KTH Information and
Communication Technology

IH1611 2014

Material Properties and Formulas

Physical Constants

DESCRIPTION	SYMBOL	VALUE
Elementary charge	q	$1.60 \cdot 10^{-19}$ C
Electron volt	eV	$1.60 \cdot 10^{-19}$ J
Boltzmann's constant	k	$1.38 \cdot 10^{-23}$ J/K = $8.62 \cdot 10^{-5}$ eV/K
Free electron mass	m_0	$9.11 \cdot 10^{-31}$ kg
Permittivity of free space	ε_0	$8.85 \cdot 10^{-12}$ F/m
Planck's constant	h	$6.63 \cdot 10^{-34}$ Js
Reduced Planck's constant (h/2π)	ħ	$1.05 \cdot 10^{-34}$ Js
Speed of light in vacuum	c	$3.00 \cdot 10^{8}$ m/s
Thermal voltage at T=300 K	kT/q	0.0259 V
Wavelength of 1 eV photon	λ	1.24·μm

Unit Conversion

QUANTITY	SYMBOL	VALUE/DIMENSION
Micrometer, micron	μm	1 μm = 10^4 Å = 10^3 nm = 10^{-4} cm
Nanometer	nm	1 nm = 10 Å = 10^{-3} μm = 10^{-7} cm
Ångström	Å	1 Å = 10^{-4} μm = 10^{-8} cm = 10^{-10} m
Electric charge (Coulomb)	C	A·s
Current (Ampere)	A	C/s
Frequency (Hertz)	Hz	1/s
Energy (Joule)	J	N·m
Power (Watt)	W	J/s
Potential (Volt)	V	W/A
Conductance (Siemens)	S	A/V
Resistance (Ohm)	Ω	V/A
Capacitance (Farad)	F	C/V

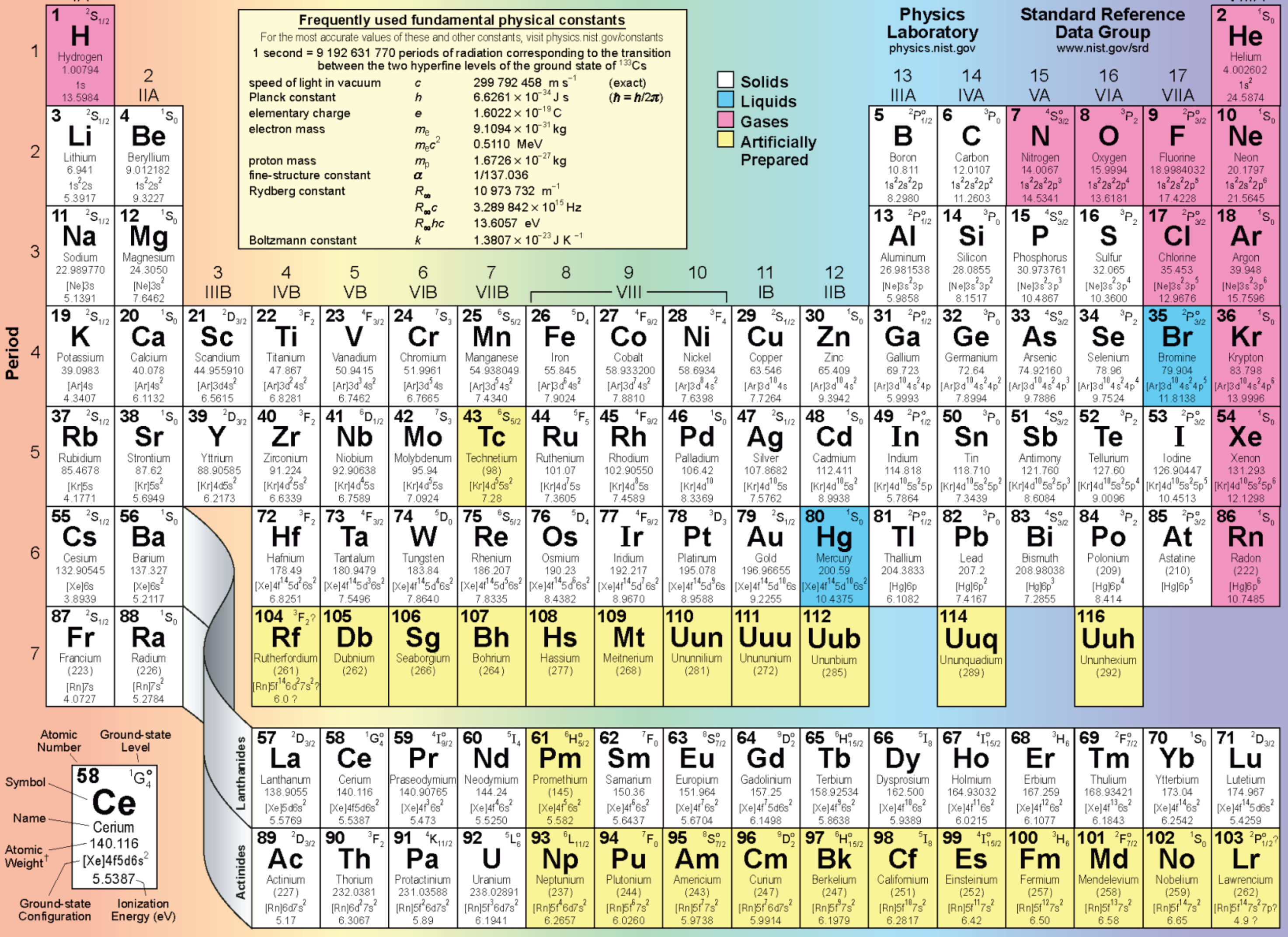
P E R I O D I C   T A B L E

Atomic Properties of the Elements

National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Physics Laboratory
physics.nist.gov

