

Index*

- absorptivity, 136
 adiabatic lapse rate, 170–1, 176
 adiabatic process, **46**, 93
 in atmosphere, 170–1
 aerosol, 166
 albedo, **160**, 163
 atmosphere (*see also* atmospheric boundary layer *and* greenhouse effect)
 absorption of radiation in, 138
 constituents of, 12, 145, 147 (table)
 H₂O cycle, 149–50
 H₂O timescale, 150
 kinetic energy of, 147–9
 mass of, 11, 147
 physical properties of, 147 (table)
 power of, 147
 scale height, 156
 temperature spectrum, 153–4
 timescales, 148–9, 152–3
 turbulence timescale, 152
 variation with height, 156–7
 velocity spectrum, 151–4
 and weather prediction, 154, 176–7
 atmospheric boundary layer (ABL), **167–76**
 convection in, 168
 depth of, 168–9
 and dynamic stability, 173
 energy dissipated in, 178
 inversions in, 168–9
 and static stability, 172
 and temperature profiles, 170–3
 and wind shear, 173
 Avogadro number, 185
 Bernoulli equation, **83–90**
 applications of, 87, 192
 for incompressible flow, 87
 limitations of, 90
 statement of, 86
 Betz limit, 194
 black-body radiation, 134
 effective temperature for earth, 160
 Boltzmann constant, 134
 boundary layer, (*see also* atmospheric boundary layer) 106–7, 158
 Brayton cycle, 95, 110
 bromine, 145, 217
 buoyancy force, 123, 128, 142, 173–4
 calculations, 18
 crude and refined, 5
 carbon, world emissions, 219
 carbon dioxide (CO₂), 10–11, 12, 138, 145, 159, 163–7, 215, 216
 absorption characteristics of, 138, 159
 atmospheric concentration of, 13–14
 atmospheric residence time, 14
 carbon monoxide (CO), 10, 14, 138, 145, 186, 210, 211, 212, 215
 U.S. automobile emissions of, 212–3
 Carnot cycle, **45–9**
 efficiency of, 48–9, 57
 Carnot, Sadi, 9
 chaos
 and transition, 124
 spiral defect, 125
 chaotic pendulum, 177
 chlorofluorocarbons (CFCs), 138, 215, 217
 Clausius, Rudolf, J.E., 9

*Page numbers in bold type indicate definitions or main entries.

INDEX

- closed system, **24**
 coal, 186, 211, 222
 coefficient of volume expansion, 123, 141
 combustion (*see* hydrocarbon fuels)
 compressor, 92, 96
 computer simulations
 of engines, 102
 of the atmosphere, 165
 conduction, 113, **115–22**
 analogy with momentum transfer, 113, 116
 instability and transition, 123
 role in convection, 129–30
 conduction equation (*see* heat conduction equation)
 conservation of energy (*see* first law of thermodynamics)
 conservation of mass (for fluids), 84–5
 convection, 113, **122–32**
 analogy with turbulent momentum transfer, 123
 and radiation imbalance, 163
 compared with conduction, 123, 126–7
 in atmospheric boundary layer, 168–9
 length, velocity and time-scales, 126
 Coriolis parameter, 153, 159
 Couette flow, 108
 cycle, thermodynamic, **27**, 31
- Dalton's law, 12
 Diesel cycle, 39, 42, 99
 diffusion
 of momentum and matter compared, 74–5
 diffusion equation, 119
 and irreversibility, 119
 diffusivity, 119
 dimensional analysis, 104
 dynamic similarity, 107
- earth
 effective black body temperature of, 160
 radius of, 11, 147
 efficiency, thermal, **10**, 48, 57, 207
 of gas turbine system, 96
 electromagnetic spectrum, 133
 electron volt, **185**
 emissivity, **136**
 energy, 28
 of atmosphere, 147
 conservation of, 29
 growth of usage, 218
 internal, 30
 kinetic, 29
 potential, 29
 world resources of, 200–1
- energy consumption, 218–20
 future estimates of, 219
 engine (*see also* heat engine), 8–11, 27–8
 emissions from, 210–15
 internal combustion (IC), 8, 9, 42, 49, 98–105
 relationship to atmosphere, 14, 65, 145
 engineering
 components and systems, 14–16
 contrast with science, 1–3
 incremental approach to, 223
 radical approach to, 223
 enthalpy, 61, **92**
 enthalpy of vaporization, 150
 equation of state, 36
 equivalence ratio, 202, **211**
 equilibrium, **26**
 dynamic, 26
 thermal, 26
 evaporation of water
 energy requirements, 150
 and radiation imbalance, 162–3
- first law of thermodynamics, 24, 29–30, 33
 applied to atmosphere, 164, 170
 for a cycle, 33
 differential form, 35
 for a differential slab, 116
 for open systems, 90–3
 for *p**dv* work, 40
 for a piston engine, 35
 statement of (open systems), 92–3
 summary of, **34–5**
 fluid, definition of, **67**
 fluid momentum, 73–4
 diffusion of, 74–5
 transfer by turbulence, 78
 forced convection, **128**, 131
 fossil fuels (*see* hydrocarbon fuels)
 Fourier's law of heat conduction, 116
 friction, 29, 43
 in fluids, 67, 74, 83, 90
 work, 92
 fuel-to-air ratio, 202, 211
 friction machine, 33, 54
- gas constant, 36
 gas turbine, 93–7
 shaft work produced by, 94
 temperature and enthalpy change in, 94
 greenhouse effect, 14–15, 138, **159–67**
 difficulty of prediction, 163, 166
 feedback factor, 164–5

