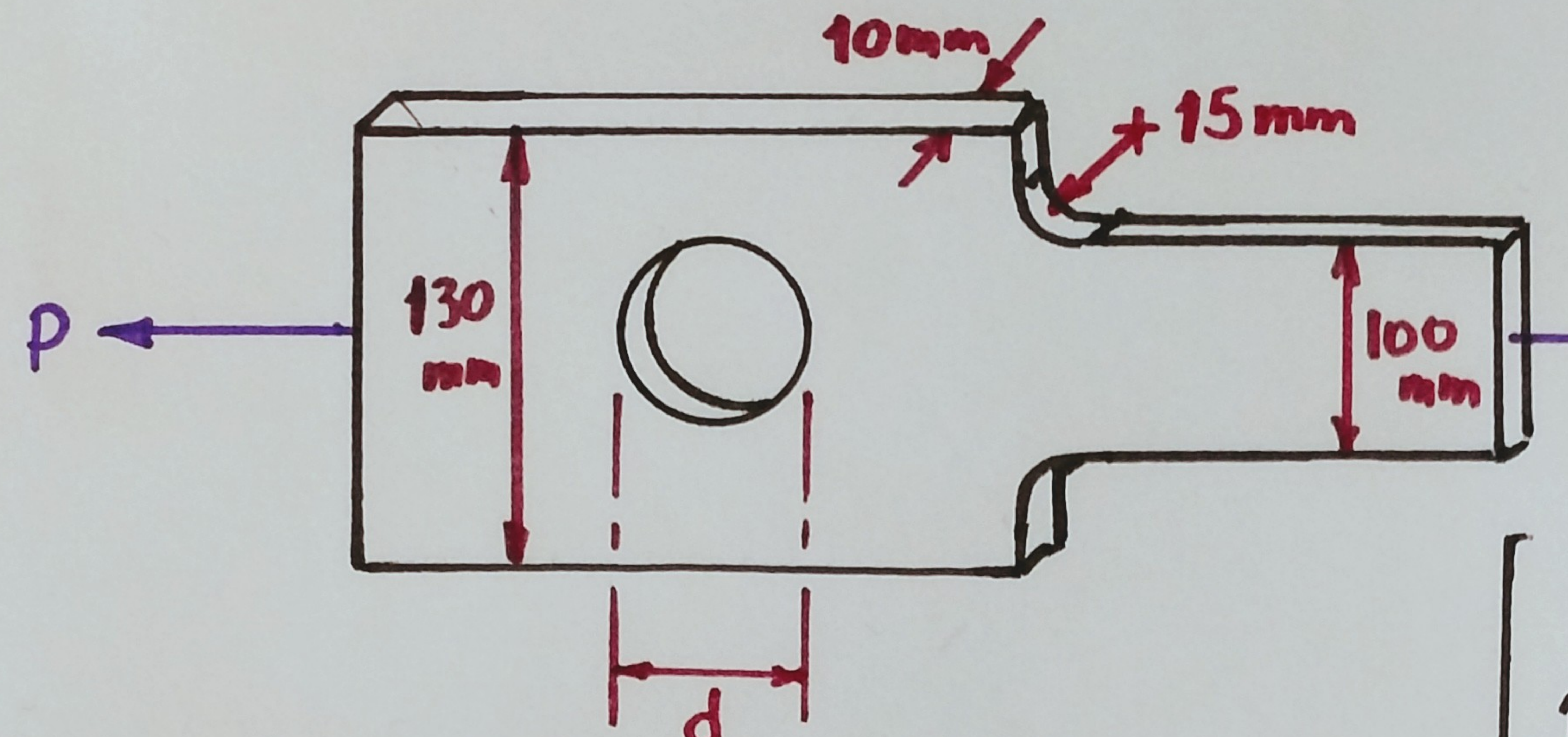


ES 2502 1/2
@WPI·ME
E05-1

Mtl. Ti-6Al-4V

$P = P_{max} = 60\,kN$

$\sigma = \sigma_{max} = 150\,MPa$

$(\sigma_y \approx 880\,MPa \Rightarrow SF \approx 6)$

@ Shoulder.

Figure 4-23/Hibbeler/10th Ed

$\frac{r}{h} = \frac{15}{100} = 0.15$; $\frac{w}{h} = \frac{130}{100} = 1.3$

$\Rightarrow k_s \approx 1.7 \Rightarrow \sigma_s = \frac{60\times10^3\,N \cdot k_s}{(0.010)(0.100)\,m^2} = 102\,MPa$; well within safety factor.

@ Hole.

Figure 4-24/Hibbeler/10th Ed

Assume an initial dimension for d.

(a) Iterate by trying different diameters; (b) or try $\neq k_h$.

