FAFA41 and 85

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

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

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

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

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

Physics in Fluids and Gases

Thermal expansion

$$\frac{\Delta L}{L} = \alpha \cdot \Delta T$$

$$\frac{\Delta V}{V} = \beta \cdot \Delta T$$

$$\beta = 3 \cdot \alpha$$

Specific Heat Capacity

$$Q = m \cdot c \cdot (T_{\text{end}} - T_{\text{start}})$$

Melting Heat

$$Q = m \cdot l_{\text{m}}$$

Steam Generation Heat

$$Q = m \cdot l_{\text{s}}$$

Effect

$$P = \frac{dW}{dt}$$

Density

$$\rho = \frac{m}{V}$$

Force

$$F = m \cdot g$$

Pressure

$$p = \frac{F}{A}$$

Water Pressure

$$p_{\text{tot}} = \rho \cdot g \cdot h + p_{\text{above}}$$

Ideal Gas Law

$$p \cdot V = n \cdot R \cdot T$$

$$p \cdot V = N \cdot k \cdot T$$

$$n = \frac{N}{N_A} = \frac{m_{\text{tot}}}{M}$$

$$\rho = \frac{p \cdot M}{R \cdot T} \qquad n_0 = \frac{p}{k \cdot T}$$

Barometric Height Formula

$$p = p_0 \cdot e^{-\frac{\rho_0 \cdot g \cdot h}{p_0}} \qquad h = \frac{p_0}{\rho_0 \cdot g} \cdot \ln \frac{p_0}{p}$$

Relative Air Moisture

$$R_{LF} = \frac{p_{\text{water}}}{p_{\text{saturated}}}$$

Van der Waal's Equation

$$\left(p + a \cdot \frac{n^2}{V^2}\right) \cdot (V - n \cdot b) = n \cdot R \cdot T$$

Critical Point

$$V_K = 3 \cdot n \cdot b, T_K = \frac{8 \cdot a}{27 \cdot R \cdot b}$$

$$p_K = \frac{a}{27 \cdot b^2}$$

The Vapor Pressure Curve

$$p = A \cdot e^{\frac{M \cdot I_v}{R \cdot T}}$$

Reynold's Number

$$Re = \frac{\rho \cdot v \cdot d}{\eta}$$

Laminar if $Re < 2300$, Turbulent if $Re > 2300$.

Volume Flow

$$\phi = v \cdot A$$

Bernoulli's Equation

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

Poiseuille's Law

$$\phi = \frac{\pi \cdot R^4}{8 \cdot \eta} \cdot \frac{(p_1 - p_2)}{L}$$

Heat Conduction

$$P = -\lambda \cdot A \cdot \frac{dT}{dx} \quad \text{(general)}$$

$$P = \lambda \cdot A \cdot \frac{T_1 - T_2}{L} \quad \text{(linear)}$$

$$P = \lambda \cdot 2\pi \cdot L \cdot \frac{T_1 - T_2}{\ln(\frac{R_2}{R_1})} \quad \text{(cylindrical)}$$

Heat Transfer

$$P = \alpha \cdot A \cdot \Delta T$$

k-number (U-number)

$$\frac{1}{k} = \frac{1}{\alpha_1} + \frac{L_1}{\lambda_1} + \frac{L_2}{\lambda_2} + \cdots + \frac{1}{\alpha_2}$$

$$P = A \cdot k \cdot \Delta T$$

Heat flow(intensity)

$$I = \frac{P}{A} = \lambda \cdot \frac{T_1 - T_2}{L} \quad \text{(linear)}$$

Heat Radiation

$$P_{\text{ideal}} = \sigma \cdot A \cdot T^4$$

$$P_{\text{real}} = e \cdot P_{\text{ideal}}$$

$$P_{\text{net}} = P_{\text{out}} - P_{\text{in}} = e \cdot \sigma \cdot A \cdot (T_{\text{out}}^4 - T_{\text{in}}^4)$$

$$\sigma = 5.67 \cdot 10^{-8}\ \text{J/(s·m}^2\text{·K}^4)$$

Wien's Displacement Law

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

Electromagnetic Fields

Coulomb's Law

$$F = \frac{1}{4 \cdot \pi \cdot \epsilon_0 \cdot \epsilon_r} \cdot \frac{Q_1 \cdot Q_2}{r^2}$$

Electrical Field

$$\vec{E} = \frac{\vec{F}}{Q}$$

$$E = \frac{U}{d}$$

Point Charge

$$E = \frac{1}{4 \cdot \pi \cdot \epsilon_0 \cdot \epsilon_r} \cdot \frac{Q}{r^2}$$

