



# Contents

- v Preface
- R J MURGATROYD  
817 The physics and dynamics of the stratosphere and mesosphere  
(with corrigenda)
- N F MOTT and Z ZINAMON  
881 The metal–nonmetal transition
- M J AITKEN  
941 Physics applied to archaeology—I. Dating
- D C LAINE  
1001 Molecular beam masers
- T ERBER AND H G LATAL  
1069 Flux compression theories
- G DEARNALEY, A M STONEHAM and D V MORGAN  
1129 Electrical phenomena in oxide semiconductor films
- E D PALIK and J K FURDYNA  
1193 Infrared and microwave magnetoplasma effects in semiconductors



# The physics and dynamics of the stratosphere and mesosphere

R. J. MURGATROYD

Meteorological Office, Bracknell

## Contents

	Page
1. Introduction . . . . .	818
2. Techniques of measurement and observations . . . . .	819
2.1. 'Indirect' methods . . . . .	819
2.2. 'Direct' methods . . . . .	822
3. Composition . . . . .	824
3.1. Observed values, neutral atmosphere . . . . .	824
3.2. Theoretical estimations and photochemistry . . . . .	826
3.3. Ionized components . . . . .	831
4. Radiation: energy sources and sinks . . . . .	833
4.1. Relation to temperature profile and general circulation . . . . .	833
4.2. The calculation of heating by solar absorption . . . . .	835
4.3. The calculation of cooling due to atmospheric radiation . . . . .	837
5. Temperature, pressure and density structure . . . . .	839
5.1. Temperature cross sections . . . . .	839
5.2. Pressure and density distributions . . . . .	842
5.3. Variability . . . . .	843
6. Winds and synoptic systems . . . . .	847
6.1. Cross sections of zonal wind components . . . . .	847
6.2. Standing and transient eddy motions . . . . .	849
6.3. Circulation changes throughout the year . . . . .	850
7. Energetics, dynamics and transport phenomena . . . . .	855
7.1. Theoretical basis . . . . .	855
7.2. Energy balances . . . . .	861
7.3. Heat and momentum transport . . . . .	861
7.4. Transport and distribution of tracers . . . . .	864
7.5. Computations using large numerical models . . . . .	866
8. Periodic motions . . . . .	867
8.1. Scales . . . . .	867
8.2. Gravity waves . . . . .	868
8.3. Tides . . . . .	870
8.4. Vertical propagation . . . . .	872
8.5. The 'quasibiennial' or '26 month' oscillation . . . . .	873
9. Conclusion . . . . .	876
Further reading . . . . .	876



# The metal-nonmetal transition

N. F. MOTT AND Z. ZINAMON

Cavendish Laboratory, Cambridge

## Contents

	Page
1. Introduction . . . . .	882
2. The Wilson band-overlap transition . . . . .	883
3. Mott-Hubbard insulators . . . . .	887
4. Kohn's proof of the insulating property . . . . .	890
5. Slater's description of Mott-Hubbard insulators . . . . .	891
6. Spin polarons . . . . .	893
7. Behaviour near the metal-nonmetal transition point . . . . .	894
8. Hubbard's Hamiltonian . . . . .	896
9. Magnetic moments . . . . .	902
10. Effect of the long-range forces . . . . .	905
11. Wigner crystallization . . . . .	907
12. The excitonic insulator . . . . .	908
13. Kohn's model for the Mott transition . . . . .	911
14. The term in the resistivity proportional to $T^2$ . . . . .	912
15. The metal-nonmetal transition in disordered systems; the Wilson band overlap transition . . . . .	913
16. The metal-nonmetal transition in disordered systems; the Mott transition . . . . .	916
17. Metal-ammonia solutions . . . . .	919
18. Resistance and magnetoresistance of crystalline $\text{Li}(\text{NH}_3)_4$ . . . . .	920
19. Transition metal oxides, sulphides and selenides . . . . .	920
19.1. $\text{Ti}_2\text{O}_3$ . . . . .	921
19.2. $\text{V}_2\text{O}_3$ . . . . .	921
19.3. $\text{VO}_2$ . . . . .	927
19.4. $\text{TaSe}_2$ and $\text{NbSe}_2$ . . . . .	929
19.5. $\text{NiS}$ . . . . .	930
19.6. $\text{Co}(\text{Se}_x\text{S}_{1-x})_2$ . . . . .	931
19.7. $\text{NiS}_2$ . . . . .	933
19.8. $\text{CrO}_2$ . . . . .	933
19.9. $\text{VO}$ . . . . .	933
20. Summary . . . . .	936
References . . . . .	937



