREFACE

It gives us great pleasure in publishing this text book on "**Thermodynamics**" for the Students of Second Year Degree Course in Mechanical and Automobile Engineering. This book is strictly written According to New Revised Credit System Syllabus of Savitribai Phule Pune University (2015 Pattern).

As per the policy of the University, Engineering Syllabi is revised every five years. Last revision was in the year 2012. New revision is coming little earlier, as university has introduced **Online** system of examination from year 2012.

As per the New Credit System, the **In Sem (Online - 50 Marks) Examinations** (Combined Phase-I and Phase-II) will be conducted based on first, second, third and fourth units. The **Online** examinations will have objective types of questions with multiple choices. **End Semester Examination (Theory Paper 50 Marks)** will be based on all the six units and that will be conducted in traditional way and the theory course will have 4 credits.

Authors have tried to introduce the subject to the average students, with a large number of solved examples. The subject matter has been developed in a logical and coherent manner with neat illustrations along with a fairly large number of solved examples and exercises. Answers to many unsolved numerical problems are also given.

### **The Main Objectives of this Text are :**

- To cover the basic principles of thermodynamics.
- To develop a very good understanding of the subject matter.
- To give practice to solve the numerical examples in thermodynamics.
- To give practice to solve the multiple choice questions in the subject.

**We have given Free Separate book of Multiple Choice Questions (MCQ's) which will be very useful to the students, especially for Online Examinations.**

We take this opportunity to express our sincere thanks to Shri. Dineshbhai Furia, Shri. Jignesh Furia, Mrs. Nirali Verma and Shri. M. P. Munde and entire team of Nirali Prakashan namely Mrs. Deepali Lachake (Co-ordinator), who really have taken keen interest and untiring efforts in publishing this text.

Finally, we express our gratitude to our family members for their continuous support and encouragement, thanks to all.

We have no doubt that like our earlier texts, student's community will respond favourably to this new venture.

The advice and suggestions of our esteemed readers to improve the text are most welcomed, and will be highly appreciated.

**23 June 2016**

**Pune**

**Authors**

# SYLLABUS

## **Unit I : Laws of Thermodynamics [6 Hrs]**

Introduction of thermodynamics, Review of basic definitions, Zeroth law of thermodynamics, Macro and Microscopic Approach, State Postulate, State, Process and Thermodynamic Cycles, First law of thermodynamics, Joules experiment, Applications of first law to flow and non flow processes and cycles. Steady flow energy equation and its application to different devices. Equivalence of Clausius and Kelvin Planck Statement, PMM I and II, Concept of Reversibility and Irreversibility.

## **Unit II : Entropy [4 Hrs]**

Entropy as a property, Clausius inequality, Principle of increase of Entropy, Change of entropy for an ideal gas and pure substance.

### **Ideal Gas [6 Hrs]**

**Ideal Gas definition Gas Laws:** Boyle's law, Charle's law, Avagadro's Law, Equation of State, Ideal Gas constant and Universal Gas constant, Ideal gas processes- on P-V and T-S diagrams Constant Pressure, Constant Volume, Isothermal, Adiabatic, Polytropic, Throttling Processes, Calculations of heat transfer, work done, internal energy. Change in entropy, enthalpy.

## **Unit III : Thermodynamic Cycles [6 Hrs]**

**Gas Power Cycles:** Air Standard Cycle, Efficiency and Mean Effective Pressure, Carnot Cycle, Otto Cycle, Diesel cycle, Dual cycle, Comparison of cycles, Brayton cycle,

**Gas Refrigeration Cycle:** Reversed Carnot, Bell Coleman Cycle.

### **Availability [4 Hrs]**

Available and unavailable energy, concept of availability, availability of heat source at constant temperature and variable temperature, Availability of non flow and steady flow systems, Helmholtz and Gibbs function, irreversibility and second law efficiency.

## **Unit IV : Properties of Pure Substances [5 Hrs]**

Formation of steam, Phase changes, Properties of steam, Use of Steam Tables, Study of P-v, T-s and Mollier diagram for steam, Dryness fraction and its determination, Study of steam calorimeters (Barrel, Separating, Throttling and combined)

Non-flow and Steady flow vapour processes, Change of properties, Work and heat transfer.

### **Thermodynamic Vapour Cycle [5 Hrs]**

**Vapour Power Cycles:** Carnot cycle, Rankine cycle, Comparison of Carnot cycle and Rankine cycle, Efficiency of Rankine cycle, Relative efficiency, Effect of superheat, boiler and condenser pressure on performance of Rankine cycle, **Vapour Refrigeration Cycles:** Reversed Carnot Vapor Cycle, Vapor Compression Cycle and representation of cycle on P-h and T-s diagram, Refrigerating effect, Compressor power and COP estimation **(Numerical treatment using R134a only and enthalpy Cp, Cv data should be provided in tabulated form).**

## **Unit V : Steam Generators [6 Hrs]**

Introduction to fuels, Theoretical amount of Oxygen / Air required for combustion. Stoichiometric Air: Fuel ratio, Excess air, lean and rich mixtures, Stoichiometric A: F ratio for petrol **(No Numerical Treatment on fuels and combustion, only basic definitions and terminologies to be covered).**

Classification, Constructional details of low pressure boilers, Features of high pressure (power) boilers, Introduction to IBR, Boiler performance calculations-Equivalent evaporation, Boiler efficiency Energy balance, Boiler draught (natural draught numerical only).