Standard Reference Data Group
www.nist.gov/srd



Frequently used fundamental physical constants

For the most accurate values of these and other constants, visit physics.nist.gov/constants

1 second = 9 192 631 770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of ^{133}Cs

speed of light in vacuum	c	299 792 458 m s^{-1}	(exact)
Planck constant	h	6.6261×10^{-34} J s	($\hbar = h/2\pi$)
elementary charge	e	1.6022×10^{-19} C	
electron mass	m_e	9.1094×10^{-31} kg	
	$m_e c^2$	0.5110 MeV	
proton mass	m_p	1.6726×10^{-27} kg	
fine-structure constant	α	1/137.036	
Rydberg constant	R_∞	10 973 732 m^{-1}	
	$R_\infty c$	$3.289\,842 \times 10^{15}$ Hz	
	$R_\infty hc$	13.6057 eV	
Boltzmann constant	k	1.3807×10^{-23} J K^{-1}	

☐ Solids
🟦 Liquids
🟪 Gases
🟨 Artificially Prepared

Period	Group 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIII	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 $^{2}S_{1/2}$ **H** Hydrogen 1.00794 1s 13.5984																	2 $^{1}S_{0}$ **He** Helium 4.002602 $1s^{2}$ 24.5874
2	3 $^{2}S_{1/2}$ **Li** Lithium 6.941 $1s^{2}2s$ 5.3917	4 $^{1}S_{0}$ **Be** Beryllium 9.012182 $1s^{2}2s^{2}$ 9.3227											5 $^{2}P^{\circ}_{1/2}$ **B** Boron 10.811 $1s^{2}2s^{2}2p$ 8.2980	6 $^{3}P_{0}$ **C** Carbon 12.0107 $1s^{2}2s^{2}2p^{2}$ 11.2603	7 $^{4}S^{\circ}_{3/2}$ **N** Nitrogen 14.0067 $1s^{2}2s^{2}2p^{3}$ 14.5341	8 $^{3}P_{2}$ **O** Oxygen 15.9994 $1s^{2}2s^{2}2p^{4}$ 13.6181	9 $^{2}P^{\circ}_{3/2}$ **F** Fluorine 18.9984032 $1s^{2}2s^{2}2p^{5}$ 17.4228	10 $^{1}S_{0}$ **Ne** Neon 20.1797 $1s^{2}2s^{2}2p^{6}$ 21.5645
3	11 $^{2}S_{1/2}$ **Na** Sodium 22.989770 [Ne]3s 5.1391	12 $^{1}S_{0}$ **Mg** Magnesium 24.3050 $[Ne]3s^{2}$ 7.6462											13 $^{2}P^{\circ}_{1/2}$ **Al** Aluminum 26.981538 $[Ne]3s^{2}3p$ 5.9858	14 $^{3}P_{0}$ **Si** Silicon 28.0855 $[Ne]3s^{2}3p^{2}$ 8.1517	15 $^{4}S^{\circ}_{3/2}$ **P** Phosphorus 30.973761 $[Ne]3s^{2}3p^{3}$ 10.4867	16 $^{3}P_{2}$ **S** Sulfur 32.065 $[Ne]3s^{2}3p^{4}$ 10.3600	17 $^{2}P^{\circ}_{3/2}$ **Cl** Chlorine 35.453 $[Ne]3s^{2}3p^{5}$ 12.9676	18 $^{1}S_{0}$ **Ar** Argon 39.948 $[Ne]3s^{2}3p^{6}$ 15.7596
4	19 $^{2}S_{1/2}$ **K** Potassium 39.0983 [Ar]4s 4.3407	20 $^{1}S_{0}$ **Ca** Calcium 40.078 $[Ar]4s^{2}$ 6.1132	21 $^{2}D_{3/2}$ **Sc** Scandium 44.955910 $[Ar]3d4s^{2}$ 6.5615	22 $^{3}F_{2}$ **Ti** Titanium 47.867 $[Ar]3d^{2}4s^{2}$ 6.8281	23 $^{4}F_{3/2}$ **V** Vanadium 50.9415 $[Ar]3d^{3}4s^{2}$ 6.7462	24 $^{7}S_{3}$ **Cr** Chromium 51.9961 $[Ar]3d^{5}4s$ 6.7665	25 $^{6}S_{5/2}$ **Mn** Manganese 54.938049 $[Ar]3d^{5}4s^{2}$ 7.4340	26 $^{5}D_{4}$ **Fe** Iron 55.845 $[Ar]3d^{6}4s^{2}$ 7.9024	27 $^{4}F_{9/2}$ **Co** Cobalt 58.933200 $[Ar]3d^{7}4s^{2}$ 7.8810	28 $^{3}F_{4}$ **Ni** Nickel 58.6934 $[Ar]3d^{8}4s^{2}$ 7.6398	29 $^{2}S_{1/2}$ **Cu** Copper 63.546 $[Ar]3d^{10}4s$ 7.7264	30 $^{1}S_{0}$ **Zn** Zinc 65.409 $[Ar]3d^{10}4s^{2}$ 9.3942	31 $^{2}P^{\circ}_{1/2}$ **Ga** Gallium 69.723 $[Ar]3d^{10}4s^{2}4p$ 5.9993	32 $^{3}P_{0}$ **Ge** Germanium 72.64 $[Ar]3d^{10}4s^{2}4p^{2}$ 7.8994	33 $^{4}S^{\circ}_{3/2}$ **As** Arsenic 74.92160 $[Ar]3d^{10}4s^{2}4p^{3}$ 9.7886	34 $^{3}P_{2}$ **Se** Selenium 78.96 $[Ar]3d^{10}4s^{2}4p^{4}$ 9.7524	35 $^{2}P^{\circ}_{3/2}$ **Br** Bromine 79.904 $[Ar]3d^{10}4s^{2}4p^{5}$ 11.8138	36 $^{1}S_{0}$ **Kr** Krypton 83.798 $[Ar]3d^{10}4s^{2}4p^{6}$ 13.9996
