

Index

- Adiabatic lapse rate, 61:
derivation of, 143–144
formula for, 63, 144
of moist air, 110–111
of planetary atmospheres,
63
- Albedo, 46, 88, 132:
effect of clouds on, 107
of Earth, 92
of planets, 47
- Ammonia (NH₃), 3, 4:
on Jupiter, 114–115
saturated vapor pressure
of, 114
- Annulus experiment, 103
- Anticyclone, 97 (*see also*
Planetary waves)
- Argon (A), 3, 4:
in primordial atmosphere,
131
- Atmospheric density, 4
Atmospheric pressure, 4
- Balanced wind, 96–97
- Barometric Law, 4–11:
application of, 40, 55, 61,
76
- Biosphere, 139–141
- Boltzmann's constant, 137
- Boyle's Law, 5, 7
- Buys Ballot's Law, 97
- Calcium silicate (*see* Wol-
lastonite)
- Carbon dioxide (CO₂):
abundance in sedimentary
rocks, 132
accumulation in primitive
atmospheres, 132–134
in atmosphere of Earth,
2–4
in atmosphere of Mars, 4,
66
in atmosphere of Venus,
4, 57, 113, 130–132
condensation of on Mars,
107, 113–114
- Carbon dioxide (*cont.*)
cycle in Earth's atmos-
phere, 127–130, 140–
141
photoionization of, 35
saturated vapor pressure
of, 114
- Carbon monoxide (CO), 3,
4:
and dissociation of CO⁺,
35
- Chapman profile, 25–27, 36
- Charles' Law, 5
- Chromosphere of Sun, 21
- Circulation, 72:
analogy with Reynolds'
experiment, 79–80
in atmosphere of Venus,
85–88
direct thermal, 83–85
of Earth's atmosphere,
72–78
of Martian atmosphere,
98–99
in tropics, 88–92, 96
- Clouds, 106–125:
on Jupiter, 115
on Mars, 113
on Venus, 85, 106, 113
- Coalescence, 118–121
- Composition:
atmospheric, 2–4
of planets, 4
primordial, 131
- Condensation, 106–125:
of carbon dioxide, 107
in evolving atmosphere,
133–134
- Condensation level, 111
- Condensation nuclei, 115–
117
- Conduction:
in thermosphere of Earth,
69
- Convection, 52, 60, 61–65:
in Martian troposphere,
67
- Coriolis force, 92–96, 97
- Corona:
of Sun, 21
- Critical level:
on Earth, 135
on Venus, 135
- Cyclone, 97 (*see also* Planet-
ary waves)
- Daily average wind, 74
- Density:
atmospheric, 4
atmospheric constituents
of Earth, 32–34
changes on Sun, 21–22
of O, O₂, and O₃ in Earth's
atmosphere, 25
of planetary ionospheres,
36–41
of planets, 14
in thermosphere of Earth,
68
variation with altitude,
4–11
variation of O in Earth's
atmosphere, 29–31
variation of O₂ in Earth's
atmosphere, 41–43
- Diffusion, 30, 32–34
in ionosphere, 38, 39–40
- Diurnal variation (*see* Tem-
perature)
- Earth:
adiabatic lapse rate, 63
albedo, 47, 92, 107
atmospheric temperature
profile, 58–59
biosphere, 139–141
carbon dioxide cycle in
atmosphere, 127–130
circulation in tropics, 88–
92
composition of atmos-
phere, 4
condensation on, 107–112
diurnal temperature varia-

- Earth (*cont.*)
 tion, 88-89
 effect of oceans on atmosphere, 2
 effective temperature, 47, 49, 107
 escape velocity, 137
 evolution of atmosphere, 131
 gravitational acceleration, 11
 greenhouse effect, 58-60, 134
 heat budget, 51-52
 mass of atmosphere, 12
 mass of oceans, 12
 mean molecular mass, 11
 ozone screen, 40-43
 physical data, 14
 planetary waves, 100-102
 scale height, 9, 11
 solar flux, 47
 solar radiation varies with latitude, 89-91
 specific heat, 63
 structure of ionosphere, 36
 surface temperature, 11, 49
 temperature of atmosphere near ground, 9
 temperature profile of atmosphere, 59, 64
 thermal emission spectrum, 50
 water vapor in atmosphere, 58, 66, 132
 Eccentricity of orbit, 15:
 effect on seasonal variations, 15
 of planets, 14
 Effective temperature:
 distinguished from surface temperature, 49
 of Earth, 107
 effect of clouds on, 107
 of planets, 46-48
 of Sun, 50
 Electromagnetic radiation, 18, 23-24 (*see also* Solar radiation, infrared radiation, ultraviolet radiation)
 Electrons, 35-40
 Emissivity, 59
 Equilibrium:
 of CO₂ on Earth, 128
 of CO₂ on Venus, 130-131
