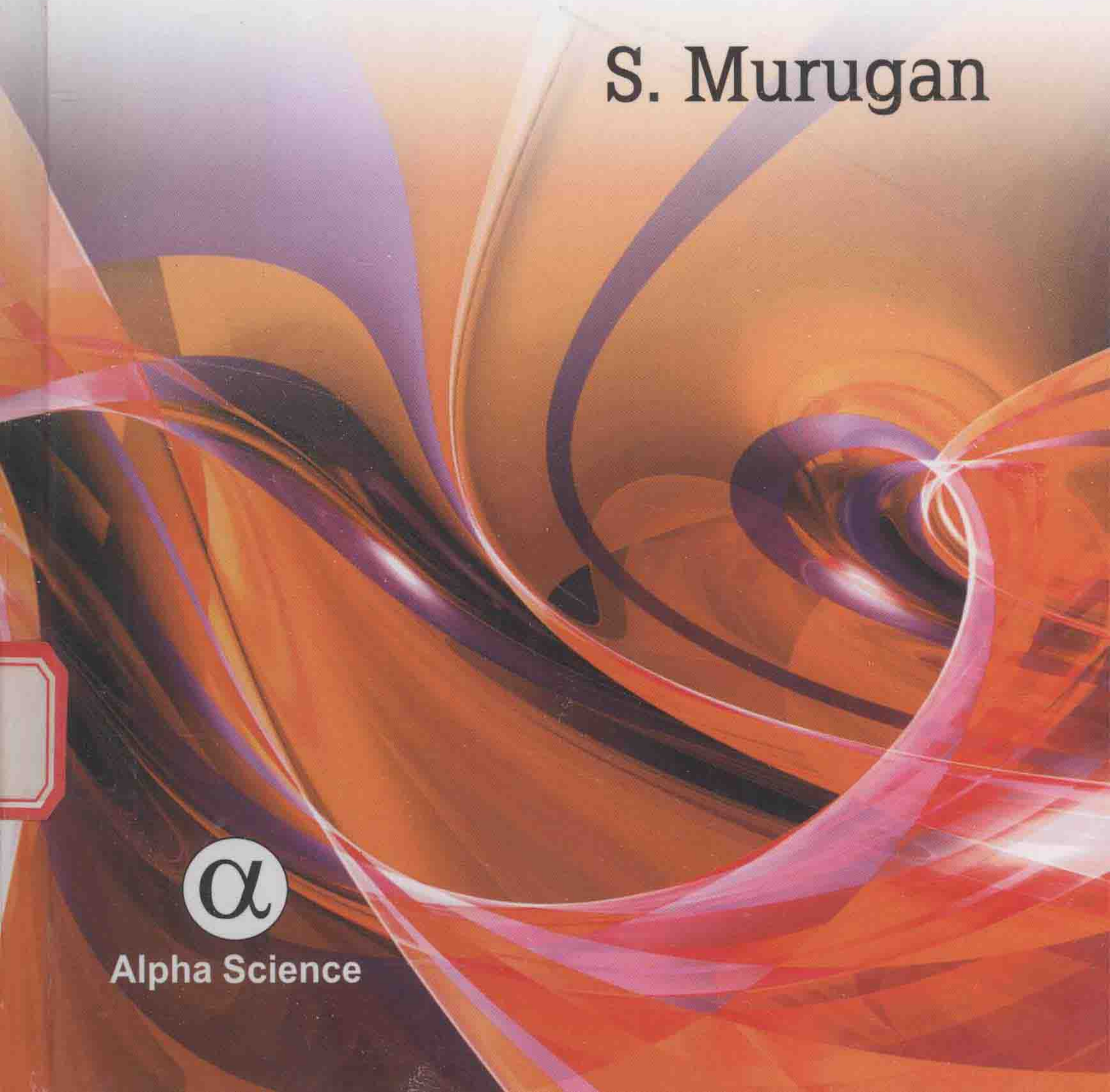
Engineering Thermodynamics

S. Murugan



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PREFACE

I am pleased to introduce the first edition of the textbook titled "Engineering Thermodynamics" to the students who have opted for "Engineering Thermodynamics" in their B.Tech Degree or AMIE as a part of their course. Thermodynamics is one of the important subjects in the courses of B.E/B.Tech Mechanical Engineering, Electrical and Electronics Engineering, Chemical Engineering, and Instrumentation Engineering, or in AMIE. The subject "Thermodynamics" requires special attention by any student as it involves both theory and analysis. Many students have an aversion to learn the subject as it has many concepts that make it a little complex. The subject is a foundation for their future, but, every student who learns it faces difficulty in understanding it thoroughly and deeply. Keeping this in mind, this book is written to make the students understand the subject easily. Although "Thermodynamics" is taught in Physics and Chemistry at the School level, the subject "Engineering Thermodynamics" is quite different for engineering students, as they apply the concepts of Thermodynamics in various applications, such as calculating engine efficiency, and heat or work values in thermal systems, such as boilers, turbines, compressors etc. The subject also deals with energy interactions in various systems, such as refrigeration and air conditioning systems.

After interaction and discussion with many readers of this subject, the author developed an interest to write this book. In each and every chapter, the necessary illustrations and examples are given, in areas where one may find some difficulty in understanding the theory. Solved and unsolved problems are given in each and every chapter, so that the readers will be able to practise different kinds of problems. This will enable the readers to solve similar kind of problems in their real time applications. Besides these problems, objective type and theory questions are also included at the end of each chapter. This will make the readers review and practise the subject with more confidence. This book is also useful to the readers of different categories who appear for competitive or aptitude examinations.

This book is written in an unconventional and a "Student friendly" style, so as to make any one be more confident in the subject. The contents of the book cover the syllabus framed by many of the Universities. The author believes that the book will definitely help the readers immensely. Any criticism or comments or suggestions are welcome for the improvement of the book.

