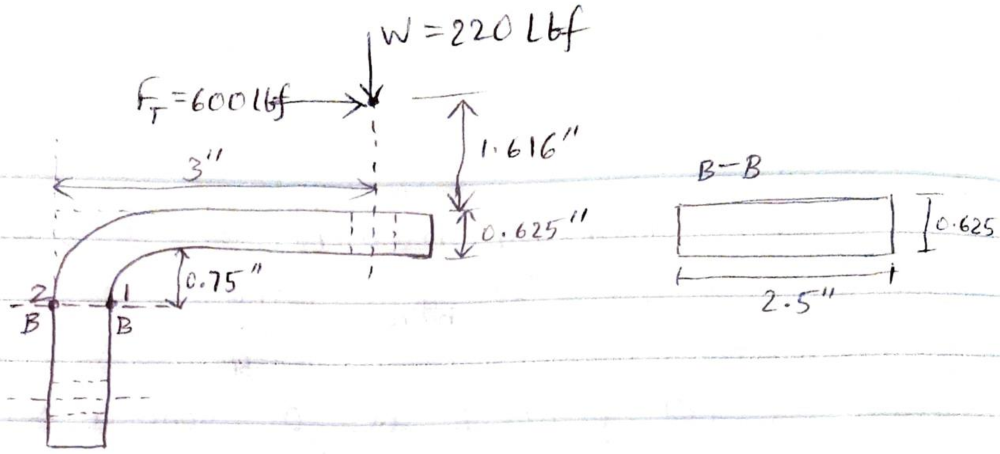
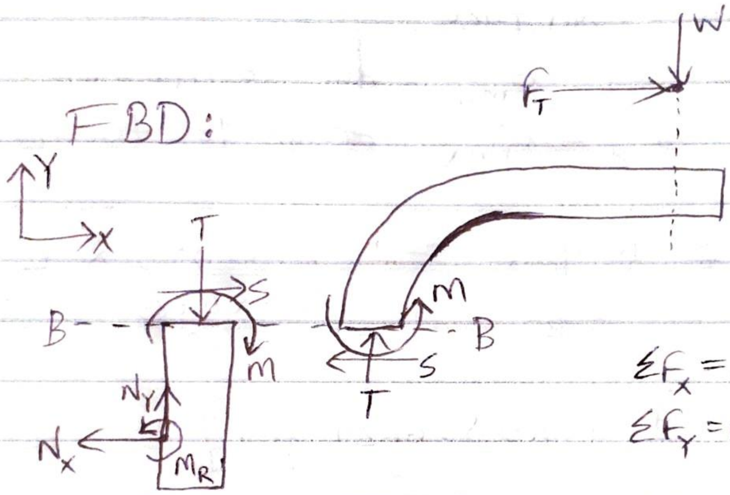
Problem1: Trailer hitch –

Q.1. a.



FBD:



$$\Sigma F_x = 0 \Rightarrow S = F_T = 600 \text{ lbf}$$

$$\Sigma F_y = 0 \Rightarrow T = W = 220 \text{ lbf}$$

$$\Sigma M = 0 \Rightarrow M = F_T \times (1.616 + 0.625 + 0.75) + W\left(3 - \frac{0.625}{2}\right)$$

$$\therefore M = 600 \times 2.991 + 220 \times 2.6875$$

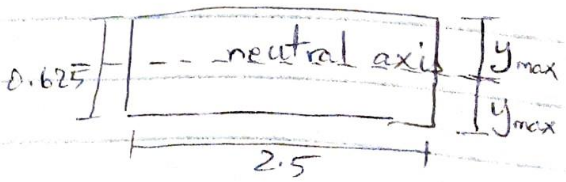
$$\therefore M = 2385.85 \text{ lbf.in} \quad \text{—— (1)}$$

Area moment of Inertia at B-B:

$$I_{BB} = \frac{bd^3}{12} = \frac{2.5 \times 0.625^3}{12} \text{ in}^4 \quad \text{—— (2)}$$

Assuming neutral axis is at center:

$$y_{max} = \frac{0.625}{2} \text{ in} \quad \text{—— (3)}$$



Bending moment at B-B:

$$\sigma_{bending} = \frac{My}{I_{BB}}$$

Let point 1 be at concave surface & point 2 at convex surface,

then, $\sigma_1 = \sigma_{min}$ due to compression

& $\sigma_2 = \sigma_{max}$ due to tension

$$\sigma_{max/min} = \pm \frac{M y_{max}}{I_{BB}} = \pm \frac{2385.85}{\frac{2.5 \times 0.625^3}{12}} \times \frac{0.625}{2}$$

