All Formulae Used in First-Year Engineering

By Jake Stockley

April 27, 2025

Foreword

This is a mostly complete list of all formulae used in first-year engineering. I cannot guarentee it to be 100% accurate, I may have missed a few or gotten some wrong, if so, please contact me at jakestockley@tuta.io or DM me on snapchat or whatsapp. Otherwise, enjoy.

NOTE: This formula sheet IS A DRAFT contains ONLY the formulae used in the first term. There will probably be a few mistakes so if you spot any TELL ME so I can update it. The second term shall be fully added sometime next week (if I have time)

Mathematical

Vectors

Unit Vectors

$$\hat{i} = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}, \quad \hat{j} = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}, \quad \hat{k} = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

Vector from vector A to vector B

$$\vec{AB} = \vec{B} - \vec{A}$$

Modulus

$$|\vec{A}| = \begin{vmatrix} x \\ y \\ z \end{vmatrix} = \sqrt{x^2 + y^2 + z^2}$$

Scalar Product

$$\vec{A} \cdot \vec{B} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix} \cdot \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} = a_1 b_1 + a_2 b_2 + a_3 b_3$$

Cross Product

$$\vec{A} \times \vec{B} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix} \times \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} = \begin{bmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - a_1 b_3 \\ a_1 b_2 - a_2 b_1 \end{bmatrix}$$

Angle between two Vectors

$$\vec{A} \cdot \vec{B} = |\vec{A}||\vec{B}| \cos(\theta)$$

Compressed Plane Equation

$$r \cdot n = d$$

Standard Plane Equation

$$Ax + By + Cz + D = 0$$

Expanded Plane Equation

$$A(x - x_0) + B(y - y_0) + C(z - z_0) = 0$$

Distance between a plane and a point

$$d = \frac{|Ax_1 + By_1 + Cz_1 + D|}{\sqrt{A^2 + B^2 + C^2}}$$

General Line Equation given Point $\vec{a}$ and Direction Vector $\vec{d}$

$$\vec{r} = \vec{a} + \lambda \vec{d}$$

Direction Vector given two Points

$$\vec{d} = \vec{B} - \vec{A}$$

Angle of two Planes

$$\cos(\theta) = \frac{n_1 \cdot n_2}{|n_1||n_2|}$$

Intersection of two Planes

$$\vec{d} = \vec{n_1} \times \vec{n_2} = \begin{bmatrix} A_1 \\ B_1 \\ C_1 \end{bmatrix} \times \begin{bmatrix} A_2 \\ B_2 \\ C_2 \end{bmatrix}$$

Complex Numbers

The Imaginary Identity

$$j^2 = -1$$

Complex Number

$$z = a + jb$$

Modulus

$$|z| = \sqrt{a^2 + b^2}$$

Polar Form

$$z = r\left(\cos(\theta) + j\sin(\theta)\right)$$

De Moivre's Theorem

$$(\cos(x) + j\sin(x))^n = \cos(nx) + j\sin(nx)$$

n^{th} Root of Polar Form

$$Z_k = \sqrt[n]{r}\left[\cos\left(\frac{\theta}{n}\right) + j\sin\left(\frac{\theta}{n}\right)\right] \quad \text{or} \quad Z_k = \sqrt[n]{r}\left[\cos\left(\frac{\theta}{n} + \frac{2k\pi}{n}\right) + j\sin\left(\frac{\theta}{n} + \frac{2k\pi}{n}\right)\right]$$

Exponential Form

$$z = re^{\theta j}$$

Matrices

Square Matrix Condition

$$n \text{ of rows} = n \text{ of columns}$$

Trace of a Matrix

$$\operatorname{tr}(A) = \sum_{i=1}^{n} a_{ii} = a_{11} + a_{22} + \cdots + a_{nn}$$

Upper Triangular Matrix

$$T_U = \begin{bmatrix} n & n & n \\ 0 & n & n \\ 0 & 0 & n \end{bmatrix}$$

Lower Triangular Matrix

$$T_L = \begin{bmatrix} n & 0 & 0 \\ n & n & 0 \\ n & n & n \end{bmatrix}$$

Diagonal matrix

$$D = \begin{bmatrix} n & 0 & 0 \\ 0 & n & 0 \\ 0 & 0 & n \end{bmatrix}$$

Null Matrix

$$N = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

Identity Matrix

$$I = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Transposed Matrix

$$A^T = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix}^T = \begin{bmatrix} a & d & g \\ b & e & h \\ c & f & i \end{bmatrix}$$

