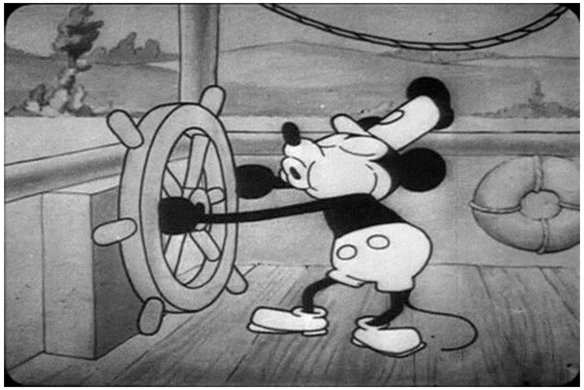
WORCESTER POLYTECHNIC INSTITUTE
MECHANICAL ENGINEERING DEPARTMENT

STRESS ANALYSIS
ES-2502, D'2020

We will get started soon...



21 April 2020

WORCESTER POLYTECHNIC INSTITUTE
MECHANICAL ENGINEERING DEPARTMENT

STRESS ANALYSIS
ES-2502, D'2020

We will get started soon...

Lecture 15:
Unit 10,11: tension/compression of slender longitudinal bars:
stress concentrations & non-linear deformations

21 April 2020

General information

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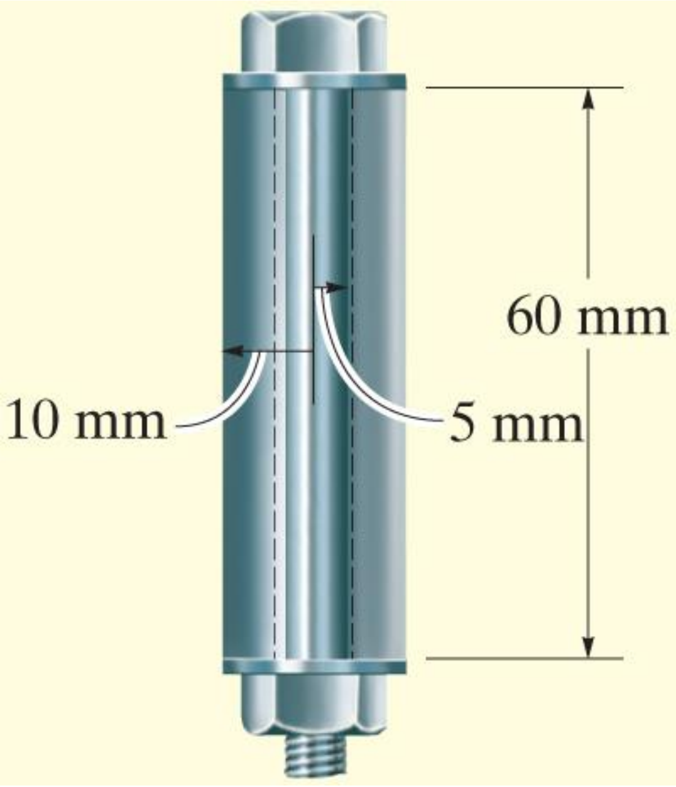
Master: Example 4.8 (also given as Homework)

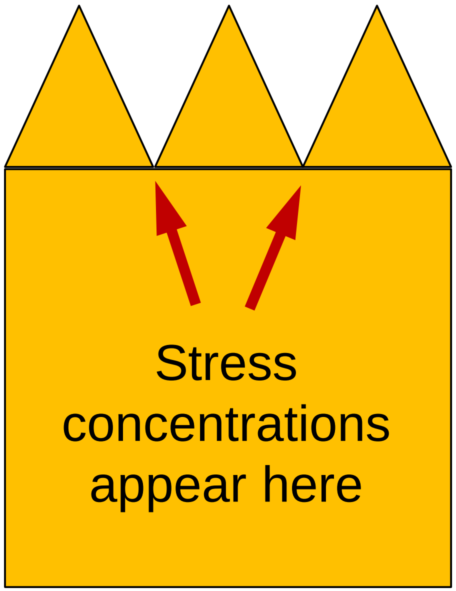
The bolt is made of 2014-T6 aluminum alloy and is tightened so it compresses a cylindrical tube made of Am 1004-T61 magnesium alloy. The tube has an outer radius of 10 mm, and both the inner radius of the tube and the radius of the bolt are 5 mm. The washers at the top and bottom of the tube are considered to be rigid and have a negligible thickness. Initially the nut is hand-tightened slightly; then, using a wrench, the nut is further tightened one-half turn. If the bolt has 20 threads per inch, determine the stress in the bolt.



Stress concentrations

Ripping open candy wrap with the help of stress concentration

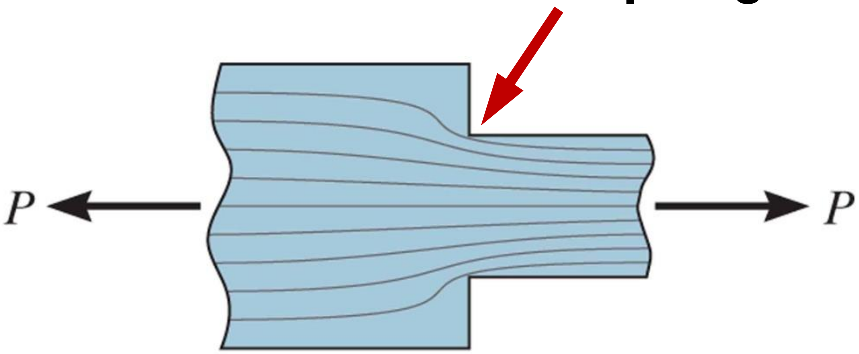
Zigzag edges added to **amplify** *applied* stresses



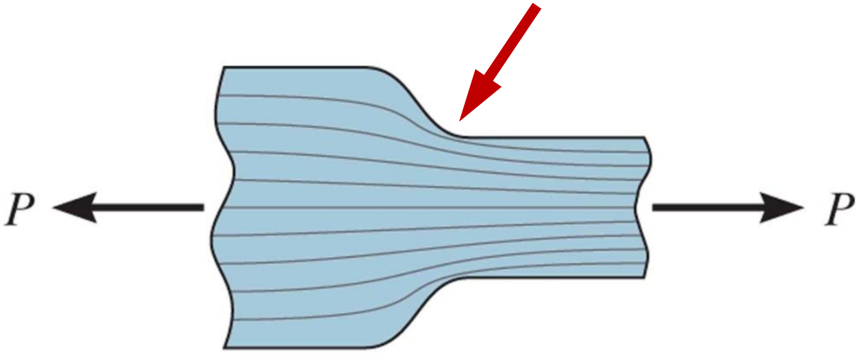
Stress concentrations: stress "flow"