S. Murugan

ACKNOWLEDGEMENTS

I would like to express my sincere thanks to Mr. N. K. Mehra, Publisher and Managing Director, Narosa Publishing House Pvt. Ltd., New Delhi, who readily accepted to publish this book. My special thanks to all the people involved in preparation of this textbook. I would also like to register my whole hearted thanks to the Editor and reviewers for their valuable comments to improve the layout of the book. It is worth noting that without the students' feedback it is impossible to get an appreciation of the book. Every comment by the students who read and gave their suggestions, made me to take a lot of time to improve the content of the book, according to their need. It is quite difficult to succeed in any task, if there is no encouragement from one's family members. It's my pleasure in thanking my parents, wife Mrs. S. Asha and daughter Mrs. M. Geetha who gave me full support in completing this task.

S. Murugan

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UNITS AND MEASUREMENT

1.1 INTRODUCTION TO THERMODYNAMICS

The science, which deals with the analysis of various machines by quantity, which involves the transfer of energy into useful work, is called thermodynamics. Many energy conversion devices require the transfer of energy into work. Thermodynamics is applied in various thermal equipments like steam turbines, boilers, condensers, cooling towers, heat exchangers, reciprocating engines, refrigerators, air conditioners, heat pumps etc. It is also used in internal combustion engines, turbo jets and rockets etc. In all these cases, the design of the thermal equipments essentially requires an in-depth knowledge of thermodynamics. Hence, the study of engineering thermodynamics is very important in the field of engineering.

1.2 UNITS

In thermodynamics, each and every parameter is measured and the final quantity is expressed in a value or number followed by a unit. Over many years, a large number of standards have been defined for physical measurements and many systems of units have been derived. There was an attempt to simplify the language of science by the adoption of a system of units. Such a system is called the SI unit system, commonly known as the International System of Units (abbreviated SI from the French le System International units), and is used universally. This system of units was the outcome of a resolution of the 9th general conference of weights and measures (CGPM) in 1960, and from that, the establishment of a complete set of rules for units of measurement, was made.