- Use direct approach: $\sigma_{max} = 150\times10^6\,Pa = k_h \cdot \frac{P}{(w-d)\cdot t}$

$= k_h \cdot \frac{60\times10^3\,N}{(0.13-d)(0.010)\,m^2}$

- Note: $k_h = k_h(d, w)$
  $\Rightarrow$ Function isn't known

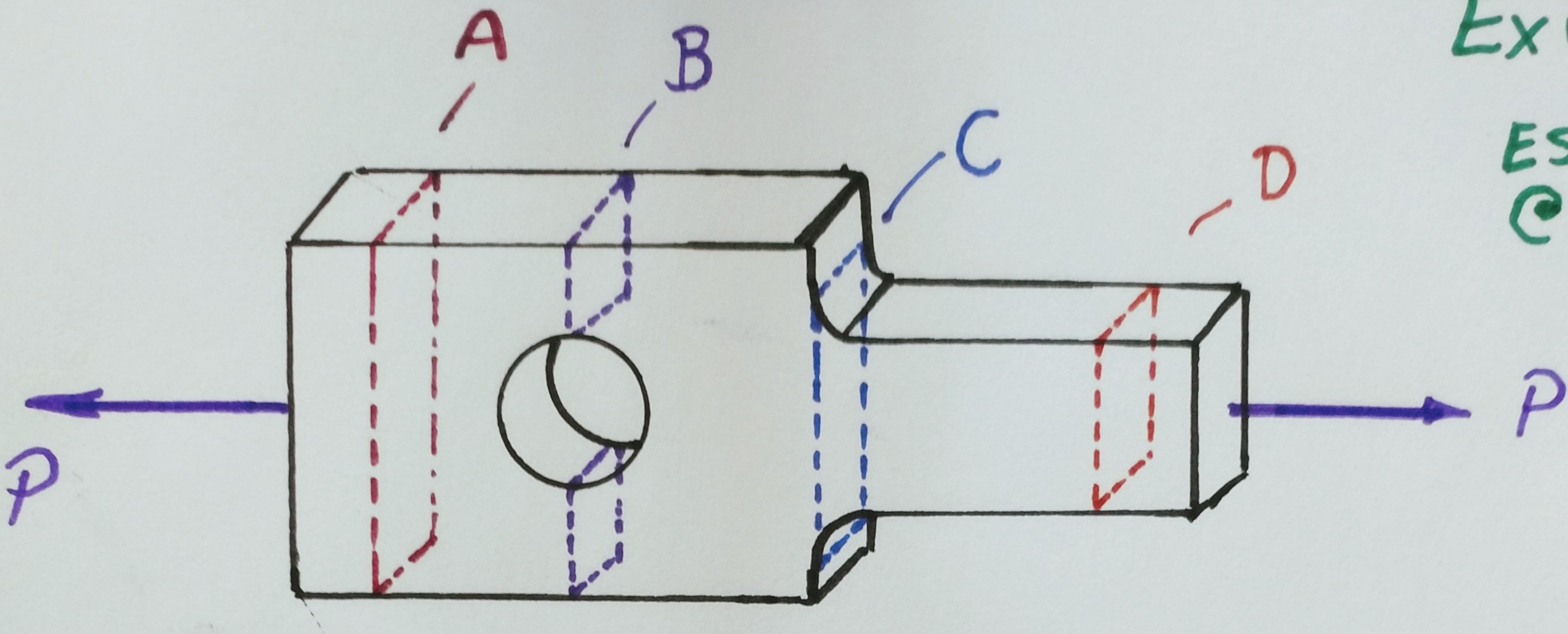
- Select d to minimize k_h (see Figure 4-24)

$\Rightarrow k_h = \frac{150\times10^6}{60\times10^3} \cdot (0.13-d)(0.010)$ – No units

