

contents

1	INTRODUCTION	1
1.1	HISTORICAL SURVEY	1
1.2	NOTATION AND UNITS	3
1.3	UNITS OF ENERGY AND MOMENTUM	4
1.4	ATOMIC MASS UNIT	5
1.5	PROPAGATION OF WAVES; PHASE AND GROUP SPEEDS	6
1.6	COMPLEX NUMBERS	8
2	PROBABILITY	11
2.1	DEFINITION OF PROBABILITY	12
2.2	SUMS OF PROBABILITIES	13
2.3	CALCULATION OF PROBABILITIES BY COUNTING	14
2.4	PROBABILITY OF SEVERAL EVENTS OCCURRING TOGETHER	14
2.5	SUMMARY OF RULES FOR CALCULATING PROBABILITIES	15
2.6	DISTRIBUTION FUNCTIONS FOR COIN FLIPPING	16
2.7	DISTRIBUTION FUNCTIONS FOR MORE THAN TWO POSSIBLE OUTCOMES	19
2.8	EXPECTATION VALUES	20
2.9	NORMALIZATION	21
2.10	EXPECTATION VALUE OF THE NUMBER OF HEADS	21
2.11	EXPERIMENTAL DETERMINATION OF PROBABILITY	22
2.12	EXPERIMENTAL ERROR	24
2.13	RMS DEVIATION FROM THE MEAN	24
2.14	RMS DEVIATION FOR COIN FLIPPING	25
2.15	ERRORS IN A COIN-FLIPPING EXPERIMENT	27
2.16	ERRORS IN AVERAGES OF REPEATED EXPERIMENTS	28
2.17	PROBABILITY DENSITIES	30
2.18	EXPECTATION VALUES FROM PROBABILITY DENSITIES	32
2.19	GAUSSIAN DISTRIBUTION	34
2.20	EXPECTATION VALUES USING A GAUSSIAN DISTRIBUTION	35
	SUMMARY	37
	PROBLEMS	38
3	SPECIAL THEORY OF RELATIVITY	42
3.1	CONFLICT BETWEEN ULTIMATE SPEED AND NEWTON'S LAWS	42

3.2 CLASSICAL MOMENTUM AND ENERGY CONSERVATION— CONFLICT WITH EXPERIMENT	43
3.3 CONSERVATION OF MASS—CONFLICT WITH EXPERIMENT	44
3.4 CORRESPONDENCE PRINCIPLE	47
3.5 INERTIAL SYSTEMS	47
3.6 NON-INERTIAL SYSTEMS	49
3.7 AXES RELATIVE TO FIXED STARS	50
3.8 GALILEAN TRANSFORMATIONS	51
3.9 GALILEAN VELOCITY TRANSFORMATIONS	52
3.10 SECOND LAW OF MOTION UNDER GALILEAN TRANSFORMATIONS	53
3.11 THIRD LAW UNDER GALILEAN TRANSFORMATIONS	54
3.12 MICHELSON-MORLEY EXPERIMENT	54
3.13 POSTULATES OF RELATIVITY	55
3.14 EXPERIMENTAL EVIDENCE FOR THE SECOND POSTULATE	57
3.15 GALILEAN TRANSFORMATIONS AND THE PRINCIPLE OF RELATIVITY	59
3.16 TRANSFORMATION OF LENGTHS PERPENDICULAR TO THE RELATIVE VELOCITY	59
3.17 TIME DILATION	60
3.18 LENGTH CONTRACTION	64
3.19 LORENTZ TRANSFORMATIONS	65
3.20 SIMULTANEITY	67
3.21 TRANSFORMATION OF VELOCITIES	71
SUMMARY	74
PROBLEMS	76
4 RELATIVISTIC MECHANICS AND DYNAMICS	79
4.1 LORENTZ TRANSFORMATIONS	79
4.2 DISCREPANCY BETWEEN EXPERIMENT AND NEWTONIAN MOMENTUM	80
4.3 MOMENTUM FROM A THOUGHT EXPERIMENT	81
4.4 EXPERIMENTAL VERIFICATION OF MASS FORMULA	83
4.5 RELATIVISTIC SECOND LAW OF MOTION	85
4.6 THIRD LAW OF MOTION AND CONSERVATION OF MOMENTUM	85
4.7 RELATIVISTIC ENERGY	86
4.8 KINETIC ENERGY	87
4.9 POTENTIAL ENERGY AND CONSERVATION OF ENERGY	88
4.10 EXPERIMENTAL VERIFICATION OF EQUIVALENCE OF MASS AND ENERGY	89
4.11 RELATIONSHIP BETWEEN ENERGY AND MOMENTUM	89
4.12 REST MASS OF Λ^0 FROM EXPERIMENT	90
4.13 TRANSFORMATION PROPERTIES OF ENERGY AND MOMENTUM	96

