# APPENDIX C | USEFUL INFORMATION

This appendix is broken into several tables.

- **Table C1**, Important Constants
- **Table C2**, Submicroscopic Masses
- **Table C3**, Solar System Data
- **Table C4**, Metric Prefixes for Powers of Ten and Their Symbols
- **Table C5**, The Greek Alphabet
- **Table C6**, SI units
- **Table C7**, Selected British Units
- **Table C8**, Other Units
- **Table C9**, Useful Formulae

Table C1 Important Constants[1]

| Symbol | Meaning | Best Value | Approximate Value |
|---|---|---|---|
| $c$ | Speed of light in vacuum | $2.99792458\times10^{8}\,\text{m/s}$ | $3.00\times10^{8}\,\text{m/s}$ |
| $G$ | Gravitational constant | $6.67408(31)\times10^{-11}\,\text{N}\cdot\text{m}^2/\text{kg}^2$ | $6.67\times10^{-11}\,\text{N}\cdot\text{m}^2/\text{kg}^2$ |
| $N_A$ | Avogadro's number | $6.02214129(27)\times10^{23}$ | $6.02\times10^{23}$ |
| $k$ | Boltzmann's constant | $1.3806488(13)\times10^{-23}\,\text{J/K}$ | $1.38\times10^{-23}\,\text{J/K}$ |
| $R$ | Gas constant | $8.3144621(75)\,\text{J/mol}\cdot\text{K}$ | $8.31\,\text{J/mol}\cdot\text{K}=1.99\,\text{cal/mol}\cdot\text{K}=0.0821\text{atm}\cdot\text{L/mol}\cdot\text{K}$ |
| $\sigma$ | Stefan-Boltzmann constant | $5.670373(21)\times10^{-8}\,\text{W/m}^2\cdot\text{K}$ | $5.67\times10^{-8}\,\text{W/m}^2\cdot\text{K}$ |
| $k$ | Coulomb force constant | $8.987551788...\times10^{9}\,\text{N}\cdot\text{m}^2/\text{C}^2$ | $8.99\times10^{9}\,\text{N}\cdot\text{m}^2/\text{C}^2$ |
| $q_e$ | Charge on electron | $-1.602176565(35)\times10^{-19}\,\text{C}$ | $-1.60\times10^{-19}\,\text{C}$ |
| $\varepsilon_0$ | Permittivity of free space | $8.854187817...\times10^{-12}\,\text{C}^2/\text{N}\cdot\text{m}^2$ | $8.85\times10^{-12}\,\text{C}^2/\text{N}\cdot\text{m}^2$ |
| $\mu_0$ | Permeability of free space | $4\pi\times10^{-7}\,\text{T}\cdot\text{m/A}$ | $1.26\times10^{-6}\,\text{T}\cdot\text{m/A}$ |
| $h$ | Planck's constant | $6.62606957(29)\times10^{-34}\,\text{J}\cdot\text{s}$ | $6.63\times10^{-34}\,\text{J}\cdot\text{s}$ |

Table C2 Submicroscopic Masses[2]

| Symbol | Meaning | Best Value | Approximate Value |
|---|---|---|---|
| $m_e$ | Electron mass | $9.10938291(40)\times10^{-31}\text{kg}$ | $9.11\times10^{-31}\text{kg}$ |
| $m_p$ | Proton mass | $1.672621777(74)\times10^{-27}\text{kg}$ | $1.6726\times10^{-27}\text{kg}$ |
| $m_n$ | Neutron mass | $1.674927351(74)\times10^{-27}\text{kg}$ | $1.6749\times10^{-27}\text{kg}$ |

1. Stated values are according to the National Institute of Standards and Technology Reference on Constants, Units, and Uncertainty, www.physics.nist.gov/cuu (http://www.physics.nist.gov/cuu) (accessed May 18, 2012). Values in parentheses are the uncertainties in the last digits. Numbers without uncertainties are exact as defined.
2. Stated values are according to the National Institute of Standards and Technology Reference on Constants, Units, and Uncertainty, www.physics.nist.gov/cuu (http://www.physics.nist.gov/cuu) (accessed May 18, 2012). Values in parentheses are the uncertainties in the last digits. Numbers without uncertainties are exact as defined.

| Symbol | Meaning | Best Value | Approximate Value |
|---|---|---|---|
| u | Atomic mass unit | $1.660538921(73)\times10^{-27}\text{kg}$ | $1.6605\times10^{-27}\text{kg}$ |

Table C3 Solar System Data

| | | |
|---|---|---|
| **Sun** | mass | $1.99\times10^{30}\text{kg}$ |
| | average radius | $6.96\times10^{8}\text{m}$ |
| | Earth-sun distance (average) | $1.496\times10^{11}\text{m}$ |
| **Earth** | mass | $5.9736\times10^{24}\text{kg}$ |
| | average radius | $6.376\times10^{6}\text{m}$ |
| | orbital period | $3.16\times10^{7}\text{s}$ |
| **Moon** | mass | $7.35\times10^{22}\text{kg}$ |
| | average radius | $1.74\times10^{6}\text{m}$ |
| | orbital period (average) | $2.36\times10^{6}\text{s}$ |
| | Earth-moon distance (average) | $3.84\times10^{8}\text{m}$ |

Table C4 Metric Prefixes for Powers of Ten and Their Symbols

| Prefix | Symbol | Value | Prefix | Symbol | Value |
|---|---|---|---|---|---|
| tera | T | $10^{12}$ | deci | d | $10^{-1}$ |
| giga | G | $10^{9}$ | centi | c | $10^{-2}$ |
| mega | M | $10^{6}$ | milli | m | $10^{-3}$ |
| kilo | k | $10^{3}$ | micro | $\mu$ | $10^{-6}$ |
| hecto | h | $10^{2}$ | nano | n | $10^{-9}$ |
| deka | da | $10^{1}$ | pico | p | $10^{-12}$ |
| — | — | $10^{0}(=1)$ | femto | f | $10^{-15}$ |

Table C5 The Greek Alphabet

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Alpha | A | $\alpha$ | Eta | H | $\eta$ | Nu | N | $\nu$ | Tau | T | $\tau$ |
| Beta | B | $\beta$ | Theta | $\Theta$ | $\theta$ | Xi | $\Xi$ | $\xi$ | Upsilon | $\Upsilon$ | $\upsilon$ |
| Gamma | $\Gamma$ | $\gamma$ | Iota | I | $\iota$ | Omicron | O | $o$ | Phi | $\Phi$ | $\phi$ |
| Delta | $\Delta$ | $\delta$ | Kappa | K | $\kappa$ | Pi | $\Pi$ | $\pi$ | Chi | X | $\chi$ |
| Epsilon | E | $\varepsilon$ | Lambda | $\Lambda$ | $\lambda$ | Rho | P | $\rho$ | Psi | $\Psi$ | $\psi$ |
| Zeta | Z | $\zeta$ | Mu | M | $\mu$ | Sigma | $\Sigma$ | $\sigma$ | Omega | $\Omega$ | $\omega$ |

Table C6 SI Units

| | Entity | Abbreviation | Name |
|---|---|---|---|
| **Fundamental units** | Length | m | meter |
| | Mass | kg | kilogram |

| | Entity | Abbreviation | Name |
|---|---|---|---|
| | Time | s | second |
| | Current | A | ampere |
| **Supplementary unit** | Angle | rad | radian |
| **Derived units** | Force | $N = kg \cdot m/s^2$ | newton |
| | Energy | $J = kg \cdot m^2/s^2$ | joule |
| | Power | $W = J/s$ | watt |
| | Pressure | $Pa = N/m^2$ | pascal |
| | Frequency | $Hz = 1/s$ | hertz |
| | Electronic potential | $V = J/C$ | volt |
| | Capacitance | $F = C/V$ | farad |
| | Charge | $C = s \cdot A$ | coulomb |
| | Resistance | $\Omega = V/A$ | ohm |
| | Magnetic field | $T = N/(A \cdot m)$ | tesla |
| | Nuclear decay rate | $Bq = 1/s$ | becquerel |

Table C7 Selected British Units

| | |
|---|---|
| Length | 1 inch (in.) = 2.54 cm (exactly) |
| | 1 foot (ft) = 0.3048 m |
| | 1 mile (mi) = 1.609 km |
| Force | 1 pound (lb) = 4.448 N |
| Energy | 1 British thermal unit (Btu) = $1.055\times10^{3}$ J |
| Power | 1 horsepower (hp) = 746 W |
| Pressure | 1 $lb/in^2$ = $6.895\times10^{3}$ Pa |