5 points total

Ex 05-1

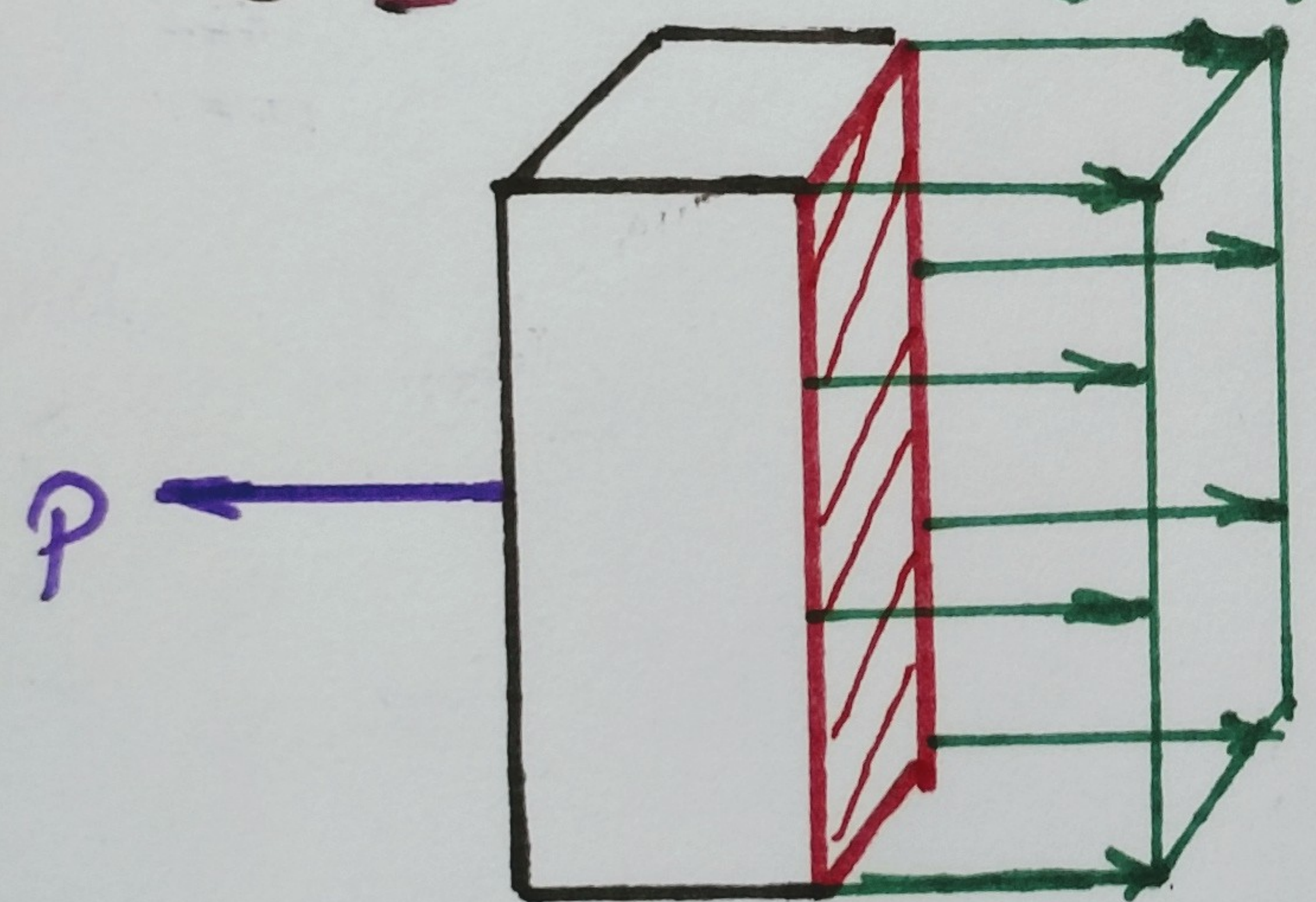
ES2502 @ WPI



