GIVE FEEDBACK

CONTINUE >

Shear stress occurs when applied forces are attempting to **slide** an object apart.

This is the last of the three basic types of direct stress—tensile, compressive and shear.

Tension is an axial stress that pulls atoms apart, while compression pushes atoms together.

Shear stress is different; it distorts the atomic lattice into a parallelogram where atoms tend to *slide* past each other.

Video object isn't supported in c++ version

< BACK GIVE FEEDBACK OK

So far we have looked at tensile and compressive stresses. Now we look at a third basic type of stress, which tries to slide an object apart. A simple example is an object glued to a wall. The weight of the object causes the adhesive to be under shear stress; gravity tries to make it slide down the wall.

Shear force

'Shear' means sliding or trying to slide.

When a steel plate is cut by a guillotine or a hole is punched in it, the failure of the material occurs not in a plane normal to the force, as is the case in tension or compression, but as a sliding failure parallel to the load applied.

Whether it fails or not, shear forces are still putting the material under shear stress.

For example, think of a sign glued to a wall. The weight of the object causes the adhesive to be under shear stress. Gravity tries to make it slide down the wall (assuming there are no hidden dowel pins or screws).	

GIVE FEEDBACK

OK

Shear is an action where a force tries to ______ an object apart.

Click the correct answer.

- slide
- pull
- tear
- bend

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Shear strength is the measure of shear stress that a material can handle. 'Handle' could mean until it breaks--the ultimate shear strength. Or it could mean until it is permanently deformed--the yield shear stress. These are the two most important properties of shear strength used in engineering.

Shear strength

Shear strength is the measure of shear stress that a material can handle. In the same way as for axial (tension and compression) stresses, there are two important types of shear stress.

Ultimate shear strength (USS) is the stress required to rupture the material in shear. This is applicable to the cutting or punching of materials.

The USS can also be used with a factor of safety (FS) to design bolted and welded connections, bending of beams and torsion in shafts.

Yield shear stress (YSS) entails an inital elastic shear stress, just like axial stress. There is then, after the yield point, further shear stress causing permanent deformation.

GIVE FEEDBACK

OK

Match the definitions for each type of shear stress:

Drag statements on the right to match the left.

The measure of shear stress that a material can handle	Shear strength
The stress required to rupture the material in shear	Ultimate shear strength
The maximum shear stress before permanent deformation occurs	Yield shear stress

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Typical values of ultimate shear stress

Most engineering materials are actually weakest in shear. On top of this, shear stresses can be generated by bending and torsion, making shear strength a critical factor. Usually an engineer will need to check tensile and shear stresses while compressive stress is less often a problem.

Typical values of ultimate shear strength (USS) of some materials are given in the table below.

Ultimate shear strength compared to ultimate tensile strength of some common metals

Material	USS (MPa)	UTS (MPa)
Aluminium	125	150
Brass	150	190
Mild steel	360	470

Shear strength is generally lower than tensile strength. Shear stress is very important because it is quite common for a material to fail in shear, especially since this is usually the weakest of the three types of direct stress—tensile, compressive and shear.

GIVE FEEDBACK

OK

Rank from lowest to highest these ultimate stresses for most engineering materials, such as steel, aluminium and brass.

↑↓ Place these in the proper order.

- Ultimate shear strength
- Ultimate tensile strength
- Ultimate compressive strength

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

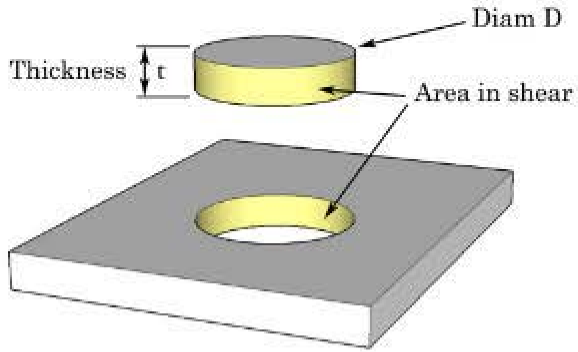
Example

Determine the force required to punch a 12 mm diameter hole in a mild steel plate 3 mm thick.

Solution

The area resisting shear is measured by the product of the circumference (πD) and the plate thickness (t).

$$\begin{aligned} A &= \pi \times D \times t \\ &= \pi \times 12 \text{ mm} \times 3 \text{ mm} \\ &= 113.1 \text{ mm}^2 \end{aligned}$$



Now find the force required to shear this area of mild steel (USS = 360MPa):

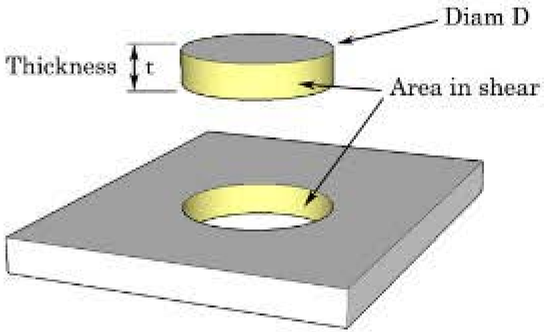
$$\tau = \frac{F}{A_s}$$

so $F = \tau \times A_s = 360 \times 113.1 = 40.71 \text{ kN}$

< BACK GIVE FEEDBACK OK

A disc of diameter 25 mm is punched out of a 3 mm brass plate. Calculate the force required in kN. Use ultimate shear stress of 150 MPa.

(Use at least two decimal places.)



Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

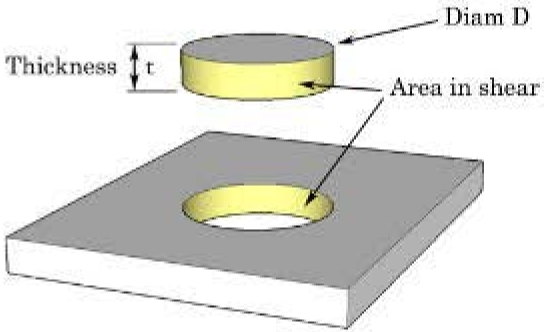
INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- 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 disc of diameter 25 mm is punched out of a 3 mm mild steel plate. Calculate the force required in kN. Use ultimate shear stress of 360 MPa.

(Use at least two decimal places, type units.)



Clear

Clear line

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

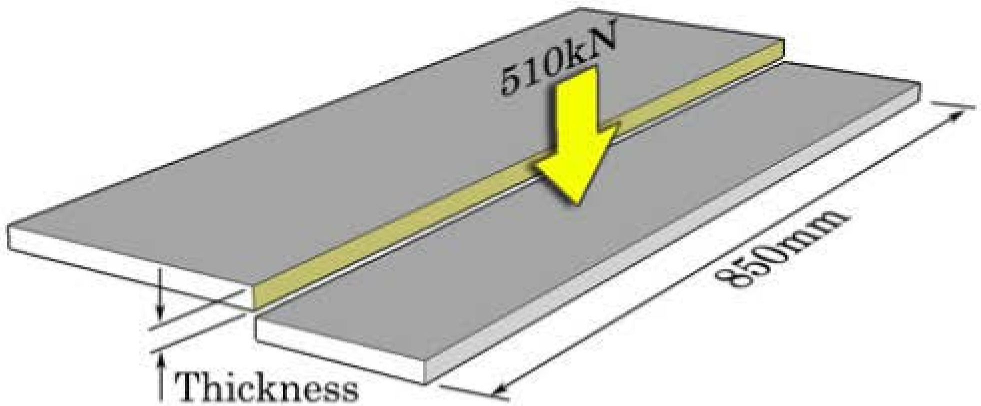
- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Example

Determine the greatest thickness of brass sheet, 850 mm wide, that can be sheared by a straight-cutting guillotine capable of applying a force of 510 kN.



GIVE FEEDBACK

CONTINUE >

Solution

The ultimate shear strength of brass is 150 N/mm^2.
The area in shear is given by the product of the width and thickness of the sheet:

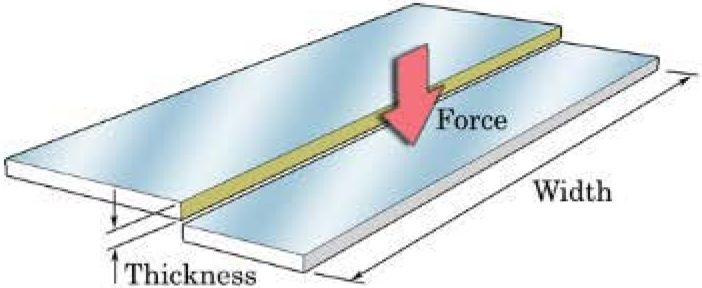
$$\begin{aligned} A &= 850 \text{ mm} \times t \\ &= 850\,t \text{ mm}^2 \end{aligned}$$

The force available is 510000 N. Therefore:

$$\begin{aligned} 510{,}000 \text{ N} &= 150 \text{ MPa} \times 850\,t \text{ mm}^2 \\ \therefore t &= 4 \text{ mm} \end{aligned}$$

Note: In most guillotines the knife edge cuts obliquely so that the cutting action progresses gradually along the line of the cut like scissors do on paper. This takes much less force than cutting the entire line all at once.

< BACK GIVE FEEDBACK OK



An aluminium sheet is 830 mm wide and is sheared by a force of 540 kN. What is the maximum thickness of the sheet in mm?

(Use USS = 125 MPa. Use at least two decimal places.)

Clear

Clear line

? Undo

Click and type your answer here

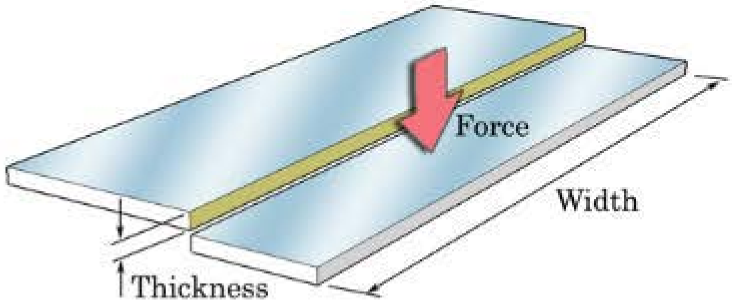
CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- 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 brass sheet is 830 mm wide and is sheared by a force of 540 kN. What is the maximum thickness of the sheet in mm? Use USS = 150 MPa. (Use at least two decimal places.)

Clear
Clear line
Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

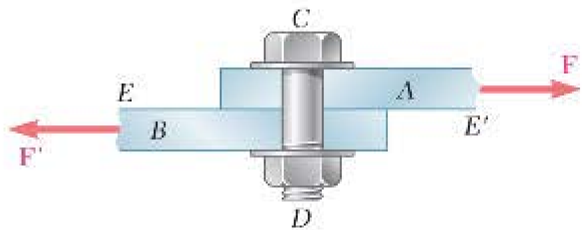
- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint Each hint will reduce the credit received for this question

When punching a hole in a plate or shearing in two, we are working with the ultimate shear strength to break things.

Often the shear force does not reach the ultimate shear strength of the material, so while no failure occurs, shear stress may still exist. **Shear stress** is produced by equal and opposite forces whose lines of action do not coincide.

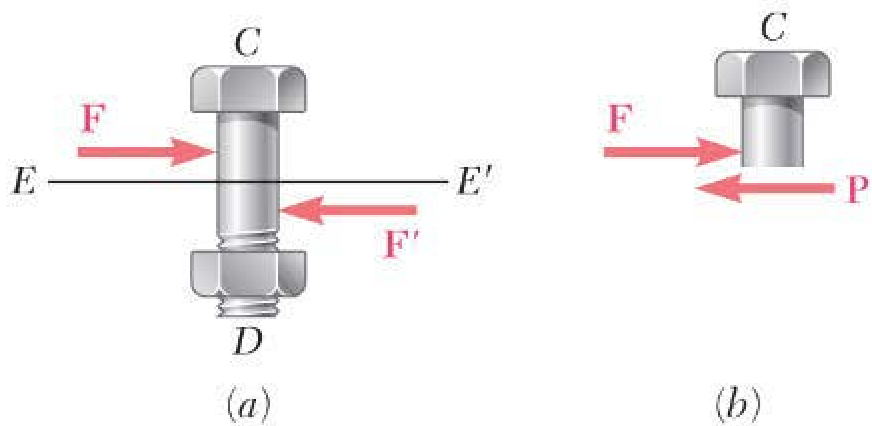
The figure below shows a simple bolt which is under shear by the force F applied by the two plates as indicated (assuming the bolt is not tight). The shear stress acts along the planes, parallel to the lines of action of the applied forces.



GIVE FEEDBACK

CONTINUE >

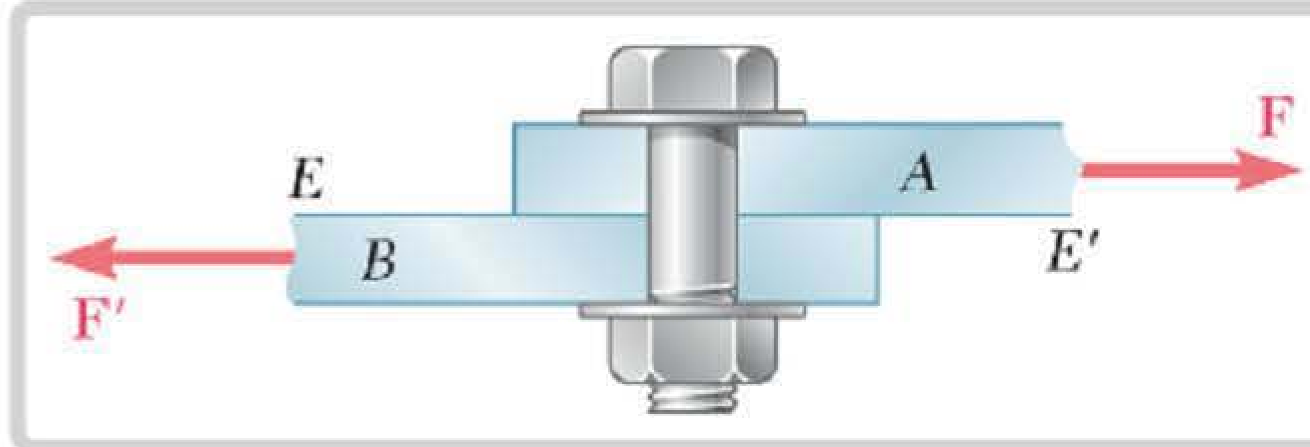
The tendency is to shear through the bolt as shown below (a). Naturally if the size and strength of the bolt is sufficient, no such failure would occur.



Shear stress (τ) is assumed to be distributed uniformly over the total area subjected to shear force, which is the cross-sectional area of the bolt.

< BACK GIVE FEEDBACK OK

This bolt has not been tightened. The stress in the bolt would be:
(A = cross-sectional area of bolt)



Use mouse to zoom. Click to keep enlarged.