Symmetrical Matrix Condition

$$A^T = A$$

The Adjoint

$$\operatorname{adj}(A) = (\operatorname{Cofactor}(A))^T$$

Cofactor

$$C_{ij} = (-1)^{i+j}\ \det(M_{ij})$$

Matrix of Cofactors

$$\text{Cofactor}\begin{pmatrix} a & b & c \\ d & e & f \\ g & h & i \end{pmatrix} = \begin{bmatrix} +\begin{vmatrix} e & f \\ h & i \end{vmatrix} & -\begin{vmatrix} d & f \\ g & i \end{vmatrix} & +\begin{vmatrix} d & e \\ g & h \end{vmatrix} \\ -\begin{vmatrix} b & c \\ h & i \end{vmatrix} & +\begin{vmatrix} a & c \\ g & i \end{vmatrix} & -\begin{vmatrix} a & b \\ g & h \end{vmatrix} \\ +\begin{vmatrix} b & c \\ e & f \end{vmatrix} & -\begin{vmatrix} a & c \\ d & f \end{vmatrix} & +\begin{vmatrix} a & b \\ d & e \end{vmatrix} \end{bmatrix}$$

Inverse of a Matrix

$$A^{-1} = \frac{\text{adj}(A)}{\det(A)}$$

Scalar Multiplication

$$qA = q\begin{bmatrix} a_1 & a_2 \\ a_3 & a_4 \end{bmatrix} = \begin{bmatrix} qa_1 & qa_2 \\ qa_3 & qa_4 \end{bmatrix}$$

Matrix Addition

$$A + B = \begin{bmatrix} a_1 & a_2 \\ a_3 & a_4 \end{bmatrix} + \begin{bmatrix} b_1 & b_2 \\ b_3 & b_4 \end{bmatrix} = \begin{bmatrix} a_1 + b_1 & a_2 + b_2 \\ a_3 + b_3 & a_4 + b_4 \end{bmatrix}$$

Matrix Multiplication Condition

$$\text{for } AB \quad n \text{ columns in } A = n \text{ rows in } B$$

2×2 **Matrix Product**

$$\begin{bmatrix} a & b \\ c & d \end{bmatrix} \times \begin{bmatrix} e & f \\ g & h \end{bmatrix} = \begin{bmatrix} ae + bg & af + bh \\ ce + dg & cf + dh \end{bmatrix}$$

2×2 **Determinant**

$$|A| = \det\begin{pmatrix} a & b \\ c & d \end{pmatrix} = ac - bd$$

3×3 **Determinant**

$$\det\begin{pmatrix} a & b & c \\ d & e & f \\ g & h & i \end{pmatrix} = a(ei - fh) - b(di - fg) + c(dh - eg)$$

2×2 **Cross Product**

$$\begin{bmatrix} a \\ b \end{bmatrix} \times \begin{bmatrix} c \\ d \end{bmatrix} = \det\begin{pmatrix} a & c \\ b & d \end{pmatrix}$$

Simultaneous Equation Matrix Form

$$\begin{matrix} ax + by + cz = \alpha \\ dx + ey + fz = \beta \\ gx + hy + iz = \gamma \end{matrix} \quad \rightarrow \quad \underbrace{\begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix}}_{A} \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} \alpha \\ \beta \\ \gamma \end{bmatrix} \quad \rightarrow \quad A^{-1}\begin{bmatrix} \alpha \\ \beta \\ \gamma \end{bmatrix} = \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

Eigenvalue and Eigenvector Equation

$$A\vec{v} = \lambda\vec{v}$$

Eigenvalues of matrix A

$$\det(A - \lambda I) = 0$$

Eigenvectors of matrix A

$$(A - I\lambda)\vec{v} = 0$$

Differentiation

Derivative from first principles

$$f'(x) = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h}$$

Derivative of the Sum

$$\frac{d}{dx}(u+v) = \frac{du}{dx} + \frac{dv}{dx}$$

eeeeeeeeeeeeeeeeeeeeeeeeeeeee

$$\frac{d}{dx}(e^x) = e^x$$

Chain Rule

$$\frac{dy}{dx} = \frac{dy}{du}\frac{du}{dx}$$

Product Rule

$$\text{if} \quad y = uv \quad \text{then} \quad \frac{dy}{dx} = \frac{du}{dx}v + \frac{dv}{dx}u$$

