A A-B-C of equations

This is an alphabetical list of equations on a undergraduate level, in a easy-to-remember form. It includes rounded physical constants, for order-of-magnitude estimates. At the end, one can find an explanatory supplement. In this part, we do not use a dot product, a cross product, or complex numbers (nevertheless, see Appendix B). A factor in the equations is sometimes denoted simply as a constant K.

$$\mathrm{au} \doteq 1{,}5 \cdot 10^{11}\,\mathrm{m} \tag{1}$$

$$A = (Ht)^{\frac{1}{3}} \tag{2}$$

$$A = (Ht)^{\frac{2}{3}} \tag{3}$$

$$A = \mathrm{e}^{Ht} \tag{4}$$

$$|\boldsymbol{B}| = \frac{\mu I}{2\pi r} \tag{5}$$

$$c = \lambda f \tag{6}$$

$$c \doteq 3 \cdot 10^{8}\,\mathrm{m\,s^{-1}} \tag{7}$$

$$c_{\mathrm{s}} = \sqrt{\frac{\gamma k T}{m}} \tag{8}$$

$$\mathrm{e} \doteq 3 \tag{9}$$

$$\mathrm{eV} \doteq 1 \cdot 10^{-19}\,\mathrm{J} \tag{10}$$

$$|\boldsymbol{E}| = \frac{U}{x - x'} \tag{11}$$

$$E_0 = mc^2 \tag{12}$$

$$E_{\mathrm{k}} = \frac{1}{2} m v^2 \tag{13}$$

$$E_{\mathrm{g}} = -\frac{GMm}{r} \tag{14}$$

$$E_{\mathrm{e}} = \frac{k_{\mathrm{e}}Qq}{r} \tag{15}$$

$$E_{\gamma} = hf \tag{16}$$

$$E_U = kT \tag{17}$$

$$E_W = Pt \tag{18}$$

$$E_W = F_{\parallel}|x - x'| \tag{19}$$

$$E_W = p(V - V') \tag{20}$$

$$E_Q = mC(T - T') \tag{21}$$

$$E_{ij} \doteq -13{,}6\,\mathrm{eV}\left(\frac{1}{i^2} - \frac{1}{j^2}\right) \tag{22}$$