5	37 $^{2}S_{1/2}$ **Rb** Rubidium 85.4678 [Kr]5s 4.1771	38 $^{1}S_{0}$ **Sr** Strontium 87.62 $[Kr]5s^{2}$ 5.6949	39 $^{2}D_{3/2}$ **Y** Yttrium 88.90585 $[Kr]4d5s^{2}$ 6.2173	40 $^{3}F_{2}$ **Zr** Zirconium 91.224 $[Kr]4d^{2}5s^{2}$ 6.6339	41 $^{6}D_{1/2}$ **Nb** Niobium 92.90638 $[Kr]4d^{4}5s$ 6.7589	42 $^{7}S_{3}$ **Mo** Molybdenum 95.94 $[Kr]4d^{5}5s$ 7.0924	43 $^{6}S_{5/2}$ **Tc** Technetium (98) $[Kr]4d^{5}5s^{2}$ 7.28	44 $^{5}F_{5}$ **Ru** Ruthenium 101.07 $[Kr]4d^{7}5s$ 7.3605	45 $^{4}F_{9/2}$ **Rh** Rhodium 102.90550 $[Kr]4d^{8}5s$ 7.4589	46 $^{1}S_{0}$ **Pd** Palladium 106.42 $[Kr]4d^{10}$ 8.3369	47 $^{2}S_{1/2}$ **Ag** Silver 107.8682 $[Kr]4d^{10}5s$ 7.5762	48 $^{1}S_{0}$ **Cd** Cadmium 112.411 $[Kr]4d^{10}5s^{2}$ 8.9938	49 $^{2}P^{\circ}_{1/2}$ **In** Indium 114.818 $[Kr]4d^{10}5s^{2}5p$ 5.7864	50 $^{3}P_{0}$ **Sn** Tin 118.710 $[Kr]4d^{10}5s^{2}5p^{2}$ 7.3439	51 $^{4}S^{\circ}_{3/2}$ **Sb** Antimony 121.760 $[Kr]4d^{10}5s^{2}5p^{3}$ 8.6084	52 $^{3}P_{2}$ **Te** Tellurium 127.60 $[Kr]4d^{10}5s^{2}5p^{4}$ 9.0096	53 $^{2}P^{\circ}_{3/2}$ **I** Iodine 126.90447 $[Kr]4d^{10}5s^{2}5p^{5}$ 10.4513	54 $^{1}S_{0}$ **Xe** Xenon 131.293 $[Kr]4d^{10}5s^{2}5p^{6}$ 12.1298
6	55 $^{2}S_{1/2}$ **Cs** Cesium 132.90545 [Xe]6s 3.8939	56 $^{1}S_{0}$ **Ba** Barium 137.327 $[Xe]6s^{2}$ 5.2117		72 $^{3}F_{2}$ **Hf** Hafnium 178.49 $[Xe]4f^{14}5d^{2}6s^{2}$ 6.8251	73 $^{4}F_{3/2}$ **Ta** Tantalum 180.9479 $[Xe]4f^{14}5d^{3}6s^{2}$ 7.5496	74 $^{5}D_{0}$ **W** Tungsten 183.84 $[Xe]4f^{14}5d^{4}6s^{2}$ 7.8640	75 $^{6}S_{5/2}$ **Re** Rhenium 186.207 $[Xe]4f^{14}5d^{5}6s^{2}$ 7.8335	76 $^{5}D_{4}$ **Os** Osmium 190.23 $[Xe]4f^{14}5d^{6}6s^{2}$ 8.4382	77 $^{4}F_{9/2}$ **Ir** Iridium 192.217 $[Xe]4f^{14}5d^{7}6s^{2}$ 8.9670	78 $^{3}D_{3}$ **Pt** Platinum 195.078 $[Xe]4f^{14}5d^{9}6s$ 8.9588	79 $^{2}S_{1/2}$ **Au** Gold 196.96655 $[Xe]4f^{14}5d^{10}6s$ 9.2255	80 $^{1}S_{0}$ **Hg** Mercury 200.59 $[Xe]4f^{14}5d^{10}6s^{2}$ 10.4375	81 $^{2}P^{\circ}_{1/2}$ **Tl** Thallium 204.3833 [Hg]6p 6.1082	82 $^{3}P_{0}$ **Pb** Lead 207.2 $[Hg]6p^{2}$ 7.4167	83 $^{4}S^{\circ}_{3/2}$ **Bi** Bismuth 208.98038 $[Hg]6p^{3}$ 7.2855	84 $^{3}P_{2}$ **Po** Polonium (209) $[Hg]6p^{4}$ 8.414	85 $^{2}P^{\circ}_{3/2}$ **At** Astatine (210) $[Hg]6p^{5}$	86 $^{1}S_{0}$ **Rn** Radon (222) $[Hg]6p^{6}$ 10.7485
7	87 $^{2}S_{1/2}$ **Fr** Francium (223) [Rn]7s 4.0727	88 $^{1}S_{0}$ **Ra** Radium (226) $[Rn]7s^{2}$ 5.2784		104 $^{3}F_{2}$? **Rf** Rutherfordium (261) $[Rn]5f^{14}6d^{2}7s^{2}$? 6.0 ?	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (266)	107 **Bh** Bohrium (264)	108 **Hs** Hassium (277)	109 **Mt** Meitnerium (268)	110 **Uun** Ununnilium (281)	111 **Uuu** Unununium (272)	112 **Uub** Ununbium (285)		114 **Uuq** Ununquadium (289)		116 **Uuh** Ununhexium (292)		