Reducing stress concentrations

Stress concentration on:
sharp edges

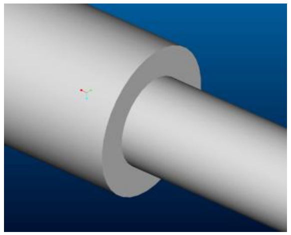


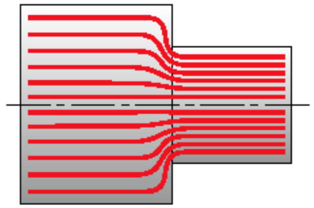
Reducing stress concentration:
rounding edges



Designing to minimize stress concentrations

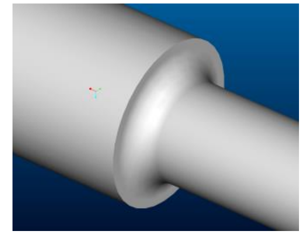
Initial design

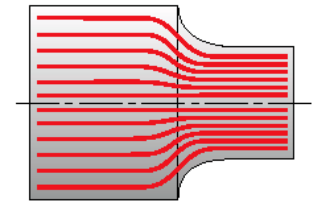




(*a*) Force flow around a sharp corner

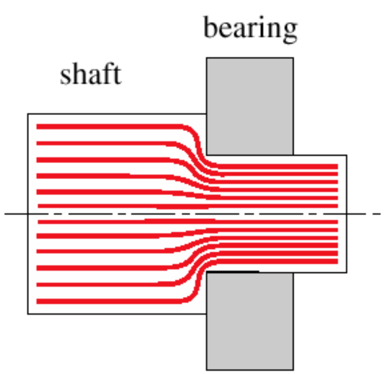
Improved design



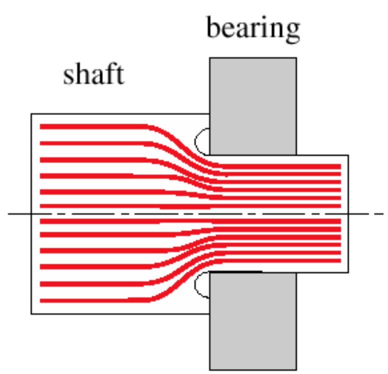


(*b*) Force flow around a radiused corner

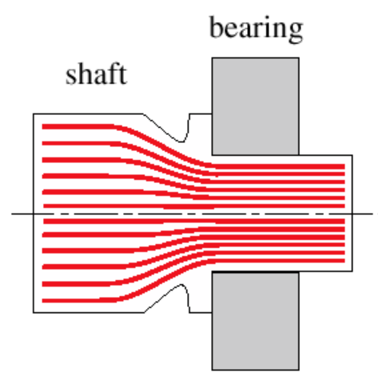
Modifications to reduce stress concentrations at a sharp corner



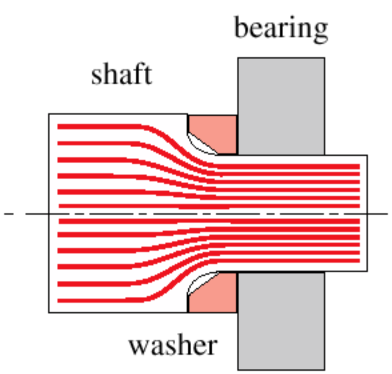
(*a*) Stress concentration at a sharp corner



(*b*) Stress concentration reduced with radius



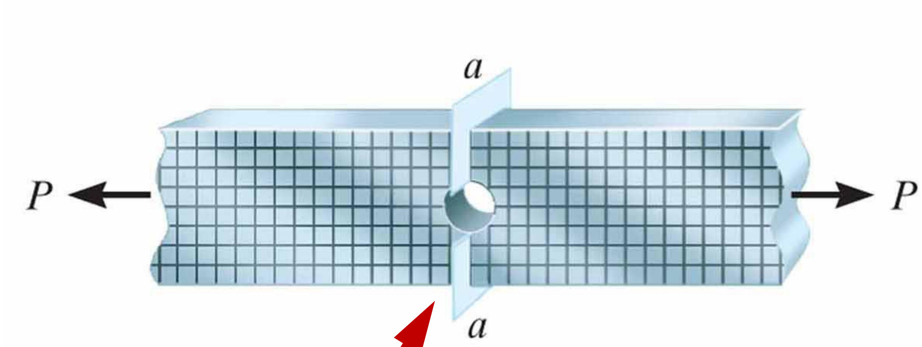
(*c*) Stress concentration reduced with groove

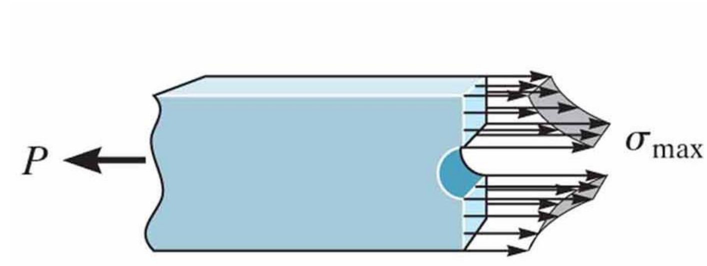


(*d*) Stress concentration reduced with washer

Stress concentrations

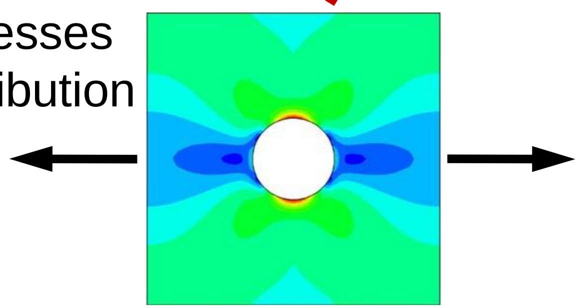
Axially loaded component with a hole: <u>stress concentration factor</u>