Table C8 Other Units

| | |
|---|---|
| Length | 1 light year (ly) = $9.46\times10^{15}$ m |
| | 1 astronomical unit (au) = $1.50\times10^{11}$ m |
| | 1 nautical mile = 1.852 km |
| | 1 angstrom(Å) = $10^{-10}$ m |
| Area | 1 acre (ac) = $4.05\times10^{3}$ $m^2$ |
| | 1 square foot ($ft^2$) = $9.29\times10^{-2}$ $m^2$ |
| | 1 barn ($b$) = $10^{-28}$ $m^2$ |
| Volume | 1 liter ($L$) = $10^{-3}$ $m^3$ |
| | 1 U.S. gallon (gal) = $3.785\times10^{-3}$ $m^3$ |

| | |
|---|---|
| Mass | 1 solar mass $= 1.99\times10^{30}$ kg |
| | 1 metric ton $= 10^{3}$ kg |
| | 1 atomic mass unit $(u) = 1.6605\times10^{-27}$ kg |
| Time | 1 year $(y) = 3.16\times10^{7}$ s |
| | 1 day $(d) = 86{,}400$ s |
| Speed | 1 mile per hour (mph) $= 1.609$ km / h |
| | 1 nautical mile per hour (naut) $= 1.852$ km / h |
| Angle | 1 degree $(^\circ) = 1.745\times10^{-2}$ rad |
| | 1 minute of arc $(') = 1/60$ degree |
| | 1 second of arc $('') = 1/60$ minute of arc |
| | 1 grad $= 1.571\times10^{-2}$ rad |
| Energy | 1 kiloton TNT (kT) $= 4.2\times10^{12}$ J |
| | 1 kilowatt hour $(\text{kW}\cdot h) = 3.60\times10^{6}$ J |
| | 1 food calorie (kcal) $= 4186$ J |
| | 1 calorie (cal) $= 4.186$ J |
| | 1 electron volt (eV) $= 1.60\times10^{-19}$ J |
| Pressure | 1 atmosphere (atm) $= 1.013\times10^{5}$ Pa |
| | 1 millimeter of mercury (mm Hg) $= 133.3$ Pa |
| | 1 torricelli (torr) $= 1$ mm Hg $= 133.3$ Pa |
| Nuclear decay rate | 1 curie (Ci) $= 3.70\times10^{10}$ Bq |

Table C9 Useful Formulae

| | |
|---|---|
| Circumference of a circle with radius $r$ or diameter $d$ | $C = 2\pi r = \pi d$ |
| Area of a circle with radius $r$ or diameter $d$ | $A = \pi r^2 = \pi d^2/4$ |
| Area of a sphere with radius $r$ | $A = 4\pi r^2$ |
| Volume of a sphere with radius $r$ | $V = (4/3)\left(\pi r^3\right)$ |

# APPENDIX D | GLOSSARY OF KEY SYMBOLS AND NOTATION

In this glossary, key symbols and notation are briefly defined.

Table D1

| Symbol | Definition |
|---|---|
| $\overline{\text{any symbol}}$ | average (indicated by a bar over a symbol—e.g., $\bar{v}$ is average velocity) |
| °C | Celsius degree |
| °F | Fahrenheit degree |
| // | parallel |
| $\perp$ | perpendicular |
| $\propto$ | proportional to |
| $\pm$ | plus or minus |
| 0 | zero as a subscript denotes an initial value |
| $\alpha$ | alpha rays |
| $\alpha$ | angular acceleration |
| $\alpha$ | temperature coefficient(s) of resistivity |
| $\beta$ | beta rays |
| $\beta$ | sound level |
| $\beta$ | volume coefficient of expansion |
| $\beta^-$ | electron emitted in nuclear beta decay |
| $\beta^+$ | positron decay |
| $\gamma$ | gamma rays |
| $\gamma$ | surface tension |
| $\gamma = 1/\sqrt{1 - v^2/c^2}$ | a constant used in relativity |
| $\Delta$ | change in whatever quantity follows |
| $\delta$ | uncertainty in whatever quantity follows |
| $\Delta E$ | change in energy between the initial and final orbits of an electron in an atom |
| $\Delta E$ | uncertainty in energy |
| $\Delta m$ | difference in mass between initial and final products |
| $\Delta N$ | number of decays that occur |
| $\Delta p$ | change in momentum |
| $\Delta p$ | uncertainty in momentum |
| $\Delta \text{PE}_\text{g}$ | change in gravitational potential energy |
| $\Delta\theta$ | rotation angle |

| Symbol | Definition |
|---|---|
| $\Delta s$ | distance traveled along a circular path |
| $\Delta t$ | uncertainty in time |
| $\Delta t_0$ | proper time as measured by an observer at rest relative to the process |
| $\Delta V$ | potential difference |
| $\Delta x$ | uncertainty in position |
| $\varepsilon_0$ | permittivity of free space |
| $\eta$ | viscosity |
| $\theta$ | angle between the force vector and the displacement vector |
| $\theta$ | angle between two lines |
| $\theta$ | contact angle |
| $\theta$ | direction of the resultant |
| $\theta_b$ | Brewster's angle |
| $\theta_c$ | critical angle |
| $\kappa$ | dielectric constant |
| $\lambda$ | decay constant of a nuclide |
| $\lambda$ | wavelength |
| $\lambda_n$ | wavelength in a medium |
| $\mu_0$ | permeability of free space |
| $\mu_\mathrm{k}$ | coefficient of kinetic friction |
| $\mu_\mathrm{s}$ | coefficient of static friction |
| $\nu_e$ | electron neutrino |
| $\pi^+$ | positive pion |
| $\pi^-$ | negative pion |
| $\pi^0$ | neutral pion |
| $\rho$ | density |
| $\rho_\mathrm{c}$ | critical density, the density needed to just halt universal expansion |
| $\rho_\mathrm{fl}$ | fluid density |
| $\bar{\rho}_\mathrm{obj}$ | average density of an object |
| $\rho / \rho_\mathrm{w}$ | specific gravity |
| $\tau$ | characteristic time constant for a resistance and inductance $(RL)$ or resistance and capacitance $(RC)$ circuit |
| $\tau$ | characteristic time for a resistor and capacitor $(RC)$ circuit |
| $\tau$ | torque |
| $\Upsilon$ | upsilon meson |
| $\Phi$ | magnetic flux |

| Symbol | Definition |
|---|---|
| $\phi$ | phase angle |
| $\Omega$ | ohm (unit) |
| $\omega$ | angular velocity |
| A | ampere (current unit) |
| $A$ | area |
| $A$ | cross-sectional area |
| $A$ | total number of nucleons |
| $a$ | acceleration |
| $a_{\mathrm{B}}$ | Bohr radius |
| $a_{\mathrm{c}}$ | centripetal acceleration |
| $a_{\mathrm{t}}$ | tangential acceleration |
| AC | alternating current |
| AM | amplitude modulation |
| atm | atmosphere |
| $B$ | baryon number |
| $B$ | blue quark color |
| $\bar{B}$ | antiblue (yellow) antiquark color |
| $b$ | quark flavor bottom or beauty |
| $B$ | bulk modulus |
| $B$ | magnetic field strength |
| $\mathrm{B}_{\mathrm{int}}$ | electron's intrinsic magnetic field |
| $\mathrm{B}_{\mathrm{orb}}$ | orbital magnetic field |
| BE | binding energy of a nucleus—it is the energy required to completely disassemble it into separate protons and neutrons |
| BE / $A$ | binding energy per nucleon |
| Bq | becquerel—one decay per second |
| $C$ | capacitance (amount of charge stored per volt) |
| $C$ | coulomb (a fundamental SI unit of charge) |
| $C_{\mathrm{p}}$ | total capacitance in parallel |
| $C_{\mathrm{s}}$ | total capacitance in series |
| CG | center of gravity |
| CM | center of mass |
| $c$ | quark flavor charm |
| $c$ | specific heat |
| $c$ | speed of light |
| Cal | kilocalorie |