Lanthanides	57 $^{2}D_{3/2}$ **La** Lanthanum 138.9055 $[Xe]5d6s^{2}$ 5.5769	58 $^{1}G^{\circ}_{4}$ **Ce** Cerium 140.116 $[Xe]4f5d6s^{2}$ 5.5387	59 $^{4}I^{\circ}_{9/2}$ **Pr** Praseodymium 140.90765 $[Xe]4f^{3}6s^{2}$ 5.473	60 $^{5}I_{4}$ **Nd** Neodymium 144.24 $[Xe]4f^{4}6s^{2}$ 5.5250	61 $^{6}H^{\circ}_{5/2}$ **Pm** Promethium (145) $[Xe]4f^{5}6s^{2}$ 5.582	62 $^{7}F_{0}$ **Sm** Samarium 150.36 $[Xe]4f^{6}6s^{2}$ 5.6437	63 $^{8}S^{\circ}_{7/2}$ **Eu** Europium 151.964 $[Xe]4f^{7}6s^{2}$ 5.6704	64 $^{9}D^{\circ}_{2}$ **Gd** Gadolinium 157.25 $[Xe]4f^{7}5d6s^{2}$ 6.1498	65 $^{6}H^{\circ}_{15/2}$ **Tb** Terbium 158.92534 $[Xe]4f^{9}6s^{2}$ 5.8638	66 $^{5}I_{8}$ **Dy** Dysprosium 162.500 $[Xe]4f^{10}6s^{2}$ 5.9389	67 $^{4}I^{\circ}_{15/2}$ **Ho** Holmium 164.93032 $[Xe]4f^{11}6s^{2}$ 6.0215	68 $^{3}H_{6}$ **Er** Erbium 167.259 $[Xe]4f^{12}6s^{2}$ 6.1077	69 $^{2}F^{\circ}_{7/2}$ **Tm** Thulium 168.93421 $[Xe]4f^{13}6s^{2}$ 6.1843	70 $^{1}S_{0}$ **Yb** Ytterbium 173.04 $[Xe]4f^{14}6s^{2}$ 6.2542	71 $^{2}D_{3/2}$ **Lu** Lutetium 174.967 $[Xe]4f^{14}5d6s^{2}$ 5.4259
Actinides	89 $^{2}D_{3/2}$ **Ac** Actinium (227) $[Rn]6d7s^{2}$ 5.17	90 $^{3}F_{2}$ **Th** Thorium 232.0381 $[Rn]6d^{2}7s^{2}$ 6.3067	91 $^{4}K_{11/2}$ **Pa** Protactinium 231.03588 $[Rn]5f^{2}6d7s^{2}$ 5.89	92 $^{5}L^{\circ}_{6}$ **U** Uranium 238.02891 $[Rn]5f^{3}6d7s^{2}$ 6.1941	93 $^{6}L_{11/2}$ **Np** Neptunium (237) $[Rn]5f^{4}6d7s^{2}$ 6.2657	94 $^{7}F_{0}$ **Pu** Plutonium (244) $[Rn]5f^{6}7s^{2}$ 6.0260	95 $^{8}S^{\circ}_{7/2}$ **Am** Americium (243) $[Rn]5f^{7}7s^{2}$ 5.9738	96 $^{9}D^{\circ}_{2}$ **Cm** Curium (247) $[Rn]5f^{7}6d7s^{2}$ 5.9914	97 $^{6}H^{\circ}_{15/2}$ **Bk** Berkelium (247) $[Rn]5f^{9}7s^{2}$ 6.1979	98 $^{5}I_{8}$ **Cf** Californium (251) $[Rn]5f^{10}7s^{2}$ 6.2817	99 $^{4}I^{\circ}_{15/2}$ **Es** Einsteinium (252) $[Rn]5f^{11}7s^{2}$ 6.42	100 $^{3}H_{6}$ **Fm** Fermium (257) $[Rn]5f^{12}7s^{2}$ 6.50	101 $^{2}F^{\circ}_{7/2}$ **Md** Mendelevium (258) $[Rn]5f^{13}7s^{2}$ 6.58	102 $^{1}S_{0}$ **No** Nobelium (259) $[Rn]5f^{14}7s^{2}$ 6.65	103 $^{2}P^{\circ}_{1/2}$? **Lr** Lawrencium (262) $[Rn]5f^{14}7s^{2}7p$? 4.9 ?

†Based upon ^{12}C. () indicates the mass number of the most stable isotope.

