GIVE FEEDBACK

CONTINUE >

Compressive stress is simply the reverse of tensile stress.

Thermal stress is something else entirely. This occurs when a change in temperature fails to expand an object because it is restrained by something else.

Ever been under a metal roof that is creaking in the sun? This is caused by the expansion and contraction of the roof, especially as the shadows of passing clouds cause temperature changes.

Introduction to compression and thermal stress

Compressive stress is simply the reverse of tensile stress, squashing the object instead of pulling it.

Compared to tensile stress, the equation, symbols and units are the same. This is why tensile and compressive stresses are grouped together under the name **axial stress**, σ (sigma).

It is good practice to label compressive stress as σ_c.

< BACK GIVE FEEDBACK CONTINUE >

We also look at thermal expansion.

When things get hotter they expand, but when they cool down they contract. In other words, thermal expansion works both ways. So, just like axial strain, which is proportional to stress, thermal expansion is proportional to temperature. This means thermal stresses can be either tensile or compressive.

Thermal stresses occur when an object is prevented from expanding or contracting.

< BACK GIVE FEEDBACK CONTINUE >

For example, a 6 m roofing sheet is heated by 20 degrees and grows 1.4 mm longer; if instead we cooled it by 20 degrees, it would shorten by 1.4 mm.

If the roofing sheet is screwed down to a rigid structure, the expansion would create stress in the sheet and creaking sounds as the sheet slips against friction, against the fasteners and roof structure. Thermal expansion is the same whether the object is heated or cooled.

< BACK GIVE FEEDBACK OK

We will now consider the opposite of tensile stress—compressive stress. The equation is identical and so are all the symbols. One difference is that we are not producing 'extension', so it is better to use the term 'deformation'. This is applicable to both tension and compression.

Since they are so similar, tensile and compressive stresses are grouped together under the term 'axial stress'.

Define compression

Compression is the opposite of tension. When the tensile forces are applied in the opposite direction, they tend to compress rather than stretch the material.

There are three basic types of strength:

Video object isn't supported in c++ version

- tensile (pulling)
- compressive (squashing)
- shear (sliding)

GIVE FEEDBACK

OK

Compression is the opposite of ______.

Click the correct answer.

- tension
- force
- area
- gravity

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Thermal stresses occur whenever something tries to expand but cannot. This explains why we need expansion joints in concrete slabs, railway tracks, bridges, pipes and machinery.

Define thermal stresses

Thermal stresses can be tensile or compressive. They are caused by the tendency of most materials to expand when heated or contract when cooled.

If such thermal expansion or contraction is fully or partially prevented, stresses are set up within the material.

This is why we need expansion joints, to prevent the build-up of damaging stresses. This expansion joint on a bridge expands and contracts with temperature changes.

GIVE FEEDBACK

OK

Regarding thermal stresses that occur in a constrained object (one that is prevented from expanding or contracting):

Drag statements on the right to match the left.

When temperature increases, the constrained object will go into _____ stress	compressive
When temperature decreases, the constrained object will go into _____ stress	tensile

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Regarding thermal expansion and contraction:

Drag statements on the right to match the left.

When temperature increases, most materials will _____	expand
When temperature decreases, most materials will _____	contract

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Compressive strength is usually higher than tensile strength for any material but brittle materials have a higher disparity. They tend to have high compressive and low tensile strengths. The best all-rounders are ductile materials, such as structural steel.

Ductile materials

We can divide most engineering materials into three groups:

- Ductile materials
- Brittle materials
- Composites

Ductile materials, such as copper, aluminium and steel, tend to have a relatively high tensile strength. This makes them suited to situations where tensile stress is encountered. Examples include structural steel, wire rope and pressure vessels.

GIVE FEEDBACK

CONTINUE >

However, when it comes to outright maximum performance, the highest tensile strength is seen in high-strength steels which have less ductility than softer steels, e.g. high-strength bolts, though even here there is always some ductility to guard against sudden failure.

< BACK GIVE FEEDBACK OK

Compared to an ordinary bolt, a high-strength bolt has:

Check all that apply.

- [ ] Higher tensile strength
- [ ] Lower ductility
- [ ] Lower tensile strength
- [ ] Higher ductility

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Most engineering materials can be divided into three groups. Which group is often used where there are tensile loads and stresses?

Click the correct answer.

- Ductile materials
- Brittle materials
- Composites

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Brittle materials, like cast iron, bricks, masonry and concrete, are much better in compressive, e.g. a column, rather than tense situations. Reinforcing in concrete is specifically used to add tensile strength to concrete where it is needed.

Brittle materials

Brittle materials, which include cast iron, bricks, masonry and concrete, have good compressive strength but poor tensile strength. Being cheaper than steel, they are chosen in the heavy masses of building foundations, piers and dams (brick, masonry and low-grade concrete), and for machine-tool framework (cast iron).

They are not used in structures and components subjected to large tensile forces, where ductile materials like steel are preferred, unless reinforcing is added.

Concrete piles are designed for compressive forces but need reinforcing steel to handle tensile and bending loads.

GIVE FEEDBACK

OK

Match the appropriate material group to each application:

Drag statements on the right to match the left.

Foundations, piers, dams	Brittle materials
Structures, cables, pressure vessels	Ductile materials

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Most engineering materials can be divided into three groups. Which group is often used where there are compressive loads and stresses, tensile stresses are low, and costs are to be kept to a minimum?

Click the correct answer.

- Ductile materials
- Brittle materials
- Composites

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

While the ultimate tensile strength is usually the most important property of a material, in some cases it is the ultimate compressive strength that matters most. This is especially true for brittle materials like concrete, masonry and cast iron.

Ultimate compressive strength

For a material like concrete, the most important property is the **ultimate compressive strength** (UCS). Specifying a 25 MPa concrete means the UCS must have a minimum of 25 MPa.

UCS is defined as follows:

$$UCS = \frac{\text{force causing crushing failure}}{\text{cross-sectional area}} = \frac{F_{max}}{A}$$

GIVE FEEDBACK

OK

A 25 MPa concrete means that the concrete must have a minimum of 25 MPa for the ______.

Click the correct answer.

- Ultimate compressive strength
- Ultimate tensile strength
- Yield compressive strength
- Allowable stress

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Composite materials use a combination of materials, which can be from the three major categories: polymers; metals; and ceramics.

Examples are fibreglass (polymer with glass fibre) and reinforced concrete (ceramic with metal fibre).

Reinforced concrete, which is used extensively in bridge and building construction, combines the high compressive strength of concrete with the superior tensile properties of steel reinforcement.

The reinforcing steel is concentrated in the area under tension, with less steel required where there are compressive stresses. This allows the concrete to be customised to match the expected stresses.

For example, for a simple beam supported at each end, the top of the beam is in compression and the bottom of the beam is in tension. The bottom is where there will be the most steel.

GIVE FEEDBACK

CONTINUE >

Fibre-reinforced composites are the polymer-based materials utilising the high strength and stiffness of filaments of glass, carbon or aramid (Kevlar).

Carbon fibres are usually embedded in epoxy, giving the strength and stiffness of metals but weighing little more than a plastic part. The fibres can also be orientated to provide tensile strength where it is most needed. Carbon fibre utilises the high tensile strength and stiffness of the carbon filaments to reinforce the polymer (typically epoxy).

< BACK GIVE FEEDBACK CONTINUE >

Another type of composite often used in automotive parts is glass fibre-reinforced thermoplastics. The fibres must be chopped very short (only a few millimetres) to allow processing in an injection moulding machine. Nylon is a popular choice for the matrix material (the plastic that the fibres are mixed into, which 'glues' the fibres together). This dramatically improves stiffness and allows the plastic to be used in a hot environment, like a car radiator.

< BACK GIVE FEEDBACK OK

Match the words in each statement relating to composite materials:

Drag statements on the right to match the left.

In reinforced concrete, the steel will be concentrated in areas of high ______ stress	tensile
Concrete has sufficient ______ strength to carry these loads with minimal reinforcing	compressive
Carbon fibre has high ______ and tensile strength	stiffness
Chopped glass fibre can be included in a ______ matrix	thermoplastic

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Reinforced concrete uses the high (please select) of reinforcing steel to increase performance without wasting steel in places where concrete has sufficient (please select) to handle the load.

Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Wood strength varies considerably with the direction of application of the load. The strength given here is for parallel (i.e. along the grain) direction of the force. The transverse (i.e. perpendicular to the grain) strength for pine timber is only 3 N/mm^2.

Calculate the ultimate compressive strength

In some design situations, compressive strength can be more important than tensile strength.
Typical average values of ultimate compressive strengths are given in this table. Some materials show a range of values for the UCS.

Ultimate compressive strength (UCS)

Material	UCS (N/mm^2) or Megapascals (MPa)	Comment
cast iron	700	Compressive strength is about four times its tensile strength
masonry (concrete and bricks)	10 to 80 (typical 20)	Wide variation, concrete ranges typically 20 to 50 MPa
wood (parallel to grain)	40 to 55	Wood is highly anisotropic (it has different properties in different directions)
wood (perpendicular to grain)	5	

GIVE FEEDBACK

OK

Match typical ultimate compressive strengths (UCS) to the listed materials:

Drag statements on the right to match the left.

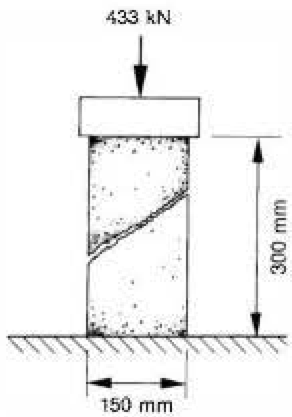
Cast iron	700 MPa
Concrete	20 to 50 MPa
Wood (perpendicular to grain)	5 MPa

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Example

A portable testing machine, used for quality control on a large construction site, carries out crushing tests on concrete by applying an axial force of 433 kN. This causes compression failure in a concrete specimen, 150 mm in diameter and 300 mm high. What is the ultimate compressive strength of the concrete?



GIVE FEEDBACK

CONTINUE >

Solution

$$\text{UCS} = \frac{\text{force causing crushing failure}}{\text{cross-sectional area}}$$

$$= \frac{433{,}000 \text{ N}}{\left(\pi \times \frac{150^2}{4}\right) \text{mm}^2}$$

$$= 24.5 \text{ N/mm}^2 \text{ (which is } 24.5 \text{ MPa)}$$

< BACK GIVE FEEDBACK OK

A concrete cylinder of 100 mm diameter is crushed by a force of 200 kN. Calculate the Ultimate Compressive Stress (UCS) in MPa.

