# STRENGTH OF MATERIALS

| PROPERTY | EXAMPLES |
|---|---|
| DENSITY $\rho = \frac{m}{V}$ mass per unit volume | STEEL $\rho = 7800\ kg/m^3$ |
| STRENGTH : How much stress it can take. Many different types: ULTIMATE TENSILE, COMPRESSIVE, SHEAR, IMPACT, FATIGUE. | MILD STEEL UTS = 470 MPa<br>" " SHEAR = 360 MPa |
| HARDNESS : Ability to resist surface indentation/abrasion | HARD Tungsten Carbide |
| STIFFNESS : Ability to resist deformation under load. | STEEL E = 210 GPa |
| TOUGHNESS : Amount of energy absorbed to fracture | M.Steel HIGH, Tungsten LOW |
| ELASTICITY : Ability to return to original size after deformation | Metals, rubber, glass |
| PLASTICITY : Ability to deform permanently without fracture | |
| DUCTILITY : Plasticity in tension | DUCTILE - Copper, Chewing gum |
| MALLEABILITY : Plasticity in compression | MALLEABLE - Lead, Plasticine |

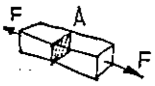
**THERMAL EXPANSION:**

COEFF.

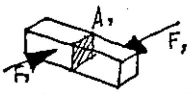
- Steel $\alpha = 11.5\ E-6$ per °C
- Brass $\alpha = 18.5\ E-6$
- Alum $\alpha = 23.9\ E-6$
- Nic.St $\alpha = 1.5\ E-6$
- PVC $\alpha = 100\ E-6$
- SILICON $\alpha = 4.2\ E-6$.

$e = \alpha \Delta T$ $\Delta T$ = Temp rise, $\alpha$ = Coeff of exp, $e$ = strain

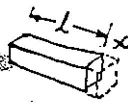
STRESS — AXIAL STRESS $f = \frac{F}{A}$



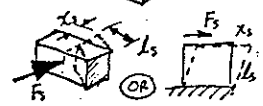

SHEAR STRESS $f_s = \frac{F_s}{A_s}$




STRAIN — AXIAL STRAIN $e = \frac{x}{l}$




SHEAR STRAIN $e_s = \frac{x_s}{l_s}$

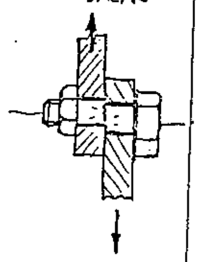
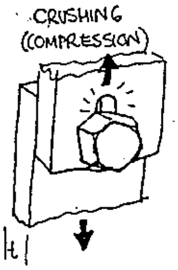
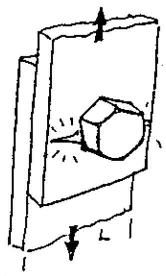



STIFFNESS YOUNG'S MODULUS / ELASTIC MODULUS $E = \frac{f}{e}$

SHEAR STIFFNESS $G = \frac{f_s}{e_s}$ $= 0.4E$

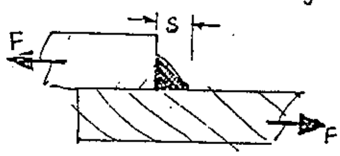
**BOLTS:** (OR RIVETS)

BOLT DIAM $d$
PLATE THICKNESS $t$
LENGTH $L$

| | SHEAR | CRUSHING (COMPRESSION) | TEARING |
|---|---|---|---|
| |  |  |  |
| TYPE OF STRESS | SHEAR (Slide apart bolt) | COMPRESSIVE (Squash hole into oval) | TENSILE (Rip plate around hole) |
| AREA UNDER FAILURE | BOLT SECTION $A_s = \frac{\pi d^2}{4}$ | SIDE OF HOLE $A_c = d.t$ | REMNANT OF PLATE $A_t = Lt - dt$. |

**WELDS:** $F = 0.707 . f . l . s$

F = FORCE
$f$ = ALLOWABLE STRESS
$l$ = WELD LENGTH
S = WELD SIZE

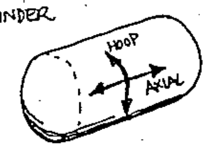



REMEMBER! $f_{allow} = \frac{1}{3} f_{ult}$

**PRESSURE VESSELS:**

P = PRESSURE
D = INSIDE DIAMETER
t = THICKNESS

CYLINDER



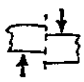

$f_H = \frac{PD}{2t}$

$f_A = \frac{PD}{4t}$

SPHERE

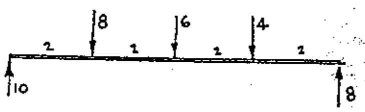
$f = \frac{PD}{4t}$

**BEAMS:**

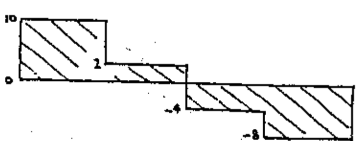


POSITIVE SHEAR

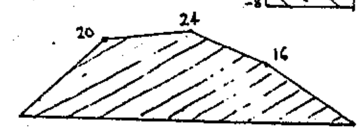
POSITIVE BENDING MOMENT




FBD

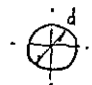


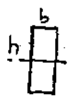

SFD




BMD

**2ND AREA MOMENTS:**

 $I = \frac{\pi D^4}{64}$

 $I = \frac{bh^3}{12}$

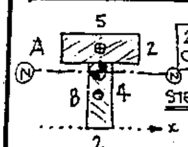
DIFFERENT AXIS: $I = I_c + Ad^2$

NOTE
- MAX M WHERE SFD = 0
- EACH POINT ON BMD = SUM OF AREA UP TO THAT POINT ON THE SFD.

BENDING STRESS: $\frac{f}{y} = \frac{M}{I} = \frac{E}{R}$

E = MODULUS OF ELASTICITY
M = BENDING MOMENT
y = DIST. FROM N.AXIS
I = 2ND MOMENT OF AREA.

2ND MOMENT FOR COMBINED AREA:



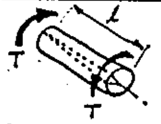

STEP 1: FIND NEUTRAL AXIS $\bar{y} = \frac{\Sigma A \times d}{\Sigma A} = \frac{10 \times 5 + 8 \times 2}{10 + 8} = 3.667$ (DIST FROM ELEMENT CENTROID TO AXIS)

STEP 2 (d = DIST FROM ELEMENT ⊕ CENTROID TO MAIN CENTROID)

| | AREA | $I_c$ | d | $Ad^2$ | I |
|---|---|---|---|---|---|
| A | 10 | 3.333 | 1.333 | 17.778 | 21.111 |
| B | 8 | 10.667 | 1.667 | 22.222 | 32.889 |
| TOTAL | 18 | — | — | — | 54.0 |

← TOTAL I = 54.

WHERE AREA = b.h
$I_c = bh^3/12$
$I = I_c + Ad^2$
(TABLE FORMAT)




$\frac{f_s}{r} = \frac{T}{J} = \frac{G\theta}{l}$

$J = \frac{\pi d^4}{32}$ POLAR 2ND MOMENT OF AREA

$\theta$ = ANGLE OF TWIST
$l$ = LENGTH
T = TORQUE

$f_s$ = SHEAR STRESS
G = MODULUS OF RIGIDITY $\approx 0.4E$