Here we will examine the torsion problem.

We have a circular bar undergoing torsion. Here are the torsion equations from Mechanics. $J$ in these equation is the torsional constant. For a circular bar $J$ is the same as the polar moment of inertia. For any other shape, $J$ is NOT the polar moment of inertia. $G$ is the shear modulus of elasticity. Look at a stress element. We only have shear stresses. The normal stresses are zero because there are no forces action horizontally or vertically.
Look at a **strain gage** on our stress element. We see the shear stresses. The resulting shear strain causes our element to change shape. The square stress element becomes a **rhombus**. **Shear strain is an angular change** as shown. Units are radians. This is a positive \( \tau_{xy} \), since it acts on the positive x face and is in the positive y direction. Since it is in the direction of a negative shear force, \( V \), it would be a negative \( \tau_{\theta} \).

What will the gages measure? **We cannot directly measure shear** strain since no length change results. But we can measure the effect of the shear by orienting our gages at an angle. The strain gage shown has two gages at 45 degrees. **Note that the diagonals of the square change length.** One gets longer and one gets shorter as indicated. Let’s look at an element at 45°.
At 45° the element is aligned in the directions of the diagonals that changed in length on the previous element. So this element will experience an elongation at 45° as shown, and a shortening in the other direction. On this element there is no shear stress.

Now let’s look at the Mohr’s circle.

Here is the Mohr’s circle for torsion. Since we have pure shear, our points will be along the y axis. The principal stresses are shown on the left and right sides of the circle. The $\tau_{xy}$ stress plots downward since it is a negative $\tau_\theta$.

Recall that angles measured on the circle are twice the angle from the real part.