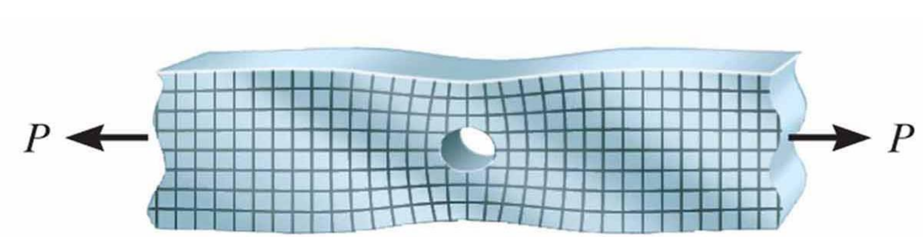


Actual stress distribution
(b)

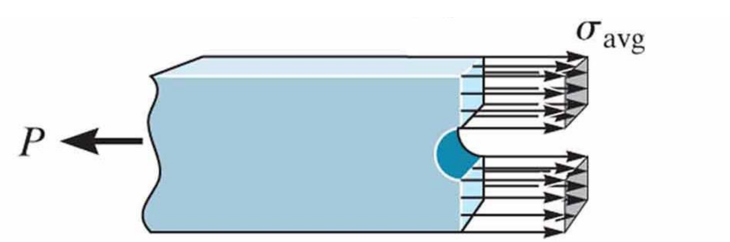
Stresses distribution



Stress concentration factor: $K = \dfrac{\sigma_{max}}{\sigma_{avg}}$



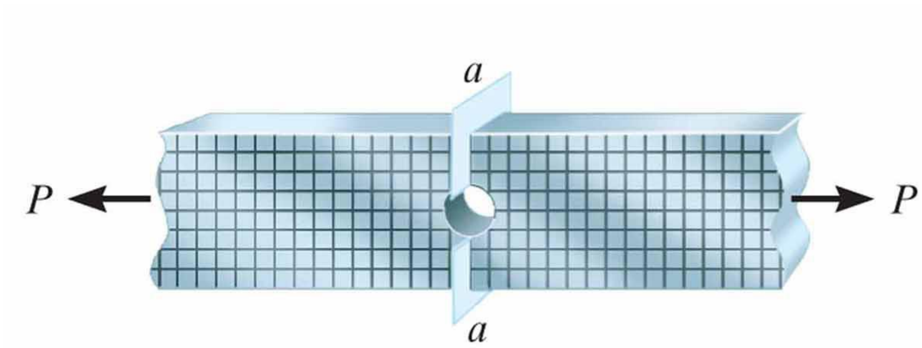
Distorted
(a)



Average stress distribution
(c)

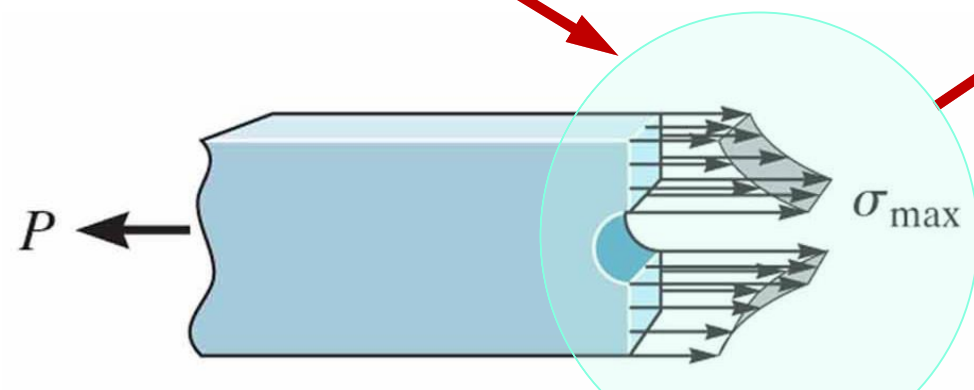
Stress concentrations

Axially loaded component with a hole: <u>stress concentration factor</u>



Internal balancing force at *a*-*a*

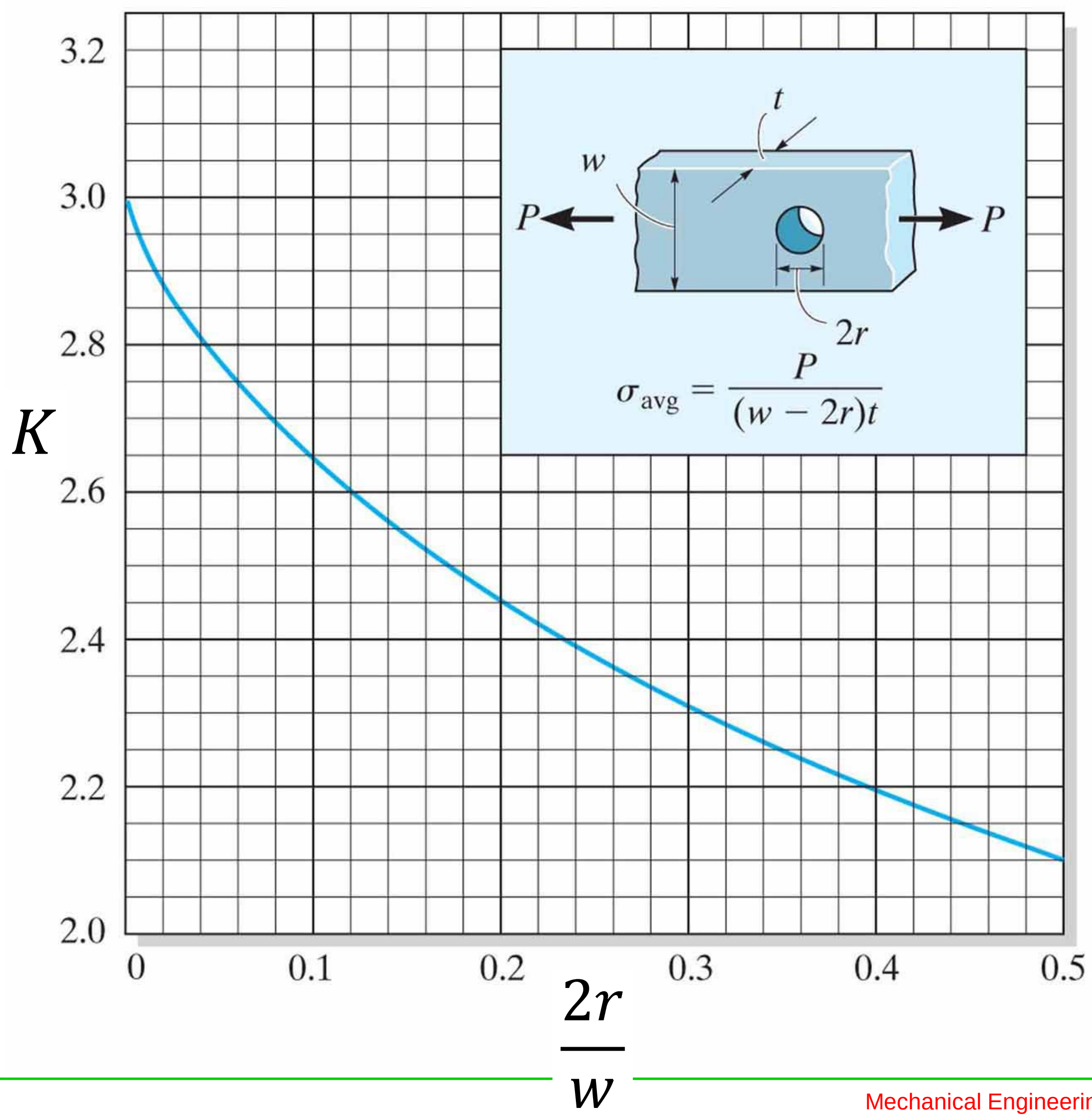
$$P = \int_{A\,@\,a\text{-}a} \sigma \, dA$$