(include units, use 2 decimal places)

± ▾ | $\frac{\square}{\square}$ | $\square^2$ ▾ | $\sqrt{\square}$ | $(\square)$ ▾ | Clear

≤ ▾ | π | $\square \times 10^{\square}$ | MPa | $f(x)$ ▾ | σ | Clear line

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↵

Click and type your answer here

CHALLENGE | SUBMIT | SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

A concrete cylinder of 100 mm diameter has a UCS of 0 MPa. Calculate the force (in kN) that will crush this cylinder. (Use five significant figures.)

+ − · ÷ Clear

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? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Define direct compressive stress

Compressive stress is simply tensile stress in reverse.

Compressive stress is exactly the same as tensile stress, except the forces are in the reverse direction. Its full name is **direct axial compressive stress**.

Direct means the stress is not complicated by other types of stress, like bending or torsion.

Axial means the stress is in line with the main axis of the part, so it can only be tension or compression.

We can shorten it to **compressive stress**, as long as we are not talking about the compressive stresses found in more complex stress situations, like bending.

GIVE FEEDBACK

OK

A load is perfectly balanced on the top of a column. The full description of the stress in the column would be (please select) ▼ axial (please select) ▼ stress.

Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Match each word to the correct description regarding direct axial compressive stress:

Drag statements on the right to match the left.

The stress is not complicated by other types of stress	Direct
The stress is in line with the main axis of the part	Axial
The stress tends to shorten the part	Compressive

Do you know the answer?

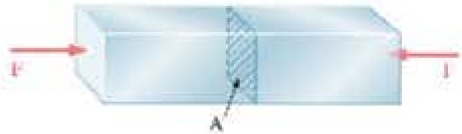
I KNOW IT | THINK SO | UNSURE | NO IDEA

The calculation of compressive stress is exactly like tensile stress, only the forces are reversed.

The direct compressive stress is the average force distributed over the cross-sectional area of the object in tension. Just like tensile stress, compressive stress can also be thought of as the share of total axial load being carried by each unit of cross-sectional area.

Direct axial stress in compression

Compressive stress is defined as the share of the total axial load carried by each unit of cross-sectional area, giving exactly the same equation as the tensile case:



$$\sigma = \frac{F}{A}$$

where:

σ_c = direct axial stress, compressive $\left(\frac{N}{mm^2} \text{ or MPa}\right)$

A = cross-sectional area (mm^2)

F = the axial compressive force (N)

This force may be assumed to be distributed uniformly over the cross-section when the object is relatively long and uniformly shaped, and loaded in pure tension.

GIVE FEEDBACK

OK

For direct axial stress, it may be assumed that the force ______.

Click the correct answer.

- is distributed uniformly over the cross-section
- is too small to measure
- is high enough to break the specimen
- is twice as high as the load on the specimen

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Compressive stress:

$$\sigma_c = \frac{F}{A}$$

where:

Drag statements on the right to match the left.

direct axial stress (compressive)	σ_c
cross-sectional area	A
axial compressive force	F

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the compressive stress in a component

If a bar of mild steel, $20\,\text{mm} \times 10\,\text{mm}$ in cross-section, is subjected to a tensile force of $18.8\,\text{kN}$, determine the stress in the material.

First, use standard measurements, Newtons and mm, to give MPa:

$$18.8\,\text{kN} = 18.8 \times 1{,}000 = 18{,}800\,\text{N}$$

$$\text{Stress } \sigma_c = \frac{F}{A}$$

$$= \frac{18{,}800\,\text{N}}{20\,\text{mm} \times 10\,\text{mm}}$$

$$= 94\,\text{MPa}$$

GIVE FEEDBACK

OK

Find the stress (in Mpa) of a round steel bar of diameter 38 mm if a tensile force of 115 kN is applied.

(Include units, use 2 decimal places.)

± ▾ | $\frac{\square}{\square}$ | $\square^2$ ▾ | $\sqrt{\square}$ | $(\square)$ ▾ | Clear | Clear line | ≤ ▾ | π | $\square \times 10^{\square}$ | MPa | f(x) ▾ | σ | ? | Undo | ↵

Click and type your answer here

CHALLENGE | SUBMIT | SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

To calculate the allowable load on a component that has a sufficient degree of safety, we need to consider the axial load and calculate the axial stress.

Determine the allowable compressive load

Like tensile stress, the factor of safety also applies to compressive stress.

The allowable stress in compression (σ_{ac}) works the same way.

Note: the compressive strength of most metals is usually higher than the tensile strength.

Allowable compressive stress: $\sigma_{ca} = \dfrac{\text{ultimate compressive strength}}{\text{factor of safety}}$

From this we can find the allowable load using: $\sigma_{ca} = \dfrac{F}{A}$

So allowable force is: $F = \sigma_{ca} \cdot A$

GIVE FEEDBACK

OK

Allowable Compressive Stress = $\frac{\text{(please select)}}{\text{(please select)}}$

Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Find the allowable stress in a brass pin that must have a factor of safety of 6. When thses pins were tested they failed in compression at 475 MPa.

(Include units, use one decimal place.)

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Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Direct axial compressive stress is common when gravity is involved, whether it comes from the weight of the structure itself or the weight of a load on top of it.

Explain how weight produces compressive stress

In static structures, direct axial compressive stress is often caused by the weight of the structure itself or by the weights of various loads supported by the structure.

For example, we may need to calculate the weight of a structural member, such as a beam or column.

In another case, we may need to calculate the weight of a load on the structure, such as a tank full of water, in order to find the compressive stresses in the structure itself.

Another example of compressive stress is the rod of a pneumatic or hydraulic cylinder, where the fluid pressure exerts a compressive force through the rod onto the load. A cylinder that raises a tipping trailer has a rod always in compression. If the cylinder is required to pull against the load then the rod will be in tensile stress.

GIVE FEEDBACK

OK

Which of the following are examples of compressive stress?

Check all that apply.

- [ ] Stress in a vertical column with a load on top
- [ ] Stress in a bicycle spoke
- [ ] Stress in a nail as it is being hammered into wood
- [ ] Stress in a nail as it is being pulled out of wood

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Density, symbol rho, is defined as mass per unit volume. It is a material property, which means it does not change regardless of the size of the object.

Define density

Weight can be calculated using the density of the material. Firstly, what is density exactly?

Density ρ (rho) of a material is defined as its mass per unit volume.

Density of a material depends on several factors:

1. Density is higher when the atomic mass is larger (e.g. lead is more dense than aluminium)
2. Density can vary if the atomic structure is more compact (e.g. diamond is more dense than graphite)
3. Density is reduced by porosity (e.g. wood is less dense than polymers)
4. Density decreases as temperature rises (due to thermal expansion)

GIVE FEEDBACK

OK

The symbol for density is ______.

Click the correct answer.

- ρ
- σ
- ε
- D

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Density of a solid generally depends on three things:

Density (please select) ▾ with higher atomic mass.

Density (please select) ▾ with more air pockets or porosity.

Density (please select) ▾ if atoms are packed more tightly.

Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The SI unit of density is kilograms per cubic metre. It comes directly from the equation for density, mass in kg divided by volume in cubic metres.

The equation for density

The SI unit of density is kilograms per cubic metre (kg/m^3), which comes from the equation:

$$\rho = \frac{m}{V}$$

where:

ρ = density using the Greek letter rho (kg/m^3)
m = mass (kg)
V = volume (m^3)

Alternatively, density may be given in tonnes per cubic metre, but this is not recommended for calculations.

GIVE FEEDBACK

OK

Density = $\frac{\text{(please select)}}{\text{(please select)}}$

Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The units for density are (please select) / (please select)

Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Here are some typical values for density, which depends on two things: how heavy the atom is (lead is a heavy atom); and whether there are voids in the structure (wood and foam plastics are full of air pockets).

Typical values of density for some solid materials are given below. Note: these typical values are approximate and there can be some variation (especially with wood).

Densities of various solids

Material	Density (kg/m^3)	Density (tonnes/m^3)
aluminium	2780	2.78
balsa wood	160	0.16
brass	8250	8.25
brick	2080	2.08
bronze	8670	8.67
cast iron	7200	7.2
concrete	2240	2.24

GIVE FEEDBACK

CONTINUE >

Densities of various solids *continued*

Material	Density (kg/m^3)	Density ($tonnes/m^3$)
copper	8870	8.87
ice	920	0.92
oregon pine timber	530	0.53
rubber	920	0.92
sand	1470	1.47
steel	7800	7.8
zinc	7020	7.02

< BACK GIVE FEEDBACK OK

A certain type of stone has a density of 2000 kg/m^3. If a slab of this stone has a volume of 0.5 cubic metres, how many kg is the slab?

(Include units, round off to nearest integer)

Clear

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Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Match the densities of the following materials:

Drag statements on the right to match the left.

Aluminium	2,780 kg/m^3
Concrete	2,240 kg/m^3
Steel	7,800 kg/m^3
Rubber	920 kg/m^3

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate weight with given density

To determine the weight of an object:

1. Find the volume: usually area x height for regular prisms
2. Find the mass: use density equation, rearrange to find mass = density x volume
3. Find the weight: use the weight formula, weight = mass x gravity

GIVE FEEDBACK

OK

Assume we are given the dimensions of an object and the density of the material. In order to find the weight, we first need to calculate the (please select) ▼ and use this to determine the (please select) ▼, then finally calculate the weight by multiplying by (please select) ▼

Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Example

Determine the weight of a tubular steel column, 3 m high with outside diameter 120 mm and inside diameter 100 mm.

Example

Determine the weight of a tubular steel column, 3 m high with outside diameter 120 mm and inside diameter 100 mm.

Solution

Cross-sectional area:

$$\begin{aligned} A &= \frac{\pi \times 0.12^2}{4} - \frac{\pi \times 0.1^2}{4} \\ &= 3.456 \times 10^{-3}\ \mathrm{m}^2 \end{aligned}$$

Volume:

$$\begin{aligned} A \times L &= 3.456 \times 10^{-3}\ \mathrm{m}^2 \times 3\ \mathrm{m} \\ &= 0.0104\ \mathrm{m}^3 \end{aligned}$$

< BACK GIVE FEEDBACK CONTINUE >

Calculate the weight of a pipe—Example

Mass:

$$\begin{aligned} V \times \rho &= 0.0104\ \mathrm{m}^3 \times 7{,}800\ \mathrm{kg/m}^3 \\ &= 80.86\ \mathrm{kg} \end{aligned}$$

Weight:

$$\begin{aligned} m\,g &= 80.86\ \mathrm{kg} \times 9.81\ \mathrm{N/kg} \\ &= 793.3\ \mathrm{N} \end{aligned}$$

< BACK   GIVE FEEDBACK   OK

A steel casting has a volume of 0.02 m^3. What is its weight? (Assume ρ = 7800 kg/m^3). *Round off the answer to nearest integer. Use gravitational acceleration g = 9.81. include the base unit for weight)*

+ − · ÷ Clear

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Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Example

What is the **stress** at the foot of a tubular steel column, 3 m high with outside diameter 120 mm and inside diameter 100 mm? It has been calculated to weigh 793.3 N.