# Physics applied to archaeology

## I. Dating

M. J. AITKEN

Research Laboratory for Archaeology and History of Art, University of Oxford

### Contents

	Page
1. Introduction . . . . .	942
2. Radiocarbon dating . . . . .	943
2.1. Introduction . . . . .	943
2.2. Man-made fluctuations in the $^{14}\text{C}$ concentration of the exchange reservoir . . . . .	948
2.3. Checks with known-age samples . . . . .	950
2.4. Causes suggested for the $^{14}\text{C}$ variations . . . . .	955
3. Potassium-argon dating and uranium series dating . . . . .	959
3.1. Potassium-argon dating . . . . .	960
3.2. Uranium series dating (including ionium dating) . . . . .	961
4. Thermoluminescent dating . . . . .	963
4.1. Introduction . . . . .	963
4.2. Evaluation of the accumulated radiation dose . . . . .	965
4.3. Radiation dosimetry . . . . .	970
4.4. Application . . . . .	973
5. Fission track dating . . . . .	975
5.1. Introduction . . . . .	975
5.2. Archaeological application . . . . .	975
6. Dating by chemical change . . . . .	976
6.1. Dating of bone by fluorine, uranium and nitrogen contents . . . . .	976
6.2. Obsidian dating . . . . .	976
6.3. Glass layer counting . . . . .	977
7. Archaeomagnetism . . . . .	978
7.1. Introduction . . . . .	978
7.2. Remanent magnetism . . . . .	979
7.3. Directional measurements . . . . .	983
7.4. Intensity measurements . . . . .	992
References . . . . .	994





# Molecular beam masers

D. C. LAINÉ

Department of Physics, University of Keele, Staffordshire

## Contents

	Page
1. Introduction . . . . .	1002
2. Early history . . . . .	1002
3. General principles and techniques . . . . .	1004
3.1. Molecular beam formation . . . . .	1004
3.2. Beam preparation . . . . .	1005
3.3. Resonant cavities . . . . .	1012
4. Theory of molecular beam masers . . . . .	1016
4.1. Dispersion theory . . . . .	1016
4.2. General polarization theory . . . . .	1017
4.3. Velocity distribution . . . . .	1017
4.4. Stability of oscillation . . . . .	1018
4.5. Synchronization of a beam maser oscillator . . . . .	1019
4.6. Beam masers operated with cavities in series . . . . .	1020
4.7. Spatial reorientation of molecules . . . . .	1021
4.8. Magnetic resonance analogues . . . . .	1022
5. Beam maser spectroscopy . . . . .	1024
5.1. Linewidth . . . . .	1026
5.2. Sensitivity . . . . .	1028
5.3. Choice of molecules . . . . .	1030
6. Beam maser amplifiers . . . . .	1038
6.1. Noise properties . . . . .	1039
6.2. Gain-bandwidth and saturation characteristics . . . . .	1040
7. Beam maser oscillators . . . . .	1041
7.1. Conditions for oscillation . . . . .	1041
7.2. Oscillator noise . . . . .	1046
7.3. Amplitude characteristics . . . . .	1049
7.4. Frequency characteristics . . . . .	1053
7.5. Transient properties . . . . .	1059
8. Future trends . . . . .	1059
Acknowledgments . . . . .	1060
References . . . . .	1060



# Flux compression theories†

T. ERBER AND H. G. LATAL‡

Department of Physics, Illinois Institute of Technology, Chicago 60616

## Contents

	Page
1. Introduction . . . . .	1069
1.1. Scope of present work . . . . .	1069
1.2. Flux expansion and flux compression . . . . .	1072
1.3. Problems in the formulation of flux compression theories . . . . .	1077
1.4. Outline of the paper . . . . .	1082
2. Basic flux compression equations . . . . .	1082
2.1. Magnetic field diffusion . . . . .	1082
2.2. Energy conservation . . . . .	1086
2.3. Methods of solution . . . . .	1088
3. Ideal flux compression . . . . .	1089
4. Flux compression in thin liners . . . . .	1095
4.1. Analytical preliminaries . . . . .	1095
4.2. Discussion of results . . . . .	1099
5. Reformulation of the theory for comparison with experiment . . . . .	1110
5.1. General considerations . . . . .	1110
5.2. Series expansions, region 1 . . . . .	1113
5.3. The fiducial points, region 2 . . . . .	1116
6. Flux compression in the limit of constant velocity . . . . .	1119
Acknowledgments . . . . .	1124
References . . . . .	1124