| Symbol | Definition |
|---|---|
| cal | calorie |
| $COP_{\text{hp}}$ | heat pump's coefficient of performance |
| $COP_{\text{ref}}$ | coefficient of performance for refrigerators and air conditioners |
| $\cos\,\theta$ | cosine |
| $\cot\,\theta$ | cotangent |
| $\csc\,\theta$ | cosecant |
| $D$ | diffusion constant |
| $d$ | displacement |
| $d$ | quark flavor down |
| dB | decibel |
| $d_{\text{i}}$ | distance of an image from the center of a lens |
| $d_{\text{o}}$ | distance of an object from the center of a lens |
| DC | direct current |
| $E$ | electric field strength |
| $\varepsilon$ | emf (voltage) or Hall electromotive force |
| emf | electromotive force |
| $E$ | energy of a single photon |
| $E$ | nuclear reaction energy |
| $E$ | relativistic total energy |
| $E$ | total energy |
| $E_0$ | ground state energy for hydrogen |
| $E_0$ | rest energy |
| EC | electron capture |
| $E_{\text{cap}}$ | energy stored in a capacitor |
| $Eff$ | efficiency—the useful work output divided by the energy input |
| $Eff_C$ | Carnot efficiency |
| $E_{\text{in}}$ | energy consumed (food digested in humans) |
| $E_{\text{ind}}$ | energy stored in an inductor |
| $E_{\text{out}}$ | energy output |
| $e$ | emissivity of an object |
| $e^+$ | antielectron or positron |
| eV | electron volt |
| F | farad (unit of capacitance, a coulomb per volt) |
| F | focal point of a lens |
| $\mathbf{F}$ | force |

| Symbol | Definition |
|---|---|
| $F$ | magnitude of a force |
| $F$ | restoring force |
| $F_{\mathrm{B}}$ | buoyant force |
| $F_{\mathrm{c}}$ | centripetal force |
| $F_{\mathrm{i}}$ | force input |
| $\mathbf{F}_{\mathrm{net}}$ | net force |
| $F_{\mathrm{o}}$ | force output |
| FM | frequency modulation |
| $f$ | focal length |
| $f$ | frequency |
| $f_0$ | resonant frequency of a resistance, inductance, and capacitance $(RLC)$ series circuit |
| $f_0$ | threshold frequency for a particular material (photoelectric effect) |
| $f_1$ | fundamental |
| $f_2$ | first overtone |
| $f_3$ | second overtone |
| $f_{\mathrm{B}}$ | beat frequency |
| $f_{\mathrm{k}}$ | magnitude of kinetic friction |
| $f_{\mathrm{s}}$ | magnitude of static friction |
| $G$ | gravitational constant |
| $G$ | green quark color |
| $\bar{G}$ | antigreen (magenta) antiquark color |
| $g$ | acceleration due to gravity |
| $g$ | gluons (carrier particles for strong nuclear force) |
| $h$ | change in vertical position |
| $h$ | height above some reference point |
| $h$ | maximum height of a projectile |
| $h$ | Planck's constant |
| $hf$ | photon energy |
| $h_{\mathrm{i}}$ | height of the image |
| $h_{\mathrm{o}}$ | height of the object |
| $I$ | electric current |
| $I$ | intensity |
| $I$ | intensity of a transmitted wave |
| $I$ | moment of inertia (also called rotational inertia) |

| Symbol | Definition |
|---|---|
| $I_0$ | intensity of a polarized wave before passing through a filter |
| $I_{\text{ave}}$ | average intensity for a continuous sinusoidal electromagnetic wave |
| $I_{\text{rms}}$ | average current |
| J | joule |
| $J/\Psi$ | Joules/psi meson |
| K | kelvin |
| $k$ | Boltzmann constant |
| $k$ | force constant of a spring |
| $K_\alpha$ | x rays created when an electron falls into an $n = 1$ shell vacancy from the $n = 3$ shell |
| $K_\beta$ | x rays created when an electron falls into an $n = 2$ shell vacancy from the $n = 3$ shell |
| kcal | kilocalorie |
| KE | translational kinetic energy |
| KE + PE | mechanical energy |
| $\text{KE}_e$ | kinetic energy of an ejected electron |
| $\text{KE}_{\text{rel}}$ | relativistic kinetic energy |
| $\text{KE}_{\text{rot}}$ | rotational kinetic energy |
| $\overline{\text{KE}}$ | thermal energy |
| kg | kilogram (a fundamental SI unit of mass) |
| $L$ | angular momentum |
| L | liter |
| $L$ | magnitude of angular momentum |
| $L$ | self-inductance |
| $\ell$ | angular momentum quantum number |
| $L_\alpha$ | x rays created when an electron falls into an $n = 2$ shell from the $n = 3$ shell |
| $L_e$ | electron total family number |
| $L_\mu$ | muon family total number |
| $L_\tau$ | tau family total number |
| $L_{\text{f}}$ | heat of fusion |
| $L_{\text{f}}$ and $L_{\text{v}}$ | latent heat coefficients |
| $\text{L}_{\text{orb}}$ | orbital angular momentum |
| $L_{\text{s}}$ | heat of sublimation |
| $L_{\text{v}}$ | heat of vaporization |
| $L_z$ | $z$ - component of the angular momentum |
| $M$ | angular magnification |

| Symbol | Definition |
|---|---|
| $M$ | mutual inductance |
| $\mathrm{m}$ | indicates metastable state |
| $m$ | magnification |
| $m$ | mass |
| $m$ | mass of an object as measured by a person at rest relative to the object |
| $\mathrm{m}$ | meter (a fundamental SI unit of length) |
| $m$ | order of interference |
| $m$ | overall magnification (product of the individual magnifications) |
| $m\left({}^{A}\mathrm{X}\right)$ | atomic mass of a nuclide |
| $\mathrm{MA}$ | mechanical advantage |
| $m_{\mathrm{e}}$ | magnification of the eyepiece |
| $m_e$ | mass of the electron |
| $m_\ell$ | angular momentum projection quantum number |
| $m_n$ | mass of a neutron |
| $m_{\mathrm{o}}$ | magnification of the objective lens |
| $\mathrm{mol}$ | mole |
| $m_p$ | mass of a proton |
| $m_{\mathrm{s}}$ | spin projection quantum number |
| $N$ | magnitude of the normal force |
| $\mathrm{N}$ | newton |
| $\mathbf{N}$ | normal force |
| $N$ | number of neutrons |
| $n$ | index of refraction |
| $n$ | number of free charges per unit volume |
| $N_{\mathrm{A}}$ | Avogadro's number |
| $N_{\mathrm{r}}$ | Reynolds number |
| $\mathrm{N}\cdot\mathrm{m}$ | newton-meter (work-energy unit) |
| $\mathrm{N}\cdot\mathrm{m}$ | newtons times meters (SI unit of torque) |
| $\mathrm{OE}$ | other energy |
| $P$ | power |
| $P$ | power of a lens |
| $P$ | pressure |
| $\mathbf{p}$ | momentum |
| $p$ | momentum magnitude |
| $p$ | relativistic momentum |
| $\mathbf{p}_{\mathrm{tot}}$ | total momentum |

| Symbol | Definition |
|---|---|
| $\mathbf{p}'_{\text{tot}}$ | total momentum some time later |
| $P_{\text{abs}}$ | absolute pressure |
| $P_{\text{atm}}$ | atmospheric pressure |
| $P_{\text{atm}}$ | standard atmospheric pressure |
| PE | potential energy |
| $\text{PE}_{\text{el}}$ | elastic potential energy |
| $\text{PE}_{\text{elec}}$ | electric potential energy |
| $\text{PE}_{\text{s}}$ | potential energy of a spring |
| $P_{\text{g}}$ | gauge pressure |
| $P_{\text{in}}$ | power consumption or input |
| $P_{\text{out}}$ | useful power output going into useful work or a desired, form of energy |
| $Q$ | latent heat |
| $Q$ | net heat transferred into a system |
| $Q$ | flow rate—volume per unit time flowing past a point |
| $+Q$ | positive charge |
| $-Q$ | negative charge |
| $q$ | electron charge |
| $q_p$ | charge of a proton |
| $q$ | test charge |
| QF | quality factor |
| $R$ | activity, the rate of decay |
| $R$ | radius of curvature of a spherical mirror |
| $R$ | red quark color |
| $\bar{R}$ | antired (cyan) quark color |
| $R$ | resistance |
| R | resultant or total displacement |
| $R$ | Rydberg constant |
| $R$ | universal gas constant |
| $r$ | distance from pivot point to the point where a force is applied |
| $r$ | internal resistance |
| $r_{\perp}$ | perpendicular lever arm |
| $r$ | radius of a nucleus |
| $r$ | radius of curvature |
| $r$ | resistivity |

