

# Contents

---

1. PLASTICS AS MATERIALS	1
Introduction	1
Brief history of plastics	2
Polymer types	4
Physics of polymers	6
Structural reasons for the differences between materials	7
The origin of the shear strength of metals and polymers	11
The equilibrium configuration of an ideal amorphous polymer chain—rubber elasticity	14
Polymer crystallization	16
Some definitions of terms used in polymers	18
2. THE GLASS TRANSITION	24
Introduction	24
Definition of the glass temperature	26
Theories of the glass transition	29
Dynamics of polymer chains	45
3. TIME-DEPENDENT ELASTICITY	51
Introduction	51
Definitions	51
Description of linear viscoelasticity by a differential equation	53
Examples of spring—dashpot models	54
More complex models	57
Stress—strain curves	60
Extension to multiple relaxation times	65
The relaxation function as a Laplace integral	71
Non-linear viscoelastic behaviour	77
4. APPLICATIONS TO POLYMERS	82
Transitions and morphology	82

Mixtures	83
Secondary transitions	85
Activation energies	90
Transitions in crystalline polymers	93
Transitions in high- and low-density polyethylene	95
Relations between $T_\beta$ , $T_g$ , and $T_m$	97
Models of crystalline polymers	97
Test methods	103
Laboratory methods	106
Forced vibrations	111
Creep and stress relaxation tests	112
The 10 second and 100 second compliance (or modulus).	
Isochronous tests	113
Ultrasonic methods	114
5. STRAIN, STRESS, AND THEIR RELATION: THE MECHANICS OF DEFORMATION	116
Displacement	116
Linear transformations	118
Principal axes and the strain ellipsoid	119
Measures of strain	123
Infinitesimal strain	124
Principal axes of infinitesimal strain	129
A measure of large strain	131
Homogeneous strain	133
Ellipsoids of strain	134
Strain invariants	135
Stress	136
Equilibrium	137
Examples of stress systems	142
Large strains	143
The torsion of a solid cylinder	150
6. ANISOTROPY	153
Introduction	153
Anisotropic elasticity	154
Contracted notation	155
Transformation of tensors	157
Aggregate of crystals	161
Space averages for aggregates with preferred orientations	162

	<i>Contents</i>	ix
Deformation of idealized polymer chains		163
Comparison of theory with experiment		167
Deformation of polymers containing crystallites		168
Optical and X-ray anisotropy in polymers		172
The changes produced in drawing fibres and sheets of thermoplastic polymers		183
7. YIELD AND FRACTURE		189
Yield criteria		190
Deviatoric stress and strain		192
Octahedral shear stress		194
Coulomb's yield criterion		194
Examples of the Coulomb criterion		195
Factors affecting brittle strength		200
Molecular theories of yield		201
Recent modifications to the Eyring and Robertson theories to include hydrostatic terms		205
Inhomogeneous yield (kink-bands; necking)		206
Fracture		212
Crazing		220
APPENDIX 1: VECTORS AND TENSORS		224
APPENDIX 2: MATRICES		229
AUTHOR INDEX		239
SUBJECT INDEX		241