# Electrical phenomena in amorphous oxide films

G. DEARNALEY,<sup>†</sup> A. M. STONEHAM,<sup>†</sup> AND  
D. V. MORGAN<sup>‡</sup>

<sup>†</sup> AERE, Harwell, Didcot, Berks.

<sup>‡</sup> Department of Electrical and Electronic Engineering, University of Leeds

## Contents

	Page
1. Introduction . . . . .	1130
1.1. Charge transport in insulators . . . . .	1131
1.2. Differential negative resistance . . . . .	1134
1.3. Dielectric breakdown . . . . .	1137
2. The forming process . . . . .	1138
2.1. Observations of forming . . . . .	1138
2.2. Models of the forming process . . . . .	1142
3. Conduction, switching and memory phenomena . . . . .	1146
3.1. Observations of conduction, switching and memory phenomena	1146
3.2. Theories of switching and memory in oxide films . . . . .	1151
3.3. Observations on triodes . . . . .	1162
4. Electron emission, luminescence and other phenomena . . . . .	1163
4.1. Electron emission . . . . .	1164
4.2. Electroluminescence in M-I-M (metal-insulator-metal) struc- tures . . . . .	1165
4.3. Theories of electron emission and electroluminescence . . . . .	1168
4.4. Injection electroluminescence in MOS (metal-oxide-semi- conductor) structures . . . . .	1169
4.5. Noise . . . . .	1171
5. Comparison with other systems . . . . .	1172
5.1. Current-controlled negative resistance and bistable switching in oxides . . . . .	1172
5.2. Comparison with the Ovshinsky devices . . . . .	1176
5.3. A comparison of switching in crystalline, microcrystalline and amorphous films . . . . .	1178
6. Practical implications . . . . .	1179
6.1. Switches . . . . .	1179
6.2. Memory arrays . . . . .	1180
6.3. Hot electron, cold cathode emitter . . . . .	1181
6.4. Alpha-numeric display panel . . . . .	1181
6.5. Electroluminescent MOS devices . . . . .	1182
6.6. Oxide-coated cathodes . . . . .	1182
6.7. MOS capacitors and transistors . . . . .	1183
6.8. Surface barrier diodes . . . . .	1184
6.9. Anodic oxides and corrosion . . . . .	1186
6.10. Anodic electret microphones . . . . .	1187
7. Conclusions . . . . .	1187
References . . . . .	1188



