Today 11.4, 11.5

$\boxed{L34}$

Today 11.4, 11.5

$\boxed{L34}$

Stress,

Strain,

Elastic

moduli

Today 11.4, 11.5

L34

Stress, Strain, Elastic moduli

Elasticity & plasticity

Today 11.4, 11.5

Friday 13.1, 13.2

$\boxed{L34}$

Today 11.4, 11.5

Friday 13.1, 13.2

$\boxed{L34}$

Newton's law of gravitation

Today 11.4, 11.5

Friday $\underbrace{13.1}_{\text{Newton's law of gravitation}}$, $\underbrace{13.2}_{\text{Weight}}$

$\boxed{L34}$

Newton's law of gravitation

Weight

ASU

Today 11.4, 11.5

Friday 13.1, 13.2

Monday 13.3, 13.4

$\boxed{L34}$

Today 11.4, 11.5

Friday 13.1, 13.2

Monday $\underbrace{13.3}_{\text{Gravitational potential energy}}$, 13.4

$\boxed{L34}$

Today 11.4, 11.5

$\boxed{L34}$

Friday 13.1, 13.2

Monday $\underbrace{13.3}_{}$, $\underbrace{13.4}_{}$

Gravitational potential energy

motion of satellites

$\boxed{L34}$

Today 11.4, 11.5

Friday 13.1, 13.2

Monday 13.3, 13.4

Wednesday Nov. 25th 13.5, 13.8

Today 11.4, 11.5

L34

Friday 13.1, 13.2

Monday 13.3, 13.4

Wednesday Nov. 25th

$\underbrace{13.5}_{\text{Kepler's laws}}$, 13.8

Today 11.4, 11.5

$\boxed{L34}$

Friday 13.1, 13.2

Monday 13.3, 13.4

Wednesday Nov. 25th $\underbrace{13.5}_{\text{Kepler's laws}}$, $\underbrace{13.8}_{\text{Black holes}}$

Today 11.4, 11.5

$\boxed{L34}$

Friday 13.1, 13.2

Monday 13.3, 13.4

Wednesday Nov. 25th 13.5, 13.8

Friday Nov. 27th Holiday

$\boxed{L34}$

Today 11.4, 11.5

Friday 13.1, 13.2

Monday 13.3, 13.4

Wednesday Nov. 25th 13.5, 13.8

Friday Nov. 27th Holiday

Monday Nov. 30th Exam #4

Today 11.4, 11.5

L34

Friday 13.1, 13.2

Monday 13.3, 13.4

Wednesday Nov. 25th 13.5, 13.8

Friday Nov. 27th Holiday

Monday Nov. 30th Exam #4

Wednesday Dec. 2nd Day of Reckoning

ASU

Today 11.4, 11.5

L34

Friday 13.1, 13.2

Monday 13.3, 13.4

Wednesday Nov. 25th 13.5, 13.8

Friday Nov. 27th Holiday

Monday Nov. 30th Exam #4

Wednesday Dec. 2nd Day of Reckoning

Friday Dec. 4th Final exam

ASU

Types of stress

Types of stress

Guitar strings under tensile stress,

Types of stress

Guitar strings under tensile stress, being stretched by forces at the ends

Types of stress

Types of stress

Diver under bulk stress

Types of stress

Diver under bulk stress, being squeezed from all sides

Types of stress

Types of stress

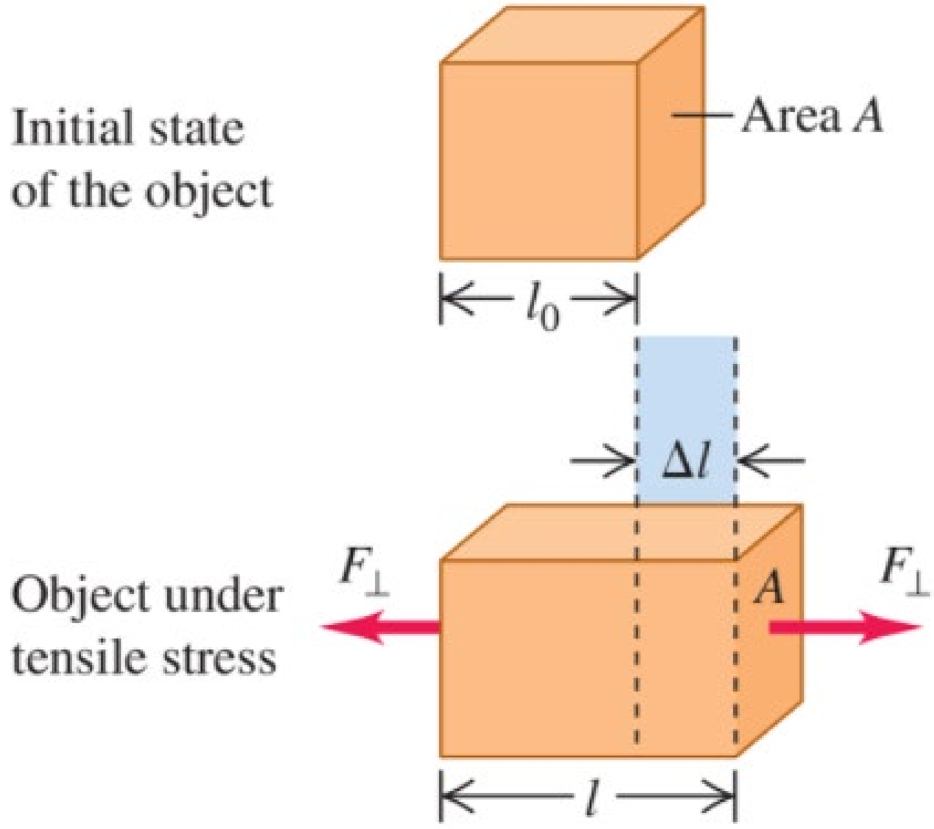
A ribbon under shear stress.

Types of stress

A ribbon under shear stress, being deformed and eventually cut by forces exerted by the scissors

Hook's law

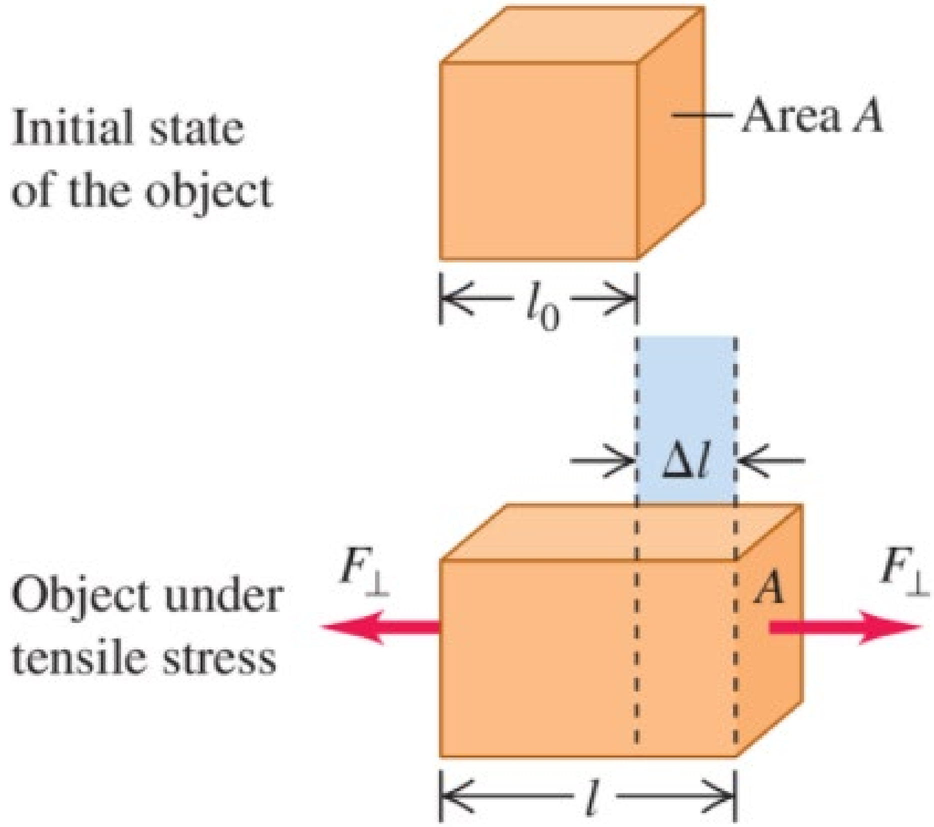
Hook's law



Initial state of the object
Area A
l_0
Δl
Object under tensile stress
$F_\perp$
A
$F_\perp$
l

Hook's law

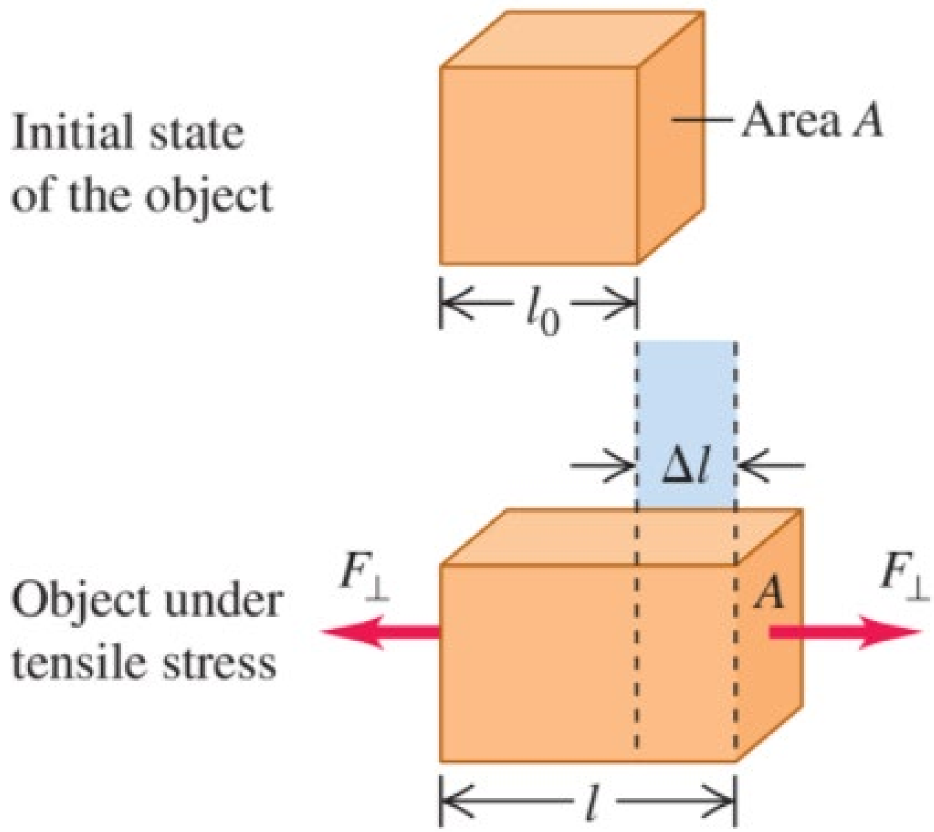
$$\frac{\text{Stress}}{\text{Strain}} = \text{Elastic modulus}$$, where