INDEX

- half-life, 189, 203
 heat conduction equation, **119**
 development of, 116–9
 and irreversibility, 119
 a steady state solution, 121
 in three dimensions, 121
 heat engine, 9, **28**, 36
 irreversible, 51
 reversible, 51
 heat exchanger, 95
 heat interaction, **31**
 across a finite temperature difference, 55
 reversible and irreversible, 44
 sign convention 32
 heat pump, 51, 52
 heat transfer
 relation to thermodynamics, 113
 summary of, 139–40
 heat transfer coefficient, 130–1
 hydroelectricity, 183, 200, 223
 hydrostatic condition, **155**, 170
 for incompressible fluid, 87
 hydrocarbon fuels, 10, 56, 183, **185–8**
 complexity of combustion process, 187
 energy in, 10, 185–6
 products of combustions, 187, 210–15
 hydrogen fuel, 188
 hydrogen fuel cell, 199
 hydroxyl radical, 211, 212, 217
- ideal flow, **83**
 ideal gas, **36**
 incompressible flow, **85**, 87
 inertial forces, 128, 142, 173–4
 infrared radiation, 133, 161
 internal combustion (IC) engine (*see* engine)
 inviscid flow, **83**
 ionosphere, 67, 157
 isothermal process, **41**
- jet engine, 98
 Joule, James P., 9
- Keenan, J.H., xii
 Kelvin, Lord, 9
 Kolmogorov, A.N., 104
 Kolmogorov scale, 104, 129
- laminar flow 67, 68, **72–77**
- mass-energy equivalence
 in hydrocarbon reactions, 186
 in nuclear reactions, 189
 mass flow rate, **85**
- Mayer, Julius, R. von, 9
 mesosphere, 157
 methane (CH₄), 138, 145, 186, 210
 reaction equations, 187
 and world population, 214
 mixing ratio, 179
 molecular weight, 12, 36
 momentum diffusion (fluid), 74
 analogy with mass diffusion, 74
 turbulent compared with laminar, 78–9
- natural gas, 186, 222
 Navier-Stokes equations (equations of fluid motion), 225–8
 nitrogen (N₂), 10, 12, 138, 185, 210
 nitrogen oxides (NO₂, NO), 10, 210
 and ozone production, 212
 U.S. emissions of, 212–3
 nitrous oxide (N₂O), 138, 215
 no slip condition, **72–3**, 158, 168
 nuclear energy, 183, **188–90**, 201, 222
 Nusselt number, **131–2**
- octane, 10, 186, 210
 imperfect combustion of, 210–13
 production of CO₂ from, 10
 open system, **24**, 90
 Otto cycle, 39, 42, 49–51
 compared with Carnot, 51
 oxygen, 10, 12, 210
 absorption characteristics of, 138, 159
 ozone (O₃), 138, 145, 157, 215, 217
 and smog, 211, 217
 in troposphere, 211–2
 in stratosphere, 217
- p-v* diagram, 27, 37
 path (thermodynamic), **27**
pdv work, 38
 perfect gas, **36**
 photochemical reactions, 211
 photochemical smog, 21, 145, 187, 211, 217
 photovoltaic power, 195, 199
 photosynthesis, 12, 183, 186, 211
 pipe flow, 69–71, 72–3, 74, 75, 76, 78–9,
 80–3, 84, 90, 108
 piston engine (*see also* engine) 8, 35
 Planck constant, 134
 Planck radiation law, 134
 population,
 growth of, 213, 218, 221
 Prandtl number, 119
 pressure
 of atmosphere, 11

