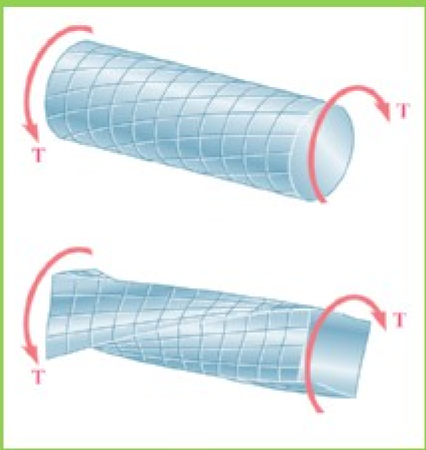
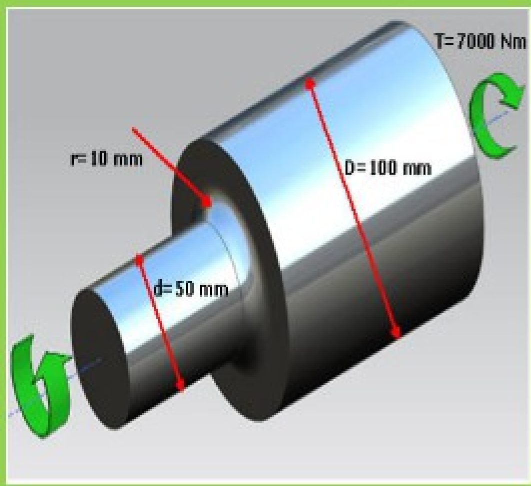
TORSION DECODED------
BY RAHUL KUMAR





STUDY THE NOTES WELL

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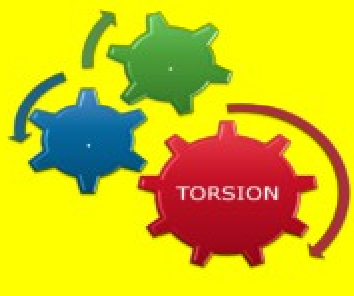


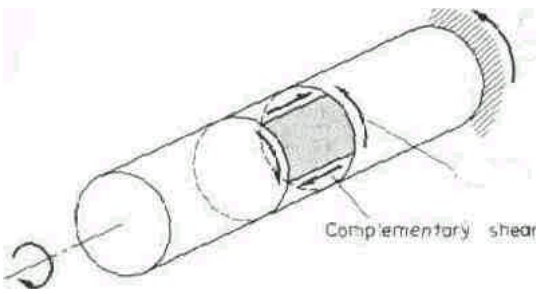
THEORY OF SIMPLE TORSION-

When torque is applied to a **uniform circular shaft** ,then every section of the shaft is subjected to a state of pure shear (Fig.), the moment of resistance developed by the shear stresses being everywhere equal to the magnitude, and opposite in sense, to the applied torque.

For derivation purpose a simple theory is used to describe the behaviour of shafts subjected to torque .

fig. shows Shear System Set Up on an Element in the Surface of a Shaft Subjected to Torsion

Resisting torque, T



Applied torque T

Assumptions

- (1) The material is homogeneous, i.e. of uniform elastic properties throughout.
- (2) The material is elastic, following Hooke's law with shear stress proportional to shear

strain.

- (3) The stress does not exceed the elastic limit or limit **of** proportionality.

(4) Circular sections remain circular.

- (5) Cross-sections remain plane. (This is certainly not the case with the torsion **of non-**circular sections.)
- (6) Cross-sections rotate as if rigid, i.e. every diameter rotates through the same angle.

BASIC CONCEPTS

1. Torsion = Twisting
2. Rotation about longitudinal axis.
3. The external moment which causes twisting are known as

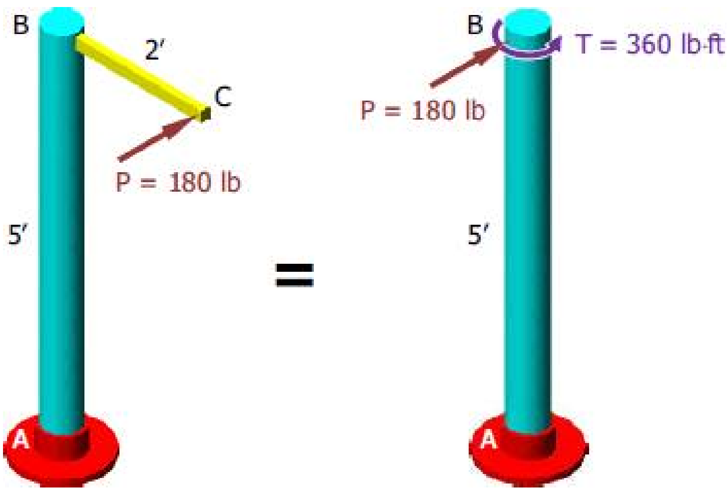
   Torque / twisting moment.
4. When twisting is done by a force (not a moment), then force required for torsion is normal to longitudinal axis having certain eccentricity from centroid.
5. Torque applied in non-circular section will cause 'warping'. Qualitative analysis is not in our syllabus
6. Torsion causes shear stress between circular planes.

7. Plane section remains plane during torsion.

It means that if you consider the shaft to be composed to infinite circular discs. The discs remain as they were before twisting. Only their position with respect to other circular discs will change.