$$\therefore \boxed{\sigma_{max/min} = \pm 14658.6624 \text{ psi}}$$

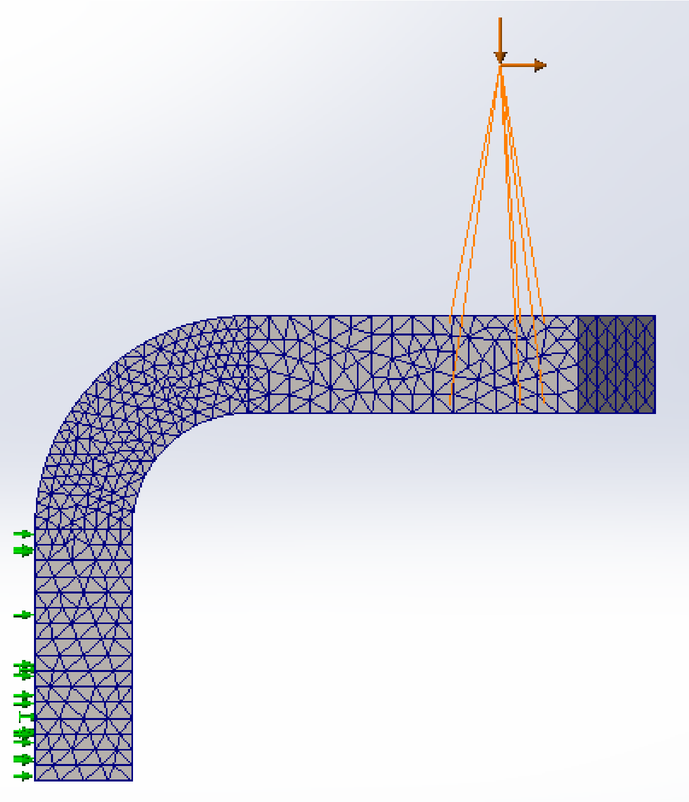
At concave surface,

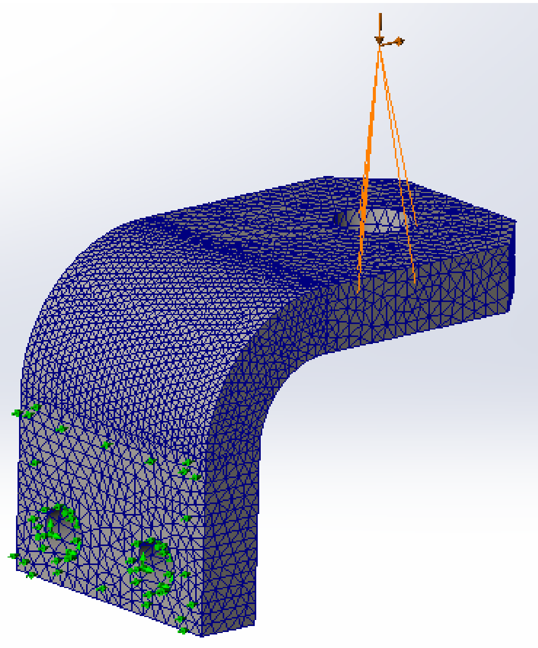
$$\sigma_1 = \sigma_{min} = -14658.6624 \text{ psi}$$

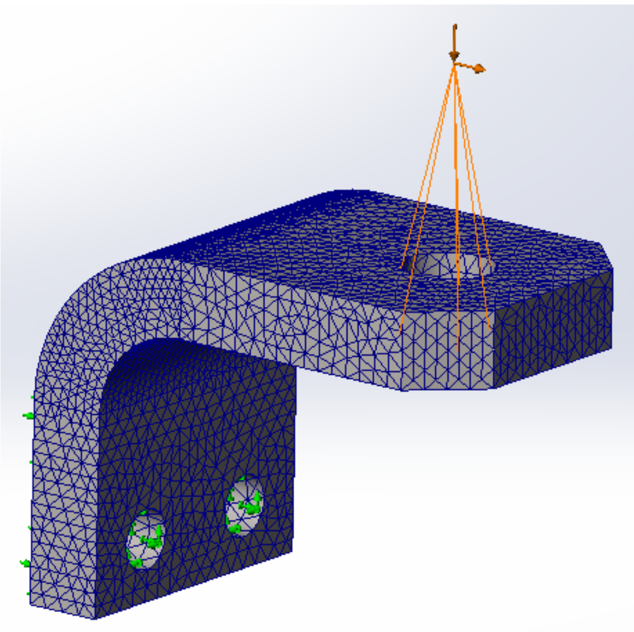
At convex surface,

$$\sigma_2 = \sigma_{max} = +14658.6624 \text{ psi}$$

Q1.b. FEA model showing fixtures, remote loads, and mesh:





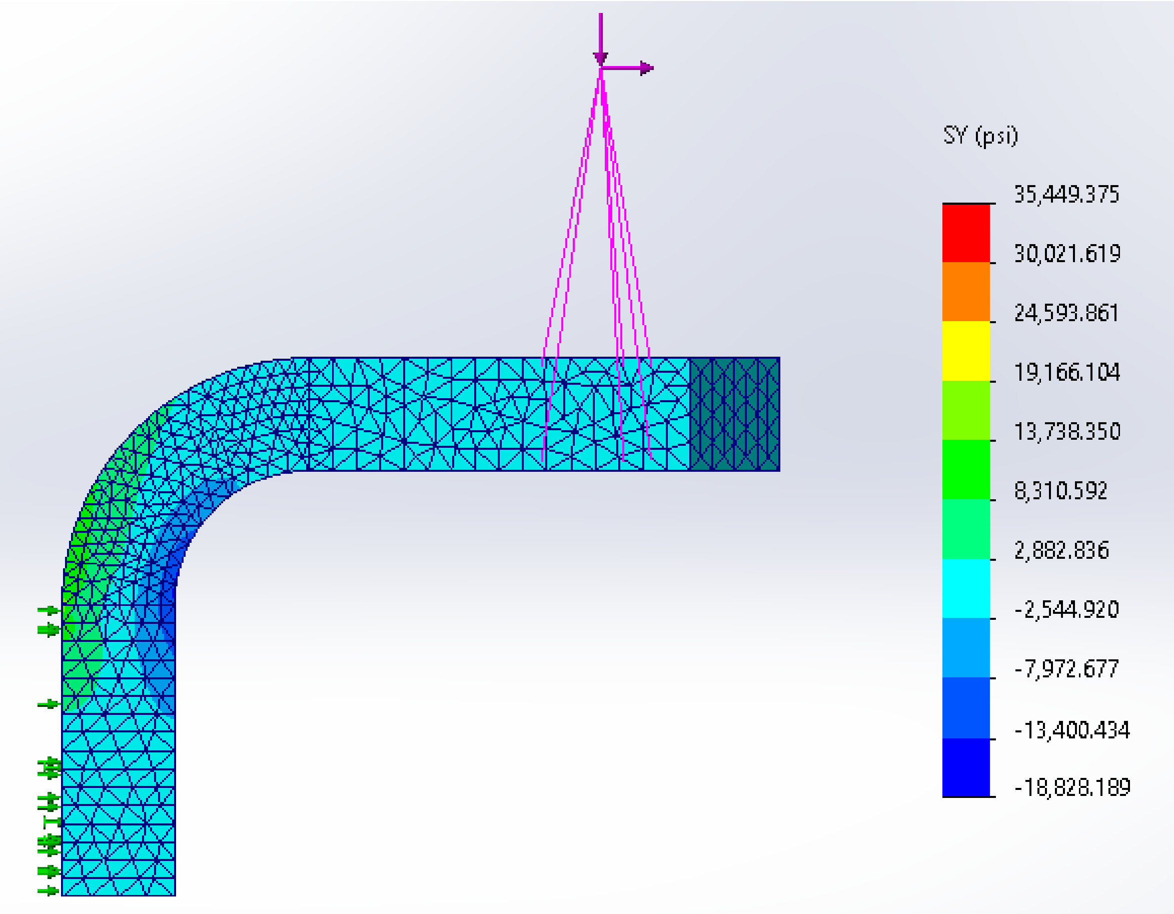


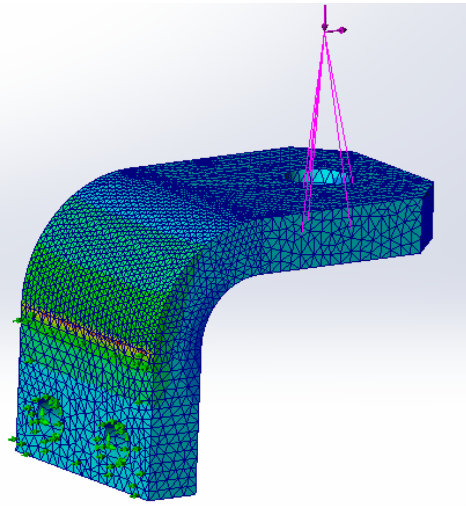
Fixtures: Fixed geometry on bolt hole walls & Roller support on side touching vehicle.

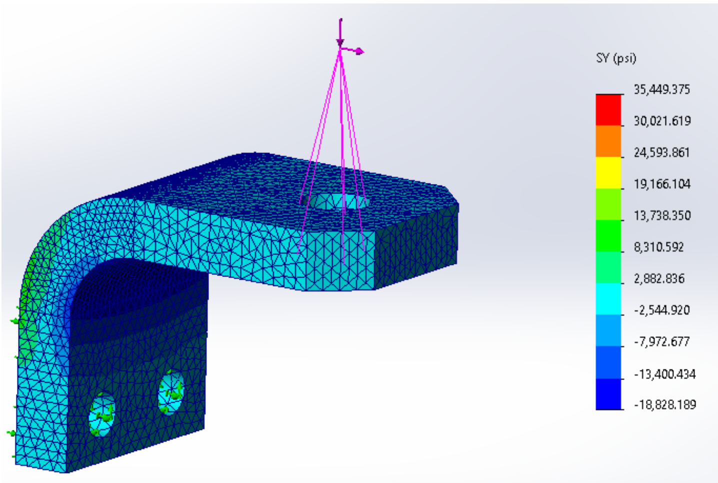
Remote load: Tow force = 600 lbf & Tongue weight = 220 lbf.

Q1.c.