Click the correct answer.

$$\frac{2F}{A^2}$$

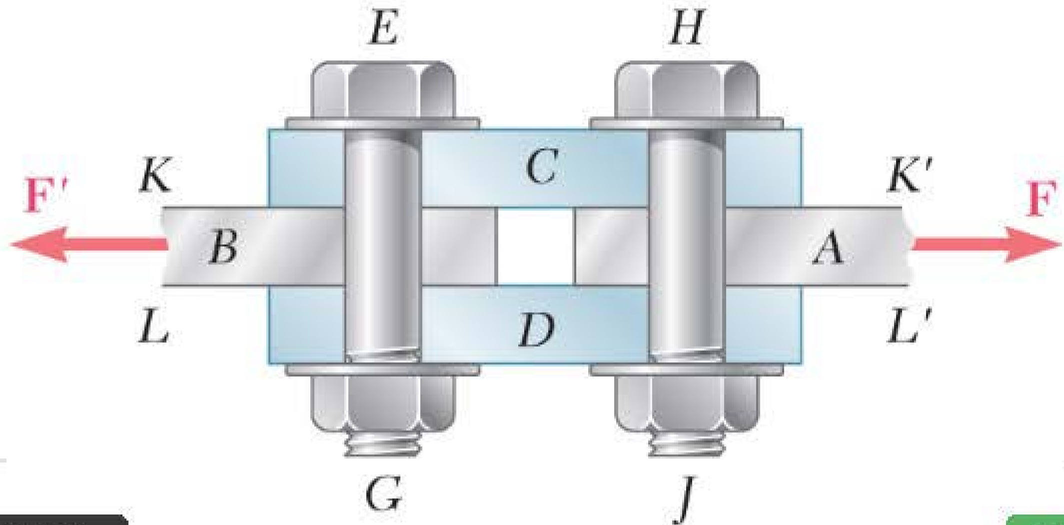
$$\frac{2F}{A}$$

$$\frac{F}{2A}$$

$$\frac{F}{A}$$

In a simple lap joint, the bolt is loaded in shear by the force applied from the two plates.

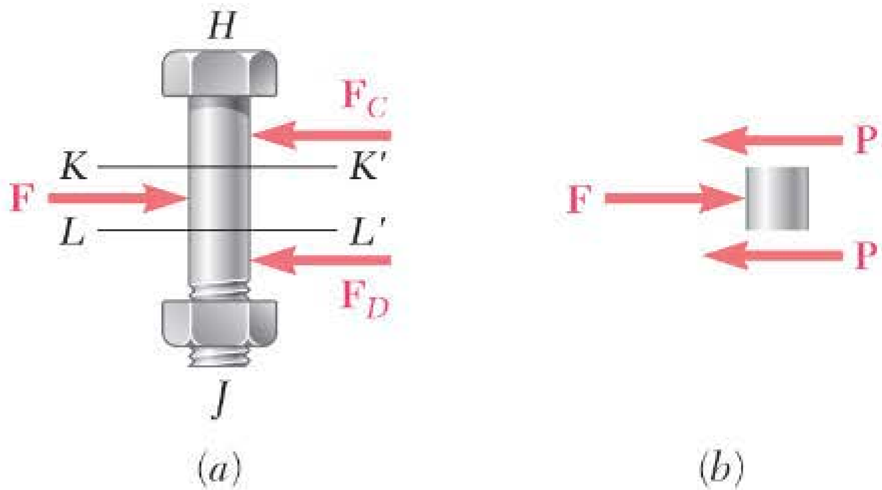
In this next example, each bolt is inserted through three plates (below).



GIVE FEEDBACK

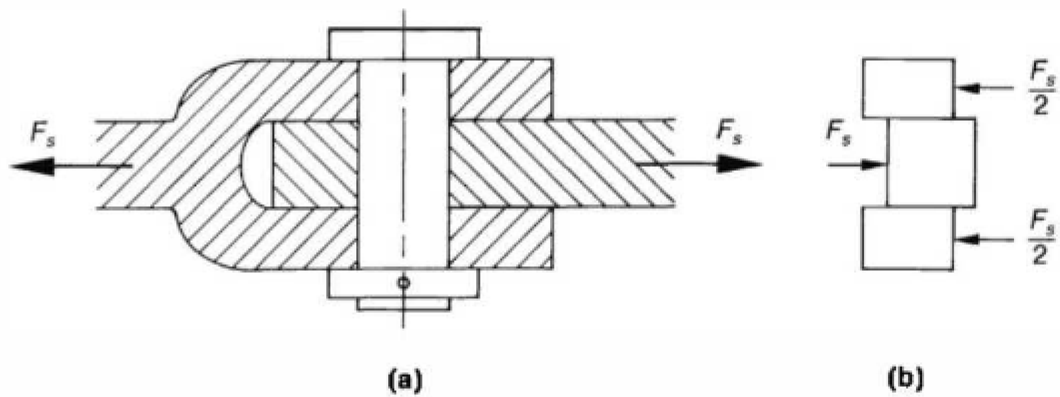
CONTINUE >

Taking the free body diagram of a single bolt below (a), we can see there are two areas of shear created by the applied force. This arrangement is common and is known as double shear, and effectively doubles the area of the bolt because it must be broken twice.



< BACK GIVE FEEDBACK CONTINUE >

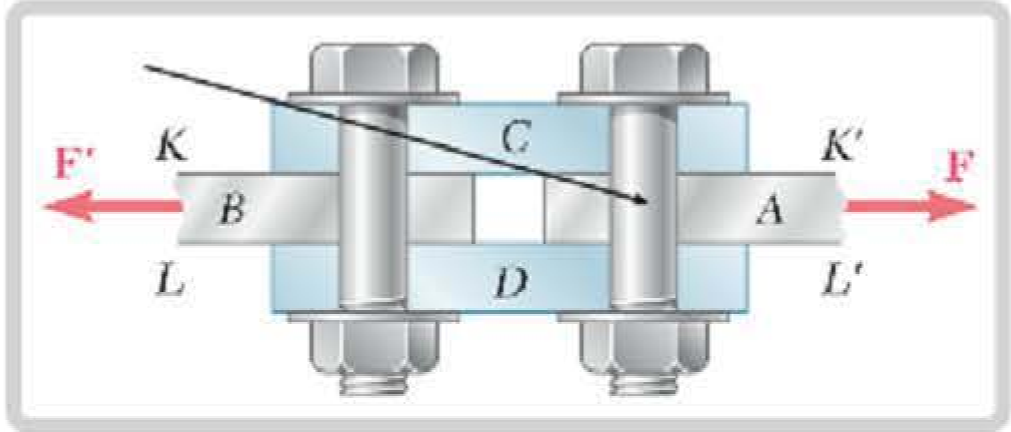
Another example (a) shows a pin in double shear. The free body diagram (b) of the pin illustrates the two areas of shear resisting the load.



(a) A simple pin coupling in double shear (b) Tendency to shear through the pin

< BACK GIVE FEEDBACK OK

This bolt has not been tightened. The stress in the bolt would be:
(A = cross-sectional area of bolt)



Use mouse to zoom. Click to keep enlarged.

Click the correct answer.

$$\frac{F}{2A}$$

$$\frac{2F}{A^2}$$

$$\frac{F}{A}$$

$$\frac{2F}{A}$$

The formula for calculating direct shear stress

Shear stress τ is assumed to be distributed uniformly over the total area subjected to shear force and may be defined as shear force per unit of the total area:

$$\tau = \frac{F_s}{A_s}$$

Remember that shear could be single shear (e.g. two overlapping plates bolted together) or double shear (e.g. clevis-type joint on the end of a cylinder).

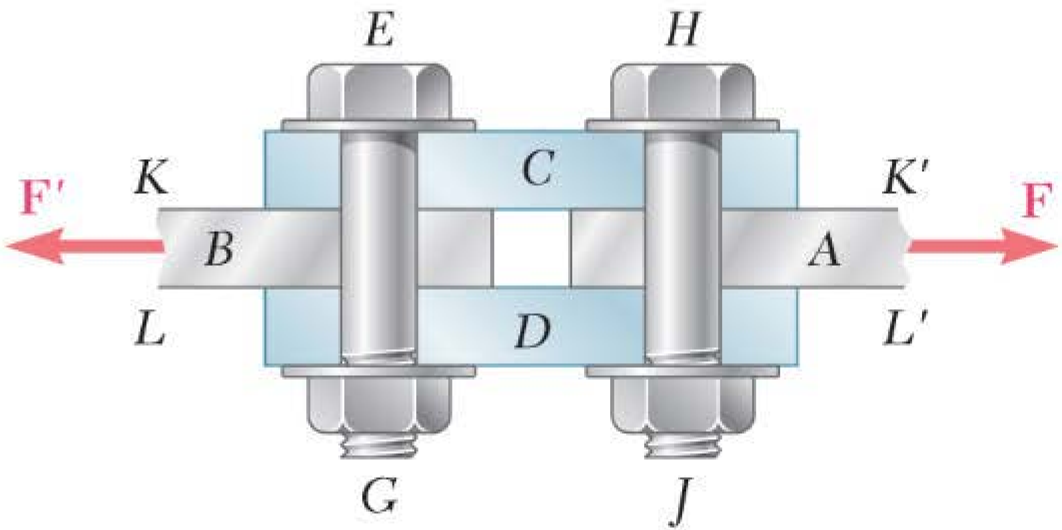
Hint: While direct shear stress is quite simple, students can have trouble determining the area in shear. One way to simplify this is to ask: 'What is the minimum area that must be sheared in order to break the joint?'

GIVE FEEDBACK

CONTINUE >

The formula for calculating direct shear stress

For example, in the case of double shear, we only have to break one bolt to break the whole thing (i.e. we must break the bolt area twice, not four times).



< BACK GIVE FEEDBACK OK

The equation for shear stress is:

$$\tau = \frac{\text{Select...}}{\text{Select...}}$$

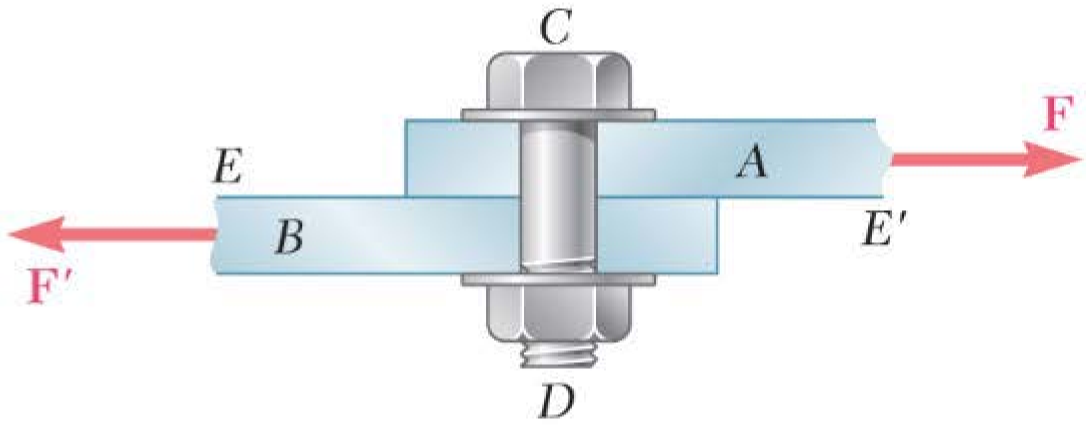
Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Example

Determine the required diameter of a single mild steel bolt, holding two overlapping strips of metal, against a shear force of 4.5 kN if the allowable stress in shear is 90 MPa.



Solution

From $\tau = \dfrac{F_s}{A_s}$ the required area is:

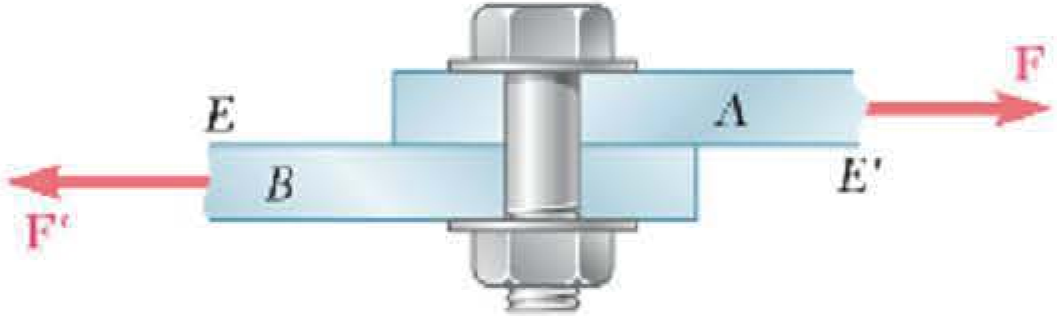
$$A_s = \frac{F_s}{f_s} = \frac{4{,}500 \text{ N}}{90 \text{ MPa}} = 50 \text{ mm}^2$$

This is a case of single shear; only one cross-sectional area need be considered. Hence:

$$D = \frac{\sqrt{4 A_s}}{\pi} = \frac{\sqrt{4 \times 50}}{\pi} = 7.98 \text{ mm}$$

Therefore an 8 mm diameter bolt will be satisfactory.

< BACK GIVE FEEDBACK OK



Determine the minimum diameter of a single mild steel bolt, holding two overlapping strips of mild steel, against a shear force of 5.5 kN if the allowable shear stress is 88 MPa. The bolt is not tightened. (include units, minimum two decimal places.)

+ − · ÷ Clear
Clear line
? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

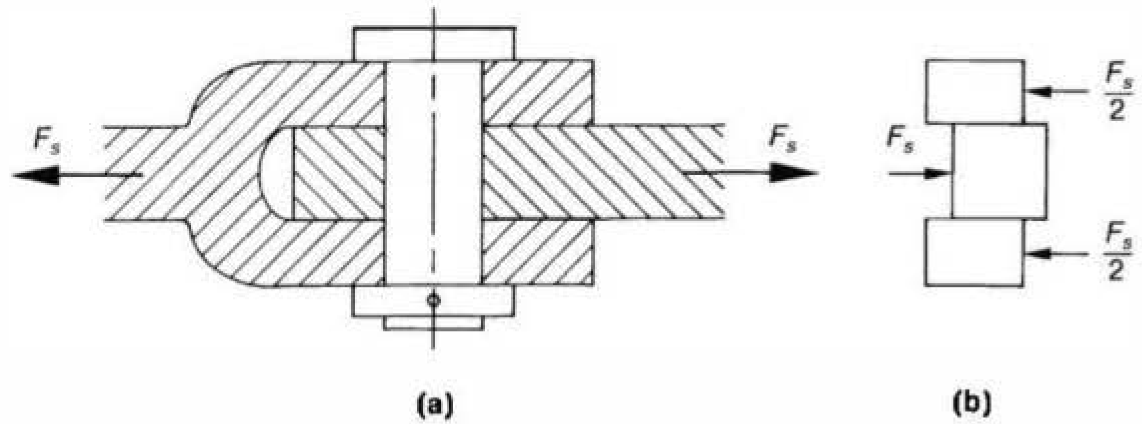
INSTRUCTIONS

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

If the diameter of the mild steel pin is 10 mm and the maximum force applied to the coupling is 11.3 kN, what is the shear stress in the material of the pin and the factor of safety (ultimate shear strength = 360 MPa)?



GIVE FEEDBACK

CONTINUE >

Solution

This is a case of double shear. Therefore the total area is:

$$A_s = 2 \times \frac{\pi \times 10^2}{4} = 157 \text{ mm}^2$$

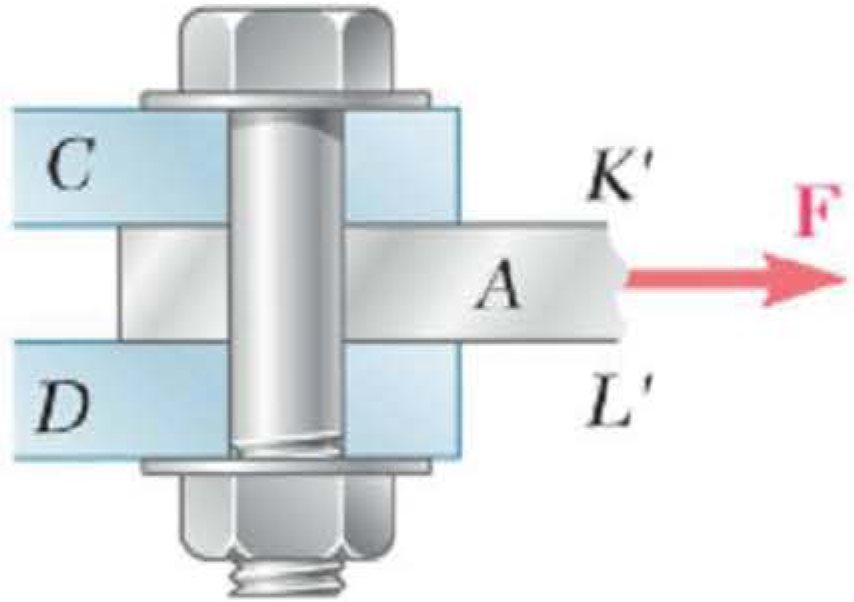
Shear stress:

$$\tau = \frac{F_s}{A_s} = \frac{11{,}300 \text{ N}}{157 \text{ mm}^2} = 72 \text{ MPa}$$

Since the ultimate shear strength of mild steel is 360 N/mm^2, the factor of safety is:

$$FS = \frac{USS}{\tau} = \frac{360}{72} = 5$$

< BACK GIVE FEEDBACK OK



Determine the minimum diameter of a single mild steel bolt, holding three overlapping strips of mild steel, against a force of 5.5 kN if the allowable shear stress is 81 MPa. The bolt is not tightened. (Include units, minimum two decimal places.)

