CAMBRIDGE

Cambridge University Press
978-0-521-71590-4 - The Mechanical Universe: Mechanics and Heat, Advanced Edition
Steven C. Frautschi, Richard P. Olenick, Tom M. Apostol and David L. Goodstein
Index
More information

INDEX

Absolute temperature, 498
Absolute zero, 497
Accelerated motion, 21
Acceleration, 20, 98, 103
  angular, 103–105, 372
  average, 8, 20
  centripetal, 104, 178, 456
  components, 98
  due to gravity, 12, 151
  in polar coordinates, 455
  instantaneous, 20, 98
Action and reaction, 116, 124, 135
Adiabatic process, 513, 515
  for ideal gas, 515
Albert of Saxony, 14, 19, 23
Amontons, Guillaume, 179
Ampère, Andre Marie, 164
Ampere, 564
Amplitude, 303
Angular acceleration, 103, 372
Angular frequency, 303
  natural, 304
Angular impulse, 338
Angular momentum, 336–337
  and galactic formation, 354
  and torque, 337
  conservation of, 336, 344, 350–353
Angular speed, 101
Angular velocity, 397
Anticyclone, 399
Antiderivative(s), 38, 55
  table of, 39
Antidifferentiation, 38, 55
Apparent weight, 208
Aphelion, 442
Apogee, 471

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-71590-4 - The Mechanical Universe: Mechanics and Heat, Advanced Edition
Steven C. Frautschi, Richard P. Olenick, Tom M. Apostol and David L. Goodstein
Index
More information

Appolonius, 437
Archimedes, 28, 41, 51, 195, 214
Archimedes principle, 214
Area, 40
  of ellipse, 446
  of parabolic segment, 41
Aristotle, 1, 11, 58, 62, 63, 134, 189
Associativity, 82, 107
Astronomical data, 571
Astronomical unit, 482, 572
Atwood's machine, 178
Average acceleration, 8, 20
Average speed, 8, 18
Average velocity, 8, 18
Avogadro's number, 574

Banked curve, 186
Barrow, Isaac, 45
Body temperature, 502
Boiling, 553
Boiling point, 492, 502
Boltzmann's constant, 499, 574
Boyle, Robert, 497
Boyle's law, 497
Brahe, Tycho, 153, 431
British units, 6, 8, 9
Bubble chamber, 276

Cailletet, Louis Paul, 556
Calorie, 247, 566
Cartesian coordinates, 76
Carnot, Nicolas Léonard Sadi, 253, 506
Carnot cycle, 521
Carnot engine, 521
Cavendish, Henry, 166
Cavendish apparatus, 166
Celsius, Anders, 502
Celsius temperature, 492, 502
Center of gravity, 127
Center of mass, 266, 365
Central force, 344
Centrifugal force, 157, 210–214, 216–218
Centripetal acceleration, 154, 179, 204
Centripetal force, 151, 156, 178, 185
Centrifuge, 157, 213
Chain rule, 35, 37, 99
Change of phase, 548–551
Characteristic time, 190
Charge, 164
  of electron, measurement, 192–196
Charles, Jacques Alexander César, 497
Charles, law of, 498
Circular motion, 101, 154–159, 161
Clapeyron, Émile, 525
Clausius, Rudolph, 525, 531
Coefficient of friction, 179–182, 185
  table, 181
Collisions, 276, 286
  elastic, 277
  inelastic, 277
Commutativity, 81, 88
Components of vectors, 78, 84, 90, 95, 105
Compression, 122, 169
Conic sections, 437
  Cartesian equations for, 446
  polar equations for, 440
Conservation
  of angular momentum, 336, 344, 350–353
  of energy, 220, 229
  of momentum, 270, 275
Conservative force, 239
Contact force, 168–172, 197
Conversion factors, 565–567
Coordinates, 75–77
  center-of-mass, 282
  polar, 76
  rectangular, 76
Copernicus, Nicolaus, 2, 4, 9, 57, 106, 153, 415
Coriolis force, 396–400
Coulomb, Charles Augustin, 164, 167, 178
Coulomb's law, 164, 167, 179
Couple, 139, 343
Cranking in space navigation, 487
Critical point, 550
Cross product, 93
Cyclone, 400