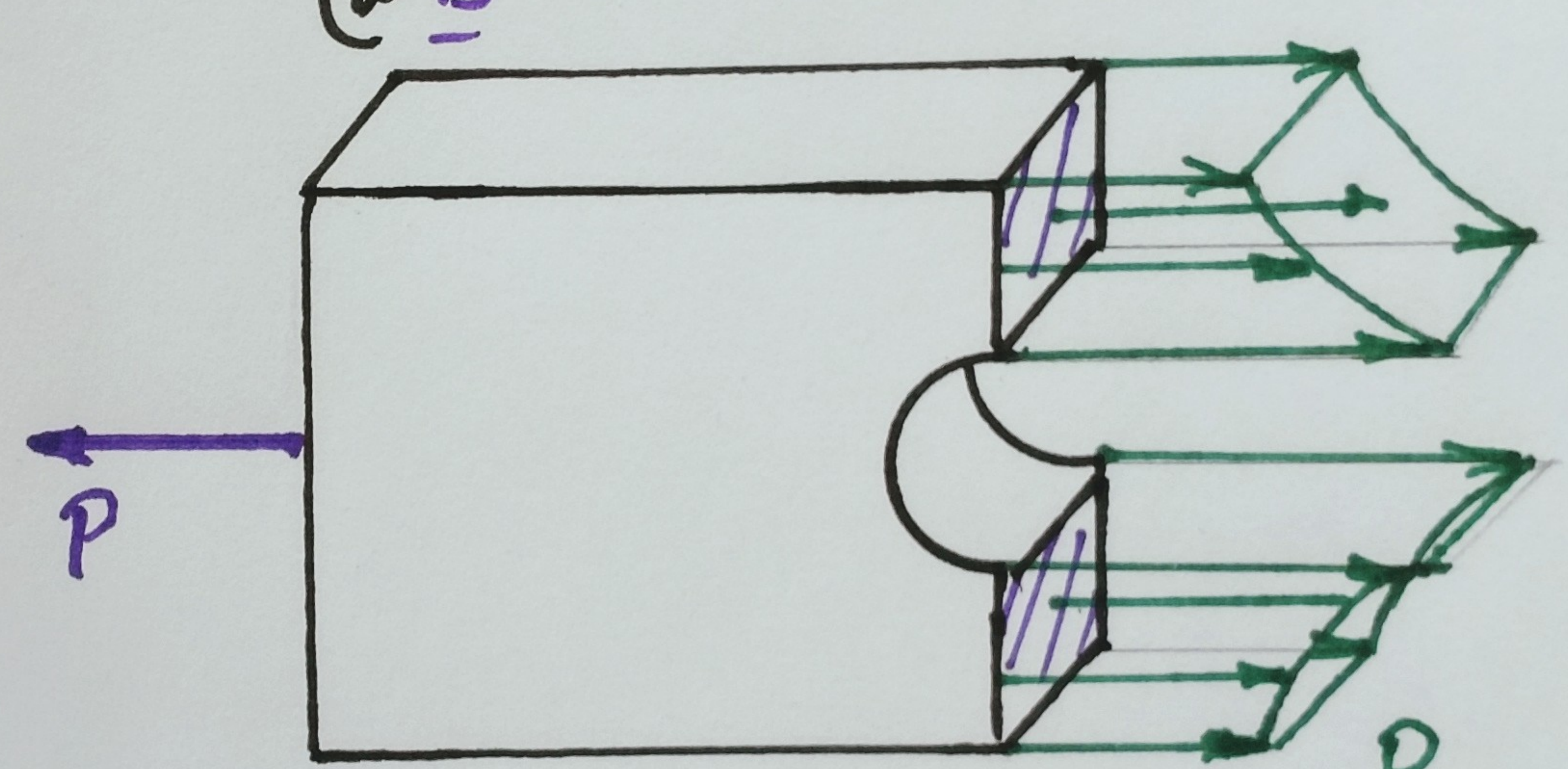
Stress distributions @ different sections along bar. "Volume."