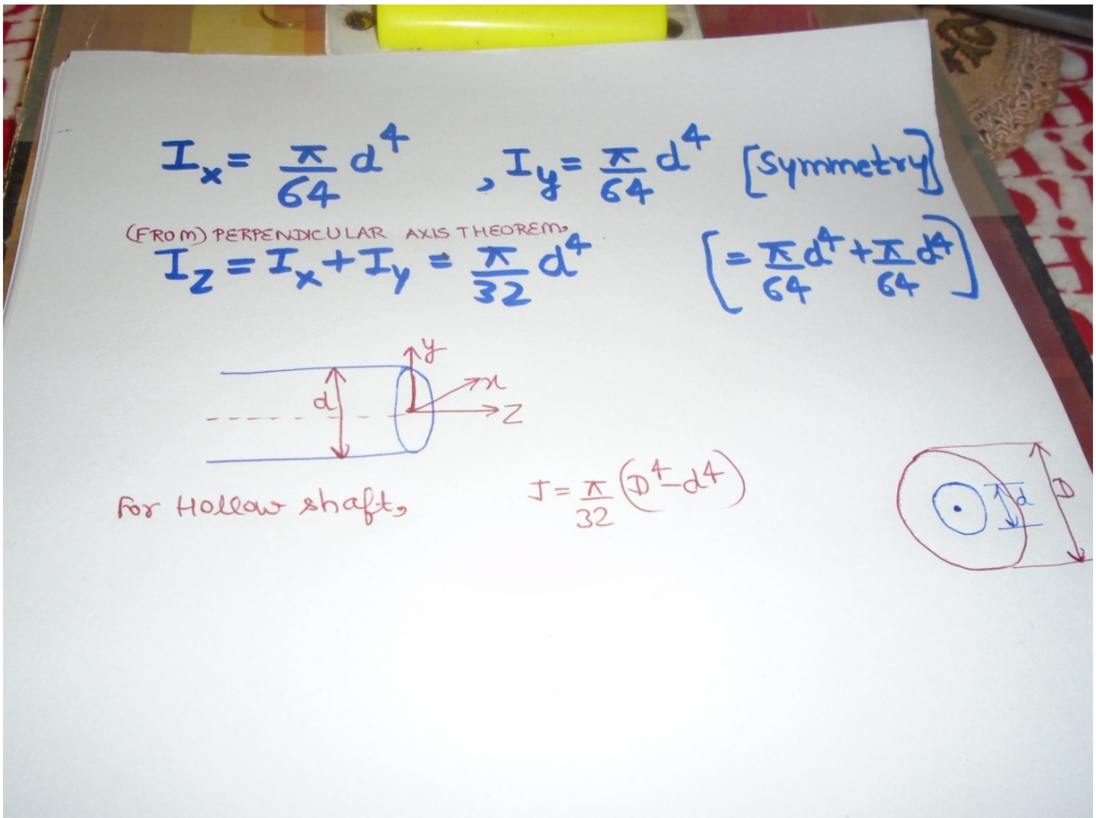
Point 4... How can twisting be done by force?

EXAMPLE:



Moment of inertia

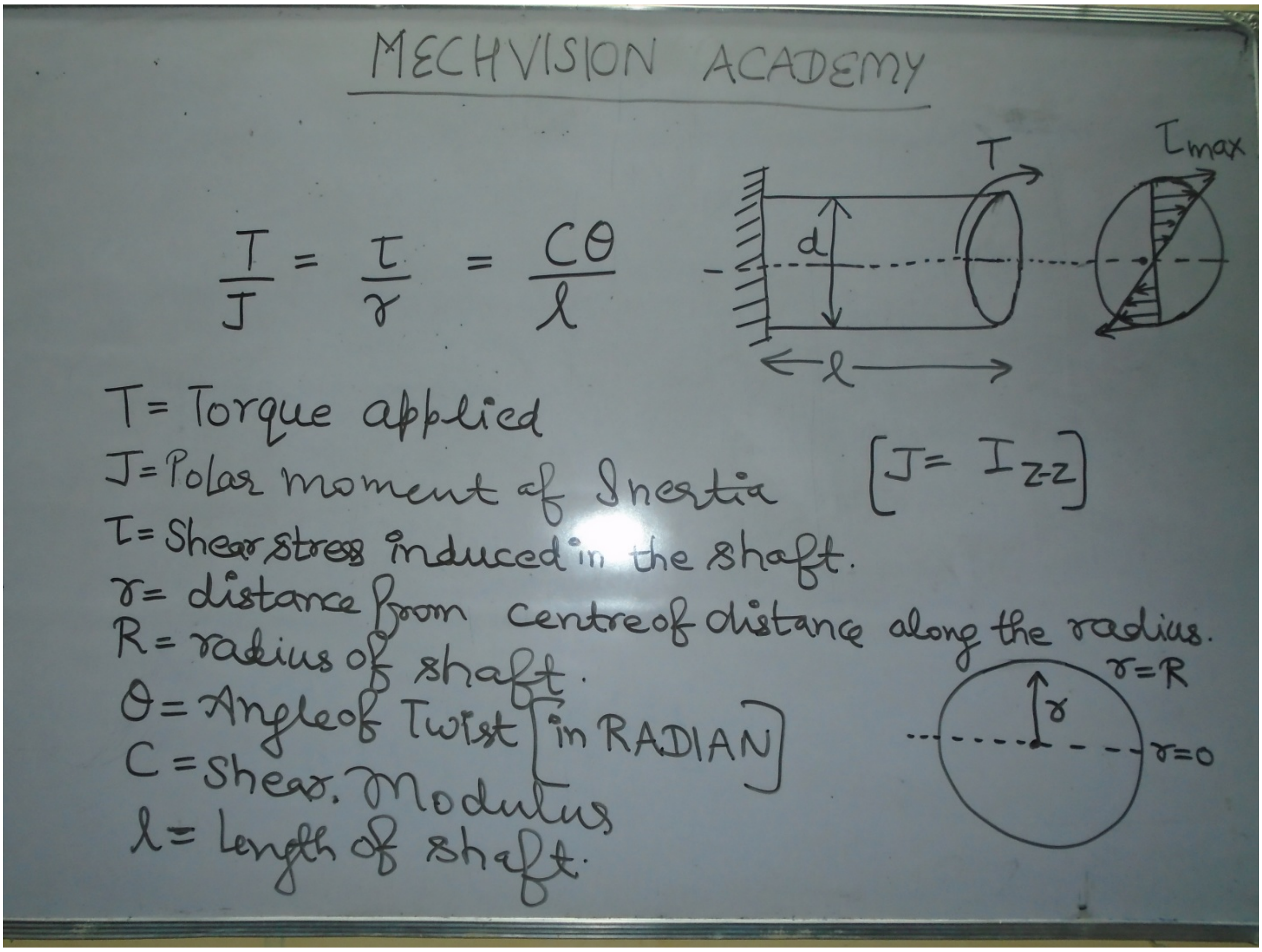
Moment of inertia in rotation motion is similar to mass in linear motion. Both for Solid and Hollow shafts, its value is given by-



