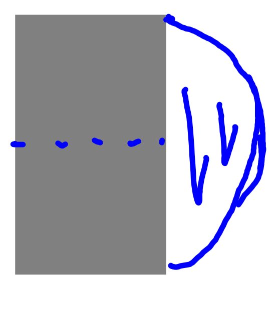
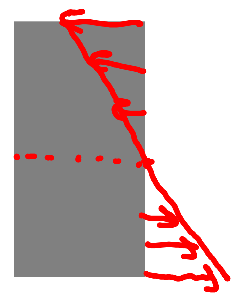
# Lecture 14 Review

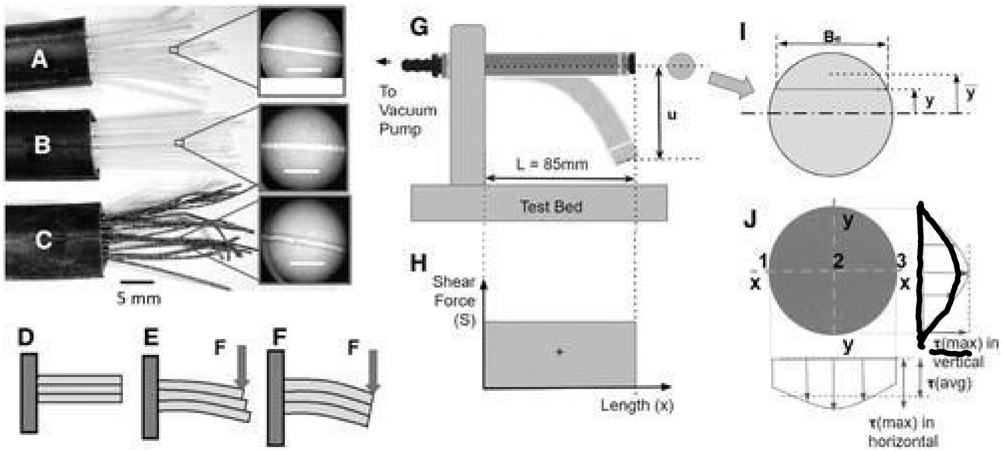
For a rectangular cross-section: at the neutral plane, the shear stress is _________ and the normal stress is _________.

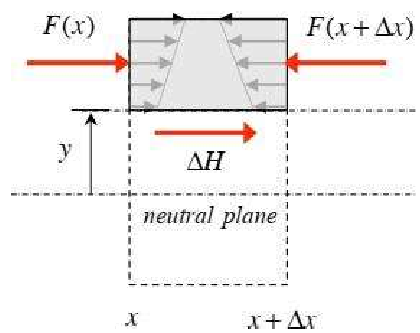
- zero, zero
- zero, maximum
- maximum, zero
- maximum, maximum





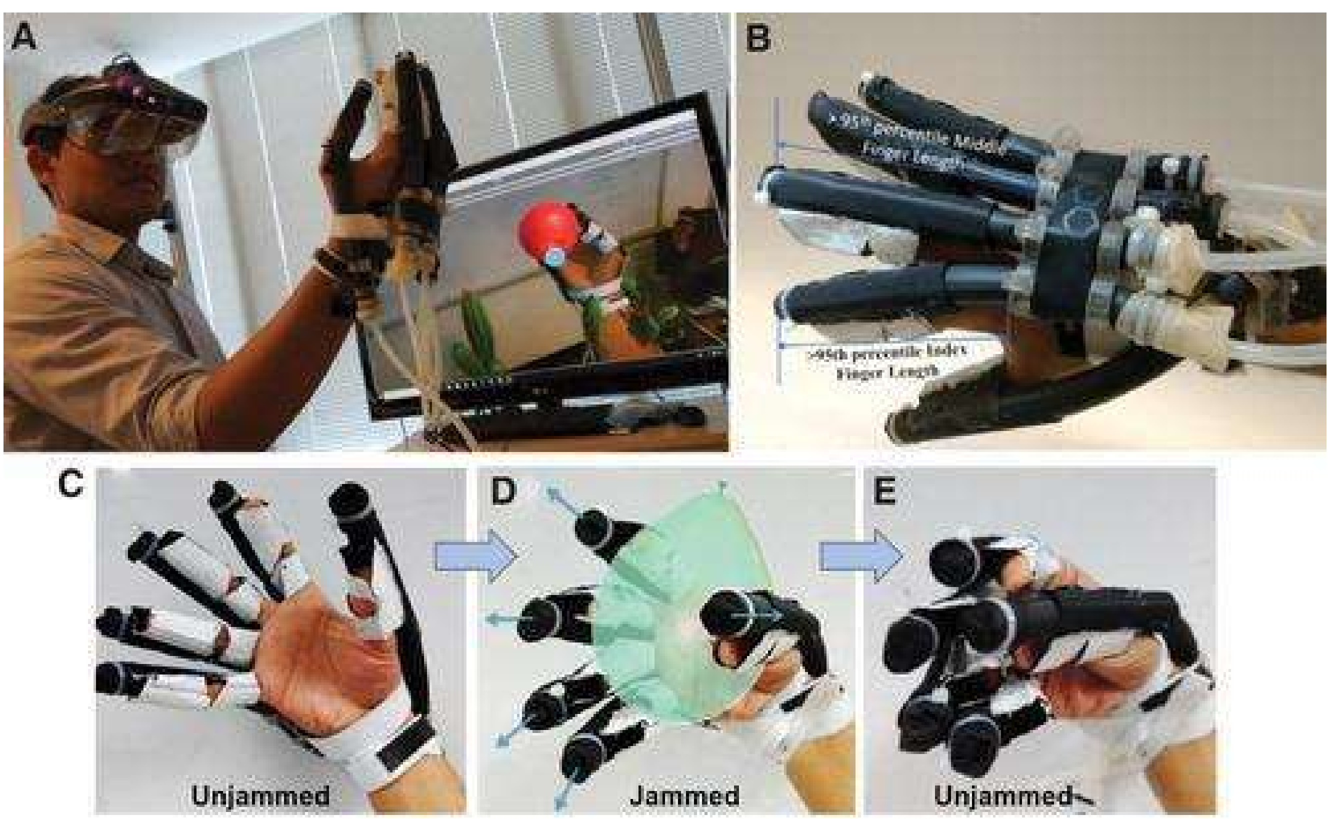
# Shear and Normal Stresses in Practical Robots