 photochemical, in atmospheres, 25, 30, 39
 Escape of atmospheric gases, 1, 135-139
 Escape velocity:
 calculation of, 136-137
 Escape velocity (*cont.*)
 of planets, 137
 Evaporation, 52, 108 (*see also* Chapter 5)
 Evolution of atmospheres, 126-141
 Exosphere, 135
 Ferrel, 78
 Freezing level, 111
 Gas constant, 5, 9-10, 32
 General circulation, 72:
 of atmosphere of Earth, 72-78
 of atmosphere of Mars, 98-99
 of atmosphere of Venus, 85-88
 Geostrophic balance, 96-97
 Gravitational acceleration, 5, 7-11, 55:
 of planets, 11, 14
 Greenhouse effect, 49-52:
 on Earth, 58-60, 107, 134
 on Mars, 133-134
 runaway, 132-134
 on Venus, 57-58, 134
 Hadley cell, 83-85:
 equatorial, 78, 88-92
 on Venus, 85-87
 Hail, 123-125
 Heat capacity, 88-89
 Heat low, 84
 Height increase and pressure decrease, 8
 Helium (He):
 in atmosphere of Earth, 3
 in primordial atmosphere, 131
 most probable velocity, 138
 on outer planets, 2, 4
 Humidity, relative, 108-110
 Hydrogen (H, H₂):
 in atmosphere of Earth, 3
 in atmospheres of outer planets, 2, 4, 139
 escape from Earth and Venus, 139
 most probable velocity, 138
 produced by photodissociation of water, 135
 Hydrogen chloride (HCl), 4
 Hydrogen fluoride (HF), 4
 Ideal gas law, 5:
 application of, 8, 82, 144
 Inclination of orbit:
 effect on seasonal variations, 14-17
 of planets, 14
 Inertial frame, 94
 Infrared radiation, 2, 50-52:
 absorption of in troposphere, 46
 in Martian troposphere, 66
 rate of emission of, by planets, 48
 in thermosphere of Earth, 68
 Inner planets, 11:
 composition of atmospheres, 4
 effective temperatures, 47, 49
 hydrogen on, 139
 sources of energy of, 46
 Inversion, 62-63:
 in Martian troposphere, 67
 Ionosphere:
 of Earth, 34, 36-41
 of Venus, 35-36
 Ions, 35-40
 Isobars, 72:
 showing geostrophic balance, 96-97
 showing pressure gradient, 82
 Isothermal atmosphere, 8, 62
 Jupiter:
 adiabatic lapse rate, 63
 albedo, 47
 appearance, 116
 clouds, 106
 cloud top temperature, 11
 composition of atmosphere, 2, 4, 115
 condensation on, 114-115
 definition of atmosphere, 2
 diurnal variation in atmospheric temperature, 89
 effective temperature, 47
 escape velocity, 137
 gravitational acceleration, 11
 mean molecular mass, 11
 physical data, 14
 scale height, 10-11
 solar flux, 15, 47
 specific heat, 63
 Kirchhoff's radiation laws, 59
 Krypton (Kr):
 in atmosphere of Earth, 3
 in primordial atmosphere, 131
 Latent heat:
 of condensation, 111
 of freezing, 111
 Law of mass action, 30, 36, 38

- Mariner spacecraft measurements:**
 on Mars, 13, 115
 on Venus, 36, 49, 87
- Mars:**
 adiabatic lapse rate, 63
 albedo, 47
 circulation of atmosphere, 98-99
 composition of atmosphere, 2-4
 condensation of carbon dioxide on, 113-114
 diffusive separation in upper atmosphere, 34
 diurnal variation of atmospheric temperature, 89
 effective temperature, 47
 escape velocity, 137
 evolution of atmosphere, 131
 gravitational acceleration, 11
 greenhouse effect, 133-134
 mean molecular mass, 11
 physical data, 14
 polar caps, 114
 scale height, 10-11
 solar flux, 47
 solar radiation varies with latitude, 89-90
 specific heat, 63
 surface pressure, 12
 surface temperature, 11, 49, 65-66
 troposphere, 65-67
 ultraviolet radiation at surface, 40
- Mass:**
 of planets, 14
 Mass, atmospheric, 12-13
 Mass, atomic, 33:
 calculation of escape velocity, 137
 in ionosphere, 38
 Mass, molecular, 9-11, 32:
 of Earth's atmosphere, 33
 in ionosphere, 40
 Mean free path, 135
- Mercury:**
 albedo, 47
 atmosphere, 139
 effective temperature, 47, 49
 escape velocity, 137
 physical data, 14
 solar flux, 47
- Mesopause, 45**
Mesosphere, 45, 64
Methane (CH₄), 3, 4
Mixing, 30-32:
 in ionosphere, 39
Monsoon, 83-85
- Moon:**
 escape velocity, 137
