

Mechanics of Materials Cheat Sheet

Axial · torsion · bending · deflection · Mohr's circle · buckling · pressure vessels

Axial load and thermal effects

Normal stress and strain

$$\sigma = P/A; \epsilon = \delta/L$$

P axial force (N); A area (m²); δ elongation; L length (m); σ (Pa)

Hooke's law

$$\sigma = E \cdot \epsilon; \tau = G \cdot \gamma$$

E, G elastic and shear moduli (Pa); γ shear strain (rad)

Axial deformation

$$\delta = P \cdot L / (A \cdot E)$$

Sum segment by segment when P, A or E changes

Poisson's ratio

$$\nu = -\epsilon_{\text{lat}} / \epsilon_{\text{long}}; G = E / [2(1 + \nu)]$$

ν dimensionless, about 0.3 for steel

Thermal strain and stress

$$\delta_T = \alpha \cdot \Delta T \cdot L; \text{fully restrained: } \sigma = -E \cdot \alpha \cdot \Delta T$$

α expansion coefficient (1/K); ΔT temperature change (K)

Torsion of circular shafts

Shear stress

$$\tau = T \cdot \rho / J; \tau_{\text{max}} = T \cdot c / J$$

T torque (N·m); ρ radius to the point; c outer radius (m)

Angle of twist

$$\phi = T \cdot L / (J \cdot G)$$

ϕ (rad); L length (m)

Polar moment of inertia

$$J = \pi \cdot d^4 / 32; \text{hollow: } J = \pi (d_o^4 - d_i^4) / 32$$

d diameters (m); J (m⁴)

Power transmission

$$P = T \cdot \omega; \omega = 2\pi \cdot n / 60$$

P power (W); ω (rad/s); n speed (rpm)

Beams

Load, shear and moment

$$dV/dx = -w; dM/dx = V$$

w downward load (N/m); V shear (N); M moment (N·m)

Flexure formula

$$\sigma = -M \cdot y / I; \sigma_{\text{max}} = M \cdot c / I = M / S$$

y distance from the neutral axis; S = I/c section modulus (m³)

Transverse shear

$$\tau = V \cdot Q / (I \cdot t); \text{rectangle: } \tau_{\text{max}} = 1.5 \cdot V / A$$

Q first moment of area above the point (m³); t width there (m)

Cantilever, end load

$$\delta_{\text{max}} = P \cdot L^3 / (3E \cdot I)$$

At the free end

Simply supported, centre load

$$\delta_{\text{max}} = P \cdot L^3 / (48E \cdot I)$$

At mid-span

Simply supported, uniform load

$$\delta_{\text{max}} = 5w \cdot L^4 / (384E \cdot I)$$

w (N/m); at mid-span

Stress transformation

Mohr's circle centre and radius

$$C = (\sigma_x + \sigma_y) / 2; R = \sqrt{[(\sigma_x - \sigma_y) / 2]^2 + \tau_{xy}^2}$$

Plane stress components (Pa)

Principal stresses

$$\sigma_{1,2} = C \pm R; \tau_{\text{max, in-plane}} = R$$

$\sigma_1 \geq \sigma_2$

Principal angle

$$\tan 2\theta_p = 2\tau_{xy} / (\sigma_x - \sigma_y)$$

θ_p measured from the x axis; rotate 2θ on the circle

Columns and pressure vessels

Euler buckling load

$$P_{\text{cr}} = \pi^2 \cdot E \cdot I / (K \cdot L)^2$$

K effective-length factor: 1 pinned–pinned, 0.5 fixed–fixed, 2 fixed–free, 0.7 fixed–pinned

Critical stress

$$\sigma_{\text{cr}} = \pi^2 \cdot E / (K \cdot L / r)^2$$

$r = \sqrt{I/A}$ radius of gyration; valid while $\sigma_{\text{cr}} < \text{yield}$

Thin-walled cylinder

$$\sigma_{\text{hoop}} = p \cdot r / t; \sigma_{\text{axial}} = p \cdot r / (2t)$$

p internal gauge pressure (Pa); r inner radius; t wall (m); $r/t \geq 10$

Thin-walled sphere

$$\sigma = p \cdot r / (2t)$$

Same in every direction in the wall