Shear Flow in Built-up Members

- Members are built-up from several parts which may slide past each other when the member is subjected to bending
- To prevent this sliding fasteners such as nails, bolts or glue may be needed
- In order to design these fasteners or determine their spacing the shear force resisted must be known
- This force is measured per unit length and is called ***shear flow q***

Shear Flow in Built-up Members

Consider the shear force along the juncture where a segment is connected to the flange of a beam.

From equilibrium, the shear force acting on the junction is

$$dF = \frac{dM}{I}\int_{A'} y\, dA'$$

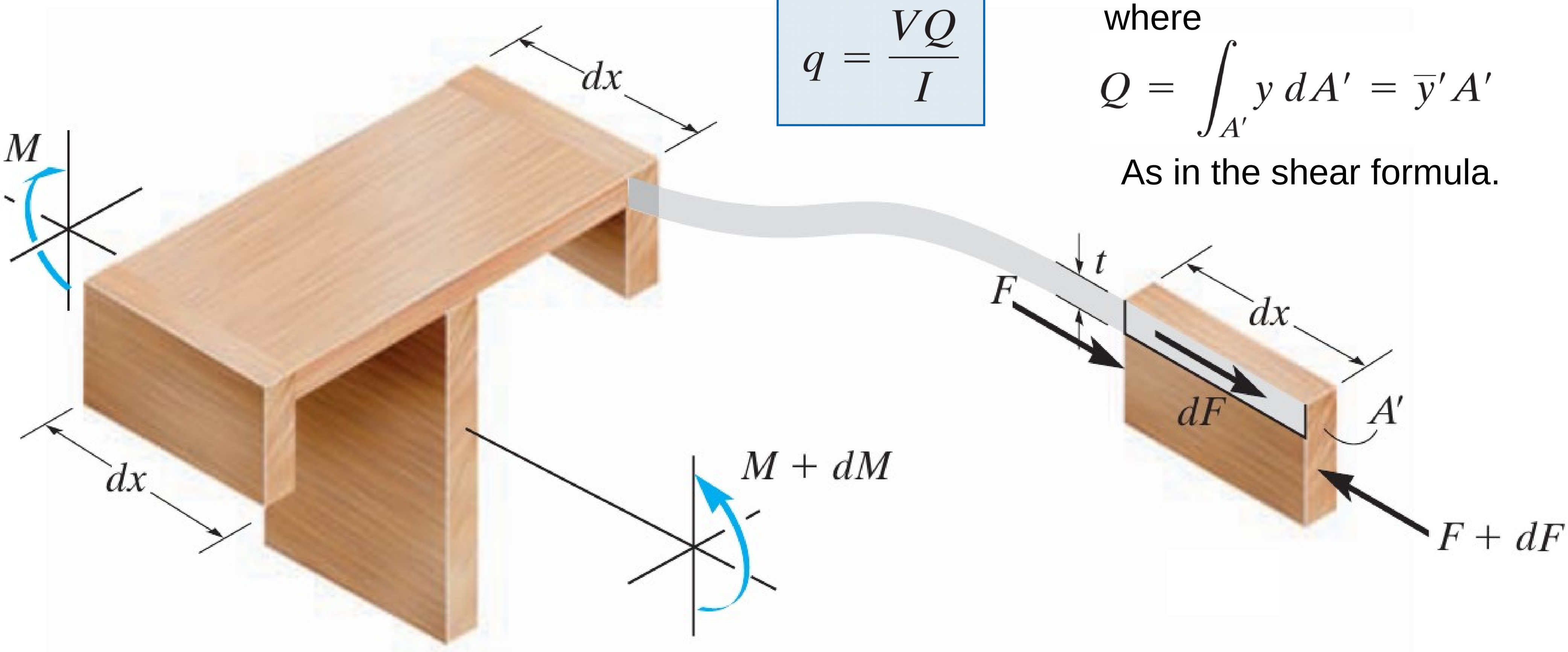
Dividing both sides by *dx* and noting *dM/dx* = V we obtain

$$\boxed{q = \frac{VQ}{I}}$$

where

$$Q = \int_{A'} y\, dA' = \bar{y}' A'$$

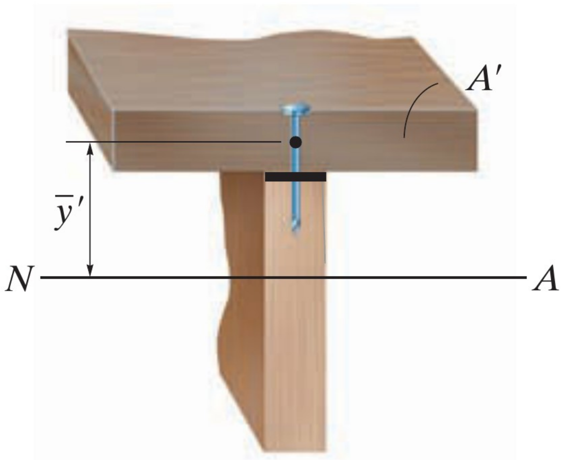
As in the shear formula.

