

(a) 10mm Bolt
 $\Rightarrow A = \left(\frac{10 \times 10^{-3}}{2}\right)^2 \pi = \underline{7.85 \times 10^{-5} \text{ m}^2}$

$$\sigma_0 = \frac{F_0}{A} = \frac{2 \times 10^3}{7.85 \times 10^{-5}} = \underline{25.5 \text{ MPa}}$$

$E_0?$ $E = 5 \exp(-t^{\frac{1}{3}}) \text{ GPa}$ if $t=0$
 $\exp(-0) = 1$

$$E_0 = 5 \text{ GPa}$$

$$\epsilon_0 = \frac{\sigma_0}{E_0} = \frac{25.5 \times 10^6}{5 \times 10^9} = \underline{5.1 \times 10^{-3} \approx 0.5\%}$$

(b) 24 hours
 $E(24 \text{ hours}) = 5 e^{-24^{\frac{1}{3}}} \text{ GPa} = 2.79 \times 10^8 \text{ Pa}$

$$\sigma_{24} = E(24) * \epsilon = (2.79 \times 10^8) (5.1 \times 10^{-3})$$

$$= \underline{1.43 \text{ MPa}}$$

$$F = \sigma A = (1.43 \times 10^6) (7.85 \times 10^{-5})$$

$$F = 111 \text{ N}$$

Strain is constant.

$$\boxed{e^{-\sqrt[3]{24}} \approx e^{-3}}$$

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(c) Bolt re-tightened to orig force
 \Rightarrow re-tightened to orig stress also.

$$\Delta \sigma = 25.5 - 1.43 = 24.07 \text{ MPa}$$

additional strain

$$E(0) = 5 \text{ GPa} \Rightarrow \text{extra } \epsilon = \frac{24.07 \times 10^6}{5 \times 10^9} = 4.81 \times 10^{-3}$$

$$\text{So } \epsilon = \underbrace{4.81 \times 10^{-3}}_{\text{2nd Tighten}} + \underbrace{5.1 \times 10^{-3}}_{\text{1st}} \approx 9.9 \times 10^{-3}$$