Clear
Clear line
Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

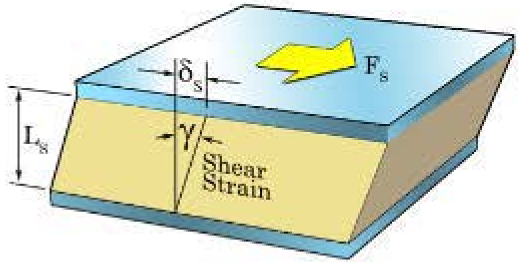
- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint Each hint will reduce the credit received for this question

Elasticity of solid materials is not limited to tension and compression. When an elastic material is subjected to shear force, deformation occurs. Tension makes the object longer, compression makes it shorter, but shear stress deforms the shape rather than the size. The angle of deformation is called the shear strain (Greek symbol gamma).

Shear strain

Elasticity of solid materials is not limited to tension and compression. When an elastic material is subjected to shear force, deformation occurs. Tension makes the object longer, compression makes it shorter, but shear stress deforms the shape rather than the size.



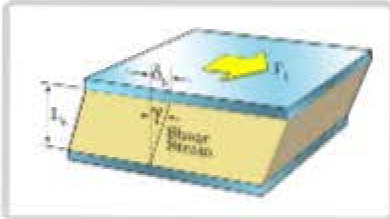
Shape deformation caused by shear force F_s

Consider, for example, a solid block of rubber between two plates as shown above. When subjected to shear force F_s, the deformation in the direction of the shear force is δ_S. This gives an angle related to the shear strain γ.

GIVE FEEDBACK

OK

Match the following symbols related to shear strain:



Use mouse to zoom. Click to keep enlarged.

Drag statements on the right to match the left.

F_s	Shear force
δ_s	Shear deformation
L_s	Length in shear
γ	Shear strain

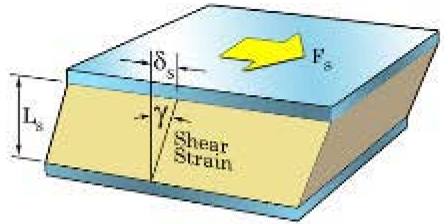
Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The formula of shear strain

Shear strain is the deformation in the direction of the shear force divided by the depth of the material. It is related to the angle of deformation.

Shear strain γ is defined as the ratio of deformation δ_S to the material depth L_S.



$$\gamma = \frac{\delta_S}{L_S}$$

where:

γ = shear strain (no units)

δ_S = deformation (mm)

L_S = depth of material (mm)

This equation looks exactly the same as the equation for axial strain (tension and compression). However, the shear strain is related to angle not length.

To avoid confusion shear uses different symbols to axial.

GIVE FEEDBACK

OK

The equation for shear strain is:

$$\gamma = \frac{\text{Select...}}{\text{Select...}}$$

Submit

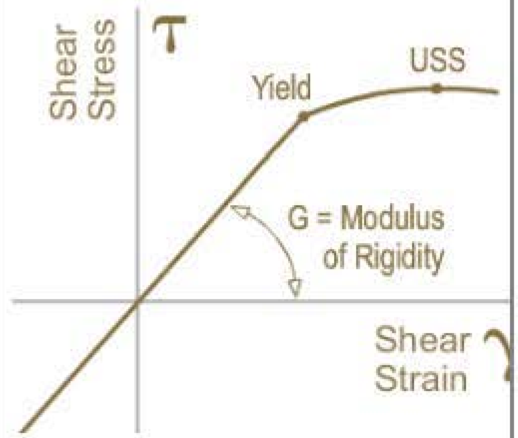
Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The stiffness in shear is called the modulus of rigidity (symbol G). The modulus of rigidity is the shear stress divided by shear strain.

The **modulus of rigidity** (G) is the stiffness of a material in shear. It is similar to the modulus of elasticity, E, only this time it is in shear, not tension. And, just like E, the modulus of rigidity G is a material property consistent for each material (within its elastic range).

Axial stresses (tension and compression) push or pull the atoms in a straight line. Shear is different; it distorts the atomic lattice into a parallelogram where atoms tend to slide past each other. The stiffness in shear is called the modulus of rigidity G, which is the slope of the elastic portion of the graph of Shear Stress vs Shear Strain.



GIVE FEEDBACK

CONTINUE >

Video object isn't supported in c++ version

An applied *shear force* distorts the material and generates *shear stress*. The relative amount of movement is the *shear strain*. The **modulus of rigidity G** is the shear stress divided by the shear strain, which is the stiffness of the material in shear.

In practice, the modulus of rigidity is conveniently measured by a torsion test.

< BACK GIVE FEEDBACK OK

Which of the following statements are true about the modulus of rigidity?

Check all that apply.

- [ ] It is the stiffness of a material in shear
- [ ] It has the symbol G
- [ ] It is equal to modulus of elasticity, E
- [ ] It is a material property

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The stiffness in shear is called the modulus of rigidity (symbol G). The modulus of rigidity is the shear stress divided by shear strain.

The formula of modulus of rigidity

Having defined shear stress (τ) and shear strain (γ), we get the modulus of rigidity (G).

$$G = \frac{\tau}{\gamma}$$

Where:
G = Modulus of rigidity (MPa)
τ = Shear stress (MPa)
γ = Shear strain ( )

Just like E, the modulus of rigidity G is a material property consistent for each material (within its elastic range).

Just like E, which has multiple names (modulus of elasticity, Young's modulus, tensile modulus), G also has more than one name (modulus of rigidity, shear modulus).

Our preferred names will be elasticity modulus for E and rigidity modulus for G.

GIVE FEEDBACK

OK

The equation for modulus of rigidity is:

$$G = \frac{\text{Select...}}{\text{Select...}}$$

Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

If the material is uniform in every direction (like metals and polymers), the modulus of rigidity is always about 40 per cent of the modulus of elasticity.

Compare the modulus of rigidity with the modulus of elasticity

The modulus of rigidity of a particular material is equal to a fixed percentage of its Young's modulus (E). For isotropic materials, i.e. materials which have the same elastic properties in all directions (true for most metals, polymers and ceramics but not for wood or fibre composites), this percentage, determined theoretically by using the molecular theory of structure of the material, is 40 per cent. Therefore:

$$G = 0.4\,E$$

GIVE FEEDBACK

OK

For most metals an approximate rule is:
The modulus of rigidity (G) is Select... ▼ of the modulus of elasticity (E).

Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the modulus of rigidity—Example

For most engineering materials the modulus of rigidity is about 40 per cent of the modulus of elasticity.

Example

What is the value of the modulus of rigidity of steel?

GIVE FEEDBACK

CONTINUE >

Example

What is the value of the modulus of rigidity of steel?

Solution

Young's modulus for steel is $E = 200{,}000 \text{ MPa}$. Therefore:

$$
\begin{aligned}
G &= 40\% \text{ of } E \\
&= 0.4 \times 200{,}000 \text{ MPa} \\
&= 80{,}000 \text{ MPa}
\end{aligned}
$$

< BACK GIVE FEEDBACK OK

An experimental alloy has a modulus of elasticity of 130 GPa. What is the approximate modulus of rigidity? (Round off to nearest GPa.)

+ − · ÷ ≤ 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

G is roughly 40 per cent of E, but where does the 40 per cent come from? There is a relationship between the pulling and sliding of atoms, and the equation involves Poisson's ratio.

Derive the modulus of rigidity using the elastic modulus and Poisson's ratio

A more precise relationship between shear modulus of rigidity (G), Young's modulus of elasticity (E) and Poisson's ratio (ν) is given by the following formula:

$$G = \frac{E}{2(1 + \nu)}$$

It can be shown, by simple substitution, that since the value of Poisson's ratio for most materials seldom varies beyond its narrow range of 0.25 to 0.35, the value of G will usually be within 37 to 40 per cent of the Young's modulus. This variation is not very significant and 40 per cent may be used as sufficiently accurate for our purposes.

GIVE FEEDBACK

OK

The precise formula relating the tensile to shear is:

$$G = \frac{E}{2(1 + \nu)}$$

Match each symbol to its definition.

Drag statements on the right to match the left.

G	Modulus of rigidity
E	Young's modulus of elasticity
ν	Poisson's ratio

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the modulus of rigidity given Poisson's ratio—Example

Example

If Poisson's ratio for steel is 0.29, what is a more accurate estimate of its shear modulus of rigidity?

GIVE FEEDBACK

CONTINUE >

Calculate the modulus of rigidity given Poisson's ratio—Example

Example

If Poisson's ratio for steel is 0.29, what is a more accurate estimate of its shear modulus of rigidity?

Solution

Modulus of rigidity:

$$G = \frac{E}{2(1 + \nu)}$$

$$= \frac{200{,}000 \text{ MPa}}{2(1 + 0.29)}$$

$$= 77{,}500 \text{ MPa}$$

< BACK GIVE FEEDBACK OK

An experimental material has a modulus of elasticity of 130 GPa and a Poisson's ratio of 3. What is the precise modulus of rigidity?

(Do not type the units, round off to nearest GPa.)

+ − · ÷ $\sqrt{\square}$ Clear

Clear line

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".

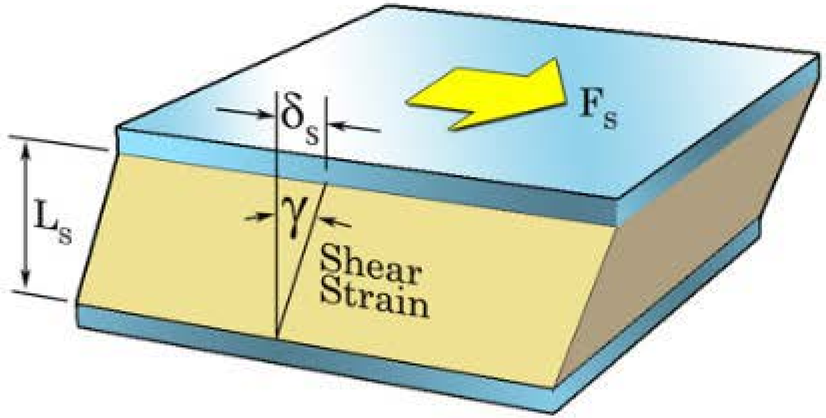
Hint

Each hint will reduce the credit received for this question

Example

An anti-vibration mounting for a machine is in the form of rubber pads and its dimensions are $200 \text{ mm} \times 200 \text{ mm} \times 10 \text{ mm}$ thick. Each pad is subjected to a periodic horizontal force, reaching a maximum of 600 N, distributed over its area.

Determine the amount of shear deformation, δ_s, corresponding to the maximum force if the modulus of rigidity of rubber is 1.5 MPa.



Determining shear deformation—Example	Find the shear stress	Find the shear strain	Find the shear deformation	Summary

GIVE FEEDBACK

OK

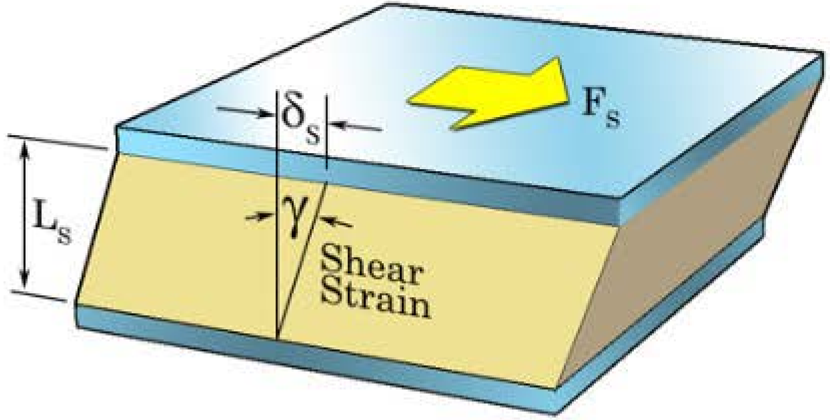
Determine total extension and safety factor

Rubber pads are $200 \text{ mm} \times 200 \text{ mm} \times 10 \text{ mm}$ thick. Maximum force 600 N. Modulus of rigidity of the rubber is 1.5 MPa.

Step 1: Find the shear stress.

Shear stress in the material of the pads is:

$$\tau = \frac{F_s}{A_s}$$
$$= \frac{600 \text{ N}}{200 \text{ mm} \times 200 \text{ mm}}$$
$$= 0.015 \text{ MPa}$$



Determining shear deformation—Example	Find the shear stress	Find the shear strain	Find the shear deformation	Summary

GIVE FEEDBACK

OK

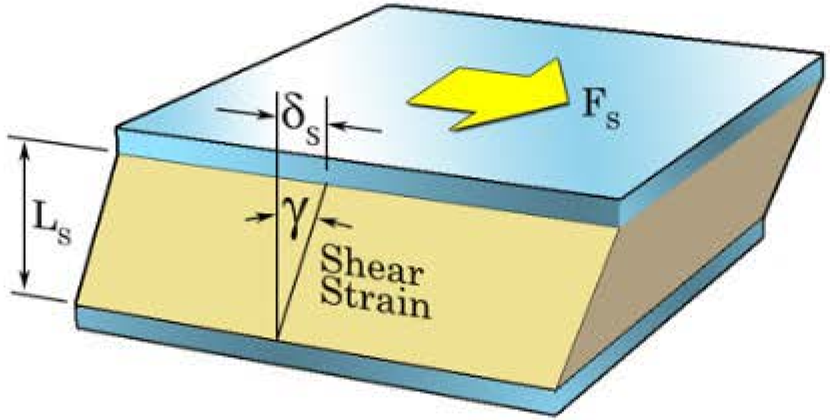
Determine total extension and safety factor

Rubber pads are $200\ \mathrm{mm} \times 200\ \mathrm{mm} \times 10\ \mathrm{mm}$ thick. Maximum force 600 N. Modulus of rigidity of the rubber is 1.5 MPa.

Step 2: Find the shear strain.