| Symbol | Definition |
|---|---|
| r or rad | radiation dose unit |
| rem | roentgen equivalent man |
| rad | radian |
| RBE | relative biological effectiveness |
| $RC$ | resistor and capacitor circuit |
| rms | root mean square |
| $r_n$ | radius of the $n$th H-atom orbit |
| $R_\mathrm{p}$ | total resistance of a parallel connection |
| $R_\mathrm{s}$ | total resistance of a series connection |
| $R_\mathrm{s}$ | Schwarzschild radius |
| $S$ | entropy |
| $\mathbf{S}$ | intrinsic spin (intrinsic angular momentum) |
| $S$ | magnitude of the intrinsic (internal) spin angular momentum |
| $S$ | shear modulus |
| $S$ | strangeness quantum number |
| $s$ | quark flavor strange |
| s | second (fundamental SI unit of time) |
| $s$ | spin quantum number |
| $\mathbf{s}$ | total displacement |
| $\sec\theta$ | secant |
| $\sin\theta$ | sine |
| $s_z$ | $z$-component of spin angular momentum |
| $T$ | period—time to complete one oscillation |
| $T$ | temperature |
| $T_\mathrm{c}$ | critical temperature—temperature below which a material becomes a superconductor |
| $T$ | tension |
| T | tesla (magnetic field strength $B$) |
| $t$ | quark flavor top or truth |
| $t$ | time |
| $t_{1/2}$ | half-life—the time in which half of the original nuclei decay |
| $\tan\theta$ | tangent |
| $U$ | internal energy |
| $u$ | quark flavor up |
| u | unified atomic mass unit |
| $\mathbf{u}$ | velocity of an object relative to an observer |
| $\mathbf{u}'$ | velocity relative to another observer |

| Symbol | Definition |
|---|---|
| $V$ | electric potential |
| $V$ | terminal voltage |
| $\mathrm{V}$ | volt (unit) |
| $V$ | volume |
| $\mathbf{v}$ | relative velocity between two observers |
| $v$ | speed of light in a material |
| $\mathbf{v}$ | velocity |
| $\bar{\mathbf{v}}$ | average fluid velocity |
| $V_\mathrm{B} - V_\mathrm{A}$ | change in potential |
| $\mathbf{v}_\mathrm{d}$ | drift velocity |
| $V_\mathrm{p}$ | transformer input voltage |
| $V_\mathrm{rms}$ | rms voltage |
| $V_\mathrm{s}$ | transformer output voltage |
| $\mathbf{v}_\mathrm{tot}$ | total velocity |
| $v_\mathrm{w}$ | propagation speed of sound or other wave |
| $\mathbf{v}_\mathrm{w}$ | wave velocity |
| $W$ | work |
| $W$ | net work done by a system |
| $\mathrm{W}$ | watt |
| $w$ | weight |
| $w_\mathrm{fl}$ | weight of the fluid displaced by an object |
| $W_\mathrm{c}$ | total work done by all conservative forces |
| $W_\mathrm{nc}$ | total work done by all nonconservative forces |
| $W_\mathrm{out}$ | useful work output |
| $X$ | amplitude |
| $\mathrm{X}$ | symbol for an element |
| ${}^{Z}X_{N}$ | notation for a particular nuclide |
| $x$ | deformation or displacement from equilibrium |
| $x$ | displacement of a spring from its undeformed position |
| $x$ | horizontal axis |
| $X_\mathrm{C}$ | capacitive reactance |
| $X_\mathrm{L}$ | inductive reactance |
| $x_\mathrm{rms}$ | root mean square diffusion distance |
| $y$ | vertical axis |
| $Y$ | elastic modulus or Young's modulus |

| Symbol | Definition |
| --- | --- |
| $Z$ | atomic number (number of protons in a nucleus) |
| $Z$ | impedance |

# Index

## Symbols

(peak) emf, **911**
$RC$ circuit, **835**

## A

aberration, **1051**
aberrations, **1049**
absolute pressure, **401**, **424**
absolute zero, **474**, **506**
AC current, **782**, **795**
AC voltage, **782**, **795**
acceleration, **40**, **76**, **136**, **165**
acceleration due to gravity, **61**, **76**
accommodation, **1031**, **1051**
Accuracy, **20**
accuracy, **26**
acoustic impedance , **677**, **683**
active transport, **460**, **460**
activity, **1253**, **1262**
adaptive optics, **1049**, **1051**
adhesive forces, **411**, **424**
adiabatic, **566**
adiabatic process, **594**
air resistance, **106**, **121**
alpha, **1233**
alpha decay, **1244**, **1262**
alpha rays, **1262**
Alternating current, **781**
alternating current, **795**
ammeter, **839**
ammeters, **829**
ampere, **766**, **795**
Ampere's law, **876**, **882**
amplitude, **612**, **639**, **955**, **970**, **971**
amplitude modulation, **960**
amplitude modulation (AM), **972**
analog meter, **839**
Analog meters, **830**
analytical method, **121**
Analytical methods, **100**
Anger camera, **1277**, **1301**
angular acceleration, **348**, **379**
angular magnification, **1047**, **1051**
angular momentum, **367**, **379**
angular momentum quantum number, **1210**, **1220**
angular velocity, **204**, **229**
antielectron, **1248**, **1262**
antimatter, **1247**, **1262**
antinode, **634**, **639**, **666**, **683**
approximation, **26**
approximations, **24**
arc length, **203**, **229**
Archimedes' principle, **406**, **425**
astigmatism, **1036**, **1051**
atom, **1178**, **1220**
atomic de-excitation, **1198**, **1220**
atomic excitation, **1198**, **1221**
atomic mass, **1239**, **1262**
atomic number, **1214**, **1221**, **1239**, **1262**
atomic spectra, **1144**, **1168**
Average Acceleration, **40**
average acceleration, **78**, **76**
Average speed, **37**
average speed, **76**
Average velocity, **37**
average velocity, **76**
Avogadro's number, **488**, **506**
axions, **1362**, **1367**
axis of a polarizing filter, **1082**, **1092**

## B

*B*-field, **858**, **882**
back emf, **913**, **937**
banked curve, **229**
banked curves, **212**
barrier penetration, **1260**, **1262**
baryon number, **1323**, **1336**
Baryons, **1323**
baryons, **1336**
basal metabolic rate, **270**, **275**
beat frequency, **635**, **639**
becquerel, **1253**, **1262**
Bernoulli's equation, **440**, **460**
Bernoulli's principle, **441**, **460**
beta, **1233**
beta decay, **1246**, **1263**
beta rays, **1263**
Big Bang, **1348**, **1367**
binding energy, **1146**, **1168**, **1256**, **1263**
binding energy per nucleon, **1257**, **1263**
bioelectricity, **790**, **795**
Biot-Savart law, **876**, **882**
birefringent, **1089**, **1092**
Black holes, **1355**
black holes, **1367**
blackbodies, **1143**
blackbody, **1168**
blackbody radiation, **1143**, **1168**
Bohr radius, **1190**, **1221**
Boltzmann constant, **486**, **506**
boson, **1320**, **1336**
bottom, **1330**, **1336**
bow wake, **663**, **683**
break-even, **1291**, **1301**
breeder reactors, **1297**, **1302**
breeding, **1297**, **1302**
bremsstrahlung, **1151**, **1168**
Brewster's angle, **1084**, **1092**
Brewster's law, **1084**, **1092**
bridge device, **840**
bridge devices, **834**
Brownian motion, **1178**, **1221**
buoyant force, **405**, **425**