$$E_{\alpha} \doteq 28 \cdot 10^6\,\mathrm{eV} \tag{23}$$

$$f = \frac{1}{T} \tag{24}$$

$$\boldsymbol{F} = m\boldsymbol{a} \tag{25}$$

$$\boldsymbol{F} = m\boldsymbol{g} \tag{26}$$

$$\boldsymbol{F} = q\boldsymbol{E} \tag{27}$$

$$F = qv|\boldsymbol{B}| \tag{28}$$

$$F = pS \tag{29}$$

$$F = -ky \tag{30}$$

$$F \doteq -mg\varphi \tag{31}$$

$$F = -\frac{GMm}{r^2} \tag{32}$$

$$F = \frac{k_\mathrm{e}Qq}{r^2} \tag{33}$$

$$F = -\frac{mv^2}{r} \tag{34}$$

$$F = -m\omega^2 y \tag{35}$$

$$F = V(\varrho' - \varrho)g \tag{36}$$

$$F = KF_\perp \tag{37}$$

$$F = K\varrho Svv \tag{38}$$

$$\boldsymbol{F}_{12} = -\boldsymbol{F}_{21} \tag{39}$$

$$g = \frac{GM_\mathrm{Z}}{R_\mathrm{Z}^2} \tag{40}$$

$$G \doteq 6 \cdot 10^{-11}\,\mathrm{N\,kg^{-2}\,m^2} \tag{41}$$

$$h \doteq 6 \cdot 10^{-34}\,\mathrm{J\,s} \tag{42}$$

$$H \doteq 0{,}07\,\mathrm{m\,s^{-1}\,pc^{-1}} \tag{43}$$

$$I = \frac{Q}{t} \tag{44}$$

$$I = \frac{1}{R}U \tag{45}$$

$$I = \frac{1}{\omega L}U \tag{46}$$

$$I = \omega CU \tag{47}$$

$$k \doteq 1 \cdot 10^{-23}\,\mathrm{J\,K^{-1}} \tag{48}$$

$$k_\mathrm{e} \doteq 9 \cdot 10^{9}\,\mathrm{N\,C^{-2}\,m^{2}} \tag{49}$$

$$m = \varrho V \tag{50}$$

$$m' = \frac{m}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{51}$$

$$m_\mathrm{p} \doteq 1 \cdot 10^{-27}\,\mathrm{kg} \tag{52}$$

$$m_\mathrm{e} \doteq 1 \cdot 10^{-30}\,\mathrm{kg} \tag{53}$$

$$m_\mathrm{Vega} \doteq 0\,\mathrm{mag} \tag{54}$$

$$m = m' - 2{,}5 \log_{10} \frac{\Phi}{\Phi'} \tag{55}$$

$$M_\mathrm{g} \doteq \left(\frac{kT}{Gm}\right)^{3/2} \rho^{-1/2} \tag{56}$$

$$M_\mathrm{Z} \doteq 6 \cdot 10^{24}\,\mathrm{kg} \tag{57}$$

$$M_\mathrm{S} \doteq 2 \cdot 10^{30}\,\mathrm{kg} \tag{58}$$

$$N = \frac{M}{m} \tag{59}$$

$$n \doteq \frac{\sin\alpha}{\sin\beta} \tag{60}$$

$$N = N_0 \exp(-\lambda t) \tag{61}$$

$$\frac{1}{o} = \frac{1}{x} + \frac{1}{x'} \tag{62}$$

$$o = \frac{r}{2} \tag{63}$$

$$\boldsymbol{p} = m\boldsymbol{v} \tag{64}$$

$$\boldsymbol{p}' = \boldsymbol{p} + \boldsymbol{F}(t' - t) \tag{65}$$

$$|\boldsymbol{p}| = \frac{E}{c} \tag{66}$$

$$p = \frac{k}{m}\varrho T \tag{67}$$

$$p = K\left(1 - \frac{\varrho}{\varrho_0}\right) \tag{68}$$

$$p = z\rho g \tag{69}$$

$$p = K\rho^{\gamma} \tag{70}$$

$$P = Fv \tag{71}$$

$$P = \Phi S \tag{72}$$

$$P = UI \tag{73}$$

$$\mathrm{pc} = \frac{1\,\mathrm{au}}{\mathrm{tg}\,1''} \tag{74}$$

$$q \doteq 1 \cdot 10^{-19}\,\mathrm{C} \tag{75}$$

$$r = a\frac{(1 - e^2)}{1 + e\cos\varphi} \tag{76}$$

$$r_0 = \frac{h^2}{4\pi^2 m_\mathrm{e} k_\mathrm{e} q^2} \tag{77}$$

$$r_\mathrm{g} = \frac{2GM}{c^2} \tag{78}$$

$$R_\mathrm{Z} \doteq 6 \cdot 10^6\,\mathrm{m} \tag{79}$$

$$R_\mathrm{S} \doteq 6 \cdot 10^8\,\mathrm{m} \tag{80}$$

$$S = 4\pi R^2 \tag{81}$$

$$t = t_* - \alpha \tag{82}$$

$$t_* \doteq 24110\,\mathrm{s} + \frac{365{,}2422 + 1}{365{,}2422}(\mathrm{UT1} - \mathrm{J2000}) + \lambda \tag{83}$$

$$t' = \frac{t}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{84}$$

$$t \doteq \frac{1}{H} \tag{85}$$

$$t = (4{,}567 \pm 0{,}001) \cdot 10^9\,\mathrm{r.} \tag{86}$$

$$T = 2\pi\sqrt{\frac{m}{k}} \tag{87}$$

$$T = 2\pi\sqrt{\frac{r}{g}} \tag{88}$$

$$T = 2\pi\sqrt{\frac{a^3}{G(M+m)}} \tag{89}$$

$$T = 2\pi\sqrt{LC} \tag{90}$$

$$T_{0\,^\circ\mathrm{C}} \doteq 273\,\mathrm{K} \tag{91}$$

$$T_\mathrm{S} \doteq 6\,000\,\mathrm{K} \tag{92}$$

$$v = at \tag{93}$$

$$v = \omega r \tag{94}$$

$$v = Hr \tag{95}$$

$$v = \sqrt{\frac{G(M+m)}{r}} \tag{96}$$

$$v = \sqrt{\frac{3kT}{m}} \tag{97}$$

$$V = \frac{4}{3}\pi R^3 \tag{98}$$

$$x = vt \tag{99}$$

$$x = \frac{1}{2}at^2 \tag{100}$$

$$x' = x\sqrt{1 - \frac{v^2}{c^2}} \tag{101}$$

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \tag{102}$$

$$y = K\sin(\omega t) \tag{103}$$

$$y = K\sin(kx - \omega t) \tag{104}$$

$$\alpha' = \alpha \tag{105}$$

$$\varepsilon = \frac{x' - x}{x} \tag{106}$$

$$\varepsilon = \alpha(T' - T) \tag{107}$$

$$\lambda\, j = B\sin\alpha \tag{108}$$

$$\lambda = \frac{K}{T} \tag{109}$$

$$\lambda' = \lambda\left(1 + \frac{v_\mathrm{r}}{c}\right) \tag{110}$$

$$\mu \doteq 1 \cdot 10^{-6}\,\mathrm{T\,A^{-1}\,m} \tag{111}$$

$$\pi \doteq 3 \tag{112}$$

$$\sigma = E\varepsilon \tag{113}$$

$$\sigma = 5 \cdot 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}} \tag{114}$$

$$\sigma^2 = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2 \tag{115}$$

$$\varphi \doteq \frac{1\,\mathrm{au}}{r} \tag{116}$$

$$\varphi = 1{,}22\,\frac{\lambda}{D} \tag{117}$$

$$\varphi = \frac{d}{o} \tag{118}$$

$$\Phi = \sigma T^4 \tag{119}$$

$$\Phi = \Phi_0\,\mathrm{e}^{-\kappa\rho x} \tag{120}$$

$$\omega = 2\pi f \tag{121}$$

(1) astronomical unit
(2) expansion of space when the universe was dominated by radiation
(3) expansion of space when the universe was dominated by matter
(4) expansion of space when the universe *is* dominated by vacuum
(5) magnetic field around wire with the current I
(6) speed of waves with the given length and frequency
(7) speed of light in vacuum
(8) speed of sound
(9) Euler number
(10) electronvolt, unit of energy
(11) electric field for the given voltage U and distance $x - x'$
(12) rest energy, annihilation
(13) kinetic energy, zero value in rest
(14) gravitational potential energy, zero value in infinity
(15) electric potential energy, zero value in infinity
(16) energy of a photon
(17) energy of a particle
(18) work done with the power P during the time t
(19) work done by the force F over the path $x - x'$, in the direction of motion
(20) work done by the pressure p and the change of volume $V - V'$
(21) heat needed for a change of temperature $T - T'$ of a body with the mass m
(22) a difference of energies between levels i, j of the hydrogen atom
(23) energy released by a thermonuclear reaction in the Sun
(24) frequency

(25) force needed for an acceleration $\boldsymbol{a}$ of a body with mass m
(26) gravitational force acting on a mass m in the gravitational field $\boldsymbol{g}$
(27) electric force acting on a charge q in the electric field $\boldsymbol{E}$
(28) magnetic force acting on a *moving* charge q in the magnetic field $\boldsymbol{B}$
(29) pressure force on an area S
(30) string restoring force
(31) pendulum restoring force
(32) gravitational force between two masses m, M
(33) electric force between two charges q, Q
(34) centripetal force needed for a motion on a circle with the radius r
(35) restoring force needed for an oscillatory motion with the angular frequency ω
(36) buoyant force (positive) plus gravitational force (negative), Archimedes law
(37) friction force, proportional to the force $F_\perp$ perpendicular to the base
(38) friction force, Stokes drag, ϱ the density of air, S the cross section of a body
(39) law of action and reaction
(40) gravitational acceleration on the surface of the Earth
(41) gravitational constant
(42) Planck constant
(43) Hubble constant, the speed of expansion of space
(44) current generated by the flux of charge Q during time t
(45) current through a resistor for the given voltage U, Ohm law, direct or alternating circuit
(46) current through a coil, alternating circuit with the angular frequency ω, delayed behind the voltage U
(47) current through a capacitor, alternating circuit with the angular frequency ω, advanced before the voltage U
(48) Boltzmann constant
(49) Coulomb constant
(50) mass from the density ρ
(51) relativistic mass
(52) proton mass
(53) electron mass
(54) brightness of Vega
(55) Pogson eq.
(56) gravitating mass, Jeans eq.
(57) Earth mass
(58) Sun mass
(186) number of particles
(60) index of refraction, Snell law
(61) radioactive decay
(62) lens eq., where o denotes the focal length, x the object distance, x' the image distance
(63) focal length of a spherical mirror
(195) linear momentum
(65) momentum conservation law
(66) photon momentum
(67) ideal gas state eq.
(68) solid matter state eq.
(69) hydrostatic pressure
(70) adiabatic pressure
(71) power, force, velocity
(72) power, flux, area
(73) power, voltage, current
(74) parsec, unit of distance