Most probable velocity, 137-138
- Neon (Ne), 3:**
 in primordial atmosphere, 131
- Neptune:**
 albedo, 47
 composition of atmosphere, 2, 4
 definition of atmosphere, 2
 effective temperature, 47
 escape velocity, 137
 physical data, 14
 solar flux, 47
- Newton's laws of motion, 5, 81, 82:**
 and Coriolis force, 93-95
- Nitrogen (N₂):**
 in atmosphere of Earth, 2-3, 9
 in atmospheres of inner planets, 4
 effect of solar radiation on, 23
 ionization of, 38
 in thermosphere of Earth, 33
- Nitrous oxide (N₂O), 3**
- Oceans:**
 absence on Mars, 66
 absence on Venus, 134
 effect on atmosphere of Earth, 2-3, 12, 107
 mass on Earth, 12
 role in carbon dioxide cycle on Earth, 127-128
 variation of pressure and density, 4-6
- Opacity, 58-59, 142**
Optical thickness, 53, 55:
 in calculation of surface temperature of primitive planets, 132
 for Earth, 58
 for Venus, 57
- Outer planets:**
 composition of atmospheres, 2-4
 effective temperatures, 47, 49
 hydrogen on, 139
- Oxygen, atmospheric:**
 cycles of, 140
 fluctuation in level, 141
- Oxygen, atomic (O), 24-31:**
 density in Earth's atmosphere, 25
 and dissociation of CO⁺, 35
- Oxygen, atomic (cont.)**
 escape from Earth's atmosphere, 138-139
 ionization of, 37-41
 most probable velocity, 138
 recombination of, 41-43
- Oxygen, molecular (O₂):**
 in atmosphere of Earth, 2-3, 9
 in atmospheres of inner planets, 4
 density in Earth's atmosphere, 25
 photodissociation of, 27-31, 41
- Ozone (O₃), 41-43:**
 absence in atmosphere of Mars, 65
 absorption of ultraviolet radiation, 45-46, 64, 141-142
 in atmosphere of Earth, 2-3, 60, 141
 density in Earth's atmosphere, 25
- Paleozoic era, 141**
Period of rotation:
 of planets, 14, 15-16
- Photochemical equilibrium, 25, 30, 39**
Photodissociation, 24-27:
 of molecular oxygen, 27-31
 of ozone, 41-43
- Photoionization, 24, 34-40:**
 in thermosphere, 45
- Photon, 24 (see also Electromagnetic radiation)**
- Photon flux (see Solar radiation, ultraviolet radiation, infrared radiation)**
- Photosphere:**
 of Sun, 20-21
- Photosynthesis, 129, 131, 140**
Planck spectrum, 19-20, 50
Planetary radiation (see Infrared radiation)
Planetary waves, 100-102, 104
- Pluto:**
 albedo, 47
 effective temperature, 47
 physical data, 14
 solar flux, 47
- Precipitation mechanisms, 124:**
 shower and drizzle formation, 122-123
 snow, hail, and rain, 123-125

- Pressure, 4:
 increase on primitive planets, 132-134
 at surfaces of Earth, Mars, and Venus, 12
 in thermosphere of Earth, 68
 variation with altitude, 4-11
 on weather maps, 72, 74, 76
- Pressure, vapor (*see* Saturated vapor pressure)
- Pressure forces, 81-83:
 action on atmosphere of Venus, 83
 factor in geostrophic balance, 96
 in Martian atmosphere, 99
- Pressure gradient, 82
- Radiative equilibrium, 53:
 model for Earth, 59-60, 64
 model for Venus, 57
- Radiative transfer theory, 52-57:
 application to Earth, 58-60
 application to Venus, 57-58
- Rain, 122-125
- Recombination process:
 of atomic oxygen, 28-31, 41
 of CO_2 , 35-36
 of O^+ , 37-39, 41-43
- Respiration and decay, 129
- Reynolds' experiment, 78-80, 101
- Runaway greenhouse effect, 132-134
- Saturated vapor pressure, 107-108:
 of ammonia, 114
 of carbon dioxide, 113-114
 over curved surface, 116-117
 over ice and supercooled water, 124
 of water, 114, 133
- Saturn:
 albedo, 47
 clouds, 106
 composition of atmosphere, 2, 4
 composition of rings, 108
 definition of atmosphere, 2
 effective temperature, 47
 escape velocity, 137
 physical data, 14
 solar flux, 47
- Scale height, 8-11, 32-33:
 of water vapor in Earth's atmosphere, 58
- Skin temperature, 59, 144
- Snow, 123-125
- Solar flux (*see* Solar radiation)
- Solar radiation:
 and atmospheric temperatures, 44-70
