

Q1

a) Force due to pressure

$$F = P \times A$$

$$= P \times (\text{diameter} \times \text{Length})$$

$$= P \times dL$$

Force due to resistance of material

$$F = 2 \sigma_H \times L t$$

$$2 \sigma_H \times L t = P d L$$

$$\sigma_H = \frac{P d L}{2 L t}$$

$$\sigma_H = \frac{P d}{2 t}$$

b) The limiting factor is longitudinal stress Not hoop stress as shown below;

$$\sigma_H = \frac{P d}{2 t}$$

$$\sigma_L = \frac{P d}{4 t}$$

$$\sigma_L = \frac{1}{2} \text{ of } \sigma_H$$

c)

$$1.0265 \text{ g/cm}^3 = 1.0265 \times 10^{-3} \text{ kg/cm}^3 = 1.0265 \times 10^3 \text{ kg/m}^3$$

$$= 1026.5 \text{ kg/m}^3$$

① d)

$$d = 5.7 \text{ m}$$

$$t = 5.7 \text{ mm} = 0.0075 \text{ m}$$

$$P = \text{~~1026.5 kN/m~~ } 1026.5 \text{ kN/m}$$

$$J = 9.81$$

$$\sigma_{\max} = \frac{200 \text{ mpa}}{2.1} = 95.24 \text{ mpa}$$

$$G_L = \frac{P d}{4 t}$$

$$P = \frac{G_L 4 t}{d} = \frac{95.24 \times 10^6 \cdot 4 \cdot 0.0075}{5.7} = 501263.16 \text{ Pa} = 0.5 \text{ Mpa}$$

$$P = \rho g h$$

$$\textcircled{1} h = \frac{P}{\rho g}$$

As the submarine is weaker longitudinally we use  $G_L$  to find pressure.

$$\textcircled{1} h = \frac{501263.16}{\text{~~1026.5~~ } \cdot 9.81} = \text{~~49.78 m~~ } 49.78 \text{ m}$$

← ?  
X

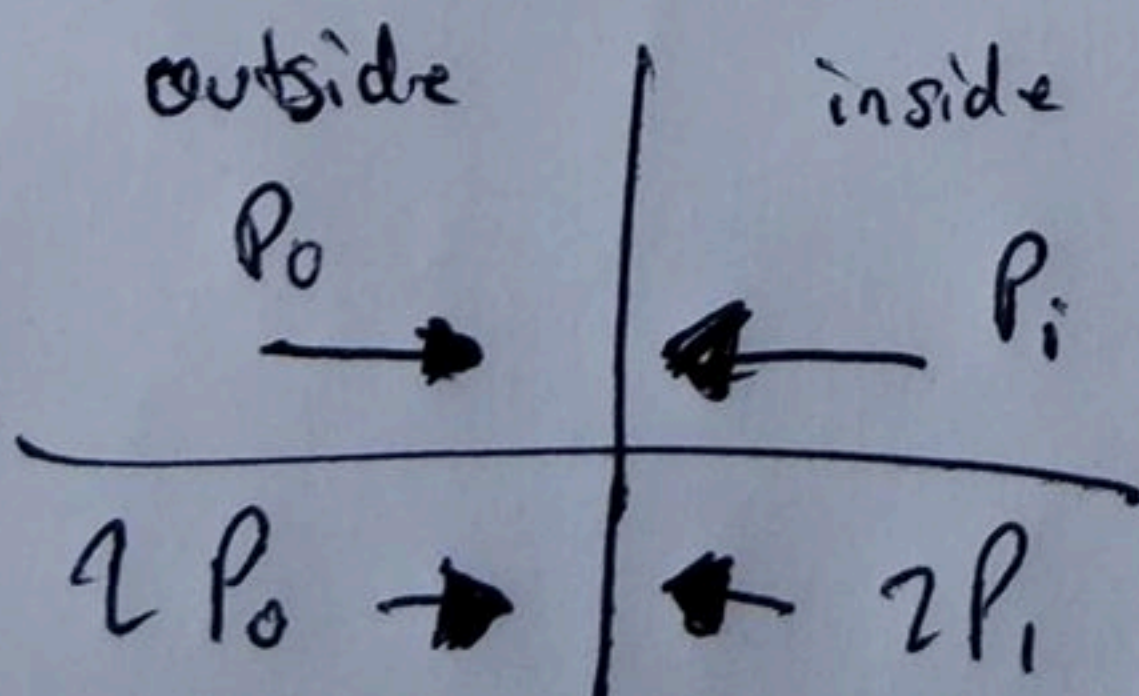
e)