Why polar moment is taken about z axis?

Moment about z –axis is resisted by moment of inertia about z axis. That inertia is known as polar moment of inertia. It is basically a terminology.

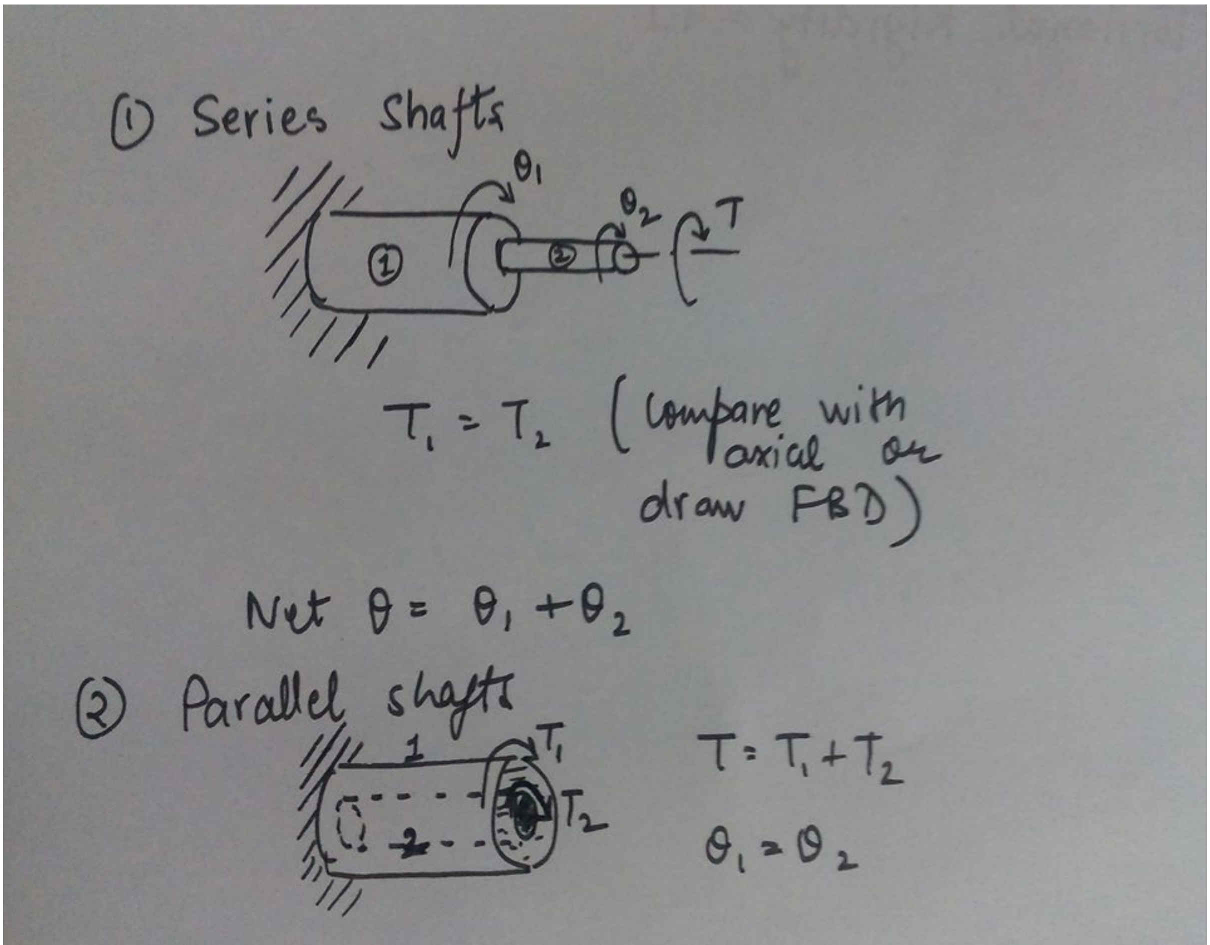
TORSION EQUATION



When Torque T is applied externally, shear stresses are generated internally.So, Shear stresses are induced in the shaft.