Example

What is the **stress** at the foot of a tubular steel column, 3 m high with outside diameter 120 mm and inside diameter 100 mm? It has been calculated to weigh 793.3 N.

Solution

The cross-sectional area of the column in square millimetres is:

$$\begin{aligned} A &= 3.456 \times 10^{-3}\ \mathrm{m}^2 \\ &= 3{,}456\ \mathrm{mm}^2 \end{aligned}$$

< BACK GIVE FEEDBACK CONTINUE >

The compressive stress at the foot of this column is its weight over the cross-sectional area:

$$\begin{aligned}\sigma_c &= \frac{F_w}{A} \\ &= \frac{793.3\ \text{N}}{3{,}456\ \text{mm}^2} \\ &= 0.23\ \text{N/mm}^2\ (\text{MPa})\end{aligned}$$

This is too small to worry about, considering that cast iron can handle 700 MPa in compression.

< BACK GIVE FEEDBACK OK

A steel casting has a volume of 0.2 m^3. The casting is mounted on a frame which has four feet, each 30 x 30 mm. What is the stress applied to the floor in MPa? *(Assume ρ = 7800 kg/m^3, use two decimal places, include units.)*

+ − · ÷ $\sqrt{\square}$ Clear

Clear line

MPa σ π ? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

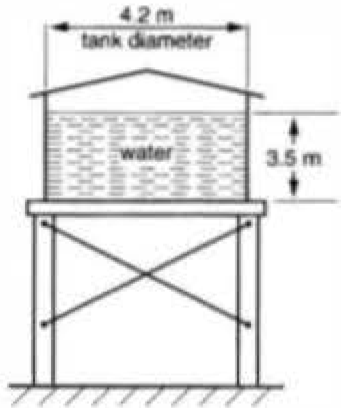
Hint

Each hint will reduce the credit received for this question

Here is an engineering example which combines a number of skills: finding the weight using density and volume, calculating self-weight and imposed loads, and determining the total compressive stress in a structural component.

Example

Tubular columns each have a cross-sectional area of $3{,}456\ \text{mm}^2$. They form four legs of a platform, supporting a 4.2 m diameter cylindrical water tank filled to a depth of 3.5 m. If the total mass of the structure and the tank without water is 2300 kg, and water density is $1{,}000\ \text{kg/m}^3$, calculate the stress in the tubular legs.



GIVE FEEDBACK

CONTINUE >

Solution

$$\text{Mass of water tank} = \frac{\pi \times 4.2^2}{4} \times 3.5 \times 1{,}000$$
$$= 48{,}490 \text{ kg}$$
$$\text{Total mass} = 48{,}490 + 2{,}300$$
$$= 50{,}790 \text{ kg}$$
$$\text{Weight of this mass} = 50{,}790 \times 9.81$$
$$= 498{,}250 \text{ N}$$

The total cross-sectional area of the four columns is:

$$4 \times 3{,}456 \text{ mm}^2 = 13{,}824 \text{ mm}^2$$

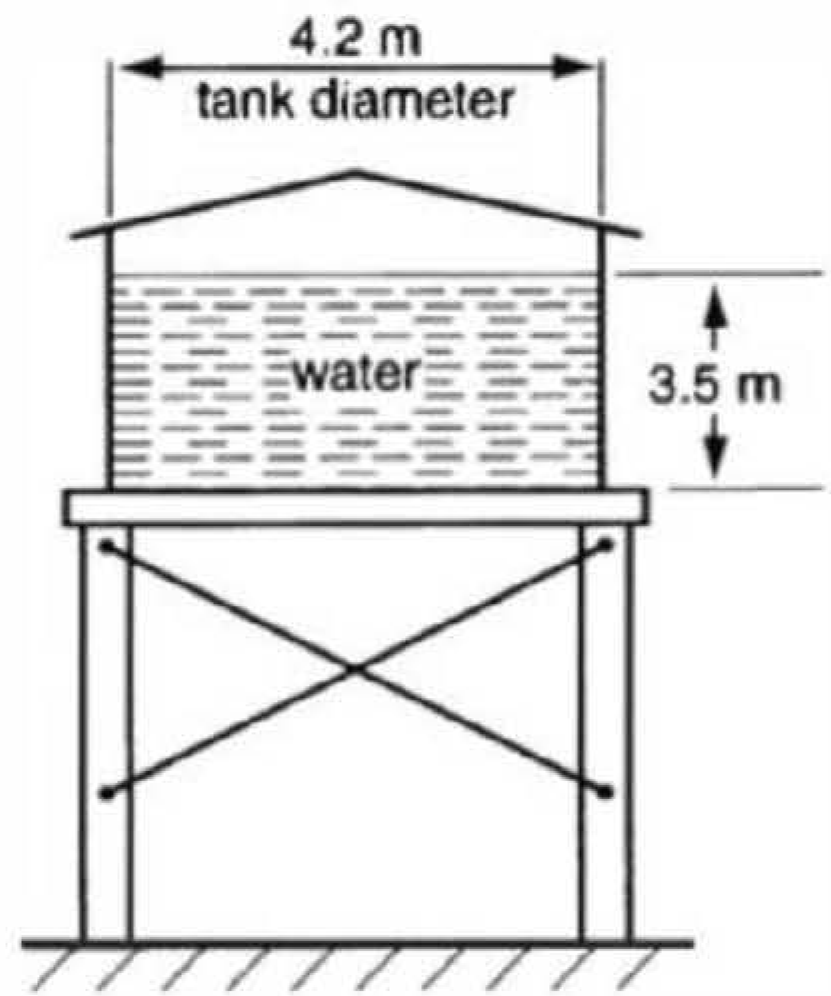
Therefore the stress in the tubular legs is:

$$\sigma_c = \frac{F_w}{A}$$

$$= \frac{498{,}250 \text{ N}}{13{,}824 \text{ mm}^2}$$

$$= 36 \text{ MPa}$$

Tubular columns each have a cross-sectional area of $3{,}456\,\mathrm{mm}^2$. They form four legs of a platform, supporting a 4.2 m diameter cylindrical water tank filled to a depth of 3.5 m. If the total mass of the structure and the tank without water is 2300 kg, and water density is $1{,}000\,\mathrm{kg/m^3}$, calculate the stress in the tubular legs.



Click the correct answer.

Force in each column = tank weight / 4 + column weight

Force in each column = 4 × (tank weight + column weight)

Force in each column = (tank weight + column weight) / 4

Force in each column = tank weight + 4 × column weight

Up to the elastic limit, there is no difference between tension and compression, except that we are now compressing the object instead of elongating it.

So when it comes to the change of length (symbol delta), it is better to use the name 'deformation' rather than 'elongation'.

After the elastic limit is reached, brittle materials tend to fracture into pieces, while ductile materials simply squash.

Differences between ductile and brittle materials in compression

Compression is exactly the reverse of tension.

Video object isn't supported in c++ version

This is true while the material behaves elastically. But instead of elongating, it will contract in proportion to an applied compressive force.

So this change of length, δ, is better named **deformation** rather than elongation.

GIVE FEEDBACK

CONTINUE >

It is a different story once we go past the elastic limit (also called the yield point). This is where ductile and brittle materials vary considerably.

Brittle materials, such as concrete or glass, tend to suffer relatively sudden crushing failure, often fracturing into many pieces. The fractures tend to be at an angle too.

On the other hand, **ductile materials** under compression simply squash, making it difficult to define an ultimate compressive strength because the specimen keeps on getting larger.

< BACK GIVE FEEDBACK OK

If a material has a tensile modulus of 48 GPa, what will be the modulus in compression? *(include units (in MPa), round off to nearest integer.)*

+ − · ÷ MPa π Clear Clear line ? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Strain is measured in compression exactly the same way as it is measured in tension. This image shows a sensitive gauge called an extensometer attached to the concrete test cylinder. As it is slowly compressed, this gauge reads the deformation and strain can be determined. This allows the calculation of Young's Modulus, the stiffnes of the concrete.

Measuring compressive strain

Regardless of whether a material is ductile or brittle, Young's modulus can be applied in the initial elastic region of stress.

This also means all the equations for tensile stress are exactly the same in compression. Just add a little *c* if you want. This is optional, but it helps to keep organised.

Extensometers are attached to the specimen to measure the very small movement of the concrete during compression.

Since high strength concrete can almost explode when it fails, the delicate sensors can be removed before reaching the ultimate compressive stress.

GIVE FEEDBACK

OK

What does an extensometer do?

Click the correct answer.

- Measures the deformation of a test piece
- Measures the force in the test piece
- Pulls or pushes the test piece to create tensile or compressive stresses
- Measures the ultimate compressive stress

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Much like we did with tension, we can calculate the modulus of elasticity directly from the specimen measurements of force, length, elongation and cross-sectional area.

Define the formula for direct calculation of E in compression

Just as with tension, we can combine the stress and strain formulas in compression to find E:

$$E = \frac{\sigma_c}{\varepsilon_c} = \frac{F_c / A}{\delta_c / L} = \frac{F_c \cdot L}{A \cdot \delta_c}$$

where:

E = Young's modulus of elasticity (MPa), the same whether in tension or compression

F_c = axial compressive force (N)

A = cross-sectional area (mm^2), the same whether in tension or compression

δ_c = deformation (mm), amount of contraction (or negative elongation, but we don't tend to use this term)

L = original length (mm)

σ_c = compressive stress (MPa)

ε_c = strain, dimensionless ( ) or can be written as (mm/mm)

GIVE FEEDBACK

OK

Match the names of the terms used in the combined equation:

$$E = \frac{\sigma_c}{\varepsilon} = \frac{F_c/A}{\delta/L} = \frac{F_c \cdot L}{A \cdot \delta}$$

Drag statements on the right to match the left.

E	modulus of elasticity
F_c	axial compressive force
A	cross-sectional area
δ	deformation
L	original length
σ_c	compressive stress
ε	strain

Do you know the answer?

Match the units used in the combined equation:

$$E = \frac{\sigma_c}{\varepsilon} = \frac{F_c/A}{\delta/L} = \frac{F_c \cdot L}{A \cdot \delta}$$

Drag statements on the right to match the left.

