INTRODUCTION TO ENGINEERING MATERIALS

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Introduction to Engineering Materials

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Third Edition

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Preface to the First Edition

Not many years ago it was possible to obtain a first degree or other qualification in engineering with no knowledge whatsoever of metallurgy or the other materials of engineering. Today it is fully accepted that a sound knowledge of the science and technology of materials is very necessary to the engineer if he is to be able efficiently to translate a design into functional 'hardware'. The selection of materials and manufacturing route is an integral part of design procedure. Because of this, materials' science and technology now feature prominently in the educational programme for all engineering technologists and technicians. Engineering, including materials' science, is also beginning to appear in the curricula of some schools.

This book was conceived against the general background of the changing patterns in engineering education, and the aim was to produce a text which dealt with the basic principles of materials science and technology in a simple, yet meaningful manner.

It is my belief that no aspect of engineering should be studied in a vacuum, but that academic studies be related to our real cost-conscious world. It is for this reason that I have included some materials' costs and a short note on the selection of materials. Although actual costs will vary from year to year, this section should be of value as it indicates the principle that any work or processing performed on a material is reflected in an increase in the cost of the material.

I wish to acknowledge the help and advice received from various individuals and organisations, and in particular to thank Professor Bob Fergusson for providing the initial stimulus for this work. I am indebted to some of my colleagues at PCL, especially Mr C. J. Beesley, Mr G. E. Drabble, and Mr M. D. Munro Mackenzie, for their assistance in reading the manuscript and suggesting improvements. I also wish to acknowledge the assistance, in the way of photographs and information, which I received from the following firms and organisations: British Aluminium Company Ltd, British Metals Sinterings Association, Bound Brook Ltd, Copper Development Association, I.C.I. Ltd (Plastics Division), International Nickel Ltd, Raleigh Industries Ltd, Sintered Products Ltd, and the Zinc Development Association. Several colleges and polytechnics provided me with question papers, and I wish to record my appreciation of their help. Finally, I am very grateful to my wife for not merely putting up with me while I was struggling with the manuscript, but for helping considerably by sustaining me with refreshment and also typing some of the manuscript.

Vernon John

1972

Preface to the Second Edition

Ten years have elapsed since this book was first published and after such a period of time an updating is necessary for any technical text. In the preparation of this edition I have attempted to satisfy two objectives; firstly to keep a basic and straightforward approach so that the text can be readily understood by students beginning their studies, and secondly to broaden the scope of the volume and so increase its suitability for degree and diploma students of both mechanical and production engineering in the later years of their courses.

When preparing a new edition of a book an author is torn between the desire to tear everything up and start again with a ream of blank paper or merely to make small cosmetic changes. This book was generally well received when it was first published and students appeared to like the general style and content. I have, therefore, retained much of the original text and confined myself to meeting most of the criticisms (fortunately, these were not too numerous) levelled at the first edition and also to making changes that reflect the development in my own teaching at PCL.

Some of the major differences between this text and the first edition are: (1) the inclusion of more worked examples within the text, (2) an increase in the sections dealing with dislocations and plastic deformation within metals, (3) a substantial enlargement of the chapter on material-forming processes, (4) a major increase in the chapters devoted to plastics materials, (5) a more detailed treatment of oxidation and corrosion and (6) the development of a small section on welding, formerly placed as an Appendix, into a full chapter within the book. In addition to these changes, an introduction to the principles of fracture mechanics has been included as an Appendix to the main text. It is my hope that these changes will find favour with both students and teachers.

I wish to thank my colleagues in the Materials section at PCL for the helpful comments freely given during the preparation of this revision and to record my indebtedness to my wife for her great help and for the typing of the draft.

Vernon John

1983

Preface to the Third Edition

There is a process of continuous development for curricula for courses in engineering. One significant development of the last decade is that the subject of engineering materials has moved into a centre-stage position, especially as a subject field within mechanical and manufacturing engineering courses. There has also been debate on the subject of a 'core curriculum'. During the preparation of this revised and enlarged edition, I have attempted to cater for current curriculum developments and changes in emphasis within syllabi. One possible failing of the last edition was, perhaps, an overemphasis on metals. I have attempted to redress this with increased coverage of non-metallic materials. My aim has been to present that body of core knowledge in materials science and technology which, in my opinion, should be a necessary part of the educational programme for any engineer.