<u>Combination of Shaft</u>

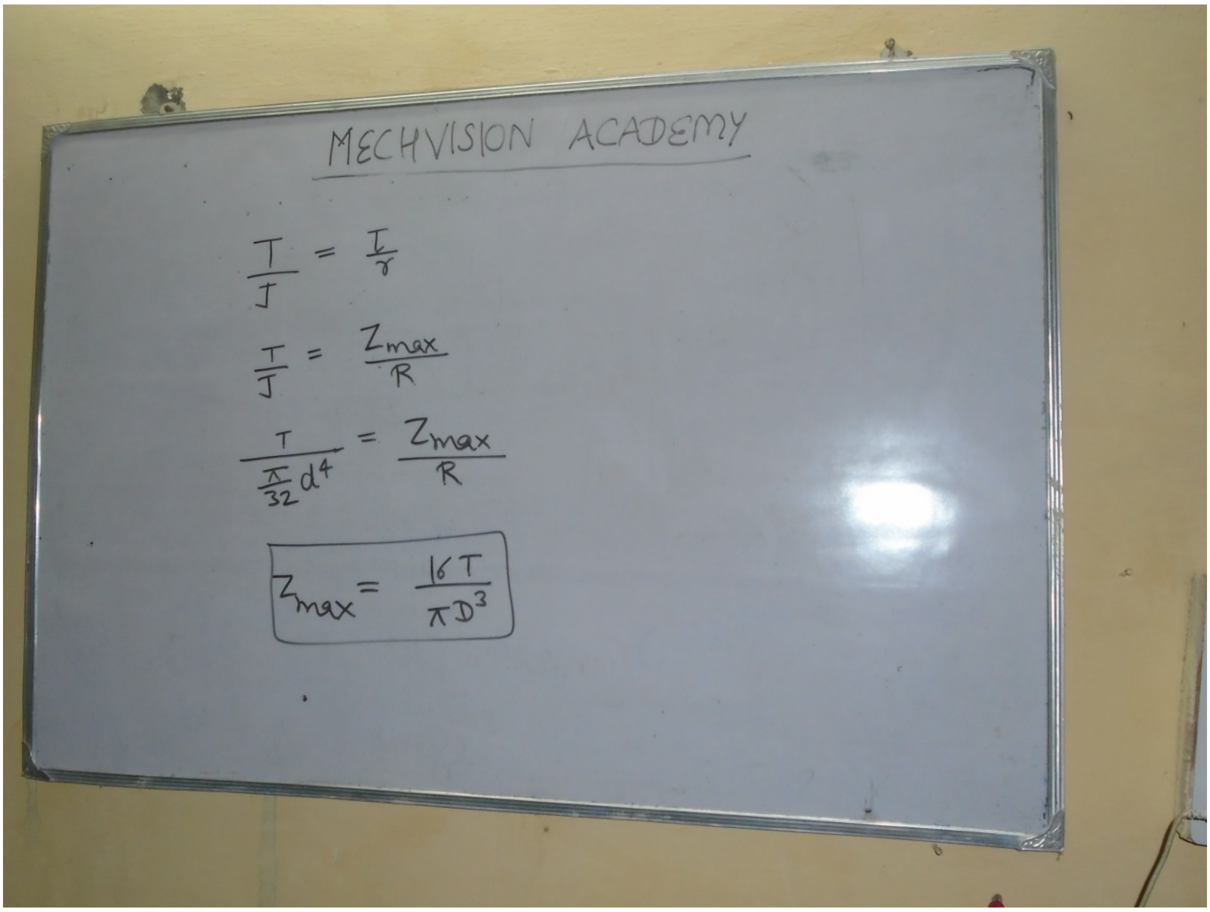
Trick : WHENEVER there is any doubt in torsion, just compare it with axial loading to clear your confusion.