$$\tau_{induced} = k_{correction} \times \frac{SA_e\hat{y}_e}{I_eB_e}, \quad (1) \quad = \frac{VA^*\bar{y}^*}{It}$$

where $A_e$ is the area of the cross section beyond the section at a distance of $y$ away from the neutral axis, $\hat{y}_e$ is the centroid of that area away from the neutral axis, and $B_e$ is the width of the section at a distance of $y$ from the neutral axis. The accuracy of the above shear stress formula depends on the aspect ratio of the cross section of the ellipse. For very high




Jadhav et al, Soft Robotics, Vol. 9, pp. 173, (Feb 14, 2022).

$$\tau = \frac{VA^*\bar{y}^*}{It}$$

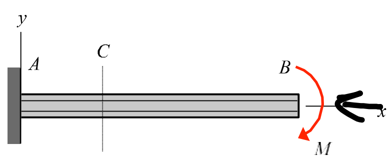
### Example 10.5

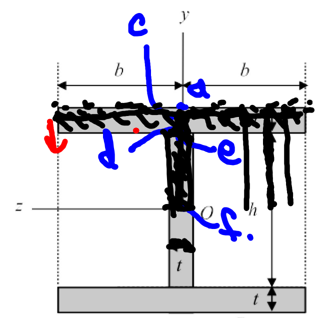
The cantilevered beam shown below is loaded in pure bending. The beam has a cross section at location C on the beam as shown below right. The origin O is located on the neutral axis of the beam.

a) Determine the second area moment $I_{Oz}$ corresponding to the neutral axis of the beam.

b) Determine the distribution of normal stress on the cross section of the beam as a function of y.

c) Determine the maximum (magnitude) normal stress occurring on the cross-sectional face at C.



cross section at C

$b = 80$ mm
$t = 20$ mm
$h = 100$ mm.
$I = 2.492 \times 10^{-5}$ m$^4$

d) Find shear stress distribution on cross-section.

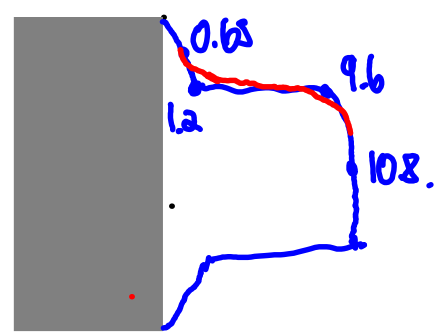
$$\tau_a = \frac{VA^*\bar{y}^*}{It} = 0$$

$$\tau_c = \frac{V\left(\frac{t}{2}\right)(2b)\left(\frac{h}{2}+\frac{3}{4}t\right)}{I(2b)} = 0.65\times10^{-3}\left(\frac{V}{I}\right)$$

$$\tau_d = \frac{V(t)(2b)\left(\frac{h}{2}+\frac{1}{2}t\right)}{I(2b)} = 1.2\times10^{-3}\left(\frac{V}{I}\right)$$

$$\tau_e = \frac{V(t)(2b)\left(\frac{h}{2}+\frac{1}{2}t\right)}{I(t)} = 9.6\times10^{-3}\left(\frac{V}{I}\right)$$

$$\tau_f = \frac{V\left[2bt+\frac{h}{2}t\right]\bar{y}_f^*}{It} = 10.8\times10^{-3}\left(\frac{V}{I}\right)$$