Hook's law

$$\frac{\text{Stress}}{\text{Strain}} = \text{Elastic modulus}, \text{ where}$$

$$\text{Tensile stress} = \frac{F_\perp}{A}$$



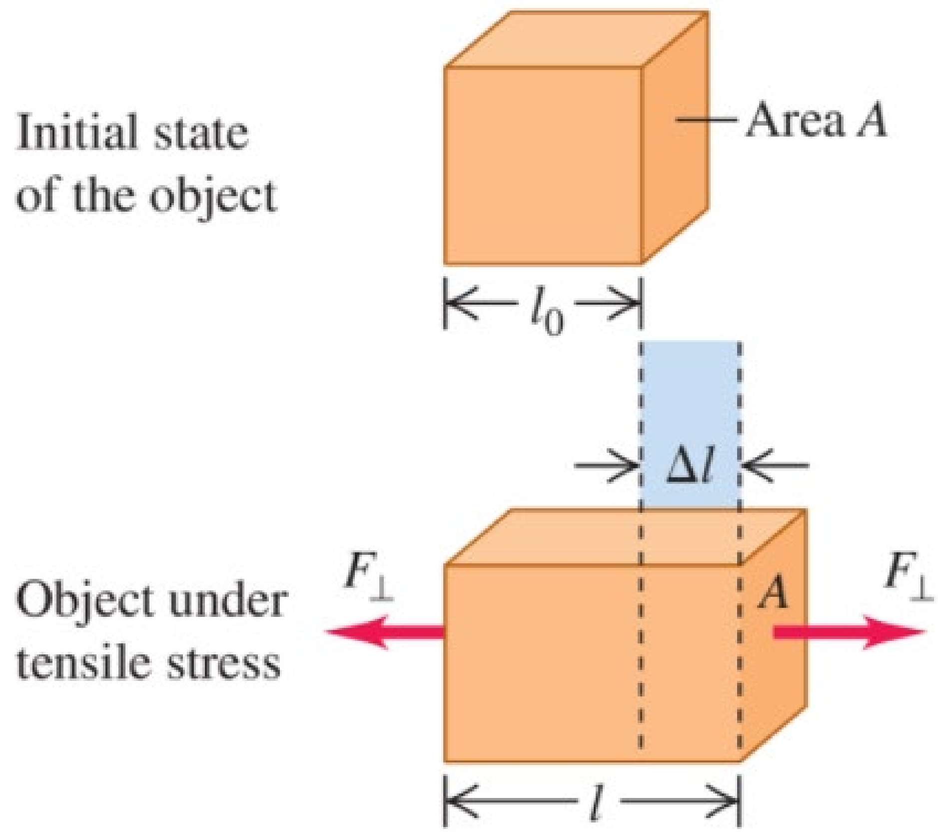
Hook's law

$$\frac{\text{Stress}}{\text{Strain}} = \text{Elastic modulus}\ ,\ \text{where}$$

$$\text{Tensile stress} = \frac{F_{\perp}}{A}$$

&

$$\text{Tensile strain} = \frac{\Delta l}{l_0}$$



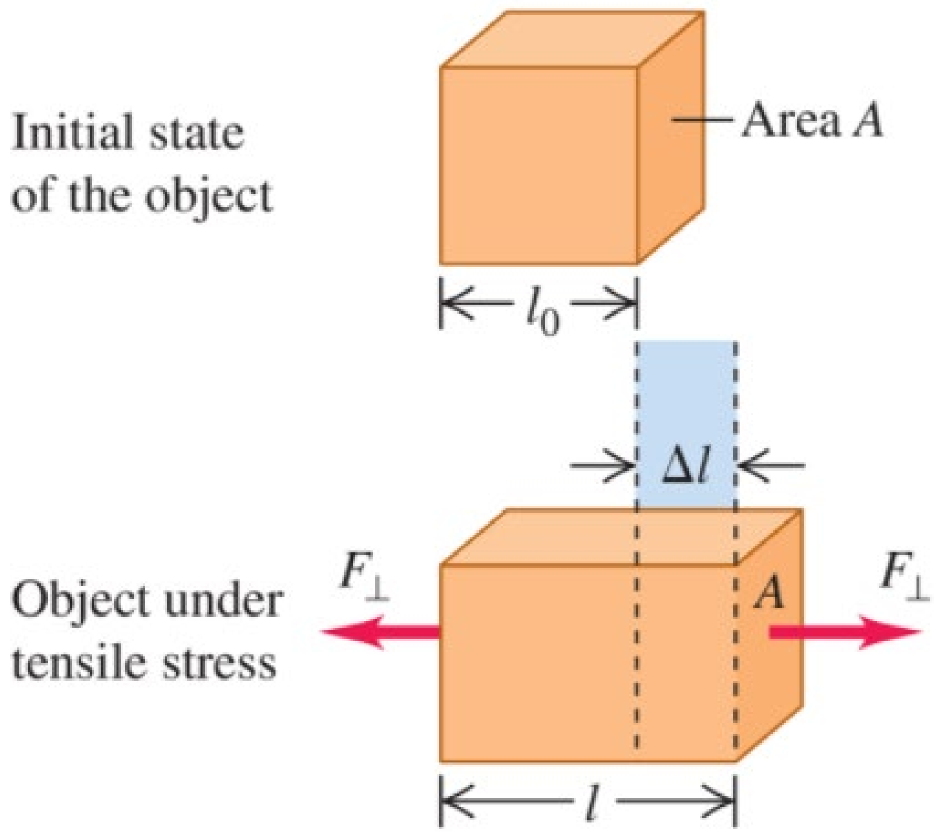
Hook's law

$$\frac{\text{Stress}}{\text{Strain}} = \text{Elastic modulus}$$, where

$$\text{Tensile stress} = \frac{F_\perp}{A}$$

&

$$\text{Tensile strain} = \frac{\Delta l}{l_0}$$



ASU

Young's modulus $\equiv Y$

Young's modulus $\equiv Y$ ¢

$$Y \equiv \frac{\text{Tensile stress}}{\text{Tensile strain}}$$

Young's modulus $\equiv Y$ ¢

$$Y \equiv \frac{\text{Tensile stress}}{\text{Tensile strain}} = \frac{(F_\perp / A)}{(\Delta l / l_0)}$$

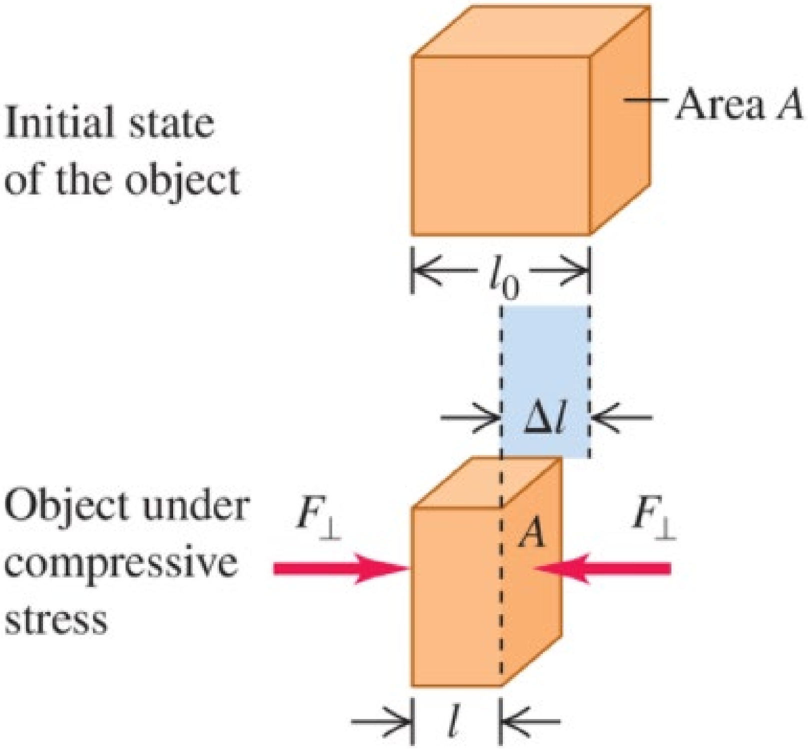
Table 11.1 **Approximate Elastic Moduli**

Material	Young's Modulus, Y (Pa)	Bulk Modulus, B (Pa)	Shear Modulus, S (Pa)
Aluminum	7.0×10^{10}	7.5×10^{10}	2.5×10^{10}
Brass	9.0×10^{10}	6.0×10^{10}	3.5×10^{10}
Copper	11×10^{10}	14×10^{10}	4.4×10^{10}
Iron	21×10^{10}	16×10^{10}	7.7×10^{10}
Lead	1.6×10^{10}	4.1×10^{10}	0.6×10^{10}
Nickel	21×10^{10}	17×10^{10}	7.8×10^{10}
Silicone rubber	0.001×10^{10}	0.2×10^{10}	0.0002×10^{10}
Steel	20×10^{10}	16×10^{10}	7.5×10^{10}
Tendon (typical)	0.12×10^{10}	—	—

ASU

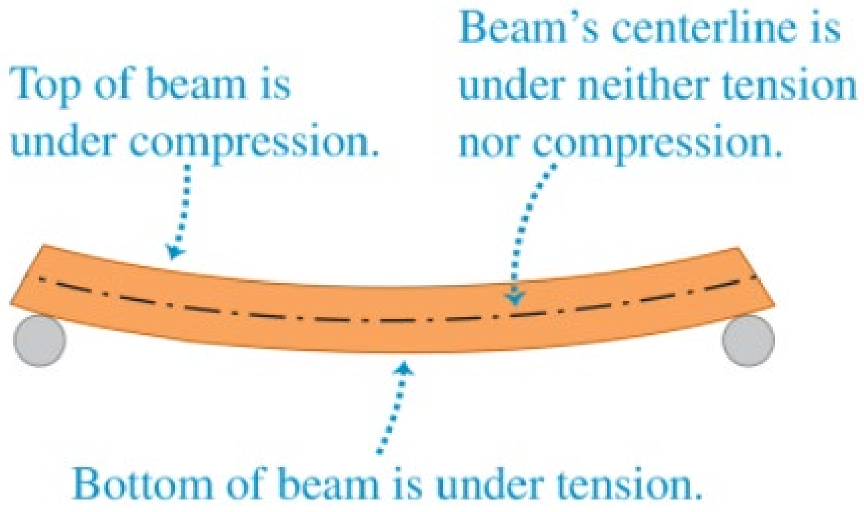
Compressive stress & strain

defined in same way except Δl is now is distance contracted

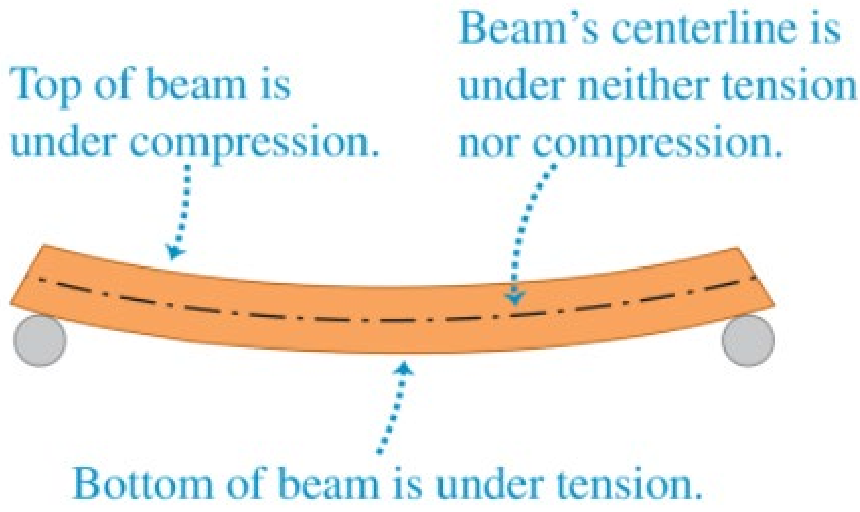


$$\text{Compressive stress} = \frac{F_\perp}{A} \qquad \text{Compressive strain} = \frac{\Delta l}{l_0}$$

