

Contents

Acknowledgements XIII

Prologue XV

Part I Questions

Introduction 3

Recommended Reading 4

1 Ancient Days and Modern Times 5

Recommended Reading 7

2 Ice Ages—Past and Future 9

The Discovery of Ice Ages 9

The Heat Balance of the Earth 10

The Sun and Its Spots 11

Earth's Orbit 14

The Discovery of Elliptical Orbits 15

Precession 16

Nutation (Wobble) 18

Volcanic Dust 20

The Cyclical Nature of Ice Ages 20

The Croll–Milanković Theory of Ice Ages 21

Recommended Reading 23

3 Global Warming Versus Returning Glaciers 25

Infrared Radiation and Absolute Temperature 27

Greenhouse Gases and Global Warming: Fourier, Tyndall, and Arrhenius 28

CO₂ and Methane 29

The Big Picture 31

Recommended Reading 35

- 4 **Earth's Fossil Fuel Supply** 37
 - Limits of Fossil Fuels 38
 - Coal 39
 - Natural Gas 39
 - Hydrated Natural Gas 40
 - Oil 40
 - Sequestration of CO₂ 42
 - CO₂ Level Calculations 43
 - The Unending Carbon Cycle 43
 - Recommended Reading 45

- 5 **Nuclear Power** 47
 - Origin of Fuel for Nuclear Fission 47
 - The Energy in Nuclear Fuel 48
 - Nuclear Energy 49
 - Isotopes 50
 - Limits of Nuclear Fuel 51
 - The Basics of Nuclear Fission 52
 - Evolution of Nuclear Reactors 53
 - Present-day Nuclear Reactors and Power Plants 54
 - Used Fuel Rods 56
 - Radiation, Radioactivity, and Health 57
 - Natural Radiation and Radioactive Waste 58
 - Disposal and Storage of Nuclear Waste 59
 - Recommended Reading 60

Part II **Answers**

Introduction 63

- 6 **Solar Energy** 65
 - Using Solar Energy 66
 - Development of Solar Cells 68
 - How Solar Cells Work 69
 - Multiple-layer Solar Cells 71
 - Solar Concentrators and Solar Thermal Systems 75
 - Solar Ponds 76
 - Solar-powered Air Conditioning 77
 - Solar Updraft Towers 78
 - Solar Power Towers 79
 - Other Thoughts and Possibilities 79
 - Recommended Reading 80

- 7 Wind, Waves, and Tides 81**
Wind 81
Characteristics and Limits of Wind Machines 83
Tides 86
Newton, the Moon, and the Tides 87
Harnessing Tidal Power 87
Usable Tidal Energy 89
Tidal Currents 90
Waves 91
Recommended Reading 93
- 8 Going with the Flow: Water, Dams, and Hydropower 95**
Basics of Hydroelectric Power 96
Water Turbines 98
Hydropower Problems 99
Hydropower Schemes 99
Dam-less Hydropower: Evaporation Schemes 100
Dam-less Hydropower: Flowing Water 102
Recommended Reading 103
- 9 Geothermal Energy: Energy from the Earth Itself 105**
Geothermal Energy 105
The Structure of the Earth 106
Carnot's Unbreachable Thermodynamic Limit 109
Using Water and Soil in Heating and Cooling Systems 110
Recommended Reading 112
- 10 Efficiency, Conservation, and Hybrid Cars 113**
Efficiency of Fossil Fuel and Nuclear Power Plants 114
Cars, Trucks, Trains, Ships, and Planes 118
Conservation 120
Recommended Reading 121
- 11 Energy Storage: Macro to Micro 123**
Pumped Hydropower 124
Compressed Air 124
Batteries 126
Flywheels 129
Capacitors and Dielectrics 130
Inductors: Storing Energy with Magnetic Fields 132
Recommended Reading 133
- 12 Green Fuel: Biodiesel, Alcohol, and Biomass 135**
Biodiesel 138
Recommended Reading 142

Part III Dreams

Introduction 145

- 13 Breeding Nuclear Fuel 147**
 Fast Breeder Reactors 148
 Clinch River Breeder Reactor Project 150
 Thermal Breeder Reactors 151
 Breeder Technology Today and Tomorrow 152
 Recommended Reading 153
- 14 Nuclear Fusion: Engine of the Sun 155**
 Cold Fusion versus Cool Fusion versus Hot Fusion 155
 Making Fusion Happen 157
 ITER, Tokamaks, Magnetic Fields, and Fusion 158
 The Combined Fusion–Breeding–Fission Process 160
 Inertial Confinement Fusion 161
 Accelerator Fusion 161
 Fusion of Helium-3 and Deuterium 162
 Lunar Resources of Helium-3 163
 Recommended Reading 165
- 15 Power from the Ocean: Thermal and Salinity Gradients 167**
 Electric Power from Ocean Thermal Gradients 167
 Electric Power from Ocean Salinity Gradients 172
 Recommended Reading 176
- 16 Fuel Cells: Hydrogen, Alcohol, and Coal 177**
 Fuel Cells and Hydrogen 177
 Fuel Cell Efficiency 179
 Fuel Cells and Cars 180
 Storing Hydrogen 182
 Producing Hydrogen 184
 Technologies for Hydrogen Production 184
 Fuel Cells and Coal 186
 Fuel Cells and Alcohol 187
 What Happens Now? 187
 Recommended Reading 188
- 17 Magnetohydrodynamics and Power Plants 189**
 Faraday Induction and the Hall Effect 190
 Benefits of MHD Power Generation 192
 Recommended Reading 193

- 18 Thermionics and the Single Fuel Home** 195
 How a Thermionic Converter Works 196
 Engineering Thermionic Systems 197
 Recommended Reading 201
- 19 Artificial Photosynthesis and Water Splitting** 203
 Plant Chemistry 205
 Artificial Photosynthesis and Water Splitting 206
 Recommended Reading 208
- 20 Planetary Engineering and Terraforming** 209
 Changing Earth's Albedo: Atmospheric Aerosols 210
 Tinkering with Planet Earth 211
 Parasols, Artificial Sunspots, Space Mirrors, Solar Sails, and
 Space Dust 212
 White Roads, Reflecting Roofs, and Shiny Balloons 213
 Back to Clouds Again 213
 Feeding Algae 214
 Terraforming Mars (and Maybe Venus) 215
 What Can Be Done? 217
 Recommended Reading 218
- 21 Space Solar Power: Energy and the Final Frontier** 219
 Lagrange and His Famous Points 219
 Geosynchronous Orbits and Solar Sails 221
 Beamed-power Microwave Transmission 222
 Space Elevators 223
 Electromagnetic Launching 226
 Recommended Reading 227

Part IV Nightmares

- Introduction** 231
- 22 Alternative Futures** 233
- Epilogue: ORBITuary** 237
- Credits** 239
- Appendix I** 241
 Units for Energy and Power 241
- Appendix II** 243
 Radiation Units 243
- Index** 245