Quotient Rule

$$\text{if} \quad y = \frac{u}{v} \quad \text{then} \quad \frac{dy}{dx} = \frac{\frac{du}{dx}v - \frac{dv}{dx}u}{v^2}$$

Curvature

$$\kappa = \left| \frac{f''(x)}{(1 + [f'(x)]^2)^{3/2}} \right|$$

Newton-Raphson Method

$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)}$$

Maclaurin Series

$$f(x) = \sum_{m=0}^{\infty} \frac{x^m}{m!} f^{(m)}(0)$$

Taylor Series

$$f(x) = \sum_{m=0}^{\infty} \frac{(x-a)^m}{m!} f^{(m)}(a)$$

Nabla Operator

$$\nabla = \begin{bmatrix} \frac{\partial}{\partial x} \\ \frac{\partial}{\partial y} \\ \frac{\partial}{\partial z} \end{bmatrix}$$

Rate of change along a vector

$$\frac{\partial\phi}{\partial\vec{a}} = \mathrm{grad}\,\phi\cdot\hat{a}$$

Div

$$\mathrm{div}(F) = \nabla\cdot F = \frac{dF_x}{dx} + \frac{dF_y}{dy} + \frac{dF_z}{dz}$$

Curl

$$\mathrm{curl}(F) = \nabla\times F = \begin{vmatrix} i & j & k \\ \frac{d}{dx} & \frac{d}{dy} & \frac{d}{dz} \\ F_x & F_y & F_z \end{vmatrix}$$

Integration

Multiple Integration

Differential Equations

Transforms

Statistics

Mechanical

Forces, Moments and Systems

Force given Acceleration

$$F = ma$$

Force given Components (2D)

$$F = \sqrt{F_x^2 + F_y^2}$$

Force's Angle from base Axis

$$\alpha = \tan^{-1}\left(\frac{F_y}{F_x}\right)$$

Moment

$$M = |F|\times\lambda$$

System Equilibrium Equations

$$\sum F_x = 0, \quad \sum F_y = 0, \quad \sum M = 0$$

Trusses

Degree of Indeterminacy

$$M - 2J + 3 = \text{degree of inderterminacy}$$

Torsion

Shear Strain at r

$$\gamma_{\max} = r\theta$$

Shear Strain given L

$$\gamma_{\max} = \frac{r\phi}{L}$$

Shear Modulus Torsion Equation

$$\tau = Gr\theta$$

Shear Stress at an internal radius ρ

$$\tau = \frac{\rho}{r}\tau_{\max}$$

Torsion Formula

$$\tau_{\max} = \frac{T_r}{I_p}$$

Torsional Rigidity Equation

$$\theta = \frac{T}{GI_P}$$

Polar Moment of Inertia

$$I_P = \int_A \rho^2 dA$$

Polar Moment of Inertia for a circle

$$I_P = \frac{\pi d^4}{32}$$

Fluids

Shear Stress / Viscosity

$$\tau = \mu\frac{du}{dy}$$

Mass Density

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

Specific Weight

$$w = \rho g$$

Specific Gravity

$$\sigma = \frac{\rho}{\rho_{\text{standard}}}$$

Compressibility

$$K = \rho\frac{dp}{d\rho}$$

Pressure

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

Pressure at Depth

$$p = \rho g h + p_{\text{atm}} = \text{Gauge pressure} + \text{Atmospheric Pressure}$$