$$h = \frac{P_i + P_o}{\rho g} = \frac{501263.16 + 0.1 \times 10^6}{\text{~~1026.5~~ } \cdot 9.81} = \text{~~54.71 m~~ } 54.71 \text{ m}$$

ECF

F)

It would double the ~~depth~~ depth available.



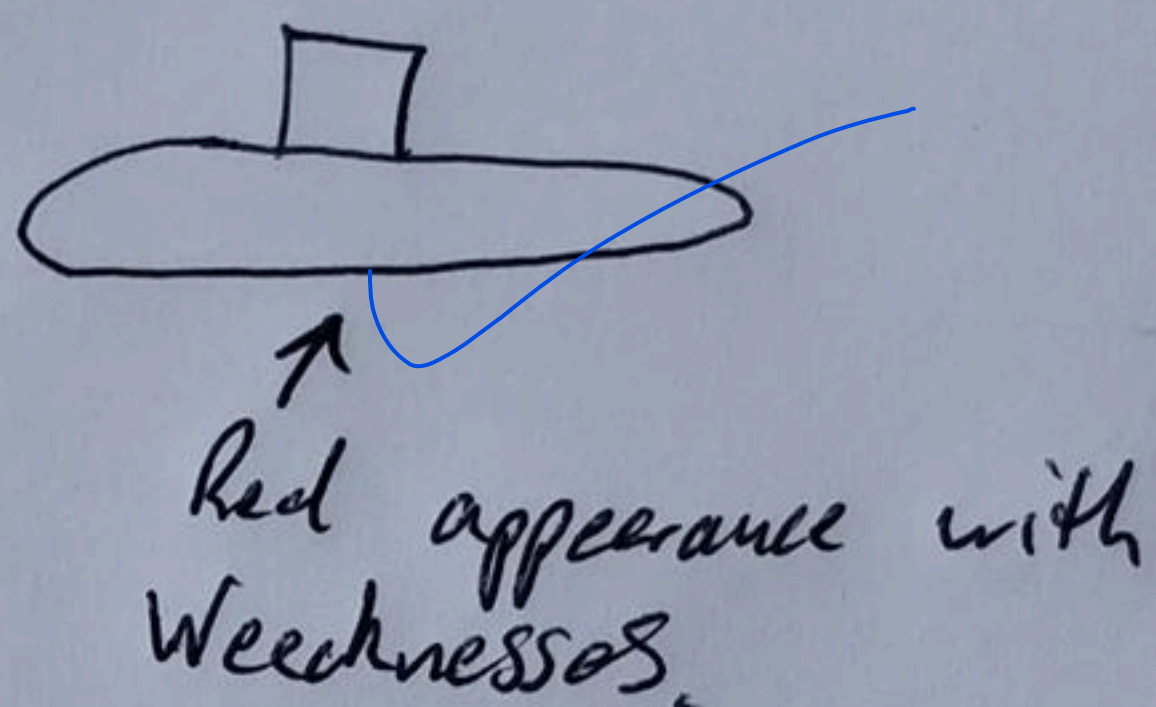
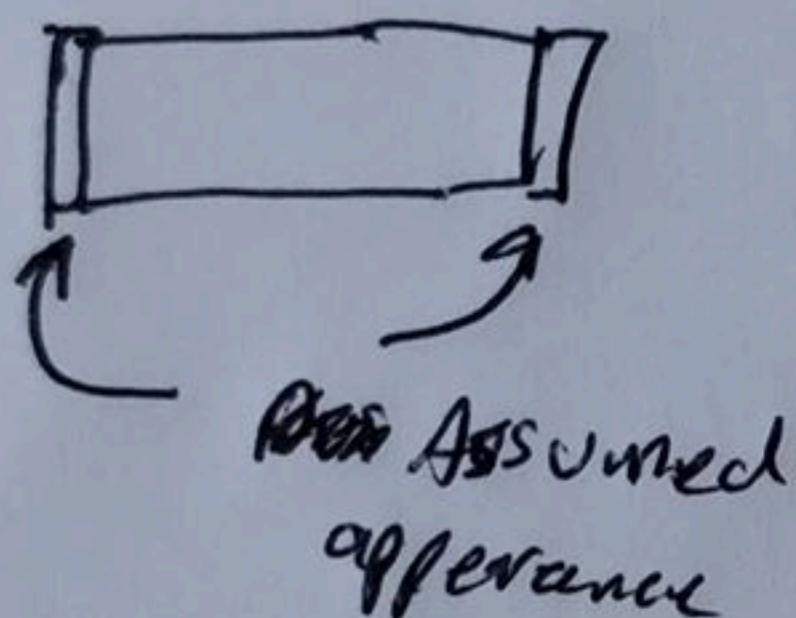
if  $P_i$  was double along with  $P_o$  the ratio would be the same,