The earlier editions of this book were well received and feedback from students indicated that the style of writing and presentation was clear and understandable. In consequence, I have retained much of the original text and illustrations in this new edition, even though the general structure of the book has been changed significantly and the number of chapters increased. The principal changes from the second edition include an introductory chapter outlining the range of materials, their basic characteristics, costs and availability to set the scene. The materials science section has been enlarged with elasticity and plasticity separated into two chapters and with new chapters dealing with polymer formation, visco-elasticity, toughness and fracture, phase transformations, and optical and thermal properties. Worked examples have been included in the text where appropriate. There has been a major increase in the textual matter covering polymers, ceramics and glasses. The formation and fabrication of materials has been reorganised with separate chapters for each class of material and a new chapter for material removal processes. The importance of non-destructive testing has been recognised by including a new chapter devoted to this subject. Material which appeared as appendices in the last edition has now been incorporated into the main text. It is hoped that these changes will find general acceptance by both teachers and students.

I hope that those engineering students who read and use this book will be stimulated and encouraged in their studies. Also, that they will develop an understanding and a feel for materials so that, as practising engineers, they will be able to select and use materials effectively and efficiently.

Questions requiring numerical answers are included at the ends of chapters. For descriptive answer questions and further numerical problems, refer to *Work Out Engineering Materials*, also by Vernon John and published by Macmillan.

Symbols Used in Text

<i>Quantity</i>	<i>Symbol</i>	
Atomic mass number (atomic weight)	M	
Atomic number	Z	
Avogadro's number	N_0	$N_0 = 6.023 \times 10^{23}$ molecules per mole
Bulk modulus of elasticity	K	
Density	ρ	
Direct strain	ε	
Direct stress	σ	
Force	F	
Fracture toughness	K_c	
Glass transition temperature	T_g	
Melting temperature	T_m	
Modulus of rigidity	G	
Poisson's ratio	ν	(Greek nu)
Shear strain	γ	
Shear stress	τ	
Temperature	T	
Time	t	
Universal constant	R_0	$R_0 = 8.314 \text{ kJ/kmol K}$
Viscosity	η	
Young's modulus of elasticity	E	

Units

The units used throughout this book conform to the SI system. The principal units that are quoted in the text are given below. Preferred SI units are printed in bold type.

<i>Quantity</i>	<i>Unit</i>	<i>Symbol</i>
mass	kilogramme	kg (1 kg = 2.205 lb)
	gramme	g
	tonne	t (Mg) (1 t = 1000 kg = 0.984 ton)
length	metre	m (1 m = 39.37 in)
	millimetre	mm
time	second	s
	minute	min
	hour	h
temperature	degree Kelvin	K
	degree Celsius	°C
amount of substance	mole	mol
	kilomole	kmol
area	square metre	m²
	square millimetre	mm ²
volume	cubic metre	m³ (1 m ³ = 35.315 ft ³)
	cubic millimetre	mm ³
density	kilogramme per cubic metre	kg/m³ (1 kg/m ³ = 10 ⁻³ g/cm ³ = 0.062 lb/ft ³)
force	newton	N (1 N = 0.225 lbf)
	kilonewton	kN
	meganeutron	MN
stress (pressure)	newton per square metre	N/m² (1 N/m ² = 0.000145 lbf/in ²)
	meganeutron per square metre	MN/m ² (1 MN/m ² = 0.0648 tonf/in ²)
	giganeutron per square metre	GN/m ²
	pascal	Pa (1 Pa = 1 N/m ²)
	bar	bar or b (1 bar = 10 ⁵ N/m ²)
	joule	J (Nm)
energy	electron volt	eV (1 eV = 1.602 × 10 ⁻¹⁹ J)

electric current	ampere	A
voltage	volt	V
quantity of electricity	coulomb	C (A s)
electrical resistance	ohm	Ω (V/A)
electrical resistivity	ohm metre	Ωm
magnetic flux	weber	Wb (V s)
magnetic flux density	tesla	T (Wb/m²) (1 T = 10 ⁴ gauss)
frequency	hertz	Hz (s⁻¹)