The SI unit system has three divisions:

1. Base units
2. Derived units
3. Supplementary units.

1.2.1 Base Units

The base unit is the first division of SI units, in which seven kinds of fundamental quantities are measured. They are given in Table 1.1.

(i) **Meter (m):** It is defined as 1650 763.73 of the wavelength in vacuum of the orange-red light emitted by $^{86}_{36}K$ in the transition of $2p_{10}$ to 5 d_5.

(ii) **Kilogram (kg):** It is defined as the mass of a platinum-iridium cylinder kept at the International Bureau of weights and measures at serves near Paris, France. Originally it is equal to the mass of a cubical decimeter of water at its maximum density.

(iii) **Second (s):** It is the time spent by 9 192 631 770 cycles of radiation from hyperfine transition in Cesium, when unperturbed by the external fields.

(iv) **Ampere (A):** It is the current, which is maintained in each of two parallel wires of infinite length placed in vacuum, 1 meter apart, so as to produce a force of 2×10^{-7} newtons per meter length.

(v) **Kelvin (K):** It is the fraction of 1/273.16 of the thermodynamic temperature of the triple point of water.

(vi) **Candela (cd):** It is the luminous intensity in a given direction due to a source which emits monochromatic radiation of frequency of 540×10^{12} Hz and whose radiant intensity in that direction is 1/683 watt per steradian.

(vii) **Mole (mol):** It is defined as the amount of substance of a system, which contains as many elementary entities as there are atoms in 0.012 kg of the carbon isotope $6C_{12}$.

Table 1.1 Basic Measurements with Units

Measurable quantity	Units	Symbol
Length	Meter	m
Mass	Kilograms	kg
Time	Seconds	s
Electric current	Ampere	A
Temperature	Kelvin	K
Luminous intensity	Candela	Cd
Amount of substance	Mole	mol

1.2.2 Derived Units

The derived units are obtained from the base units. For example, the unit of density is kg/m^3, which is obtained from the base units of mass (kg) and length (m).

1.2.3 Supplementary Units

Two supplementary units are defined in SI units. 1. Radian 2. Steradian. These two units are meant for plane and solid angles respectively. They are given in Table 1.2.

(a) **Radian (rad):** It is the plane angle between two radii of a circle, which cut on the circumference of an arc equal in length to the radius.

(b) Steradian (sr): It is the solid angle, which has its vertex in the centre of a sphere, and cuts off an area of the surface of the sphere, equal to that of a square, with sides of equal length to the radius of the same sphere.

Table: 1.2 Angular Measurements with Units

Measurable quantity	Units	Symbol
Plane angle	Radian	rad
Solid angle	Steradian	sr

1.3 OTHER SYSTEMS OF UNITS

Some other systems of units are still in use. They are (i) CGS (ii) FPS (iii) MKS.

1.4 DEFINITION AND MEASUREMENT OF PROPERTIES

1.4.1 Mass and Weight

The amount of matter contained by a body is known as the mass. The basic unit of mass is the kilogram. Weight is the force exerted by gravity on the mass of a body or substance. The weight of the body varies from place to place, because the value of the constant of proportionality varies from place to place. As per Newton's second law of motion, the weight $w = 1/g_c$. mg

Where, g_c = Constant of proportionality ($g_c = 1$)

m = Mass

g = Acceleration due to gravity.

1.4.2 Force

Force is that which produces or tends to produce a change in the state of rest or of uniform motion, of a body. Newton's second law of motion states that the applied force or impressed force is directly proportional to the rate of change of momentum.

Suppose,

m = Mass of the body

u = Initial velocity of the body

v = Final velocity of the body

a = Constant acceleration

t = Time required to change the velocity from u to v

Momentum = Mass × velocity