(75) elementary charge
(76) conic section (ellipse, hyperbola)
(77) atom radius
(78) gravitational radius
(79) Earth radius
(80) Sun radius
(81) surface area of a sphere
(82) hour angle, sidereal time, right ascension
(83) sidereal time (in seconds), tropical year, UT1 denotes the universal time, J2000 the standard epoch, λ the geographic longitude
(84) time dilation
(85) age of the universe
(86) age of the solar system
(87) period of a string
(88) period of a pendulum
(89) period of a planet orbiting the Sun, Kepler law
(90) period of an LC circuit
(91) absolute temperature scale
(92) temperature on the surface of the Sun
(93) speed from the acceleration
(94) speed from the angular speed
(95) speed from the expansion of space
(96) Kepler speed
(97) thermal speed
(98) volume of a sphere
(99) distance for a uniform motion
(100) distance for an accelerated motion
(101) length contraction
(102) arithmetic average
(103) harmonic motion
(104) wave motion
(105) law of reflection
(106) relative length difference
(107) thermal expansion
(108) diffraction on a grating
(109) Wien law
(110) Doppler effect
(111) permeability of vacuum
(112) Ludolph number
(113) stress, modulus, relative length difference
(114) Stefan–Boltzmann constant
(115) standard deviation squared, variance
(116) parallax
(117) diffraction limit
(118) field of view
(119) black body flux, to half-space
(120) light absorption, opacity κ
(121) angular frequency

B A-B-C of equations (cont.)

This is a continuation on a graduate level.

$$\dot{} \equiv \frac{\partial}{\partial t} \tag{122}$$

$$\nabla \equiv \left(\frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z} \right) \tag{123}$$

$$_{,i} = \frac{\partial}{\partial x_i} \tag{124}$$

$$\boldsymbol{a} \cdot \boldsymbol{b} = (a_1 b_1, a_2 b_2, a_3 c_3) \tag{125}$$

$$\boldsymbol{a} \times \boldsymbol{b} = (a_2 b_3 - a_3 b_2, a_3 b_1 - a_1 b_3, a_1 b_2 - a_2 b_1) \tag{126}$$

$$\dot{a} = \frac{2}{n} \boldsymbol{a} \cdot \hat{T} \tag{127}$$

$$\dot{a} = -\frac{2}{na} \frac{\partial \mathcal{R}}{\partial \lambda} \tag{128}$$

$$\dot{A}^2 = H_0^2 \left(\frac{\Omega_\mathrm{m}}{A} + \frac{\Omega_\mathrm{r}}{A^2} + \Omega_\Lambda A^2 + 1 - \Omega_\mathrm{m} - \Omega_\mathrm{r} - \Omega_\Lambda \right) \tag{129}$$

$$A'_{ij} = \frac{A_{ij} - D_{ij} - O_{ij}}{F_{ij} - D'_{ij} - O'_{ij}} \tag{130}$$

$$A_{21} n_2 + (B_{21} n_2 - B_{12} n_1) \frac{1}{4\pi} \int I_f \varphi_{12} \mathrm{d}f + C_{21} n_2 - C_{12} n_1 = 0 \tag{131}$$

$$A_V \doteq 3\, E(B-V) \tag{132}$$

$$\nabla \cdot \boldsymbol{B} = 0 \tag{133}$$

$$\frac{\partial \boldsymbol{B}}{\partial t} = -\nabla \times \boldsymbol{E} \tag{134}$$

$$B_f = \frac{2hf^3}{c^2} \frac{1}{\mathrm{e}^{\frac{hf}{kT}} - 1} \tag{135}$$

$$\cos c = \cos a \cos b + \sin a \sin b \cos \gamma \tag{136}$$

$$C_{\mathrm{J}} = \frac{1}{2}(\dot{x}^2 + \dot{y}^2 + \dot{z}^2) - \frac{1}{2}n^2(x^2 + y^2) - \frac{GM_1}{r_1} - \frac{GM_2}{r_2} \tag{137}$$

$$E = M + e \cos E \tag{138}$$

$$E_n = -\frac{k_{\mathrm{e}} q^2}{2r_0}\frac{1}{n^2} \tag{139}$$

$$2\langle E_{\mathrm{k}} \rangle = -\langle E_{\mathrm{g}} \rangle \tag{140}$$

$$\nabla \cdot \boldsymbol{E} = \frac{1}{\varepsilon}\rho_{\mathrm{e}} \tag{141}$$

$$\frac{\partial \boldsymbol{E}}{\partial t} = \mu\varepsilon\nabla \times \boldsymbol{B} - \mu\boldsymbol{j} \tag{142}$$

$$f(x) = \sum_{i=0}^{\infty} \frac{f^{(i)}(x_0)}{i!}(x - x_0)^i \tag{143}$$

$$f_{;i} = f_{,i} \tag{144}$$

$$f^i{}_{;j} = f^i{}_{,j} + f^k \Gamma^i{}_{kj} \tag{145}$$

$$f^{ij}{}_{;k} = f^{ij}{}_{,k} + f^{lj}\Gamma^i{}_{lk} + f^{il}\Gamma^j{}_{lk} \tag{146}$$

$$f_i = g_{ik} f^k \tag{147}$$

$$f_{\mathrm{G}} = \frac{1}{\sqrt{2\pi}\sigma}\,\mathrm{e}^{-\frac{(x-\mu)^2}{2\sigma^2}} \tag{148}$$