For a description of the data, visit physics.nist.gov/data

NIST SP 966 (September 2003)

Mathematical Formulas

GAMMA FUNCTION

$$\int_0^\infty x^{n-1}e^{-x}dx = \Gamma(n)$$

$$\Gamma(1) = \Gamma(2) = 1 \quad \Gamma(3) = 2 \quad \Gamma(4) = 6$$

$$\Gamma(\tfrac{1}{2}) = \sqrt{\pi} \qquad \Gamma(\tfrac{3}{2}) = \frac{\sqrt{\pi}}{2} \qquad \Gamma(\tfrac{5}{2}) = \frac{3\sqrt{\pi}}{4}$$

HYPERBOLIC FUNCTIONS

$$\sinh x = \frac{e^x - e^{-x}}{2} \qquad \cosh x = \frac{e^x + e^{-x}}{2} \qquad \tanh x = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$

$$\operatorname{sech} x = \frac{2}{e^x + e^{-x}} \qquad \operatorname{csch} x = \frac{2}{e^x - e^{-x}} \qquad \coth x = \frac{e^x + e^{-x}}{e^x - e^{-x}}$$

MACLAURIN SERIES EXPANSIONS

$$\mathrm{e}^x = \sum_{n=0}^{\infty} \frac{x^n}{n!} = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \cdots \text{ for all } x$$

$$\sinh x = \sum_{n=0}^{\infty} \frac{x^{2n+1}}{(2n+1)!} = x + \frac{x^3}{3!} + \frac{x^5}{5!} + \cdots \text{ for all } x$$

$$\cosh x = \sum_{n=0}^{\infty} \frac{x^{2n}}{(2n)!} = 1 + \frac{x^2}{2!} + \frac{x^4}{4!} + \cdots \text{ for all } x$$

$$\tanh x = \sum_{n=1}^{\infty} \frac{B_{2n}4^n(4^n-1)}{(2n)!} x^{2n-1} = x - \frac{1}{3}x^3 + \frac{2}{15}x^5 - \frac{17}{315}x^7 + \cdots \text{ for } |x| < \frac{\pi}{2}$$

LINEAR DIFFERENTIAL EQUATIONS

$y = y_{hom} + y_{part}$ $\qquad$ y_{part} can be found by assuming a polynomial of the same degree as P(x)

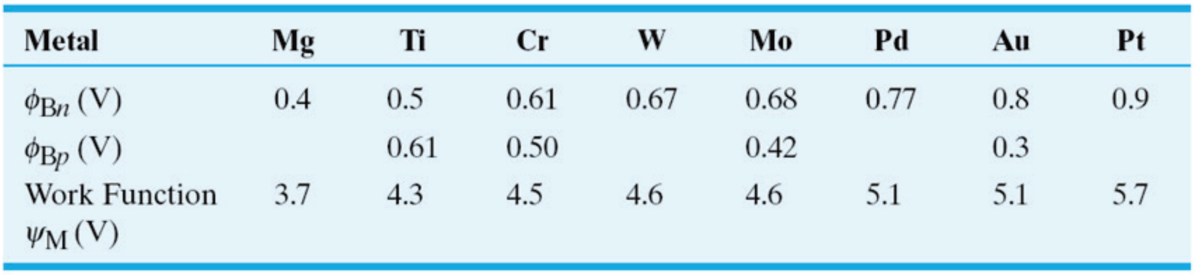
FIRST ORDER: $\quad \frac{dy}{dx} + ay = P(\mathrm{x}) \qquad y_{hom} = Ae^{-ax}$

SECOND ORDER: $\quad \frac{d^2y}{dx^2} - a^2y = P(x) \qquad y_{hom} = Ae^{-ax} + Be^{ax}$