Actual stress distribution

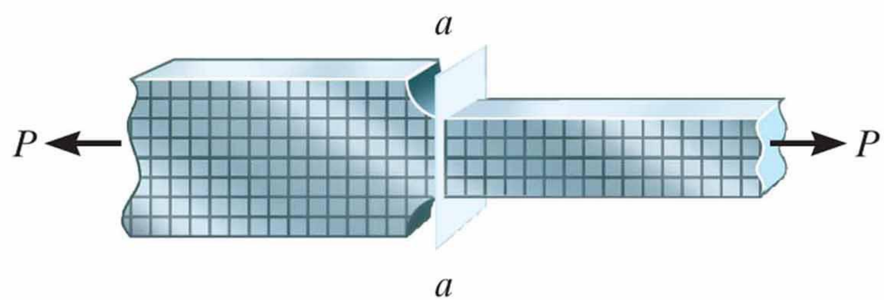
Stress concentration factor

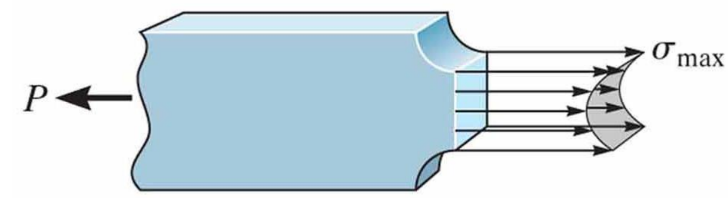
Axially loaded component with a hole



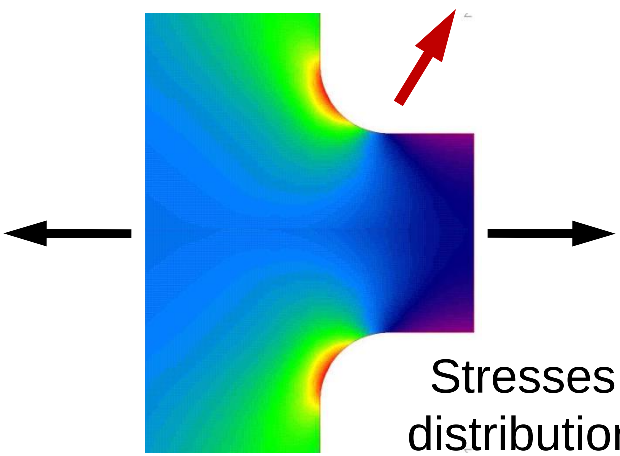
Stress concentrations

Axially loaded component with edges: <u>stress concentration factor</u>



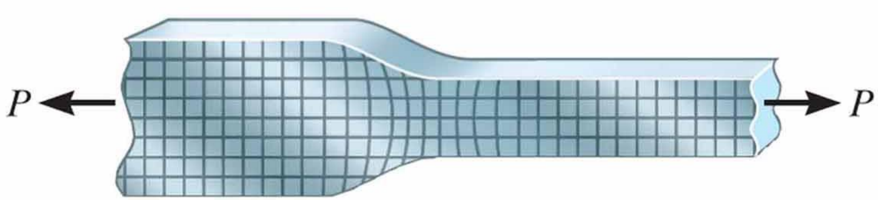


Actual stress distribution
(b)

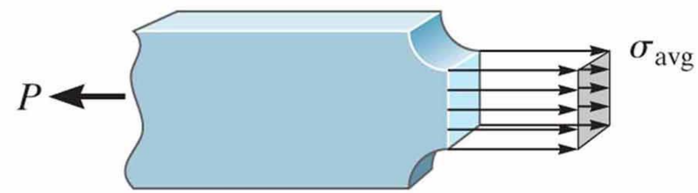


Stresses distribution

Stress concentration factor: $K = \dfrac{\sigma_{max}}{\sigma_{avg}}$



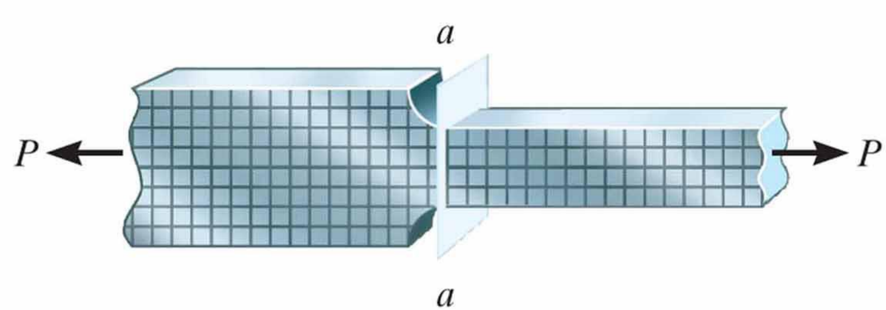
Distorted
(a)