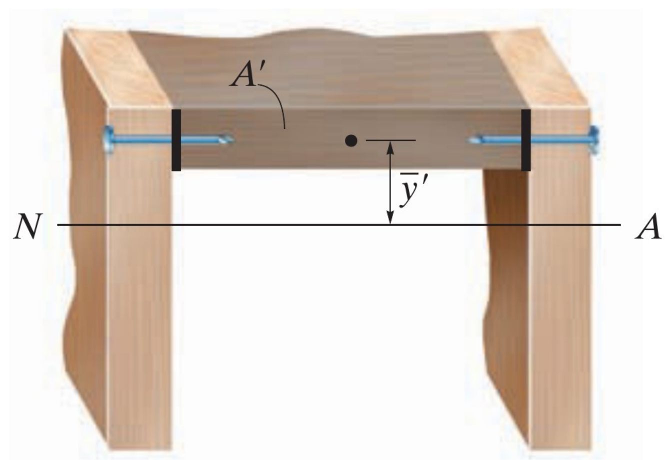


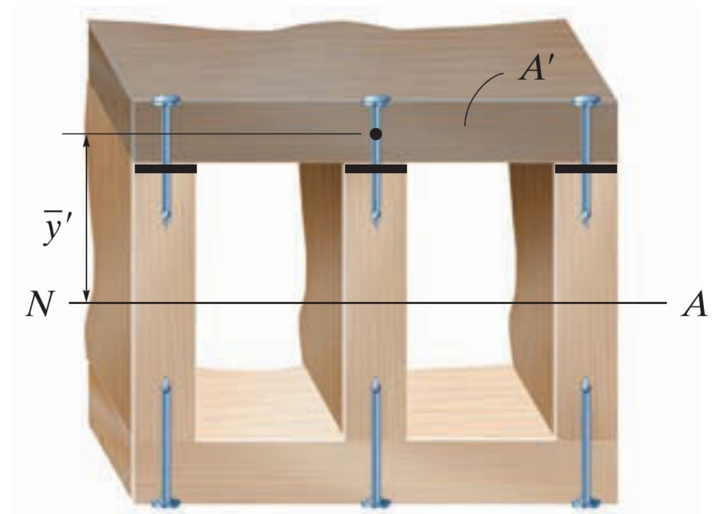
Shear Flow in Built-up Members

It is important to correctly determine *Q* when computing the shear flow.

Shaded areas show the areas used to determine *Q* to compute the shear follow resisted by the fasteners on surface shown with thick segments.