## **Unit VI : Psychrometry [6 Hrs]**

Psychrometry and Psychrometric Properties, Basic Terminologies, Psychrometric Relations, Psychrometric Chart, Psychrometric Processes, Thermodynamics of Human Body, Comfort Conditions **(Numerical treatment using Psychrometric chart only).**

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## LAWS OF THERMODYNAMICS

### 1.1 INTRODUCTION

Thermodynamics is a science that deals with matter, energy and interactions between matter and energy.

The subject of thermodynamics is based essentially on three main concepts, these are

- **Energy**, is an idea central to the development of all branches of science and engineering. A fundamental postulate of thermodynamics is that matter has energy (which can be in several forms) and energy is conserved.
- **Thermodynamic Equilibrium**; a state which every isolated system with no internal constraints eventually attains.
- **Entropy**; which determines whether a specified type of the change can occur or not.

### 1.2 SCOPE OF THERMODYNAMICS

Every engineering activity involves an interaction between energy and matter, thus it is hard to imagine an area which does not relate to thermodynamics in some respect. Therefore, a good understanding of thermodynamic principles has been an essential part of engineering education.

One does not need to go very far to see some application areas of thermodynamics. These areas are where one lives. Many household utensils and appliances are designed, by using thermodynamic principles. For example, electric heaters, LPG stove, heating and air conditioning systems, the refrigerator, pressure cooker, water heater, shower, electric iron. On large scale, thermodynamics plays a major part in the design and analysis of automotive engines, rockets, jet engines, and conventional power plants (thermal power plants) and also nuclear power plants. At this stage, it is essential to mention that human body is an interesting application area of thermodynamics.

Under thermodynamics, we study the working and performance of (i) Conventional or nuclear power plant, (ii) Compression Ignition (C.I.) and Spark Ignition (S.I.) engines, (iii) Gas turbines, (iv) Steam turbines, (v) Refrigerators, (vi) Air conditioners, (vii) Air compressors, (viii) Refrigerant compressors, (ix) Pumps, etc.

## 1.3 BASIC DEFINITIONS

### 1.3.1 Working Substance

In heat engine, a fluid is used to receive heat, expand and produce work output. In refrigerators and heat pumps, a fluid is used to receive heat at a low temperature and reject at higher temperature. Such a fluid with essential properties is known as a working substance.

A working substance absorbs heat and rejects heat. Working substance does work or work is done on it. It is compressed or expanded, heated or cooled so that the desired energy transfer is achieved.

Examples of working substances are: air in an air compressor, water in hydraulic turbines, air and fuel mixture in gas turbines and I. C. engines, steam in a steam power plant, carbon dioxide or water in nuclear power plant.

#### Pure Substance

This has a homogeneous and invariable chemical composition, even if the substance changes its phase from solid to liquid or liquid to vapour.

Water is a pure substance; the chemical composition (formula) of  $H_2O$  will not change, even if it undergoes phase change from ice to water and water to vapour.

### 1.3.2 System

Thermodynamic system or simply a system, is defined as a quantity of matter or a region in space chosen for study. The region outside the system is called as *surroundings*. The real or imaginary surface that separates the system from its surroundings is called the *boundary*.

These are illustrated in **Fig. 1.1**.

The boundary of a system can be fixed or movable.

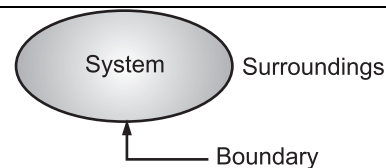
#### Classification of Systems:

(i) System may be classified as closed, open and isolated.

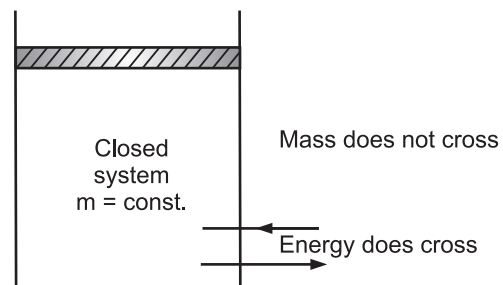
##### (a) Closed System (Non-flow system):

It consists of fixed amount of mass and no mass can cross its boundary. That is, no mass can enter or leave a closed system as shown in **Fig. 1.2**. But energy, in the form of heat or work can cross the boundary and the volume of a closed system does not have to be fixed.

It consists of fixed mass while volume changes. Boundaries of such system are real and moving. For example, pressure cooker, stirling cryogenerator.



**Fig. 1.1: System, surroundings and boundary**



**Fig. 1.2: Mass cannot cross the boundaries of a closed system but energy can**

# A Text Book Of Thermodynamics



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Author : **Dr. S. N. Sapali, Dr. S. V. Dingare, Dr. S. S. Kore, Dr. S. S. Ghorpade**

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