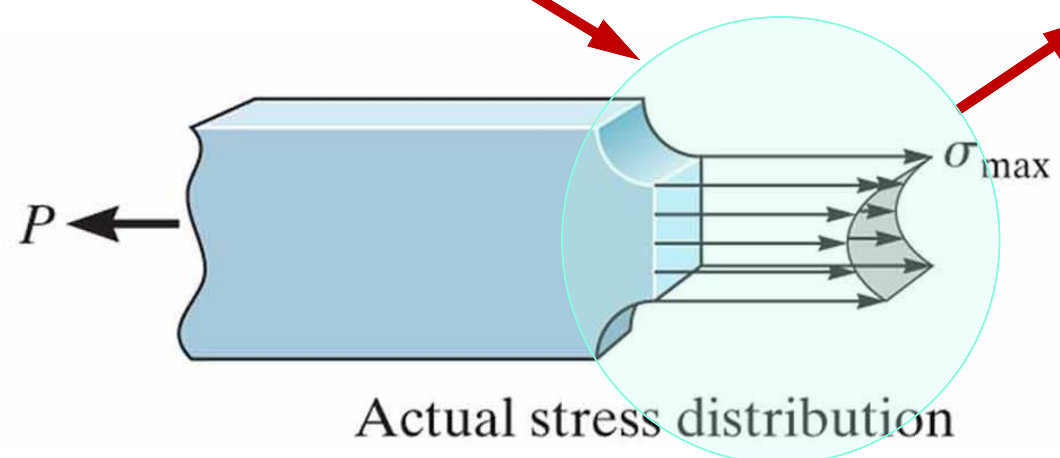
Average stress distribution
(c)