Bending stress given by stress in Y-direction:

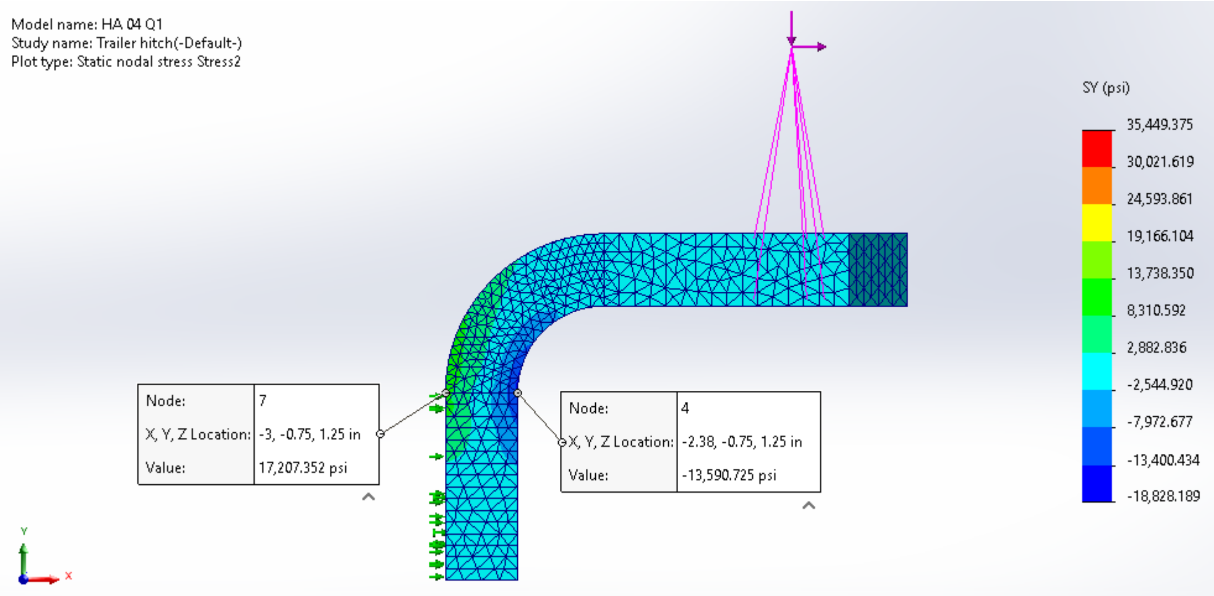






Q1.d.

Using probe to get values of bending stress at concave & convex sides of section B-B:



Q1.e. Comparing bending stress between FEA & classical:

At concave side,

Classical: $\sigma_1 = -14658.66\, psi$

FEA: $\sigma_1 = -13590.725\, psi$

Difference w.r.t. classical: 7.3%

At convex side,

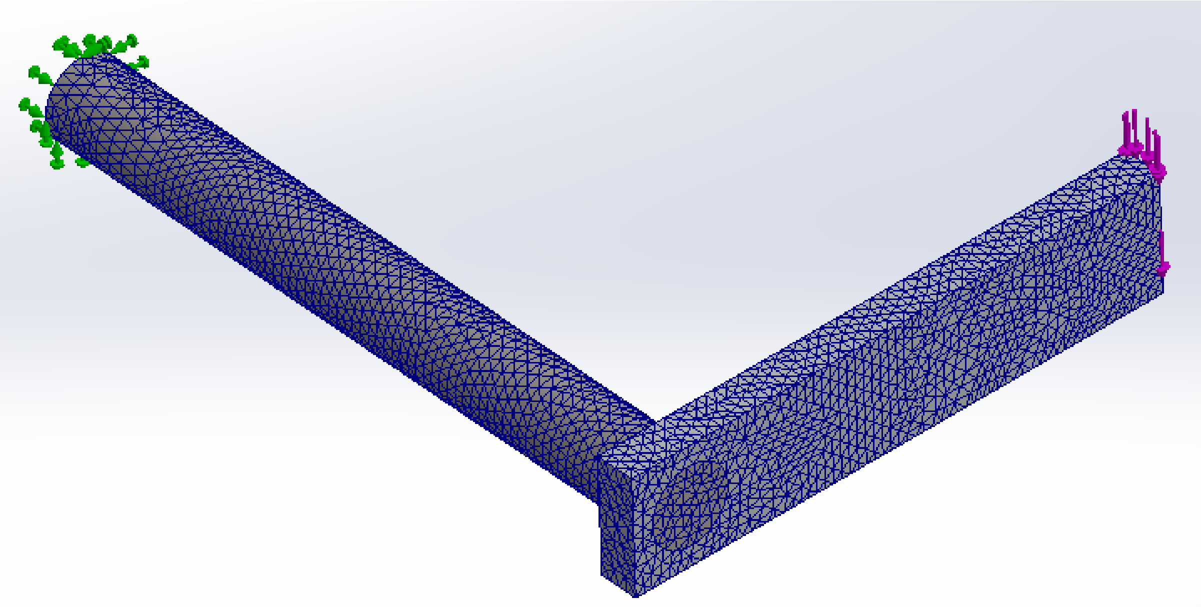
Classical: $\sigma_2 = 14658.66\, psi$

FEA: $\sigma_2 = 17207.352\, psi$

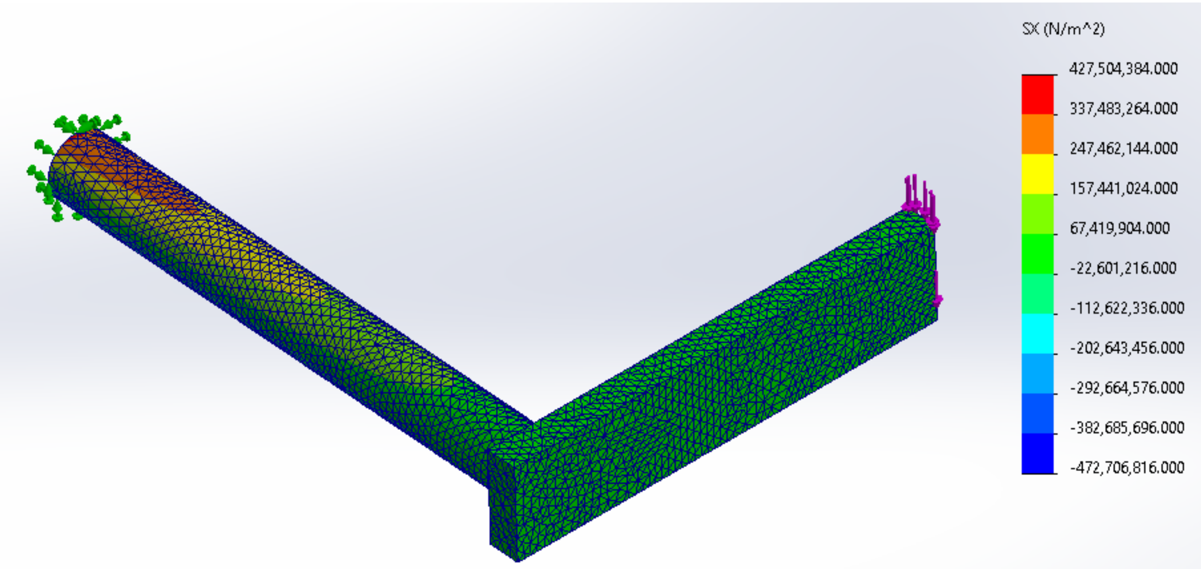
Difference w.r.t. classical: 17.4%

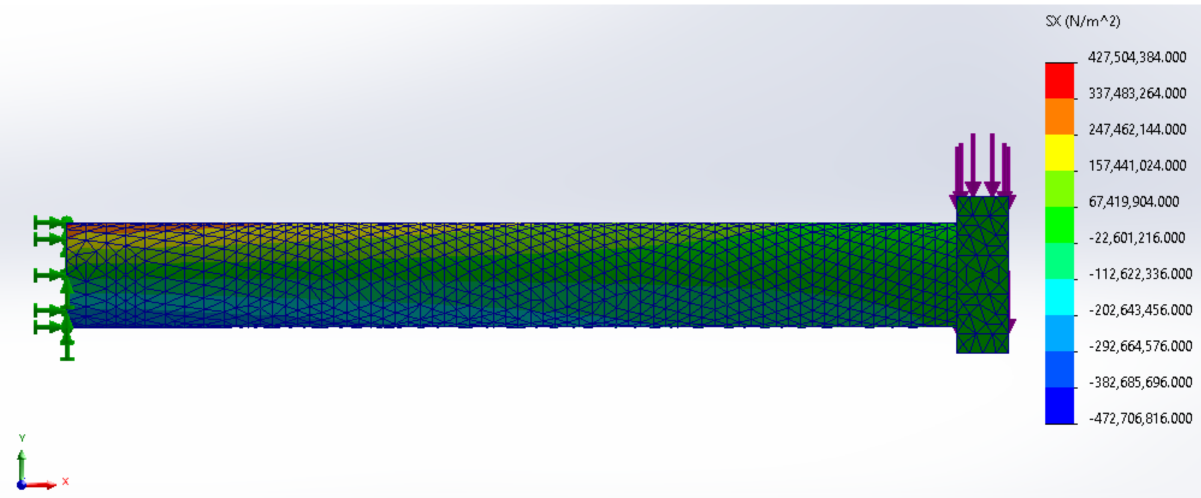
Conclusion: The FEA results are within 20% of the classical values for bending stress where we consider assumptions of 2D, uniform cross-section, neutral axis at centre. This can be taken care by considering a factor of safety of 1.2 or above for safe design in actual working conditions.