## C

capacitance, **745**, **756**, **835**, **840**
capacitive reactance, **930**, **937**
capacitor, **744**, **756**, **835**, **840**
capillary action, **417**, **425**
carbon-14 dating, **1251**, **1263**
Carnot cycle, **574**, **594**
Carnot efficiency, **574**, **594**
Carnot engine, **574**, **594**
carrier particle, **165**
carrier particles, **164**
carrier wave, **960**, **972**
cathode-ray tube, **1221**
cathode-ray tubes, **1180**
Celsius, **473**
Celsius scale, **506**
center of gravity, **323**, **339**
center of mass, **218**, **229**
centrifugal force, **215**, **229**
centrifuge, **207**
centripetal acceleration, **206**, **229**
centripetal force, **210**, **229**
change in angular velocity, **349**, **379**
change in entropy, **583**, **594**
change in momentum, **290**, **308**
Chaos, **1364**
chaos, **1368**
characteristic time constant, **926**, **937**
characteristic x rays, **1151**, **1168**
charm, **1330**, **1336**
chart of the nuclides, **1242**, **1263**
chemical energy, **263**, **275**
classical physics, **10**, **26**
Classical relativity, **118**
classical relativity, **121**
classical velocity addition, **1131**
coefficient of linear expansion, **479**, **506**
coefficient of performance, **582**, **594**
coefficient of volume expansion, **481**, **506**
coherent, **1062**, **1092**
cohesive forces, **411**, **425**
Colliding beams, **1317**
colliding beams, **1336**
color, **1331**, **1336**
color constancy, **1039**, **1051**
commutative, **97**, **122**, **121**
complexity, **1363**, **1368**
component (of a 2-d vector), **121**
components , **100**
compound microscope, **1041**, **1051**
Compton effect, **1155**, **1168**
Conduction, **529**
conduction, **543**
conductor, **697**, **717**, **717**
Conductors, **709**
confocal microscopes, **1091**, **1092**
conservation laws, **825**, **840**
Conservation of energy, **242**
conservation of mechanical energy, **256**, **275**
conservation of momentum principle, **293**, **308**
Conservation of total , **1323**
conservation of total baryon number, **1323**, **1336**
conservation of total electron family number, **1336**
conservation of total $L_\mu$ , **1323**
conservation of total muon family number, **1336**
conservative force, **254**, **275**
constructive interference, **632**, **639**
constructive interference for a diffraction grating, **1067**, **1092**
constructive interference for a double slit, **1064**, **1092**
contact angle, **417**, **425**
Contrast, **1090**
contrast, **1092**
Convection, **529**
convection, **544**
converging (or convex) lens, **1000**
converging lens, **1020**
converging mirror, **1020**
conversion factor, **17**, **26**

Coriolis force, **215**, **229**
corner reflector, **994**, **1020**
correspondence principle, **1142**, **1168**
cosmic microwave background, **1349**, **1368**
cosmological constant, **1359**, **1368**
cosmological red shift, **1348**, **1368**
Cosmology, **1346**
cosmology, **1368**
Coulomb force, **703**, **717**
Coulomb forces, **702**
Coulomb interaction, **708**, **717**
Coulomb's law, **701**, **717**
critical angle, **991**, **1020**
Critical damping, **624**
critical damping, **639**
critical density, **1359**, **1368**
critical mass, **1295**, **1302**
critical point, **498**, **506**
Critical pressure, **498**
critical pressure, **506**
critical temperature, **498**, **506**, **1365**, **1368**
criticality, **1296**, **1302**
curie, **1253**, **1263**
Curie temperature, **855**, **882**
current, **808**, **840**
Current sensitivity, **830**
current sensitivity, **840**
cyclical process, **570**, **594**
cyclotron, **1316**, **1336**

**D**

Dalton's law of partial pressures, **501**, **506**
dark matter, **1359**, **1368**
daughter, **1263**
daughters, **1243**
de Broglie wavelength, **1158**, **1168**
decay, **1232**, **1243**, **1263**
decay constant, **1251**, **1263**
decay equation, **1245**, **1245**, **1249**, **1263**
decay series, **1243**, **1263**
deceleration, **40**, **76**
defibrillator, **754**, **756**
deformation, **185**, **194**, **606**, **639**
degree Celsius, **473**, **506**
degree Fahrenheit, **473**, **506**
Density, **391**
density, **425**
dependent variable, **69**, **76**
derived units, **14**, **26**
destructive interference, **632**, **639**
destructive interference for a double slit, **1064**, **1092**
destructive interference for a single slit, **1071**, **1092**
dew point, **502**, **506**
dialysis, **459**, **460**
diastolic pressure, **402**, **425**, **425**
Diastolic pressure, **420**
dielectric, **748**, **756**
dielectric strength, **756**
dielectric strengths, **748**
diffraction, **1061**, **1092**
diffraction grating, **1066**, **1092**
Diffusion, **457**
diffusion, **460**
digital meter, **840**
digital meters, **830**
dipole, **708**, **717**
Direct current, **781**
direct current, **795**
direction, **95**
direction (of a vector), **121**
direction of magnetic field lines, **858**, **882**
direction of polarization, **1081**, **1092**
Dispersion, **996**
dispersion, **1020**
displacement, **32**, **76**
Distance, **34**
distance, **76**
Distance traveled, **34**
distance traveled, **76**
diverging lens, **1002**, **1020**
diverging mirror, **1020**
domains, **854**, **882**
Doppler effect, **659**, **684**
Doppler shift, **659**, **684**
Doppler-shifted ultrasound, **681**, **684**
Double-slit interference, **1188**
double-slit interference, **1221**
down, **1325**, **1336**
drag force, **181**, **194**
drift velocity, **769**, **795**
dynamic equilibrium, **318**, **339**
Dynamics, **134**, **135**, **166**
dynamics, **165**

**E**

eddy current, **906**, **937**
efficiency, **265**, **275**
Elapsed time, **36**
elapsed time, **77**
elastic collision, **296**, **296**, **308**
elastic potential energy, **608**, **639**
electric and magnetic fields, **970**
electric charge, **693**, **717**
electric current, **766**, **795**
electric field, **709**, **717**, **955**, **972**
electric field lines, **718**, **972**
Electric field lines, **953**
electric field strength, **704**, **972**
electric fields, **704**
electric generator, **937**
Electric generators, **909**
electric potential, **733**, **756**
electric power, **778**, **795**
Electrical energy, **263**
electrical energy, **275**
electrocardiogram (ECG), **794**, **795**
electromagnet, **882**
electromagnetic force, **692**, **718**
electromagnetic induction, **900**, **938**
electromagnetic spectrum, **972**
electromagnetic waves, **951**, **954**, **970**, **972**
Electromagnetism, **855**
electromagnetism, **882**
electromagnets, **855**
electromotive force, **817**
electromotive force (emf), **840**, **972**
electron, **718**
Electron capture, **1249**
electron capture, **1263**
electron capture equation, **1249**, **1263**
electron family number , **1323**, **1336**
electron volt, **735**, **756**
electrons, **693**
electron's antineutrino, **1247**, **1263**
electron's neutrino, **1249**, **1263**
electrostatic equilibrium, **709**, **718**
electrostatic force, **701**, **718**
electrostatic precipitators, **715**, **718**
Electrostatic repulsion, **698**
electrostatic repulsion, **718**
electrostatics, **712**, **718**
electroweak epoch, **1352**, **1368**
electroweak theory, **1332**, **1336**
emf, **825**
emf induced in a generator coil, **911**, **938**
emissivity, **540**, **544**
endoscope, **993**
energies of hydrogen-like atoms, **1191**, **1221**
energy, **242**, **275**
energy stored in an inductor , **925**, **938**
energy-level diagram, **1189**, **1221**
English units, **13**, **26**
entropy, **583**, **594**
equipotential line, **756**
equipotential lines, **742**
escape velocity, **1355**, **1368**
event horizon, **1355**, **1368**
external force, **136**, **165**
external forces, **135**
External forces, **166**
Extremely low frequency (ELF), **959**
extremely low frequency (ELF), **972**
eyepiece, **1041**, **1051**

**F**

Fahrenheit, **473**
Fahrenheit scale, **506**
far point, **1034**, **1051**
Faraday cage, **711**, **718**
Faraday's law of induction, **901**, **938**
Farsightedness, **1034**
farsightedness, **1051**
fermion, **1320**, **1336**
ferromagnetic, **854**, **882**
Feynman diagram, **1315**, **1336**
Fiber optics, **992**
fiber optics, **1020**
fictitious force, **215**, **229**
field, **718**
fine structure, **1209**, **1221**
first law of thermodynamics, **556**, **594**
first postulate of special relativity, **1105**, **1131**
fission fragments, **1293**, **1302**
flat (zero curvature) universe, **1360**, **1368**
flavors, **1325**, **1336**
Flow rate, **436**
flow rate, **460**
fluid dynamics, **436**, **460**
fluids, **391**, **425**
Fluorescence, **1198**
fluorescence, **1221**
focal length, **1000**, **1020**
focal point, **1000**, **1020**
Food irradiation, **1286**
food irradiation, **1302**

force, **135**, **165**
Force, **166**
force constant, **607**, **640**
force field, **161**, **162**, **165**, **703**
fossil fuels, **273**, **275**
free charge, **718**
free charges, **709**
free electron, **718**
free electrons, **697**
free radicals, **1287**, **1302**
free-body diagram, **135**, **166**, **154**, **165**
free-fall, **61**, **77**, **139**, **165**
Frequency, **610**
frequency, **640**, **955**, **972**
frequency modulation, **960**
frequency modulation (FM), **972**
friction, **137**, **166**, **194**, **275**
Friction, **176**, **257**
full-scale deflection, **830**, **840**
fundamental, **666**, **684**
fundamental frequency, **634**, **640**
fundamental particle, **1325**, **1336**
fundamental units, **14**, **26**