Stress concentrations

Axially loaded component with edges: <u>stress concentration factor</u>



Internal balancing force at *a*-*a*

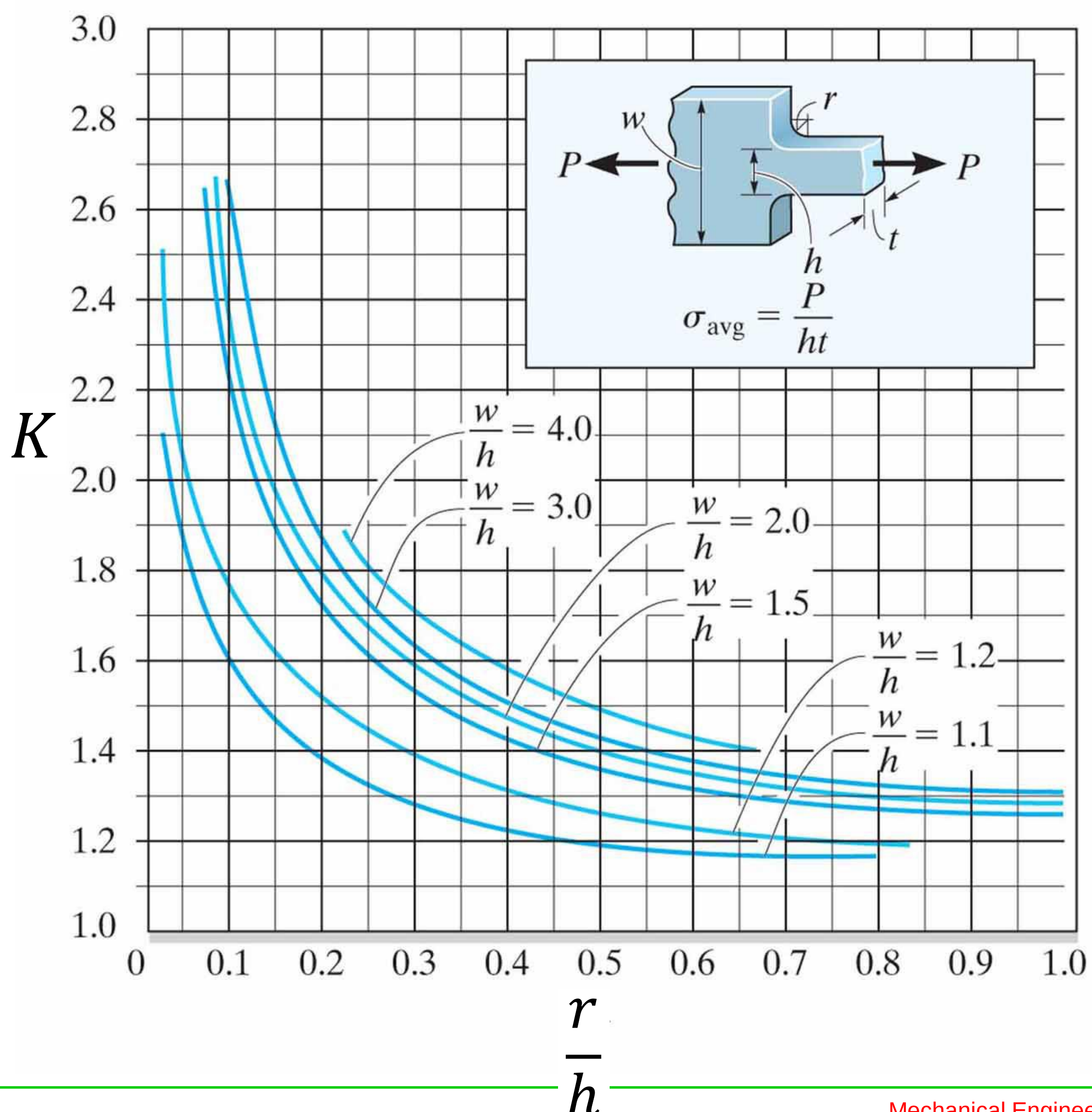


Actual stress distribution

$$P = \int_{A\,@\,a\text{-}a} \sigma \, dA$$

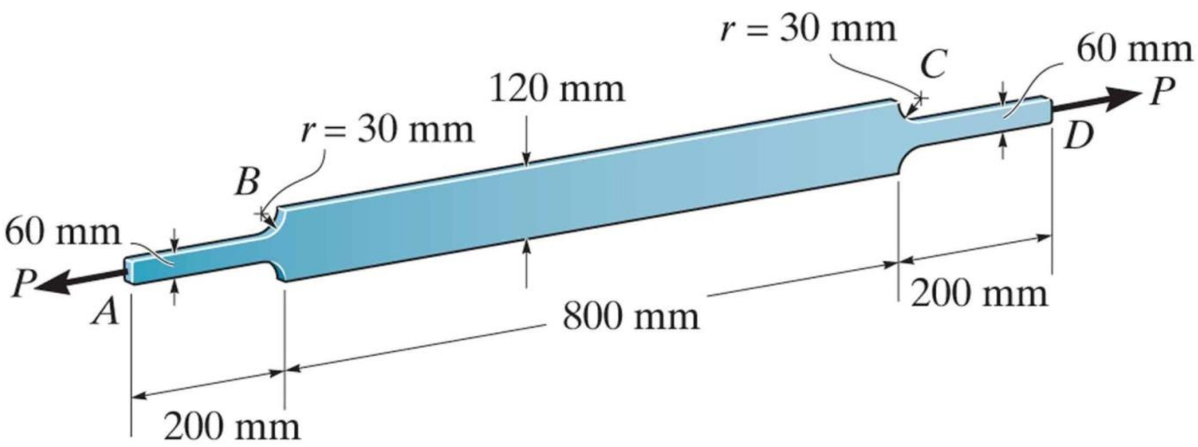
Stress concentration factor

Axially loaded component with edges



Axial load: example O

The A-36 steel plate has a thickness of 12 mm. If there are shoulder fillets at B and C, and $\sigma_{Allow} = 150\ \mathrm{MPa}$, determine the maximum axial load P that it can support. Calculate its elongation, neglecting the effect of the fillets.

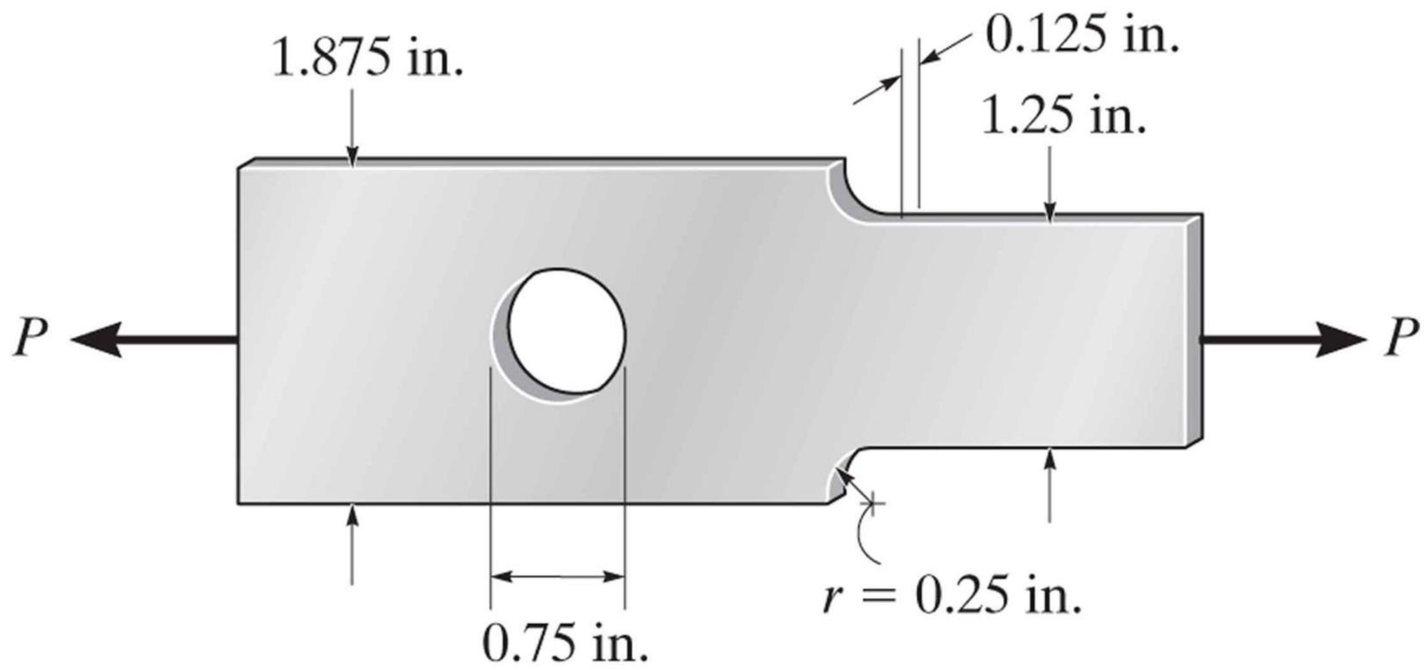


Approach:

1) Determine stress concentration factors
2) Compute maximum load
3) Compute elongation