$$f_{\mathrm{L}} = \frac{\gamma}{\pi}\frac{1}{(x-\mu)^2 + \gamma^2} \tag{149}$$

$$f_{\mathrm{P}} = \frac{\lambda^k\,\mathrm{e}^{-\lambda}}{k!} \tag{150}$$

$$f_{\mathrm{Ny}} = \frac{1}{2\delta} \tag{151}$$

$$\int_V \nabla \cdot \boldsymbol{f} \mathrm{d}V = \oint_S \boldsymbol{f} \cdot \mathrm{d}\boldsymbol{S} \tag{152}$$

$$\int_S \nabla \times \boldsymbol{f} \cdot \mathrm{d}\boldsymbol{S} = \oint_s \boldsymbol{f} \cdot \mathrm{d}\boldsymbol{s} \tag{153}$$

$$F(\omega) = \int_{-\infty}^{\infty} f(t)\, \mathrm{e}^{\mathrm{i}\omega t}\, \mathrm{d}t \tag{154}$$

$$\boldsymbol{F} = m\ddot{\boldsymbol{r}} \tag{155}$$

$$\boldsymbol{F} = -2\vec{\omega} \times \boldsymbol{v} \tag{156}$$

$$\boldsymbol{F} = (Q_{\mathrm{abs}} + Q_{\mathrm{sca}}) \frac{1}{c} \Phi S \left(\hat{r} - \frac{\boldsymbol{v} \cdot \hat{r}}{c} \hat{r} - \frac{\boldsymbol{v}}{c} \right) \tag{157}$$

$$\boldsymbol{F} = -\frac{2}{3} \frac{1}{c} \int \epsilon \sigma T^4 \mathrm{d}\boldsymbol{S} \tag{158}$$

$$F = \frac{2GMm}{r^3} R \tag{159}$$

$$g_{ik} = \boldsymbol{e}_i \boldsymbol{e}_k \tag{160}$$

$$g_{ik} = \begin{pmatrix} -c^2 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \tag{161}$$

$$g_{ik} = \begin{pmatrix} -c^2(1 - r_{\mathrm{g}}/r) & 0 & 0 & 0 \\ 0 & (1 - r_{\mathrm{g}}/r)^{-1} & 0 & 0 \\ 0 & 0 & r^2 & 0 \\ 0 & 0 & 0 & (r \sin \vartheta)^2 \end{pmatrix} \tag{162}$$

$$g_{ik} = \begin{pmatrix} -c^2 & 0 & 0 & 0 \\ 0 & A^2(1 - Kr^2)^{-1} & 0 & 0 \\ 0 & 0 & (Ar)^2 & 0 \\ 0 & 0 & 0 & (Ar \sin \vartheta)^2 \end{pmatrix} \tag{163}$$

$$g^{ik} = (g_{ik})^{-1} \tag{164}$$

$$H = \frac{p^2}{2m} - \frac{GMm}{q} \tag{165}$$

$$H = \frac{p^2}{2m} - \frac{k_\mathrm{e} e^2}{q} \tag{166}$$

$$\mathrm{H} + \mathrm{H} \leftrightarrows \mathrm{H}^* \tag{167}$$
$$\mathrm{H} + \gamma \leftrightarrows \mathrm{H}^* \tag{168}$$
$$\mathrm{H} + \gamma \leftrightarrows \mathrm{p}^+ + \mathrm{e}^- \tag{169}$$
$$\mathrm{H}^- + \gamma \leftrightarrows \mathrm{H} + \mathrm{e}^- \tag{170}$$

$$I(\vec{\alpha}) = I_0 \left[1 + \Re\left(\mu\, \mathrm{e}^{ik\vec{\alpha}\cdot\boldsymbol{B}}\right)\right] \tag{171}$$

$$I_f \equiv \frac{\mathrm{d}E}{\mathrm{d}t \mathrm{d}S \cos\vartheta \mathrm{d}\Omega \mathrm{d}f} \tag{172}$$

$$\frac{1}{c}\frac{\partial I_f}{\partial t} + \hat{k}\cdot\nabla I_f = j_f\rho - \kappa_f \rho I_f \quad \text{pro } \forall\hat{k} \tag{173}$$

$$I_f = I_f(0)\,\mathrm{e}^{-\kappa_f \rho x} + S_f(1 - \mathrm{e}^{-\kappa_f \rho x}) \tag{174}$$

$$I = \frac{U}{R} \tag{175}$$

$$\dot{I} = \frac{U}{L} \tag{176}$$

$$\int I \mathrm{d}t = UC \tag{177}$$

$$\sum_{i=1}^{N} I_i = 0 \tag{178}$$

$$j_f \varrho = \frac{hf}{4\pi} n_2 A_{21} \varphi_{12} \tag{179}$$

$$j_f \varrho = \kappa_f^{\mathrm{sca}} \rho \frac{1}{4\pi} \int I_f \mathrm{d}\Omega \tag{180}$$

$$\boldsymbol{L} = \boldsymbol{r} \times \boldsymbol{p} \tag{181}$$

$$\dot{\boldsymbol{L}} = \boldsymbol{M} \tag{182}$$

$$\frac{\mathrm{d}L_R}{\mathrm{d}R} = 4\pi R^2 \varrho\, \varepsilon \tag{183}$$

$$\frac{\mathrm{d}M_R}{\mathrm{d}R} = 4\pi R^2 \varrho \tag{184}$$

$$\boldsymbol{M} = \boldsymbol{r} \times \boldsymbol{F} \tag{185}$$

$$N = \sqrt{S} \tag{186}$$

$$N = \sqrt{N_{\mathrm{star}}^2 + N_{\mathrm{sky}}^2 + N_{\mathrm{dark}}^2 + N_{\mathrm{readout}}^2 + N_{\mathrm{discrete}}^2} \tag{187}$$

$$N = \int N_i \mathrm{d}\vec{\Gamma} \tag{188}$$

$$N_i = \frac{g_i}{\mathrm{e}^{\frac{E_i - \mu}{kT}} - 1} \tag{189}$$

$$N_i = \frac{g_i}{\mathrm{e}^{\frac{E_i - \mu}{kT}} + 1} \tag{190}$$

$$\frac{N_i}{N_j} \overset{\mathrm{lte}}{=} \frac{g_i}{g_j}\, \mathrm{e}^{-\frac{E_{ij}}{kT}} \tag{191}$$

