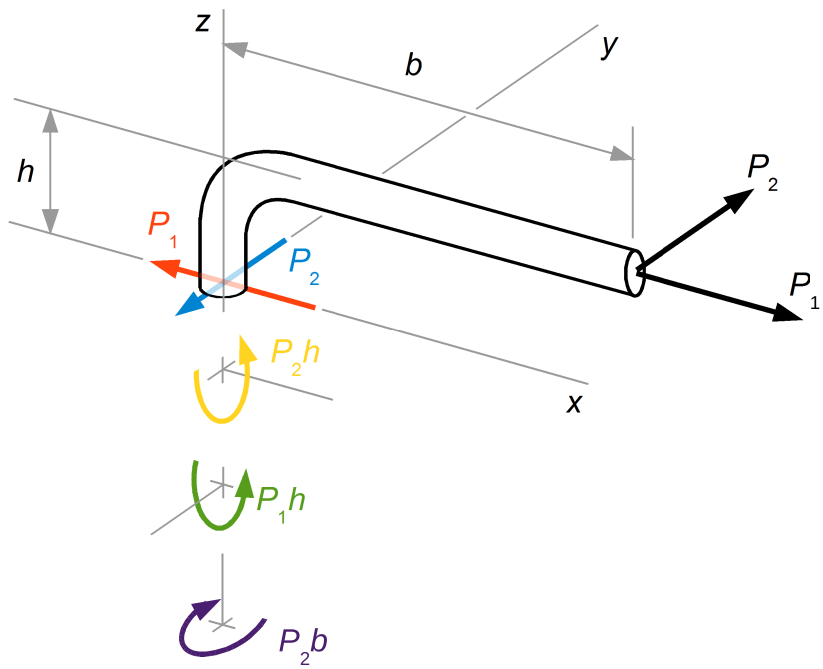
SOLUTION

Depending on your level of experience, you might be able to figure this one out by mere inspection. However, if you are at a loss, remember the free-body diagram is always your friend. Consider the equilibrium of everything above section *a – a*. When we separate this piece from the rest of the post, we note that internal reactions must be present at this location for there to be static equilibrium:



We see that internal reactions equal in magnitude but of opposite directions to the external loads must be present at the cross section for $\sum F_x=0$ and $\sum F_y=0$ to be satisfied. These internal forces have been drawn in red and blue, respectively.

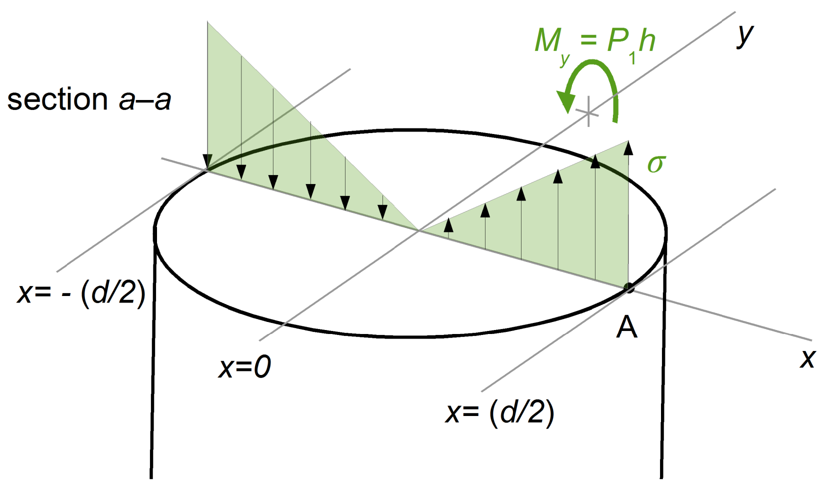
Furthermore, there also has to be equilibrium of moments. For $\sum M_x=0$ to be satisfied (that is, the sum of all moments about the *x* axis must be zero) a moment of magnitude $P_2 \cdot h$ must be present and acting in the direction shown. This internal moment has been drawn in yellow. Similarly, a moment of magnitude $P_1 \cdot h$ about the *y* axis must be present on the cross section for $\sum M_y=0$ to hold. This internal moment has been drawn in green. Finally, there has to be a torque present on the cross section (i.e. a moment about the *z* axis) to prevent rotation about the z axis due to the action of force P_2. The magnitude of this torque is $P_2 \cdot b$ and it acts on the direction shown. This internal torque has been drawn in purple.