Gauss Law For Electric Fields

$$\Phi_E = \oint \overrightarrow{E} \cdot d\overrightarrow{A} = \frac{Q_{\text{net}}}{\epsilon_0 \epsilon_r}$$

Electrical Potential

$$U = \frac{w}{q}, \quad W = q \cdot U$$

Electrical Voltage

$$U_{PQ} = U_P - U_Q$$

$$W_{PQ} = q \cdot U_{PQ}$$

Capacitor

$$Q = C \cdot U$$

$$C = \frac{\epsilon_r \cdot \epsilon_0 \cdot A}{d} \quad \text{(plate capacitor)}$$

$$W = \frac{1}{2} \cdot C \cdot U^2 \quad \text{(energy storage)}$$

Current

$$I = \frac{Q}{t}, \quad i(t) = \frac{dq}{dt}$$

Ohm's Law

$$U = R \cdot I$$

Resistors in serie and parallell

$$\text{Serie:} R_{ers} = R_1 + R_2 + R_3 + ...$$

$$\text{Parallell:} \frac{1}{R_{ers}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$$

Capacitors in serie and parallell

$$\text{Serie:} \frac{1}{C_{ers}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ...$$

$$\text{Parallell:} C_{ers} = C_1 + C_2 + C_3 + ...$$

Inner resistance

$$U_{pol} = \epsilon - R_i \cdot I$$

Resistance in material

$$R = \rho \cdot \frac{L}{A}$$

$$R_T = R_0(1 + \alpha(T - T_0))$$

Voltage Sharing and Current Sharing

$$U_2 = \frac{R_2}{R_1 + R_2} \cdot E$$

$$I_1 = \frac{R_2}{R_1 + R_2} \cdot I_0$$

Faraday's Induction Law

$$U_{\text{ind}} = -\frac{d\Phi_m}{dt}$$

Coil

$$U = L \cdot \frac{di}{dt}$$

$$L = \frac{\mu_0 \cdot \mu_r \cdot N^2 \cdot A}{l}$$

$$W = \frac{1}{2} \cdot L \cdot I^2$$

Effect

$$P = U \cdot I = R \cdot I^2 = \frac{U^2}{R}$$

$$P = \frac{W}{t}$$

Magnetic Flux

$$\Phi = B \cdot A \cdot \cos\theta$$

Where θ is the angle between the normal of $\overrightarrow{\boldsymbol{A}}$ and $\overrightarrow{\boldsymbol{B}}$.

Charge in Magnetic Fields

$$F = q(\overrightarrow{v} \times \overrightarrow{B})$$

For a straight conductor:

$$F = I(\overrightarrow{l} \times \overrightarrow{B})$$

Magnetic Fields Created by Live Conductors

Long straight conductor:

$$B = \frac{\mu_r \cdot \mu_0 \cdot I}{2 \cdot \pi \cdot r}$$

Coil:

$$B = \frac{\mu_r \cdot \mu_0 \cdot N \cdot I}{l}$$

Toroid:

$$B = \frac{\mu_0 \cdot \mu_r \cdot N \cdot I}{2 \cdot \pi \cdot R}$$

Alternating Voltage, Alternating Current

$$u(t) = \hat{u} \cdot \sin(\omega \cdot t)$$

$$i(t) = \hat{i} \cdot \sin(\omega \cdot t + \varphi)$$

$$\omega = 2 \cdot \pi \cdot f \qquad f = \frac{1}{T}$$

$$U = u_{\text{eff}} = \frac{\hat{u}}{\sqrt{2}} \qquad I = i_{\text{eff}} = \frac{\hat{i}}{\sqrt{2}}$$

$$P = U \cdot I \cdot \cos(\varphi)$$

Where φ is the angle phase angle between voltage and current.

Addition of Sinus Waves

$$\sum_{i=1}^{N} A_i \cdot \sin(\omega \cdot t + \alpha_i) = A \cdot \sin(\omega \cdot t + \alpha)$$

Where $A = \sqrt{X^2 + Y^2}$ and $\tan\alpha = \frac{Y}{X}$, where X and Y is given by:

$$X = \sum_{i=1}^{N} A_i \cdot \cos\alpha_i, \quad Y = \sum_{i=1}^{N} A_i \cdot \sin\alpha_i$$