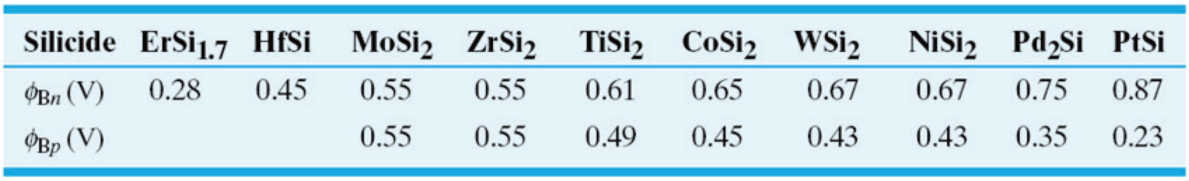
Semiconductor Formulas

Fermi-Dirac statistics	$f(E) = \frac{1}{1+e^{\frac{(E-E_F)}{kT}}}$	k: Boltzmann's constant [eV/K] T: Temperature [K] E_F: Fermi Level [eV]
Poisson's equation	$\frac{d^2V}{dx^2} = -\frac{dE}{dx} = -\frac{\rho}{\varepsilon_S}$	V: Potential [V] E: Electric field [V/cm] ρ: Charge density [C/cm^3] ε_S: Semiconductor permittivity [F/cm]
Continuity equation for electrons	$\frac{\partial n}{\partial t} = \frac{1}{q}\frac{\partial J_n}{\partial x} - \frac{n-n_o}{\tau_n} + G$	n: Electron carrier concentration [cm^{-3}] J_n: Electron current density [A/cm^2] τ_n: Electron recombination lifetime [s] G: External electron generation rate [cm^{-3}s^{-1}]
Continuity equation for holes	$\frac{\partial p}{\partial t} = -\frac{1}{q}\frac{\partial J_p}{\partial x} - \frac{p-p_o}{\tau_p} + G$	p: Hole carrier concentration [cm^{-3}] J_p: Hole current density [A/cm^2] τ_p: Hole recombination lifetime [s] G: External hole generation rate [cm^{-3}s^{-1}]
Einstein relationship	$D = \frac{kT}{q}\mu$	D: Diffusion coefficient of carriers[cm^2/s] μ: Mobility of carriers[cm^2/Vs]
Diffusion Length	$L = \sqrt{D\tau}$	D: Diffusion coefficient of carriers[cm^2/s] τ: Carrier recombination lifetime [s]
MOS capacitor equations	$V_g = V_{fb} + \phi_s + V_{ox}$	V_g: Gate voltage [V] V_{fb}: Flatband voltage [V] ϕ_s: Surface potential [V] V_{ox}: Voltage over oxide [V]
	$V_{ox} = -\frac{Q_{sub}}{C_{ox}}$	Q_{sub}: Charge in semiconductor [C/cm^2] C_{ox}: Oxide capacitance [F/cm^2]
NMOSFET	$V_t = V_{t0} + (m-1)V_{sb}$	V_t: threshold voltage [V] V_{t0}: threshold voltage at zero V_{sb} [V] m: bulk-charge factor [ ] V_{sb}: Potential between source and bulk [V]
	$m = 1 + \frac{\varepsilon_s T_{oxe}}{\varepsilon_{ox} W_{dmax}}$	ε_s: Permittivity of semiconductor [F/cm] T_{oxe}: Effective oxide thickness [cm] ε_{ox}: Permittivity of oxide [F/cm] W_{dmax}: Maximum depletion layer width [cm]
	$I_{ds} = \frac{W}{L} C_{oxe}\mu_{ns}(V_{gs} - V_t - \frac{m}{2}V_{ds})V_{ds}$	W: Gate width [cm] L: Gate length [cm] C_{oxe}: Effective oxide capacitance [F/cm^2] μ_{ns}: Electron surface mobility [cm^2/Vs] V_{gs}: Potential between gate and source [V] V_{ds}: Potential between drain and source [V]

Work function and Schottky barrier heights of metals and silicides to Si



Metal	**Mg**	**Ti**	**Cr**	**W**	**Mo**	**Pd**	**Au**	**Pt**
ϕ_{Bn} (V)	0.4	0.5	0.61	0.67	0.68	0.77	0.8	0.9
ϕ_{Bp} (V)		0.61	0.50		0.42		0.3	
Work Function ψ_M (V)	3.7	4.3	4.5	4.6	4.6	5.1	5.1	5.7

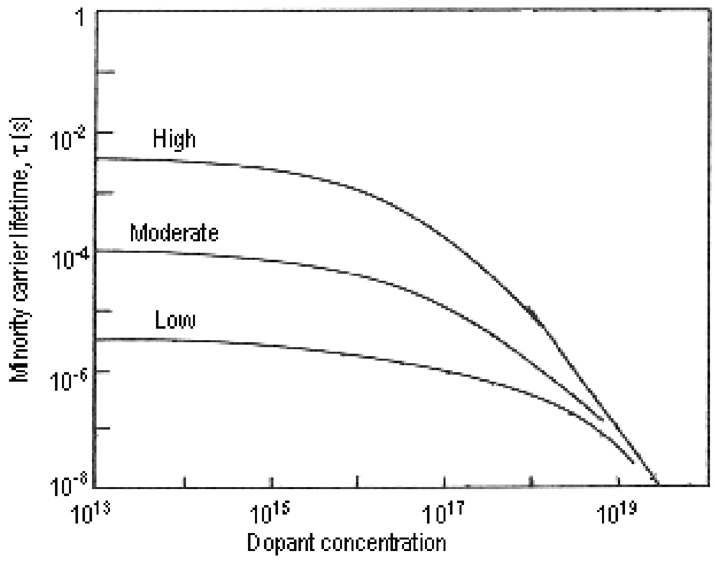


Silicide	**$ErSi_{1.7}$**	**HfSi**	**$MoSi_2$**	**$ZrSi_2$**	**$TiSi_2$**	**$CoSi_2$**	**WSi_2**	**$NiSi_2$**	**Pd_2Si**	**PtSi**
ϕ_{Bn} (V)	0.28	0.45	0.55	0.55	0.61	0.65	0.67	0.67	0.75	0.87
ϕ_{Bp} (V)			0.55	0.55	0.49	0.45	0.43	0.43	0.35	0.23

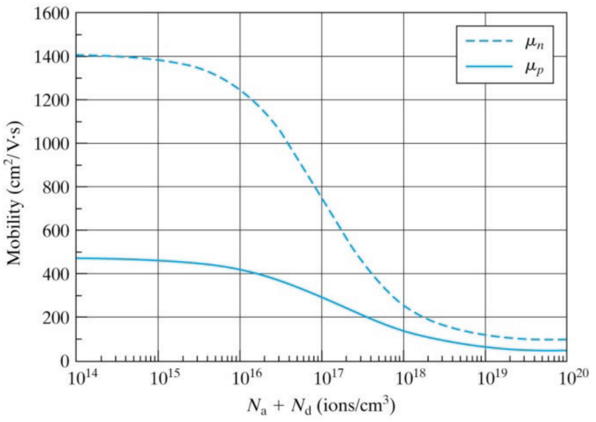
Egenskaper hos Si (T=300 K)