From $G = \frac{\tau}{\gamma}$, shear strain is:

$$\gamma = \frac{\tau}{G} = \frac{0.015}{1.5} = 0.01$$



Determining shear deformation—Example	Find the shear stress	Find the shear strain	Find the shear deformation	Summary

GIVE FEEDBACK

OK

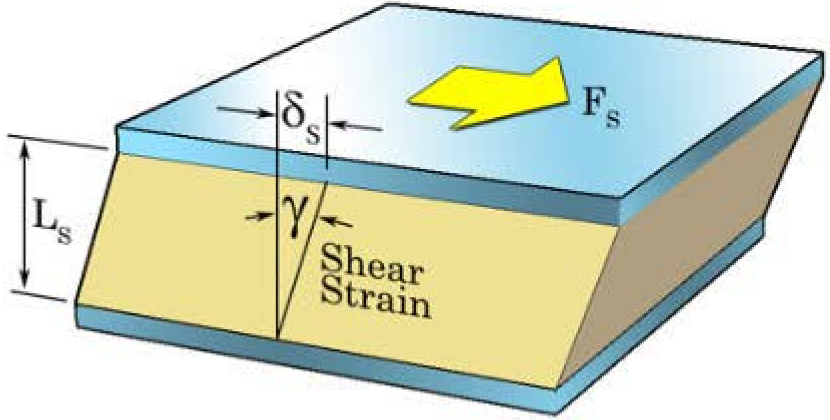
Determine total extension and safety factor

Rubber pads are $200\ \mathrm{mm} \times 200\ \mathrm{mm} \times 10\ \mathrm{mm}$ thick. Maximum force 600 N. Modulus of rigidity of the rubber is 1.5 MPa.

Step 3: Find the shear deformation.

From $\gamma = \frac{\delta_s}{L_s}$, shear deformation δ_s is:

$$\delta_s = \gamma L_s$$
$$= 0.01\ \mathrm{mm} \times 10\ \mathrm{mm}$$
$$= 0.1\ \mathrm{mm}$$



Determining shear deformation—Example	Find the shear stress	Find the shear strain	Find the shear deformation	Summary

GIVE FEEDBACK

OK

Determine total extension and safety factor

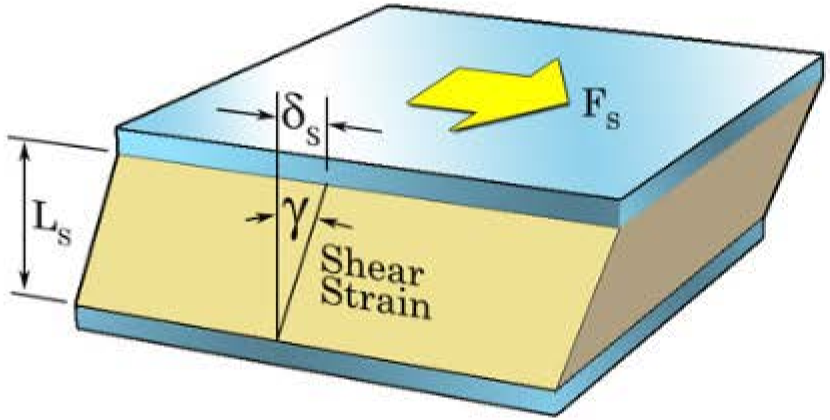
Rubber pads are $200\ \mathrm{mm} \times 200\ \mathrm{mm} \times 10\ \mathrm{mm}$ thick. Maximum force 600 N. Modulus of rigidity of the rubber is 1.5 MPa.

Shear stress: $\tau = \dfrac{F_s}{A_s} = \dfrac{600\ \mathrm{N}}{200\ \mathrm{mm} \times 200\ \mathrm{mm}} = 0.015\ \mathrm{MPa}$

From $G = \dfrac{\tau}{\gamma}$, shear strain is: $\gamma = \dfrac{\tau}{G} = \dfrac{0.015}{1.5} = 0.01$

Therefore from $\gamma = \dfrac{\delta_s}{L_s}$, shear deformation δ_s is:

$\delta_s = \gamma L_s = 0.01\ \mathrm{mm} \times 10\ \mathrm{mm} = 0.1\ \mathrm{mm}$

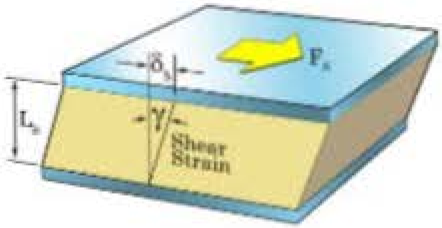


Determining shear deformation—Example	Find the shear stress	Find the shear strain	Find the shear deformation	Summary

GIVE FEEDBACK

OK

This is a rubber pad of 200 x 200 x 18 mm with shear force of 2500 N. Modulus of rigidity of the rubber is 1.5 MPa. If stress is 0.0625, find the shear strain to four decimal places. (Do not enter units.)



Clear

Clear line

? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

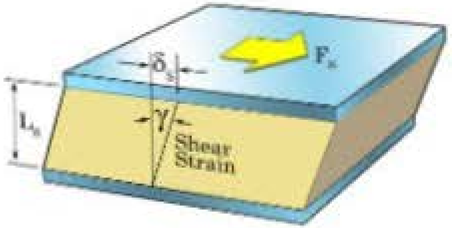
INSTRUCTIONS

- 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

Rubber pad of 200 x 200 x 18 mm with shear force of 2500 N. Modulus of rigidity of the rubber is 1.5 MPa. If stress is 0.0625, and the shear strain is 0.04166667, find the shear deformation in mm. (To four decimal places, do not enter units.)



Clear

Clear line

?

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

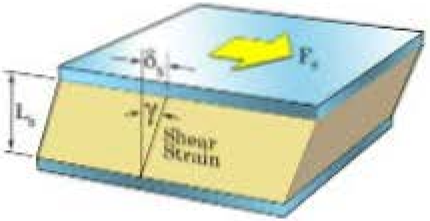
INSTRUCTIONS

- 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

Rubber pad of 200 x 200 x 18 mm with shear force of 2500 N. Modulus of rigidity of the rubber is 1.5 MPa. If stress is 0.0625, and the shear strain is 0.04166667, find the shear deformation in mm. (To two decimal places, do not enter units.)



+ − · ÷ Clear
Clear line
? Undo

Click and type your answer here

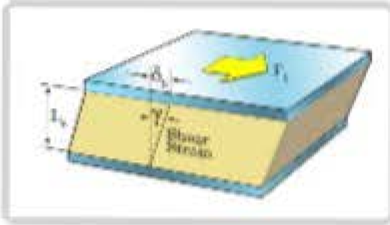
CHALLENGE SUBMIT SHOW ANSWER

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

Rubber pads are $200 \text{ mm} \times 200 \text{ mm} \times 10 \text{ mm}$ thick. Maximum force is 600 N. Modulus of rigidity of the rubber is 1.5 MPa. Sort the following steps into the right order to determine the strain deformation.



Use mouse to zoom. Click to keep enlarged.

↑↓ Place these in the proper order.

$$\tau = \frac{F_s}{A_s} = \frac{600\text{ N}}{200\text{ mm} \times 200\text{ mm}} = 0.015\text{ MPa}$$

$$\gamma = \frac{\tau}{G} = \frac{0.015}{1.5} = 0.01$$

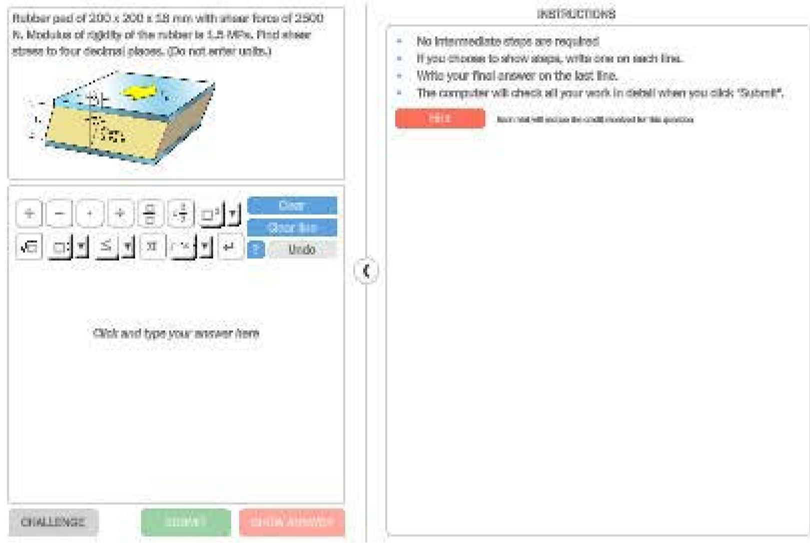
$$\delta_s = \gamma L_s = 0.01\text{ mm} \times 10\text{ mm} = 0.1\text{ mm}$$

Do you know the answer?

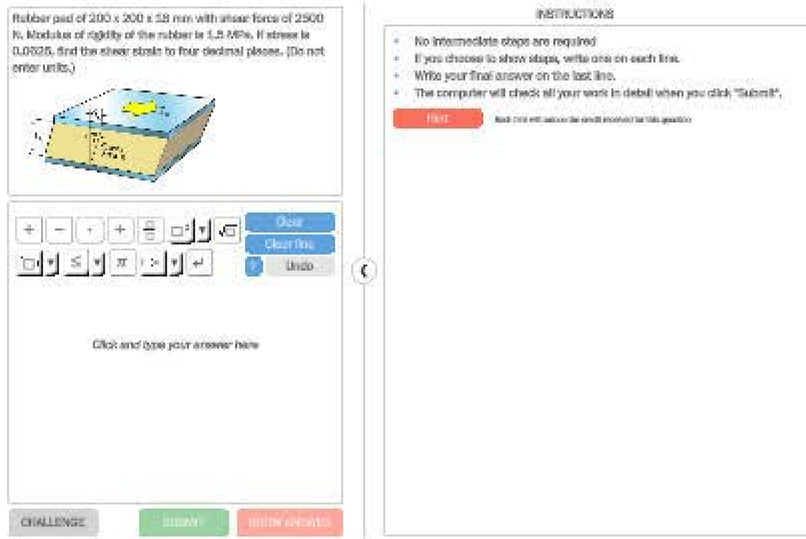
I KNOW IT | THINK SO | UNSURE | NO IDEA

To calculate the shear deformation in this example we need to find the shear stress, then the shear strain and finally the deformation.

SMALL MEDIUM LARGE



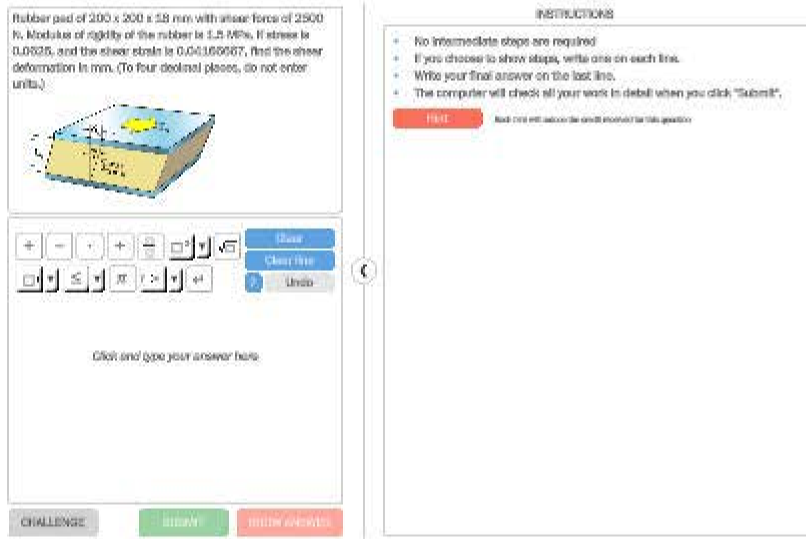
To calculate the shear deformation in this example we need to find the shear stress, then the shear strain and finally the deformation.



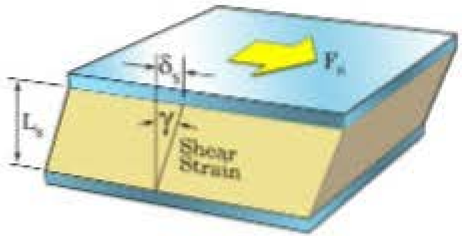
SMALL
MEDIUM
LARGE

To calculate the shear deformation in this example we need to find the shear stress, then the shear strain and finally the deformation.

SMALL MEDIUM LARGE



Rubber pad of 200 x 200 x 18 mm with shear force of 2500 N. Modulus of rigidity of the rubber is 1.5 MPa. Find shear stress to four decimal places. (Do not enter units.)



+ − · ÷

Clear

Clear line

? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

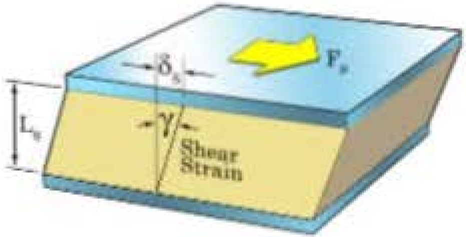
INSTRUCTIONS

- 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

Rubber pad of 200 x 200 x 18 mm with shear force of 2500 N. Modulus of rigidity of the rubber is 1.5 MPa. If stress is 0.0625, find the shear strain to four decimal places. (Do not enter units.)



+ − · ÷ π ↵

Clear

Clear line

?

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

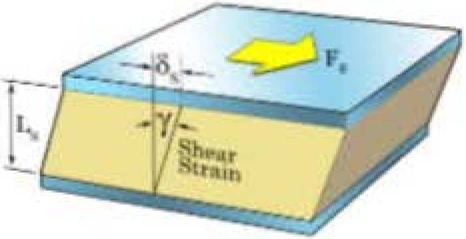
INSTRUCTIONS

- 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

Rubber pad of 200 x 200 x 18 mm with shear force of 2500 N. Modulus of rigidity of the rubber is 1.5 MPa. Find shear stress to four decimal places. (Do not enter units.)



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

Torsion is the type of loading that causes an object to twist. This twisting action occurs when two equal and opposite torques act on the component. Examples include a power transmission shaft, a torsion bar, a spring or even a screwdriver.

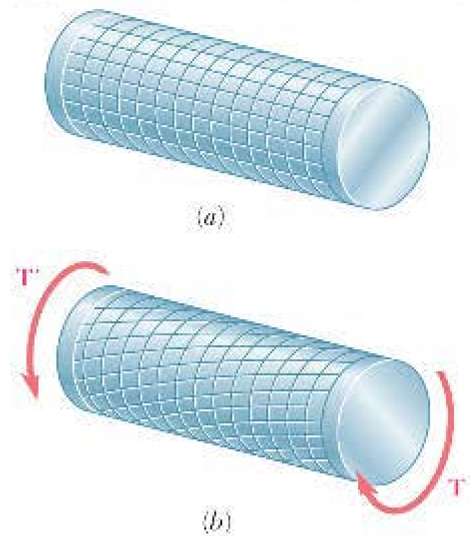
Torsion

Torsion is the type of loading that causes an object to twist.

This twisting action occurs when two equal and opposite torques are applied to a component. Examples include a power transmission shaft, a torsion bar, a spring or even a screwdriver.

As twisting occurs (b), each circular cross-section of the bar rotates slightly relative to the next cross-section immediately adjacent to it.

This induces internal shear stresses, within the material of the bar, in the plane of each cross-section. (There are other minor stresses beyond our analysis here.)



Torsion on a cylindrical bar

GIVE FEEDBACK

OK

Torsion causes the cross-section of the cylindrical shaft to be under
Select... stress.

Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Torsion causes an object to Select... .

Submit

Do you know the answer?

I KNOW IT

THINK SO

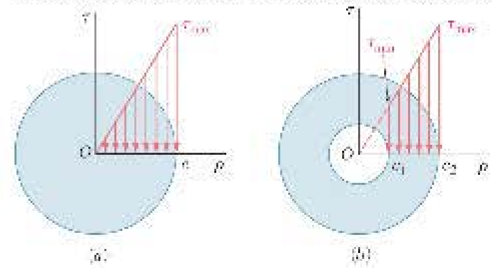
UNSURE

NO IDEA

Torsional stress is zero at the centre and increases to a maximum at the outside diameter.