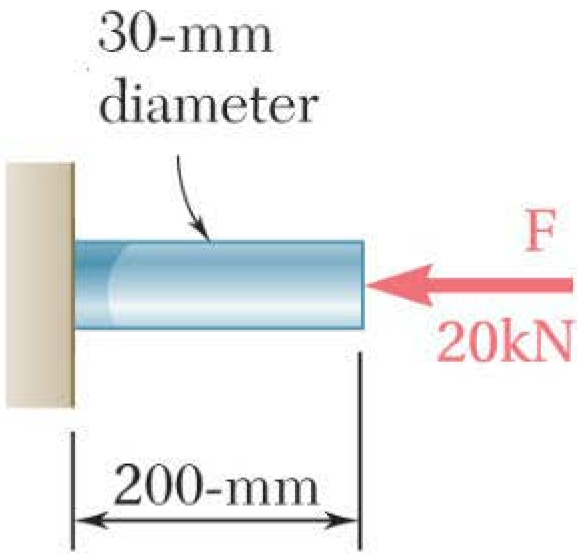
E	(MPa)
F_c	(N)
A	(mm^2)
δ	(mm)
L	(mm)
σ_c	(MPa)
ε	( )

Total deformation and safety factor

A 30 mm diameter aluminium rod is compressed by a 20 kN force.

The ultimate tensile strength of aluminium is 150 MPa and Young's modulus is 70 GPa.

Determine the total amount of deformation and the safety factor.



Determining safety factor—Example	Stress in the 30 mm rod	Strain in the 30 mm rod	Elongation of the 30 mm rod	Safety factor

GIVE FEEDBACK

OK

Total deformation and safety factor

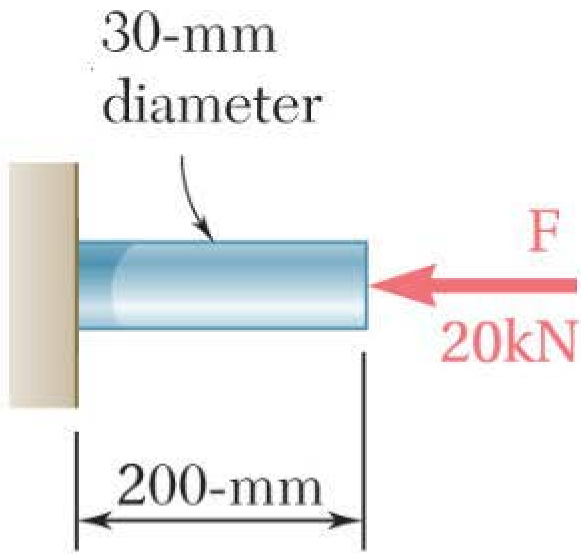
Find stress in the 30 mm diameter section of length 200 mm:

Stress:

$$\sigma_2 = \frac{F}{A_2}$$

$$= \frac{20{,}000 \text{ N}}{\frac{\pi \cdot 30^2}{4} \text{mm}^2}$$

$$= 28.29 \text{ MPa}$$



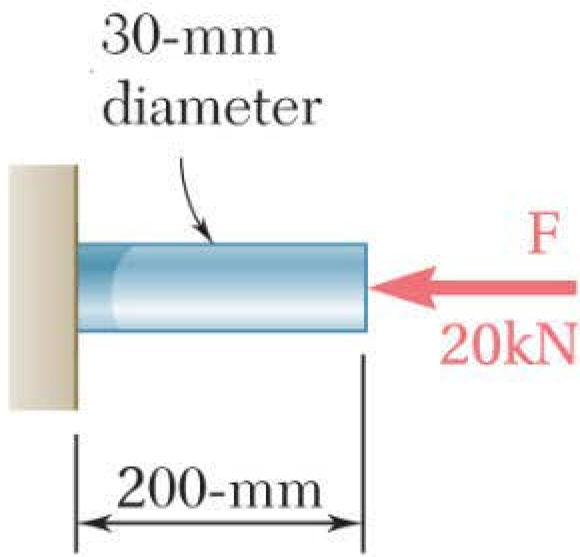
Determining safety factor—Example	Stress in the 30 mm rod	Strain in the 30 mm rod	Elongation of the 30 mm rod	Safety factor

GIVE FEEDBACK

OK

Now find strain in the Φ30 x 200 mm section:

$$\varepsilon_2 = \frac{\sigma_2}{E} = \frac{28.29}{70{,}000} = 0.404 \times 10^{-3}$$

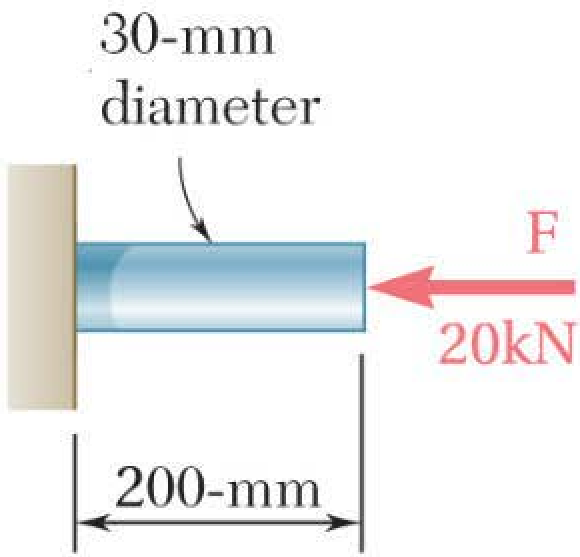


Determining safety factor—Example	Stress in the 30 mm rod	Strain in the 30 mm rod	Elongation of the 30 mm rod	Safety factor

Total deformation and safety factor

Calculate elongation in the Φ30 mm section:

$$\delta_2 = \varepsilon_2 L_2$$
$$= 0.404 \times 10^{-3} \cdot 200 \text{ mm}$$
$$= 0.0808 \text{ mm}$$



Determining safety factor—Example	Stress in the 30 mm rod	Strain in the 30 mm rod	Elongation of the 30 mm rod	Safety factor

GIVE FEEDBACK

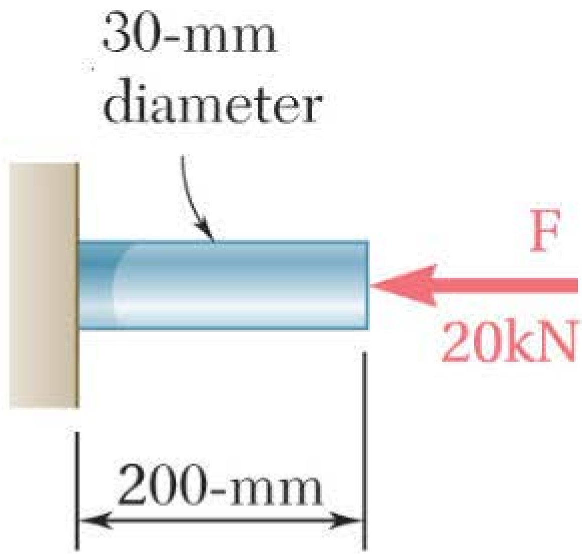
OK

Total deformation and safety factor

The safety factor must be based on the **maximum stress** in the material, which occurs in the Φ30 mm section and is equal to 28.29 MPa.

Safety factor:

$$FS = \frac{UTS}{\sigma}$$
$$= \frac{150}{28.29}$$
$$= 5.3$$



Determining safety factor—Example	Stress in the 30 mm rod	Strain in the 30 mm rod	Elongation of the 30 mm rod	Safety factor

GIVE FEEDBACK

OK

A steel rod has a diameter of 35 mm and length 4000 mm. It is under a tensile force of 150 kN. By how much will it stretch (in mm)? *(Minimum 2 decimal places. Include units.)*

+ − · ÷ $\frac{\square}{\square}$ $\square^2$ $\sqrt{\square}$ Clear

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Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Solve any axial stress problem using equations for stress, strain and modulus

Like tension, any problem involving stress and strain can be solved using this simple method. Simply write down the three equations for stress, strain and modulus. Next, fill in every variable that is given in the question. Now solve whichever equation has two of the three variables. Use this information to solve the next equation and again for the last of the three equations.

The three fundamentals equations can be used in compression, with the seven variables (quantities):

Stress: $\sigma_c = \frac{F_c}{A}$ Strain: $\varepsilon_c = \frac{\delta_c}{L}$ Modulus: $E = \frac{\sigma_c}{\varepsilon_c}$

To solve any problem involving stress and strain on an object (tension or compression):

1. Determine (from the question) as many of these seven quantities as possible
2. Once you have any two quantities in an equation, that equation can be solved
3. Use the new quantitiy from this equation to help solve another one

Repeat this process until you find the term you are after (or you find all seven quantities).

This method will work for any solvable problem in tension or compression (axial stresses).

GIVE FEEDBACK

OK

Axial stress refers to ______.

Click the correct answer.

- any stress that is tensile or compressive
- only tensile stresses
- only compressive stresses
- only stresses in the elastic region

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

An aluminium bolt is 12 mm diameter and 250 mm long. If it is stretched by 0.6 mm, how much force was on the bolt? Sort the following formulas into the order in which they must be calculated while solving this question.

Stress: $\sigma = \frac{F}{A}$ Strain: $\varepsilon = \frac{\delta}{L}$ Modulus: $E = \frac{\sigma}{\varepsilon}$ Area $A = \frac{\pi \cdot D^2}{4}$

(Hint: Find the area first, then sort the rest of the equations.)

↑↓ **Place these in the proper order.**

- Find Area $A = \frac{\pi \cdot D^2}{4}$
- Find Strain using: $\varepsilon = \frac{\delta}{L}$
- Find Stress using: $E = \frac{\sigma}{\varepsilon}$
- Find Force using: $\sigma = \frac{F}{A}$

Do you know the answer?

A stainless steel (316) guitar string of diameter 0.3 mm and length 855 mm is tensioned to 48 N. You are required to calculate the amount of stretch (elongation). Sort the following formulas into the order in which they must be calculated while solving this question.

Stress: $\sigma = \frac{F}{A}$ Strain: $\varepsilon = \frac{\delta}{L}$ Modulus: $E = \frac{\sigma}{\varepsilon}$ Area $A = \frac{\pi \cdot D^2}{4}$

↑↓ Place these in the proper order.

- Find Area $A = \frac{\pi \cdot D^2}{4}$
- Find Stress: $\sigma = \frac{F}{A}$
- Find Strain using: $E = \frac{\sigma}{\varepsilon}$
- Find elongation using: $\varepsilon = \frac{\delta}{L}$

Do you know the answer?

A stainless steel (316) guitar string of diameter #(0.3,0.4,1) mm and length #(840,870,0) mm is tensioned to #(45,55,0) N. You need to calculate the amount of stretch. Which variables can be derived from the question before using any of the three formulas?