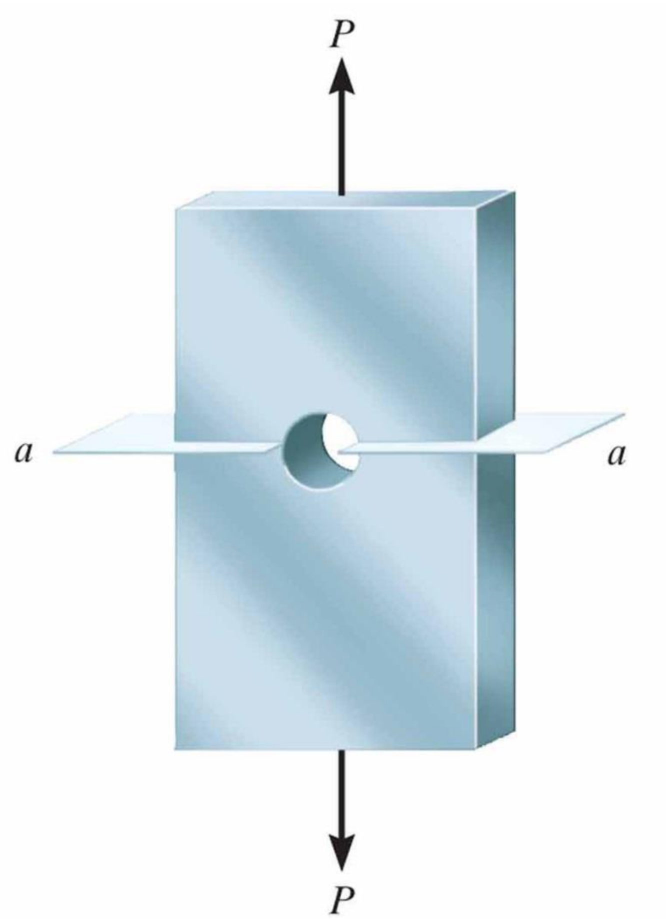
Axial load: example P

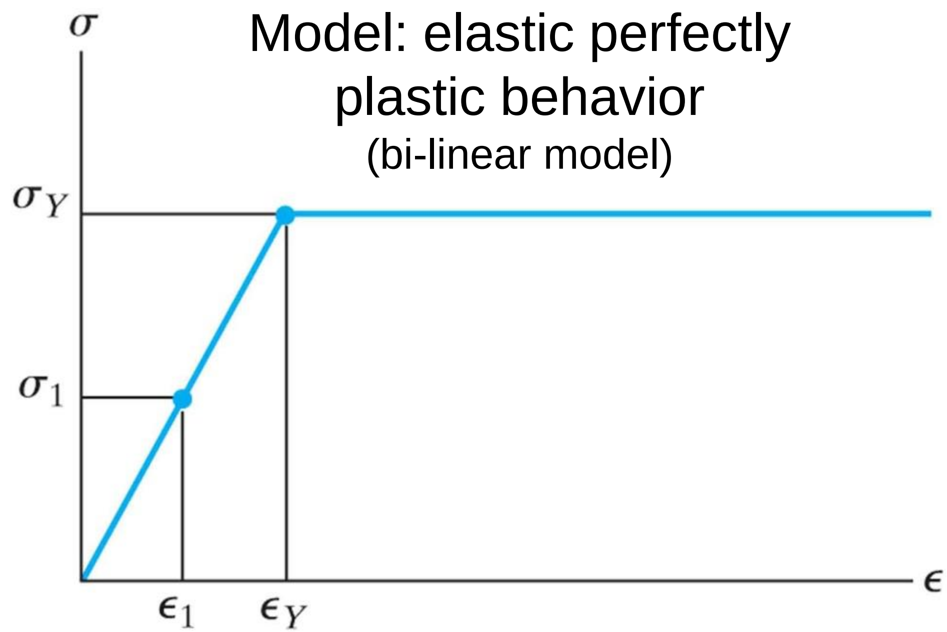
Determine the maximum axial force P that can be applied to the bar. The bar is made from steel and has an allowable stress of $\sigma_{Allow} = 21$ ksi.



Inelastic axial deformation

Plastic deformations





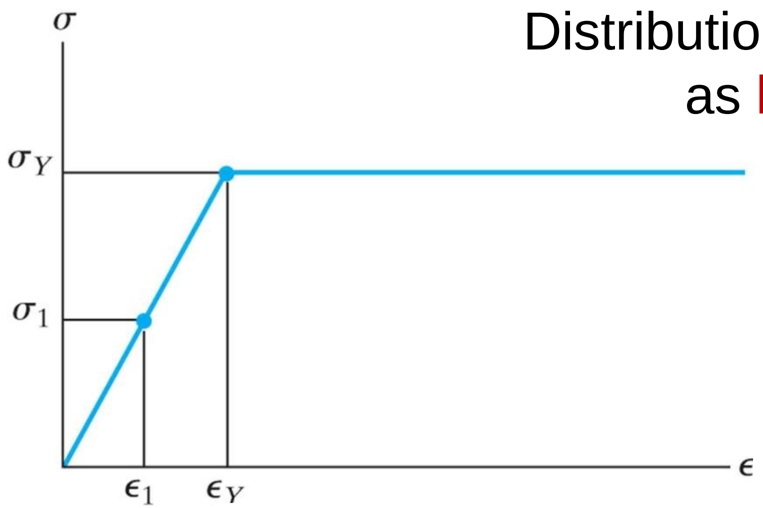
Model: elastic perfectly plastic behavior

(bi-linear model)

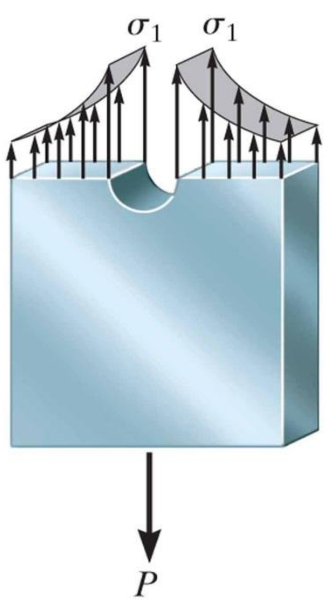
Inelastic axial deformation

Plastic deformations

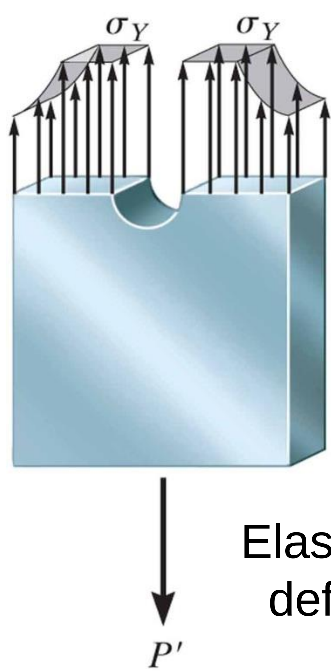
Distribution of **internal stresses** as **load increases**



Elastic deformations



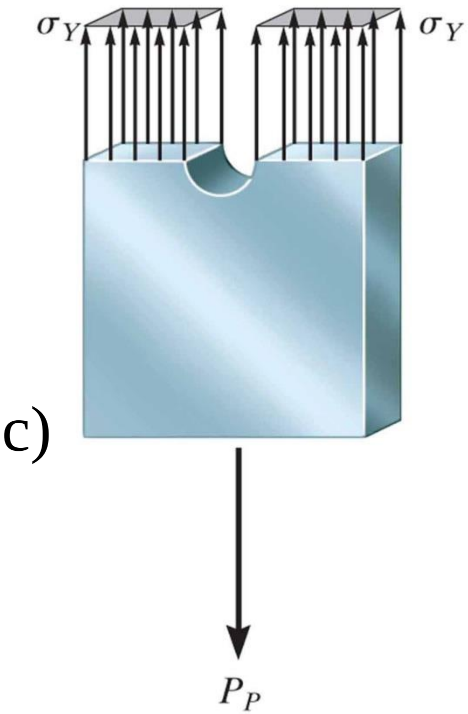
(a)



(b)