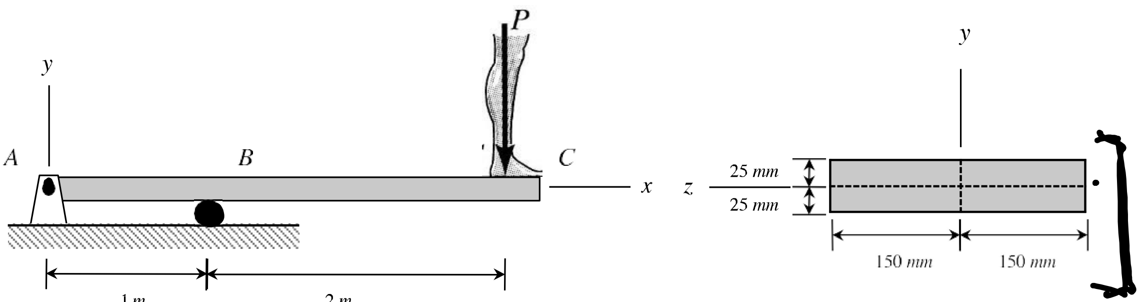

$$\bar{y}_f^* = \frac{\bar{y}_1A_1+\bar{y}_2A_2}{(A_1+A_2)}$$

$$\bar{y}_f^* = \frac{\left(\frac{h}{4}\right)\left(\frac{h}{2}t\right)+\left(\frac{h}{2}+\frac{t}{2}\right)(2bt)}{\left(\frac{h}{2}t\right)+(2bt)}$$

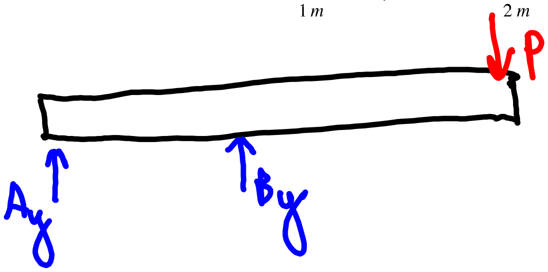
$$\bar{y} = \frac{1}{A}\int y\,dA.$$

### *Example 10.10*

A timber plank is to be used as a diving board. The diving board is held down at end A by a steel strap that is secured by anchor bolts and rests on a roller at location B. Calculate the maximum permissible load $P_{max}$ such that the maximum normal stress in the diving board does not exceed 11 $MPa$.

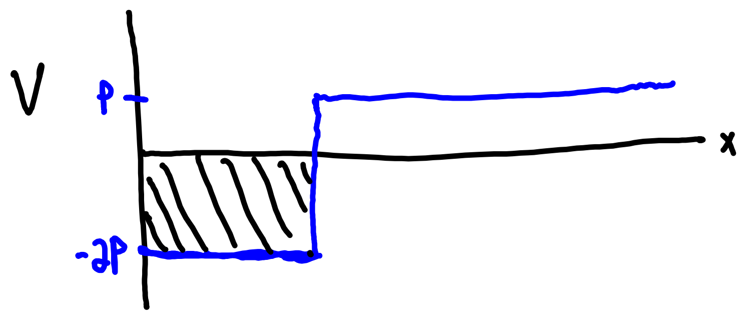



plank cross section

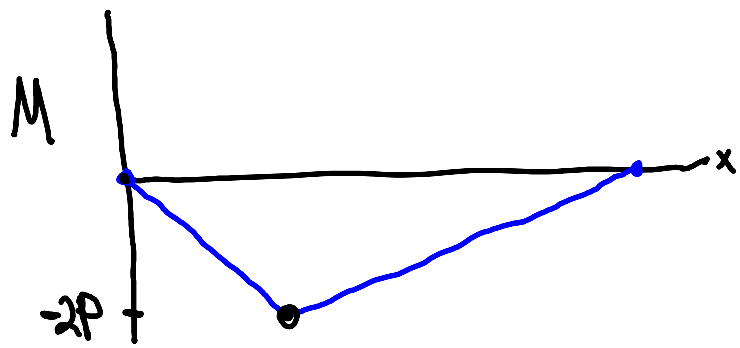



$B_y = 3P$

$A_y = -2P$




$$\sigma_{max} = \frac{-My}{I} = \frac{(2P)(h/2)}{\left(\frac{bh^3}{12}\right)} = \frac{12P}{bh^2}$$




$$P = \frac{bh^2}{12}|\sigma_{max}|$$

$$P_{max} = \frac{(0.3m)(0.05m)^2}{12}(11 \times 10^6\ Pa)$$

$$P_{max} = 687\ N = 70\ kg = 154\ lbs.$$