RC-Circuit

Capacitor Discharge:

$$u(t) = U_0 \cdot e^{-\frac{t}{\tau}}$$

Capacitor charging

$$u(t) = U_0 \cdot \left(1 - e^{-\frac{t}{\tau}}\right)$$

Time Constant:

$$\tau = R \cdot C$$

Impedance
Kapacitive:

$$Z_C = X_C = \frac{1}{\omega \cdot C}$$

Inductive:

$$Z_L = X_L = \omega \cdot L$$

$$Z = \frac{U}{I}$$

$$Z_{\text{totseries}} = \sqrt{R^2 + (\omega L - 1/\omega C)^2}$$

$$\tan\varphi = \frac{\omega L - 1/\omega C}{R}$$

Average Effect:

$$P_{\text{eff}} = U_{\text{eff}} \cdot I_{\text{eff}} \cdot \cos\varphi$$

Resonance:

$$\omega_0 = \frac{1}{\sqrt{L \cdot C}}$$

$$f_0 = \frac{1}{2 \cdot \pi \cdot \sqrt{L \cdot C}}$$

Transformer

$$\frac{U_1}{U_2} = \frac{N_1}{N_2} \quad \frac{I_2}{I_1} = \frac{N_1}{N_2}$$

Impedance Transform:

$$Z_2 = Z_1 \left(\frac{N_2}{N_1} \right)^2$$

Tables

The Basic Units of the SI System

Physical Quantity	SI Unit	Abbreviation
Length	1 meter	1 m
Mass	1 kilogram	1 kg
Time	1 second	1 s
Electric Current	1 ampere	1 A
Temperature	1 kelvin	1 K
Brightness	1 candela	1 cd
Ammount of Substance	1 mole	1 mol

Derived SI base units

Quantity	Unit	SI base unit
Acceleration, a	$1\ \mathrm{m/s^2}$	$1\ \mathrm{m \cdot s^{-2}}$
Work, A	$1\ \mathrm{J} = 1\ \mathrm{Nm}$	$1\ \mathrm{kg \cdot m^2 \cdot s^{-2}}$
Density, ρ	$1\ \mathrm{kg/m^3}$	$1\ \mathrm{kg \cdot m^{-3}}$
Effect, P	$1\ \mathrm{W} = 1\ \mathrm{J/s}$	$1\ \mathrm{kg \cdot m^2 \cdot s^{-3}}$
Charge, Q	$1\ \mathrm{C}$	$1\ \mathrm{A \cdot s}$
Voltage, U	$1\ \mathrm{V} = 1\ \mathrm{J/C}$	$1\ \mathrm{kg \cdot m^2 \cdot s^{-3} \cdot A^{-1}}$
Electric field, E	$1\ \mathrm{N/C} = \mathrm{V/m}$	$1\ \mathrm{kg \cdot m \cdot s^{-3} \cdot A^{-1}}$
Frequency, f	$1\ \mathrm{Hz}$	$1\ \mathrm{s^{-1}}$
Inductance, L	$1\ \mathrm{H}$	$1\ \mathrm{kg \cdot m^2 \cdot s^{-2} \cdot A^{-2}}$
Capacitance, C	$1\ \mathrm{F}$	$1\ \mathrm{kg^{-1} \cdot m^{-2} \cdot s^4 \cdot A^2}$
Force, F	$1\ \mathrm{N}$	$1\ \mathrm{kg \cdot m \cdot s^{-2}}$
Magnetic field, B	$1\ \mathrm{T}$	$1\ \mathrm{kg \cdot s^{-2} \cdot A^{-1}}$
Resistance, R	$1\ \Omega$	$1\ \mathrm{kg \cdot m^2 \cdot s^{-3} \cdot A^{-2}}$
Pressure, p	$1\mathrm{Pa} = 1\ \mathrm{N/m^2}$	$1\ \mathrm{kg \cdot m^{-1} \cdot s^{-2}}$

SI-prefix

SI-prefix	Symbol	Decimal
Yotta	Y	$1e24$
Zetta	Z	$1e21$
Exa	E	$1e18$
Peta	P	$1e15$
Tera	T	$1e12$
Giga	G	$1e9$
Mega	M	$1e6$
Kilo	k	$1e3$
Hecto	h	$1e2$
Deca	da	$1e1$
Deci	d	$1e-1$
Centi	c	$1e-2$
Milli	m	$1e-3$
Micro	µ	$1e-6$
Nano	n	$1e-9$
Pico	p	$1e-12$
Femto	f	$1e-15$
Atto	a	$1e-18$
Zepto	z	$1e-21$
Yocto	y	$1e-24$