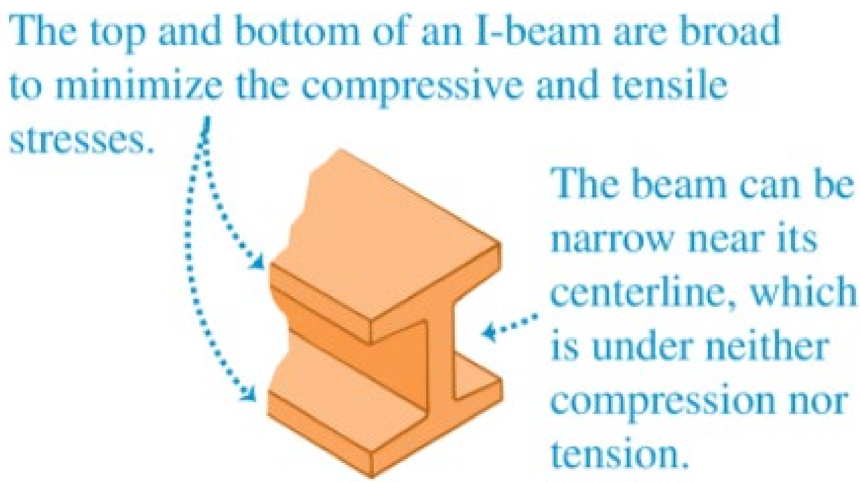
(a)


Top of beam is under compression.
Beam's centerline is under neither tension nor compression.
Bottom of beam is under tension.

(a)


Top of beam is under compression.
Beam's centerline is under neither tension nor compression.
Bottom of beam is under tension.

(b)


The top and bottom of an I-beam are broad to minimize the compressive and tensile stresses.
The beam can be narrow near its centerline, which is under neither compression nor tension.

A steel rod 2.0 m long has a cross-sectional area of $0.30\ \mathrm{cm}^2$. It is hung by one end from a support, and a 550 kg milling machine is hung from its other end. Determine the stress on the rod and the resulting strain and elongation.

A steel rod 2.0 m long has a cross-sectional area of $0.30\ \text{cm}^2$. It is hung by one end from a support, and a 550 kg milling machine is hung from its other end. Determine the stress on the rod and the resulting strain and elongation. $L = 2\,m$

A steel rod 2.0 m long has a cross-sectional area of $0.30\ cm^2$. It is hung by one end from a support, and a 550 kg milling machine is hung from its other end. Determine the stress on the rod and the resulting strain and elongation.

$L = 2\,m$

$A = 0.3\ cm^2$

A steel rod 2.0 m long has a cross-sectional area of 0.30 cm^2. It is hung by one end from a support, and a 550 kg milling machine is hung from its other end. Determine the stress on the rod and the resulting strain and elongation.

$L = 2 \text{ m}$

$A = 0.3 \text{ cm}^2 \left(\frac{\text{m}}{100 \text{ cm}}\right)^2$

A steel rod 2.0 m long has a cross-sectional area of $0.30\ cm^2$. It is hung by one end from a support, and a 550 kg milling machine is hung from its other end. Determine the stress on the rod and the resulting strain and elongation.

$L = 2m$

$A = 0.3\ cm^2 \left(\frac{m}{100cm}\right)^2 = 3 * 10^{-5} m$

A steel rod 2.0 m long has a cross-sectional area of 0.30 cm^2. It is hung by one end from a support, and a 550 kg milling machine is hung from its other end. Determine the stress on the rod and the resulting strain and elongation.

$L = 2m$

$A = 0.3\,cm^2 \left(\frac{m}{100cm}\right)^2 = 3 * 10^{-5} m$, $M = 550kg$

A steel rod 2.0 m long has a cross-sectional area of $0.30\ \text{cm}^2$. It is hung by one end from a support, and a 550 kg milling machine is hung from its other end. Determine the stress on the rod and the resulting strain and elongation.

$L = 2m$

$A = 0.3\,cm^2 \left(\frac{m}{100cm}\right)^2 = 3*10^{-5} m$, $M = 550kg$

$Stress = \frac{F_\perp}{A}$

A steel rod 2.0 m long has a cross-sectional area of $0.30\ \text{cm}^2$. It is hung by one end from a support, and a 550 kg milling machine is hung from its other end. Determine the stress on the rod and the resulting strain and elongation.

$L = 2m$

$A = 0.3\ cm^2 \left(\frac{m}{100cm}\right)^2 = 3*10^{-5} m$, $M = 550 kg$

$$\text{Stress} = \frac{F_{\perp}}{A} = \frac{(550kg)(9.8\ m/s^2)}{3*10^{-5} m}$$

A steel rod 2.0 m long has a cross-sectional area of $0.30\ cm^2$. It is hung by one end from a support, and a 550 kg milling machine is hung from its other end. Determine the stress on the rod and the resulting strain and elongation.

$L = 2m$

$A = 0.3\ cm^2 \left(\frac{m}{100cm}\right)^2 = 3*10^{-5} m$, $M = 550kg$

$Stress = \frac{F_\perp}{A} = \frac{(550kg)(9.8\ m/s^2)}{3*10^{-5} m} = 1.8*10^{8} Pa$

A steel rod 2.0 m long has a cross-sectional area of $0.30\ cm^2$. It is hung by one end from a support, and a 550 kg milling machine is hung from its other end. Determine the stress on the rod and the resulting strain and elongation.

$L = 2m$

$A = 0.3\ cm^2 \left(\frac{m}{100cm}\right)^2 = 3 * 10^{-5} m, \quad M = 550 kg$

$$\text{Stress} = \frac{F_\perp}{A} = \frac{(550kg)(9.8\ m/s^2)}{3*10^{-5} m} = 1.8*10^{8} Pa$$

$$Y = \frac{(F_\perp / A)}{(\Delta l / l)} = \frac{\text{Stress}}{\text{Strain}}$$

A steel rod 2.0 m long has a cross-sectional area of $0.30\ \text{cm}^2$. It is hung by one end from a support, and a 550 kg milling machine is hung from its other end. Determine the stress on the rod and the resulting strain and elongation.

$L = 2\,m$

$A = 0.3\,cm^2 \left(\frac{m}{100\,cm}\right)^2 = 3*10^{-5}\,m, \quad M = 550\,kg$

$$\text{Stress} = \frac{F_\perp}{A} = \frac{(550\,kg)(9.8\,m/s^2)}{3*10^{-5}\,m} = 1.8*10^{8}\,Pa$$

$$Y = \frac{(F_\perp/A)}{(\Delta l/l)} = \frac{\text{Stress}}{\text{Strain}} \Rightarrow \text{Strain} = \frac{\Delta l}{l} = \frac{(F_\perp/A)}{Y}$$

A steel rod 2.0 m long has a cross-sectional area of $0.30\ \text{cm}^2$. It is hung by one end from a support, and a 550 kg milling machine is hung from its other end. Determine the stress on the rod and the resulting strain and elongation.

$$L = 2\,m$$

$$A = 0.3\,cm^2\left(\frac{m}{100\,cm}\right)^2 = 3*10^{-5}\,m, \quad M = 550\,kg$$

$$\text{Stress} = \frac{F_\perp}{A} = \frac{(550\,kg)(9.8\,m/s^2)}{3\ldots} = 1.8*10^{8}\ldots$$

$$Y = \frac{(F_\perp/A)}{(\Delta l/l)} = \frac{\text{stress}}{\text{strain}}$$

$$\Rightarrow \quad \frac{\Delta l}{l} = \frac{1.8*10^{8}}{\boxed{20*10^{10}}}$$

Table 11.1 **Approximate Elastic Moduli**

Material	Young's Modulus, Y (Pa)
Aluminum	7.0×10^{10}
Brass	9.0×10^{10}
Copper	11×10^{10}
Iron	21×10^{10}
Lead	1.6×10^{10}
Nickel	21×10^{10}
Silicone rubber	0.001×10^{10}
Steel	20×10^{10}
Tendon (typical)	0.12×10^{10}

A steel rod 2.0 m long has a cross-sectional area of 0.30 cm^2. It is hung by one end from a support, and a 550 kg milling machine is hung from its other end. Determine the stress on the rod and the resulting strain and elongation.

$L = 2m$

$A = 0.3\,cm^2 \left(\frac{m}{100cm}\right)^2 = 3*10^{-5} m$, $M = 550kg$

$$\text{Stress} = \frac{F_\perp}{A} = \frac{(550kg)(9.8\,m/s^2)}{3*10^{-5} m} = 1.8*10^8 Pa$$

$$Y = \frac{(F_\perp / A)}{(\Delta l / l)} = \frac{\text{Stress}}{\text{Strain}} \Rightarrow \text{Strain} = \frac{\Delta l}{l} = \frac{(F_\perp / A)}{Y}$$

$$\Rightarrow \frac{\Delta l}{l} = \frac{1.8*10^8}{20*10^{10}} = 0.9*10^{-3}$$

ASU

A steel rod 2.0 m long has a cross-sectional area of $0.30\ cm^2$. It is hung by one end from a support, and a 550 kg milling machine is hung from its other end. Determine the stress on the rod and the resulting strain and elongation. $L = 2m$

$$A = 0.3\ cm^2 \left(\frac{m}{100cm}\right)^2 = 3*10^{-5} m\ ,\quad M = 550 kg$$

$$Stress = \frac{F_\perp}{A} = \frac{(550kg)(9.8\ m/s^2)}{3*10^{-5} m} = 1.8*10^8 Pa$$

$$Y = \frac{(F_\perp / A)}{(\Delta l / l)} = \frac{Stress}{Strain} \Rightarrow Strain = \frac{\Delta l}{l} = \frac{(F_\perp / A)}{Y}$$

$$\Rightarrow \quad \frac{\Delta l}{l} = \frac{1.8*10^8}{20*10^{10}} = 0.9*10^{-3} = 9*10^{-4}$$

A steel rod 2.0 m long has a cross-sectional area of $0.30\ \text{cm}^2$. It is hung by one end from a support, and a 550 kg milling machine is hung from its other end. Determine the stress on the rod and the resulting strain and elongation.