Resultant Hydrostatic Force

$$R = \rho g A \bar{y}$$

Depth of Pressure

$$D = \sin^2(\phi)\frac{I_O}{A\bar{y}}$$

Parallel Axis Theorem

$$I_O = I_G + A\bar{d}^2$$

Buoyancy

$$R_n = \rho_n g V_n$$

First Moment of Area

$$Q_{x/y} = \int_A (y/x) dA$$

Position of a Centroid

$$\bar{x} = \frac{Q_y}{A}, \qquad \bar{y} = \frac{Q_x}{A}$$

Electronic

Current

Current

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

Kirchhoff's First Law

$$\sum_{i=1}^{n} I_i = 0$$

Electric Fields

Energy of a Charge in an Electric Field

$$E = Vq$$

Electric Field Strength

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

Force on a charge in a field

$$F = qE$$

Resistance

Current and Voltage through a Resistor

$$V = IR$$

Power dissipated through a Resistor

$$P = IV, \quad P = I^2R, \quad P = \frac{V^2}{R}$$

Resistors in Series

$$R_T = R_1 + R_2 + \cdots + R_n$$

Resistors in Parallel

$$R_T = \left(R_1^{-1} + R_2^{-1} + \cdots + R_n^{-1}\right)^{-1}$$

Impedance

Complex Form

$$Z = R + jX$$

Absolute Value

$$|Z| = \sqrt{R^2 + X^2}$$

Net Reactance

$$X = X_L - X_C$$

Current and Voltage given Impedance

$$V = IZ$$

Admittance

$$Y = Z^{-1}$$

Capacitance

Capacitor Defining Equation

$$I = C \times \frac{dV}{dt}$$

Capacitance of a Parallel Plate Capacitor

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

Charge stored

$$Q = CV$$

Energy Stored

$$E = \frac{1}{2}CV^2$$

Capacitors in Series

$$C_T = (C_1^{-1} + C_2^{-1} + \cdots + C_n^{-1})^{-1}$$

Capacitors in Parallel

$$C_T = C_1 + C_2 + \cdots + C_n$$

RC cutoff frequency

$$f_c = \frac{1}{2\pi RC}$$

RC filter quality

$$Q = \frac{1}{\omega RC}$$

Capacitor Charging quantity X

$$X_t = X_0 \times \left(1 - e^{-\frac{t}{RC}}\right)$$

Capacitor Discharging quantity X

$$X_t = X_0 \times e^{-\frac{t}{RC}}$$

Capacitor Reactance

$$X = \frac{1}{2\pi fC}$$

RC phase difference

$$\Delta\theta = \tan^{-1}\left(\frac{1}{\omega RC}\right)$$

Inductance

Inductor Defining Equation

$$V = L\frac{dI}{dt}$$

Inductance of a coil

$$L = \frac{\mu N^2 A}{l}$$

Inductor Reactance

$$X_L = 2\pi fL$$

Inductors in Parallel

$$L_{total} = \left(L_1^{-1} + L_2^{-1} + \cdots + L_n^{-1}\right)^{-1}$$

Inductors in Series

$$L_{\text{total}} = L_1 + L_2 + \cdots + L_n$$

RL cutoff frequency

$$f_c = \frac{R}{2\pi L}$$

RL filter quality

$$Q = \frac{\omega L}{R}$$

Transformers

Induced E.M.F

$$V = -N\frac{\Delta\Phi}{\Delta t}$$

Power and current

$$\frac{V_{\text{secondary}}}{V_{\text{primary}}} = \frac{I_{\text{primary}}}{I_{\text{secondary}}} = \text{Power}$$

Turn Ratio

$$n = \frac{N_{\text{primary}}}{N_{\text{secondary}}} = \frac{V_{\text{primary}}}{V_{\text{secondary}}}$$

Inductive Reactance

$$X_L = 2\pi f\frac{\mu N^2 A}{l}$$

Mutual Inductance

$$L_M = k\sqrt{L_1 L_2}$$

Reflected Resistance

$$R_{\text{pri}} = \frac{R_L}{n^2}$$

Efficiency

$$\eta = \left(\frac{P_{\text{out}}}{P_{\text{in}}}\right)100\%$$

RLC circuits

Impedance

$$|Z_T| = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

Q-Factor

$$Q = \frac{E_{\text{Stored}}}{E_{\text{Lost per cycle}}}$$

Parallel Circuit Q-Factr

$$Q = \frac{R}{X_L}$$

Resonant Frequency

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

Material

Elastic Deformation

Hooke's Law

$$F = kd$$

Tensile Engineering Stress

$$\sigma = \frac{F}{A_0}$$

Normal Tensile Strain

$$\varepsilon_z = \frac{\Delta l}{l_0}$$

Lateral Tensile Strain

$$\varepsilon_x = \frac{\Delta d}{d_0}$$

Rigidity

$$E = \frac{\sigma}{\varepsilon}$$

Poisson's Ratio

$$\nu = -\frac{\varepsilon_x}{\varepsilon_z} = -\frac{\varepsilon_y}{\varepsilon_z}$$