INDEX

- pressure (*cont.*)
 and hydrostatics, 155
 variation with height, 156
 variation in pipe flow, 80–3
 and work, 38
- pressure work
 in Bernoulli equation, 85, 91
 in closed systems, 91
- process, thermodynamic, 25, 27
- properties of a system, 24, 27
 extensive, 34–5
 intensive, 34–5
- pump, 92
- radiation, 132–9
 absorption by gases, 137–9
 and greenhouse effect, 159–63
 and matter, 132
 and ozone, 138, 212, 215, 217
 in a vacuum, 133
 in the atmosphere, 114, 138–9, 159–62, 212, 217
- Rayleigh number, 124
 critical value, 124
 and onset of convection, 124–5
- reflectivity, 136
- refrigerator, 51
- relativity, special theory of, 186
- renewable energy 190–200
- reversible process, 42–5
 and Carnot cycle, 45
 for heat interaction, 44
 for work interaction, 43
- Reynolds, Osborne, 69
- Reynolds number, 69, 123, 124
 and transition, 69, 71
 of clouds and smoke stacks, 71
 of pipe flow, 69
- Richardson, L.F., 102
- Richardson number, 173–5
 and pollution, 175
- second law of thermodynamics 24, 51–6
 generality of, 56–8
 statements of, 54, 56
 tests for irreversibility, 55–6
 and windmill efficiency, 207
- shaft work, 92
- shear, 75
- shear stress, 67, 75–6, 79, 81
- smog (*see* photochemical smog)
- smokestacks, 175, 184
- specific heat, 40
- spectrum
 electromagnetic, 133
 kinetic energy, 151
- state (thermodynamic), 24, 27
- steady flow, 85
- stratosphere, 157, 217
- streamline, 87
- streamtube, 86
- Stefan-Boltzmann constant, 134
- Stefan-Boltzmann law, 134, 148, 160, 165
 example in an infinite medium, 137
- stoichiometric reaction, 210
- stress (*see* shear stress)
- sulphur compounds, 166, 211
- sun (*see also* radiation), 148
 available energy from, 198–9
 power generated by, 148
 power into atmosphere, 148, 160
 radius of, 177
 temperature of, 148
- sun spot cycle, 153
- system, thermodynamic, 24
 boundary of, 24
 closed, 24
 isolated, 29
 properties of, 24, 27
 specifying the boundaries of, 25–6
 state of, 24, 27
 surroundings, 25
- temperature, 26
 global trend in, 167
 inversion, 127, 158, 169, 171–2
 profiles in atmosphere, 168–9, 170–3
 reservoir, 51
- thermal conductivity, 115
 of common substances, 116
- thermal diffusivity, 119
- thermal eddy diffusivity, 126
- thermodynamics, 9, 21, 65
 contrast with heat transfer, 113
 first law, 24, 29, 30, 34
 second law, 24, 54, 56
- thrust, 98, 193
- transmissivity, 136
- transition (in fluid flow), 68–72, 123–5
- troposphere, 156–7, 158
- turbine, 92
- turbulence, 68–71, 76, 77–80, 82–3, 99–105
 cascade, 101–2
 dissipation of, 101, 159, 178
 eddy, 78, 101
 and enhanced stresses, 79

INDEX

-
- irregular motion of, 68
 - and mean flow, 68, 78
 - mixing effectiveness of, 79–80
 - suppression of, 173–4
 - turbulence characteristic velocity, 100, 126
 - turbulence lengthscale, 100, 126
 - turbulence timescale (mixing time),
 - 99–105**, 126
 - ultraviolet radiation, 159, 217
 - unburned hydrocarbons (HCs), 210–11
 - and ozone production, 211–12
 - U.S. vehicle emissions of, 212–13
 - units, 18
 - universal gas constant, 36
 - unsteady flow, **85**
 - vehicles
 - distribution of, 216
 - world population of, 8, 11, 213
 - velocity gradient (*also see*, shear), 75
 - velocity profile, 75–6, 79, 82
 - virtual temperature, 179
 - viscosity, 69, 70–1, 103, 123
 - comparison for air and water, 70
 - dynamic, 71, 76
 - kinematic, 71
 - volume ratio, 12
 - water
 - atmospheric concentration of, 13
 - available energy from, 200
 - in atmosphere and oceans, 149–50
 - enthalpy of vaporization of, 150
 - water vapor, 145
 - absorption characteristics of, 138
 - and greenhouse effect, 138–9, 159, 163
 - released in combustion, 10
 - wind
 - available energy from, 196–8
 - windmill (wind turbine), 191–5
 - interference factor, 193
 - maximum power output, 194
 - and second law, 207
 - wind tunnel, 89
 - wood
 - combustion of, 185
 - work interaction, 8, **32**
 - net for a cycle, 33, 34
 - p**dv*, 38
 - p**dv* in atmosphere, 170
 - reversible and irreversible, 43–4
 - shaft, 92
 - sign convention, 32
 - stirring, 44
 - Zeldovich mechanisms, 210