To sum up, we have the following internal reactions present at the cross section:

- Shear forces of magnitudes P_1 and P_2 .
- Bending moments of magnitudes $P_1 \cdot h$ and $P_2 \cdot h$
- A torque of magnitude $P_2 \cdot b$.

Each one of these internal reactions will have a different effect on the state of stress at the cross section, and at point A .

For ease of visualization, we turn our attention to the section of the post *below* the cross section. All internal reactions on this side of the cross section have to be equal in magnitude but of opposite direction of those we have drawn in the figure above. We will consider the internal loads mentioned in the answer choices one by one:

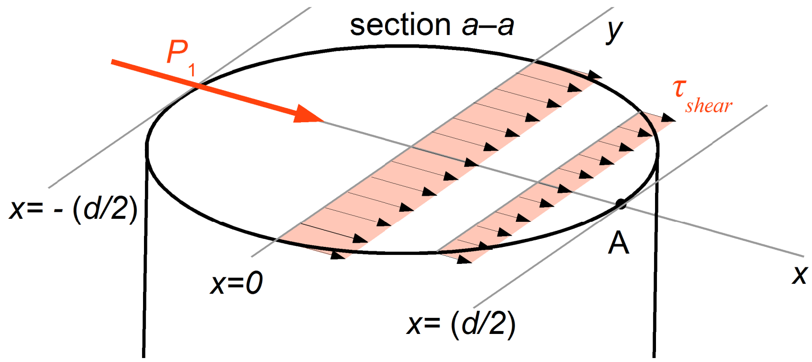


The normal stresses produced by the moment $M_y = P_1 \cdot h$ are tensile for $x > 0$ and compressive for $x < 0$. The magnitude of the stress is schematically represented as the triangular distributions in the figure above. At point A , the normal tensile stress due to the applied moment $M_y = P_1 \cdot h$ is the greatest, and it is given by the flexure formula:

$$\sigma_{A,\,\text{due to }M_x} = \frac{\left(P_1 \cdot h\right)\left(\dfrac{d}{2}\right)}{I} \quad (1)$$

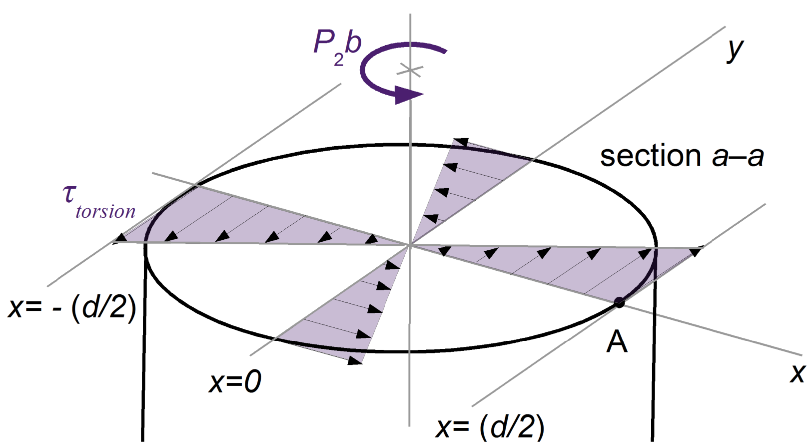
where $I = (\pi \cdot d^4)/64$ is the cross section moment of inertia. From equation (1), it is clear that the normal stress at A is not independent of h . Answer choice (A) can be ruled out.

Now consider the shear stress due to the shear force of magnitude P_1 acting along the x axis:



The shear stress is not uniform, but is distributed across the section, The shear stress is highest for $x=0$ and zero for $x=d/2$. Hence, the shear stress at A due to the shear force of magnitude P_1 is zero. Answer choice (B) can be ruled out.

Now consider the torque applied at the cross section:



The torsional stress induced by the applied torque varies in magnitude from zero at the shaft center to a maximum value at the outermost surface. So, although the applied torque does produce a torsional stress, this stress is NOT zero at point A , therefore answer choice (C) can be eliminated.

By process of elimination, we can conclude that the correct answer is (D). You can also verify this by visualizing the normal stress distribution produced by the bending moment $M_x = P_2 \cdot h$. In this case, point A is in the neutral axis and thus the normal stress there due P_2 to is always zero, independently of the magnitude of h , hence the correct answer is (D).