Shear Engineering Stress

$$\tau = \frac{F}{A_0}$$

Shear Strain

$$\gamma = \frac{\Delta x}{y} = \tan(\theta) \approx \theta \ RAD$$

Shear Modulus

$$G = \frac{\tau}{\gamma}$$

Shear Modulus given Poisson's Ratio

$$G = \frac{E}{2 \times (1 + \nu)}$$

Angle of twist due to two moments

$$\alpha = \frac{32 \times M \times l_0}{\pi \times d_0^4 \times G}$$

Bulk Modulus

$$P = -K\frac{\Delta V}{V_0}$$

Bulk Modulus given Poisson's Ratio

$$K = \frac{E}{3 \times (1 - (2 \times \nu))}$$

UTS

$$UTS = \frac{P_{\max}}{A_i}$$

Fracture Strength

$$\sigma_f = \frac{P_f}{A_i}$$

Strain Hardening Ratio

$$r_{\mathrm{SH}} = \frac{\sigma_u}{\sigma_o}$$

Resilience Modulus

$$U_r \approxeq \frac{1}{2}\sigma_y \varepsilon_y$$

Toughness

$$U_t = \frac{\text{Energy}}{\text{Volume}} = \int_0^{\varepsilon_f} \sigma dx\varepsilon$$

Toughness Approximations

$$U_t \approx \left(\frac{\sigma_0 + \sigma_u}{2}\right)\left(\varepsilon_u - \frac{1}{2}\varepsilon_0\right), \quad U_t \approx \left(\frac{\sigma_0 + \sigma_u}{2}\right)\varepsilon_f$$

True Stress

$$\sigma_t = \sigma_n(1 + \varepsilon_n)$$

True Strain

$$\varepsilon_t = \ln(1 + \varepsilon_n)$$

Percent Elongation

$$\varepsilon_{pf} = \frac{L_f - L_i}{L_i}$$

Area Reduction

$$\%RA = 100\frac{A_i - A_f}{A_i}$$

Atomic Structure

Atomic Packing Factor

$$APF = \frac{\text{no. atoms/unit cell} \times \text{volume of atom}}{\text{volume of unit cell}}$$

R of SC, BCC, FCC and HCP

$$R = \frac{a}{2}, \quad R = \frac{\sqrt{3}a}{4}, \quad R = \frac{\sqrt{2}a}{4}, \quad R = \frac{a}{2} \text{ and } c = \sqrt{\frac{8}{3}}a$$

V for HCP

$$V = 3\sqrt{2}a^3$$

Crystalline Material Density

$$\rho = \frac{\text{Atomic mass of unit cell}}{\text{Volume of unit cell}} = \frac{nA}{V_c N_A}$$

Mole Calculation Formula

$$n = \frac{m}{M}$$

Lattice Vacancies Equilibrium Equation

$$N_v = N e^{\frac{-Q_v}{kT}}$$

Material Properties

Degree of cold working

$$\%CW = \frac{A_o - A_d}{A_o} \times 100$$

Hall-Petch Equation

$$\sigma_o = \sigma_0 + k_y d^{-\frac{1}{2}}$$

Module Independent

Energy

Power

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

Work Done

$$W = F \times d$$

Periodic Functions and Waves

Angular Frequency

$$\omega = 2\pi f$$

RMS of a sinusoidal wave

$$RMS = \frac{\text{Peak Amplitude}}{\sqrt{2}}$$

RMS of any wave

$$RMS = \sqrt{\frac{1}{T}\int_{T_1}^{T_2} [f(t)]^2 \, dt}$$

General Wave-Function Equation

$$v(t) = A\cos(\omega t + \theta)$$

Average Wave Power

$$P_{average} = \frac{\int_0^T p(t)dx}{T}$$