$$54.71 \times 2 = 119.42 \text{ m}$$

X

① G) It shows a ratio between inside and outside pressure, As long as it is maintained the sub can go deeper.

F) The question implies that the sub is a perfect cylinder with rigid ends.



Also the internal pressure has to be suitable for human lungs.

(2)  
a)

Define the Problem - by finding out the customer needs.

Developing a problem statement which should suggest possible solutions very basically. Also establish criteria for success.

Gather Relevant Info - Such as find solutions that already exist, considering economic factors that may play a part in solution. Consider the cost to you and also the customer.

Generate Multiple Solutions - Include initial brainstorm session which should include people from different areas / departments.

Also allowing people to take risks within the design.

Analyse and select Solution - The following should be considered:

- Manufacture ability - Can it be made? - Market Analysis - is it worth it?
- Ergonomics
- Safety
- Reliability
- Strength and robustness

Test and implement Solution - Firstly apply for relevant patents,

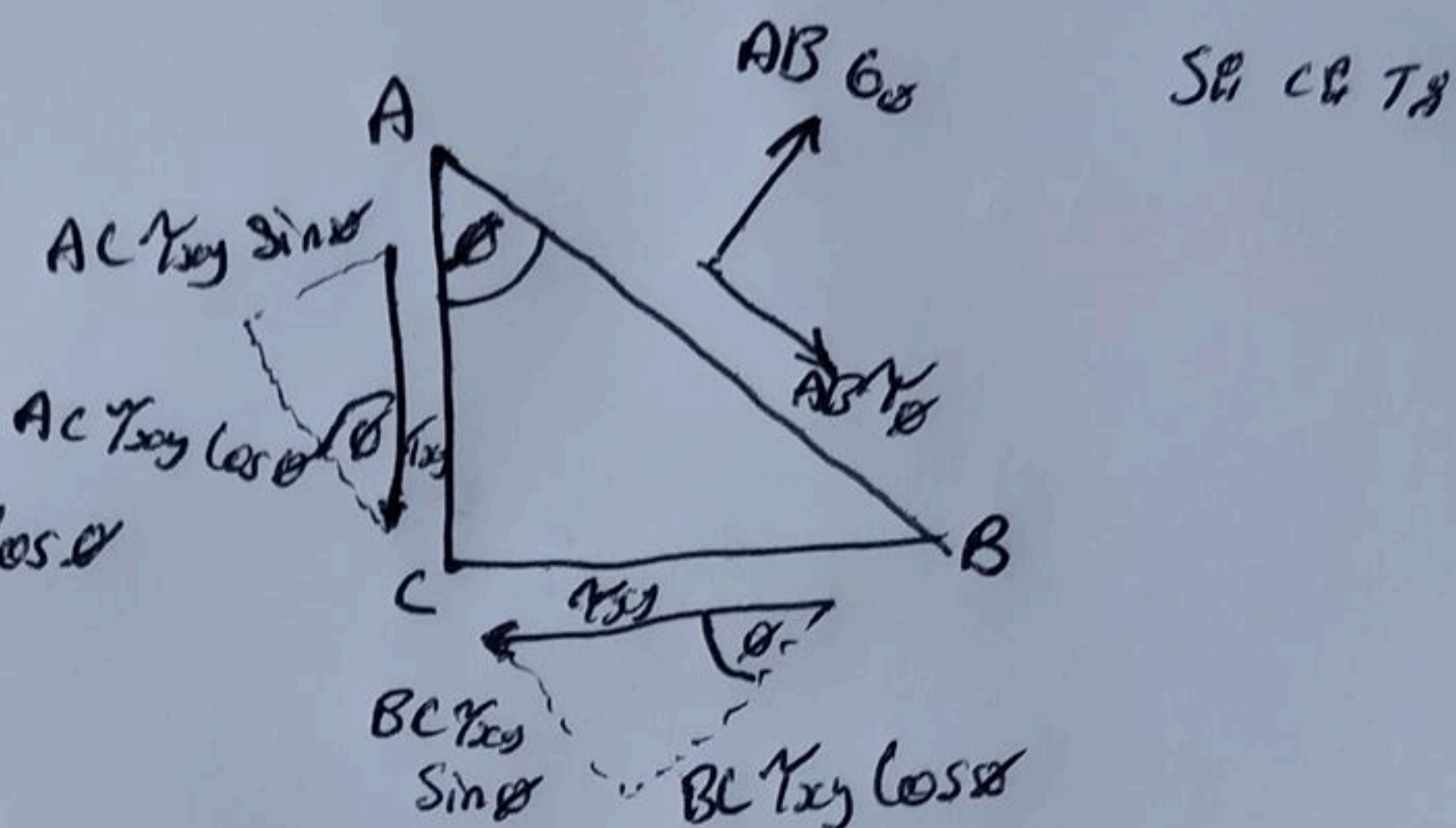
Creating design documentation including any legislation related information e.g. emissions tests? Finally prototype design and test under 'real world conditions' to test and confirm design and prove ability of manufacturing techniques.

b) FEA along with CAE could be used early whilst generating multiple solutions, and when analysing given designs. This would streamline the process and eliminate bad designs early on, saving time and money. It could also show potential manufacturing issues.

(4) a)

As the element is in equilibrium:

$$AB \cos \theta = AC \tau_{xy} \sin \theta + BC \tau_{xy} \cos \theta$$



$$\cos \theta = \frac{AC}{AB} \tau_{xy} \sin \theta + \frac{BC}{AB} \tau_{xy} \cos \theta$$

From Trig:

$$\cos \theta = \tau_{xy} \sin \theta \cos \theta + \tau_{xy} \sin \theta \cos \theta$$

$$AB \cos \theta = AC$$

$$AB \sin \theta = BC$$

$$\cos \theta = 2 \tau_{xy} \sin \theta \cos \theta$$

$$\cos \theta = \frac{AC}{AB}$$

$$\sin \theta = \frac{BC}{AB}$$

From question:

$$\cos \theta \sin \theta = \frac{1}{2} \sin 2\theta$$

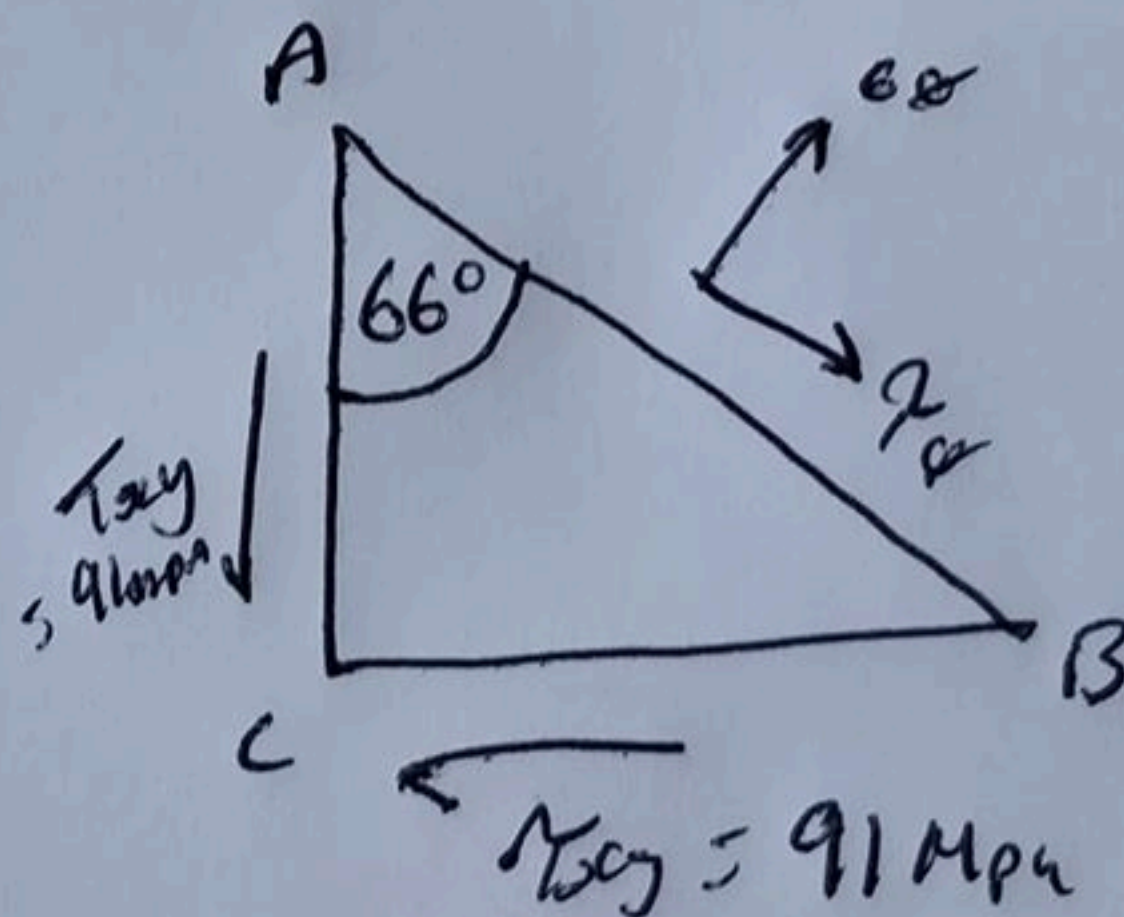
$$\cos \theta = \tau_{xy} \sin 2\theta$$

b)