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$$Y = \frac{(F_\perp/A)}{(\Delta l/l)} = \frac{\text{Stress}}{\text{Strain}} \Rightarrow \text{Strain} = \frac{\Delta l}{l} = \frac{(F_\perp/A)}{Y}$$

$$\Rightarrow \frac{\Delta l}{l} = \frac{1.8*10^{8}}{20*10^{10}} = 0.9*10^{-3} = 9*10^{-4}$$

$$\Rightarrow \Delta l = l * 9*10^{-4}$$

A steel rod 2.0 m long has a cross-sectional area of 0.30 cm^2. It is hung by one end from a support, and a 550 kg milling machine is hung from its other end. Determine the stress on the rod and the resulting strain and elongation.

$L = 2m$

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$$Stress = \frac{F_\perp}{A} = \frac{(550kg)(9.8\ m/s^2)}{3*10^{-5} m} = 1.8*10^8 Pa$$

$$Y = \frac{(F_\perp/A)}{(\Delta l/l)} = \frac{Stress}{Strain} \Rightarrow Strain = \frac{\Delta l}{l} = \frac{(F_\perp/A)}{Y}$$

$$\Rightarrow \frac{\Delta l}{l} = \frac{1.8*10^8}{20*10^{10}} = 0.9*10^{-3} = 9*10^{-4}$$

$$\Rightarrow \Delta l = l * 9*10^{-4} = 18*10^{-4} m$$

A steel rod 2.0 m long has a cross-sectional area of 0.30 cm^2. It is hung by one end from a support, and a 550 kg milling machine is hung from its other end. Determine the stress on the rod and the resulting strain and elongation.

$L = 2m$

$A = 0.3\ cm^2 \left(\frac{m}{100cm}\right)^2 = 3*10^{-5} m, \quad M = 550 kg$

$Stress = \frac{F_\perp}{A} = \frac{(550kg)(9.8\ m/s^2)}{3*10^{-5} m} = 1.8*10^{8} Pa$

$Y = \frac{(F_\perp/A)}{(\Delta l/l)} = \frac{Stress}{Strain} \Rightarrow Strain = \frac{\Delta l}{l} = \frac{(F_\perp/A)}{Y}$

$\Rightarrow \frac{\Delta l}{l} = \frac{1.8*10^{8}}{20*10^{10}} = 0.9*10^{-3} = 9*10^{-4}$

$\Rightarrow \Delta l = l * 9*10^{-4} = 18*10^{-4} m = 1.8*10^{-3} m$

ASU

A steel rod 2.0 m long has a cross-sectional area of 0.30 cm^2. It is hung by one end from a support, and a 550 kg milling machine is hung from its other end. Determine the stress on the rod and the resulting strain and elongation.

$L = 2m$

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$$\boxed{\text{Stress} = \frac{F_\perp}{A} = \frac{(550kg)(9.8\,m/s^2)}{3*10^{-5}m} = 1.8*10^8\,Pa}$$

$$Y = \frac{(F_\perp/A)}{(\Delta l/l)} = \frac{\text{stress}}{\text{strain}} \Rightarrow \text{Strain} = \frac{\Delta l}{l} = \frac{(F_\perp/A)}{Y}$$

$$\Rightarrow \boxed{\frac{\Delta l}{l} = \frac{1.8*10^8}{20*10^{10}} = 0.9*10^{-3} = 9*10^{-4}}$$

$$\Rightarrow \Delta l = l * 9*10^{-4} = 18*10^{-4}m = 1.8*10^{-3}m$$

$$= 1.8\,mm$$

Bulk stress and strain

$$P = \frac{F_\perp}{A}$$

Bulk stress and strain

$$P = \frac{F_\perp}{A}$$

pressure in fluid

Bulk stress and strain

$$P = \frac{F_\perp}{A}$$

Force fluid applies to immersed object

pressure in fluid

Bulk stress and strain

$$P = \frac{F_\perp}{A}$$

Force fluid applies to immersed object

pressure in fluid

Area that force is exerted over

Bulk stress and strain

$$P = \frac{F_\perp}{A}$$

Force fluid applies to immersed object

pressure in fluid

Area that force is exerted over

$$\text{Bulk (volume) strain} = \frac{\Delta V}{V_0}$$

Bulk stress and strain

$$P = \frac{F_\perp}{A}$$

Force fluid applies to immersed object

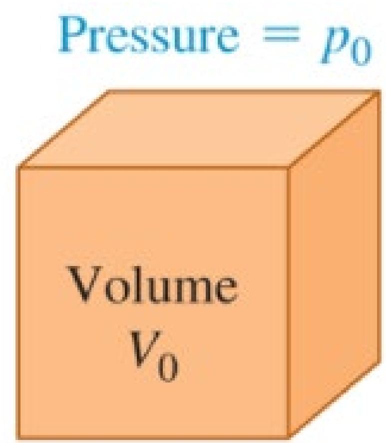
pressure in fluid

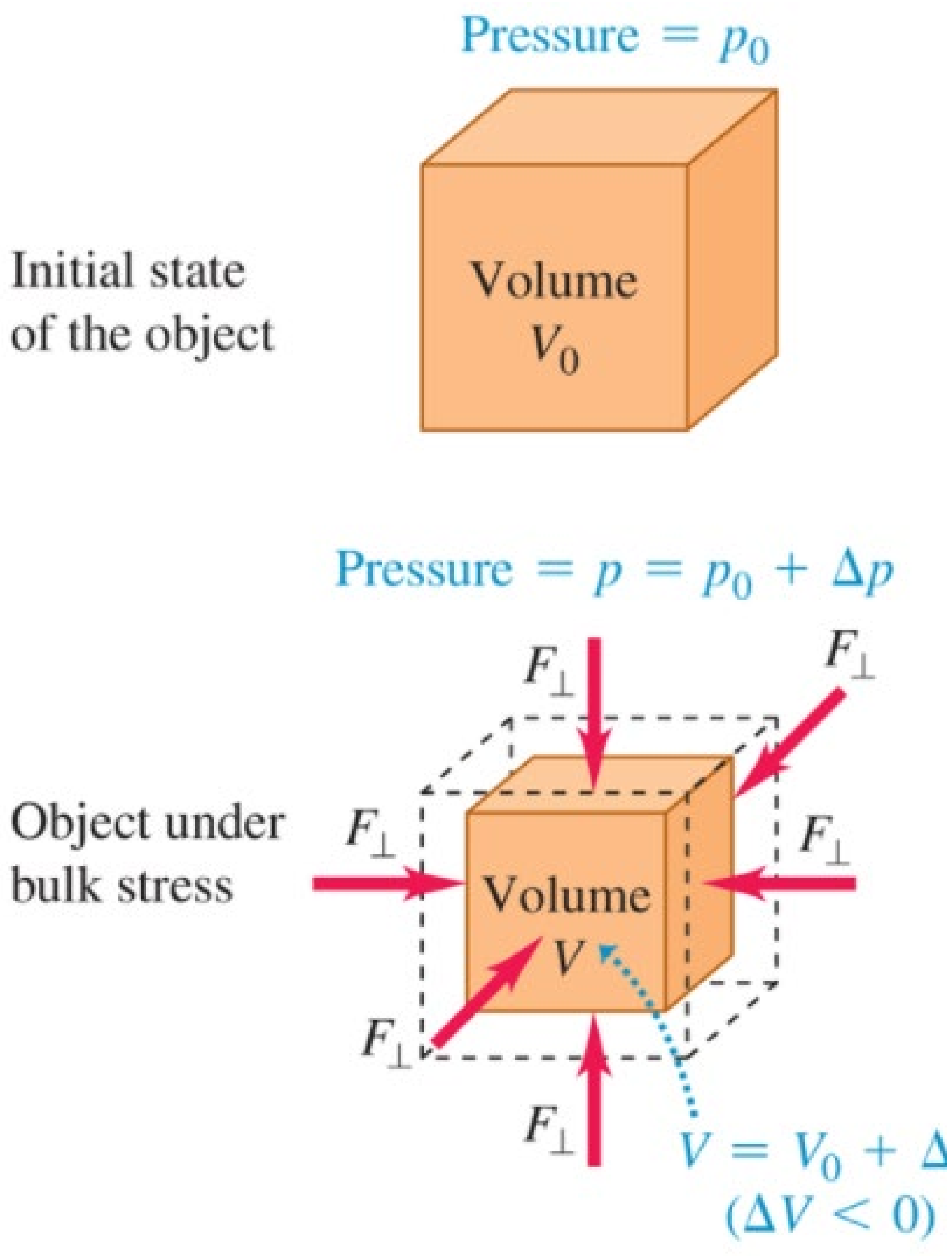
Area that force is exerted over

$$\text{Bulk (volume) strain} = \frac{\Delta V}{V_0}$$

$$\text{Bulk stress} = \Delta p$$

Initial state of the object




Pressure = p_0
Initial state of the object
Volume V_0
Pressure = $p = p_0 + \Delta p$
Object under bulk stress
$F_\perp$
$F_\perp$
$F_\perp$
$F_\perp$
$F_\perp$
$F_\perp$
Volume V
$V = V_0 + \Delta$
$(\Delta V < 0)$

Bulk modulus $\equiv B$

Bulk modulus $\equiv B$ &

$$B \equiv \frac{\text{Bulk stress}}{\text{Bulk strain}}$$

Bulk modulus $\equiv B$ &

$$B \equiv \frac{\text{Bulk stress}}{\text{Bulk strain}} = -\frac{\Delta P}{\Delta V / V_0}$$

Bulk modulus $\equiv B$ &

$$B \equiv \frac{\text{Bulk stress}}{\text{Bulk strain}} = -\frac{\Delta P}{\Delta V / V_0}$$

Compressibility $\equiv K$

Bulk modulus $\equiv B$ ¢

$$B \equiv \frac{\text{Bulk stress}}{\text{Bulk strain}} = -\frac{\Delta P}{\Delta V / V_0}$$

Compressibility $\equiv k$ ¢

$$k \equiv \frac{1}{B}$$

	Compressibility, *k*	
Liquid	**Pa^{-1}**	**atm^{-1}**
Carbon disulfide	93×10^{-11}	94×10^{-6}
Ethyl alcohol	110×10^{-11}	111×10^{-6}
Glycerin	21×10^{-11}	21×10^{-6}
Mercury	3.7×10^{-11}	3.8×10^{-6}
Water	45.8×10^{-11}	46.4×10^{-6}

Table 11.1 Approximate Elastic Moduli

Material	Young's Modulus, Y (Pa)	Bulk Modulus, B (Pa)	Shear Modulus, S (Pa)
Aluminum	7.0×10^{10}	7.5×10^{10}	2.5×10^{10}
Brass	9.0×10^{10}	6.0×10^{10}	3.5×10^{10}
Copper	11×10^{10}	14×10^{10}	4.4×10^{10}
Iron	21×10^{10}	16×10^{10}	7.7×10^{10}
Lead	1.6×10^{10}	4.1×10^{10}	0.6×10^{10}
Nickel	21×10^{10}	17×10^{10}	7.8×10^{10}
Silicone rubber	0.001×10^{10}	0.2×10^{10}	0.0002×10^{10}
Steel	20×10^{10}	16×10^{10}	7.5×10^{10}
Tendon (typical)	0.12×10^{10}	—	—

A hydraulic press contains $0.25\ \mathrm{m}^3$ $(250\ \mathrm{L})$ of oil. Find the decrease in the volume of the oil when it is subjected to a pressure increase $\Delta p = 1.6 \times 10^7\ \mathrm{Pa}$ (about 160 atm or 2300 psi). The bulk modulus of the oil is $B = 5.0 \times 10^9\ \mathrm{Pa}$ (about 5.0×10^4 atm), and its compressibility is $k = 1/B = 20 \times 10^{-6}\ \mathrm{atm}^{-1}$.

