FAFA35

General Formulas

Circumference of a Circle

$$O = 2 \cdot \pi \cdot r$$

Area of a Circle

$$A = \pi \cdot r^2$$

Surface Area of a Ball

$$A = 4 \cdot \pi \cdot r^2$$

Volume of a Ball

$$V = \frac{4}{3} \cdot \pi \cdot r^3$$

Volume of a Cylinder (base times height)

$$V = A \cdot h$$

Logarithms

$$\log(a \cdot b) = \log(a) + \log(b)$$

$$\log(a^c) = c \cdot \log(a)$$

$$\lg(a) = d \implies a = 10^d$$

$$\ln(a) = d \implies a = e^d$$

Thermodynamics

Heat Expansion

$$\frac{\Delta L}{L} = \alpha \Delta T, \quad \frac{\Delta V}{V} = \beta \Delta T, \quad \beta = 3\alpha$$

Heat

$$Q = mc\Delta T, \quad l_s = \frac{Q_s}{m}, \quad l_{å} = \frac{Q_{å}}{m}$$

Fluid Pressure

$$p_{tot} = p_{\text{fluid}} + p_{\text{air}} = \rho g h + p_{\text{air}}$$

Ideal Gas Law

$$pV = NkT \quad \text{or} \quad pV = nRT$$

$$\text{where} \quad n = \frac{m_{tot}}{M} = \frac{N}{N_A} \quad \text{and} \quad R = kN_A$$

Gas Density and Particle Density

$$\rho = \frac{m_{tot}}{V} = \frac{pM}{RT}, \quad n_o = \frac{N}{V} = \frac{p}{kT}$$

Barometric Height Formula

$$p = p_0 e^{-\rho_0 g h / p_0}, \quad h = \frac{p_0}{\rho_0 g} \ln \frac{p_0}{p}$$

Relative Moisture

$$R_M = \frac{p_{\text{water}}}{p_{\text{saturation}}}$$

Van der Waal's Equation

$$\left(p + a\frac{n^2}{V^2}\right)(V - nb) = nRT$$

Molecule Radius

$$r = \left(\frac{3b}{16\pi N_A}\right)^{1/3}$$

Bernoullis Equation

$$p_1 + \frac{\rho v_1^2}{2} + \rho g y_1 = p_2 + \frac{\rho v_2^2}{2} + \rho g y_2$$

Pressure (Microscopic)

$$p = \frac{2}{3} n_o \frac{m_{\text{en}}}{2} \langle v^2 \rangle = \frac{2}{3} n_o \langle W_{\text{kin}} \rangle_{\text{en}}$$

Temperature (Microscopic)

$$\langle W_{\text{kin}} \rangle_{\text{en}} = \frac{3}{2} kT$$

Inner Energy (change)

$$\Delta U = \frac{f}{2} Nk\Delta T = \frac{f}{2} nR\Delta T$$

First Theorem

$$Q = \Delta U + W \quad \text{with} \quad W = \int_1^2 pdV$$

Isokor

$$W \equiv 0$$

Isobar

$$W = p\,(V_2 - V_1)$$

Isotherm

$$W = nRT \ln\left(\frac{V_2}{V_1}\right)$$

Adiabat

$$W = -\Delta U$$

Molar Heat Capacity

$$C = Mc, \quad C_V = \frac{f}{2}R, \quad C_p = C_V + R$$

Adiabat(Poissons Equations)

$$T_1 V_1^{(\gamma-1)} = T_2 V_2^{(\gamma-1)}$$
$$p_1 V_1^{\gamma} = p_2 V_2^{\gamma}$$

Quotient

$$\gamma \equiv \frac{C_p}{C_V} = \frac{c_p}{c_V} = 1 + \frac{2}{f}$$

Circuit Process

$$Q_{\text{net}} = W_{\text{net}} = \oint pdV$$

Efficiency

$$\eta = \frac{W_{\text{net}}}{Q_{\text{in}}} = \frac{Q_{\text{in}} - |Q_{\text{out}}|}{Q_{\text{in}}} = 1 - \frac{|Q_{\text{out}}|}{Q_{\text{in}}}$$

Ideal Efficiency

$$\eta = \frac{T_{\text{warm}} - T_{\text{cold}}}{T_{\text{warm}}} = 1 - \frac{T_{\text{cold}}}{T_{\text{warm}}}$$

Cold Factor (def. and Ideal)

$$K_f \equiv \frac{Q_{\text{in}}}{|W_{\text{net}}|}, \quad K_f = \frac{T_{\text{cold}}}{T_{\text{warm}} - T_{\text{cold}}}$$

Heat Factor (def. and Ideal)

$$V_f \equiv \frac{Q_{\text{out}}}{|W_{\text{net}}|}, \quad V_f = \frac{T_{\text{warm}}}{T_{\text{warm}} - T_{\text{cold}}}$$

Gauss Distribution

$$f(v_z) = \sqrt{\frac{m_{\text{en}}}{2\pi kT}} e^{-m_{\text{en}} v_z^2/(2kT)}$$

Maxwell–Boltzmann Distribution

$$f(v) = 4\pi v^2 \left(\frac{m_{\text{en}}}{2\pi kT}\right)^{3/2} e^{-m_{\text{en}} v^2/(2kT)}$$