Stress: $\sigma = \frac{F}{A}$ Strain: $\varepsilon = \frac{\delta}{L}$ Modulus: $E = \frac{\sigma}{\varepsilon}$

Check all that apply.

- [ ] E
- [ ] L
- [ ] A
- [ ] F
- [ ] σ
- [ ] ε
- [ ] δ

Do you know the answer?

Calculate the defomation in component under compression—Example

An axial compressive load of 190 kN is applied to a cylindrical component 80 mm in diameter and 300 mm long, made of brass. Calculate the compressive stress, the compressive strain and the amount of axial deformation under load.

GIVE FEEDBACK

CONTINUE >

An axial compressive load of 190 kN is applied to a cylindrical component 80 mm in diameter and 300 mm long, made of brass. Calculate the compressive stress, the compressive strain and the amount of axial deformation under load.

Solution

Cross-sectional area:

$$A = \frac{\pi \times 80^2}{4}$$
$$= 5{,}027 \text{ mm}^2$$

Compressive stress:

$$\sigma_c = \frac{F}{A} = \frac{190{,}000\ \text{N}}{5{,}027\ \text{mm}^2} = 37.8\ \text{MPa}$$

< BACK GIVE FEEDBACK CONTINUE >

Young's modulus for brass is 90000 MPa (see Table of elastic moduli).

Hence axial strain is:

$$\begin{aligned} \varepsilon_c &= \frac{\sigma_c}{E} \\ &= \frac{37.8}{90{,}000} \\ &= 0.00042 \end{aligned}$$

Finally, the amount of axial deformation under load is:

$$\begin{aligned} \delta_c &= \varepsilon_c \cdot L \\ &= 0.00042 \times 300 \text{ mm} \\ &= 0.126 \text{ mm} \end{aligned}$$

< BACK GIVE FEEDBACK OK

A nylon bush (modulus 3 GPa) has a diameter of 75 mm and length of 350 mm, and supports a compressive load of 48 kN. You are required to calculate the amount of deformation. Sort the following formulas into the order in which they must be calculated while solving this question.

Stress: $\sigma = \frac{F}{A}$ Strain: $\varepsilon = \frac{\delta}{L}$ Modulus: $E = \frac{\sigma}{\varepsilon}$ Area $A = \frac{\pi \cdot D^2}{4}$

↑↓ Place these in the proper order.

- Find Area $A = \frac{\pi \cdot D^2}{4}$
- Find Stress: $\sigma_c = \frac{F_c}{A}$
- Find Strain using: $E = \frac{\sigma_c}{\varepsilon_c}$
- Find deformation using: $\varepsilon_c = \frac{\delta_c}{L}$

Do you know the answer?

A nylon bush (modulus 3 GPa) has a diameter of 75 mm and length of 350 mm. If it is compressed by 0.6 mm, how much force was applied to the bush? Sort the following formulas into the order in which they must be calculated while solving this question.

Stress: $\sigma = \frac{F}{A}$ Strain: $\varepsilon = \frac{\delta}{L}$ Modulus: $E = \frac{\sigma}{\varepsilon}$ Area $A = \frac{\pi \cdot D^2}{4}$

(Hint: Find the area first, then sort the 3 equations for Stress/Strain/Modulus)

↑↓ **Place these in the proper order.**

- Find Area $A = \frac{\pi \cdot D^2}{4}$
- Find Strain using: $\varepsilon_c = \frac{\delta_c}{L}$
- Find Stress using: $E = \frac{\sigma_c}{\varepsilon_c}$
- Find Force using: $\sigma_c = \frac{F_c}{A}$

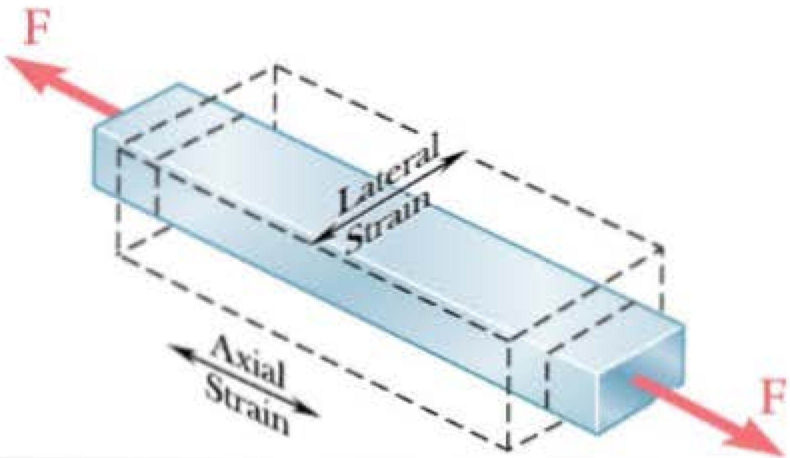
Do you know the answer?

When a bar is in tension it gets slightly thinner. When it is compressed, it gets thicker. Axial strain is the proportion of change in length. Lateral strain is the proportion of change in width.

Lateral strain

When a material is compressed in the axial direction, the axial contraction is always accompanied by some lateral expansion at right angles to the applied force, i.e. the material expands sideways.

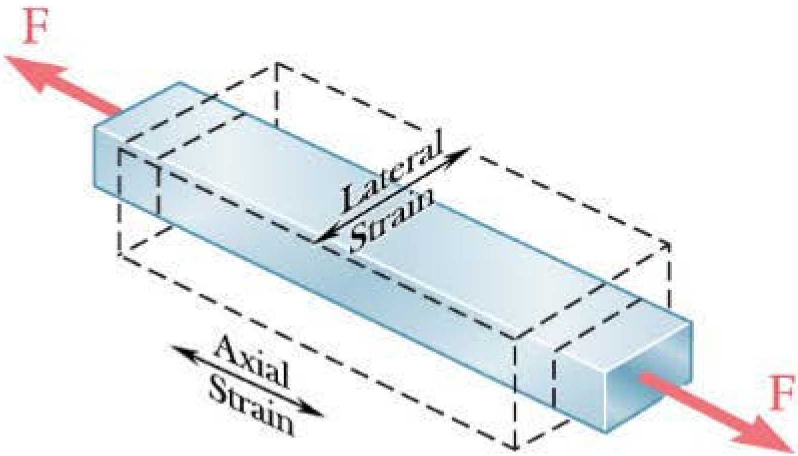
These lateral deformations can be expressed in relative terms, in millimetres per millimetre, and are called **lateral strains**.



GIVE FEEDBACK

OK

An object is loaded in tension. The axial strain is caused by the (please select) ▼ and the lateral strain is caused by the (please select) ▼



Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The ratio of lateral strain to axial strain is called Poisson's ratio. It uses the curly Vee symbol, which is the Greek letter 'nu'. This is only measured in the elastic range.

Poisson's ratio

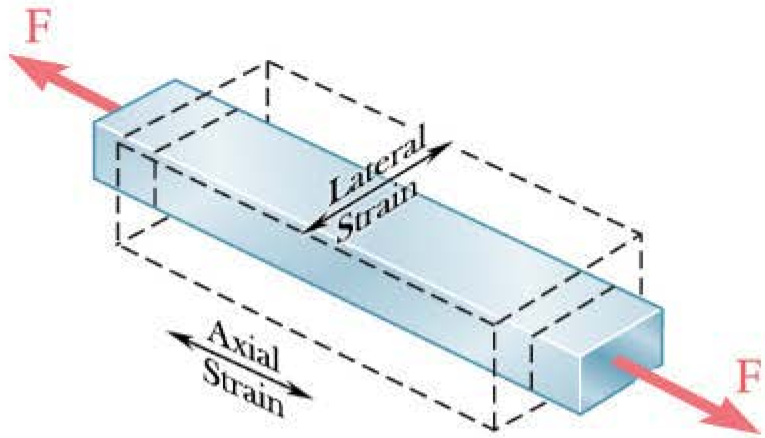
It has been shown by experimental evidence that for any given material within its elastic limit, lateral strains have a fixed relation to the axial strains caused by the force. This constant is known as **Poisson's ratio**, named after the French scientist who formulated this concept.

Poisson's ratio is a definite property of a material and its value applies equally to materials in tension or in compression. Poisson's ratio is given the symbol ν, which is the Greek letter 'nu'.

GIVE FEEDBACK

CONTINUE >

$$\text{Poisson's ratio } \nu = \frac{\text{lateral strain}}{\text{axial strain}}$$



< BACK GIVE FEEDBACK OK

Poisson's ratio = $\frac{\text{(please select)}}{\text{(please select)}}$

Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The allowable units for Poisson's ratio are:

Check all that apply.

- [ ] mm/mm
- [ ] mm
- [ ] (no units)
- [ ] MPa
- [ ] N/m

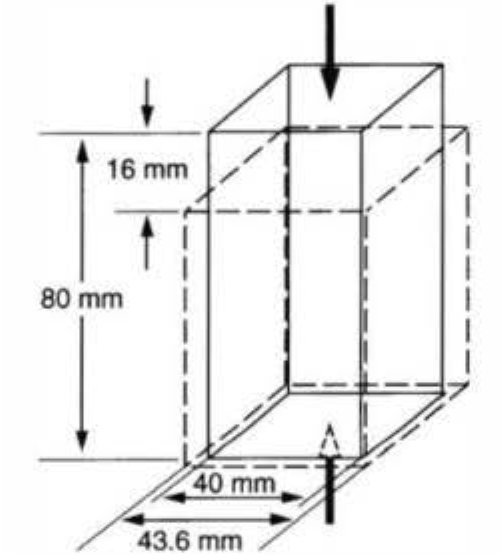
Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

When calculating Poisson's ratio, the lateral strain can be taken on any of the width dimensions.

Example

A piece of rubber is $80\text{ mm} \times 40\text{ mm} \times 40\text{ mm}$. When compressed along the 80 mm axis by 16 mm, its dimensions increase by 3.6 mm in each of the other two directions. Calculate Poisson's ratio of the rubber.



GIVE FEEDBACK

CONTINUE >

Solution

Axial strain:

$$\varepsilon_A = \frac{16 \text{ mm}}{80 \text{ mm}} = 0.2$$

Lateral strain:

$$\varepsilon_L = \frac{3.6 \text{ mm}}{40 \text{ mm}} = 0.09$$

Poisson's ratio:

$$\nu = \frac{\varepsilon_L}{\varepsilon_A} = \frac{0.09}{0.2} = 0.45$$

Units for Poisson's ration are the same as strain, which is none.