A hydraulic press contains 0.25 m^3 (250 L) of oil. Find the decrease in the volume of the oil when it is subjected to a pressure increase $\Delta p = 1.6 \times 10^7$ Pa (about 160 atm or 2300 psi). The bulk modulus of the oil is $B = 5.0 \times 10^9$ Pa (about 5.0×10^4 atm), and its compressibility is $k = 1/B = 20 \times 10^{-6} \text{ atm}^{-1}$. $V_0 = 0.25 m^3$

A hydraulic press contains $0.25\ \mathrm{m}^3$ (250 L) of oil. Find the decrease in the volume of the oil when it is subjected to a pressure increase $\Delta p = 1.6 \times 10^7$ Pa (about 160 atm or 2300 psi). The bulk modulus of the oil is $B = 5.0 \times 10^9$ Pa (about 5.0×10^4 atm), and its compressibility is $k = 1/B = 20 \times 10^{-6}\ \mathrm{atm}^{-1}$.

$V_0 = 0.25\,m^3$, $\Delta P = 5 \times 10^9\,Pa$

ASU

A hydraulic press contains 0.25 m^3 (250 L) of oil. Find the decrease in the volume of the oil when it is subjected to a pressure increase $\Delta p = 1.6 \times 10^7$ Pa (about 160 atm or 2300 psi). The bulk modulus of the oil is $B = 5.0 \times 10^9$ Pa (about 5.0×10^4 atm), and its compressibility is $k = 1/B = 20 \times 10^{-6} \text{ atm}^{-1}$.

$V_0 = 0.25 m^3$, $\Delta P = 5*10^9 Pa$

$B = 5*10^9 Pa$

A hydraulic press contains 0.25 m^3 (250 L) of oil. Find the decrease in the volume of the oil when it is subjected to a pressure increase $\Delta p = 1.6 \times 10^7$ Pa (about 160 atm or 2300 psi). The bulk modulus of the oil is $B = 5.0 \times 10^9$ Pa (about 5.0×10^4 atm), and its compressibility is $k = 1/B = 20 \times 10^{-6} \text{ atm}^{-1}$.

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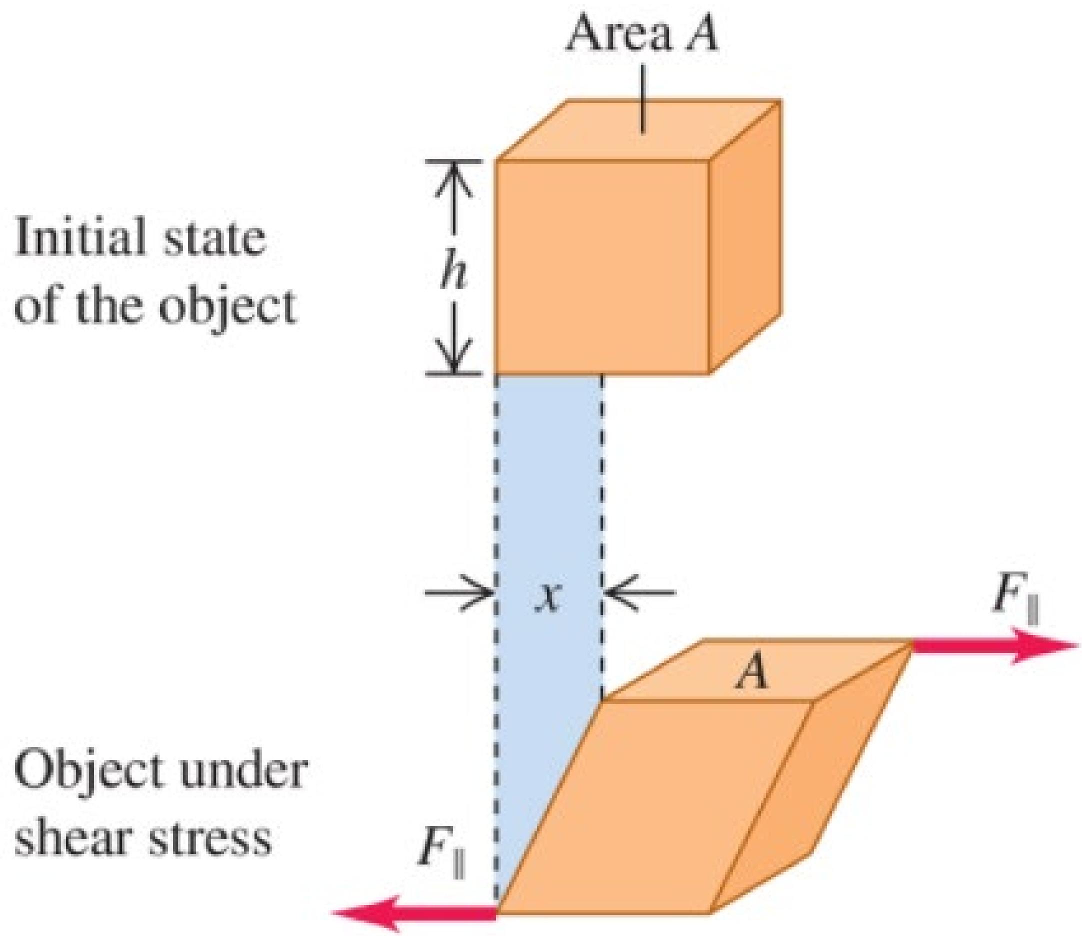
$$\Rightarrow -\Delta V = 0.8 * 10^{-3}\, m^3 = 8 * 10^{-4}\, m^3$$

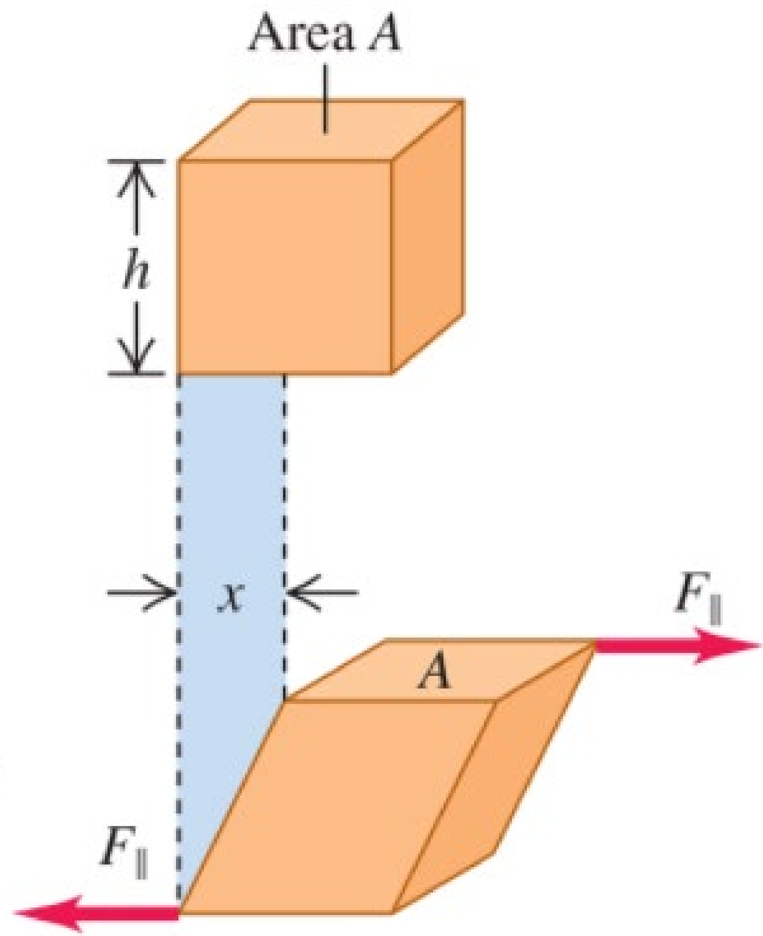
ASU

Shear stress & strain



Shear stress & strain

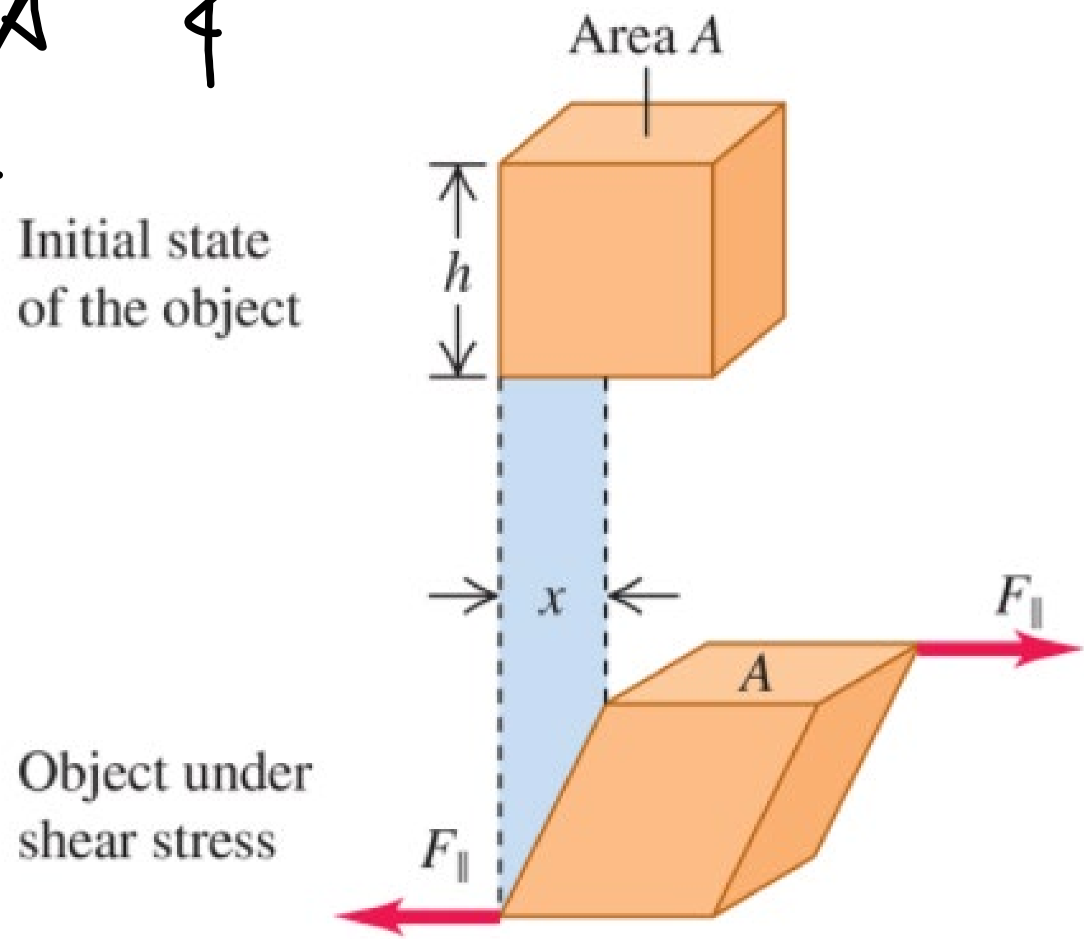
Shear stress $= \frac{F_{\parallel}}{A}$