Elastic + plastic deformations

Plastic deformations

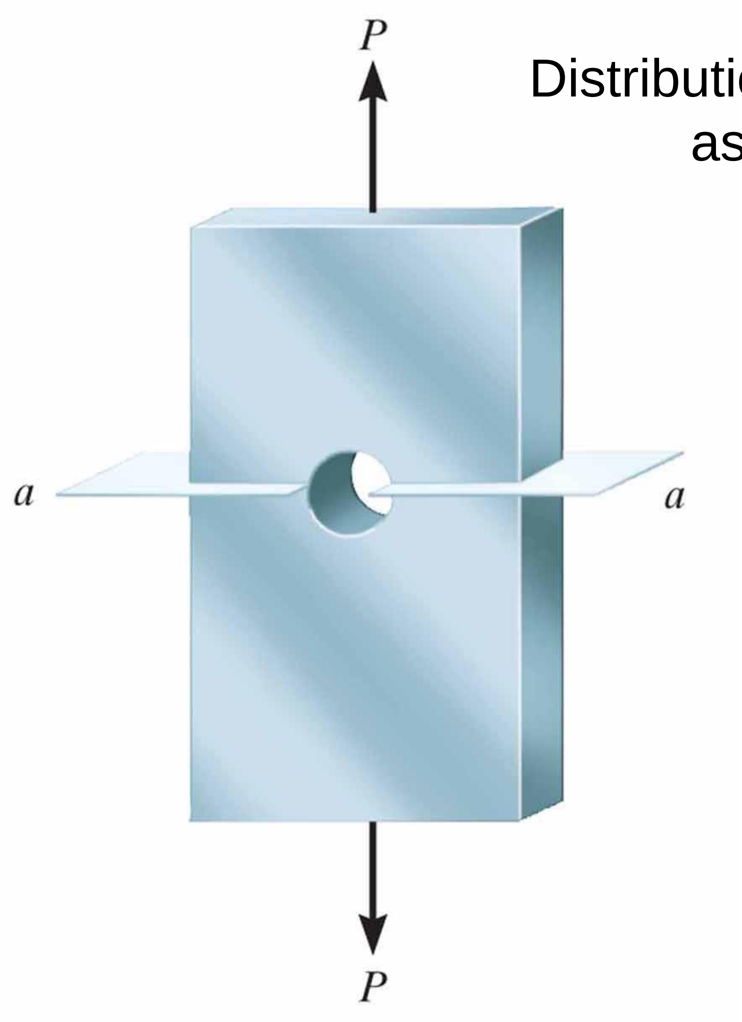


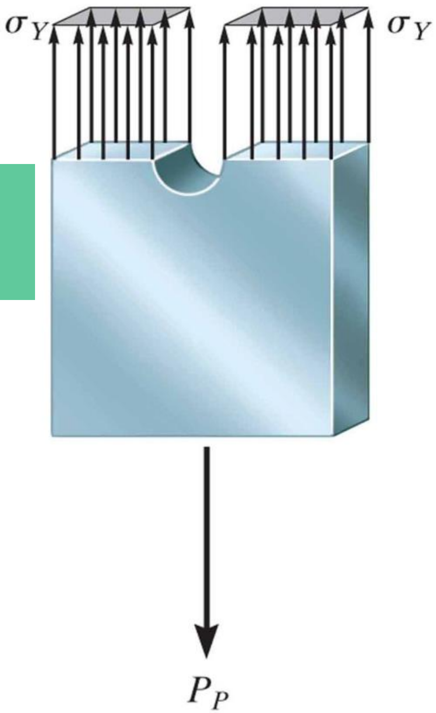
(c)

Inelastic axial deformation

Plastic deformations

Distribution of **internal stresses** as **load increases**

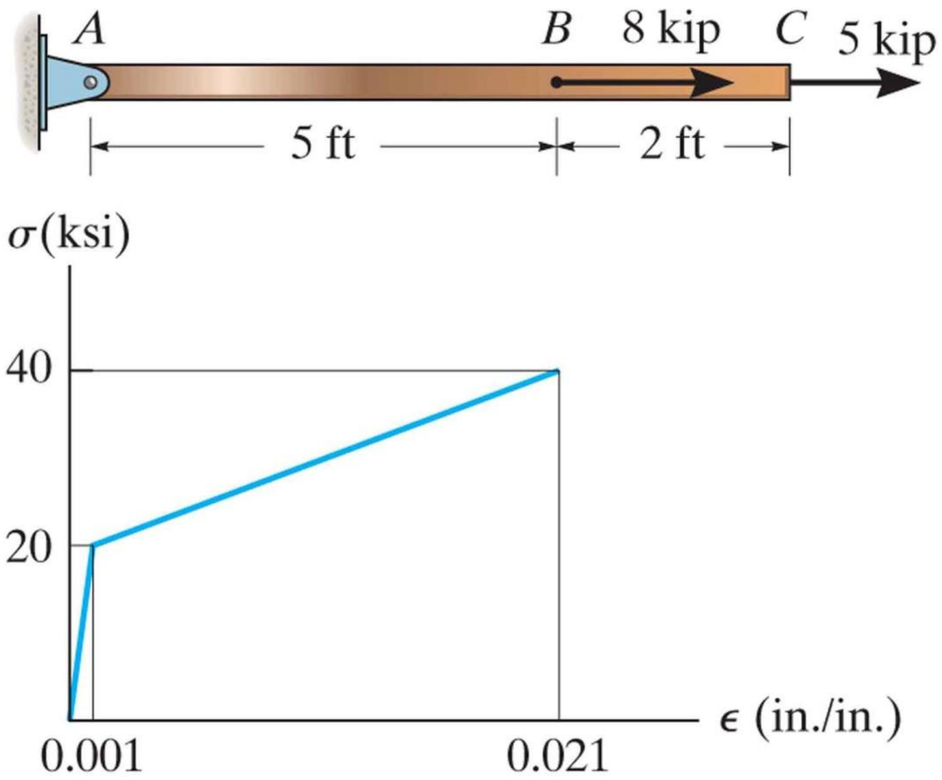




Plastic deformations

Axial load, plastic deformations: example A

The bar has a cross-sectional area of 0.5 in^2 and is made of a material that has a stress–strain diagram that can be approximated by the two line segments shown. Determine the elongation of the bar due to the applied loading.



Reading assignment

- Chapters 4 and 5 of textbook
- Review notes and text: ES2001, ES2501

Homework assignment

- As indicated on webpage of our course