Damped oscillation, 313
Damping coefficient, 314
Density, 364, 365
Derivative(s), 18–21, 27–37, 32–35, 96–99
  and acceleration, 20, 21, 98
  and slope, 28–31, 52
  and speed, 18–20
  and velocity, 18–20, 97
  table of, 37
Descartes, René, 51, 76, 114, 263
Determinant for cross product, 95
Dewar, James, 559
Diatomic gas, 501, 514
Differential equation, 120, 189–192, 299
Differentiation, 18–21, 27–37, 52–55, 96–99
  rules for, 32–37, 98–99
Dimension, 8, 9, 81
Dimensional analysis, 190
Directrix, 439
Displacement, 78
Distributivity, 89
Dot product, 88
Dynamics, 114
Dyne, 118–119

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-71590-4 - The Mechanical Universe: Mechanics and Heat, Advanced Edition
Steven C. Frautschi, Richard P. Olenick, Tom M. Apostol and David L. Goodstein
Index
More information

e (base of natural logarithm), 37
Eccentricity, of conic sections, 439
  and energy, 461
  of planetary orbits (table), 436, 572
Ecliptic, 414
Effective potential, 352, 464
Efficiency
  of heat engines, 520
  of machines, 252
Einstein, Albert, 12, 22, 165, 203, 213, 216
Electric charge, 167
Electric field, 192–195
Electromagnetic force, 164
Electron, charge of, 192–196, 573
Ellipse, 438, 439
Energy, 219–261
  and eccentricity, 461
  and work, 221–227, 232
  conservation, 220, 229, 238
  effective potential, 464
  gravitational potential, 221–223, 231, 236–240
  in simple harmonic motion, 307
  in thermodynamics, 500, 513
  internal, 501, 513
    of ideal gas, 501, 513
  kinetic, 220, 228–236
  of a spring, 227, 231, 233–236
  potential, 220–222, 230
  rotational, 351, 381
Energy conversion, 221, 226, 228–240, 246, 250, 253
Engine
  Carnot, 521
  steam, 506
Entropy, 525, 532
  and disorder, 544
  and second law of thermodynamics, 539
Equality, of vectors, 77
Equilibrant, 128, 344
Equilibrium, 120–133, 136–139, 183, 241–244, 259
  neutral, 243
  stable, 242–244, 259
  unstable, 242–244
Equilibrium, phase, 548
Equilibrium state, 551
Erg, 227, 567
Escape velocity, 240
Euler, Leonhard, 115, 363
Exponential function, 36–37
External force, 268

Fahrenheit, Daniel, 502
Fahrenheit temperature, 492, 502
Falling bodies, law of, 12, 13, 15–18, 24–25
Faraday, Michael, 146, 164, 554
Farquharson, Bert, 328
Fermat, Pierre de, 10, 28, 44, 51
Feynman, Richard P., 354
Field lines, electric, 146
Firestorms, 349
First law of motion, 114, 265
First law of thermodynamics, 253, 513
Focus, of a conic section, 437
Foot-pound, 227
Force, 114–139
  central, 344
  centrifugal, 157, 210–214, 216–218
  centripetal, 151, 156–159, 178, 185–187
  conservative, 239
  contact, 168–172, 197
  Coriolis, 396–400
  electromagnetic, 164, 165, 167–169, 171, 180, 197
  external, 124, 126–127
  gravitational, 142–143
  inertial, 208–217
  strong, 165, 167–168
  weak, 165, 167–168
Foucault pendulum, 399
Forced oscillation, 316
Franklin, Benjamin, 167
Frame of reference, 62–63, 120–121, 203–218
  center-of-mass, 282
  inertial, 203–207, 213
  linearly accelerating, 205, 208–210, 216
  rest, 282
  uniformly rotating, 210–215, 216–218
Free-body diagram, 123–125, 131, 138, 173–177
Frequency, 303
  angular, 303
  natural, 304
Friction, 179–187, 199–201, 246
  coefficient of, 179–182, 185
    table, 181
  kinetic, 180–183
  rolling, 186
  static, 180, 182, 183
F ring of Saturn, 488
Fundamental theorems of calculus, 45–46

