Thermal physics

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MACMILLAN PHYSICAL SCIENCE SERIES

Thermal physics

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Preface

Thermal physics is a well-established subject. It developed from the classical thermodynamics that grew out of a study of the behaviour of heat engines in the early part of the nineteenth century, and the basic theory was virtually complete by the end of that century. However, despite its practical origins and the large number of books written about it, many students find thermal physics a 'theoretical' and difficult subject. One reason for this is that many of the concepts are rather subtle, so that the student, while able to follow the mathematics involved, is unable to appreciate the physics. Consequently, the subject appears as a vast collection of equations that lacks a structure and an outlook, and students are unable to apply the principles of thermal physics to new situations.

In this book I have tried to provide an account of the elements of thermal physics, suitable for a first introduction to the subject, that will appeal to undergraduates in physics and engineering. The treatment is based on my experience of teaching thermal physics to undergraduates in the University of London for a number of years. The subject is treated from an experimental standpoint, basic concepts are treated in some detail and, it is hoped, a clear picture is presented of the essential features and characteristics of thermal physics without making the subject appear forbidding.

SI units are used throughout this book. Some worked examples are included, as well as a number of problems for the reader to attempt. These problems form an essential part of the book and should be worked through carefully. Solutions are provided for most of the problems.

It is impossible to write a book on thermal physics without being influenced by the work of others. I am indebted to many authors and I have found the following books particularly valuable: *Heat and Thermodynamics* by M. W. Zemansky, *Elements of Classical Thermodynamics* by A. B. Pippard, *Thermal Physics* by P. C. Riedi, *Equilibrium Thermodynamics* by C. J. Adkins and *Thermal Physics* by C. P. B. Finn. I am also indebted to F. C. Frank for several stimulating conversations.

Nomenclature

A	area
a	thermal diffusivity
B	availability
B_a	applied magnetic flux density
C	heat capacity
C_p	heat capacity at constant pressure
C_v	heat capacity at constant volume
$C_{p,m}$	molar heat capacity at constant pressure
c	specific heat capacity, molecular speed, speed of light in vacuum
c_p	specific heat capacity at constant pressure
c_s	speed of sound in a gas
d	molecular separation
E	electric field strength, e.m.f., Young's modulus, irradiance within a cavity
E_p	potential energy
E_k	kinetic energy
F	Helmholtz function, Faraday's constant, load, force, form factor
G	Gibbs function
G_m	molar Gibbs function
g	specific Gibbs function, acceleration of free fall
H	enthalpy
H_a	applied magnetic field strength
H_m	molar enthalpy
h	specific enthalpy, heat transfer coefficient (surface emissivity), height, Planck's constant
I	electric current
J	Massieu function
K	bulk modulus
k	Boltzmann's constant, thermal conductivity
L	length
l	mean free path, specific latent heat
M	magnetisation

M_m	mass of one mole
m	magnetic moment, molecular mass, mass
N_A	Avogadro's constant
n	number density of molecules
p	pressure
$\hat{p}$	reduced pressure
Q	heat, quantity of heat, electric charge
q	infinitesimal quantity of heat
R	resistance, radius, radiant emittance, gas constant
r	resistance, radius, compression factor
S	entropy
S_m	molar entropy
s	specific entropy, perimeter
T	thermodynamic temperature
$\hat{T}$	reduced temperature
T^*	magnetic temperature
t	Celsius temperature, time
U	internal energy
U_m	molar internal energy
$\bar{U}$	total heat transfer coefficient
u	specific internal energy, radiant energy per unit volume
u, v, w	velocity components
V	volume
$\hat{V}$	reduced volume
V_m	molar volume
v	specific volume, fluid speed
W	work, quantity of work
W_F	flow work
w	infinitesimal quantity of work
X	generalised force
x	generalised displacement, distance, thickness
Z	stored charge, compressibility factor
α	absorptance (absorption factor), angle of rotation
β	cubic expansivity (isobaric expansivity)
γ	ratio of the principal heat capacities, electrical conductivity
η	thermal efficiency, viscosity
θ	empirical temperature, angle
μ_o	permeability of a vacuum
μ	isenthalpic Joule–Thomson coefficient
ρ	density
σ	Stefan–Boltzmann constant, specific surface free energy, molecular diameter
κ	compressibility
λ	linear expansivity, wavelength
ω	angular velocity

ϕ	magnetic flux, radiant flux, angle, isothermal Joule–Thomson coefficient
χ_m	magnetic susceptibility
τ	torque, efficiency temperature function

Dimensionless groups

(Nu)	Nusselt number
(Pr)	Prandtl number
(Re)	Reynolds number
(Gr)	Grashof number

Subscripts

l	liquid phase
g	gas phase
v	vaporisation
s	sublimation
f	fusion