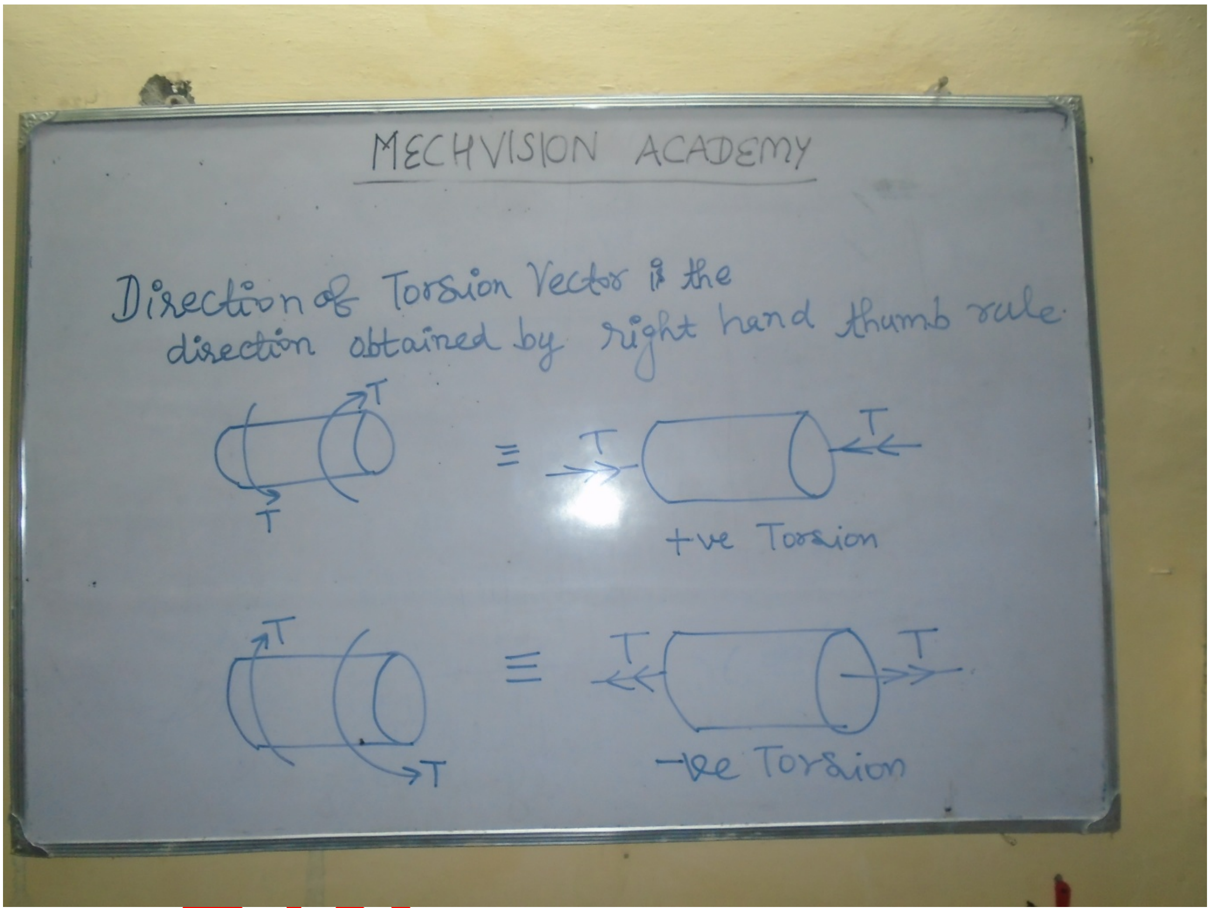
- In parallel, the torque applied is resisted by both by sharing. Just like if there were two bars in parallel (sandwich type) and force was applied at one end, they together will resist the force.

Pure Torsion of shafts: A special case.

Use this ONLY for circular shafts.



Sign Convention for torsion



If both the T inward in body ------ then T +

otherwise - T -

Inward +, Outward –ve

You will find that torque will be shown by a straight arrow. Do not get confused. Keep above convention in mind.

The torque which may be applied to a solid shaft of 90 mm outer diameter without exceeding an allowable shearing stress of 75 MPa, is

A. 21.6 kN
B. 10.8 kN

In previous question, if the solid shaft is subjected by a hollow shaft of the same mass and of 90 mm inner diameter, the torque which may be applied is

A. 17.1 kN
B. 11.4 kN
C. 22.8 kN

Let me give you guys a hint. 'SAME MASS' is the hint. Now solve.

Mass of solid shaft = Mass of hollow shaft here.

Since densities are same,Volume

V of solid shaft = V of hollow shaft here.

$= \frac{75 \times \pi \times 127^3}{16}[1 - 0.707^4]]$ $\qquad 75 = \frac{32T}{\pi d^3}$

$= 22628251.43 \qquad \Rightarrow \qquad T = \frac{75 \times \pi \times 90^3}{16}$

$=$

Since, mass same.

$\Rightarrow \frac{\pi}{4} D^2 \times l = \frac{\pi}{4} \times (D_0^2 - D_i^2) \times l$

$\Rightarrow 90^2 = D_0^2 - 90^2$

$\Rightarrow 2 \times 90^2 = D_0^2$

$\Rightarrow D_0 = 127.27 \text{ mm}$

$T = \tau \times Z$

$= \frac{\pi D_0^3}{16} [(1 - K^4)] \qquad K = \frac{D_i}{D_0}$

$= \frac{75 \times \pi \times 127^3}{16} \times [1 - 0.707^4] \qquad = \frac{90}{127.27}$

