

# Statics and Strength of Materials Formula Sheet

BY/REVISED - A. Jones

Not given here are the conditions under which the formulae are accurate or useful.

## Basic Statics

### Free Body Diagram

The FBD is a picture of any system for which you would like to apply mechanics equations and of all the external forces and torques which act on the system.

### Action & Reaction

If  $\vec{A}$  acts on  $\vec{B}$ , then  $\vec{B}$  acts on  $\vec{A}$ . If  $\vec{M}$  acts on  $\vec{A}$ , then  $\vec{A}$  acts on  $\vec{M}$ . If  $\vec{F}$  acts on  $\vec{B}$ , then  $\vec{B}$  acts on  $\vec{F}$ . (With  $\vec{F}$  and  $\vec{F}'$  acting on the same line of action.)

### Force and Moment Balance

These equations apply to every FBD in equilibrium.

$$\sum \vec{F} = 0$$

All external forces

$$\sum \vec{M}_{A,C} = 0$$

All external moments about pt C

- The torque  $\vec{M}_{A,C}$  of a force depends on the reference point C. But, for a body in equilibrium, and for any point C, the sum of all the torques relative to point C must add to zero.
- Writing the force balance equations with a unit vector gives a scalar equation.  $\vec{e} \cdot (\sum \vec{F}) = 0 \Rightarrow \sum F_x = 0$
- Writing the moment balance equations with a unit vector gives a scalar equation.  $\vec{e} \cdot (\sum \vec{M}_{A,C}) = 0 \Rightarrow \sum \text{moment about axis in direction } \vec{e} \text{ through } C = 0$

### Some Statics Facts and Definitions

- The moment of a force is unchanged if the force is slid along the line of action.
- The main purpose for words "centroid", "center", and "average" have to do with finding.
- Translational body.** If a body is in equilibrium, not only the forces acting on it show the two forces must be equal and opposite and have a common line of action.
- Translational body.** If a body is in equilibrium but only three forces acting on it show the three forces must be coplanar and have lines of action that intersect at one point.
- Truss.** A collection of weightless two-force bodies connected with hinges (pins) or ball and socket joints (balls).
- Method of joints.** Draw free body diagrams of each of the joints in a truss.
- Method of sections.** Draw free body diagrams of various regions of a truss. Try to make the FBD nice for the sections go through only three bars with unknown forces (pins).
- Constant thickness and force components are often used for truss-like bodies.
- Hydrostatics**  $p = \rho gh$ ,  $F = \int p dA$

## Stress, strain, and Hooke's Law

	Stress	Strain	Hooke's Law
Normal:	$\sigma = F_{\perp}/A$	$\epsilon = \Delta L/L_0 = \frac{\Delta L}{L_0}$	$\sigma = E\epsilon$ ( $\epsilon = \sigma/E$ or $\sigma = E\epsilon$ ) Area = $10^{-6} \text{m}^2$ long
Shear:	$\tau = F_{\parallel}/A$	$\gamma = \text{change of geometry right angle}$	$\tau = G\gamma$ $G = \frac{E}{2(1+\nu)}$

## Stress and deformation of some things

	Equilibrium	Geometry	Results
Tension	$F = \sigma A$	$\epsilon = \Delta L/L$	$\sigma = \frac{E\epsilon}{L}$ $\Delta L = \frac{FL}{EA}$
Torsion	$T = \int r \tau dA$	$\gamma = \rho \phi/L$	$\tau = \frac{E\phi}{L} \rho$ $\phi = \frac{TL}{GJ}$
Bending and Shear in Beams	$M = - \int y \sigma dA$ $\frac{dM}{dx} = V$ , $\frac{dV}{dx} = -w$ $V = \int -w dx$ $\tau dA = dM/dx$	$\epsilon = -y/\rho = -\phi x$ $\phi'' = \frac{d^2\phi}{dx^2} = \frac{1}{\rho}$	$\sigma'' = \frac{E}{\rho}$ $\epsilon = -\frac{y}{\rho}$ $\tau = \frac{VQ}{Ib}$
Pressure Vessels	$\sigma_{\text{hoop}} = r \frac{d\sigma}{dr}$		$\sigma = \frac{Pr}{t}$ (cylinder) $\sigma_1 = \frac{Pr}{t}$ (cylinder) $\sigma_2 = \frac{Pr}{2t}$ (cylinder)

## Buckling

$$\text{Critical buckling load} = F_{\text{buck}} = \frac{\pi^2 EI}{L^2}$$

pin-ended	clamped-free	clamped-clamped	clamped-free
$k_{eff} = 0$	$k_{eff} = 0.5$	$k_{eff} = 0.75$	$k_{eff} = 1.5$

## Mohr's Circle

Rotating the surface of interest an angle  $\theta$  in physical space corresponds to a rotation of  $2\theta$  on the Mohr's circle in the stress-strain plane.

$$\sigma = \frac{\sigma_1 + \sigma_2}{2} + \frac{\sigma_1 - \sigma_2}{2} \cos 2\theta$$

$$\tau = \frac{\sigma_1 - \sigma_2}{2} \sin 2\theta = \sqrt{(\frac{\sigma_1 - \sigma_2}{2})^2 + \tau_{xy}^2}$$

$$\tan 2\theta = \frac{2\tau_{xy}}{\sigma_1 - \sigma_2} = \frac{2\tau}{\sigma_1 - \sigma_2}$$

## Miscellaneous

- Power to a shaft:  $P = T\omega$
- Saint Venant's Principle: Far from the region of loading, the stresses in a structure would only change slightly if it is fixed at one end or the other.

## Cross Section Geometry

	Definition	Composite	centroid (x, y, z)	radius of gyration (x, y, z)	portable
$A =$	$\int dA$	$\sum A_i$	$x(\frac{A_1}{A} + \frac{A_2}{A})$	$x^2/A$	AA
$I =$	$\int r^2 dA$		$y(\frac{A_1}{A} + \frac{A_2}{A})$	$y^2/A$	AA
$J =$	$\int r^2 dA$	$\sum (I_i + d_i^2 A_i)$	$x(\frac{A_1}{A} + \frac{A_2}{A})$	$x^2/A$	AA <sup>2</sup> /12
$Q =$	$\int y dA$	$\sum \frac{y_i A_i}{2}$	centroid	centroid	centroid
$Q =$	$\int y dA = y' A'$	$\sum y_i A_i$			$\frac{1}{2} \sqrt{A^2 - y^2}$

# Statistics And Strength Of Materials

**K Morrison**



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web  $m \times c \times \Delta t$  equation 1 where m is the total mass of the solution solute plus solvent c is the specific heat of the solution and  $\Delta t$  is the observed temperature change the specific heat of the solution is generally assumed to be the same as that of

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mol rxn write equations to similarly represent the dissolving process for

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