Average energy

$$\langle W_{\text{kin}} \rangle = \left\langle \frac{m_{\text{en}} v^2}{2} \right\rangle = \frac{m_{\text{en}}}{2} \langle v^2 \rangle = \frac{3}{2} kT$$

Maxwell-Boltzmann velocities

$$v_{rms} = \sqrt{\langle v^2 \rangle} = \sqrt{\frac{3kT}{m}}$$

$$v_{max} = \sqrt{\frac{2kT}{m}}$$

$$\langle v \rangle = \int_0^{\infty} f_{MB} \cdot v \cdot dv = \sqrt{\frac{8kT}{\pi m}}$$

Mean Free Path

$$l = \frac{1}{n_o \pi d^2 \sqrt{2}}$$

Heat Conduction

$$P = k \cdot A \cdot \left|\frac{\mathrm{d}T}{\mathrm{d}x}\right|, R = \frac{\Delta x}{kA}$$

Thermal resistance

$$\Delta T = R_{therm} \cdot P \;\; if \;\; R_{therm} = \frac{\Delta x}{kA}$$

Heat Transfer

$$P = \alpha \cdot A \cdot |\Delta T|\,,\ R = \frac{1}{\alpha A}$$

Stefan-Boltzmann's law

$$P = A\sigma\left(T^4 - T_0^4\right), \sigma = 5.67 \cdot 10^{-8}\mathrm{W/m^2K^4}$$

$$P_{real} = \varepsilon \cdot P_{ideal}$$

Wien's law

$$\lambda_{max} \cdot T = 2.898 \cdot 10^{-3}\mathrm{K \cdot m}$$

Planck's law

$$\rho(f)df = \frac{8\pi h f^3}{c^3} \cdot \frac{1}{e^{hf/kT} - 1}df$$

The solar constant

$$\text{Average value} \approx 1380\ W/m^2$$

Atomic Physics

Photon energy

$$E_{Photon} = \frac{hc}{\lambda} = hf = \hbar\omega$$

Photoelectric effect

$$hf = W_{Out} + K = W_{Out} + eU_0$$

DeBroglie wavelength

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

Square well potential

$$E_n = \left(\frac{h^2}{8mL^2}\right) \cdot n^2$$

$$\Psi_n(x) = \sqrt{\frac{2}{L}}\sin\left(n\frac{\pi x}{L}\right)$$

Bohr radius

$$r = \frac{\epsilon_0 h^2}{\pi\mu e^2}\frac{n^2}{Z} \approx a_0 \cdot \frac{n^2}{Z}$$

$$a_0 = 0.529\ \text{Å}$$

Rydberg's formula

$$\frac{1}{\lambda} = R_M \cdot Z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$R_M = \frac{e^4}{8\varepsilon_0^2 h^3 c} \cdot \mu$$

$$\mu = \frac{m \cdot M}{m + M}\ \text{Reduced mass}$$

$$R_M = R_\infty \cdot \frac{M}{M + m}$$

$$R_\infty = 109737.31568\ \mathrm{cm^{-1}}$$

Energy levels in Hydrogen

$$E_n = -Z^2\frac{E_0}{n^2}\ \text{ where }\ E_0 = \frac{mk^2e^4}{2\hbar^2} = 13.6\ \text{eV}$$

Quantized angular momentum z component

$$L = \hbar\sqrt{l(l+1)}$$

Quantized angular momentum

$$L_z = m_l\hbar$$

Ratio between the proton mass and the electron mass

$$\frac{m_p}{m_e} = 1836.152673$$

Characteristic X-ray emission

$$\frac{1}{\lambda_{K_\alpha}} = \frac{3}{4}R_\infty \cdot (Z-1)^2$$

$$\frac{1}{\lambda_{L_\alpha}} = \frac{5}{36}R_\infty \cdot (Z-7.4)^2$$

Bremsstrahlung

$$\lambda_{min} = \frac{hc}{eU}$$

Reduced mass

$$\mu = \frac{m_1 m_2}{m_1 + m_2}$$

Moment of inertia

$$I = \mu r^2$$

Angular momentum

$$L = \mu r v = \mu r^2 \omega = I\omega$$

Quantized angular momentum

$$|L| = \hbar\sqrt{l(l+1)}$$

Rotational energy diatomic molecule

$$E_{rot} = \frac{l(l+1)\hbar^2}{2I},\ I = \mu r^2$$

Rotational constant

$$B = E_{0r} = \frac{\hbar^2}{2I}$$

Vibrational energy diatomic molecule

$$E_{vib} = \hbar\omega_0 \cdot (\nu + 1/2)$$

Fermi energy at T=0 K

$E_F = \frac{h^2}{8m}\left(\frac{3}{\pi}n\right)^{2/3}$, where n is the electron density

Fermi temperature

$$T_F = \frac{E_F}{k}$$

Fermi speed

$$u_F = \sqrt{\frac{2E_F}{m_e}}$$

Free electrons in conductors

$n_e = f \cdot \frac{\rho \cdot N_A}{M}$, where f is the number of free electrons per atom

Resestivity

$$\rho = \frac{m_e v_{av}}{n_e e^2 \lambda}$$

Mean free path

$$\lambda = \frac{vt}{n_{ion}\pi r^2 vt} = \frac{1}{n_{ion}\pi r^2} = \frac{1}{n_{ion}A}$$

Specific heat due to conduction electrons

$$c_v = \frac{1}{2}\pi^2 \cdot R \cdot \frac{T}{T_F}$$