Difference between direct shear and torsional shear

Unlike direct shear, stresses due to torsion are not distributed uniformly over the cross-sectional area of the bar. In fact there is no stress at all at the centre of the cross-sectional area.

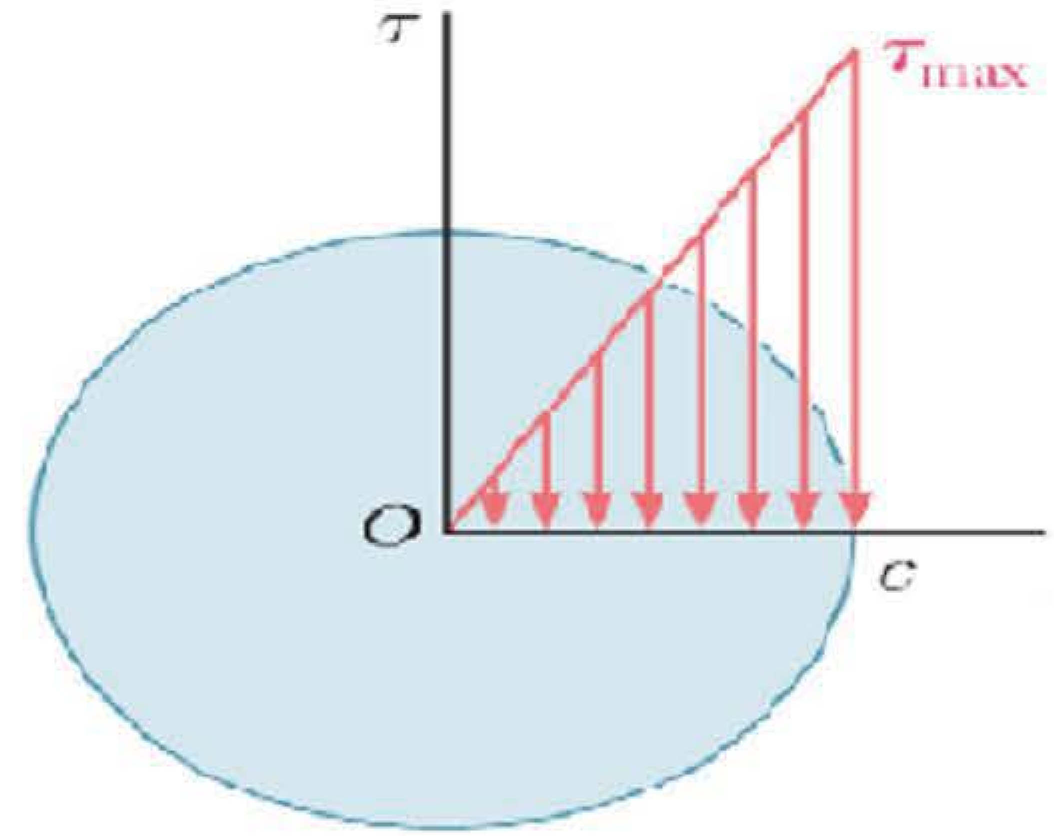


On the other hand, torsional shear stress reaches its maximum value at the maximum distance from the centre, i.e. on the outside of the shaft.

GIVE FEEDBACK

OK

Regarding torsional stress, which of the following statements are true about this diagram?



Check all that apply.

- [ ] Stresses due to torsion are not distributed uniformly
- [ ] Stress is maximum at the centre
- [ ] There is no shear stress at the centre of the cross-sectional area
- [ ] Torsional shear stress reaches its maximum value at the maximum distance from the centre

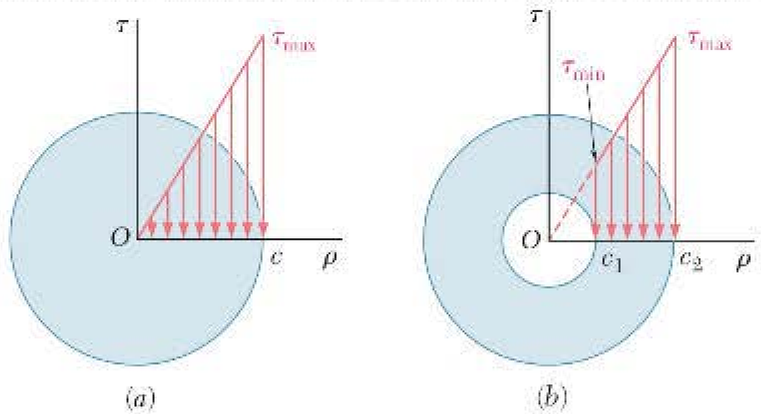
Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Maximum torsional shear stress

We are mostly concerned with the maximum shear stress produced by the applied torque. The maximum torsional shear stress in a solid or hollow cylinder is always at the outside radius of the shaft.

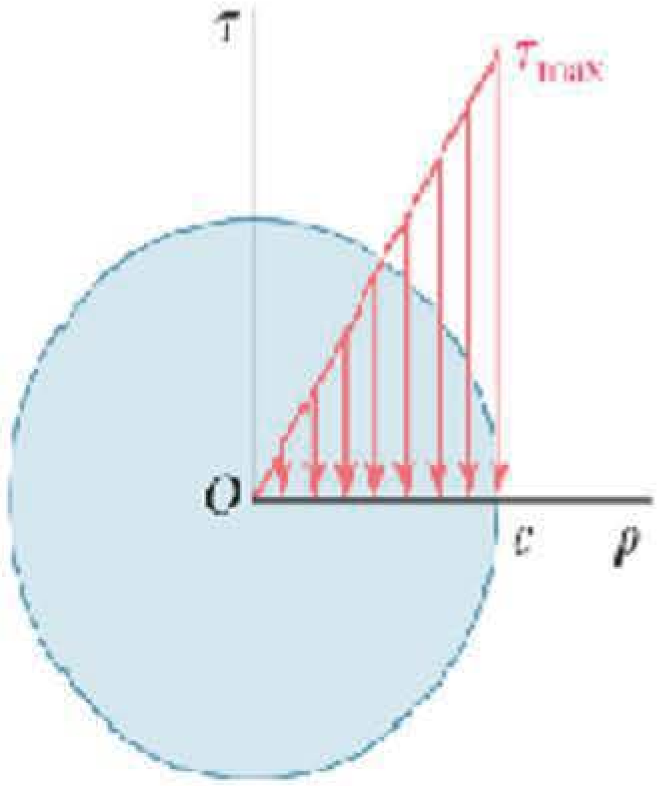
A hollow cylinder (b) is simply treated like a solid cylinder (a) with the inside missing, so the same equation can be used.

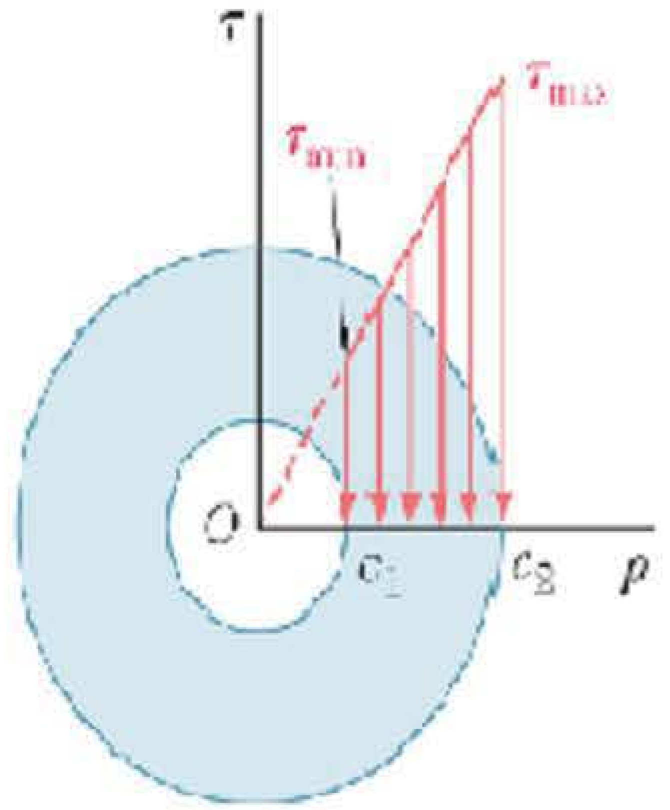


GIVE FEEDBACK

OK

Comparing the maximum torsional shear stress for a solid shaft to that of a hollow shaft, which of the following statements are true?





Check all that apply.

- [ ] Shear stress increases with distance away from the centre
- [ ] Both have the maximum stress at the outside of the shaft
- [ ] The hollow shaft has highest stress on the inside
- [ ] Both have the same minimum shear stress

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Shear stress due to torsion:

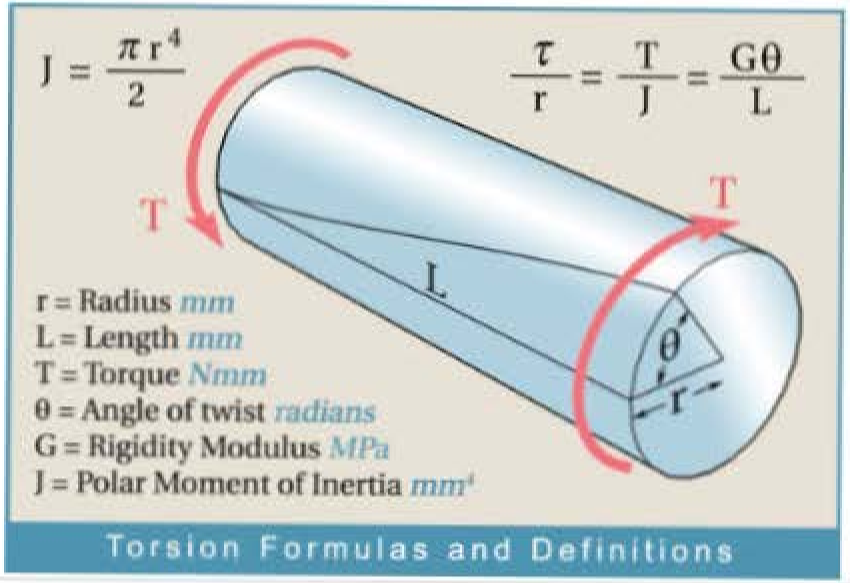
$$\boxed{\tau = \frac{T\,r}{J}}$$

where:
T is torque (Nmm)
r is the radius of the cylinder (mm)
J is a geometrical property of the cross-section known as its **polar moment of inertia** (mm^4)

GIVE FEEDBACK CONTINUE >

We can now visit our torsional stress summary diagram. This combined equation allows the user to choose any two of the three parts of the equation. For example, by choosing the first and second parts we get the same shear stress equation as shown at the top of the page (after rearranging of course).

Now we can begin to get familiar with the combined equation for torsional stress (below). We will visit this many times as we build our knowledge of torsional stress.



< BACK

GIVE FEEDBACK

OK

Match the variables to their meaning for the torsional shear stress equation:

$$\tau = \frac{T\,r}{J}$$

Drag statements on the right to match the left.

T	Torque
r	Radius of the cylinder
J	Polar moment of inertia
τ	Torsional shear stress

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Match the units for each variable in the torsional shear stress equation:

$$\tau = \frac{T\,r}{J}$$

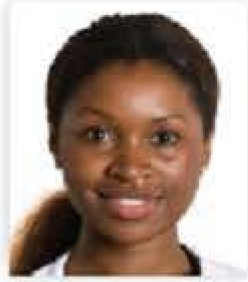
Drag statements on the right to match the left.

T	Nmm
r	mm
J	mm^4
τ	MPa

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The formula for calculating the polar moment of inertia for a solid cylinder



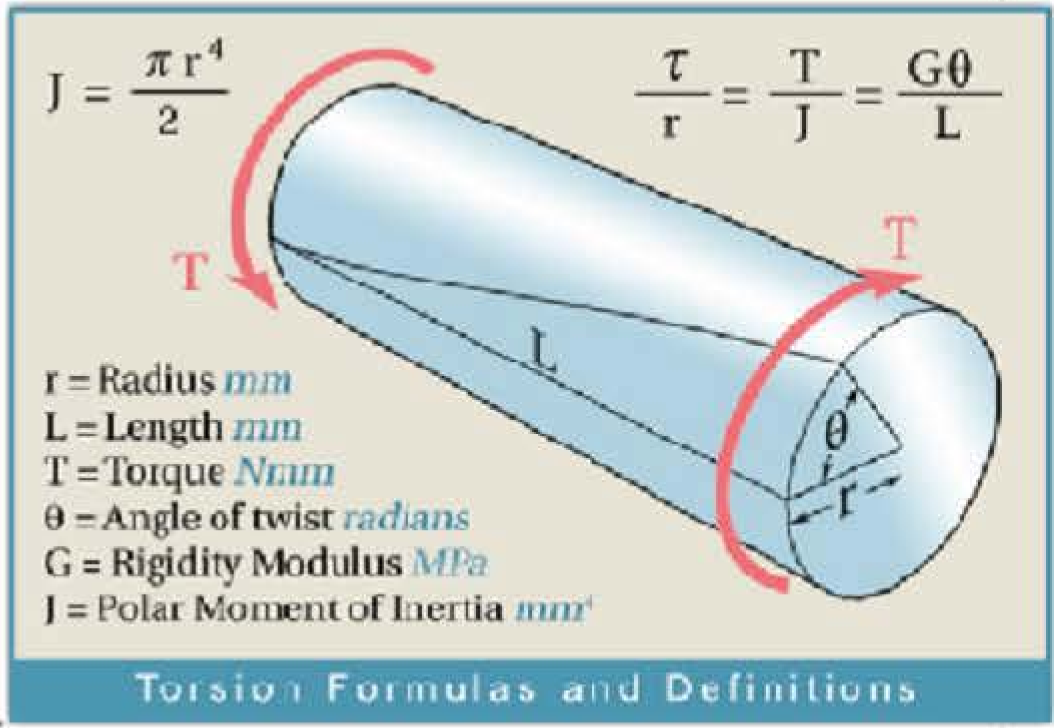
The polar moment of inertia is a special function of the diameter of the cylinder in torsion. It has the symbol J and the units are millimeters to the fourth. Seems a bit strange at first.

Note that mm squared is area, mm cubed is volume, but mm to the fourth is not something we can picture—we just have to work with it from the formula. It also means the polar moment of inertia is very sensitive to diameter. Double the diameter and J increases by 16 times.

J is a geometrical property of the cross-section known as its **polar moment of inertia.**

$$J = \frac{\pi \cdot D^4}{32}$$ or, in terms of radius,

$$J = \frac{\pi \cdot r^4}{2}$$



where:

D (diameter in mm) = 2 x (radius in mm)

J = polar moment of inertia (mm^4)

Note that J is related to the fourth power of diameter. This means that doubling the shaft diameter will increase J by $2^4 = 16$ times!

So J is very sensitive to diameter.

GIVE FEEDBACK

OK

J is a geometrical property of the cross-section known as its polar moment of inertia.

$$J = \frac{\pi \cdot D^4}{32} \text{ or, in terms of radius, } J = \frac{\pi \cdot r^4}{2}$$

Match the units to the variables in this equation.

Drag statements on the right to match the left.

J	mm^4
D	mm
r	mm

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The equation related to torsional stress is:

$$J = \frac{\pi \cdot D^4}{32} \text{ or, in terms of radius, } J = \frac{\pi \cdot r^4}{2}$$

Identify which of the statements below are true for this equation.

Check all that apply.