# Infrared and microwave magnetoplasma effects in semiconductors

E. D. PALIK† AND J. K. FURDYNA‡

† Naval Research Laboratory, Washington, DC, USA

‡ Department of Physics, Purdue University, Lafayette, Indiana, USA

## Contents

	Page
1. Introduction . . . . .	1195
2. Development of the dielectric tensor for a free-carrier magnetoplasma . . . . .	1198
2.1. Electrodynamical preliminaries . . . . .	1198
2.2. The conductivity tensor . . . . .	1199
2.3. Choice of coordinates . . . . .	1204
3. The dispersion equation . . . . .	1207
3.1. Wave propagation at an arbitrary angle to $B_0$ . . . . .	1207
3.2. The Faraday configuration . . . . .	1209
3.3. The Voigt configuration . . . . .	1210
3.4. Polarization for arbitrary $\theta$ in other coordinate systems . . . . .	1211
4. Macroscopic description of measurable effects . . . . .	1212
4.1. Wave propagation in an unbounded medium . . . . .	1212
4.2. The infinite half-space . . . . .	1214
4.3. The plane-parallel slab . . . . .	1216
4.4. Mode interference phenomena: the Faraday and Voigt effects . . . . .	1218
4.5. Small samples and semiconductor powders . . . . .	1221
5. The lossless case . . . . .	1223
5.1. Faraday geometry . . . . .	1223
5.2. Intermediate geometries . . . . .	1230
5.3. Voigt geometry . . . . .	1233
6. The lossy case . . . . .	1235
6.1. Absorption for $B_0 = 0$ . . . . .	1235
6.2. Absorption for $B_0 \neq 0$ : Faraday geometry . . . . .	1236
6.3. Absorption for $B_0 \neq 0$ : Voigt geometry . . . . .	1237
6.4. Dispersive contributions of finite $\nu$ . . . . .	1238
7. Experimental examples for an isotropic free-carrier system . . . . .	1239
7.1. Free-carrier absorption . . . . .	1239
7.2. Plasma and magnetoplasma reflection . . . . .	1239
7.3. Helicon waves . . . . .	1240
7.4. Cyclotron resonance and related resonances . . . . .	1242
7.5. Faraday effect . . . . .	1246
7.6. Voigt effect . . . . .	1249
7.7. Interference fringes . . . . .	1250
8. Multiple-carrier systems . . . . .	1251
8.1. The conductivity tensor . . . . .	1251
8.2. Propagation constants of normal modes . . . . .	1252
8.3. Minority carriers . . . . .	1256
8.4. Compensated semimetals and Alfvén-wave propagation . . . . .	1259
8.5. Intrinsic narrow-gap semiconductors . . . . .	1264
9. Effective mass anisotropy: the many-valley model . . . . .	1266
9.1. Equation of motion for a single valley . . . . .	1266
9.2. The conductivity and dielectric tensors: the lossless representation . . . . .	1268
9.3. Wave phenomena in the presence of anisotropic bands . . . . .	1272
9.4. Limiting cases . . . . .	1275



	Page
10. Nonlocal effects . . . . .	1277
10.1. General considerations . . . . .	1277
10.2. Consequences of spatial dispersion: a qualitative view . . . . .	1278
10.3. Faraday geometry: a quantitative discussion . . . . .	1280
10.4. The Voigt geometry: a quantitative discussion . . . . .	1282
11. Quantum effects . . . . .	1284
11.1. Transverse magnetoconductivity in extrinsic narrow gap semiconductors . . . . .	1285
11.2. Effect of orbital quantization on Alfvén waves . . . . .	1288
11.3. Miscellaneous comments . . . . .	1290
12. Coupled magnetoplasma—longitudinal optical phonon modes in polar semiconductors . . . . .	1290
12.1. The lattice dielectric constant . . . . .	1290
12.2. The addition of free carriers; coupled longitudinal optical phonon—plasmon modes . . . . .	1292
12.3. The effect of a magnetic field . . . . .	1293
12.4. Experimental results . . . . .	1298
12.5. Coupled modes for the anisotropic mass; p-type PbTe . . . . .	1298
12.6. Polaron effects . . . . .	1299
12.7. Phonon-assisted and harmonic cyclotron resonance . . . . .	1300
Acknowledgments . . . . .	1300
 Appendix	
A1. Interpretation of charge motion in a magnetoplasma . . . . .	1300
A1.1. Displacement coordinates in the Faraday geometry . . . . .	1300
A1.2. The plasmon and cyclotron oscillators . . . . .	1302
A1.3. Coupled modes upon leaving the Faraday geometry . . . . .	1303
A1.4. Displacement coordinates in the Voigt geometry . . . . .	1304
A1.5. Magnetoplasmons with arbitrary direction of propagation . . . . .	1304
A1.6. Interpretation of zeroes in $\kappa_{1,2}$ . . . . .	1305
A1.7. A point of view . . . . .	1306
A2. The $\omega$ - $q$ analysis and the polariton formalism . . . . .	1306
A2.1. The wave vector and the dielectric constant . . . . .	1306
A2.2. Energy density of radiation in a dispersive medium . . . . .	1307
A2.3. Phase velocity . . . . .	1309
A3. Kramers—Kronig analysis . . . . .	1310
A3.1. Dispersion relations for $B_0 = 0$ . . . . .	1310
A3.2. Dispersion relations for $B_0 \neq 0$ . . . . .	1311
A4. Magneto-optics of birefringent crystals . . . . .	1313
A4.1. The $B_0 = 0$ case . . . . .	1313
A4.2. The $B_0 \neq 0$ case . . . . .	1314
A5. Magneto-optics at non-normal incidence . . . . .	1316
A5.1. The $B_0 = 0$ case . . . . .	1316
A5.2. The $B_0 \neq 0$ case . . . . .	1316
References . . . . .	1317

