

# CLASSICAL PHYSICS OF MATTER

<b>Introduction</b>	<b>6</b>
<b>Chapter 1 From atoms to the phases of matter</b>	<b>8</b>
1 A puzzle	8
2 Atoms: the building blocks of matter	8
2.1 The concept of an atom	8
2.2 Atomic sizes	11
2.3 Isotopes and ions	14
2.4 Atomic masses	15
2.5 Interactions between atoms	16
3 Atomic descriptions of the phases of matter	19
3.1 The gas phase	20
3.2 The liquid phase	23
3.3 The solid phase	24
4 Macroscopic variables	26
4.1 Density	26
4.2 Pressure	26
4.3 Temperature	28
4.4 Internal energy	31
4.5 Molar quantities	31
4.6 Response functions	33
5 Macroscopic equilibrium in ideal gases	34
5.1 Experiments on gases	35
5.2 The absolute temperature scale	37
5.3 The equation of state of an ideal gas	38
5.4 Internal energy equations of ideal gases	42
5.5 A puzzle resolved	43
6 Macroscopic descriptions of the phases of matter	44
6.1 The generic <i>PVT</i> surface and phases of matter	44
6.2 The generic <i>UPT</i> surface and latent heats	46
7 Closing items	48
<b>Chapter 2 Microscopic models of gases</b>	<b>52</b>
1 Introduction	52
2 Chance and probability	53
2.1 Probability	53
2.2 Average values	55
2.3 Fluctuations	57
2.4 Dicing with Boltzmann	58
3 The pressure of a gas	61
3.1 Molecular bombardment	61
3.2 The simple gas model	62
3.3 Calculating the pressure	63
4 Distributions of speed and translational energy in gases	68
4.1 Measuring the distribution of molecular speeds	68
4.2 Analysing the experiment in terms of translational energy	71



4.3	What do the distributions of speed and translational energy depend on?	72
4.4	Distribution functions	73
5	Statistical mechanics	76
5.1	From chance to practical certainty	76
5.2	Defining configurations in a gas	78
5.3	Assigning probabilities to configurations	79
5.4	The Boltzmann distribution law	80
5.5	The distribution of molecular speed	84
5.6	The distribution of molecular translational energy	87
6	The equipartition of energy	92
6.1	Application to gases	94
6.2	Application to solids	97
7	Closing items	98
	Appendix to Chapter 2 Computer simulations	103
	<b>Chapter 3 Thermodynamics and entropy</b>	<b>105</b>
1	Engine efficiency — an effect of thermodynamics	105
2	The first law of thermodynamics	107
2.1	Systems, states and processes	107
2.2	Heat and work	109
2.3	The first law of thermodynamics	112
2.4	The first law and heat capacities	117
2.5	Isothermal and adiabatic processes	122
3	The second law of thermodynamics	127
3.1	Reversible and irreversible processes	127
3.2	Adiabatic accessibility and the second law	128
3.3	Defining entropy	132
3.4	Entropy and heat flow	138
3.5	But what is entropy anyway?	139
4	Entropy, engines and refrigerators	141
4.1	Heat engines	141
4.2	Refrigerators	147
4.3	The third law of thermodynamics	150
5	Closing items	150
	<b>Chapter 4 The physics of fluids</b>	<b>154</b>
1	Introduction	154
2	Fluids at rest	155
2.1	Pressure in a fluid	155
2.2	The pressure experienced by a diver	156
2.3	The pressure experienced by a mountaineer	159
2.4	Buoyancy and Archimedes' principle	166
3	Ideal fluids in motion	169
3.1	Ideal flow	169
3.2	Conservation of mass and the equation of continuity	171
3.3	Conservation of energy and Bernoulli's equation	172
3.4	Bernoulli's principle in action	174



4	Non-ideal fluids in motion	175
4.1	Viscosity	175
4.2	Dynamical similarity and Reynolds number	178
4.3	Turbulence and its onset	181
4.4	The boundary layer	183
5	Flight	186
6	Closing items	187
<b>Chapter 5 Consolidation and skills development</b>		<b>190</b>
1	Introduction	190
2	Overview of Chapters 1 to 4	190
2.1	The atomic hypothesis	191
2.2	The macroscopic view	192
2.3	A statistical approach to physics	193
2.4	The laws of thermodynamics	194
2.5	The meaning of temperature	195
2.6	The physics of fluids	196
3	Writing precise physical statements	197
4	Basic skills and knowledge test	201
5	Interactive questions	206
6	<i>Physica</i> problems	206
<b>Answers and comments</b>		<b>207</b>
<b>Acknowledgements</b>		<b>229</b>
<b>Index</b>		<b>230</b>