$$f(v) \overset{\mathrm{lte}}{=} \sqrt{\frac{2}{\pi}} \left(\frac{m}{kT}\right)^{3/2} v^2\, \mathrm{e}^{-\frac{mv^2}{2kT}} \tag{192}$$

$$p \overset{\mathrm{lte}}{=} \frac{1}{3} a T^4 \tag{193}$$

$$p = \frac{1}{c} \int I \cos^2\vartheta \, \mathrm{d}\Omega \tag{194}$$

$$p = \frac{1}{3V} \int N_i v |\boldsymbol{p}| \mathrm{d}\vec{\Gamma} \tag{195}$$

$$\frac{\mathrm{d}p}{\mathrm{d}R} = -\frac{G M_R \varrho}{R^2} \tag{196}$$

$$\frac{\mathrm{d}p}{\mathrm{d}R} = -\frac{G}{R^2} \left(M_R + 4\pi R^3 \frac{p}{c^2}\right) \left(\rho + \frac{p}{c^2}\right) \left(1 - \frac{r_{\mathrm{g}}}{R}\right)^{-1} \tag{197}$$

$$\frac{\mathrm{d}p}{\mathrm{d}T} = \frac{l_{\mathrm{h}}}{T(V' - V)} \tag{198}$$

$$P_{20}(\cos\vartheta) = \frac{1}{2}(3\cos^2\vartheta - 1) \tag{199}$$

$$p(B|A) = p(A|B)\frac{p(B)}{p(A)} \tag{200}$$

$$p = \int \Psi\Psi^* \mathrm{d}V \tag{201}$$

$$\mathrm{p} + \mathrm{p} \rightarrow \mathrm{D} + \mathrm{e}^+ + \nu_\mathrm{e} \tag{202}$$
$$\mathrm{e}^+ + \mathrm{e}^- \rightarrow 2\gamma \tag{203}$$
$$\mathrm{D} + \mathrm{p} \rightarrow {}^3\mathrm{He} + \gamma \tag{204}$$
$${}^3\mathrm{He} + {}^3\mathrm{He} \rightarrow \alpha + 2\mathrm{p} \tag{205}$$

$$\dot{p} = -\frac{\partial H}{\partial q} \tag{206}$$

$$\dot{q} = \frac{\partial H}{\partial p} \tag{207}$$

$$\delta Q + \mu \mathrm{d}N = \mathrm{d}U + \delta W \tag{208}$$

$$r_\mathrm{H} = a\left(\frac{m}{3M}\right)^{1/3} \tag{209}$$

$$\mathcal{R}_{21} = -\frac{Gm_1}{r_{12}} + \frac{Gm_1}{r_1^3}\boldsymbol{r}_1 \cdot \boldsymbol{r}_2 \tag{210}$$

$$\langle \mathcal{R}_{21} \rangle \doteq C_0 + C_1(e_1^2 + e_2^2) + C_3 e_1 e_2 \cos(\varpi_1 - \varpi_2) \tag{211}$$

$$R_{ik} - \frac{1}{2}Rg_{ik} + \Lambda g_{ik} = \frac{8\pi G}{c^4}T_{ik} \tag{212}$$

$$R^l{}_{ijk} = \frac{f_{i;jk} - f_{i;kj}}{f_l} \tag{213}$$

$$R_{ik} = R^l{}_{ilk} \tag{214}$$

$$R = g^{ik}R_{ik} \tag{215}$$

$$R_z(\varphi) \equiv \begin{pmatrix} \cos\varphi & -\sin\varphi & 0 \\ \sin\varphi & \cos\varphi & 0 \\ 0 & 0 & 1 \end{pmatrix} \tag{216}$$

$$\boldsymbol{r}' = R_z(\Omega) \times R_x(i) \times R_z(\omega)\boldsymbol{r} \tag{217}$$

$$\ddot{\boldsymbol{r}} + G(M+m)\frac{\boldsymbol{r}}{r^3} = 0 \tag{218}$$

$$\mathrm{Re} = \frac{xv}{\nu} \tag{219}$$

$$S_{\mathrm{adu}} = \int \frac{\Phi_f St_{\mathrm{exp}}}{hf} TQ\eta \,\mathrm{d}f \tag{220}$$

$$\boldsymbol{S} = \nu\nabla\boldsymbol{v} \tag{221}$$

$$\dot{\boldsymbol{S}} = E\nabla\boldsymbol{v} \tag{222}$$

$$S_f \equiv \frac{j_f}{\kappa_f} \tag{223}$$

$$S_f \overset{\mathrm{lte}}{=} B_f \tag{224}$$

$$t' = \gamma\left(t + \frac{\beta}{c}x\right) \tag{225}$$

$$\frac{\mathrm{d}T}{\mathrm{d}R}\Big|_{\mathrm{rad}} = -\frac{3\kappa\varrho L_R}{16\pi acR^2T^3} \tag{226}$$

$$\frac{\mathrm{d}T}{\mathrm{d}R}\Big|_{\mathrm{ad}} = \frac{1}{C_p\varrho}\frac{\mathrm{d}p}{\mathrm{d}R} \tag{227}$$

$$\left|\frac{\mathrm{d}T}{\mathrm{d}R}\right|_{\mathrm{ad}} < \left|\frac{\mathrm{d}T}{\mathrm{d}R}\right|_{\mathrm{rad}} \tag{228}$$

$$T^{ik} = \begin{pmatrix} \rho c^2 & 0 & 0 & 0 \\ 0 & p & 0 & 0 \\ 0 & 0 & p & 0 \\ 0 & 0 & 0 & p \end{pmatrix} \tag{229}$$

$$u = \frac{1}{c}\int I \mathrm{d}\Omega \tag{230}$$

$$\frac{\partial u}{\partial t} = \chi \nabla \cdot \nabla u \tag{231}$$

$$\frac{\partial^2 u}{\partial t^2} = c^2 \nabla \cdot \nabla u \tag{232}$$

$$u = A\,\mathrm{e}^{\mathrm{i}(\boldsymbol{k}\cdot\boldsymbol{r}-\omega t)} \tag{233}$$