$$AB \cos \theta = \tau_{xy} \sin 2\theta$$

$$= 91 \times 10^6 \cdot \sin 2(66)$$

$$= 67.6 \text{ MPa}$$

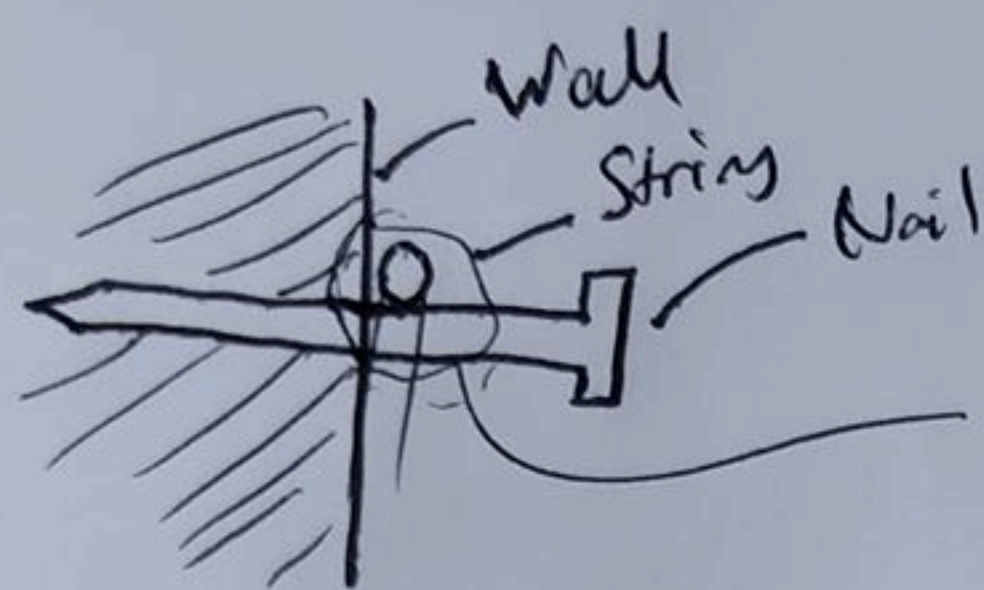


$$c) \tau_{\theta} = -\tau_{xy} \cos 2\theta$$

$$= -91 \times 10^6 \cdot \cos 2(66)$$

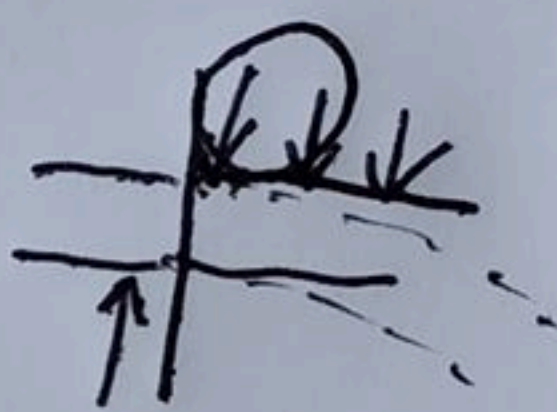
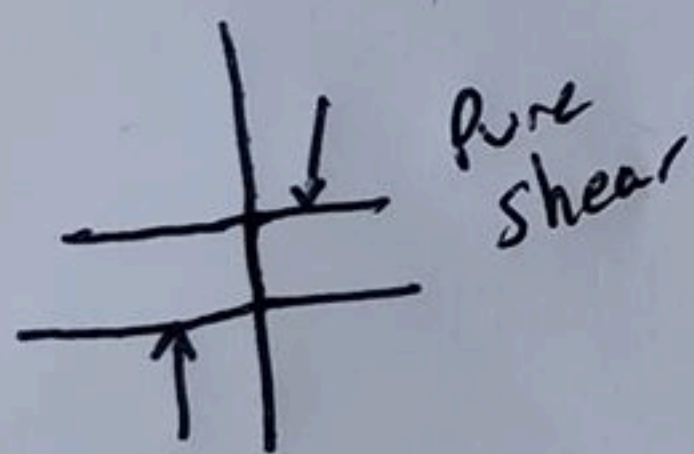
$$= -6.09 \times 10^5 \text{ Pa}$$

④ d) A Nail in a wall holding up a painting



gravity pulling string down due to weight of painting.  
Shear  
Resistive Force of the wall

e) The string has a thickness, therefore the force is not purely shear, it will have a small amount of bending moment.



Some bending will occur.

Also shear strain assumes no change in volume, to some degree the string ~~will~~ would deform.