Shear stress & strain

Shear stress $= \frac{F_{\parallel}}{A}$ &

Shear strain $= \frac{x}{h}$



Shear modulus $\equiv S$

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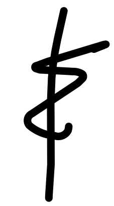

$$S \equiv \frac{\text{shear stress}}{\text{shear strain}}$$

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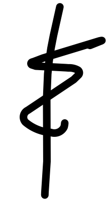
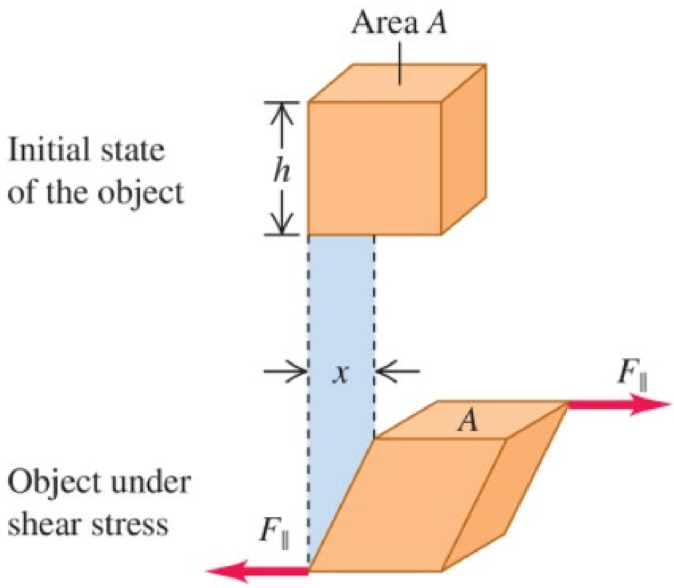


$$S \equiv \frac{\text{shear stress}}{\text{shear strain}} = \frac{(F_{\parallel}/A)}{(x/h)}$$

Suppose the object in Fig. 11.18 is the brass base plate of an outdoor sculpture that experiences shear forces in an earthquake. The plate is 0.80 m square and 0.50 cm thick. What is the force exerted on each of its edges if the resulting displacement x is 0.16 mm?



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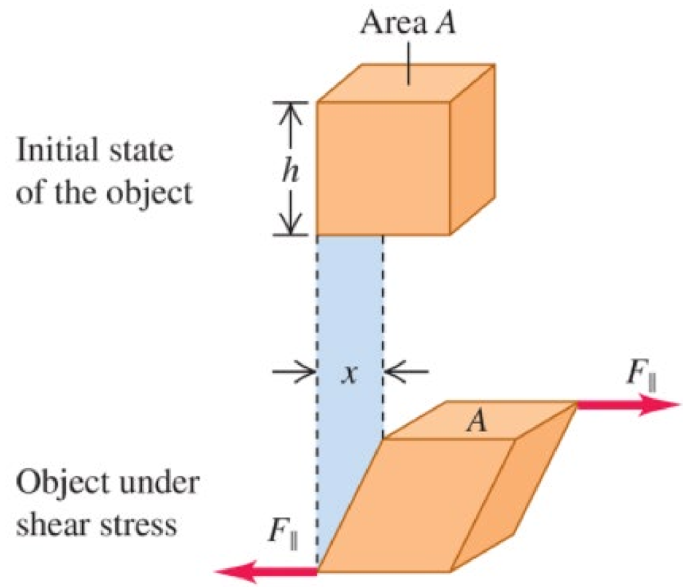
$A = (0.8m * 0.005m) = 0.004m^2$



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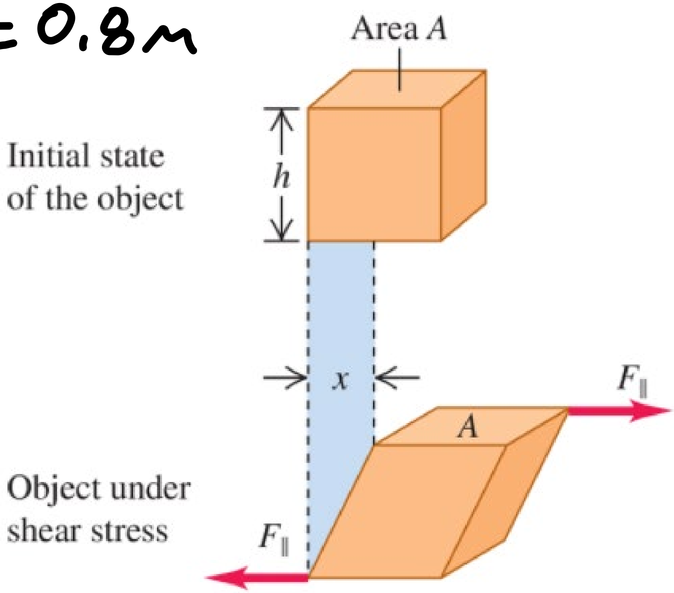

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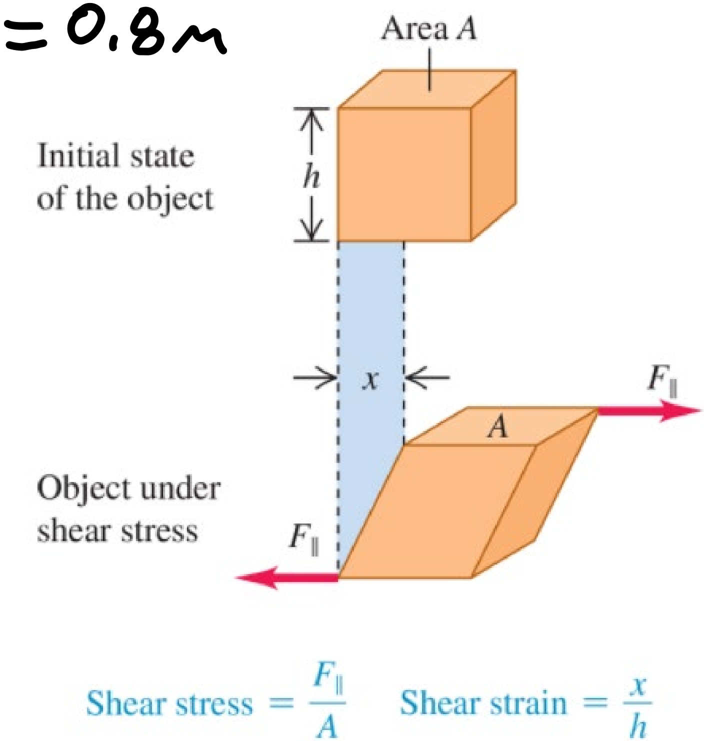
$A = (0.8m * 0.005m) = 0.004m^2$, $h = 0.8m$

$x = 0.16mm = 0.00016m$



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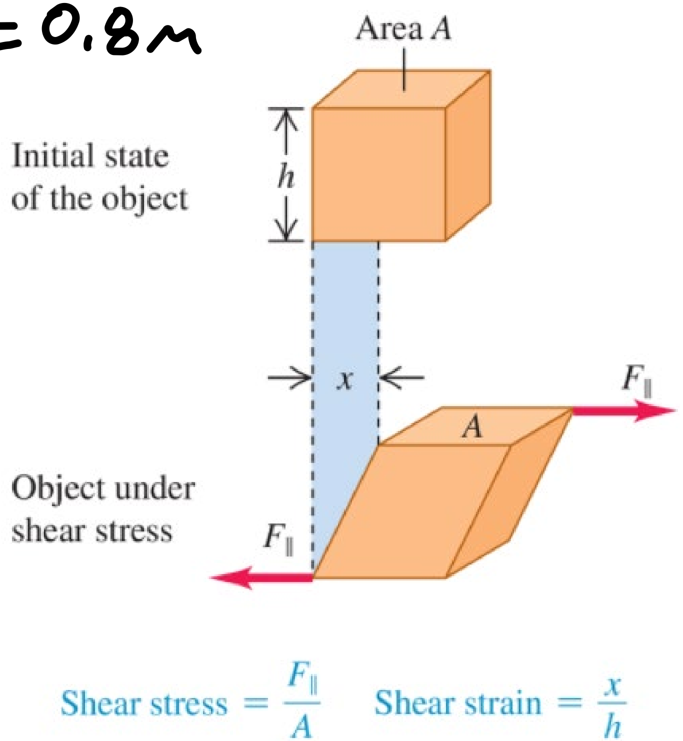
$$S = \frac{(F_{\parallel}/A)}{(x/h)}$$



ASU

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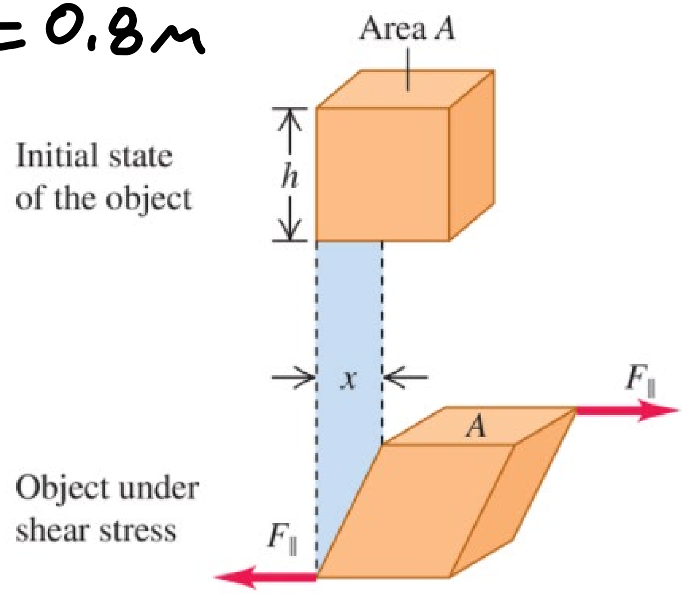
$$S = \frac{(F_{\parallel}/A)}{(x/h)} \Rightarrow$$

$$F_{\parallel} = S\left(\frac{x}{h}\right)A$$



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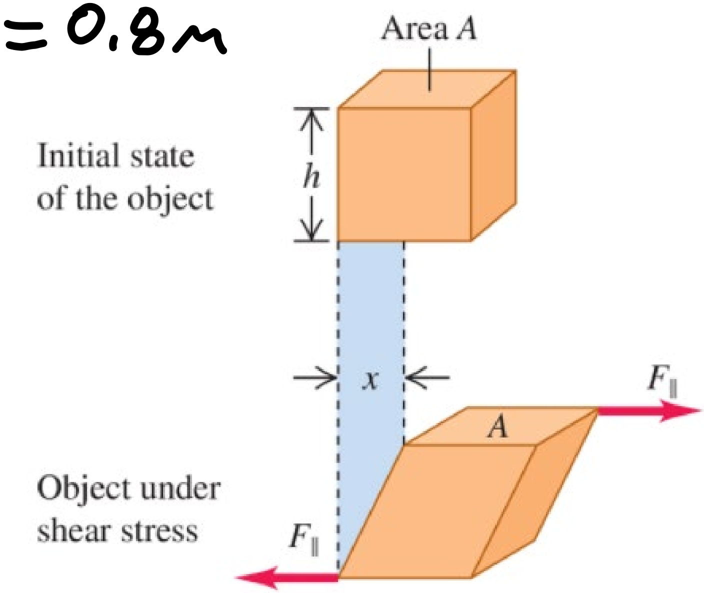
$$S = \frac{(F_{\parallel}/A)}{(x/h)} \Rightarrow$$

$$F_{\parallel} = S\left(\frac{x}{h}\right)A, \text{ where}$$

$S = 3.5 * 10^{10}$ Pa



Shear stress $= \frac{F_{\parallel}}{A}$ Shear strain $= \frac{x}{h}$

Material	Young's Modulus, Y (Pa)	Bulk Modulus, B (Pa)	Shear Modulus, S (Pa)
Aluminum	7.0×10^{10}	7.5×10^{10}	2.5×10^{10}
Brass	9.0×10^{10}	6.0×10^{10}	3.5×10^{10}