$$U = -\frac{GM}{r}\sum_{\ell=0}^{n}\sum_{m=-\ell}^{\ell}\left(\frac{R}{r}\right)^{\ell} P_{\ell m}(\cos\vartheta)\left[C_{\ell m}\cos(m\varphi) + S_{\ell m}\sin(m\varphi)\right] \tag{234}$$

$$\nabla \cdot \nabla U = 4\pi G\varrho \tag{235}$$

$$\sum_{i=1}^{N} U_i = 0 \tag{236}$$

$$\frac{\partial \boldsymbol{v}}{\partial t} + \boldsymbol{v}\cdot\nabla\boldsymbol{v} = -\frac{1}{\rho}\nabla p + \frac{1}{\rho}\nabla\cdot\boldsymbol{S} \tag{237}$$

$$x' = \gamma(x - Vt) \tag{238}$$

$$\frac{X}{1-X} = \frac{(2\pi m_\mathrm{e} kT)^{3/2}}{h^3}\frac{n}{n_\mathrm{e} n_\mathrm{p}}\,\mathrm{e}^{-\frac{E_\mathrm{i}}{kT}} \tag{239}$$

$$\frac{\partial^2 x^i}{\partial \tau^2} + \frac{\partial x^j}{\partial \tau}\frac{\partial x^k}{\partial \tau}\Gamma^i{}_{kj} = 0 \tag{240}$$

$$\alpha + \alpha \leftrightarrows {}^8\mathrm{Be}^* \tag{241}$$

$${}^8\mathrm{Be}^* + \alpha \rightarrow {}^{12}\mathrm{C} \tag{242}$$

$$\sin\alpha = \sin\beta\frac{\sin a}{\sin b} \tag{243}$$

$$\beta \equiv \frac{v}{c} \tag{244}$$

$$\gamma \equiv \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \tag{245}$$

$$\Gamma^{i}{}_{kj} = \frac{1}{2} g^{im} \left(g_{mk,j} + g_{mj,k} - g_{kj,m} \right) \tag{246}$$

$$\langle \Delta x \rangle \langle \Delta p \rangle \geq \frac{\hbar}{2} \tag{247}$$

$$\kappa_f \varrho = \frac{hf}{4\pi} (n_1 B_{12} - n_2 B_{21}) \varphi_{12} \tag{248}$$

$$\kappa_f^{\mathrm{abs}} = \frac{3(1-A)}{4 r \rho_{\mathrm{d}}} \tag{249}$$

$$\lambda' = \lambda \left[1 + \frac{g(y'-y)}{c^2} \right] \tag{250}$$

$$\mu = \frac{\int I(\vec{\alpha}') \, \mathrm{e}^{\mathrm{i} k \vec{\alpha}' \cdot \boldsymbol{B}} \, \mathrm{d}\alpha'}{I_0} \tag{251}$$

$$\nu = \alpha c_{\mathrm{s}} z \tag{252}$$

$$\frac{\partial \varrho}{\partial t} + \boldsymbol{v} \cdot \nabla \varrho = -\varrho \nabla \cdot \boldsymbol{v} \tag{253}$$

$$\mathrm{d}\tau_f \equiv \kappa_f \rho \mathrm{d}x \tag{254}$$

$$\Phi = \int I \cos \vartheta \mathrm{d}\Omega \tag{255}$$

$$\Phi(1-A) - K \nabla u \cdot \hat{n} - 4 \epsilon \sigma u^4 \overset{\mathrm{lte}}{=} 0 \tag{256}$$

$$\chi^2 \equiv \sum_{i=1}^{n} \left(\frac{y_i - f(x_i)}{\sigma_i} \right)^2 \tag{257}$$

$$\mathrm{i}\hbar \frac{\partial \Psi}{\partial t} = \frac{\hbar^2}{2m} \nabla \cdot \nabla \Psi - \frac{k_{\mathrm{e}} Q q}{r} \Psi \tag{258}$$

$$\Psi_{n\ell m} = \sum_{n=0}^{\infty} \sum_{\ell=0}^{n} \sum_{m=-\ell}^{\ell} K \, \mathrm{e}^{-\frac{r}{n r_0}} \left(\frac{2r}{n r_0} \right)^{\ell} L_{n-\ell-1}^{2\ell+1} \left(\frac{2r}{n r_0} \right) Y_{\ell m}(\vartheta, \varphi) \tag{259}$$

(122) partial derivative with respect to time
(123) operator of gradient (čes. stoupání), $\nabla\cdot$ divergence (rozbíhavost), $\nabla\times$ rotation (stáčení)
(124) partial derivative with respect to coordinate