< BACK GIVE FEEDBACK OK

A new type of elastomer is (rubbery polymer) formed into a block 80 mm x 40 mm x 40 mm. When compressed by 15 mm along the 80 mm axis, it increases by 3.5 mm in the 40 mm width dimensions. Calculate Poisson's ratio of the elastomer.

(Do not type the units, use three decimal places.)

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Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
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Hint

Each hint will reduce the credit received for this question

A range of Poisson's ratios of engineering materials

Rubber has about the highest Poisson's ratio, almost 0.5, which is the highest value theoretically possible. This means the volume remains constant during stretching or compression. For some grades of concrete, it can be as low as 0.1, and for cork and foam rubbers it is practically zero.

So if rubber is used for a cushioning mount (e.g. engine mount), it must have room to expand, otherwise it is a rigid mount.

Foam materials have a Poisson's ratio of almost zero. They show no sign of expanding in width during compression, so the lateral strain is almost zero. However, for the majority of engineering materials (like metals), the value of Poisson's ratio lies within the narrow range of 0.25 to 0.35, mostly around 0.3.

GIVE FEEDBACK

OK

Match Poisson's ratio for the materials below:

Drag statements on the right to match the left.

Rubber	0.45
Concrete	0.1 to 0.2
Foam and cork	Approximately zero
Metals	0.25 to 0.35

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Coefficient of thermal expansion

Virtually all solids expand when heated and contract when cooled. This can be useful, such as when shrink-fitting gear wheels on shafts. On the other hand, it can cause damage when thermal expansion is restricted. This is why expansion joints are used on steampipes, railway tracks and bridge spans.

Different materials expand by different amounts. Typically ceramics expand the least, metals expand a bit more and polymers expand the most. This is measured by experiment. This measure is known as the **coefficient of thermal expansion**, α (Greek letter alpha), of the material.

It can also called the **coefficient of linear thermal expansion** to differentiate it from the **coefficient of volumetric thermal expansion**, β.

GIVE FEEDBACK

OK

The symbol used for the coefficient of thermal expansion is ______.

Click the correct answer.

- α
- ε
- C
- ν

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Virtually all solids expand when heated and contract when cooled. Different materials expand by different amounts. Rank the following groups of engineering materials in order of increasing coefficient of thermal expansion (i.e. from lowest to highest):

↑↓ Place these in the proper order.

- Ceramics
- Metals
- Polymers

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Put simply, the coefficient of thermal expansion is the strain per degree rise in temperature.

Units for the coefficient of thermal expansion

The **coefficient of thermal expansion** is the amount of elongation as a fraction of a millimetre for every millimetre of original length, which is due to a temperature rise of one Kelvin. The units are written as: mm/(mm.K).

Since a temperature difference of one Kelvin is exactly equal to a temperature difference of one degree Celsius, this unit is often stated as mm/mm.°C, without affecting the numerical value of the constant.

Furthermore, since the millimetres can be cancelled out, the unit is sometimes referred to as 'per degree'.

Note: it is often written in textbooks and datasheets like this:

For steel, for example: $\alpha = 12\,\mu m \cdot m^{-1} \cdot K^{-1}$, i.e. 12 microns per metre per Kelvin.

See table: Coefficients of thermal expansion.

GIVE FEEDBACK

OK

Which statements are true about the coefficient of thermal expansion?

Check all that apply.

- [ ] The units can be written as 'per degree' or '/K'
- [ ] It can be calculated using Kelvin or Celsius
- [ ] A value of 200 in Kelvin can be written as either 200K or 200^{o}K
- [ ] Heating by 10K will expand an object by the same amount as it would contract if cooled by 10K

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The units for coefficient of thermal expansion are:

Click the correct answer.

- mm/(mmK)
- mm/mm
- K
- mm/K

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

In the unit definition of coefficient of thermal expansion, what does K stand for?

Click the correct answer.

- Kelvin
- Kilometres
- Stiffness
- Nothing, it is just a symbol

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The coefficient of thermal expansion is a very small number. So it is usually given in microns per mm rather than mm per mm. Typical values of the coefficient are shown in this table.

Typical values of the coefficient of thermal expansion

Coefficients of thermal expansion

Material	α (mm/mm.K)	α (µm/mm.K)
aluminium	0.000024	24
brass	0.000021	21
bronze	0.000020	20
copper	0.000017	17
steel	0.000012	12
cast iron	0.000010	10
concrete	0.000010	10
glass	0.000008	8
PVC	0.000050	50
polypropylene	0.000150	150
tungsten carbide	0.000006	6

GIVE FEEDBACK

OK

Match the typical values for coefficient of thermal expansion (in µm/mm.K)

Drag statements on the right to match the left.

Aluminum	24
Steel	12
Concrete	10
Glass	8
Polypropylene (plastic)	150

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

To calculate the amount of thermal expansion of a solid material: expansion equals coefficient times temperature change times original length.

Calculate the amount of thermal expansion of a solid material

The coefficient of thermal expansion is the strain per degree rise in temperature:

$\alpha = \dfrac{\varepsilon}{\Delta T}$, which gives a strain of: $\varepsilon = \alpha \cdot \Delta T$.

From the definition of strain: $\varepsilon = \dfrac{\delta_L}{L}$, which gives deformation $\delta_T = \varepsilon \cdot L$, substituting thermal strain into this equation gives:

$$\delta_T = \alpha \cdot \Delta T \cdot L$$

where:

δ_T = thermal deformation (mm)

α = coefficient of thermal expansion (mm/mm.K)

ΔT = change in temperature (K), which is the same as $^\circ C$

L = original length (mm)

GIVE FEEDBACK

OK

The coefficient of a thermal expansion equation is:

$\delta_T = \alpha \cdot \Delta T \cdot L$

Match each variable to the correct definition:

Drag statements on the right to match the left.

δ_T	Thermal deformation
α	Coefficient of thermal expansion
ΔT	Change of temperature
L	Original length

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The coefficient of a thermal expansion equation is:

$\delta_T = \alpha \cdot \Delta T \cdot L$

Match the units for each variable:

Drag statements on the right to match the left.

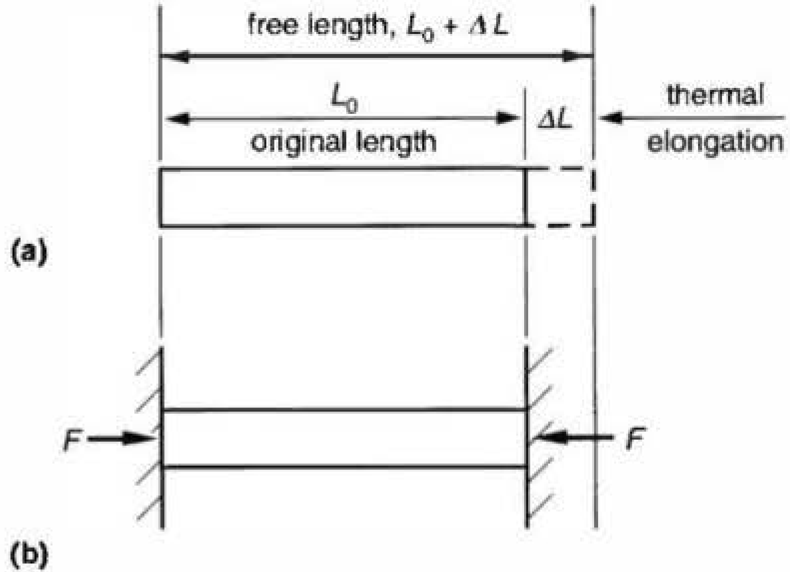
δ_T	mm
α	mm/mm.K
ΔT	K or ^{o}C
L	mm

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Example

If an aluminium rod is 1.2 m long at 15 °C, what will be its free length at 40 °C?



GIVE FEEDBACK

CONTINUE >

Solution

The amount of thermal expansion is:

$$\begin{aligned}\delta_L &= \alpha L \Delta T \\ &= 2.4\text{e-}05 \times 1{,}200 \times (40 - 15) \\ &= 0.72 \text{ mm}\end{aligned}$$

Therefore, the final length of the rod will be:

$$\begin{aligned}L &= L_0 + \delta_L \\ &= 1{,}200 \text{ mm} + 0.72 \text{ mm} \\ &= 1{,}200.72 \text{ mm}\end{aligned}$$

< BACK GIVE FEEDBACK OK

An aluminium rod is 1200mm long at 16 °C. By how much will it have expanded when it is heated to 38 °C?

(Include units, minimum 2 decimal places.)

± ▾ | $\frac{□}{□}$ | $1\frac{2}{3}$ | $□^2$ ▾ | $\sqrt{□}$ | (□) ▾ | Clear | Clear line

≤ ▾ | π | mm | f(x) ▾ | δ | ↵ | ? | Undo

Click and type your answer here

CHALLENGE | SUBMIT | SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint | Each hint will reduce the credit received for this question

How thermal stresses arises

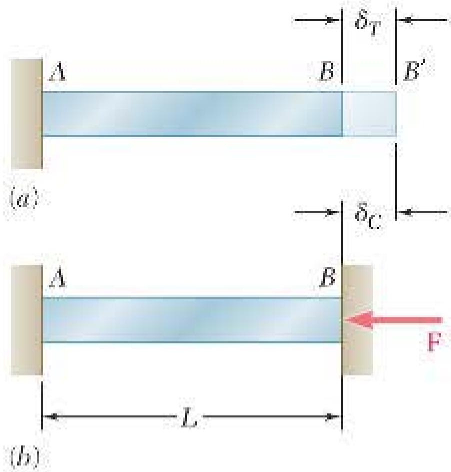
An increase in length caused by thermal expansion of 0.72 mm over a 1200 mm long bar may seem trivial, but even this can be a problem for precision machines. It can also be a problem if the object is prevented from expanding, causing stress.

It is a problem for accurate or delicate instruments, which is why precision machines are operated in a temperature-controlled room.

It can also be a problem for stress because 0.72 mm is enough deflection to cause significant stress if the object cannot expand. This is why expansion joints are installed in many situations.

GIVE FEEDBACK

CONTINUE >



(a) Free thermal expansion
(b) Thermal expansion contained between unyielding (rigid) supports

< BACK GIVE FEEDBACK OK

Thermal expansion of metals is minimal but can still be a problem when the component is:

Check all that apply.