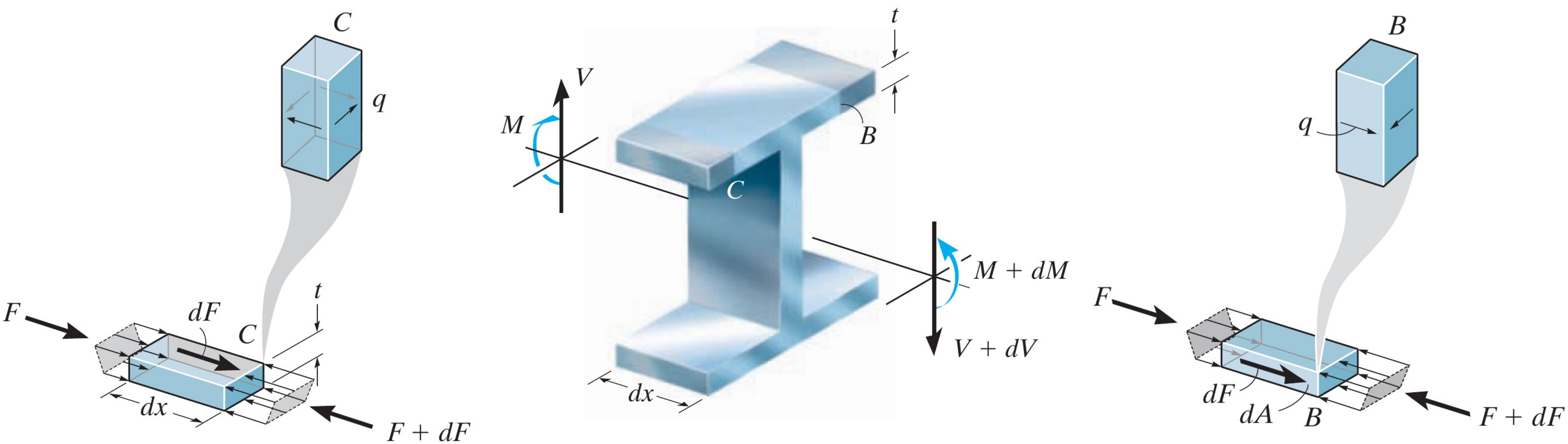
q is resisted by 1 fastener

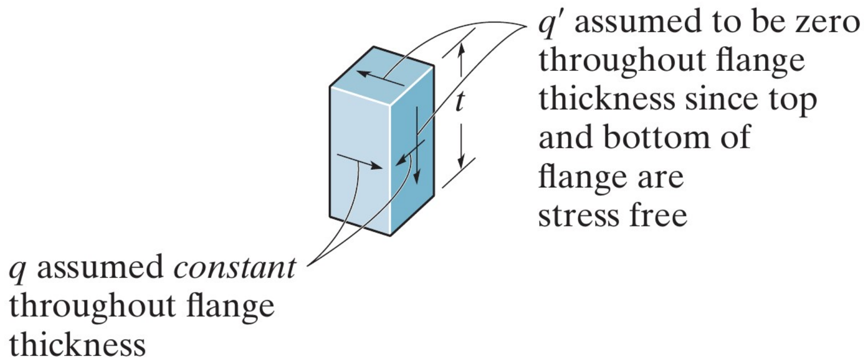
q is resisted by 2 fasteners i.e. q/2 is supported by each fastener

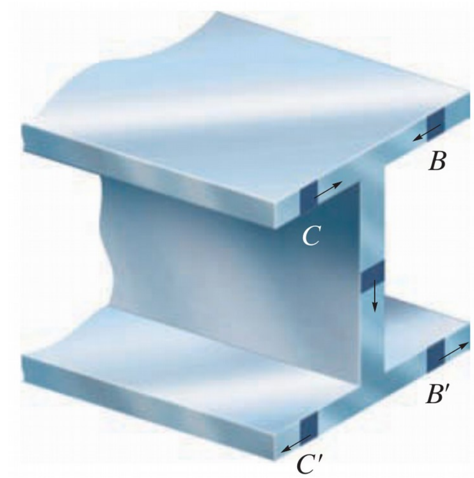
q is resisted by 3 fasteners i.e. q/3 is supported by each fastener

Shear Flow in Thin-Walled Members

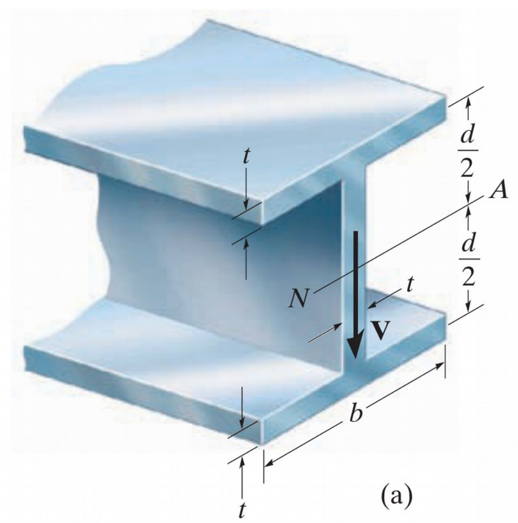
Shear flow equation $q = VQ/I$ can be used to find the shear flow distribution throughout a *thin walled* member's cross section.