(125) dot (scalar) product, $|\boldsymbol{a} \cdot \boldsymbol{b}| = ab\cos\alpha$
(126) cross (vector) product, $|\boldsymbol{a} \times \boldsymbol{b}| = ab\sin\alpha$
(127) Gauss eq., a change of an orbital element due to an acceleration, transversal component, unit ($\mathrm{m\,s^{-1}}$), hence the mean motion n
(128) Lagrange eq., a change of an orbital element due to a perturbation (potential), unit
(129) Fridman eq., matter, radiation, and dark energy state equations (A^{-3}, A^{-4}, A^0), remainder from normalisation ($A = 1$)
(130) reduction of a CCD image, dark, offset, flat
(131) collisional equilibrium, emission, absorption, stimulated emission, collisions, level populations in non-lte
(132) extinction vs. reddening, $E(B-V) = B-V-(B-V)_0$
(133) Maxwell eq., closed magnetic field lines
(134) Maxwell eq., electro–magnetic field, $\boldsymbol{B} \perp \boldsymbol{E}$, factor 1, minus convention
(135) Planck eq., local thermodynamic equilibrium, „black body“, common exponential $\mathrm{e}^{-\cdots}$, or $\mathrm{e}^{+\cdots}$ in the denominator, -1 due to an expansion ($\mathrm{e}^x \doteq 1+x+\ldots$), unit ($\mathrm{J\,\cancel{s^{-1}}\,m^{-2}\,\cancel{Hz^{-1}}}$), hence hf and f^2/c^2
(136) spherical law of cosines, similar as planar
(137) Jacobi integral of the 3-body problem, speed, centrifugal, potential terms
(138) Kepler eq., transcendental in E
(139) energy levels of the hydrogen atom, electric energy at the Bohr radius r_0
(140) virial theorem, bound state, total energy $\langle E_\mathrm{k}\rangle + \langle E_\mathrm{g}\rangle$ negative
(141) Maxwell eq., electric field lines emanating from charges, ε permittivity (čes. pronikavost)
(142) Maxwell eq., electro–magnetic field, units must be different for opposite derivatives, factor $\mu\varepsilon = 1/c^2$, μ permeability (čes. prostupnost), from $\boldsymbol{B} \to \boldsymbol{E}$, charge transport ($\boldsymbol{j}$) also changes field ($\dot{\boldsymbol{E}}$), minus convention
(143) Taylor series, nth derivative, if not ∞, approximation in a limited range
(144) covariant derivative of a scalar, scalar is independent on the basis $\boldsymbol{e}_i$
(145) covariant derivative of a vector, Christoffel symbol, correction depends on all vector components (sum over k), remaining indices remain, minus if covariant ($f_{i;j}$)
(146) covariant derivative of a tensor, simply two indices, two corrections
(148) Gauss distribution, thermal broadening
(149) Lorentz distribution pressure broadening
(150) Poisson distribution photon statistics, k number of photons, $\lambda = t/\bar{t}$, $\bar{t}$ mean time between 2 photons
(151) Nyquist frequency, maximum at a given sampling, aliasing if $f > f_\mathrm{Ny}$
(152) Gauss theorem
(153) Stokes theorem
(154) Fourier transformation
(155) 2nd Newton law
(156) Coriolis force, in a non-inertial frame!
(157) radiation pressure force, Doppler effect, Poynting–Robertson effect
(158) Yarkovsky effect force, thermal emission
(159) tidal force, gradient times scale
(160) covariant metric, basis vectors components, functions of coordinates
(161) Minkowski metric, flat spacetime
(162) Schwarzschild metric, black hole
(163) Fridman–Lemâitre–Robertson–Walker metric, homogeneous universe, expansion of the spatial coordinates, $K \simeq 1/R^2$ curvature, positive or negative
(164) contravariant metric, inverse of
(165) hamiltonian of the 2-body problem, total energy $E_\mathrm{k} + E_\mathrm{p}$, coordinate q, conjugate momentum p
(166) hamiltonian of the hydrogen atom, ditto

(167) collisional excitation, deexcitation, bound–bound, quantized
(168) radiative excitation, deexcitation, bound–bound, quantized
(169) ionisation, recombination, bound–free, not quantized
(170) hydrogen anion, bound–free, not quantized
(171) interferometric fringes, in the focal plane (α), μ complex visibility, $\Re\mu$ contrast, $\Im\mu$ phase, if $\mu = 1$ unresolved, otherwise $\mu(\boldsymbol{B})$
(172) monochromatic intensity, unit ($\mathrm{J\,\cancel{s^{-1}}\,m^{-2}\,\cancel{Hz^{-1}}}$)
(173) radiation transfer eq., temporal evolution, advection, emission, absorption, all directions $\hat{k}$ interrelated due to scattering (j_f)!
(174) formal solution of the radiation transfer eq., stationary, absorption, emission (along the same path), input intensity $I(0)$ is even non-lte!
(175) Ohm law, I on the l.h.s., because we choose U (and R), cf. easy-to-remember symmetry of R, L, C!
(176) inductance (coil) in a non-stationary circuit, $\dot{I}$ on the l.h.s, because…, I creates $\boldsymbol{B}$
(177) capacitance (capacitor) in a non-stationary circuit, $\int I\mathrm{d}t$ on the l.h.s, because…, Q is accumulated
(178) Kirchhoff circuital law, charge conservation
(179) emission coefficient, line transition, Einstein coefficient, A_{21} emission, corresponding concentration, $\phi_{12}(f)$ line profile
(180) emission coefficient, scattering, all directions $\hat{k}$ interrelated
(181) angular momentum (čes. moment hybnosti)
(182) 2nd Newton law for rotation
(183) 3rd stellar structure eq., thermal equilibrium, stationary ($\delta Q = 0$, $\mathrm{d}U = 0$, $\delta W = 0$), specific power ε ($\mathrm{W\,kg^{-1}}$), neutrino cooling ($-\varepsilon_\nu$)
(184) 1st stellar structure eq., continuity
(185) torque (čes. moment síly)
(186) photon noise, for $\mathrm{e^-}$, not adu! i.e., the smallest number of quanta
(187) sources of noise, star itself, sky, dark, readout, discretisation
(188) number of particles from the distribution function
(189) Bose–Einstein distribution, bosons (γ, $\mathrm{W^\pm}$, $\mathrm{Z^0}$, D, α)
(190) Fermi–Diract distribution, fermions ($\mathrm{p^+}$, n, $\mathrm{e^-}$, ν, u, d, T)
(191) Boltzmann distribution, level populations in local thermodynamic equilibrium
(192) Maxwell–Boltzmann distribution, $|\boldsymbol{v}|$ (not v_x)
(193) radiation pressure, $a = 4\sigma/c$, state eq. for *
(194) radiation pressure, 2nd moment
(195) pressure from the distribution function, collisions proportional to concentration n, velocity v (frequency), linear momentum $|\boldsymbol{p}|$ (pressure force)
(196) 2nd stellar structure eq., hydrostatic equilibrium, pressure gradient, gravity
(197) Tolman–Oppenheimer–Volkoff eq., relativistic hydrostatic equilibrium, p/c^2 as a source of gravity, M_R corrected similarly, keeping units (kg), Schwarzschild r_g as in the metric
(198) Clausius–Clapeyron eq., phase transitions on the $P(T)$ diagram, l_h specific heat of evaporation or melting, $V' - V$ corresponding change of volume (negative for $\mathrm{H_2O}$!)
(199) a Legendre polynomial
(200) Bayes theorem, conditional probability of $p(A\,\mathrm{and}\,B)$
(201) quantum probability, Ψ normalisation
(202) proton–proton chain, weak interaction
(203) proton–proton chain, annihilation
(204) proton–proton chain, strong interaction
(205) proton–proton chain, strong interaction
(206) Hamilton eq., conjugate momenta
(207) Hamilton eq., generalized coordinates

(208) 1st law of thermodynamics, Q heat added to the system and $\mu \mathrm{d}N$ chemical reactions (sum of) can either increase the internal energy U, or the system can perform some work W