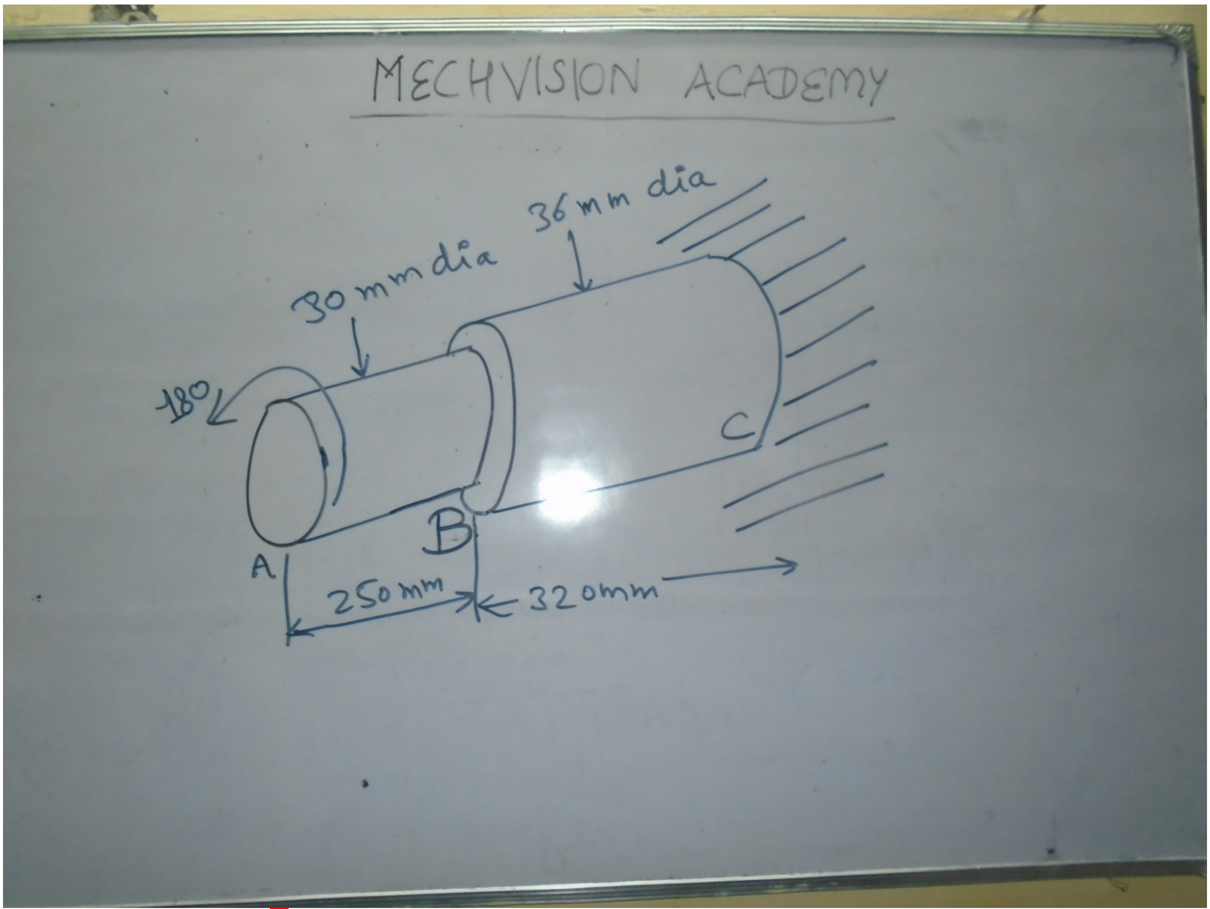
$= 0.707$

$= \frac{22628251.43}{10^6}$ N mm

$= 22.6$ KNm

#7

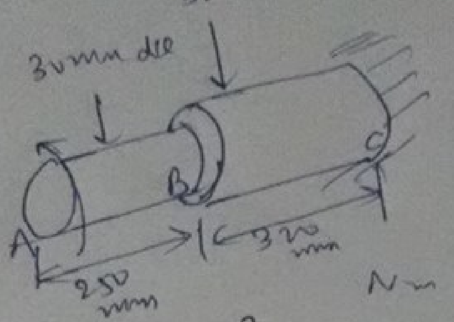
The solid brass rod AB (G=39 GPa) is bonded to the solid aluminum rod BC (G = 27 GPa) as shown in figure. The angle of twist at A and B are ________ and _________, respectively.



The twist applied at ab is also experienced by bc or converse

As I told earlier, whenever in confusion, compare with axial force. if an axial force was acting at ab, it would have been experienced by bc too.

Yes. find twist due to both and add.



AB (G = 39 GPa)
BC (G = 27 GPa)

$\theta_A = ?$ $\theta_B = ?$

$$\theta_B = \frac{180 \times 10^3 \times 320 \times 32}{27 \times 10^3 \times \pi \times 36^4} = 0.012\,rad$$

N × mm / (N/mm² × mm⁴)

$= 0.012\,rad$

$$\theta_{AB} = \frac{180 \times 10^3 \times 250 \times 32}{39 \times 10^3 \times \pi \times 30^4} = 0.0145\,rad$$

~~$\theta_B = 0.012\,rad$~~

$\theta_B = \theta_B + \theta_{AB}$

$= 0.026\,rad.$

#8

In the previous question, what will be the angle of twist at A and B are ________ and _________, respectively if torque was applied at B?

at A will be zero ?

BC pe 0.012 aur AB pe zero

kyunki applied torsion sirf BC pe hi lag raha hai.