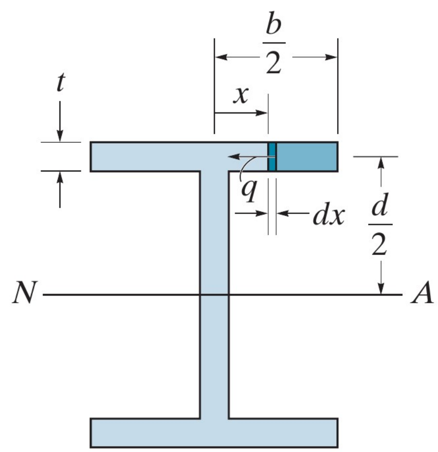






Shear Flow in Thin-Walled Members



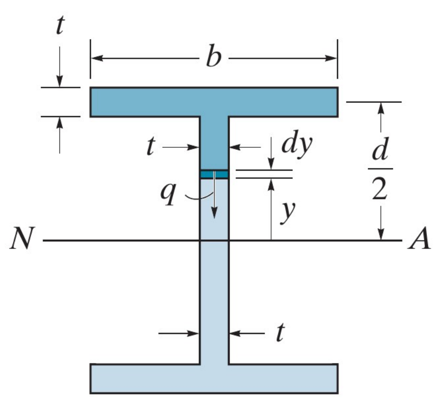


For the flange

$$q = \frac{VQ}{I} = \frac{V[d/2](b/2 - x)t}{I} = \frac{Vtd}{2I}\left(\frac{b}{2} - x\right)$$

$$Q = \overline{y}'A' = [d/2](b/2 - x)t$$

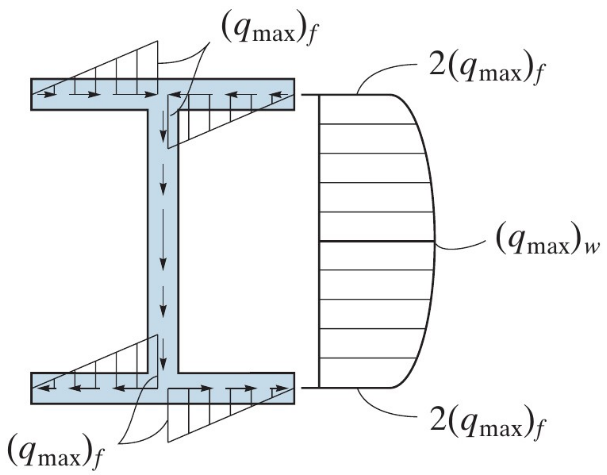
For the web:

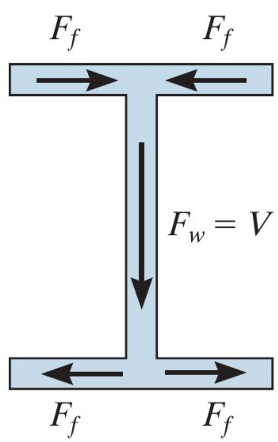


$$q = \frac{VQ}{I} = \frac{Vt}{I}\left[\frac{db}{2} + \frac{1}{2}\left(\frac{d^2}{4} - y^2\right)\right]$$

$$\begin{aligned} Q = \sum \overline{y}'A' &= [d/2]\,(bt) \\ &+ [y + (1/2)(d/2 - y)]\,t(d/2 - y) \\ &= bt(d/2) + (t/2)(d^2/4 - y^2) \end{aligned}$$

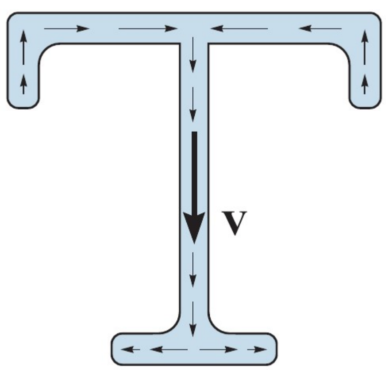
Shear Flow in Thin-Walled Members

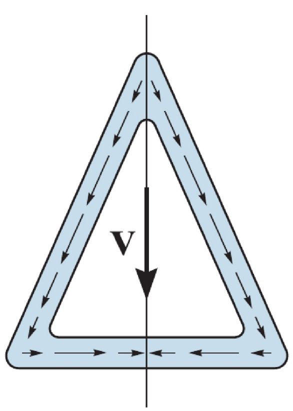


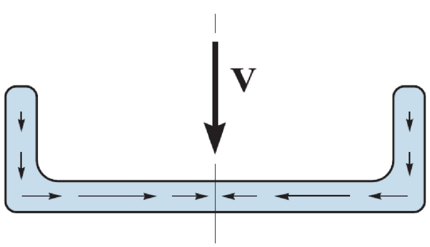


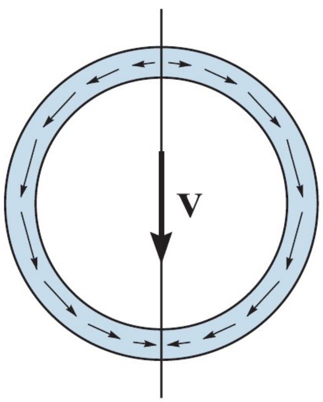
The shear flow *q*:

- Varies linearly along the flanges or sections perpendicular to the shear force
- Varies parabolically along inclined segments or segments parallel to the shear force
- Acts always parallel to the walls of the member
- "Flows" inward in the beams top flange, flows downward in the web and outwards in the bottom flange





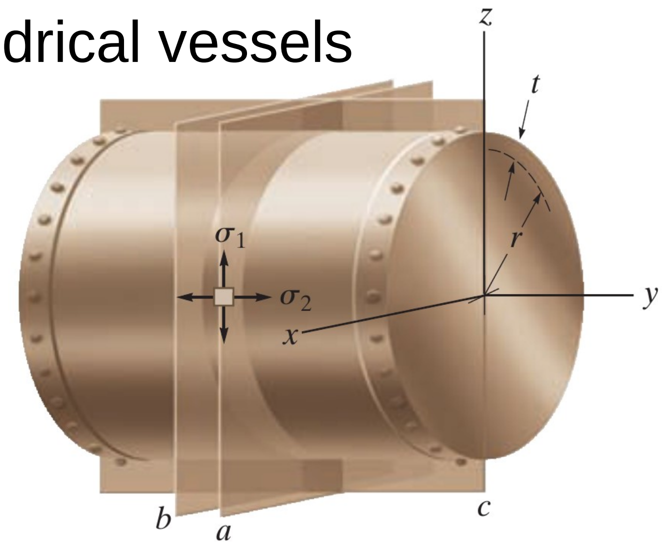




Thin-Walled Pressure Vessels

- ***Thin*** wall means the radius over thickness ratio is $r/t \geq 10$
- The stress through thickness is assumed to be uniform (since thickness is small)
- Pressure is the gauge pressure that is above atmospheric pressure

Cylindrical vessels

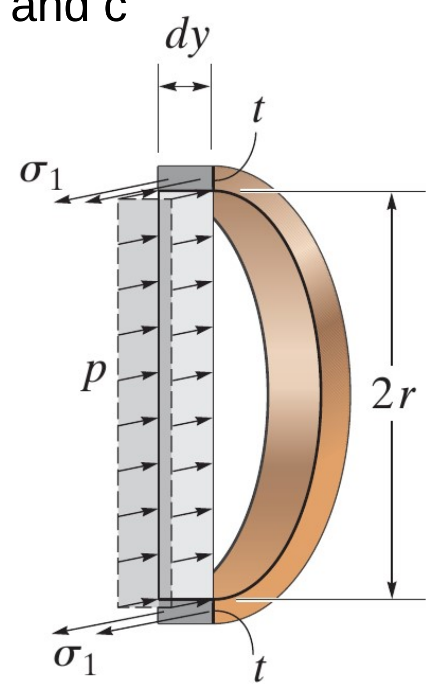


The element is subjected to

σ_1 ***circumferential*** or ***hoop*** stress and

σ_2 ***longitudinal*** stress

Consider force equilibrium in the *x* direction of a thin section extracted from the vessel by cutting through planes a, b and c