QUANTITY	SYMBOL	VALUE/DIMENSION
Bandgap	$\mathbf{E_g}$	1.12 eV, indirect
Intrinsic carrier concentration	$\mathbf{n_i}$	10^{10} cm^{-3}
Effectiv Density of states in E_C	$\mathbf{N_c}$	$2.8\cdot10^{19}$ cm^{-3}
Effectiv Density of states in E_v	$\mathbf{N_v}$	$1.0\cdot10^{19}$ cm^{-3}
Electron effective mass	$\mathbf{m_n/m_0}$	0.26
Hole effective mass	$\mathbf{m_p/m_0}$	0.39
Electron/Hole thermal velocity	v_{th}^{e}/v_{th}^{h}	$2.3\cdot10^7$ / $1.7\cdot10^7$ cm/s
Electron affinity	χ	4.05 eV
Relative permittivity	ε_r	11.9
Electric breakdown field	$\mathcal{E}_{crit}$	~$4\cdot10^5$ V/cm

Si carrier lifetime τ in low, moderate and high quality Si crystals



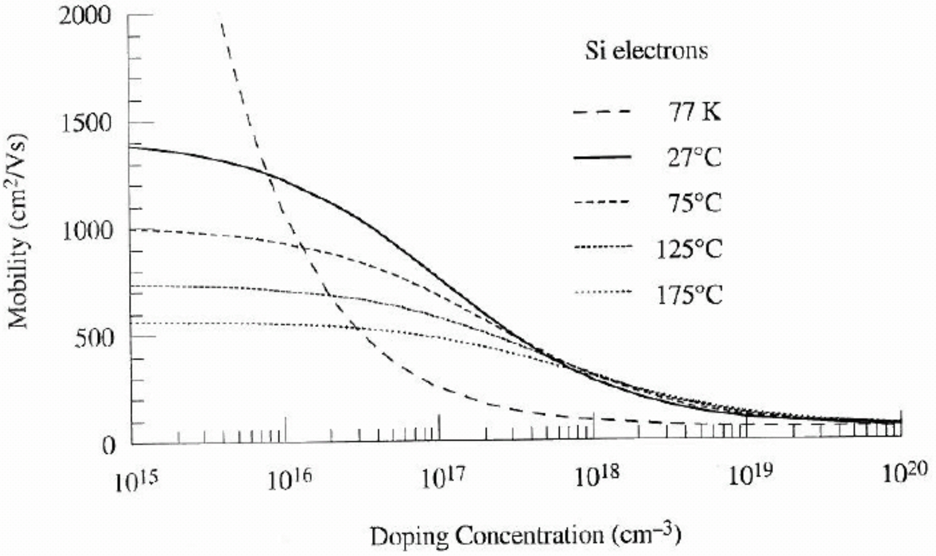
Si electron and hole mobility at T=300 K [cm^2/Vs]

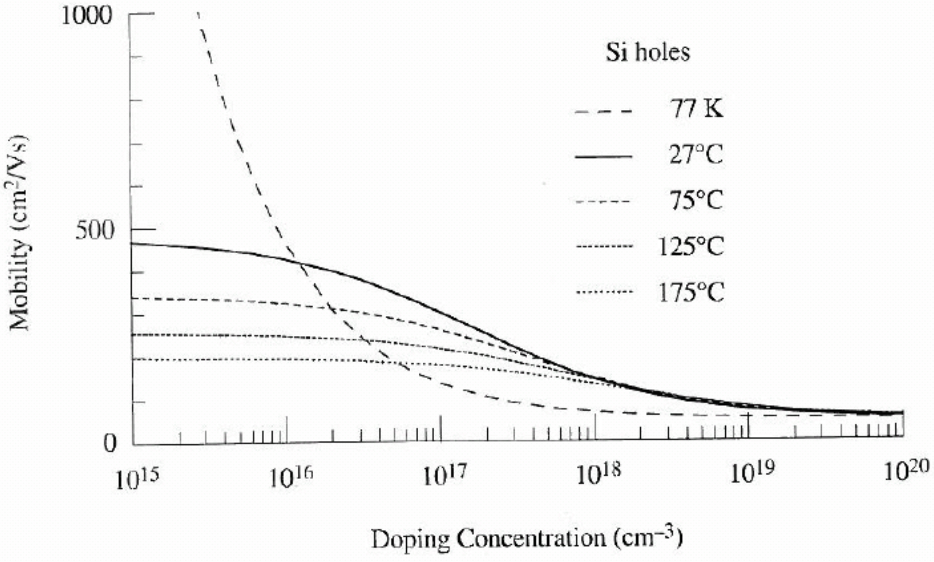


$$\mu_n = \frac{1318}{1+\left(\frac{N_a+N_d}{10^{17}}\right)^{0.85}} + 92$$

$$\mu_p = \frac{420}{1+\left(\frac{N_a+N_d}{1.6\cdot 10^{17}}\right)^{0.7}} + 50$$

Si electron and hole mobility a various temperatures

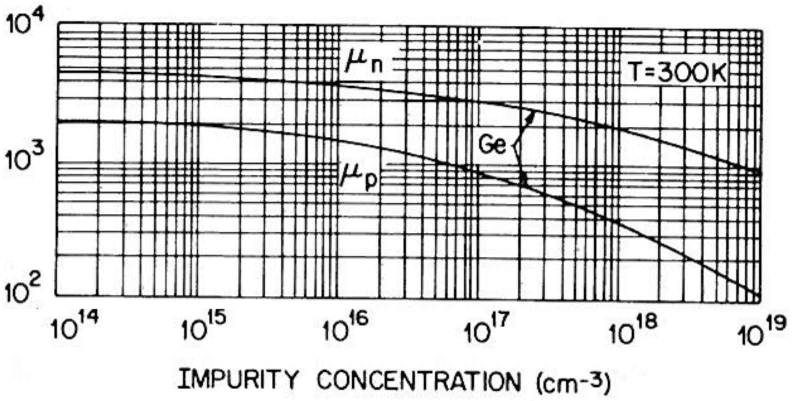




Egenskaper hos Ge (T=300 K)