@ A

$\sigma = \frac{P}{A_A}$

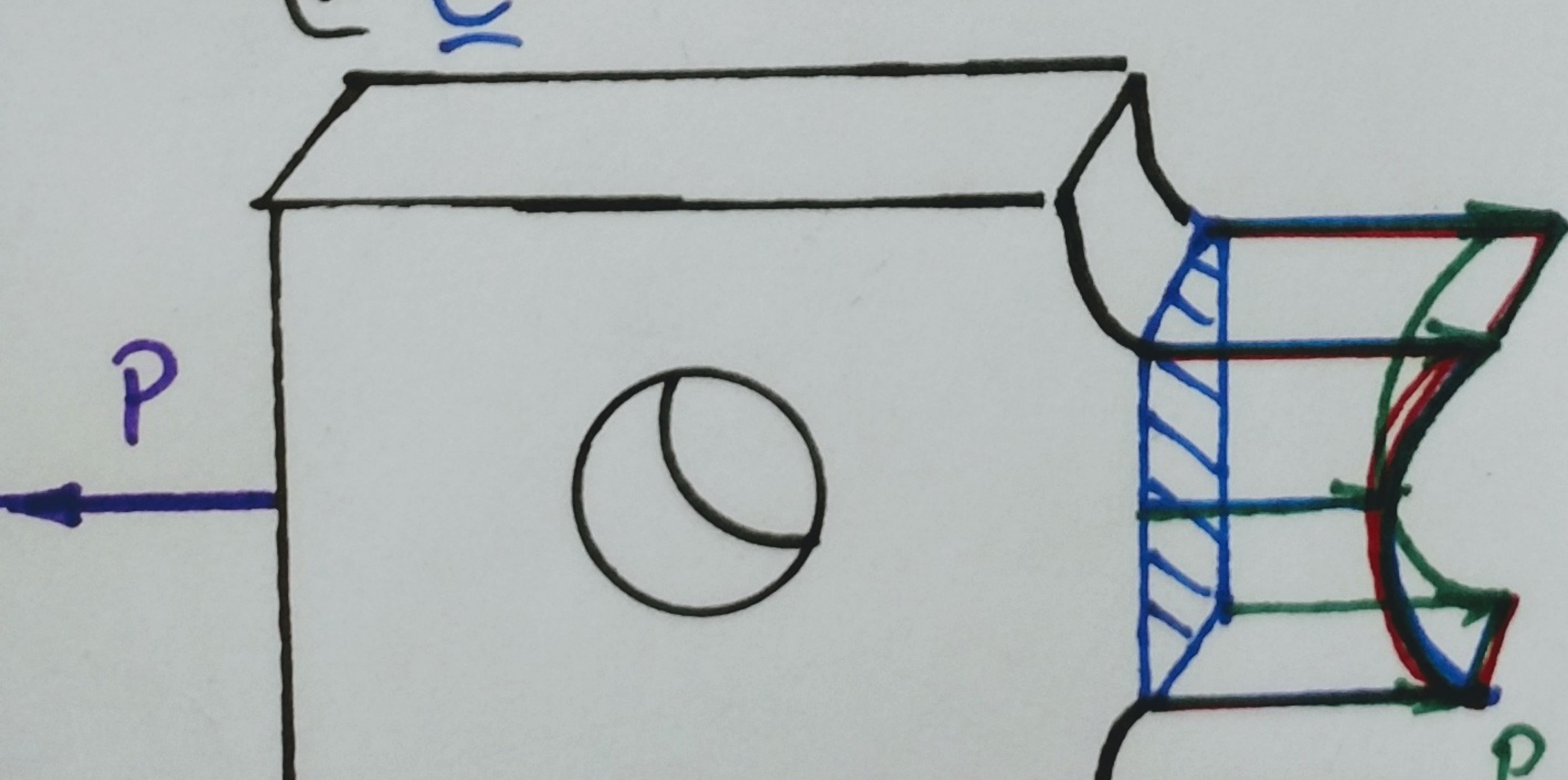


@ B

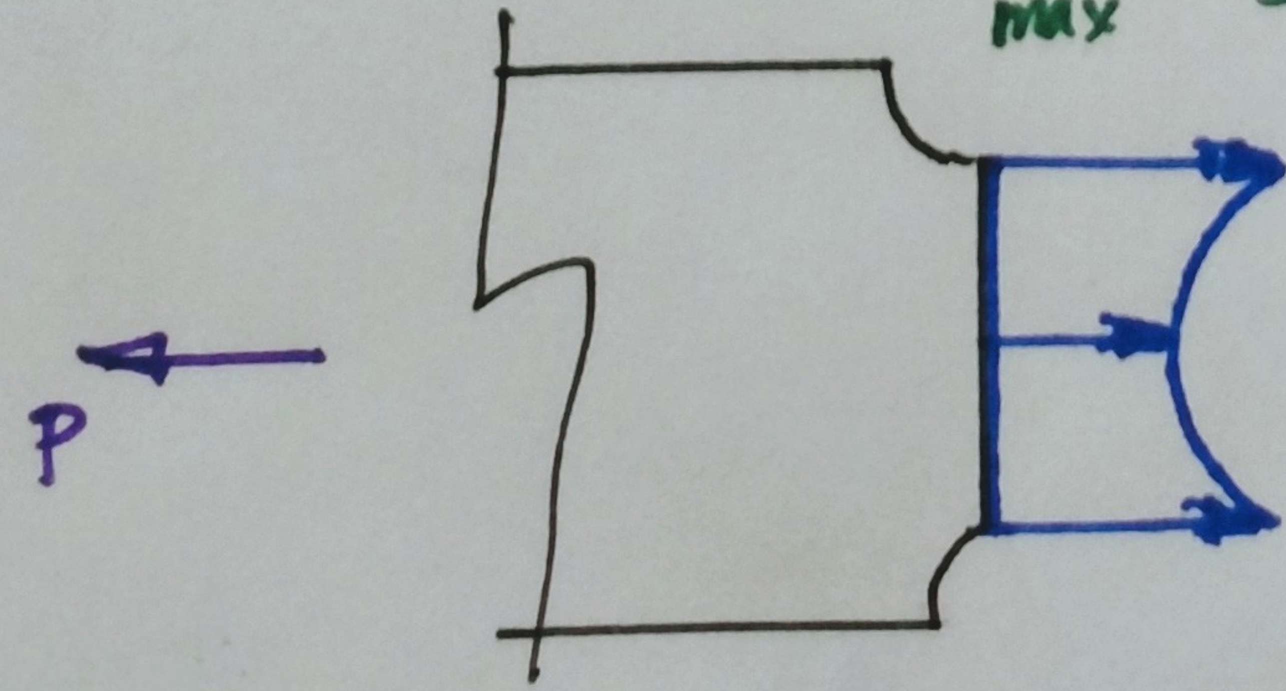


$\sigma_{max} = K_h \cdot \frac{P}{A_B}$

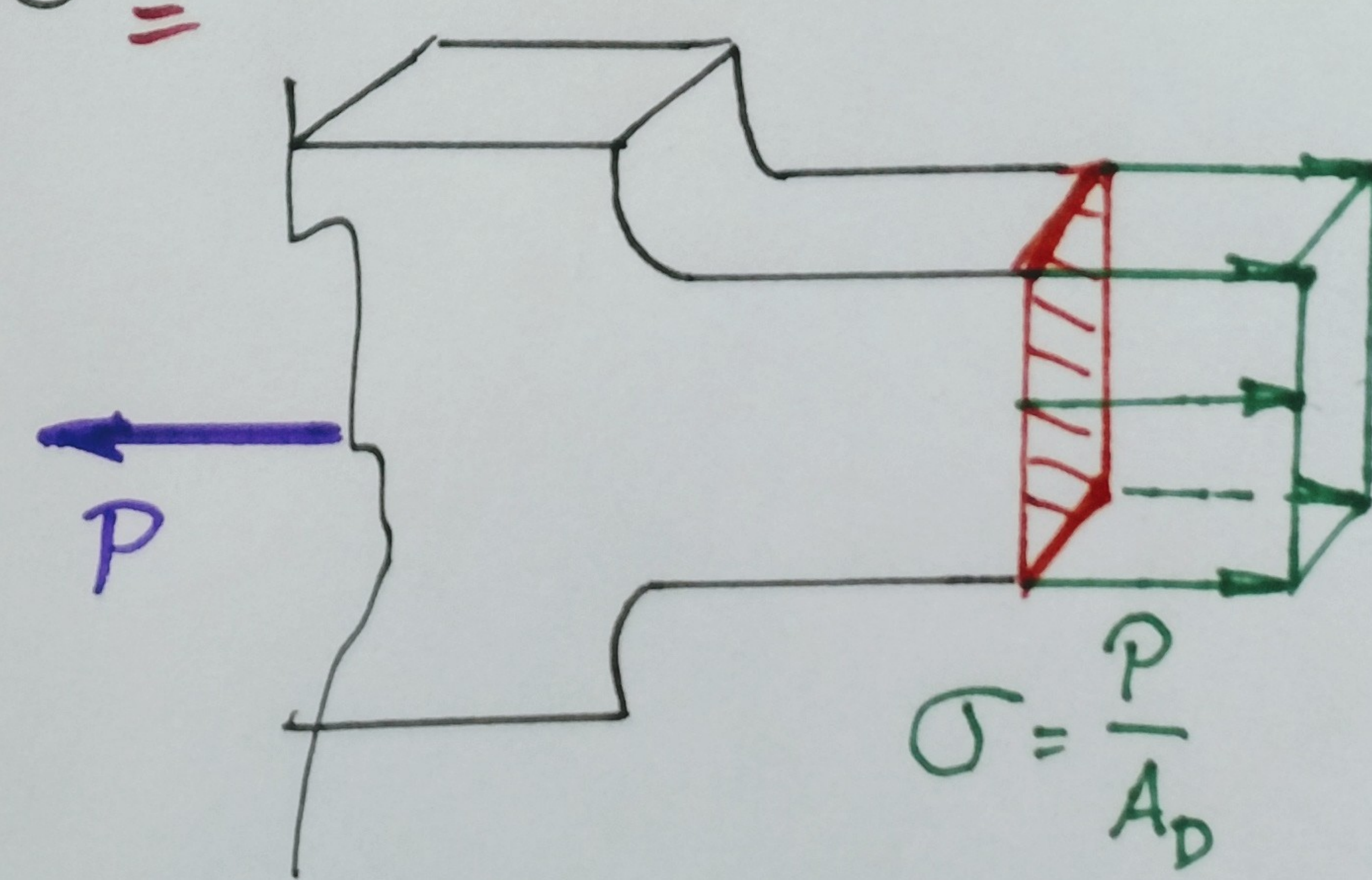
@ C



$\sigma_{max} \cong K_s \frac{P}{A_C}$



@ D



$\sigma = \frac{P}{A_D}$

$$\Rightarrow 150 \times 10^6 = K_h \frac{60 \times 10^3}{(0.13-d)(0.010)} ; [Pa]$$

$$K_h = \frac{150 \times 10^6}{\underbrace{60 \times 10^3}_{2500}} (0.13-d)(0.010)$$ dimensionless

$$K_h = K_h\left(\frac{d}{w}\right)$$

$d_1 = 0.040$ mm $\Rightarrow 2.25 = K_{h_1} \Rightarrow \frac{d_1}{0.130} \approx 0.310$

$d_2 = 0.020$ mm $\Rightarrow 2.75 = K_{h_2} \Rightarrow \frac{d_2}{0.130} \cong 0.154$

$d_3 = 0.010$ mm $\Rightarrow 3.00 = K_{h_3} \Rightarrow \frac{d_3}{0.130} \approx 0.080$

$\Rightarrow$ It is clear that larger diameters are prefered; produce smaller stress concentrations.