- [ ] A high-precision machine part
- [ ] Prevented from expanding
- [ ] A high-density material
- [ ] Very long

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

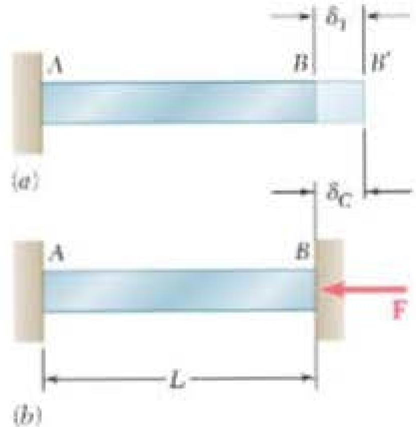
This is a simple method for calculating thermal stress against rigid supports: first, allow the object to expand freely and find extension; second, determine the stress required to compress the bar back to the original length.

Calculating thermal stress due to rigid supports

In situations where thermal expansion is fully prevented by unyielding supports, we can treat the problem in simple steps:

(a) Find the thermal deformation δ_T due to the temperature increase

(b) Determine the stress required to compress the bar back by δ_F to the original length L



GIVE FEEDBACK

OK

To determine the stress due to temperature rise for a rigidly constrained object:

(a) Find the Select... ▼ that would occur if the object was unconstrained

(b) Determine the Select... ▼ required to cause this amount of strain

Submit

Do you know the answer?

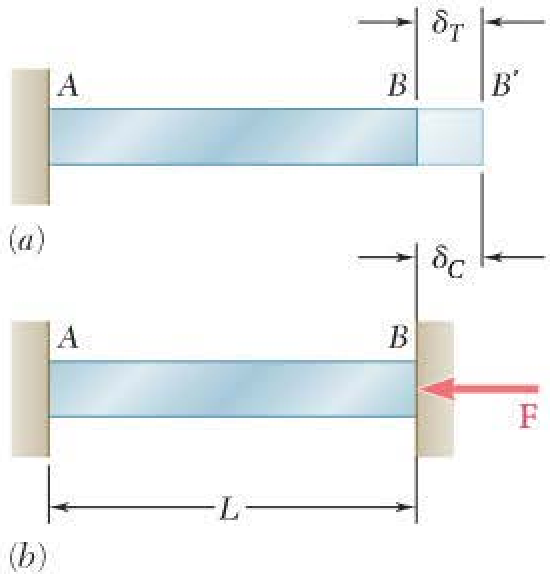
I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate thermal stress for a bar with semi-rigid supports

A 1.2 m long aluminium rod at 15°C is heated to 40°C.

Young's modulus is 70 GPa
(expansion coefficient
α = 0.000024).

Find the thermal stress if the ends are rigidly restrained.



Determining thermal stress (rigid)—Example	Find thermal strain	Find the thermal stress	Summary (semi-rigid)

GIVE FEEDBACK

OK

Calculate thermal stress for a bar with semi-rigid supports

A 1.2 m long aluminium rod at 15°C is heated to 40°C.

(a) Let the bar extend freely and calculate the deformation δ_T:

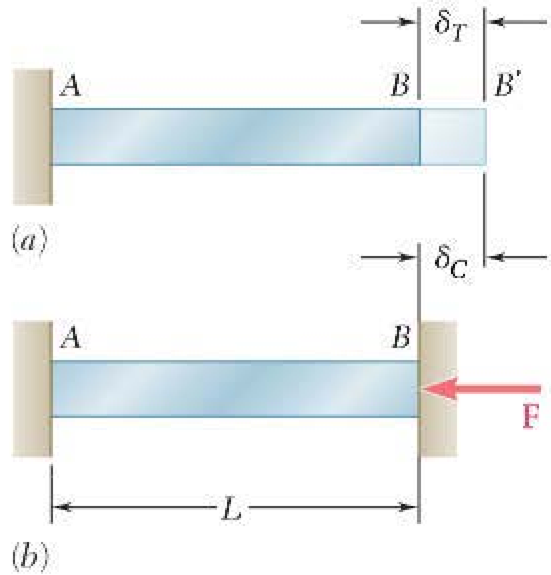
From the definition of α:

$\varepsilon = \alpha \cdot \Delta T$

$= 2.4e\text{-}05 \times (40 - 15)$

$= 2.4e\text{-}05 \times 25$

$= 0.0006$



Determining thermal stress (rigid)—Example	Find thermal strain	Find the thermal stress	Summary (semi-rigid)

GIVE FEEDBACK

OK

Calculate thermal stress for a bar with semi-rigid supports

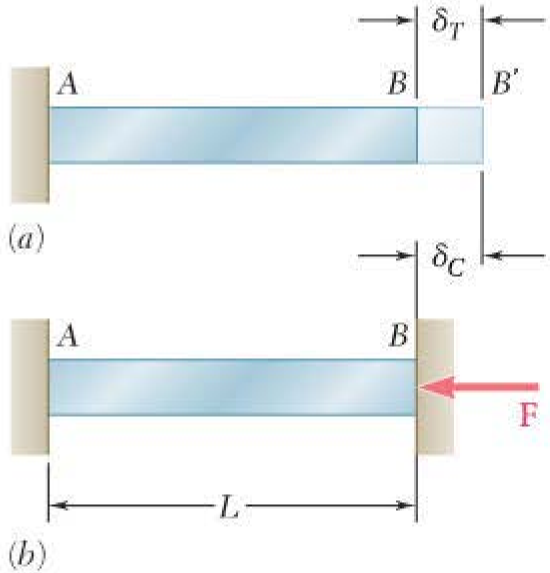
A 1.2 m long aluminium rod at 15 °C is heated to 40 °C.

(b) Compress the bar back to the original size.

Determine final stress σ using the definition of modulus:

$$E = \frac{\sigma}{\varepsilon}$$

$$\sigma = E\,\varepsilon$$
$$= 70{,}000 \times 0.0006$$
$$= 42 \text{ MPa}$$



Determining thermal stress (rigid)—Example	Find thermal strain	Find the thermal stress	Summary (semi-rigid)

GIVE FEEDBACK

OK

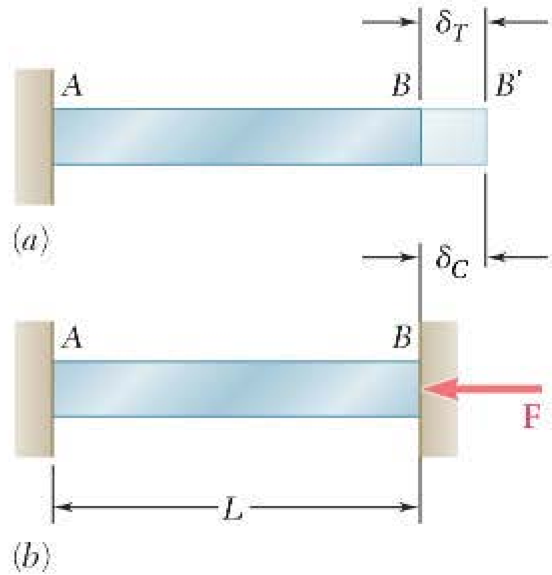
Calculate thermal stress for a bar with semi-rigid supports

Solving thermal stress with rigid supports:

$$\varepsilon = \frac{\delta_L}{L} = \frac{0.72}{1{,}200} = 0.0006$$

Where from the thermal equation:
$\delta_T = E \cdot \alpha \cdot \Delta T = 0.72 \text{ mm}$

Stress is:
$\sigma = E\,\varepsilon = 70{,}000 \times 0.0006 = 42 \text{ MPa}$



Determining thermal stress (rigid)—Example	Find thermal strain	Find the thermal stress	Summary (semi-rigid)

GIVE FEEDBACK

OK

An aluminium rod is 1200 mm long at 16°C and rigidly held on each end. Find the stress generated if it is heated to 38°C. Some aluminium properties you may need: Coeff of themal expansion α = 24x10^{-6} mm/mmK, Modulus of Elasticity = 70 GPa.

(Include units, minimum 2 decimal places.)

± ▾ $\frac{\square}{\square}$ $1\frac{2}{3}$ $\square^2$ ▾ $\sqrt{\square}$ $(\square)$ ▾ Clear

≤ ▾ π MPa $f(x)$ ▾ σ ↵ Clear line

? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

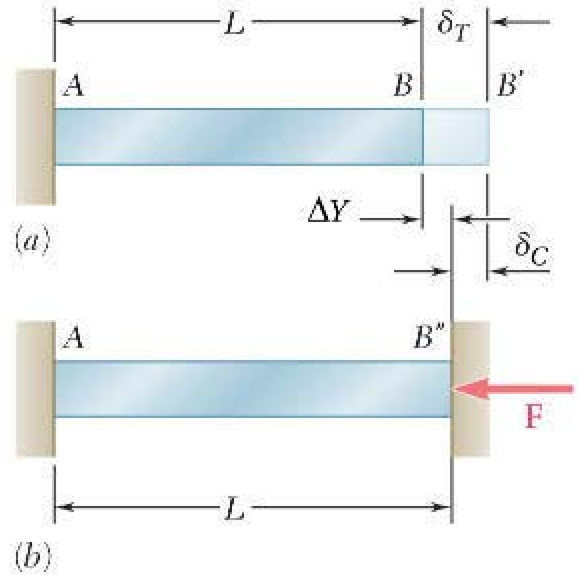
Each hint will reduce the credit received for this question

Calculate thermal stress for a bar with semi-rigid supports

A 1.2 m long aluminium rod at 15°C is heated to 40°C.

Young's modulus is 70 GPa (expansion coefficient $\alpha = 0.000024$).

Find the thermal stress if the ends are semi-rigidly restrained and deflect by $\Delta Y = 0.48\ \text{mm}$.



Determining thermal stress (semi-rigid)—Example	Find thermal strain	Find the thermal deformation	Find the thermal stress	Find the thermal stress	Summary (semi-rigid)

GIVE FEEDBACK

OK

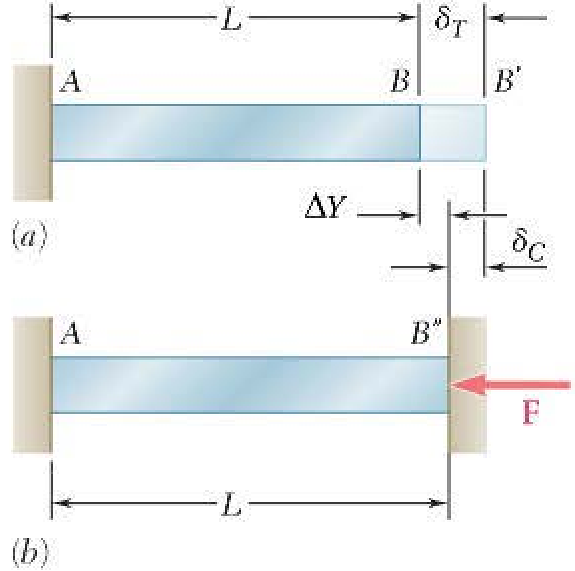
Calculate thermal stress for a bar with semi-rigid supports

A 1.2 m long aluminium rod at 15°C is heated to 40°C.