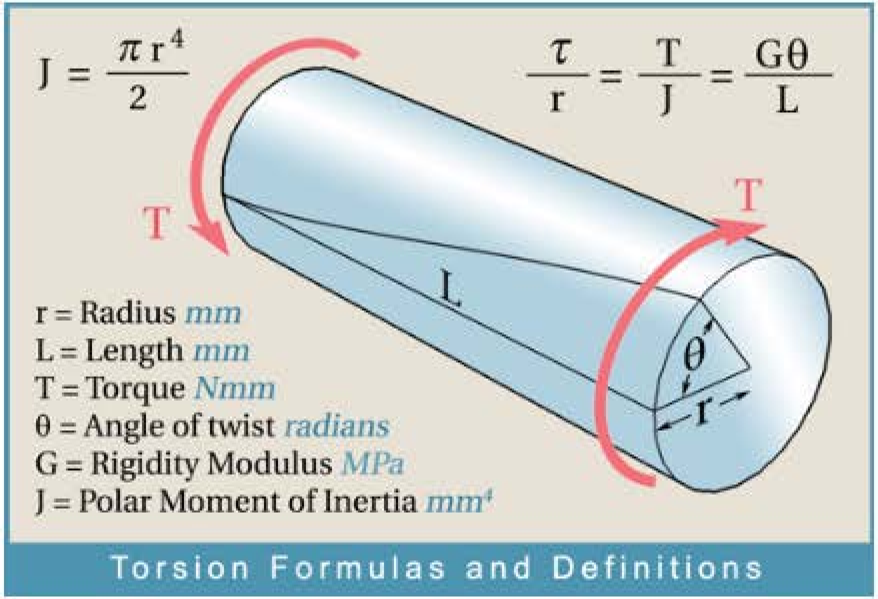
- [ ] J is the polar moment of inertia
- [ ] Units for J are mm^4
- [ ] Doubling the diameter will increase J by 16 times
- [ ] Doubling the radius will increase J by 8 times

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Determine shear stress for a solid cylinder

Calculate the torsional shear stress in a 50 mm diameter shaft if it is subjected to a torque of 1400 N.m.



Calculate torsional shear stress	Convert to correct units	Calculate polar moment of inertia	Find the torsional shear stress	Summary

GIVE FEEDBACK

OK

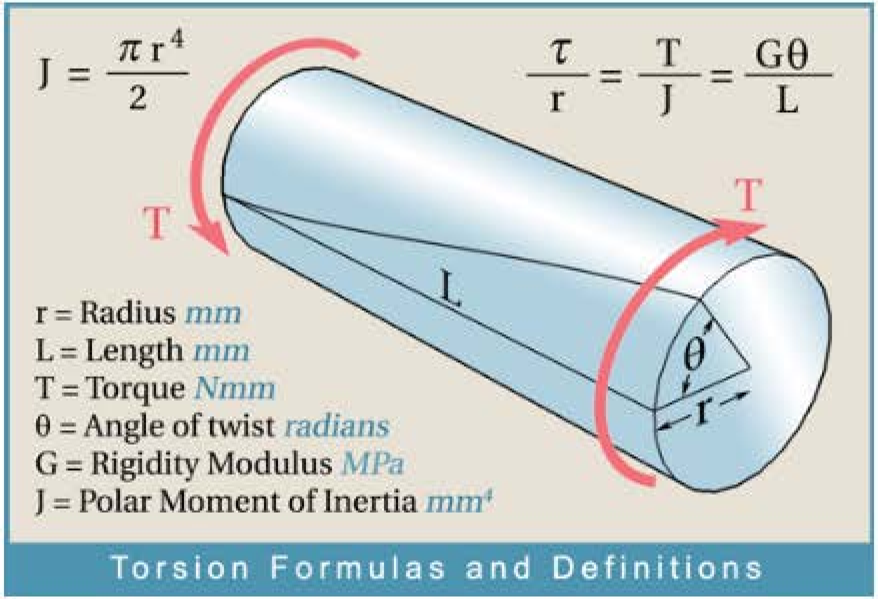
Determine shear stress for a solid cylinder

Calculate the torsional shear stress in a 50 mm diameter shaft if it is subjected to a torque of 1400 N.m.

Make sure all variables are in correct units (N, mm, Nmm, MPa).

Torque:

$$\begin{aligned} T &= 1{,}400\ \mathrm{N\,m} \\ &= 1{,}400 \times 10^{3}\ \mathrm{N\,mm} \end{aligned}$$



Calculate torsional shear stress	Convert to correct units	Calculate polar moment of inertia	Find the torsional shear stress	Summary

GIVE FEEDBACK

OK

Determine shear stress for a solid cylinder

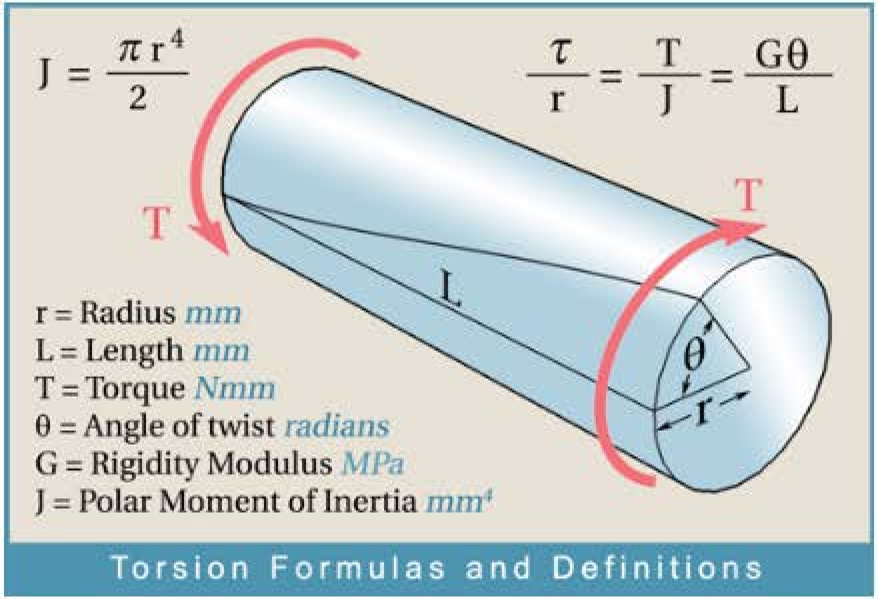
Calculate the torsional shear stress in a 50 mm diameter shaft if it is subjected to a torque of 1400 N.m.

Polar moment of inertia:

$$J = \frac{\pi D^4}{32}$$

$$= \frac{\pi \times 50^4}{32}$$

$$= 613.6 \times 10^3 \text{ mm}^4$$



Calculate torsional shear stress	Convert to correct units	Calculate polar moment of inertia	Find the torsional shear stress	Summary

GIVE FEEDBACK

OK

Determine shear stress for a solid cylinder

Calculate the torsional shear stress in a 50 mm diameter shaft if it is subjected to a torque of 1400 N.m.

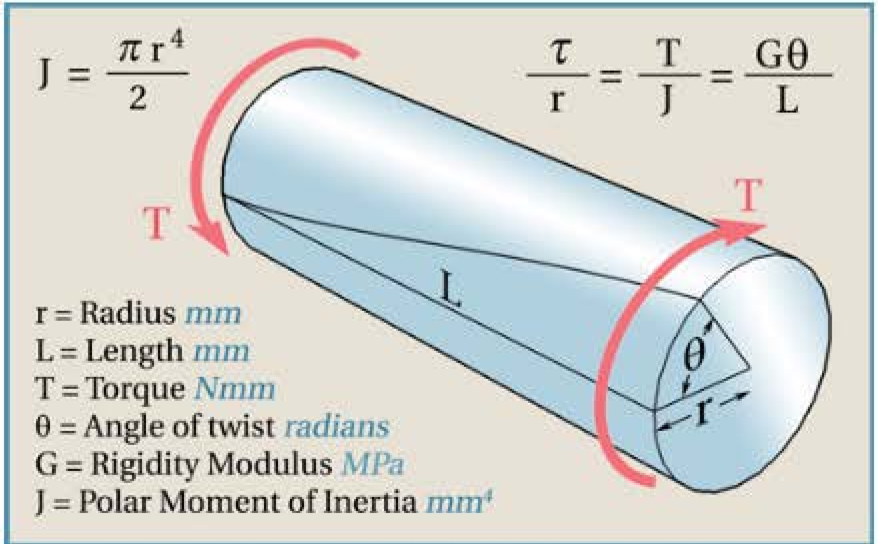
Radius: $r = \frac{D}{2} = 25\text{ mm}$

Now find the torsional shear stress:

$$\tau = \frac{T\,r}{J}$$

$$= \frac{1{,}400 \times 10^3\text{ N mm} \times 25\text{ mm}}{613.6 \times 10^3\text{ mm}^4}$$

$$= 57\text{ MPa}$$



Torsion Formulas and Definitions

Calculate torsional shear stress	Convert to correct units	Calculate polar moment of inertia	Find the torsional shear stress	Summary

GIVE FEEDBACK

OK

Determine shear stress for a solid cylinder

Make sure all variables are in correct units (N, mm, Nmm, MPa).

Torque:

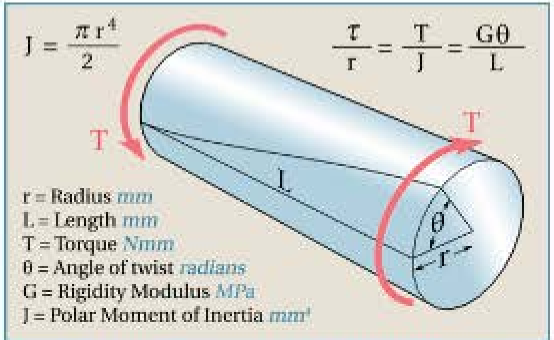
$$T = 1{,}400 \times 10^3 \text{ N mm}$$

Polar moment of inertia:

$$J = \frac{\pi D^4}{32} = \frac{\pi \times 50^4}{32} = 613.6 \times 10^3 \text{ mm}^4$$

Torsional shear stress is:

$$\tau = \frac{T\,r}{J} = \frac{1{,}400 \times 10^3 \text{ N mm} \times 25 \text{ mm}}{613.6 \times 10^3 \text{ mm}^4}$$
$$= 57 \text{ MPa}$$



Torsion Formulas and Definitions

Calculate torsional shear stress	Convert to correct units	Calculate polar moment of inertia	Find the torsional shear stress	Summary

GIVE FEEDBACK

OK

Calculate the torsional shear stress in a shaft diameter 56 mm if it is subjected to a torque of 1400 N.m. The polar moment of inertia is 965499. Find the torsional shear stress in MPa. (Minimum two decimal places, include units.)

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

Clear line

$\leq$ ▾ π MPa $f(x)$ ▾ τ ↵ ? 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 the torsional shear stress in a solid shaft diameter D = 55 mm. It is subjected to a torque of 1400 N.m. First, find the polar moment of inertia. *(Minimum 0 decimal place(s), include units in* mm^4*)*

+ − · ÷ Clear

Clear line

π mm

? 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 the torsional shear stress in a shaft diameter 56 mm if it is subjected to a torque of 1400 N.m. The polar moment of inertia is 965499. Find the torsional shear stress in MPa. (Minimum two decimal places, type units.)

+ − · ÷ 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

A solid shaft diameter 55 mm is subjected to a torque of 1400 N.m. Find the polar moment of inertia. (Minimum 0 decimal place(s), include units.)

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

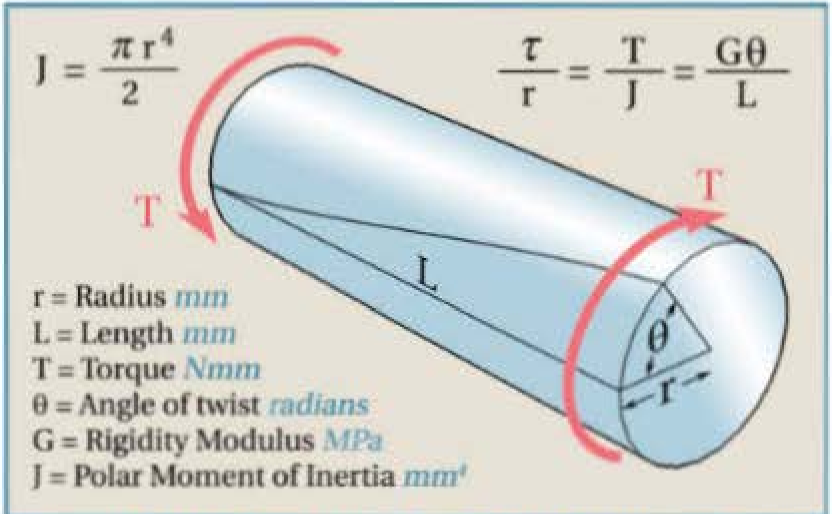
INSTRUCTIONS

- 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

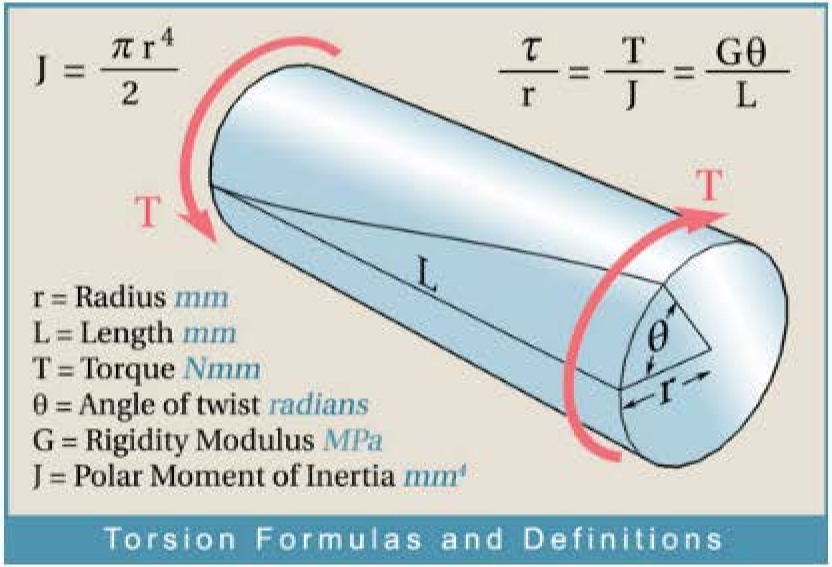
To determine the torsional shear stress for a solid shaft first find the polar moment J, use this to calculate shear stress and stick to known units N, mm, MPa and Nmm.



Torsion Formulas and Definitions

SMALL MEDIUM LARGE

To determine the torsional shear stress for a solid shaft first find the polar moment J, use this to calculate shear stress and stick to known units N, mm, MPa and Nmm.



SMALL MEDIUM LARGE

Calculate the torsional shear stress in a shaft diameter 56 mm if it is subjected to a torque of 5400 N.m. The polar moment of inertia is 965499. Find the torsional shear stress in MPa. (Minimum two decimal places, include units.)

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

The formula for calculating the polar moment of inertia for a hollow cylinder

For a hollow cylinder or pipe with outside diameter D_o and inside diameter D_i:

$$r = \frac{D_o}{2}$$

To solve these questions we simply calculate the outer J_o and subtract the inner J_i:

$$J_{\text{pipe}} = J_o - J_i$$

$$J_{\text{pipe}} = \frac{\pi(D_o^4)}{32} - \frac{\pi(D_i^4)}{32}$$

Simplifying: $J_{\text{pipe}} = \dfrac{\pi(D_o^4 - D_i^4)}{32}$

GIVE FEEDBACK

OK

For a hollow cylinder or pipe, with outside diameter D_o and inside diameter D_i, the polar moment of inertia is:

Check all that apply.

- [ ] $J_{\text{pipe}} = \dfrac{\pi(D_i^4)}{32}$
- [ ] $J_{\text{pipe}} = \dfrac{\pi(D_o - D_i)^4}{32}$
- [ ] $J_{\text{pipe}} = \dfrac{\pi(D_o^4)}{32} - \dfrac{\pi(D_i^4)}{32}$
- [ ] $J_{\text{pipe}} = \dfrac{\pi(D_o^4 - D_i^4)}{32}$

Do you know the answer?