**G**

galvanometer, **830**, **840**
gamma, **1233**
gamma camera, **1277**, **1302**
Gamma decay, **1250**
gamma decay, **1263**
gamma ray, **968**, **972**, **1168**
Gamma rays, **1148**
gamma rays, **1263**
gauge boson, **1337**
gauge bosons, **1320**
gauge pressure, **401**, **425**
gauss, **860**, **882**
Geiger tube, **1237**, **1263**
general relativity, **1353**, **1368**
geometric optics, **983**, **1020**
glaucoma, **422**, **425**
gluons, **1315**, **1337**, **1337**
Gluons, **1333**
grand unified theory, **1337**
Grand Unified Theory (GUT), **1332**
gravitational constant, **219**
gravitational constant, *G*, **229**
gravitational potential energy, **249**, **276**
Gravitational waves, **1356**
gravitational waves, **1368**
gray (Gy), **1279**, **1302**
greenhouse effect, **542**, **544**
grounded, **713**, **718**, **718**
grounding, **742**, **756**
GUT epoch, **1352**, **1368**

**H**

Hadrons, **1320**
hadrons, **1337**
half-life, **1250**, **1263**
Hall effect, **866**, **882**
Hall emf, **866**, **882**
harmonics, **666**, **684**
head, **94**
head (of a vector), **121**
head-to-tail method, **94**, **122**, **121**
Hearing, **650**, **671**
hearing, **684**
heat, **516**, **544**
heat engine, **561**, **594**
heat of sublimation, **528**, **544**
heat pump, **595**
heat pump's coefficient of performance, **580**
heat transfer, **472**
Heisenberg uncertainty principle, **1163**
Heisenberg's uncertainty principle , **1165**, **1168**
henry, **923**, **938**
hertz, **972**
Higgs boson, **1334**, **1337**
high dose, **1280**, **1302**
hologram, **1204**, **1221**
Holography, **1204**
holography, **1221**
Hooke's law, **185**, **194**
horizontally polarized, **1081**, **1092**
Hormesis, **1281**
hormesis, **1302**
horsepower, **268**, **276**
Hubble constant, **1348**, **1368**
hues, **1038**, **1051**
Human metabolism, **559**
human metabolism, **595**
Huygens's principle, **1060**, **1092**
Hydrogen spectrum wavelength, **1188**
hydrogen spectrum wavelengths, **1221**
hydrogen-like atom, **1190**, **1221**
hydrogen-spectrum wavelengths, **1187**
hyperopia, **1034**, **1051**

**I**

ideal angle, **229**
ideal banking, **212**, **229**
ideal gas law, **486**, **506**
ideal speed, **229**
Ignition, **1291**
ignition, **1302**
Image distance , **1006**
impedance, **931**, **938**
impulse, **290**, **308**
Incoherent, **1062**
incoherent, **1093**
independent variable, **69**, **77**
index of refraction, **987**, **1020**
inductance, **922**, **938**
induction, **698**, **718**, **898**, **938**
inductive reactance, **928**, **938**
inductor, **923**, **938**
inelastic collision, **298**, **308**
inertia, **136**, **166**
Inertia, **166**
inertial confinement, **1291**, **1302**
inertial frame of reference, **153**, **166**, **1105**, **1131**
inflationary scenario, **1353**, **1368**
Infrared radiation, **963**
infrared radiation, **1168**
infrared radiation (IR), **972**
Infrared radiation (IR), **1153**
infrasound, **671**, **684**
ink jet printer, **714**
ink-jet printer, **718**
Instantaneous acceleration, **43**
instantaneous acceleration, **77**
Instantaneous speed, **37**
instantaneous speed, **77**
Instantaneous velocity, **37**
instantaneous velocity, **77**
insulator, **718**
insulators, **698**
intensity, **637**, **640**, **656**, **684**, **970**, **972**
intensity reflection coefficient, **678**, **684**
Interference microscopes, **1090**
interference microscopes, **1093**
internal energy, **557**, **595**
Internal kinetic energy, **296**, **296**
internal kinetic energy, **308**
internal resistance, **816**, **840**
intraocular pressure, **422**, **425**
intrinsic magnetic field , **1209**, **1221**
intrinsic spin, **1209**, **1221**
ionizing radiation, **1148**, **1168**, **1234**, **1263**
ionosphere, **710**, **718**
irreversible process, **568**, **595**
isobaric process, **562**, **595**
isochoric, **564**
isochoric process, **595**
isolated system, **294**, **308**
isothermal, **566**
isothermal process, **595**
isotopes, **1240**, **1263**

**J**

joule, **244**, **276**
Joule's law, **810**, **840**
junction rule, **824**, **840**

**K**

Kelvin, **474**
Kelvin scale, **506**
kilocalorie, **516**, **544**
kilogram, **14**, **26**
kilowatt-hour, **276**
kilowatt-hours, **269**
kinematics, **32**, **77**, **107**, **121**
kinematics of rotational motion, **352**, **379**
kinetic energy, **246**, **276**
kinetic friction, **176**, **194**
Kirchhoff's rules, **824**, **840**

**L**

Laminar, **446**
laminar, **460**
laser, **1201**, **1221**
laser printer, **718**
Laser printers, **714**
Laser vision correction, **1037**
laser vision correction, **1051**
latent heat coefficient, **544**
latent heat coefficients, **524**
law, **9**, **26**
law of conservation of angular momentum, **371**, **379**
law of conservation of charge, **696**, **718**
law of conservation of energy, **262**, **276**
law of inertia, **136**, **166**, **166**
law of reflection, **1020**, **1020**
law of refraction, **989**
Length contraction , **1113**
length contraction, **1131**
Lenz's law, **901**, **938**
leptons, **1320**, **1337**
linear accelerator, **1318**, **1337**
linear hypothesis, **1281**, **1302**
Linear momentum, **288**
linear momentum, **308**
liquid drop model, **1293**, **1302**

liter, **436**, **460**
longitudinal wave, **631**, **640**
loop rule, **825**, **840**
Lorentz force, **859**, **882**
loudness, **671**, **684**
low dose, **1280**, **1302**

**M**

MACHOs, **1362**, **1368**
macrostate, **590**, **595**
magic numbers, **1242**, **1263**
magnetic confinement, **1291**, **1302**
magnetic damping, **906**, **938**
magnetic field, **858**, **882**, **955**, **972**
magnetic field lines, **858**, **882**, **972**
Magnetic field lines, **953**
magnetic field strength, **972**
magnetic field strength (magnitude) produced by a long straight current-carrying wire, **875**, **883**
magnetic field strength at the center of a circular loop, **876**, **883**
magnetic field strength inside a solenoid, **877**, **883**
magnetic flux, **900**, **938**
magnetic force, **859**, **883**
magnetic monopoles, **857**, **883**
Magnetic resonance imaging (MRI), **881**
magnetic resonance imaging (MRI), **883**
magnetized, **854**, **883**
magnetocardiogram (MCG), **882**, **883**
magnetoencephalogram (MEG), **882**, **883**
magnification, **1006**, **1021**
magnitude, **95**
magnitude (of a vector), **121**
magnitude of kinetic friction, **194**
magnitude of kinetic friction $\mathbf{f}_k$, **177**
magnitude of static friction, **194**
magnitude of static friction $\mathbf{f}_s$, **177**
magnitude of the intrinsic (internal) spin angular momentum, **1213**, **1221**
mass, **136**, **166**
Mass, **166**
mass number, **1239**, **1263**
massive compact halo objects, **1362**
maximum field strength, **970**, **972**
Maxwell's equations, **876**, **883**, **952**, **972**
mechanical advantage, **330**, **339**
mechanical energy, **256**, **276**, **756**
Mechanical energy, **736**
mechanical equivalent of heat, **516**, **544**
meson, **1314**, **1337**, **1337**
Mesons, **1323**
metabolic rate, **270**, **276**
metastable, **1200**, **1221**
meter, **14**, **26**, **883**
Meters, **873**
method of adding percents, **22**, **27**
metric system, **15**, **27**
Michelson-Morley experiment, **1105**, **1131**
Microgravity, **223**
microgravity, **229**
microlensing, **1361**, **1368**
microshock sensitive, **789**, **795**
microstate, **590**, **595**
Microwaves, **962**, **1153**
microwaves, **972**, **1168**
micturition reflex, **424**, **425**
mirror, **1021**
model, **9**, **27**, **38**, **77**
moderate dose, **1280**, **1302**
Modern physics, **12**
modern physics, **27**
mole, **488**, **506**
moment of inertia, **357**, **357**, **379**
motion, **106**, **121**
motor, **883**
Motors, **870**
muon family number, **1323**, **1337**
Mutual inductance, **922**
mutual inductance, **938**
myopia, **1034**, **1051**