(a) Let the bar extend freely and calculate the deformation δ_T:

From the definition of α:

$$\varepsilon = \alpha \cdot \Delta T$$
$$= 2.4\text{e-}05 \times (40 - 15)$$
$$= 2.4\text{e-}05 \times 25$$
$$= 0.0006$$



Determining thermal stress (semi-rigid)—Example	Find thermal strain	Find the thermal deformation	Find the thermal stress	Find the thermal stress	Summary (semi-rigid)

GIVE FEEDBACK

OK

Calculate thermal stress for a bar with semi-rigid supports

A 1.2 m long aluminium rod at 15°C is heated to 40°C.

(a) Let the bar extend freely and calculate the deformation δ_T:

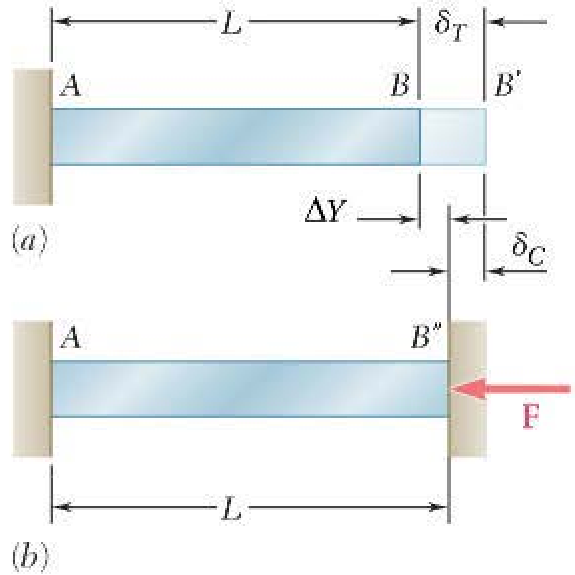
From the definition of strain:

$$\varepsilon = \frac{\delta_T}{L}$$

$$\delta_T = \varepsilon L$$

$$= 0.0006 \times 1{,}200$$

$$= 0.72 \text{ mm}$$



Determining thermal stress (semi-rigid)—Example	Find thermal strain	Find the thermal deformation	Find the thermal stress	Find the thermal stress	Summary (semi-rigid)

GIVE FEEDBACK

OK

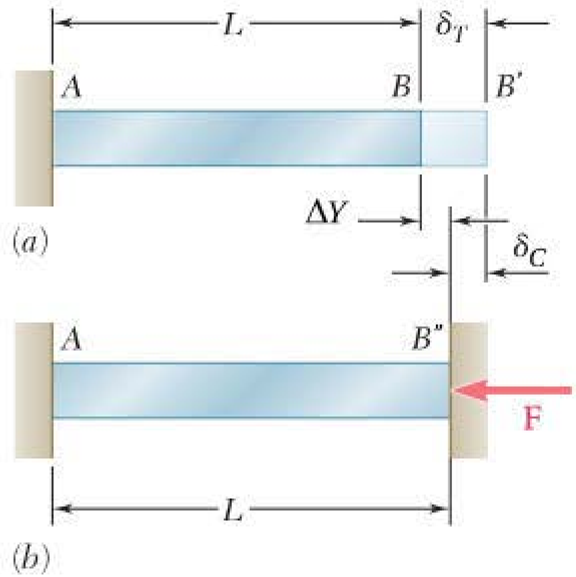
Calculate thermal stress for a bar with semi-rigid supports

A 1.2 m long aluminium rod at 15°C is heated to 40°C.

(b) Compress the bar back to the original size $+\Delta Y$.

Determine final strain ε:

$$\varepsilon = \frac{\delta_F}{L} = \frac{(\delta_T - \Delta Y)}{L}$$
$$= \frac{(0.72 - 0.48)}{1{,}200}$$
$$= \frac{0.24}{1{,}200}$$
$$= 0.0002$$



Determining thermal stress (semi-rigid)—Example	Find thermal strain	Find the thermal deformation	Find the thermal stress	Find the thermal stress	Summary (semi-rigid)

GIVE FEEDBACK

OK

Calculate thermal stress for a bar with semi-rigid supports

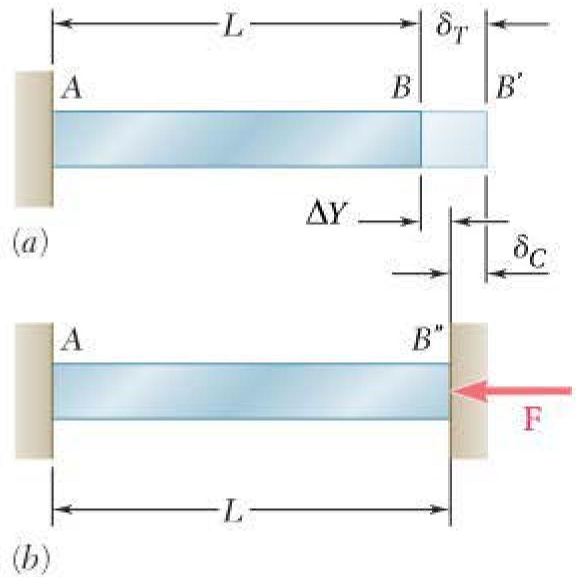
A 1.2 m long aluminium rod at 15 °C is heated to 40 °C.

(b) Compress the bar back to the original size plus ΔY.

Determine final stress σ using the definition of modulus:

$$E = \frac{\sigma}{\varepsilon}$$

$$\sigma = E\,\varepsilon$$
$$= 70{,}000 \times 0.0002$$
$$= 14 \text{ MPa}$$



Determining thermal stress (semi-rigid)—Example	Find thermal strain	Find the thermal deformation	Find the thermal stress	Find the thermal stress	Summary (semi-rigid)

GIVE FEEDBACK

OK

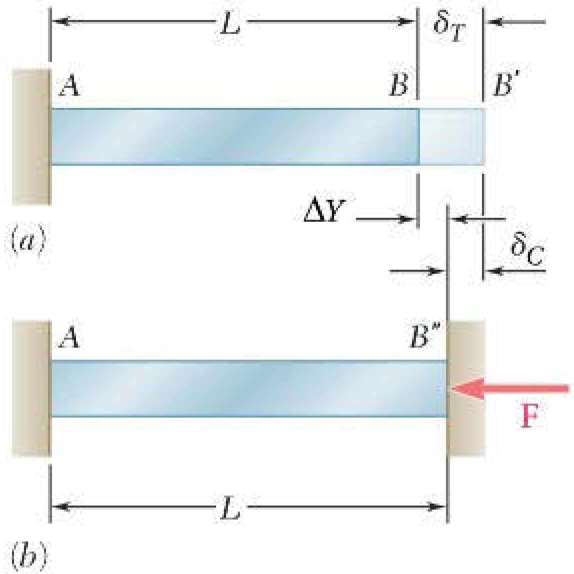
Calculate thermal stress for a bar with semi-rigid supports

Solving thermal stress with semi-rigid supports:

$$\varepsilon = \frac{(\delta_L - \Delta Y)}{L} = \frac{0.72 - 0.48}{1{,}200} = 0.00021$$

Where from the thermal equation:
$\delta_T = E \cdot \alpha \cdot \Delta T = 0.72$ mm

Stress is: $\sigma = E\,\varepsilon = 70{,}000 \times 0.0002 = 14$ MPa



Determining thermal stress (semi-rigid)—Example	Find thermal strain	Find the thermal deformation	Find the thermal stress	Find the thermal stress	Summary (semi-rigid)

GIVE FEEDBACK

OK

An aluminium rod is 1200 mm long at 16°C and held on each end with semi-rigid supports that flex a total of 0.25 mm. Find the stress generated if it is heated to 38°C. Some aluminium properties you may need: Coeff of themal expansion $\alpha = 24 \times 10^{-6}$ mm/mmK, Modulus of Elasticity = 70 GPa.

(Include units, minimum 2 decimal places.)

Clear

Clear line

?

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
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Hint

Each hint will reduce the credit received for this question

Direct calculation of thermal stress with rigid supports

If a bar of length L is heated by temperature ΔT but the semi-rigid supports deflect by ΔY, find the stress in the bar.

From the thermal equation find δ_T:

$\delta_T = E \cdot \alpha \cdot \Delta T$

Now find strain:

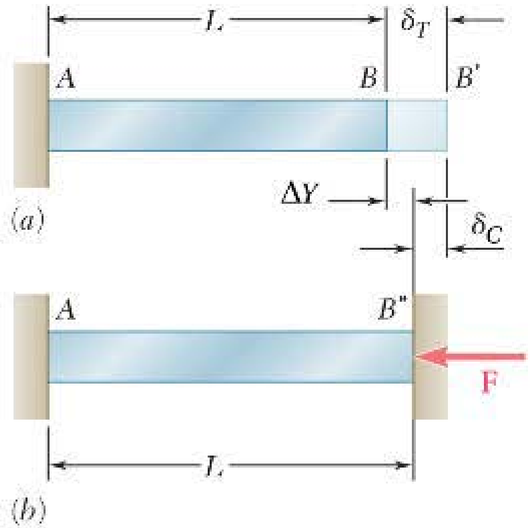
$$\text{Strain} = \frac{\text{amount of prevented deformation}}{\text{original length}}$$

$$\varepsilon = \frac{(\delta_T - \Delta Y)}{L}$$

Then from the modulus equation:

Stress $\sigma = E\,\varepsilon$

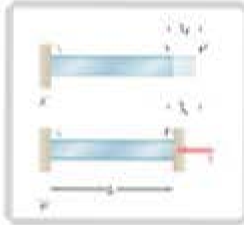
$$\sigma_T = E\,\frac{(\delta_T - \Delta Y)}{L}$$



GIVE FEEDBACK

OK

If a bar of length L is heated by temperature ΔT with semi-rigid supports deflecting by ΔY, find the stress in the bar.
Sort the solution to this problem into the correct order of steps:



Use mouse to zoom.
Click to keep enlarged.

↑↓ Place these in the proper order.

- Find ΔT using $\Delta T = T_{final} - T_{initial}$
- Find (free) thermal deformation δ_T using $\delta_T = E \cdot \alpha \cdot \Delta T$
- Find (constrained) compressive deformation δ_c using $\delta_c = \delta_T - \Delta Y$
- Find the compressive strain using $\varepsilon_c = \dfrac{\delta_c}{L}$
- Find compressive stress using $\sigma_c = E\, \varepsilon_c$

Do you know the answer?