g (gravitational acceleration), 20
  latitude dependence of, 211–213
Galactic formation, 354
Galilean relativity, 204–207, 215–216
Galileo, 3, 4, 9, 11–19, 57–58, 60–63, 114, 119, 175, 204, 215–216, 220–223, 309
Galileo's law
  of falling bodies, 12, 13, 15–18, 24–25
  of inertia, 60–62
  of odd numbers, 14, 15
Gas constant, 499

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-71590-4 - The Mechanical Universe: Mechanics and Heat, Advanced Edition
Steven C. Frautschi, Richard P. Olenick, Tom M. Apostol and David L. Goodstein
Index
More information

Gas, kinetic theory, 494
Gassendi, Pierre, 62
Gay-Lussac, Joseph Louis, 498
Gay-Lussac, law of, 498
Gibbs, Josiah Willard, 75, 77
Gravitation, 142–149, 163–164, 165–167, 197
Gravitational constant, 142–143, 166–167, 197
Gravity, acceleration due to, 20, 149–151, 160, 211–213
Gravity assist, 485
Gyroscope, 415
Gyroscopic precession, 416

Halley, Edmund, 142, 427
Halley's comet, 472
Harmonic motion, 297
Harmonic oscillator, 303
Harrison, John, 309
Heat, 243, 246–249, 259, 260
Heat engine, 515, 519–521
Heat of fusion, 549
  table, 549
Heat of vaporization, 549
  table, 549
Heat reservoir, 520–521
Heat transfer, 246–247
Heaviside, Oliver, 77
Helium, 501, 560
Helix, 99
Helmholtz, Herman von, 246–247, 249
Helmholtz free energy, 543
Hertz, 303, 564
Hipparchus, 415
Hohman transfer orbit, 478, 480
Hooke, Robert, 169
Hooke's law, 169–172, 241
Horsepower, 252
Huygens, Christian, 309, 384
Hyperbola, 438

Ideal gas, 498
  adiabatic process, 515
  internal energy of, 501
  kinetic theory of, 494–496
Impact parameter, 281
Impetus, 63–65
Impulsive force, 286
Inclined plane, 250–251
Indefinite integral, 47
Inertia, 60–65, 68–69, 114
Inertial force, 208–210
Inertial reference frame, 62–63, 115, 213
Initial velocity, 65
Instantaneous acceleration, 20–21, 98
Instantaneous speed, 18–20, 78, 103

Integral, 44–48
  definite, 47
  indefinite, 47
  line, 224–226
Integrand, 44–45
Integration, 44–52, 55–56
Internal energy, of ideal gas, 501, 513
International System of Units, 6, 563
Irreversible process, 532
Isothermal process, 515

Jet propulsion, 275
Joule, James Prescott, 219, 246–249, 513, 557
Joule, unit of energy, 227, 564, 567
Joule's apparatus, 247–248
Joule–Thomson effect, 557
Jupiter, 350

Kammerlingh-Onnes, Heike, 559, 560
Kármán, Theodore von, 327, 328
Kelvin, Lord (William Thomson), 498, 557
Kelvin temperature, 498, 564
Kelvin temperature scale, 498
Kepler, Johannes, 3, 4, 51, 153, 344, 433
Kepler's laws of planetary motion, 142
  first law, 345, 435
  second law, 346, 434
  third law, 142, 156, 436, 463
Kepler problem, 451, 457
Keplerian system, 459
Kilogram, 564
Kilowatt, 253
Kilowatt hour, 253
Kinematics, 114
Kinetic energy, 220, 228
Kinetic friction, 180–183