$\Rightarrow$ Figure 4-24 reaches a max, $\left(\frac{d}{w}\right)$, of $0.5 \Rightarrow d_{max} = 0.065$ mm

$\Rightarrow d_{4_{max}} = 0.065$ mm $\Rightarrow 1.625 = K_{h_4}$ / with $\frac{d_{4max}}{0.130} = 0.5$

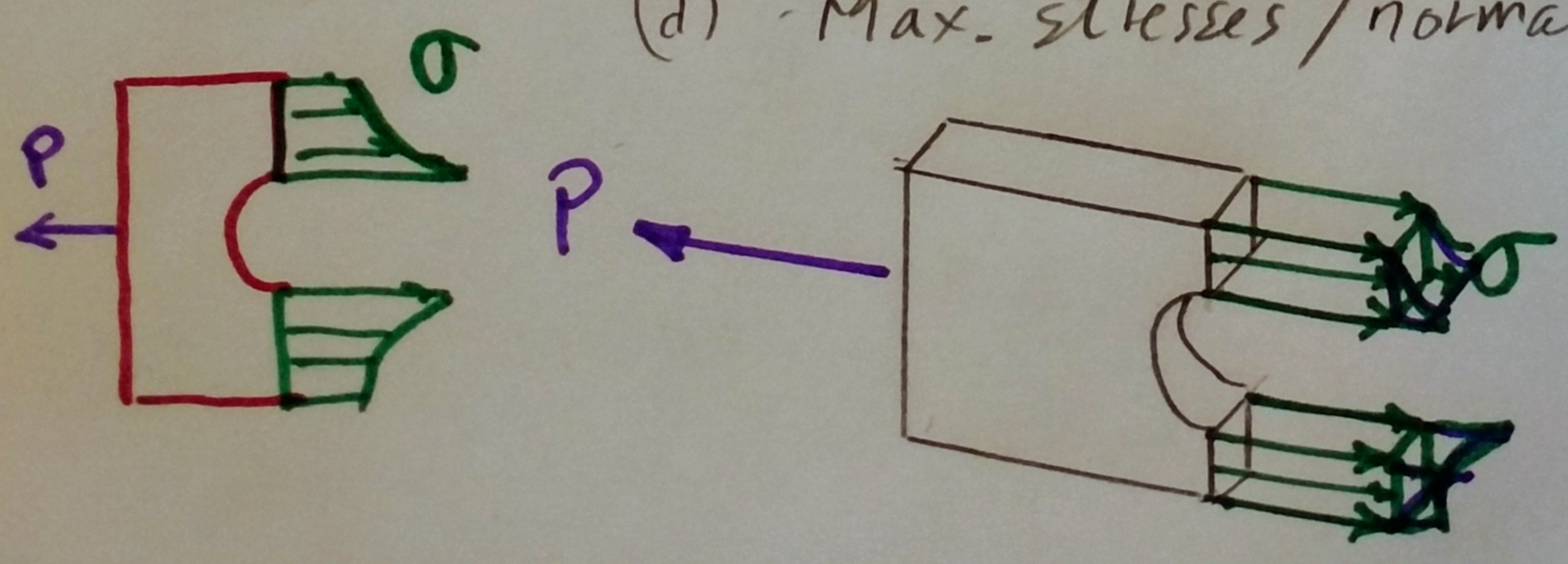
Observations:

(a) a number of diametres can be used,

(b) a preferred diameter is that that minimizes stress concentrations, e.g., $d_{4_{max}} = 65$ mm,

(c) final diameter/selection will depend on manufacturing capabilities and application,

(d) Max. stresses / normal @ hole.



Stress dist. @ hole. (Normal) "Volume".