4.14	TRANSFORMATIONS FOR FREQUENCY AND WAVELENGTH	99
4.15	TRANSVERSE DÖPPLER EFFECT	101
4.16	LONGITUDINAL DOPPLER EFFECT	102
	SUMMARY	104
	PROBLEMS	105
	5 QUANTUM PROPERTIES OF LIGHT	110
5.1	ENERGY TRANSFORMATION FOR PARTICLES OF ZERO REST MASS	111
5.2	FORM-INVARIANCE OF $E = h\nu$	112
5.3	THE DUANE-HUNT LAW	113
5.4	PHOTOELECTRIC EFFECT	115
5.5	COMPTON EFFECT	1119
5.6	PAIR PRODUCTION AND ANNIHILATION	123
5.7	UNCERTAINTY PRINCIPLE FOR LIGHT WAVES	126
5.8	MOMENTUM, POSITION UNCERTAINTY	128
5.9	PROBABILITY INTERPRETATION OF AMPLITUDES	129
	SUMMARY	131
	PROBLEMS	133
	6 MATTER WAVES	136
6.1	PHASE OF A PLANE WAVE	136
6.2	INVARIANCE OF THE PHASE OF A PLANE WAVE	138
6.3	TRANSFORMATION EQUATIONS FOR WAVEVECTOR A,ND FREQUENCY	139
6.4	PHASE SPEED OF DE BROGLIE WAVES	141
6.5	PARTICLE INCIDENT ON INTERFACE SEPARATING DIFFERENT POTENTIAL ENERGIES	143
6.6	WAVE RELATION AT INTERFACE	144
6.7	DE BROGLIE RELATIONS	145
6.8	EXPERIMENTAL DETERMINATION OF A	146
6.9	BRAGG EQUATION	147
6.10	DIFFRACTION OF ELECTRONS	148
6.11	UNCERTAINTY PRINCIPLE FOR PARTICLES	152
6.12	UNCERTAINTY AND SINGLE SLIT DIFFRACTION	152
6.13	UNCERTAINTY IN BALANCING AN OBJECT	155
6.14	ENERGY-TIME UNCERTAINTY	155
6.15	PROBABILITY INTERPRETATION OF WAVEFUNCTION	156
6.16	EIGENFUNCTIONS OF ENERGY AND MOMENTUM OPERATORS	158
6.17	EXPECTATION VALUES FOR MOMENTUM IN A PARTICLE BEAM	160
6.18	OPERATOR FORMALISM FOR CALCULATION OF MOMENTUM EXPECTATION VALUES	162
6.19	ENERGY OPERATOR AND EXPECTATION VALUES	164
6.20	SCHRÖDINGER EQUATION	165