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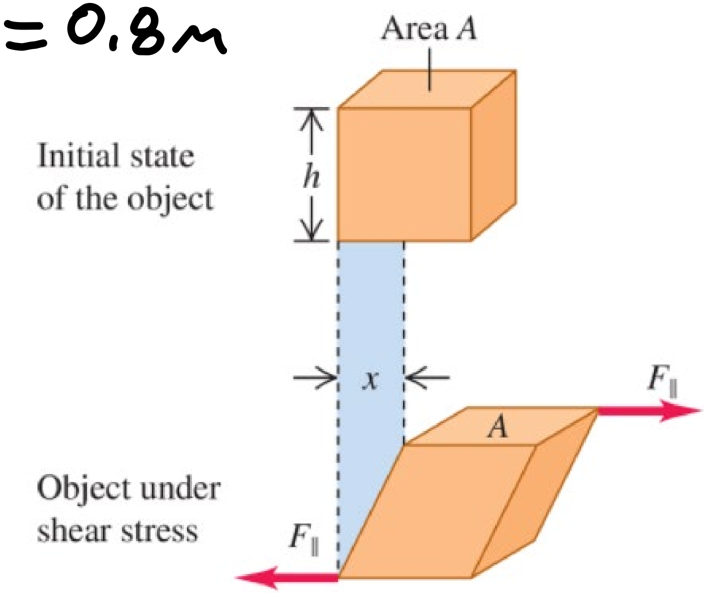
$$S = \frac{(F_{\parallel}/A)}{(x/h)} \Rightarrow$$

$F_{\parallel} = S\left(\frac{x}{h}\right)A$, where

$S = 3.5 * 10^{10}$ Pa   So

$$F_{\parallel} = (3.5 * 10^{10})\left(\frac{1.6 * 10^{-4}}{0.8}\right) * 4 * 10^{-3} N$$



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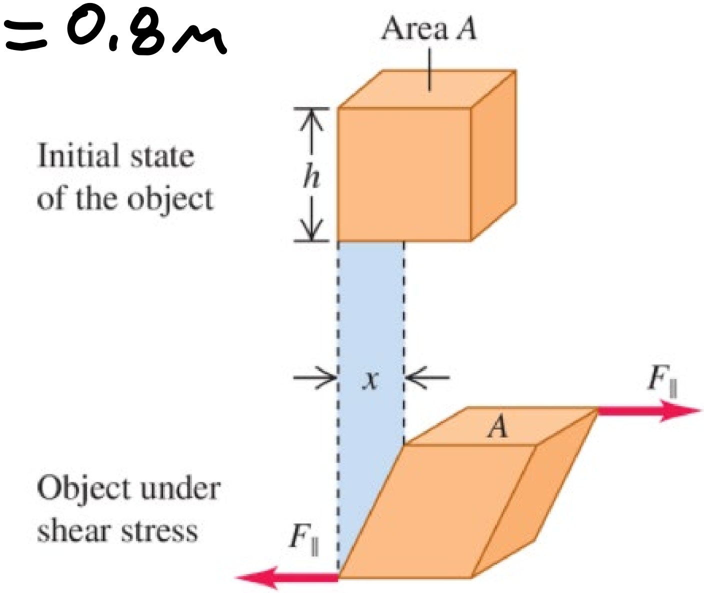
$F_{\parallel} = (3.5 * 10^{10})\left(\frac{1.6 * 10^{-4}}{0.8}\right) * 4 * 10^{-3} N$

$\Rightarrow \quad F_{\parallel} = 28 * 10^{3} N$



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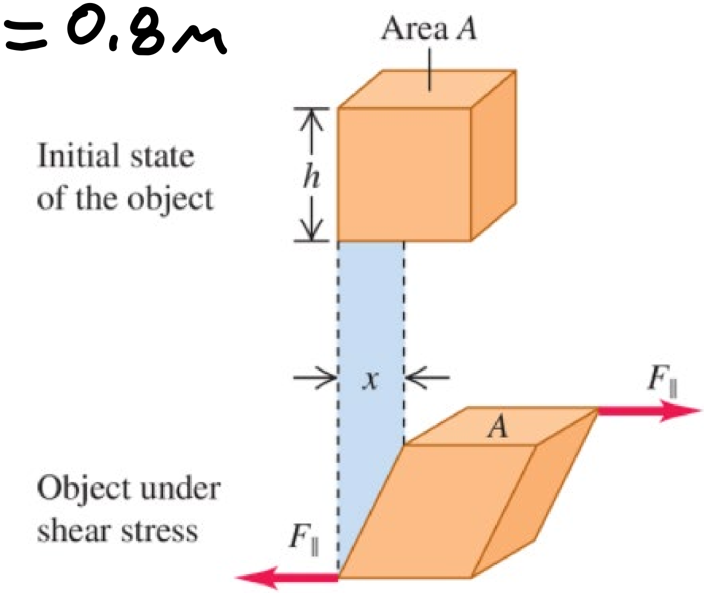
$S = \dfrac{(F_{\parallel}/A)}{(x/h)} \Rightarrow$



$F_{\parallel} = S\left(\frac{x}{h}\right)A$, where

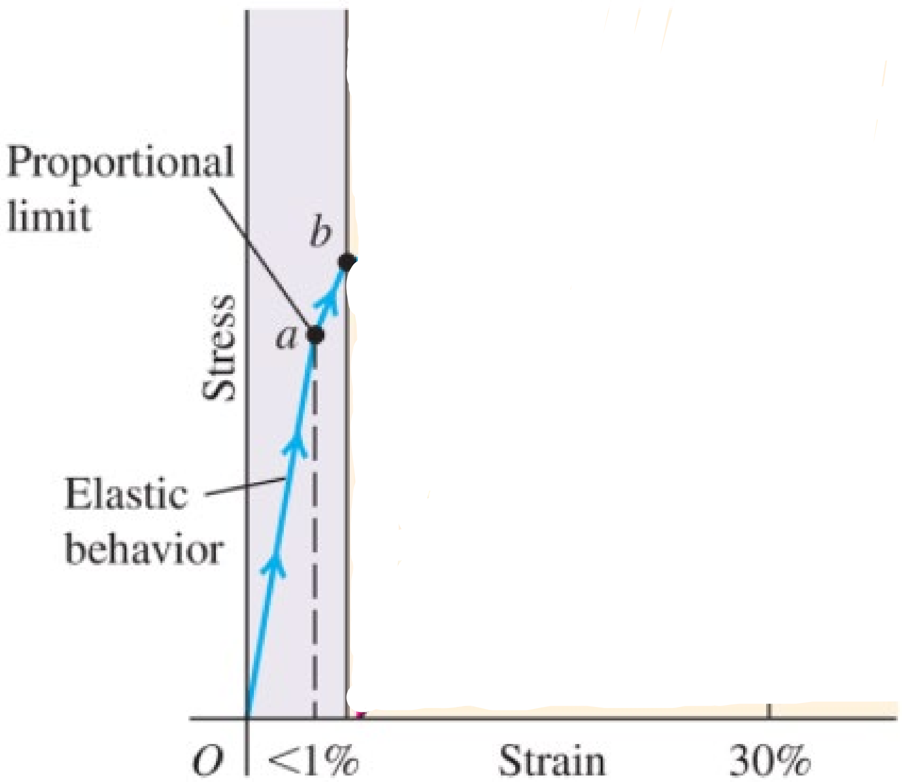
$S = 3.5 * 10^{10}$ Pa So

$F_{\parallel} = (3.5 * 10^{10})\left(\dfrac{1.6 * 10^{-4}}{0.8}\right) * 4 * 10^{-3}\,N$

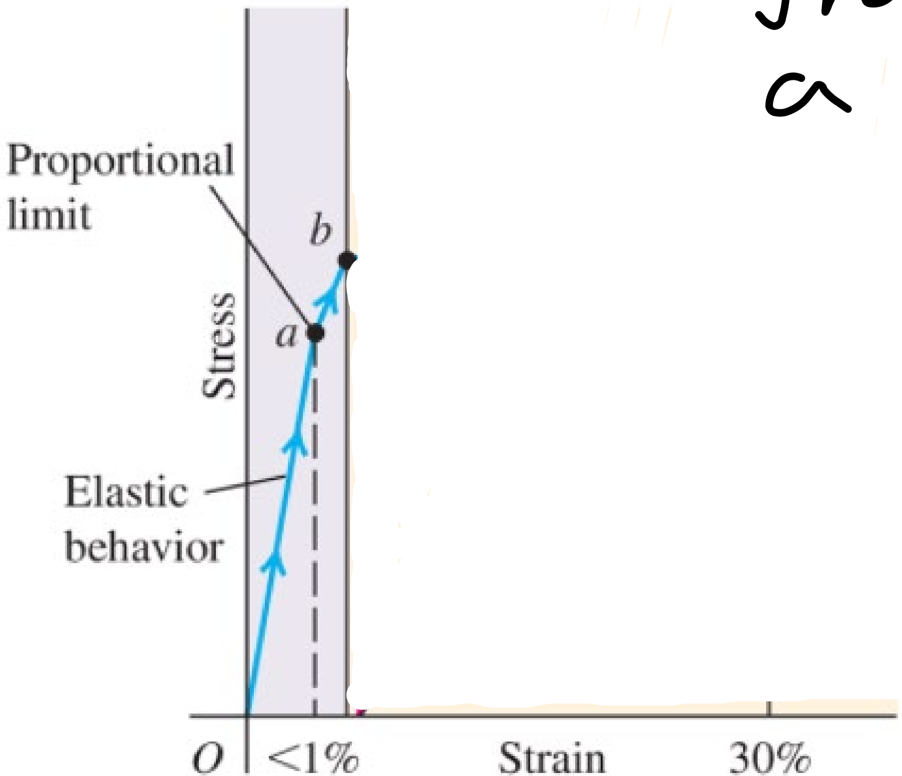
Shear stress $= \dfrac{F_{\parallel}}{A}$ Shear strain $= \dfrac{x}{h}$