(209) Hill radius, proportional to r, the 3rd square root of m's as in Kepler

(210) perturbation function, cartesian coordinates, as potential, direct term, indirect term (in $\hat{r}_1$, projected to $\hat{r}^2$, renormalized)

(211) perturbation function, orbital elements, after expansion and averaging over λ, λ'

(212) Einstein eq., curvature (measured by R_{ik}), minus curvature due to coordinates, plus cosmology term, energy–momentum–stress as a source of gravity, units m^{-1}

(213) Riemann tensor, a difference of two vector translations (along jk and kj), sum over l

(214) Ricci tensor, just a sum over l

(215) Ricci scalar, contraction by the metric

(216) rotation matrix, rotation of a vector, not of a base, counter-clockwise

(219) Reynolds number, advection/viscosity (as in N.–S.), ∇ approximated as „$1/x$“

(217) orbit orientation, argument of pericentre, inclination, longitude of the ascending node; „argument“ from pericentre, „longitude“ from a fixed direction

(218) the 2-body problem, in *relative* coordinates, hence the sum of masses

(220) signal in analog–digital units, factors are the number of photons, transmission, quantum efficiency (e^-), and amplification (adu).

(221) deviatoric stress tensor, liquid, stress only if moving, kinematic viscosity

(222) deviatoric stress tensor, solid, stress even if not moving, Young modulus

(223) source function

(224) Kirchhoff radiative law, source function in the local thermodynamic equilibrium

(225) Lorentz transformation, both coordinates, factors γ, β, units s

(226) 4th stellar structure eq., radiative, opaque layer of gas, steep gradient, flux always multiplied by κ, surface area (R^2), and derivative of S.–B. (T^3) in the denominator

(227) 4th stellar structure eq., convective, adiabatic ($\delta Q = 0$), simple relation ($\mathrm{d}T$, $\mathrm{d}P$), same units (C_p, V).

(228) Schwarzschild criterion, opaque is *always/* convective, shallow is more efficient

(229) energy–momentum–stress tensor, fluid, comoving frame ($u^i = 0$)

(230) radiative energy density, 0th moment, over solid angle, $\iint \sin\vartheta \mathrm{d}\vartheta \mathrm{d}\varphi$

(231) heat diffusion eq., thermal diffusivity $\chi = K/(\rho C)$, conductivity ($\mathrm{W\,m^{-1}\,K^{-1}}$), capacity ($\mathrm{J\,kg^{-1}\,K^{-1}}$), flux $\vec{\Phi} = -K\nabla T$, divergence of $(-\nabla \cdot \vec{\Phi})$

(232) wave eq., speed of light (or sound), 2nd derivatives

(233) planar wave, complex notation

(234) geopotential, 0th term monopole (point mass), 1st dipole (centre of mass), 2nd quadrupole, associated Legendre polynomials, spherical functions

(235) Poisson eq., $\boldsymbol{F} = -\nabla U$

(236) Kirchhoff circuital law

(237) Navier–Stokes eq., temporal evolution, advection, pressure, stress, i.e., a difference $(\nabla \cdot \boldsymbol{S})$ of viscous forces ($\boldsymbol{S} = \nu \nabla \boldsymbol{v}$) in neighbouring layers, hence 2nd derivative

(238) Lorentz transformation relative speed V, factors γ, β, units m

(239) Saha eq., $X = n_e/n$, $n = N/V$, ratio of ionized to recombined, common exponential, ratio of *relevant* concentrations, term with m^3 units, no c

(240) geodetic eq., as $\boldsymbol{F} = m\boldsymbol{a}$, 2nd derivative, proper time, affine connection (m^{-1}), same units

(241) 3-α reaction, unstable beryllium

(242) 3-α reaction, only a fraction

(243) spherical law of sines, as planar $\sin\alpha/a$

(244) relativistic factor

(245) relativistic factor

(246) Christoffel symbol, $g_{ik;j} = 0$, i.e., the metric does not change, if we compensate for the metric change, the r.h.s. of the affine connection, if Γ unknown, we need to invert it, hence

g^{im}, one upper index is summation, one lower index is summation, only 3 combinations of (j, k, m), minus if asymmetric

(247) uncertainty principle, the operators of momentum ($\hat{p}$) and coordinate ($\hat{x}$) do not commutate ($\hbar/2$ is a remainder)

(248) gas opacity, line transition, Einstein coefficients, B_{12} absorption, B_{21} stimulated emission (negative a.), corresponding concentrations, $\phi_{12}(f)$ line profile

(249) dust opacity, absorption, geometric ($\lambda \ll 2\pi r$), unit $\mathrm{m}^2\,\mathrm{kg}^{-1}$, cross section of spheres $N\pi r^2$, per unit mass

(250) gravitational redshift, Pound & Rebka (1959)

(251) van Cittert–Zernike theorem, interferometric visibility, the Fourier of the source ($I(\alpha')$), spatial frequencies $\boldsymbol{B}/\lambda \equiv (u, v)$, in „cycles per baseline“

(252) α-parametrisation of viscosity, unit $\mathrm{m}^2\,\mathrm{s}^{-1}$, maximum speed and maximum size of vortices, Shakura & Sunyaev (1969)

(253) continuity eq., temporal evolution, advection, expansion

(254) optical depth, thick ($\tau \gg 1$) vs. thin ($\tau \ll 1$)

(255) radiative flux, 1st moment, sometimes $1/(4\pi)$ factor

(256) thermal equilibrium on a surface (BC), irradiation, conduction, emission

(257) comparison of observations with the model, σ_i uncertainties, $N - M$ degrees of freedom, cf. probability p that the value of χ^2 is that high only by chance

(258) Schrödinger eq., temporal evolution, diffusion of Ψ, confinement by U, weighting by Ψ, i due to a wave solution $\mathrm{e}^{\mathrm{i}(\boldsymbol{k}\cdot\boldsymbol{r}-\omega t)}$, units of $\hbar$ (J s)

(259) wave function of the hydrogen atom, Laguerre polynomials, quantum numbers n, ℓ, m, exponential cut by the Bohr radius (r_0), atom is bound, higher energy levels (nr_0), special function, spherical function, i.e., orbitals (s, p, d, ...), for p, e^- oscillates in a figure ∞, 8, ..., a state is a superposition