6.21	SCHRÖDINGER EQUATION FOR VARIABLE POTENTIAL	167
6.22	SOLUTION OF THE SCHRÖDINGER EQUATION FOR A CONSTANT POTENTIAL	169
	6.23 BOUNDARY CONDITIONS	170
	SUMMARY	172
	PROBLEMS	175
7	EXAMPLES OF THE USE OF SCHRÖDINGER'S EQUATION	178
	7.1 FREE PARTICLE GAUSSIAN WAVE PACKET	178
	7.2 PACKET AT $t = 0$	180
	7.3 PACKET FOR $t > 0$	181
	7.4 STEP POTENTIAL; HIGH ENERGY $E > V_0$	183
	7.5 BEAM OF INCIDENT PARTICLES	185
	7.6 TRANSMISSION AND REFLECTION COEFFICIENTS	186
	7.7 ENERGY LESS THAN THE STEP HEIGHT	187
	7.8 TUNNELING FOR A SQUARE POTENTIAL BARRIER	188
	7.9 PARTICLE IN A BOX	190
	7.10 BOUNDARY CONDITION WHEN POTENTIAL GOES TO INFINITY	192
	7.11 STANDING WAVES AND DISCRETE ENERGIES	192
	7.12 MOMENTUM AND UNCERTAINTY FOR A PARTICLE IN A BOX	194
7.13	LINEAR MOLECULES APPROXIMATED BY PARTICLE IN A BOX	195
	7.14 HARMONIC OSCILLATOR	196
	7.15 GENERAL WAVEFUNCTION AND ENERGY FOR THE HARMONIC OSCILLATOR	198
	7.16 COMPARISON OF QUANTUM AND NEWTONIAN MECHANICS FOR THE HARMONIC OSCILLATOR	204
	7.17 CORRESPONDENCE PRINCIPLE IN QUANTUM THEORY	207
	SUMMARY	208
	PROBLEMS	209
8	HYDROGEN ATOM AND ANGULAR MOMENTUM	213
	8.1 PARTICLE IN A BOX	213
8.2	BALMER'S EXPERIMENTAL FORMULA FOR THE HYDROGEN SPECTRUM	215
	8.3 SPECTRAL SERIES FOR HYDROGEN	216
	8.4 BOHR MODEL FOR HYDROGEN	217
	8.5 QUANTIZATION IN THE BOHR MODEL	218
	8.6 REDUCED MASS	220
	8.7 SCHRÖDINGER EQUATION FOR HYDROGEN	221
8.8	PHYSICAL INTERPRETATION OF DERIVATIVES WITH RESPECT TO r	223
	8.9 SOLUTIONS OF THE SCHRÖDINGER EQUATION	225
	8.10 BINDING ENERGY AND IONIZATION ENERGY	230
	8.11 ANGULAR MOMENTUM IN QUANTUM MECHANICS	230
	8.12 ANGULAR MOMENTUM COMPONENTS IN SPHERICAL COORDINATES	231

8.13 EIGENFUNCTIONS OF L_z ; AZIMUTHAL QUANTUM NUMBER	232
8.14 SQUARE OF THE TOTAL ANGULAR MOMENTUM	233
8.15 LEGENDRE POLYNOMIALS	234
8.16 SUMMARY OF QUANTUM NUMBERS FOR THE HYDROGEN ATOM	235
8.17 ZEEMAN EFFECT	236
8.18 SPLITTING OF LEVELS IN A MAGNETIC FIELD	237
8.19 SELECTION RULES	238
8.20 NORMAL ZEEMAN SPLITTING	239
8.21 ELECTRON SPIN	240
8.22 SPIN-ORBIT INTERACTION	240
8.23 HALF-INTEGRAL SPINS	241
8.24 STERN-GERLACH EXPERIMENT	242
8.25 SUMS OF ANGULAR MOMENTA	242
8.26 ANOMALOUS ZEEMAN EFFECT	243
8.27 RIGID DIATOMIC ROTATOR	244
SUMMARY	246
PROBLEMS	249
9 PAULI EXCLUSION PRINCIPLE AND THE PERIODIC TABLE	254
9.1 DESIGNATION OF ATOMIC STATES	255
9.2 NUMBER OF STATES IN AN n SHELL	256
9.3 INDISTINGUISHABILITY OF PARTICLES	256
9.4 PAULI EXCLUSION PRINCIPLE	258
9.5 EXCLUSION PRINCIPLE AND ATOMIC ELECTRON STATES	260
9.6 ELECTRON CONFIGURATIONS	262
9.7 INERT GASES	263
9.8 HALOGENS	265
9.9 ALKALI METALS	265
9.10 PERIODIC TABLE OF THE ELEMENTS	266
9.11 X-RAYS	270
9.12 ORTHO- AND PARA-HYDROGEN	273
SUMMARY	273
PROBLEMS	275
10 CLASSICAL STATISTICAL MECHANICS	279
10.1 PROBABILITY DISTRIBUTION IN ENERGY FOR SYSTEMS IN THERMAL EQUILIBRIUM	280
10.2 BOLTZMANN DISTRIBUTION	281
10.3 PROOF THAT $P(E)$ IS OF EXPONENTIAL FORM	282
10.4 PHASE SPACE	283
10.5 PHASE SPACE DISTRIBUTION FUNCTIONS	285
10.6 MAXWELL-BOLTZMANN DISTRIBUTION	287
10.7 EVALUATION OF β	288
10.8 EVALUATION OF $NP(O)_\rho$	291
10.9 MAXWELL-BOLTZMANN DISTRIBUTION INCLUDING POTENTIAL ENERGY	292
10.10 GAS IN A GRAVITATIONAL FIELD	293