Latent heat, 549
Launch opportunity, 479
Launch window, 479
Leibniz, Gottfried Wilhelm, 21–23, 31–32, 34, 39, 44–47, 51–52
Leibniz notation, for derivatives, 31–32
  for integrals, 44–47
Leonardo da Vinci, 14–17, 21, 23, 24
Lever, 126, 250
Linde, Karl von, 559
Line integral, 224–226
Lines of force, electric, 146
  gravitational, 146–148
Liquefaction, 553
Logarithms (base e), 36–37
LORAN, 438

Magnetic force, 164
Magnetism, 164

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-71590-4 - The Mechanical Universe: Mechanics and Heat, Advanced Edition
Steven C. Frautschi, Richard P. Olenick, Tom M. Apostol and David L. Goodstein
Index
More information

Magnitude, of vector quantity, 78
Major axis of an ellipse, 439
Mars, 434
Mass, 117–119, 134, 564
  center of, 266, 365
Maxwell, James Clerk, 164, 215–216
Mean distance from the sun, 482, 572
Mechanical advantage, 250–251, 260–261
Melting, 549
Meter, 6–7, 563
Michelson, A. A., 215–216
Millikan, Robert Andrews, 192–197
Millikan oil-drop experiment, 192–197, 202
Minor axis of an ellipse, 443
Moment of inertia, 365, 372
  table, 379
Momentum, 114–115, 118, 264
  angular, 336–337
  conservation of, 270, 275
Monatomic gas, 501
Motion
  circular, 101
  constant-acceleration, 20
  in a plane, 100
  in a resistive medium, 187–192
  in space, 96
  of planet, 457–459
  of projectile, 64–66
  rotational, 383
  simple harmonic, 297
  translational, 383

Natural frequency, 304
Newton, Isaac, 4, 5, 10, 22, 32, 42, 51, 113–116, 141–142, 145, 147–148, 151–154, 159, 163, 187, 427
Newton, unit of force, 118–119, 564
Newtonian synthesis, 4, 154
Newton's law of gravitation, 142–145, 147–149, 160, 164, 165–166
Newton's laws of motion, 114–117, 119–120, 134–135, 265
  first law, 114, 265
  second law, 114–115, 134, 144, 155, 265
  third law, 116–117, 122–123, 265
Normal force, 170
Nutation, 419

Oersted, Hans Christian, 164
Orbit, of planet or satellite, 462
Oresme, Nicole, 14, 19, 21
Oscillation, 297
  critically damped, 315
  damped, 313
  damped forced, 321
  forced, 316
  overdamped, 316
  underdamped, 316
Oscillatory motion, 297

Pappus, theorems of, 368
Parabola, 41, 66, 438
Parabolic segment, 41–42
Parabolic trajectory, 65–66, 68
Parallel axis theorem, 380
Parallelogram law, 82
Parking orbit, 479
Pendulum
  conical, 156–157, 161, 226
  Foucault, 399
  physical, 384
  simple, 231–233, 309
  torsion, 387
Perigee, 471
Perihelion, 442
Period, 303
  of orbital motion, 101, 156
Periodic motion, 297
Perpendicular axis theorem, 378
Phase, 548
Phase diagram, 548
Phase equilibrium, 548
Phase transition, 549
Physical pendulum, 384
Pictet, Raoul Pierre, 556
Plane motion, 100
Planetary motion, 151–156, 161
Plato, 1, 2
Polar coordinates, 100
Position vector, 96, 100
Potential energy, 220–222, 230
Pound, 118–119
Power, 252–253, 261, 564
Precession, 416
  angular velocity of, 422
  gyroscopic, 416
  of Earth, 426
  of equinoxes, 415, 427
Prefixes, in SI units, 7
  for units, 7
Pressure, 493, 564
Products of vectors
  cross product, 93
  dot, or scalar product, 88
Projectile motion, 63–68, 70–73, 80, 83, 119–120, 136, 151–152
Proton, 167
Ptolemy, 134, 153
Pulley, 251
Pumping in space navigation, 487