$$\Sigma F_x = 0 \qquad 2[\sigma_1(t\,dy)] - p(2r\,dy) = 0$$

$$\boxed{\sigma_1 = \frac{pr}{t}}$$

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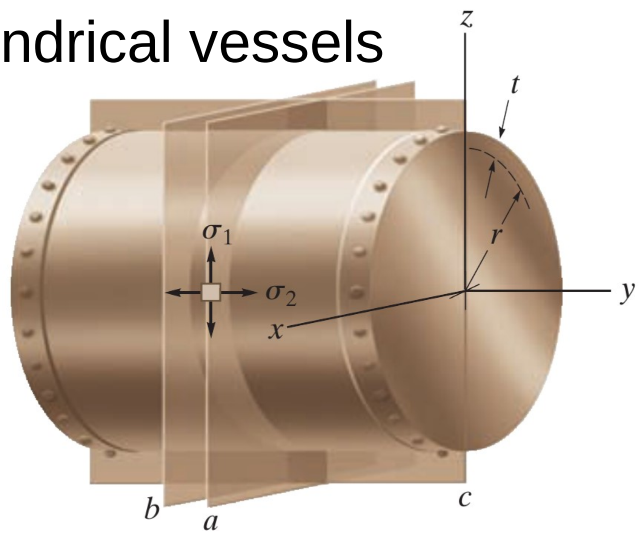
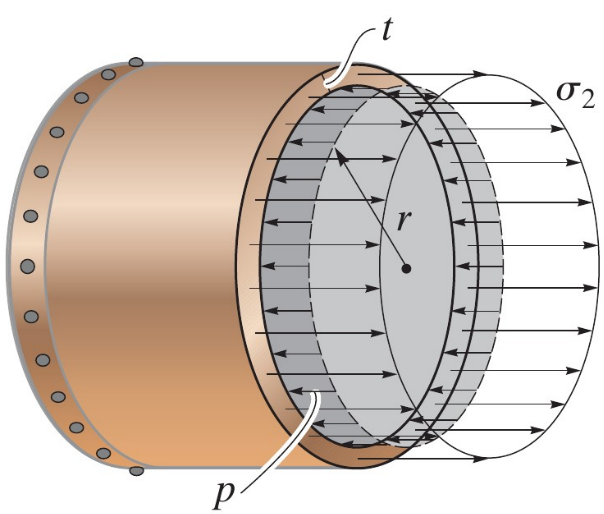
Cylindrical vessels



The element is subjected to
σ_1 ***circumferential*** or ***hoop*** stress and
σ_2 ***longitudinal*** stress

Consider force equilibrium in the *y* (longitudinal) direction of the left portion of the vessel cut by plane b



$$\Sigma F_y = 0 \quad \sigma_2(2\pi r t) - p(\pi r^2) = 0$$

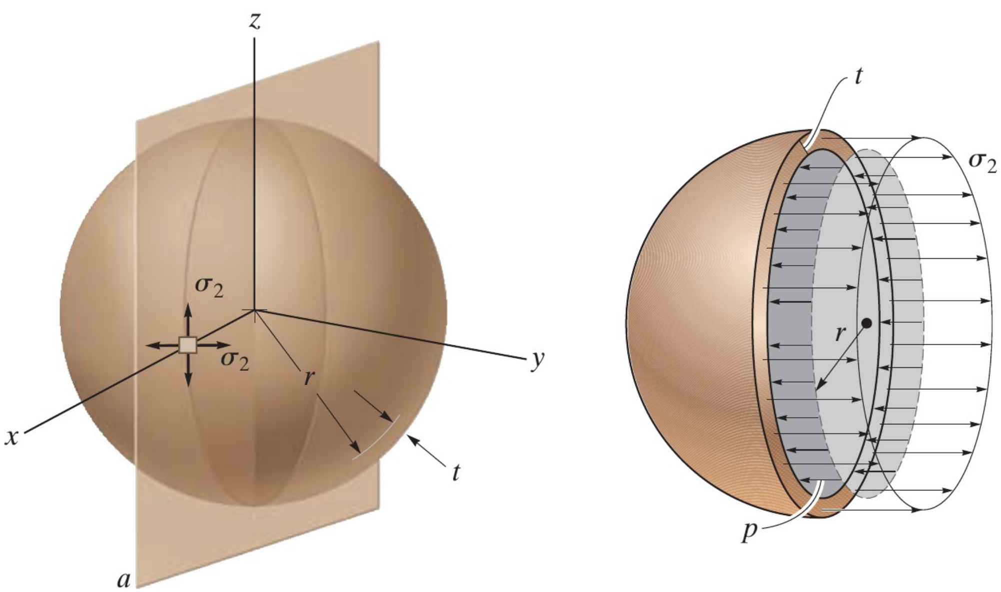
$$\boxed{\sigma_2 = \frac{pr}{2t}}$$

$$\sigma_1 = 2\sigma_2$$

Thin-Walled Pressure Vessels

- ***Thin*** wall means the radius over thickness ratio is $r/t \geq 10$
- The stress through thickness is assumed to be uniform (since thickness is small)
- Pressure is the gauge pressure that is above atmospheric pressure

Spherical vessels



Consider force equilibrium in the *y* direction of the left portion of the vessel cut by plane *a*

$$\Sigma F_y = 0$$

$$\sigma_2(2\pi r t) - p(\pi r^2) = 0$$

$$\boxed{\sigma_2 = \frac{pr}{2t}}$$

The element is subjected to ***biaxial*** stress $\sigma_1 = \sigma_2$

σ_3 is neglected, however, varies from $\sigma_3 = p$ inside the vessel to $\sigma_3 = 0$ outside.