QUANTITY	SYMBOL	VALUE/DIMENSION
Bandgap	$\mathbf{E_g}$	0.67 eV, indirect
Intrinsic carrier concentration	$\mathbf{n_i}$	$2.4\cdot10^{13}$ cm^{-3}
Effectiv Density of states in E_C	$\mathbf{N_c}$	$1.0\cdot10^{19}$ cm^{-3}
Effectiv Density of states in E_v	$\mathbf{N_v}$	$6.0\cdot10^{18}$ cm^{-3}
Electron effective mass	$\mathbf{m_n/m_0}$	0.12
Hole effective mass	$\mathbf{m_p/m_0}$	0.21
Electron/Hole thermal velocity	v_{th}^{e}/v_{th}^{h}	$3.1\cdot10^7$ / $1.9\cdot10^7$ cm/s
Electron affinity	χ	4.0 eV
Relative permittivity	ε_r	16
Electric breakdown field	$\mathcal{E}_{crit}$	~ $2\cdot10^5$ V/cm

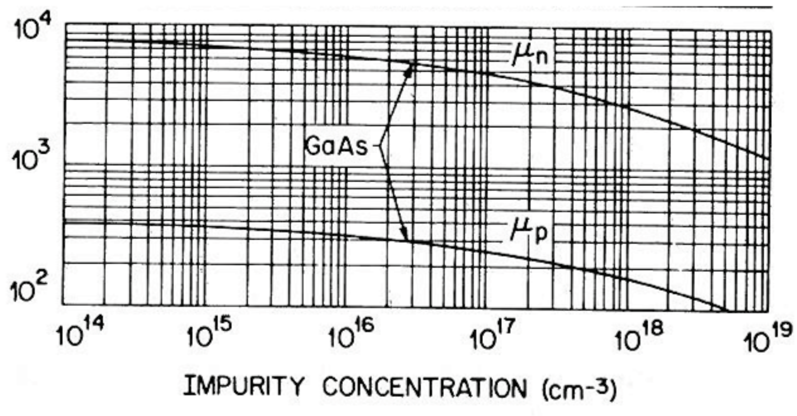
Ge electron and hole mobility at T=300 K [cm^2/Vs]



Egenskaper hos GaAs (T=300 K)

QUANTITY	SYMBOL	VALUE/DIMENSION
Bandgap	$\mathbf{E_g}$	1.42 eV, direct
Intrinsic carrier concentration	$\mathbf{n_i}$	$9 \cdot 10^6$ cm^{-3}
Effectiv Density of states in E_C	$\mathbf{N_c}$	$4.7 \cdot 10^{17}$ cm^{-3}
Effectiv Density of states in E_v	$\mathbf{N_v}$	$7.0 \cdot 10^{18}$ cm^{-3}
Electron effective mass	$\mathbf{m_n/m_0}$	0.067
Hole effective mass	$\mathbf{m_p/m_0}$	0.34
Electron/Hole thermal velocity	v_{th}^{e}/v_{th}^{h}	$4.4 \cdot 10^7$ / $1.8 \cdot 10^7$ cm/s
Electron affinity	χ	4.07 eV
Relative permittivity	ε_r	13.1
Electric breakdown field	$\mathcal{E}_{crit}$	~8 10^5 V/cm

GaAs electron and hole mobility at T=300 K [cm^2/Vs]



Egenskaper hos GaP (T=300 K)

QUANTITY	SYMBOL	VALUE/DIMENSION
Bandgap	E_g	2.24 eV, indirect
Intrinsic carrier concentration	n_i	~ 1 cm^{-3}
Effectiv Density of states in E_c	N_c	$1.8 \cdot 10^{19}$ cm^{-3}
Effectiv Density of states in E_v	N_v	$1.9 \cdot 10^{19}$ cm^{-3}
Electron effective mass	m_n/m_0	0.30
Hole effective mass	m_p/m_0	0.71
Electron/Hole thermal velocity	v_{th}^e/v_{th}^h	$2 \cdot 10^7$ / $1.3 \cdot 10^7$ cm/s
Electron affinity	χ	3.8 eV
Relative permittivity	ε_r	11.1
Electric breakdown field	$\mathcal{E}_{crit}$	~ 10^6 V/cm

Egenskaper hos SiC (4H) (T=300 K)

QUANTITY	SYMBOL	VALUE/DIMENSION
Bandgap	E_g	3.2 eV, indirect
Intrinsic carrier concentration	n_i	-
Effectiv Density of states in E_C	N_c	$1.7 \cdot 10^{19}$ cm^{-3}
Effectiv Density of states in E_v	N_v	$2.5 \cdot 10^{19}$ cm^{-3}
Electron effective mass	m_n/m_0	0.39
Hole effective mass	m_p/m_0	0.82
Electron/Hole thermal velocity	v_{th}^e/v_{th}^h	$1.9 \cdot 10^7$ / $1.2 \cdot 10^7$ cm/s
Electron affinity	χ	3.91
Relative permittivity	ε_r	10
Electric breakdown field	$\mathcal{E}_{crit}$	$2.2 \cdot 10^6$ V/cm