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-71590-4 - The Mechanical Universe: Mechanics and Heat, Advanced Edition
Steven C. Frautschi, Richard P. Olenick, Tom M. Apostol and David L. Goodstein
Index
More information

Speed (*cont.*)
of sound wave, 427
of water wave, 423
Stability, 278
and potential energy, 281
Standards, 6
Static friction, 211
Steam engine, 302
Stiffness, 199
Stokes, George Gabriel, 233
Stokes's law, 233
Strong force, 195
Sublimation, 345
Subtraction of vectors, 89
Superposition principle, 162
Surface, *PVT*, 347
Système International, 7
Systems of units, 6, 118

Tacoma Narrows Bridge, 409
Tangent line, 44
Temperature, 288
Temperature scales, 296
Tension, 200
Terminal velocity, 234
Thermal efficiency, 318
Carnot cycle, 320
Thermal equilibrium, 337
Thermodynamics
first law, 310
second law, 318
Thermometer, 299
Thilorier, 351
Thompson, Benjamin (Count Rumford), 309
Thomson, Joseph John, 230
Thomson, William (Lord Kelvin), 294, 354
Threshold
of audibility, 429
of pain, 428
Tides, 543
Torque, 444
and angular momentum, 445
Transfer orbit, 526
Transverse waves, 419
Trigonometric functions, 59
Triple point, 346
table, 346
Tychonic theory, 479

Uniform circular motion, 176, 184
Uniformly accelerated motion, 33
Unit conversion factors, 7
Unit vectors, 97, 499
Units
conversion of, 7, 565
International System of, 7, 563
systems of, 5
Universal gas constant, 296, 574
Universal gravitational constant, 196, 573

Van der Waals, Johannes Diderik, 297, 354, 357
Van Marum, Martin, 351
Vector product, 106
Vector quantity, 83
Vector sum, 87
Velocity, angular, 464, 502
average, 179
in polar coordinates, 500
instantaneous, 179, 190
terminal, 234
Viscosity, 202, 233
table, 234
Volt, 564
Vortices, 448

Water waves, 418
Watt, James, 302
Watt, 567
Wave
frequency, 419
longitudinal, 419
sinusoidal, 419
speed, 419
transverse, 419
water, 418
Wavelength, 419
Weak force, 195
Weighing the earth, 196
Weight, 117
and mass, 117
Work, 247, 249, 268
done by a varying force, 249, 268
and energy, 249, 270
in isothermal expansion, 312
in volume change, 305

Zero vector, 85

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-71590-4 - The Mechanical Universe: Mechanics and Heat, Advanced Edition
Steven C. Frautschi, Richard P. Olenick, Tom M. Apostol and David L. Goodstein
Index
More information

average, 8, 18
in polar coordinates, 455
instantaneous, 18–20, 97–98
terminal, 189–192, 194–195
Viscosity, 187–195, 214–215, 246
table, 188
Volt, 564
Vortices, 349

Watt, James, 252, 506
Watt, 252–253, 564
Weak force, 165
Weighing the earth, 166
Weight, 118, 128–129, 208–209
and mass, 118, 135–136, 212
Weightlessness, 209
Wheel and axle, 251
Work, 221–227, 254–255
and energy, 255
done by a varying force, 223–226
in isothermal expansion, 515
in volume change, 507–510
rotational, 382

Young's modulus, 172

Zero vector, 81
Zodiac, 414

© Cambridge University Press www.cambridge.org