Constants

Name	Variable	Value	Unit
Speed of light in a vacuum	c	$299\,792\,458$	m/s
Planck's constant	h	$6.626\,070\,15 \cdot 10^{-34}$	Js
Planck's constant	h	$4.135\,667\,87 \cdot 10^{-15}$	eVs
Planck's constant	$\hbar$	$1.054\,573 \cdot 10^{-34}$	Js
Planck's constant	$\hbar$	$0.658\,212 \cdot 10^{-15}$	eVs
The Elemental Charge	e	$1.602\,176\,634 \cdot 10^{-19}$	C
Bohr Radius	a_0	$0.529\,177 \cdot 10^{-10}$	m
Electron Mass	m_e	$0.910\,938 \cdot 10^{-30}$	kg
Electron Mass	m_e	$0.510\,999$	MeV/c^2
Proton Mass	m_p	$1.672\,6219 \cdot 10^{-27}$	kg
Proton Mass	m_p	938.2723	MeV/c^2
Proton Mass	m_p	$1836.152\,70$	m_e
Neutron Mass	m_n	$1.674\,929 \cdot 10^{-27}$	kg
Neutron Mass	m_n	939.5656	MeV/c^2
Neutron Mass	m_n	$1838.683\,62$	m_e
Boltzmanns Constant	k	$1.380649 \cdot 10^{-23}$	J/K
Boltzmanns Constant	k	$0.861\,739 \cdot 10^{-4}$	eV/K
Avogadros Constant	N_A	$6.02\,214\,076 \cdot 10^{23}$	mol^{-1}
Rydbergs Constant	R_y	$\frac{\hbar^2}{2ma_0^2}$	
Rydbergs Constant	R_y	13.6057	eV
Rydbergs Constant	R_y	$109\,737.32$	cm^{-1}
The General Gas Constant	R	8.3145	J/(mol $\cdot$ K)
The Fine Structure Constant	α	$\frac{e^2}{4\pi\varepsilon_0\hbar c} = \frac{1}{137.036}$	
Dielectric Constant for Vacuum	ε_0	$0.885\,419 \cdot 10^{-11}$	As/Vm
Permeability of Vacuum	μ_0	$1.256\,637 \cdot 10^{-6}$	Vs/Am
Permeability of Vacuum	μ_0	$4\pi \cdot 10^{-7}$	Vs/Am
The Bohr Magnetone	μ_B	$\frac{e\hbar}{2m} = 9.274\,02 \cdot 10^{-24}$	Am^2
The Acceleration of Gravity	g	9.80665m/s^2	

Pressure for Satturated Steam (boiling pressure) at Different Temperatures

	Water	Mercury
t/°C	Vapor Pressure/Pa	Vapor Pressure/Pa
-30	38.1	$637.0 \cdot 10^{-6}$
-20	103	$2.41 \cdot 10^{-3}$
-15	165	$4.52 \cdot 10^{-3}$
-10	260	$8.08 \cdot 10^{-3}$
-5	401	$14.3 \cdot 10^{-3}$
0	610	$24.7 \cdot 10^{-3}$
5	872	$40.7 \cdot 10^{-3}$
10	$1.23 \cdot 10^{3}$	$65.0 \cdot 10^{-3}$
15	$1.70 \cdot 10^{3}$	0.103
20	$2.34 \cdot 10^{3}$	0.160
25	$3.17 \cdot 10^{3}$	0.246
30	$4.24 \cdot 10^{3}$	0.370
35	$5.64 \cdot 10^{3}$	0.553
40	$7.37 \cdot 10^{3}$	0.810
50	$12.3 \cdot 10^{3}$	1.69
60	$19.9 \cdot 10^{3}$	3.37
70	$31.2 \cdot 10^{3}$	6.43
80	$47.3 \cdot 10^{3}$	11.9
90	$70.1 \cdot 10^{3}$	21.1
100	$101.3 \cdot 10^{3}$	36.4
110	$143.2 \cdot 10^{3}$	61.0
120	$198.4 \cdot 10^{3}$	99.4
130	$270.0 \cdot 10^{3}$	158.1
150	$476.0 \cdot 10^{3}$	$374.0 \cdot 10^{3}$
200	$1.55 \cdot 10^{6}$	$2.30 \cdot 10^{3}$
250	$3.97 \cdot 10^{6}$	$9.92 \cdot 10^{3}$
300	$8.59 \cdot 10^{6}$	$32.9 \cdot 10^{3}$
350	$16.5 \cdot 10^{6}$	$89.7 \cdot 10^{3}$
374	$22.1 \cdot 10^{6}$	$137.0 \cdot 10^{3}$
400	–	$210.0 \cdot 10^{3}$

Length Expansion Coefficient

Substance	$\alpha/(10^{-6}\mathrm{K}^{-1})$	Substance	$\alpha/(10^{-6}\mathrm{K}^{-1})$
Aluminum	23	Glass (typical value)	6.0
Silver	19	Tungsten	4.3
Brass	19	Marble(typical value)	2.5
Copper	17	Invar	2.0
Iron	12	Graphite	2.0
Steel	11	Diamond	1.2
Platinum	9.0	Quartz	0.4