Problem 2: L-shaped cantilever beam –

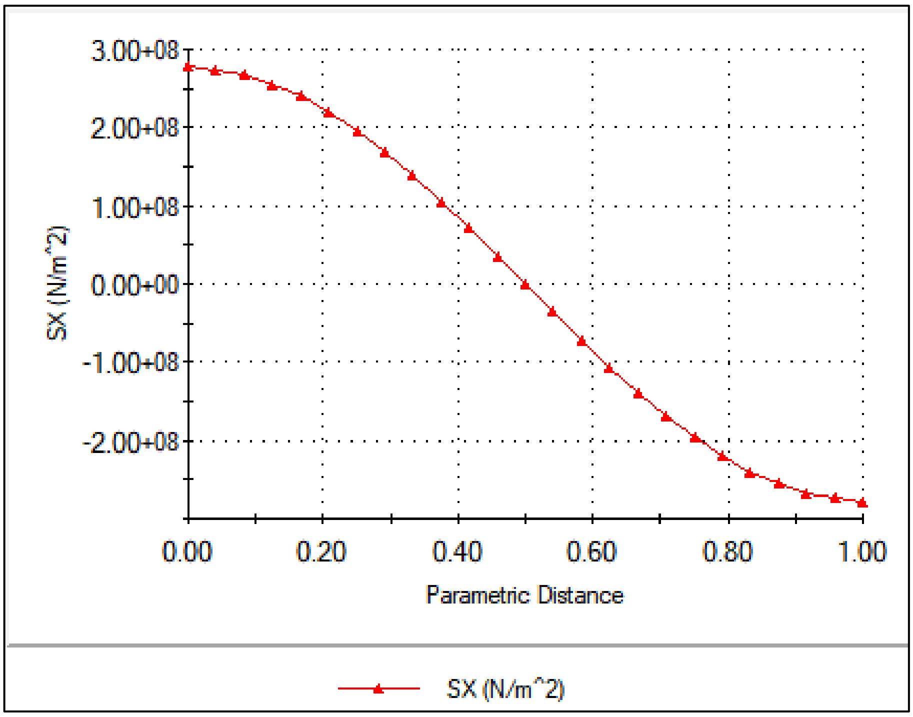


Q2.a. Bending stress given by stress in X-direction:

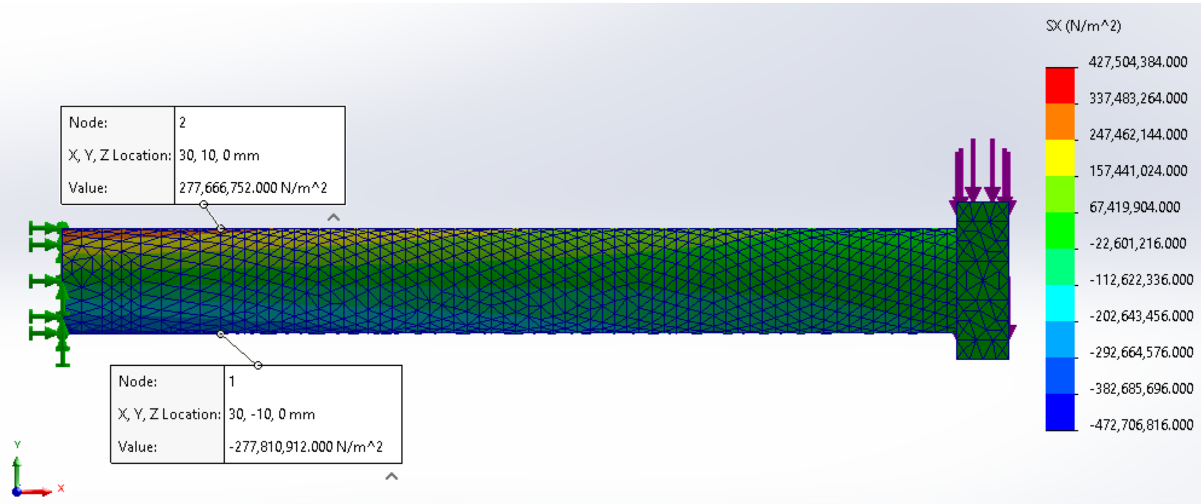




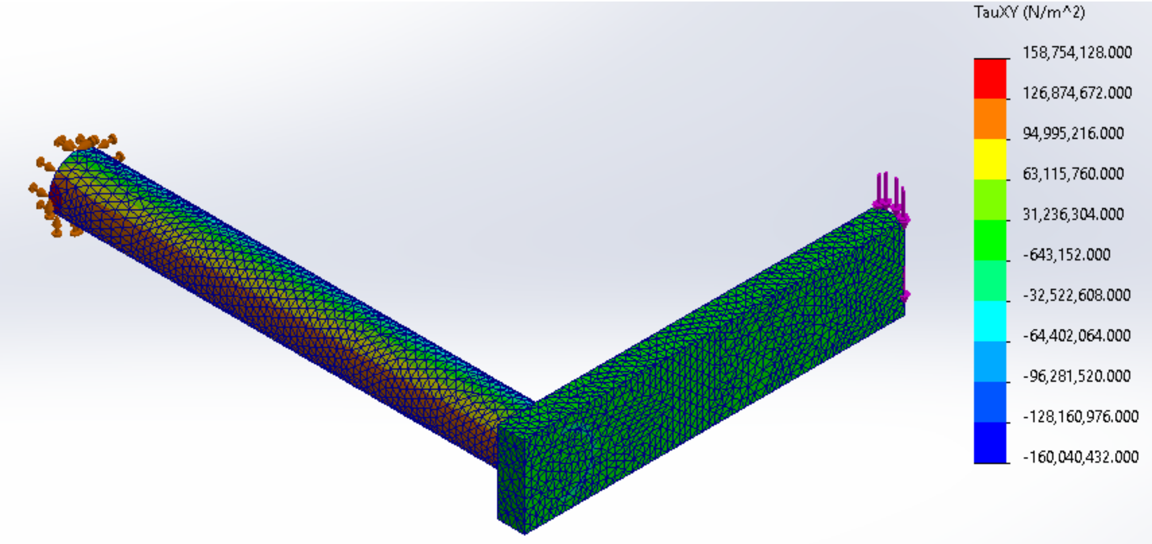
Q2.b. Using probe feature to create a XY plot of bending stress from the top to bottom of beam AB at section Z-Z:



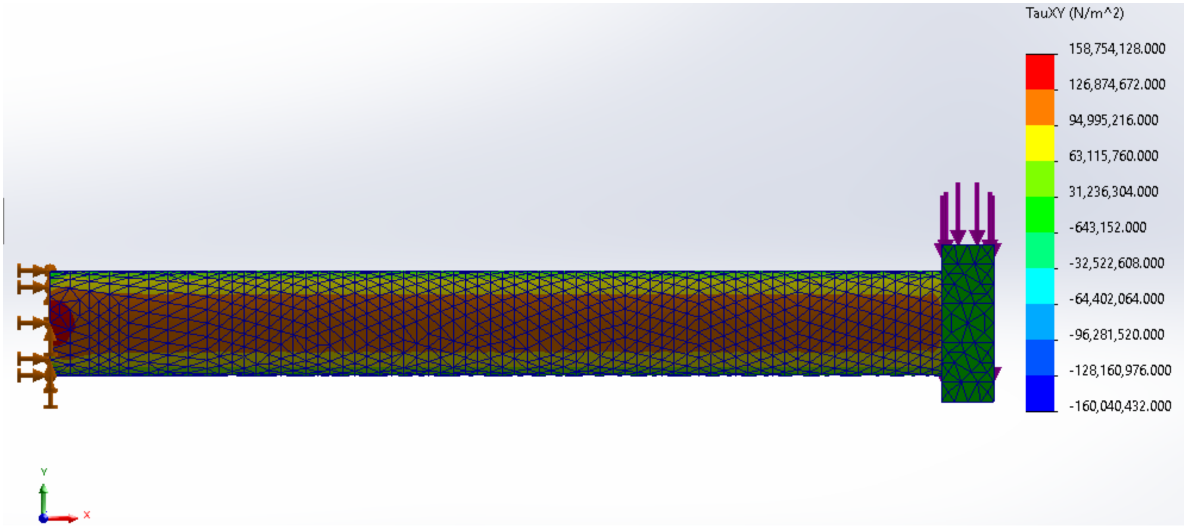
Using probe to get values of bending stress at top & bottom of section Z-Z:

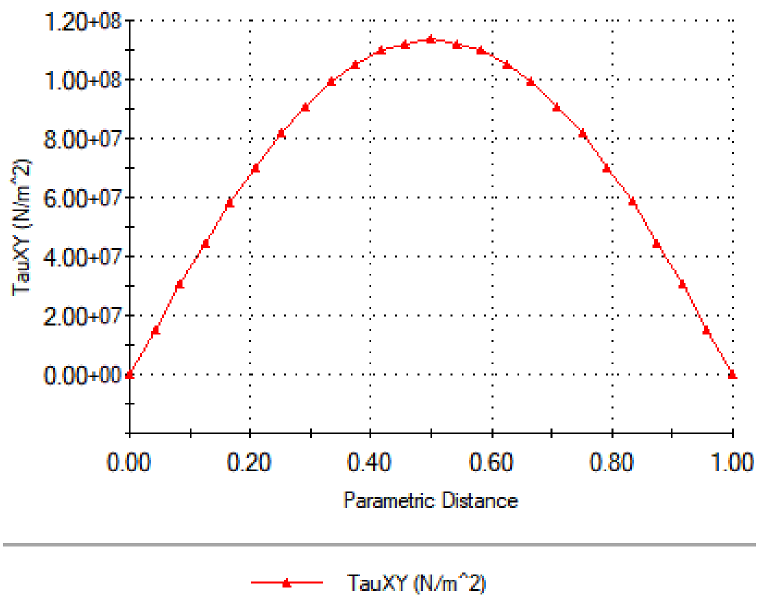


Q2.c. Shear stress τxy:



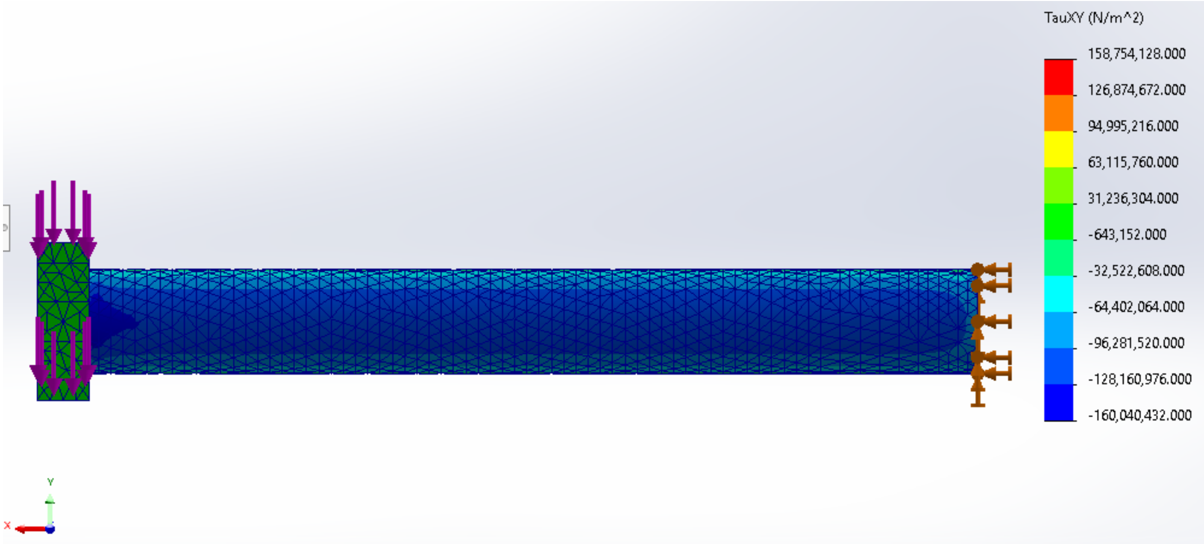
XY plot of shear stress τxy at section Z-Z using the probe feature, front side:

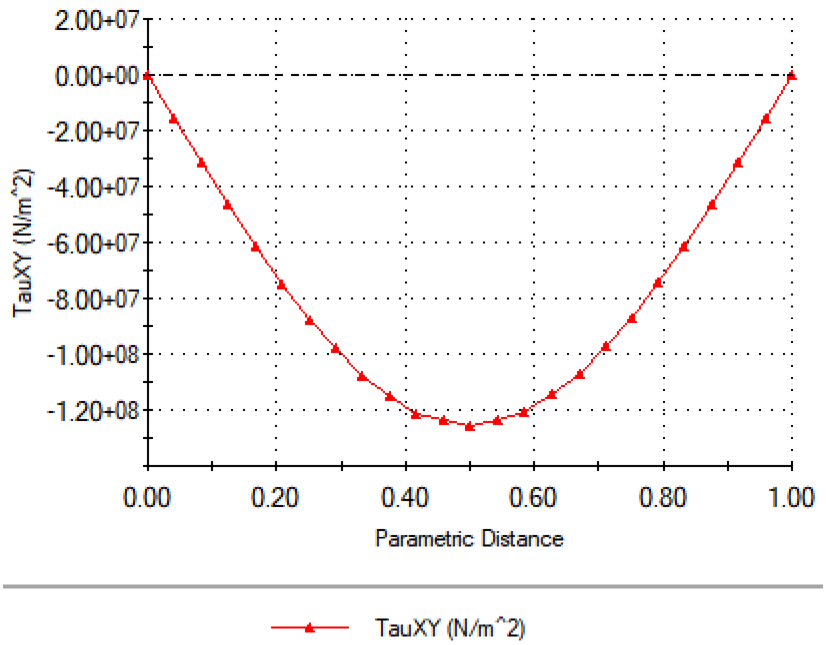




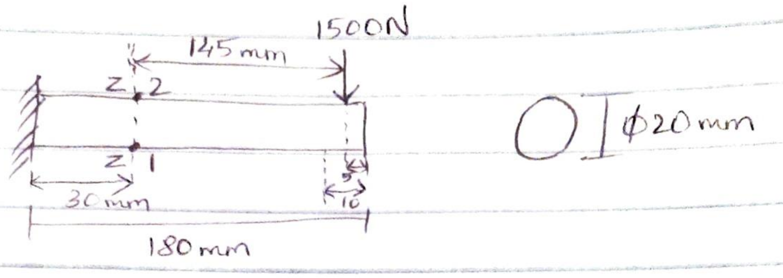
XY plot of shear stress τxy at section Z-Z using the probe feature:

Back side,





Q.2.d.



Bending moment at Z-Z:

$$M = 1500 \times 0.145 = 217.5 \text{ Nm}$$

$$y_{max} = 10 \text{ mm} = 0.01 \text{ m}$$

$$I_{zz} = \frac{\pi D^4}{64} = \frac{\pi (0.02)^4}{64} = 7.854 \times 10^{-9} \text{ m}^4$$

$$\sigma_{max/min} = \pm \frac{M y_{max}}{I_{zz}} = \pm \frac{217.5 \times 0.01}{7.854 \times 10^{-9}} = 276928953 \text{ N/m}^2$$

$$= 0.27693 \times 10^9 \text{ Pa}$$

$$= 0.27693 \text{ GPa}$$

Bending stress at top,

$$\sigma_2 = \sigma_{max} = +276928953 \text{ N/m}^2$$

Bending stress at bottom,

$$\sigma_1 = \sigma_{min} = -276928953 \text{ N/m}^2$$

Q2.e. Comparing bending stress between FEA & classical:

At bottom,

Classical: $\sigma_1 = -276{,}928{,}953 \ N/m^2$

FEA: $\sigma_1 = -277{,}810{,}912 \ N/m^2$

Difference w.r.t. classical: 0.3%

At top,

Classical: $\sigma_2 = 276{,}928{,}953 \ N/m^2$

FEA: $\sigma_2 = 277{,}666{,}752 \ N/m^2$

Difference w.r.t. classical: 0.3%

Conclusion: The FEA results are within 0.5% of the classical values for bending stress where we consider assumptions of 2D, uniform cross-section, neutral axis at centre. We can say that the results closely align as the geometry is simple and our assumptions are sufficiently considering the actual loading condition. Nonetheless, considering a factor of safety of 1.2 or above for safe design is good practice.