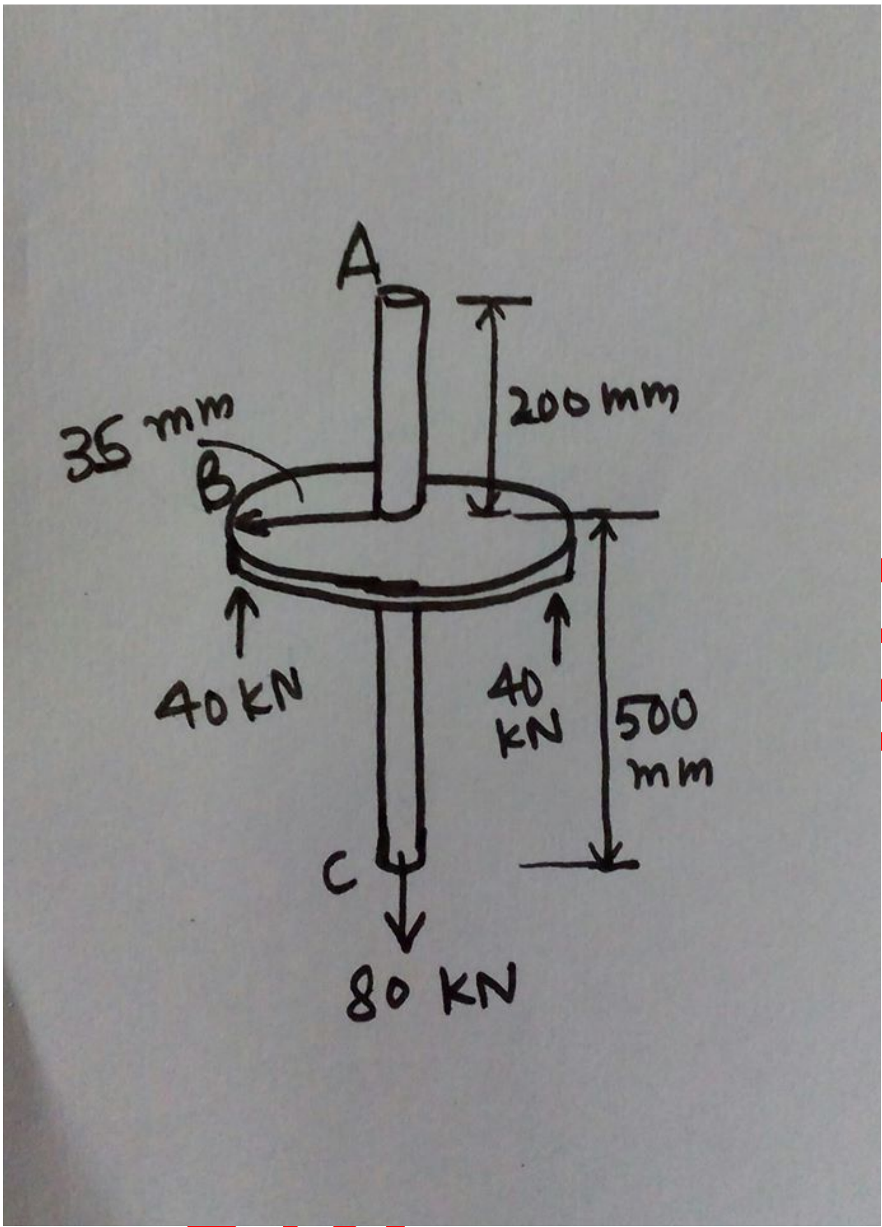
IF end B rotate hoga to end A bhi utna hi rotate hoga na ?

Bhiya lekin BC wall k reference me to 0.012 radian ghum gaya hoga na. And since no torque on AB it will be unaffected.so with reference to plane B, A reflection is 0 but w.r.t wall it should be 0.012 radian na ?

By comparing with axial force on ab only single force is there due to this it accelerate so strain 0 here also same

What was the deflection of AB?

It Will be zero. Right?


A
200 mm
35 mm
B
40 KN
40 KN
500 mm
C
80 KN

Twist occurs when one end rotates WITH RESPECT TO the other. Here, the amount by which b will turn, A will also get turned since A is free. Compare with axial case. Clear to all?

is problem me reference plane bich me ha but in our question it is at extreme end , this disc problem me bhi yadi ap reference point of application 80kn se lege to defection of AB will be same as BC . don't u think so ?

Understand the difference between rotation and twist. Twist = Relative rotation.

That does not matter. The end A is free to rotate na. How can it get twisted. Rotation aur twisting me difference smjho. A be utna h rotate hoga jitna B hoga. Tabhi toh twisting zero h.

Sir twisting is nothing elongation na sir??

No. Twisting in torsion = elongation in axial load

#9

Compare with axial stiffness and axial rigidity ,

Observe what similarity you can find.