Resistivity for Common Conductive Materials

Substance	$\rho/(10^{-8}\Omega\mathrm{m})$	Substance	$\rho/(10^{-8}\Omega\mathrm{m})$
Silver	1.59	Iron	10.0
Copper	1.68	Platinum	10.6
Gold	2.44	Constantan	49.0
Aluminum	2.82	Stainless Steel	69.0
Tungsten	5.60	Nichrome	120

Volume Expansion Coefficient

Substance	$\beta/(10^{-6}\mathrm{K}^{-1})$	Substance	$\beta/(10^{-6}\mathrm{K}^{-1})$
Acetone	1490	Glycerine	500
Gasoline	950	Water	210
Ethanol	750	Mercury	180

Density

Solid Substance	$\rho/(10^3\text{kg/m}^3)$	Fluid	$\rho/(10^3\text{kg/m}^3)$
Aluminum	2.70	Acetone	0.79
Lead	11.3	Blood	1.06
Gold	19.3	Ethanol	0.79
Iron	7.87	Ether	0.72
Copper	8.93	Glycol	1.12
Platinum	21.5	Mercury	13.6
Silver	10.5	Water	1.00
Tungsten	19.3	Vinegar	1.12

Specific Heat Capacity

Solid Substance	$c/(\text{kJ kg}^{-1}\text{K}^{-1})$	Fluid	$c/(\text{kJ kg}^{-1}\text{K}^{-1})$
Aluminum	0.90	Water	4.19
Marble	0.88	Sea Water	3.90
Porslin	0.84	Ether	3.72
Glas (typical value)	0.83	Methanol	2.55
Iron	0.44	Ethanol	2.49
Copper	0.39	Glycol	2.39
Brass	0.38	Vinegar	2.06
Silver	0.24	Olive Oil	1.97
Tungsten	0.14	Mercury	0.14

Viscosity

Fluid	$\eta/(10^{-3}\text{Pa}\cdot\text{s})$	Gas	$\eta/(10^{-6}\text{Pa}\cdot\text{s})$
Glycerine	1480	Oxygen	20.2
Engine Oil	1000	Helium	19.4
Mercury	1.55	Air	18.4
Ethanol	1.20	Nitrogen Gas	17.6
Water	1.00	Carbon Dioxide	14.8
Acetone	0.32	Hydrogen Gas	8.7

Specific Melting Heat and Steam Generating Heat, Meting Point and Boiling Point

Substance	I_S/(kJ/kg)	Melting Point/°C	$I_å$/(kJ/kg)	Boiling Point/°C
Helium			21	−269
Nitrogen Gas	26	−210	200	−196
Oxygen Gas	14	−218	210	−183
Methane	17	−182	130	−161
Ethanol	105	−114	841	78
Ether	113	−116	377	35
Mercury	12	−39	293	357
Water	333	0	2260	100
Sodium	113	98	4200	892
Lead	23	328	860	1744
Aluminum	398	660	10500	2467
Platinum	101	1769	2370	3827

Constants in Van der Waal's Equation and Molecule Radii

Gas	Chemical Name	$a/(10^{-2}\mathrm{Pam^6mol^{-2}})$	$b/(10^{-5}\mathrm{m^3mol^{-1}})$	$r/(10^{-10}\mathrm{m})$
Ammonia	NH_3	42.1	3.71	1.54
Argon	Ar	13.6	3.22	1.47
Helium	He	0.345	2.37	1.33
Carbon Dioxide	CO_2	36.3	4.27	1.62
Carbon Monoxide	CO	15.0	3.99	1.58
Krypton	Kr	23.4	3.98	1.58
Mercury	Hg	81.7	1.70	1.19
Nitrogen Gas	N_2	14.0	3.94	1.57
Oxygen Gas	O_2	13.7	3.18	1.47
Water Vapor	H_2O	55.2	3.05	1.45
Hydrogen Gas	H_2	2.47	2.66	1.38
Xenon	Xe	42.4	5.11	1.72

Triple Point

Substance	Name	$T_{\mathrm{T}}/\mathrm{K}$	$p_{\mathrm{T}}/\mathrm{kPa}$
Ammonia	NH_3	195.4	6.07
Carbon Dioxide	CO_2	216.55	517
Nitrogen Gas	N_2	63.18	12.5
Neon	Ne	24.56	432
Oxygen Gas	O_2	54.36	0.152
Water	H_2O	273.16	0.610
Hydrogen Gas	H_2	13.80	7.04