**N**

natural frequency, **627**, **640**
near point, **1034**, **1051**
Nearsightedness, **1034**
nearsightedness, **1051**
negatively curved, **1360**, **1368**
Nerve conduction, **790**
nerve conduction, **795**
net external force, **137**, **166**
net rate of heat transfer by radiation, **541**, **544**
net work, **245**, **276**
neutral equilibrium, **326**, **339**
neutralinos, **1362**, **1368**
neutrino, **1246**, **1263**
neutrino oscillations, **1362**, **1368**
neutron, **1239**, **1263**
Neutron stars, **1356**
neutron stars, **1368**
Neutron-induced fission, **1293**
neutron-induced fission, **1302**
newton, **138**
newton-meters, **244**
Newton's first law of motion, **136**, **136**, **166**, **166**
Newton's second law of motion, **136**, **166**
Newton's third law of motion, **142**, **167**, **166**
Newton's universal law of gravitation, **218**, **229**
node, **666**, **684**
Nodes, **634**
nodes, **640**
non-inertial frame of reference, **215**, **229**
nonconservative force, **257**, **276**
normal force, **146**, **166**
north magnetic pole, **853**, **883**
note, **684**
notes, **671**
Nuclear energy, **263**
nuclear energy, **276**
Nuclear fission, **1292**
nuclear fission, **1302**
Nuclear fusion, **1287**
nuclear fusion, **1302**
nuclear magnetic resonance (NMR), **881**, **883**
nuclear radiation, **1232**, **1263**
nuclear reaction energy, **1245**, **1263**
nucleons, **1239**, **1263**
nucleus, **1263**
nuclide, **1239**, **1263**
Null measurements, **832**
null measurements, **840**
numerical aperture, **1051**
numerical aperture $(NA)$, **1043**

**O**

objective lens, **1041**, **1051**
ohm, **771**, **795**
ohmic, **771**, **795**
ohmmeter, **840**
ohmmeters, **834**
Ohm's law, **771**, **795**, **808**, **840**
optically active, **1088**, **1093**
orbital angular momentum, **1208**, **1221**
orbital magnetic field, **1208**, **1221**
order, **1064**, **1093**
order of magnitude, **15**, **27**
oscillate, **606**, **640**, **972**
Osmosis, **459**
osmosis, **460**
osmotic pressure, **459**, **460**
Otto cycle, **572**, **595**
over damping, **640**
overdamped, **624**
overtones, **634**, **640**, **666**, **684**

**P**

parallel, **810**, **840**
parallel plate capacitor, **744**, **756**
parent, **1243**, **1263**
Partial pressure, **501**
partial pressure, **506**
Particle physics, **1312**
particle physics, **1337**
particle-wave duality, **1158**, **1168**
Particle-wave duality, **1166**
Pascal's principle, **398**
Pascal's Principle, **425**
Pauli exclusion principle, **1215**, **1221**
peak emf, **938**
percent relative humidity, **504**, **506**
percent uncertainty, **22**, **27**
perfectly inelastic collision, **298**, **308**
period, **610**, **640**
periodic motion, **610**, **640**
permeability of free space, **875**, **883**
perpendicular lever arm, **320**, **339**
phase angle, **935**, **938**
phase diagram, **506**
phase diagrams, **499**
phase-contrast microscope, **1090**, **1093**
phon, **672**, **684**
Phosphorescence, **1200**
phosphorescence, **1221**
photoconductor, **713**, **718**
photoelectric effect, **1144**, **1168**
photomultiplier, **1238**, **1263**
photon, **1145**, **1154**, **1168**
photon energy, **1145**, **1168**
photon momentum, **1155**, **1168**
physical quantity, **13**, **27**
Physics, **6**

physics, **27**
pion, **1312**, **1337**
pit, **202**, **229**
pitch, **652**, **671**, **684**
Planck's constant, **1143**, **1168**
planetary model of the atom, **1185**, **1221**
point charge, **703**, **718**
point masses, **302**, **308**
Poiseuille's law, **449**, **460**
Poiseuille's law for resistance, **448**, **460**
polar molecule, **708**, **718**, **749**, **756**
polarization, **698**, **718**, **1093**
Polarization, **1081**
polarization microscope, **1091**, **1093**
polarized, **709**, **718**, **1081**, **1093**
population inversion, **1201**, **1221**
position, **32**, **77**
positively curved, **1360**, **1368**
positron, **1249**, **1263**
positron decay, **1248**, **1263**
positron emission tomography (PET), **1277**, **1302**
potential difference, **733**, **817**, **840**
potential difference (or voltage), **756**
potential energy, **254**, **255**, **276**
potential energy of a spring, **254**, **276**
potentiometer, **833**, **840**
power, **266**, **276**, **1001**, **1021**
power factor, **935**, **938**
precision, **20**, **27**
presbyopia, **1034**, **1051**
pressure, **393**, **395**, **425**, **425**
Pressure, **398**
probability distribution, **1162**, **1168**
projectile, **106**, **121**
Projectile motion, **106**
projectile motion, **121**
Proper length , **1113**
proper length, **1131**
Proper time , **1108**
proper time, **1131**
proton, **718**
proton-proton cycle, **1289**, **1302**
protons, **693**, **1239**, **1264**
*PV* diagram, **498**, **506**

## Q

quality factor, **1279**, **1302**
quantized, **1142**, **1168**
quantum chromodynamics, **1331**, **1334**, **1337**, **1337**
quantum electrodynamics, **1315**, **1337**
Quantum gravity, **1353**, **1368**
quantum mechanical tunneling, **1260**, **1264**
Quantum mechanics, **12**
quantum mechanics, **27**, **1142**, **1168**
quantum numbers, **1210**, **1221**
quark, **308**, **1337**
quarks, **295**, **1325**
quasars, **1356**, **1368**

## R

*R* factor, **544**
$R$ factor, **533**
rad, **1278**, **1302**
Radar, **962**
radar, **972**
radians, **203**, **229**
radiant energy, **263**, **276**
radiation, **529**, **539**, **544**, **544**
radiation detector, **1237**, **1264**
radio waves, **952**, **959**, **972**
radioactive, **1232**, **1264**
Radioactive dating, **1251**
radioactive dating, **1264**
radioactivity, **1232**, **1264**
radiolytic products, **1287**, **1302**
radiopharmaceutical, **1274**, **1302**
radiotherapy, **1284**, **1302**
radius of a nucleus, **1240**, **1264**
radius of curvature, **203**, **230**
rainbow, **1021**
range, **112**, **121**
range of radiation, **1234**, **1264**
rate of conductive heat transfer, **531**, **544**
rate of decay, **1253**, **1264**
ray, **982**, **1021**
Ray tracing, **1002**
Rayleigh criterion, **1073**, **1093**
RC circuit, **840**
real image, **1005**, **1021**
reflected light is completely polarized, **1084**
reflected light that is completely polarized, **1093**
refraction, **985**, **1021**
relative biological effectiveness, **1279**
relative biological effectiveness (RBE), **1302**
relative humidity, **502**, **506**
relative osmotic pressure, **459**, **460**
relative velocities, **118**
relative velocity, **121**
relativistic Doppler effects, **1133**, **1131**
Relativistic kinetic energy, **1127**
relativistic kinetic energy, **1131**
Relativistic momentum, **1122**
relativistic momentum, **1131**
relativistic velocity addition, **1118**, **1132**
Relativity, **12**
relativity, **27**, **118**, **121**, **1104**, **1132**
Renewable forms of energy, **273**
renewable forms of energy, **276**
resistance, **771**, **795**, **808**, **840**
resistivity, **773**, **795**
resistor, **808**, **835**, **840**
resonance, **627**, **640**
resonant, **956**, **972**
resonant frequency, **934**, **938**
resonate, **627**, **640**
Rest energy, **1124**
rest energy, **1132**
rest mass, **1122**, **1132**
restoring force, **606**, **640**
resultant, **95**, **121**
resultant vector, **94**, **121**
retinex, **1051**
retinex theory of color vision, **1040**, **1052**
retinexes, **1040**
reverse dialysis, **460**, **460**
Reverse osmosis, **460**
reverse osmosis, **461**
reversible process, **567**, **595**
Reynolds number, **454**, **461**
right hand rule 1, **860**
right hand rule 1 (RHR-1), **883**
right hand rule 2, **874**
right hand rule 2 (RHR-2), **883**
right-hand rule, **377**, **379**
RLC circuit, **972**
rms current, **783**, **795**
rms voltage, **783**, **795**
rods and cones, **1038**, **1052**
roentgen equivalent man, **1279**
roentgen equivalent man (rem), **1302**
rotation angle, **202**, **230**
rotational inertia, **357**, **379**
rotational kinetic energy, **361**, **362**, **379**
Rydberg constant, **1187**, **1192**, **1221**