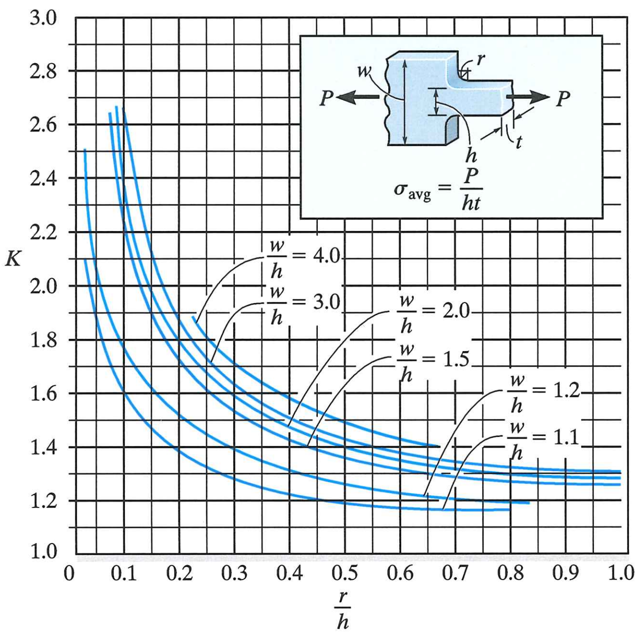


Fig. 4–24

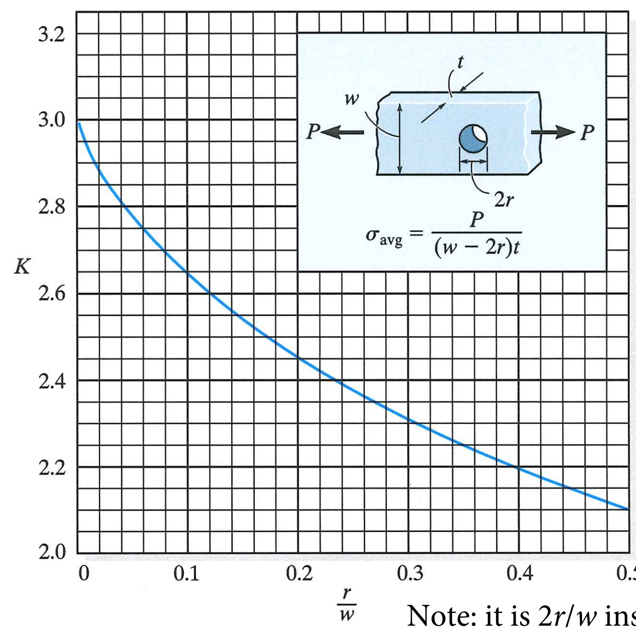


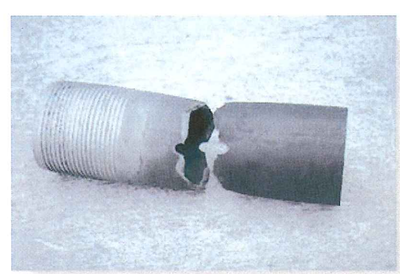
Fig. 4–25

Note: it is $2r/w$ instead of r/w.
Textbook (10th ed) is correct.

4

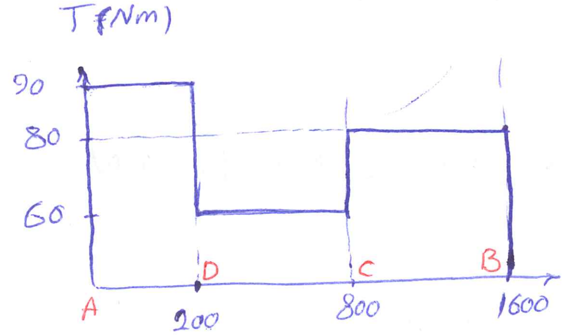
Important Points

- *Stress concentrations* occur at sections where the cross-sectional area suddenly changes. The more severe the change, the larger the stress concentration.
- For design or analysis, it is only necessary to determine the maximum stress acting on the smallest cross-sectional area. This is done using a *stress concentration factor*, K, that has been determined through experiment and is only a function of the geometry of the specimen.
- Normally the stress concentration in a ductile specimen that is subjected to a static loading will *not* have to be considered in design; however, if the material is *brittle*, or subjected to *fatigue* loadings, then stress concentrations become important.



Failure of this steel pipe in tension occurred at its smallest cross-sectional area, which is through the hole. Notice how the material yielded around the fractured surface.

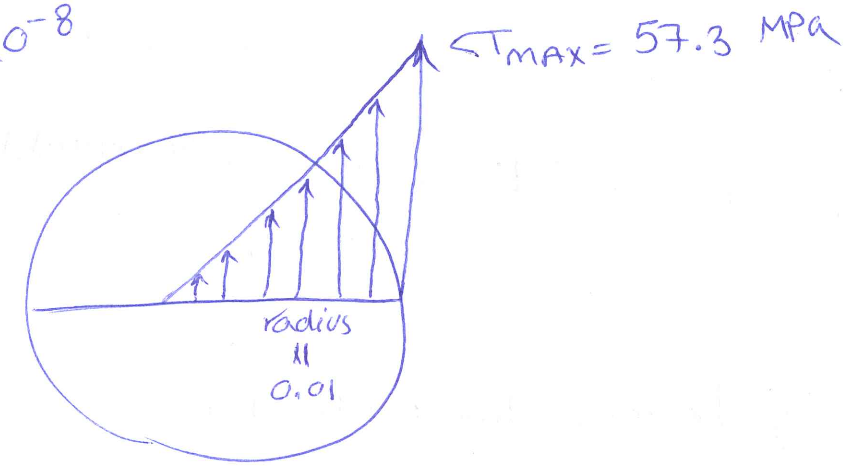
ES-2502 / E05-02



So, the Maximum Shear Stress happens at the Maximum Torque (A-B)

$J = \frac{\pi d^4}{32} \xrightarrow{d = 0.02} J = \frac{\pi (0.02^4)}{32} = 1.57 \times 10^{-8}\ m^4$

$\tau = \frac{TC}{J} = \frac{90 \times 0.01}{1.57 \times 10^{-8}} = 57.3\ MPa$



Correct Torque diagram : ~~25 Points~~

Calculate J : ~~5 Points~~

5 points total

τ : ~~10 Points~~

Shear Stress distribution: ~~10 Points~~