10.11	DISCRETE ENERGIES	294
10.12	DISTRIBUTION OF THE MAGNITUDE OF MOMENTUM	295
10.13	EXPERIMENTAL VERIFICATION OF MAXWELL DISTRIBUTION	296
10.14	DISTRIBUTION OF ONE COMPONENT OF MOMENTUM	298
10.15	SIMPLE HARMONIC OSCILLATORS	300
10.16	DETAILED BALANCE	303
10.17	TIME REVERSIBILITY	305
	SUMMARY	306
	PROBLEMS	308
11	QUANTUM STATISTICAL MECHANICS	312
11.1	EFFECTS OF THE EXCLUSION PRINCIPLE ON STATISTICS OF PARTICLES	313
11.2	DETAILED BALANCE AND FERMI-DIRAC PARTICLES	313
11.3	FERMI ENERGY AND FERMI-DIRAC DISTRIBUTION	315
11.4	ONE DIMENSIONAL DENSITY OF STATES FOR PERIODIC BOUNDARY CONDITIONS	316
11.5	DENSITY OF STATES IN THREE DIMENSIONS	318
11.6	COMPARISON BETWEEN THE CLASSICAL AND QUANTUM DENSITIES OF STATES	319
11.7	EFFECT OF SPIN ON THE DENSITY OF STATES	320
11.8	NUMBER OF STATES PER UNIT ENERGY INTERVAL	320
11.9	FREE PARTICLE FERMI ENERGY-NONDEGENERATE CASE	321
11.10	FREE ELECTRONS IN METALS-DEGENERATE CASE	323
11.11	HEAT CAPACITY OF AN ELECTRON GAS	324
11.12	WORK FUNCTION	325
11.13	PHOTON DISTRIBUTION	326
11.14	PLANCK RADIATION FORMULA	328
11.15	SPONTANEOUS EMISSION	331
11.16	RELATIONSHIP BETWEEN SPONTANEOUS AND STIMULATED EMISSION	332
11.17	ORIGIN OF THE FACTOR $1 + n_i$ IN BOSON TRANSITIONS	333
11.18	BOSE-EINSTEIN DISTRIBUTION FUNCTION	335
	SUMMARY	336
	PROBLEMS	338
112	SOLID STATE PHYSICS	341
12.1	CLASSIFICATION OF CRYSTALS	341
12.2	REFLECTION AND ROTATION SYMMETRIES	342
12.3	CRYSTAL BINDING FORCES	346
12.4	SOUND WAVES IN A CONTINUOUS MEDIUM	347
12.5	WAVE EQUATION FOR SOUND WAVES IN A DISCRETE MEDIUM	349
12.6	SOLUTIONS OF THE WAVE EQUATION FOR THE DISCRETE MEDIUM	351
12.7	NUMBER OF SOLUTIONS	352
12.8	LINEAR CHAIN WITH TWO MASSES PER UNIT CELL	354

14.7 MODELS OF THE NUCLEUS	421
SUMMARY	427
PROBLEMS	429
15 TRANSFORMATION OF THE NUCLEUS	431
15.1 LAW OF RADIOACTIVE DECAY	431
15.2 HALF-LIFE	433
15.3 LAW OF DECAY FOR UNSTABLE DAUGHTER NUCLEI	433
15.4 RADIOACTIVE SERIES	433
15.5 ALPHA-PARTICLE DECAY	441
15.6 THEORY OF ALPHA-DECAY	443
15.7 BETA DECAY	447
15.8 PHASE SPACE AND THE: THEORY OF BETA DECAY	450
15.9 ENERGY IN β^+ DECAY	452
15.10 ELECTRON CAPTURE	453
15.11 GAMMA DECAY AND INTERNAL CONVERSION	454
15.12 LOW ENERGY NUCLEAR REACTIONS	454
15.13 THRESHOLD ENERGY	456
15.14 NUCLEAR FISSION AND FUSION	457
15.15 RADIOACTIVE CARBON DATING	458
SUMMARY	458
PROBLEMS	461
16 ELEMENTARY PARTICLES	464
16.1 LEPTONS	464
16.2 MESONS	466
16.3 BARYONS	467
16.4 CONSERVATION LAWS	468
16.5 DETECTION OF PARTICLES	472
16.6 HYPERCHARGE, ISOTOPIC SPIN PLOTS	473
16.7 QUARKS	474
16.8 MESONS IN TERMS OF QUARKS	477
SUMMARY	478
PROBLEMS	479
APPENDICES	
APPENDIX 1	483
APPENDIX 2	491
APPENDIX 3	496
APPENDIX 4	504
BIBLIOGRAPHY	505
INDEX	507