$\Rightarrow \boxed{F_{\parallel} = 28 * 10^{3}\,N = 2.8 * 10^{4}\,N}$

Blue line ≡ elastic



Blue line ≡ elastic from O to point a : proportional



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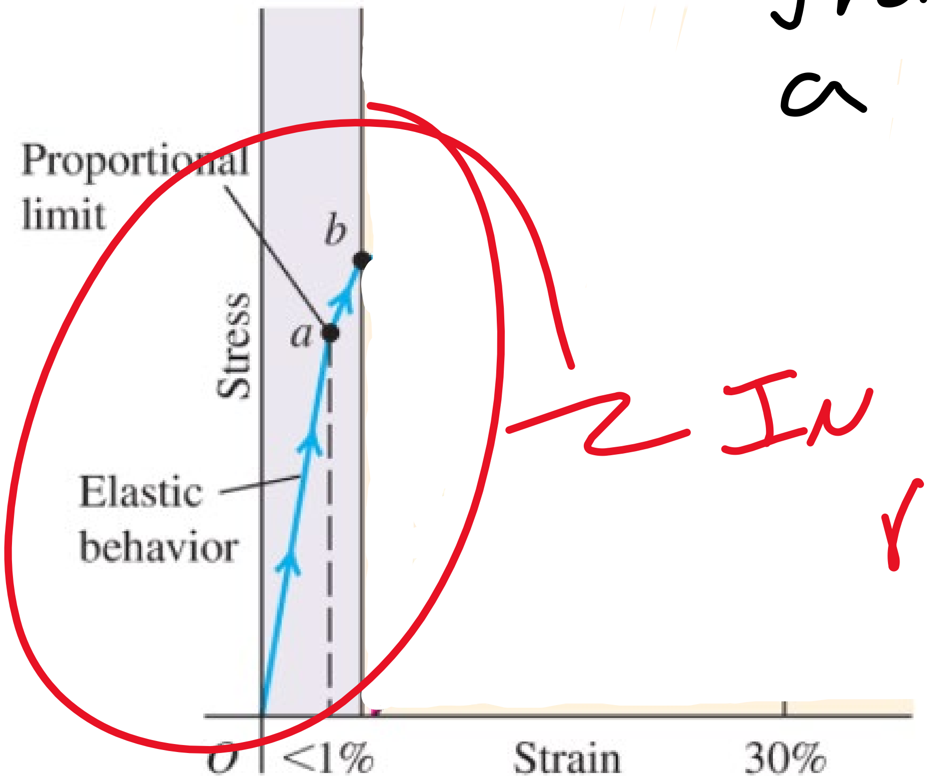
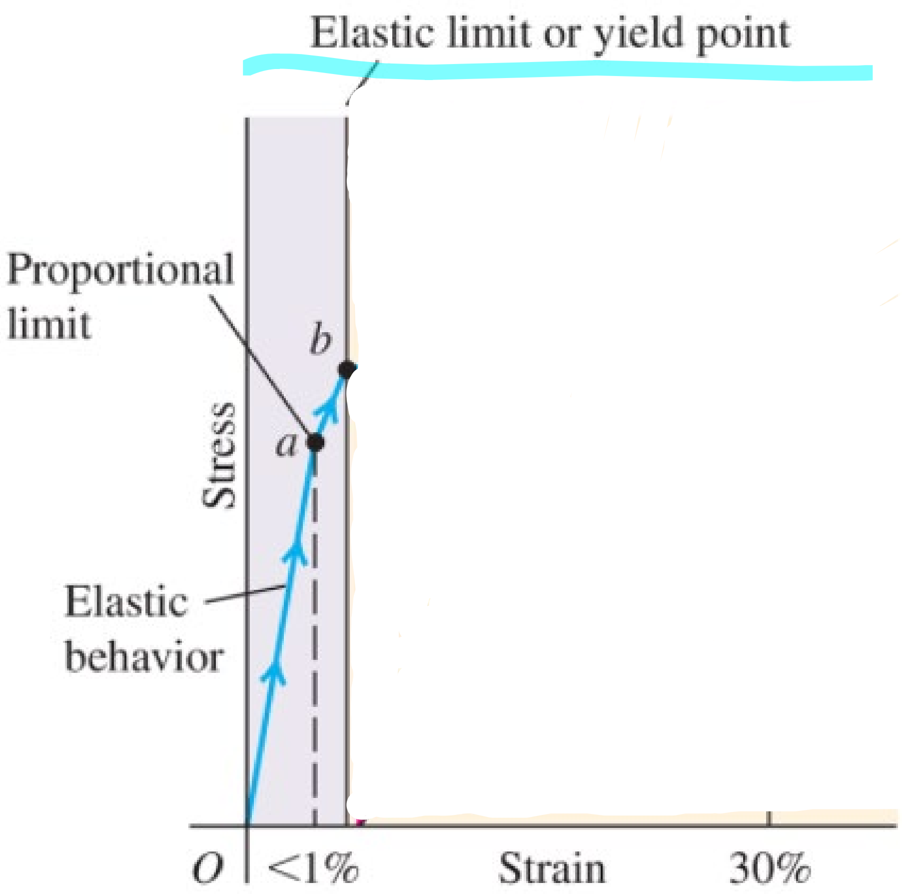
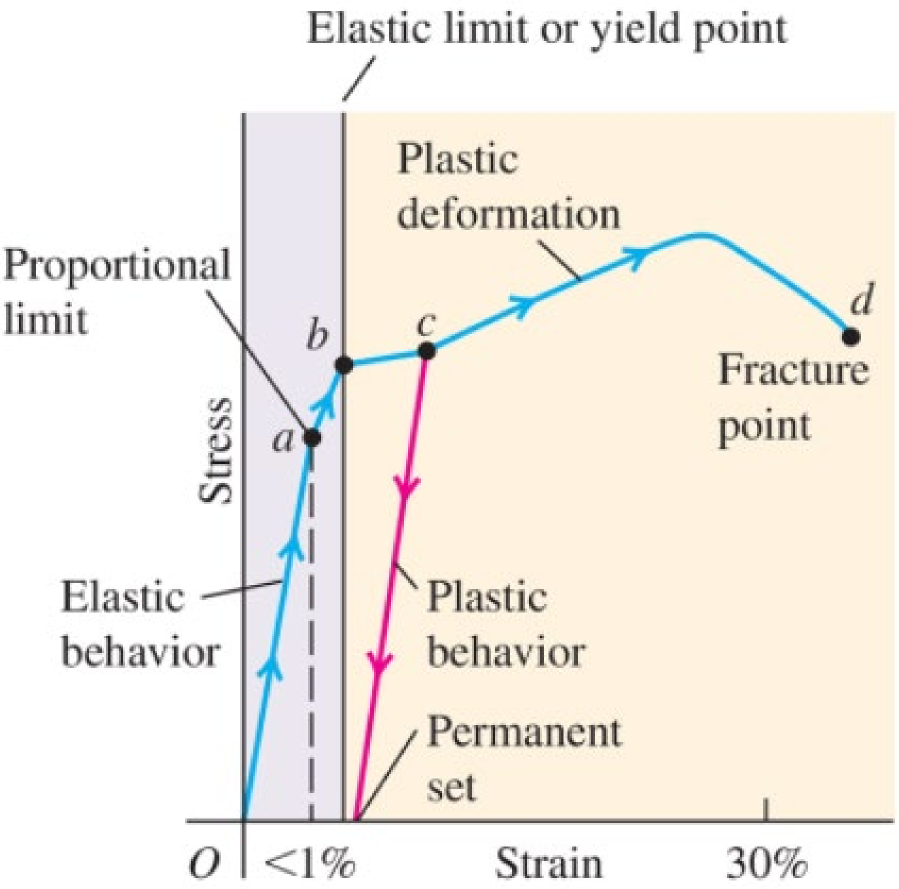
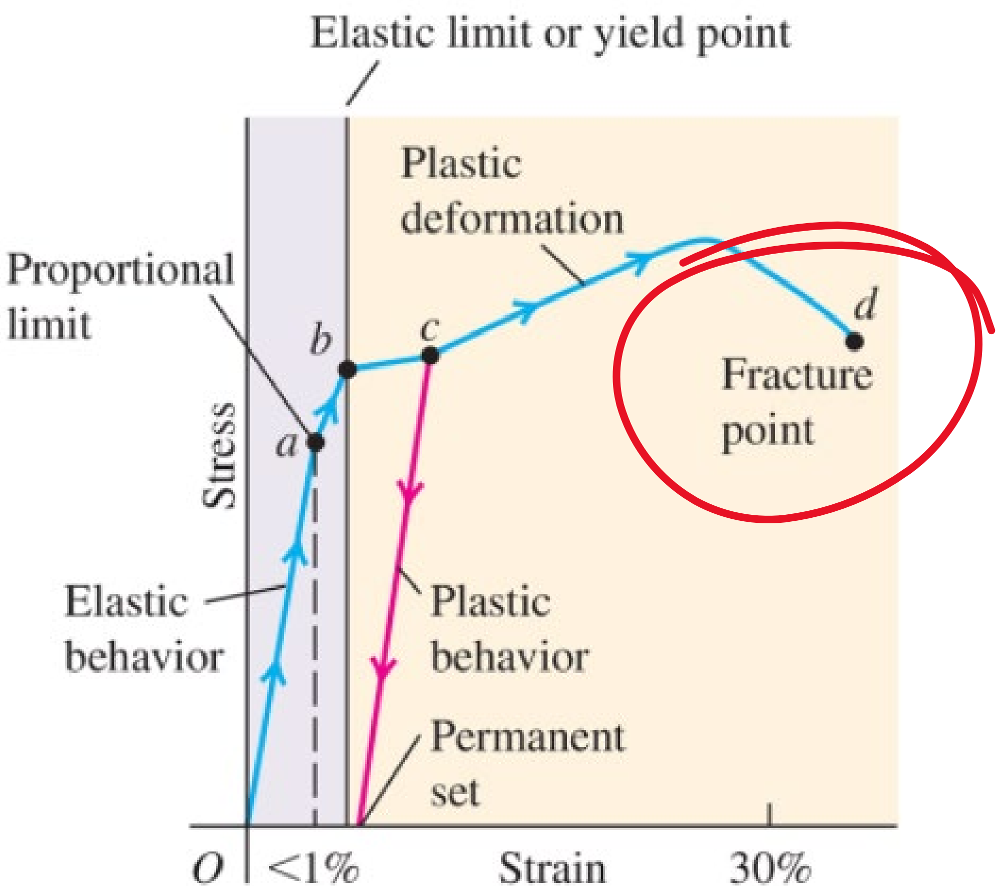


In elastic region, item can go back to original shape


Elastic limit or yield point
Proportional limit
b
a
Stress
Elastic behavior
O
<1%
Strain
30%


Elastic limit or yield point
Plastic deformation
Proportional limit
b
c
d
a
Fracture point
Stress
Elastic behavior
Plastic behavior
Permanent set
O
<1%
Strain
30%



Material	Breaking Stress (Pa or N/m^2)
Aluminum	2.2×10^8
Brass	4.7×10^8
Glass	10×10^8
Iron	3.0×10^8
Steel	$5-20 \times 10^8$
Tendon (typical)	1×10^8