 and chemical change, 23-43
 flux as function of distance, 13-14, 47
 flux as function of latitude, 89-92
 penetration of Venus cloud cover, 85
 spectrum of, 18-23, 50 (*see also* Ultraviolet radiation)
- Solar spectrum (*see* Solar radiation)
- Solar wind, 18
- Specific heat, 144:
 of planetary atmospheres, 63
- Splintering, 125
- Stability condition, 80
- Stable flow, 80
- Stefan-Boltzmann Law, 48, 68, 85
- Stokes' Law, 118
- Stratopause, 44-45:
 temperature of, 142
- Stratosphere, 45, 64
- Sublimation, 124-125
- Sun, 17-23:
 composition of, 2
- Supercooling, 108-110, 111:
 and precipitation, 123-125
- Supersaturation, 108-110, 117
- Temperature:
 of atmosphere of Earth near ground, 9
 and discussion of Barometric Law, 5, 8-11
 diurnal variation in planetary atmospheres, 88-89
 effect of atmospheric constituents on, 2
 effect on densities of atmospheric constituents, 33-34
 in lower atmosphere of Venus, 87
 of planetary atmospheres, 44-70
 related to saturated vapor pressure, 108
 of solar atmosphere, 20-21
- Temperature (*cont.*)
 of stratopause, 142
 in thermosphere of Earth, 68-70
- Temperature, surface:
 of Earth, 2, 49
 effect of changes on Earth's atmosphere, 12
 of Mars, 49, 65-66
 of planets, 49
 of primitive planets, 132-134
 of Venus, 12, 49
- Terminal velocity of water drop, 118-119
- Thermosphere, 44:
 temperature of, 45, 68-70
- Time step, 98
- Trade wind, 78
- Tropopause, 45
- Troposphere, 45:
 convection in, 65
 of Earth, 46, 59-60, 64, 111
 of Mars, 65-67
- Turbulence, 78-80
- Ultraviolet radiation, 23, 35 (*see also* Solar radiation):
 absorption in thermosphere, 45, 69
 ozone screen on Earth, 46, 141
 photodissociation of O_2 , 27-28
 photodissociation of ozone, 40-43
 photodissociation of water vapor, 135
 photoionization in planetary atmospheres, 34-40
- Unstable flow, 80
- Uranus:
 albedo, 47
 composition of atmosphere, 2, 4
 definition of atmosphere, 2
 effective temperature, 47
 escape velocity, 137
 physical data, 14
 solar flux, 47
- Vapor pressure (*see* Saturated vapor pressure)
- Venera spacecraft measurements, 3, 12, 49, 87
- Venus:
 adiabatic lapse rate, 63
 albedo, 47
 carbon dioxide in atmosphere, 130-132

- Venus (*cont.*)
 circulation in atmosphere, 85-88
 cloud cover, 85, 106, 113
 composition of atmosphere, 2-4, 113
 condensation on, 113
 diffusive separation in upper atmosphere, 34
 diurnal variation of atmospheric temperature, 89
 effective temperature, 47, 49
 escape velocity, 137
 evolution of atmosphere, 131
 gravitational acceleration, 11
 greenhouse effect, 57-58, 134
 mean molecular mass, 11
 physical data, 14
 pressure forces in atmosphere, 83-85
 pressure at top of clouds, 113-114
 radiative-convective the-
- Venus (*cont.*)
 ory applied to atmosphere, 64-65
 scale height, 10-11
 solar flux, 47, 90
 specific heat, 63
 structure of ionosphere, 35-36
 surface pressure, 12, 85, 89
 surface temperature, 11, 49, 85, 131
 temperature at top of clouds, 113
- Viscosity, 81
- Water vapor (H₂O), 106-125:
 absorption of radiation by, 51, 106-109
 in atmosphere of Earth, 2-4, 58, 66, 132
 in atmosphere of Mars, 4
 in atmosphere of Venus, 4, 57, 134
 photodissociation of, 135, 139
 in primitive atmospheres, 132-134
- Water vapor (*cont.*)
 saturated vapor pressure, 114
- Weather maps, 72-73:
 of Earth, 96-97, 101
 of Mars, 99
- Weather prediction, numerical, 98-99, 105
- Weather systems:
 of Earth, 97, 100
 of planets, 72
- Weather and turbulence, 78-80
- Wien's radiation law, 50
- Wind vectors, 73-74, 76-78
- Winds, 71-105:
 balanced, 96-97
 daily average, 74
 geostrophic, 96-97
 global, 72-78
- Wollastonite (calcium silicate):
 reaction with carbon dioxide, 130
- Xenon (Xe):
 in Earth's atmosphere, 3
 in primordial atmosphere, 131