Match the variables to their meaning for the following:

$$J = \frac{\pi(D_o^4 - D_i^4)}{32}$$

Drag statements on the right to match the left.

D_o	Outside diameter
D_i	Inside diameter
J	Polar moment of area

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Example

Calculate the torsional shear stress in a hollow shaft which has an outside diameter $D_o = 55 \text{ mm}$ and an inside diameter $D_i = 38 \text{ mm}$, if it is subjected to a torque of 1400 N.m.

GIVE FEEDBACK

CONTINUE >

Example

Calculate the torsional shear stress in a hollow shaft which has an outside diameter $D_o = 55 \text{ mm}$ and an inside diameter $D_i = 38 \text{ mm}$, if it is subjected to a torque of 1400 N.m.

Solution

Torque:

$$\begin{aligned} T &= 1{,}400 \text{ N m} \\ &= 1{,}400 \times 10^3 \text{ N mm} \end{aligned}$$

Extreme radius:

$$\begin{aligned} r_o &= \frac{D_o}{2} \\ &= 27.5 \text{ mm} \end{aligned}$$

< BACK GIVE FEEDBACK CONTINUE >

Polar moment of inertia:

$$J = \frac{\pi(D_o^4 - D_i^4)}{32}$$

$$= \frac{\pi(55^4 - 38^4)}{32}$$

$$= 693.7 \times 10^3 \text{ mm}^4$$

Hence the maximum value of the torsional shear stress is:

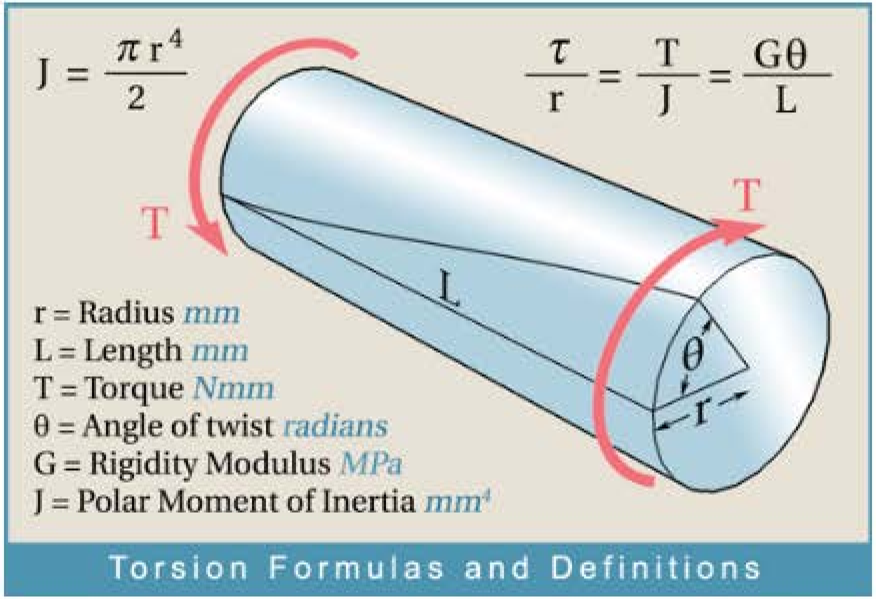
$$\tau = \frac{T\,r}{J}$$

$$= \frac{1{,}400 \times 10^3 \text{ N mm} \times 27.5 \text{ mm}}{693.7 \times 10^3 \text{ mm}^4}$$

$$= 55.5 \text{ MPa}$$

Determine shear stress for a hollow cylinder

Calculate the torsional shear stress in a hollow shaft which has an outside diameter $D_o = 55 \text{ mm}$ and an inside diameter $D_i = 38 \text{ mm}$, if it is subjected to a torque of 1400 N.m.



Pipe torsional shear stress	Convert to correct units	Calculate polar moment of inertia	Find the shear stress	Summary

GIVE FEEDBACK

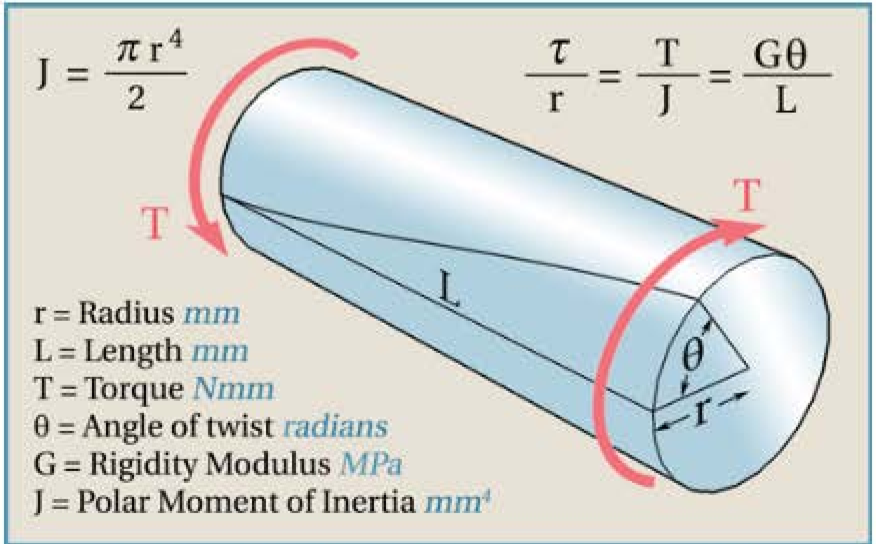
OK

Determine shear stress for a hollow cylinder

Calculate the torsional shear stress in a hollow shaft which has an outside diameter $D_o = 55\ \mathrm{mm}$ and an inside diameter $D_i = 38\ \mathrm{mm}$, if it is subjected to a torque of 1400 N.m.

Convert to correct units:

$$\begin{aligned} T &= 1{,}400\ \mathrm{N\,m} \\ &= 1{,}400 \times 10^{3}\ \mathrm{N\,mm} \end{aligned}$$



Torsion Formulas and Definitions

Pipe torsional shear stress	Convert to correct units	Calculate polar moment of inertia	Find the shear stress	Summary

GIVE FEEDBACK

OK

Determine shear stress for a hollow cylinder

Calculate the torsional shear stress in a hollow shaft which has an outside diameter $D_o = 55$ mm and an inside diameter $D_i = 38$ mm, if it is subjected to a torque of 1400 N.m.

Outside radius:

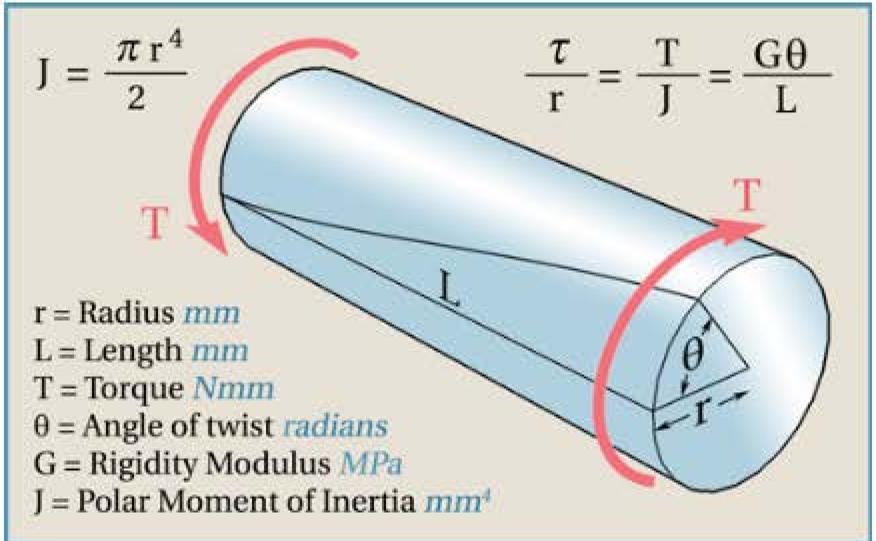
$$r_o = \frac{D_o}{2} = 27.5 \text{ mm}$$

Polar moment of inertia:

$$J = \frac{\pi(D_o^4 - D_i^4)}{32}$$

$$= \frac{\pi(55^4 - 38^4)}{32}$$

$$= 693.7 \times 10^3 \text{ mm}^4$$



Torsion Formulas and Definitions

Pipe torsional shear stress	Convert to correct units	Calculate polar moment of inertia	Find the shear stress	Summary

GIVE FEEDBACK

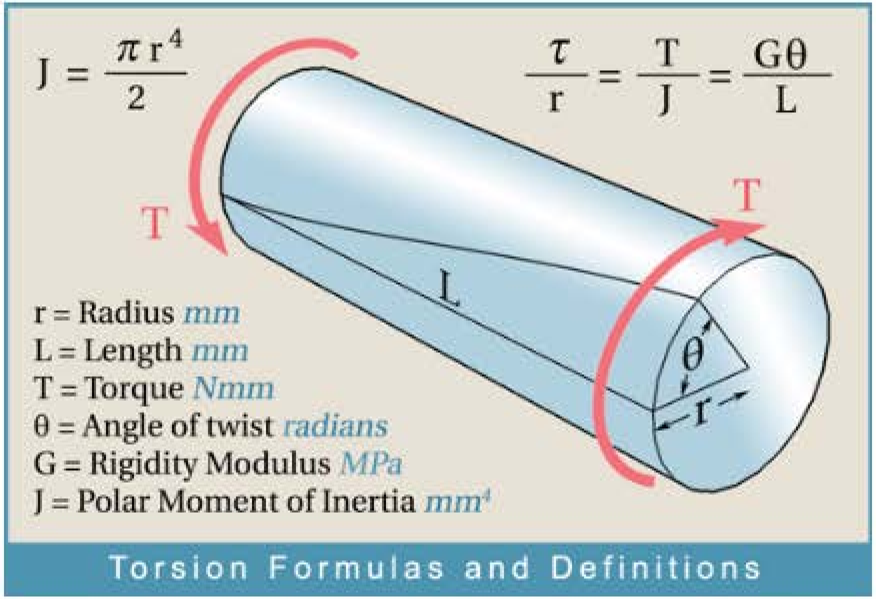
OK

Determine shear stress for a hollow cylinder

Calculate the torsional shear stress in a hollow shaft which has an outside diameter $D_o = 55$ mm and an inside diameter $D_i = 38$ mm, if it is subjected to a torque of 1400 N.m.

Now find the shear stress:

$$\tau = \frac{T\,r}{J}$$
$$= \frac{1{,}400 \times 10^3 \text{ N mm} \times 27.5 \text{ mm}}{693.7 \times 10^3 \text{ mm}^4}$$
$$= 55.5 \text{ MPa}$$



Pipe torsional shear stress	Convert to correct units	Calculate polar moment of inertia	Find the shear stress	Summary

GIVE FEEDBACK

OK

Determine shear stress for a hollow cylinder

Torque: $T = 1{,}400 \times 10^3$ N mm

Polar moment of inertia:

$$J = \frac{\pi(D_o^4 - D_i^4)}{32} = \frac{\pi(55^4 - 38^4)}{32}$$

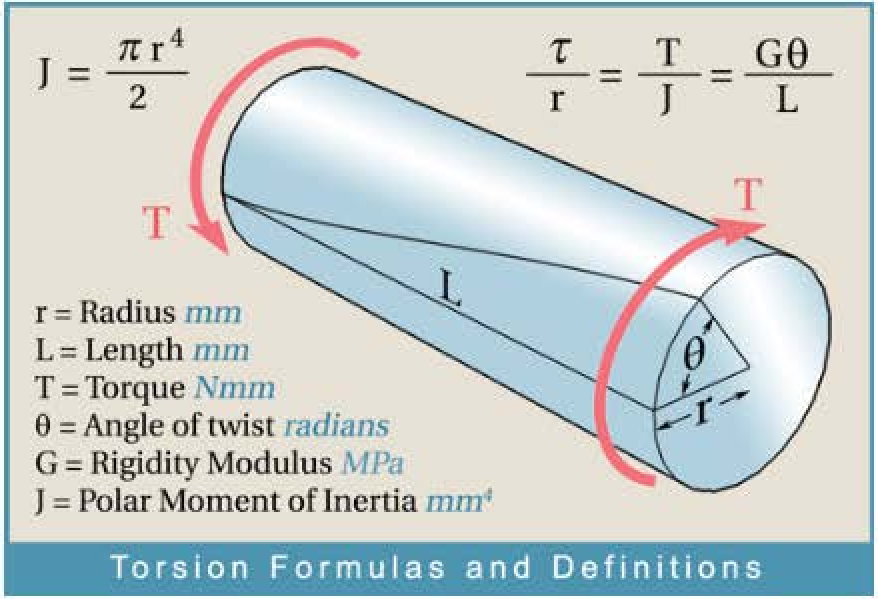
$$= 693.7 \times 10^3 \text{ mm}^4$$

Maximum torsional shear stress:

Extreme radius: $r_o = \dfrac{D_o}{2} = 27.5$ mm

$$\tau = \frac{T\,r}{J} = \frac{1{,}400 \times 10^3 \text{ N mm} \times 27.5 \text{ mm}}{693.7 \times 10^3 \text{ mm}^4}$$

$$= 55.5 \text{ MPa}$$



Pipe torsional shear stress | Convert to correct units | Calculate polar moment of inertia | Find the shear stress | Summary

GIVE FEEDBACK

OK

A hollow shaft, which has an outside diameter Do = 55 mm and an inside diameter Di = 38 mm, if it is subjected to a torque of 1400 N.m. Find the polar moment of inertia. (Minimum zero decimal place(s), include units.)

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

$(\square)$ ▾ ≤ ▾ π mm ▾ τ 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

A hollow shaft, which has an outside diameter Do = 55 mm and an inside diameter Di = 38 mm, is subjected to a torque of 1400 N.m. The polar moment of inertia is 693653. Find the torsional shear stress in MPa. (Minimum 2 decimal places, include units.)

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

Clear line

≤ ▾ π MPa $f(x)$ ▾ τ ↵ ? Undo

Click and type your answer here

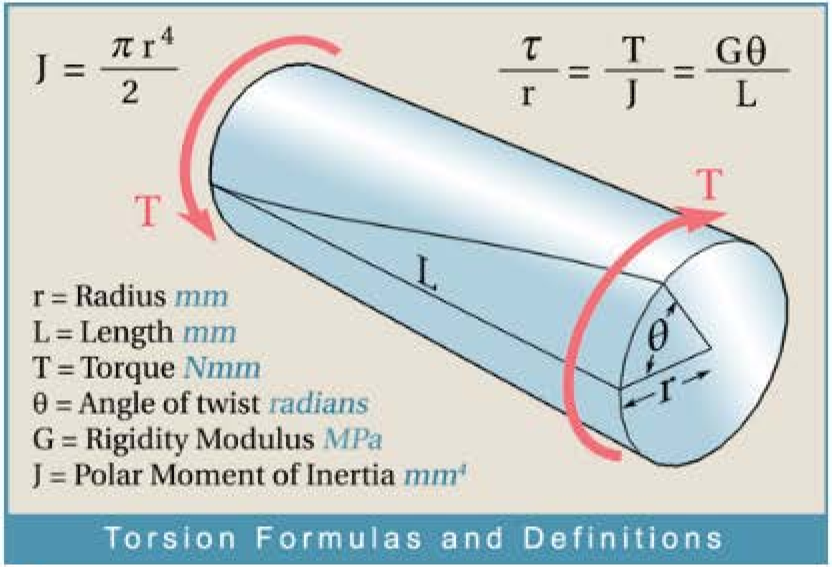
CHALLENGE SUBMIT SHOW ANSWER

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 determine the torsional shear stress for a hollow shaft (tube or pipe) first find the polar moment J, then use this to calculate shear stress and stick to the units N, mm, MPa, Nmm.