## S

saturation, **502**, **506**
scalar, **35**, **77**, **100**, **121**, **737**, **756**
Schwarzschild radius, **1355**, **1368**
scientific method, **10**, **27**
scintillators, **1238**, **1264**
screening, **708**, **718**
second, **14**, **27**
second law of motion, **289**, **308**
second law of thermodynamics, **569**, **570**, **574**, **595**
second law of thermodynamics stated in terms of entropy, **595**
second postulate of special relativity, **1105**, **1132**
Self-inductance, **923**
self-inductance, **938**
semipermeable, **459**, **461**, **790**, **796**
series, **808**, **840**
shear deformation, **191**, **194**
shell, **1216**, **1221**
shielding, **1282**, **1302**
shock hazard, **785**, **796**, **918**, **938**
short circuit, **785**, **796**
shunt resistance, **830**, **840**
SI unit of torque, **321**
SI units, **13**, **27**
SI units of torque, **339**
sievert, **1279**, **1302**
significant figures, **23**, **27**
simple circuit, **771**, **796**
Simple Harmonic Motion, **611**
simple harmonic motion, **640**
simple harmonic oscillator, **611**, **640**
simple pendulum, **616**, **640**
simplified theory of color vision, **1038**, **1052**
single-photon-emission computed tomography (SPECT), **1302**
single-photon-emission computed tomography(SPECT), **1277**
slope, **69**, **77**
solenoid, **876**, **883**
Solid-state radiation detectors, **1238**
solid-state radiation detectors, **1264**
sonic boom, **662**, **684**
sound, **650**, **684**
sound intensity level, **656**, **684**
sound pressure level, **659**, **684**
south magnetic pole, **853**, **883**
space quantization, **1209**, **1221**
special relativity, **1132**
special relativity., **1104**

specific gravity, **408**, **425**
specific heat, **518**, **544**
speed of light, **972**
spin projection quantum number, **1213**, **1221**
spin quantum number, **1213**, **1222**
spontaneous symmetry breaking, **1353**, **1368**
stable equilibrium, **324**, **339**
Standard Model, **1334**
standard model, **1337**
standing wave, **633**, **956**, **972**
static electricity, **692**, **718**
static equilibrium, **318**, **328**, **339**, **339**
static friction, **176**, **194**
statistical analysis, **592**, **595**
Stefan-Boltzmann law of radiation, **540**, **544**
step-down transformer, **915**, **938**
step-up transformer, **915**, **938**
Stimulated emission, **1201**
stimulated emission, **1222**
Stokes' law, **184**, **194**
strain, **190**, **194**
strange, **1325**, **1337**
strangeness, **1323**, **1337**
stress, **190**, **194**
sublimation, **500**, **506**, **544**
Sublimation, **528**
subshell, **1216**, **1222**
Superconductors, **1364**, **1368**
supercriticality, **1296**, **1302**
superforce, **1352**, **1368**
superposition, **632**, **640**
Superstring theory, **1335**, **1358**, **1368**
superstring theory, **1337**
surface tension, **412**, **425**
synchrotron, **1317**, **1337**
synchrotron radiation, **1317**, **1337**
system, **136**, **166**
systolic pressure, **402**, **425**, **425**
Systolic pressure, **420**

**T**

tagged, **1274**, **1303**
tail, **94**, **121**
tangential acceleration, **350**, **379**
tau family number, **1337**
Television, **961**
Temperature, **472**
temperature, **507**
temperature coefficient of resistivity, **776**, **796**
Tensile strength, **186**
tensile strength, **194**
tension, **149**, **166**
terminal speed, **456**, **461**
terminal voltage, **818**, **840**
tesla, **859**, **883**
test charge , **703**, **718**
the second law of thermodynamics stated in terms of entropy, **585**
theory, **9**, **27**
theory of quark confinement, **1331**, **1337**
therapeutic ratio, **1284**, **1303**
thermal agitation, **962**, **973**
thermal conductivity, **532**, **544**
thermal energy, **257**, **263**, **276**, **493**, **507**
thermal equilibrium, **478**, **507**
thermal expansion, **479**, **507**
thermal hazard, **785**, **796**, **918**, **938**
Thermal stress, **483**
thermal stress, **507**
thin film interference, **1076**, **1093**
thin lens, **1003**
thin lens equations, **1006**
thought experiment, **1353**, **1368**
three-wire system, **918**, **938**
thrust, **143**, **167**, **166**
timbre, **672**, **684**
time, **36**, **77**
Time dilation, **1107**
time dilation, **1132**
TOE epoch, **1352**, **1369**
tone, **672**, **684**
top, **1330**, **1337**
Torque, **320**
torque, **339**, **357**, **379**
Total energy , **1124**
total energy, **1132**
total internal reflection, **991**
trajectory, **106**, **121**
transformer, **938**
transformer equation, **915**, **938**
Transformers, **914**
transverse wave, **631**, **640**, **956**, **973**
triple point, **500**, **507**
Tunneling, **1261**
tunneling, **1264**
turbulence, **446**, **461**
TV, **973**
twin paradox, **1132**

**U**

ultra high frequency, **961**
ultra-high frequency (UHF), **973**
ultracentrifuge, **209**, **230**
ultrasound, **671**, **684**
Ultraviolet (UV) microscopes, **1089**
ultraviolet (UV) microscopes, **1093**
Ultraviolet radiation, **1151**
ultraviolet radiation, **1168**
ultraviolet radiation (UV), **965**, **973**
uncertainty, **21**, **27**
uncertainty in energy, **1165**, **1168**
uncertainty in momentum, **1163**, **1168**
uncertainty in position, **1163**, **1168**
uncertainty in time, **1165**, **1168**
under damping, **640**
underdamped, **624**
uniform circular motion, **202**, **230**
units, **13**, **27**
unpolarized, **1082**, **1093**
unstable equilibrium, **324**, **339**
up, **1325**, **1337**
useful work, **271**, **276**

**V**

Van de Graaff, **1316**, **1337**
Van de Graaff generator, **718**
Van de Graaff generators, **712**
vapor, **501**, **507**
Vapor pressure, **501**
vapor pressure, **507**
vector, **35**, **77**, **93**, **121**, **718**, **737**, **756**
vector addition, **115**, **121**, **706**, **718**
vectors, **91**, **704**
velocity, **115**, **121**
vertically polarized, **1081**, **1093**
very high frequency, **961**
very high frequency (VHF), **973**
virtual image, **1008**, **1021**
virtual particles, **1313**, **1337**
viscosity, **447**, **461**
viscous drag, **455**, **461**
Visible light, **964**
visible light, **973**, **1152**, **1169**
voltage, **733**, **808**, **840**
voltage drop, **808**, **841**
voltmeter, **841**
Voltmeters, **829**

**W**

watt, **267**, **276**
wave, **629**, **640**
wave velocity, **629**, **640**
wavelength, **630**, **640**, **955**, **973**
wavelength in a medium, **1059**, **1093**
waves, **606**
weakly interacting massive particles, **1362**
weight, **138**, **166**
Weight, **145**
Wheatstone bridge, **834**, **841**
WIMPs, **1362**, **1369**
work, **242**, **276**
work-energy theorem, **246**, **276**, **362**, **380**, **379**

**X**

x ray, **1169**
x rays, **1149**, **1222**
X rays, **1193**
X-ray, **968**, **973**
x-ray diffraction, **1197**, **1222**
xerography, **713**, **719**

**Y**

*y*-intercept, **69**, **77**

**Z**

z-component of spin angular momentum, **1222**
z-component of the angular momentum, **1222**
$z$-component of spin angular momentum, **1213**
$z$-component of the angular momentum, **1211**
Zeeman effect, **1208**, **1222**
zeroth law of thermodynamics, **478**, **507**
zircon, **1021**