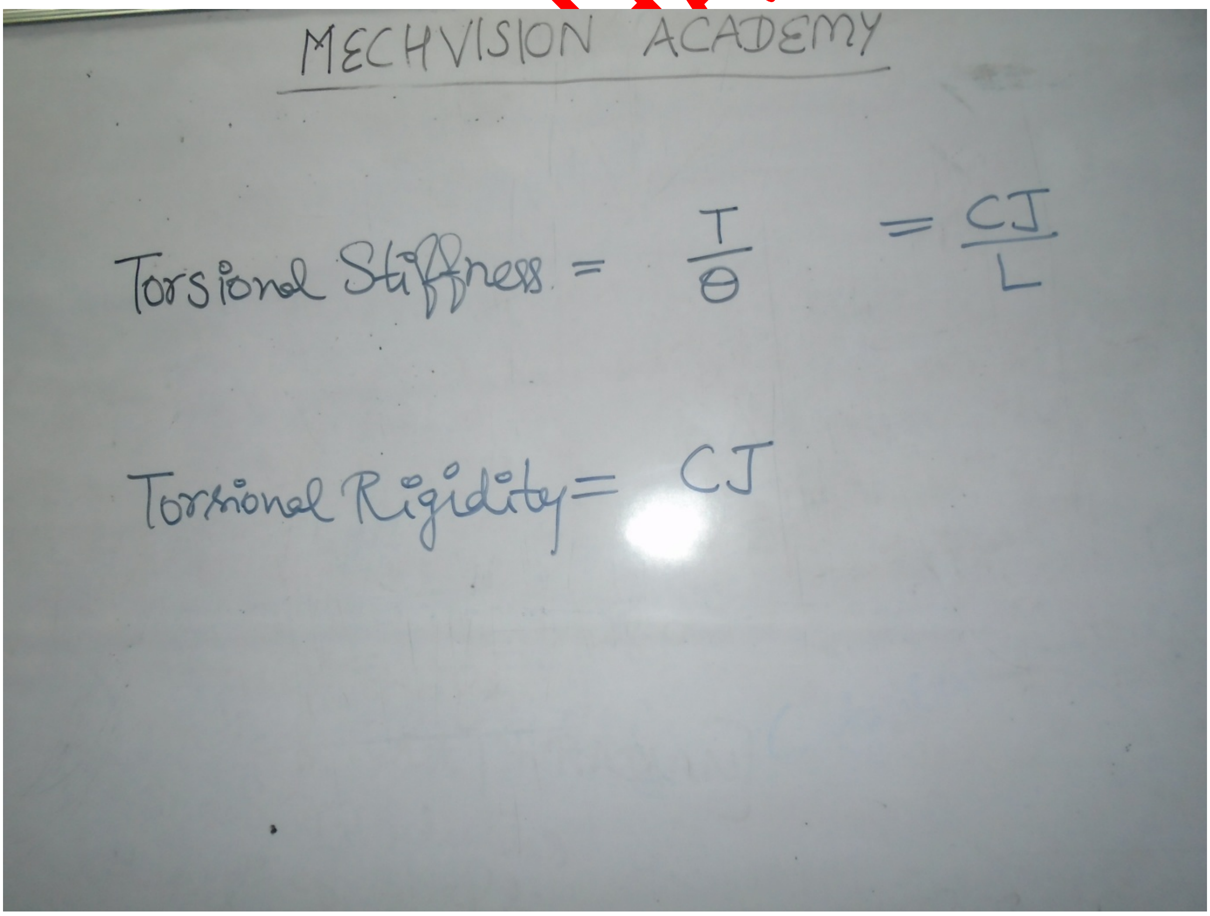
E is REPLACED by G and A by J

Youngs modulus = SHear modulus

Area = Area moment of inertia

physical significance of torsional rigidity and torsional stiffnesss ??

Just like axial deflection, resistance to deflection = resistance to twist



#10

An aluminum bar of solid circular cross section is twisted by torque T acting at the ends. The dimensions and shear modulus of elasticity are as follows: L = 1.2 m, d = 30 mm and G = 28 GPa.

1. The torsional stiffness of the bar is

A. 1860 Nm

B. 1395 Nm

C. 2325 Nm

D. 1162 Nm

2. If the bar is twisted by an angle of 4 degree, the maximum shear strain is

A. 291 X 10^(-6) rad

B. 890 X 10^(-6) rad

C. 246 X 10^(-6) rad

D. 873 X 10^(-6) rad

#11

One of the most basic yet most useful funda of mechanical engg is used in this question.

The design specification of a 2 m long solid circular transmission shaft require that the angle of twist of the shaft not exceed 3 degrees when the torque of 9 kN.m is applied. Which of the following is the required diameter of the shaft if the shaft is made of a steel with an allowable shearing stress of 90 MPa and a modulus of rigidity of 77 GPa?

A. 41.06 mm

B. 79.9 mm

C. 39.9 mm

D. 82.1 mm

Look,
there are two limiting cases given:
1. Based on twist angle
theta = TL/GJ

This will give d = 82.1

2. Based on shearing stress
tau = T.r/J

This will give d = 79.9 mm

For design purpose, we have to use the higher value because it will be safe.
So, d = 82.1 mm

yup you're right the keyword is 'design spec' we've to look out for while solving such questions

You have to look carefully in such questions. Do not consider any data as redundant in SOM, Design and mechanics

Using Torsion formula.

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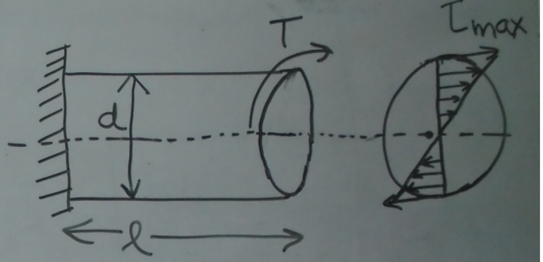
$$\frac{T}{J} = \frac{\tau}{r} = \frac{C\theta}{l}$$



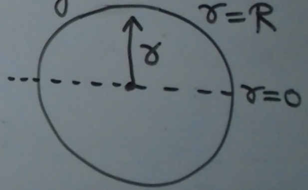
T = Torque applied

J = Polar moment of Inertia   [$J = I_{z-z}$]

τ = Shear stress induced in the shaft.

r = distance from centre of distance along the radius.

R = radius of shaft.



θ = Angle of Twist [in RADIAN]

C = Shear Modulus

l = length of shaft.