Mechanical Engineering Cheatsheet

A quick reference guide covering fundamental concepts, formulas, and principles in mechanical engineering. Ideal for students, engineers, and professionals.

Thermodynamics

Basic Concepts

Zeroth Law:	If two thermodynamic systems are each in thermal equilibrium with a third, then they are in thermal equilibrium with each other.
First Law:	Energy can neither be created nor destroyed. Conservation of energy: $\Delta U = Q - W$, where U is internal energy, Q is heat added, and W is work done.
Second Law:	The total entropy of an isolated system can only increase over time or remain constant in ideal cases. Entropy is a measure of disorder.
Third Law:	As temperature approaches absolute zero, the entropy of a system approaches a minimum or zero value.
Enthalpy (H):	A thermodynamic property defined as $H = U + PV$, where U is internal energy, P is pressure, and V is volume.
Entropy (S):	A measure of the disorder of a system. $\Delta S = Q/T$ for a reversible process at constant temperature.

Thermodynamic Processes

Isothermal:	Constant temperature process. PV = constant.
Adiabatic:	No heat transfer. PV^γ = constant, where γ is the heat capacity ratio (C_p/C_v).
Isobaric:	Constant pressure process. V/T = constant.
Isochoric (Isometric):	Constant volume process. P/T = constant.
Polytropic:	Process described by PV^n = constant, where n is the polytropic index.
Throttling:	Adiabatic process where enthalpy remains constant. Used in refrigeration.

Heat Engines and Refrigerators

Heat Engine Efficiency (η):	$\eta = W/Q_H = 1 - (Q_C/Q_H)$, where W is work done, Q_H is heat input, and Q_C is heat rejected.
Carnot Efficiency (ηCarnot):	$\eta_{Carnot} = 1 - (T_C/T_H)$, where T_C is the cold reservoir temperature, and T_H is the hot reservoir temperature (in Kelvin).
Coefficient of Performance (COP) - Refrigerator:	$COP_R = Q_C/W = Q_C/(Q_H - Q_C)$
Coefficient of Performance (COP) - Heat Pump:	$COP_{HP} = Q_H/W = Q_H/(Q_H - Q_C)$

Fluid Mechanics

Fluid Properties

Density (ρ):	Mass per unit volume: $\rho = m/V$
Specific Weight (γ):	Weight per unit volume: $\gamma = \rho g$, where g is acceleration due to gravity.
Specific Gravity (SG):	Ratio of a fluid's density to the density of water: $SG = \rho_{fluid}/\rho_{water}$
Viscosity (μ):	Measure of a fluid's resistance to flow. Dynamic viscosity.
Kinematic Viscosity (ν):	Ratio of dynamic viscosity to density: $\nu = \mu/\rho$
Surface Tension (σ):	Force per unit length acting at the interface between two fluids.

Fluid Statics

Pressure (P):	Force per unit area: $P = F/A$
Hydrostatic Pressure:	$P = \rho g h$, where h is the depth from the surface.
Buoyancy (FB):	Upward force exerted by a fluid that opposes the weight of an immersed object: $F_B = \rho_{fluid} V_{displaced} g$
Manometry:	Use of liquid columns to measure pressure differences.

Fluid Dynamics

Continuity Equation:	$A_1V_1 = A_2V_2$ (for incompressible fluids)
Bernoulli's Equation:	$P + (1/2)\rho V^2 + \rho g h$ = constant (along a streamline)
Reynolds Number (Re):	$Re = (\rho V D)/\mu$, where V is flow velocity, D is characteristic length, and μ is dynamic viscosity. Indicates laminar ($Re < 2100$) or turbulent flow ($Re > 4000$).
Darcy-Weisbach Equation:	$\Delta P = f (L/D) (\rho V^2/2)$, where f is the friction factor.

Materials Science

Material Properties

Young's Modulus (E):	Measure of stiffness or resistance to elastic deformation: E = Stress/Strain
Poisson's Ratio (ν):	Ratio of transverse strain to axial strain.
Yield Strength (σy):	Stress at which a material begins to deform plastically.
Tensile Strength (σu):	Maximum stress a material can withstand before breaking.
Hardness:	Resistance to localized plastic deformation (e.g., indentation).
Ductility:	Ability of a material to deform plastically before fracture.

Stress and Strain

Stress (σ):	Force per unit area: σ = F/A
Strain (ε):	Deformation per unit length: ε = ΔL/L
Shear Stress (τ):	Stress acting parallel to a surface.
Shear Strain (γ):	Angular deformation.
Hooke's Law:	σ = Eε (in the elastic region)

Material Types

Metals: High strength, ductility, and thermal/electrical conductivity. Examples: Steel, Aluminum, Copper.
Ceramics: High hardness, brittleness, and resistance to high temperatures. Examples: Alumina, Silicon Carbide.
Polymers: Low density, flexibility, and can be easily molded. Examples: Polyethylene, Polypropylene.
Composites: Combination of two or more materials to achieve enhanced properties. Examples: Carbon fiber reinforced polymer (CFRP).

Mechanics of Materials

Stress Analysis

Axial Stress (σ):	Stress due to axial force: σ = P/A, where P is the axial force and A is the cross-sectional area.
Bending Stress (σb):	Stress due to bending moment: σb = My/I, where M is the bending moment, y is the distance from the neutral axis, and I is the moment of inertia.
Shear Stress in Beams (τ):	τ = VQ/Ib, where V is the shear force, Q is the first moment of area, I is the moment of inertia, and b is the width of the beam.
Torsional Shear Stress (τ):	τ = Tr/J, where T is the torque, r is the radius, and J is the polar moment of inertia.
Principal Stresses:	Maximum and minimum normal stresses at a point.

Beam Deflection

Deflection Formulas:	Vary based on loading and support conditions. Common cases include cantilever beams and simply supported beams with various loads.
Cantilever Beam with Point Load at End:	Maximum deflection (δ) = (PL3)/(3EI), where P is the load, L is the length, E is Young's modulus, and I is the moment of inertia.
Simply Supported Beam with Uniform Load:	Maximum deflection (δ) = (5wL4)/(384EI), where w is the uniform load per unit length.

Failure Theories

Maximum Shear Stress Theory (Tresca): Failure occurs when maximum shear stress exceeds the shear strength of the material.
Distortion Energy Theory (von Mises): Failure occurs when the distortion energy reaches the distortion energy at yield in a simple tension test.
Maximum Principal Stress Theory: Failure occurs when the maximum principal stress exceeds the tensile strength of the material.