SMALL MEDIUM LARGE

A hollow shaft, which has an outside diameter Do = 55 mm and an inside diameter Di = 38 mm, if it is subjected to a torque of 1400 N.m. Find the polar moment of inertia. (Minimum zero decimal place(s). Include units.)

Clear

Clear line

Undo

Click and type your answer here

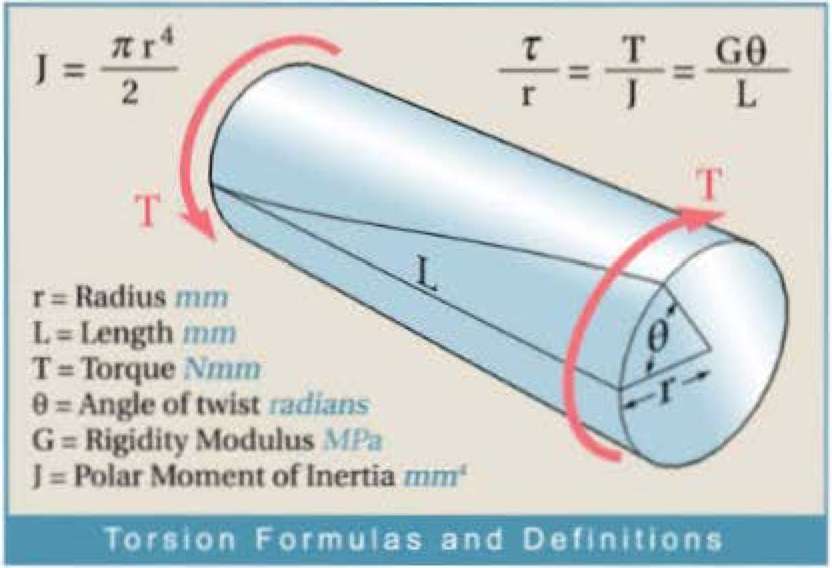
CHALLENGE SUBMIT SHOW ANSWER

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".

HELP

To determine the torsional shear stress for a hollow shaft (tube or pipe) first find the polar moment J, then use this to calculate shear stress and stick to the units N, mm, MPa, Nmm.



SMALL MEDIUM LARGE

A hollow shaft has an outside diameter of 55 mm and an inside diameter of 38 mm, if it is subjected to a torque of 0 N.m. Find the polar moment of inertia. (Minimum zero decimal place(s), do not type units.)

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

Clear

Clear line

$(\square)$ ▾ ≤ ▾ π $f(x)$ ▾ ↵

? 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

A hollow shaft, which has an outside diameter 55 mm and an inside diameter 38 mm, is subjected to a torque of 1400 N.m. The polar moment of inertia is 693653. Find the torsional shear stress in MPa. (Minimum three decimal places, do not type units.)

+ − · ÷ Clear

Clear line

≤ 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

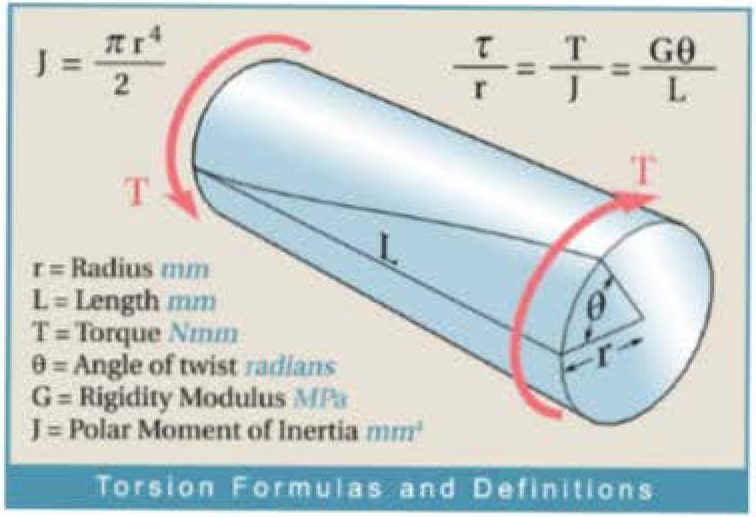
Each hint will reduce the credit received for this question

When looking at the angle of twist, the deformation is an angle rather than a length. We measure angles in radians.

Angle of twist

Torsional deformation is the **angle of twist**, θ (radians).

When torque is applied to a cylindrical bar it will be twisted through an angle θ, as shown in the figure below.



GIVE FEEDBACK

OK

When torque is applied to a cylindrical bar, the torsional deformation ______.

Check all that apply.

- [ ] is the angle of twist
- [ ] is zero because it is a cylinder
- [ ] has the symbol θ
- [ ] is higher than a pipe of the same diameter

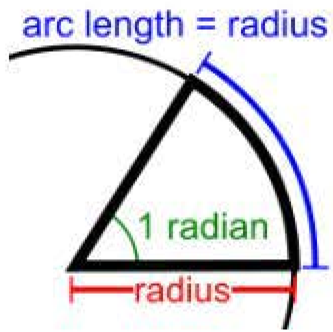
Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The angle of twist is measured in radians. A radian is an alternative way to measure angles, instead of using degrees. Radians are preferred because they simplify formulas.

The unit of the angle of twist

The **radian** is defined as the angle that creates an arc length that is equal to the radius. From the diagram it is easy to see it should be a little less than 60 degrees (equilateral triangle with one side curved).



Since π is defined as the ratio of circumference to diameter, we already know that circumference $= \pi D$.

One complete circumference is 360°, so one radius of arc length = 360/2π = 180/π degrees.

Thus 1 radian = $180/\pi$ degrees (or about 57.3°).

GIVE FEEDBACK

OK

Convert 1.1 radians to degrees. (One decimal place, do not type units.)

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

The radian is:

Check all that apply.

- [ ] The angle that creates an arc length that is equal to the radius
- [ ] A little less than 60 degrees
- [ ] Equal to $180/\pi$ degrees
- [ ] The radius of the shaft

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Convert 80 degrees to radians. (Three decimal places, do not type units.)

+ − · ÷ $\frac{\square}{\square}$ $1\frac{2}{3}$ $\square^2$ ▼ Clear

Clear line

$\sqrt{\square}$ $(\square)$ ▼ $\leq$ ▼ π $f(x)$ ▼ ↵ ? 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".

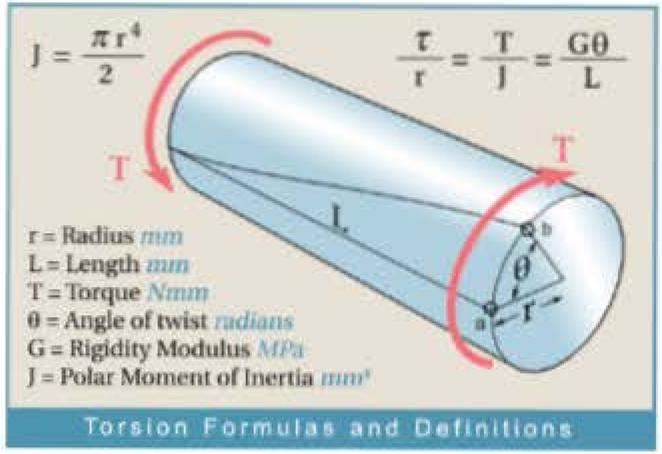
Hint Each hint will reduce the credit received for this question

Torsional shear strain is the angle of twist per unit of length. Just like axial strain, it has no units. Don't forget to always use radians for angles.

Torsional shear strain

Torsional shear strain, γ, is defined as the ratio of the circumferential distance $a\,b$ at radius r to the corresponding length L. Distance $a\,b = r\,\theta$, if the angle is expressed in radians. Hence:

$$\gamma = \frac{r\,\theta}{L}$$



GIVE FEEDBACK

OK

Match the symbols to their names for the torsional formula below:

$$\gamma = \frac{r\,\theta}{L}$$

Drag statements on the right to match the left.

γ	Torsional shear strain
r	Radius
θ	Angle of twist
L	Length

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Match the symbols to their units for the torsional formula (L is in mm):

$$\gamma = \frac{r\,\theta}{L}$$

Drag statements on the right to match the left.

γ	MPa
r	mm
θ	radians

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

By combining the equation for shear stress and the equation for shear strain, we can get an equation that will directly calculate the angle of twist (in radians).

The formula for calculating the angle of twist

We have previously determined that torsional shear stress is given by:

$$\tau = \frac{T\,r}{J}$$

It follows from the definition of shear modulus of rigidity that:

$$G = \frac{\text{stress}}{\text{strain}} = \frac{\tau}{\gamma} = \frac{T\,r}{J} \times \frac{L}{r\,\theta} = \frac{TL}{J\,\theta}$$

If this expression is transposed to make the angle of twist its subject, we get:

$$\theta = \frac{TL}{JG}$$

where:

θ = angle of twist (radians)

T = applied torque (Nmm)

L = length of the bar (mm)

G = shear modulus of rigidity (MPa)

J = polar moment of inertia (mm^4)

GIVE FEEDBACK

OK

Match the symbols to their units for the torsional equation:

$$\theta = \frac{TL}{JG}$$

Drag statements on the right to match the left.

T	Nmm
θ	radians
L	mm
G	MPa
J	mm^4

Do you know the answer?

Match the symbols to their descriptions for the torsional equation:

$$\theta = \frac{TL}{JG}$$

Drag statements on the right to match the left.

T	Applied torque
θ	Angle of twist
L	Length of the bar
G	Shear modulus of rigidity
J	Polar moment of inertia

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Example

Calculate the angle of twist of the shaft in the previous example (Torque = 1400 Nm, diameter = 50 mm) if the material is steel and the shaft is 1530 mm long.

Example

Calculate the angle of twist of the shaft in the previous example (Torque = 1400 Nm, diameter = 50 mm) if the material is steel and the shaft is 1530 mm long.

Solution

The modulus of rigidity of steel is $G = 80{,}000\ \mathrm{MPa}$. Substitute:

$$\begin{aligned}\theta &= \frac{TL}{JG}\\ &= \frac{1{,}400 \times 10^{3}\ \mathrm{N\,mm} \times 1{,}530\ \mathrm{mm}}{613.6 \times 10^{3}\ \mathrm{N\,mm}^{4} \times 80{,}000\ \mathrm{MPa}}\\ &= 0.04364\ \mathrm{rad}\end{aligned}$$

Converting radians to degrees gives $\theta = \frac{180}{\pi} \cdot 0.04364 = 2.5°$.

< BACK GIVE FEEDBACK OK

A solid shaft diameter D = 55 mm is subjected to a torque of 1400 N.m. Find the polar moment of inertia. (Round off to nearest integer, include units.)

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

Clear line

? Undo

≤ ▾ π mm ▾ ↵

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 solid shaft diameter D = 55 mm is subjected to a torque of 1400 N.m. Find the polar moment of inertia. (Round off the nearest integer, include units.)

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

A shaft has a diameter of 55 mm and a length of 4 m, and is subjected to a torque of 1400 Nm. The polar moment of inertia is 898361 and modulus of rigidity is 80GPa. Find the angle of twist in degrees. (Minimum 2 decimal places, do not include units.)

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

$(\square)$ ▾ $\le$ ▾ π $f(x)$ ▾ $\overline{\square}$ θ 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

A shaft has a diameter of 45 mm and a length of 17 m, and is subjected to a torque of 1400 Nm. The polar moment of inertia is 402578 and modulus of rigidity is 80GPa. Find the angle of twist in radians. (Minimum 3 decimal places, include units.)

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

$(\square)$ ▾ ≤ ▾ π rad $f(x)$ ▾ θ Clear line

? Undo

↵

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

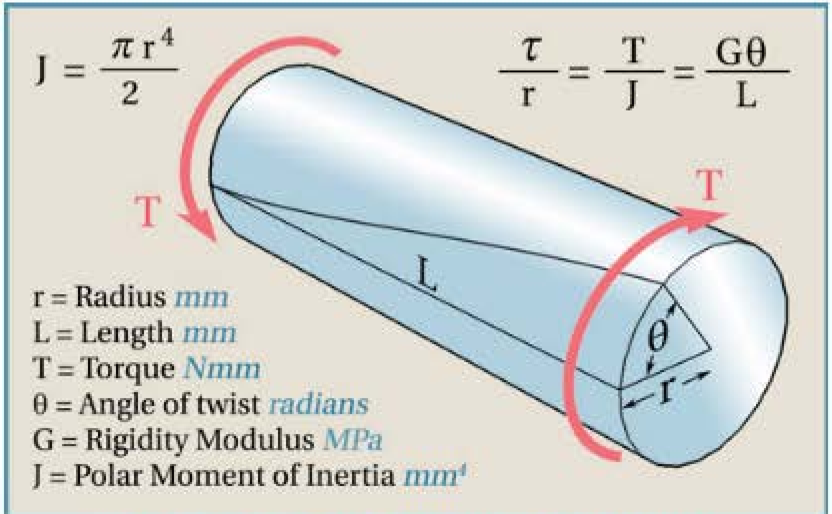
INSTRUCTIONS

- 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

To determine the angle of twist for a solid shaft first find the polar moment J, then use this to calculate the angle of twist and stick to the units N, mm, MPa and Nmm.



Torsion Formulas and Definitions

SMALL MEDIUM LARGE

A solid shaft diameter D = 55 mm is subjected to a torque of 1400 N.m. Find the polar moment of inertia. (Round off to nearest integer. Include units.)

Clear
Clear line
Undo

Click and type your answer here

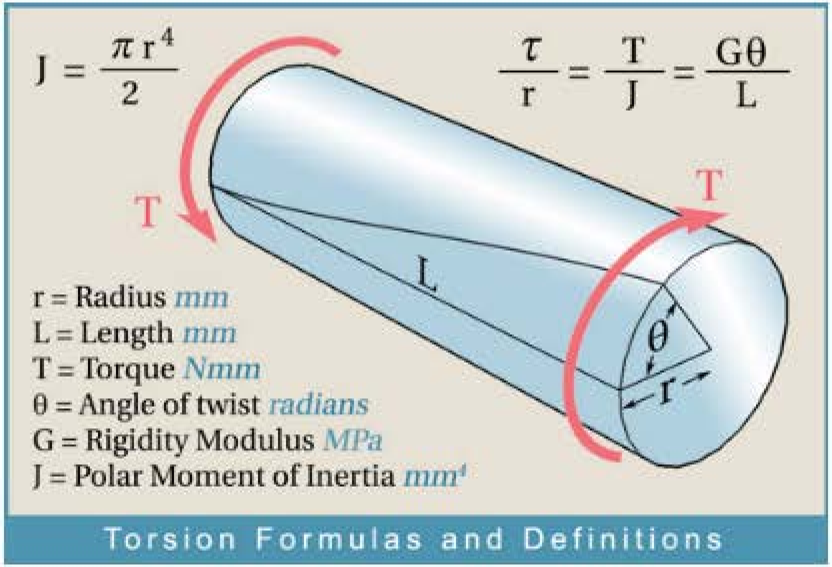
CHALLENGE

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

To determine the angle of twist for a solid shaft first find the polar moment J, then use this to calculate the angle of twist and stick to the units N, mm, MPa and Nmm.



SMALL MEDIUM LARGE

A shaft has a diameter of 55 mm and a length of 4 m, and is subjected to a torque of 1400 Nm. The polar moment of inertia is 898361 and modulus of rigidity is 80GPa. Find the angle of twist in degrees. (Minimum 2 decimal places, do not include units.)

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