MECHANICAL ENGINEERING SCIENCE

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POISSON'S RATIO

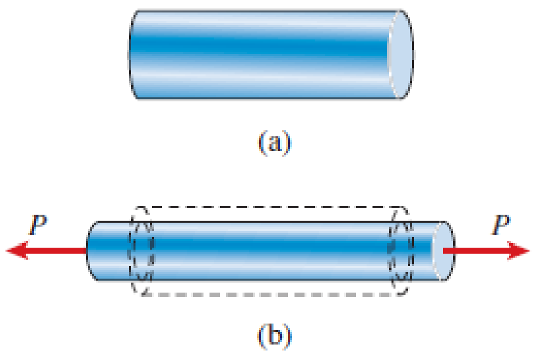
- When a prismatic bar is loaded in tension, the axial elongation is accompanied by lateral contraction (that is, contraction normal to the direction of the applied load).

- The lateral strain ε' at any point in a bar is proportional to the axial strain ε at that same point if the material is linearly elastic.

- ***The ratio of these strains is a property of the material known as Poisson's ratio***.

- This dimensionless ratio, usually denoted by the Greek letter ν (nu), can be expressed by the equation

$$\nu = -\frac{\text{lateral strain}}{\text{axial strain}} = -\frac{\epsilon'}{\epsilon}$$



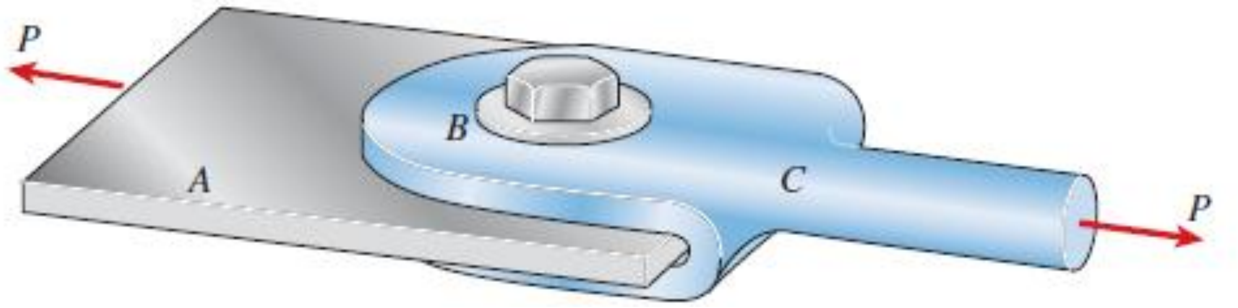
POISSON'S RATIO

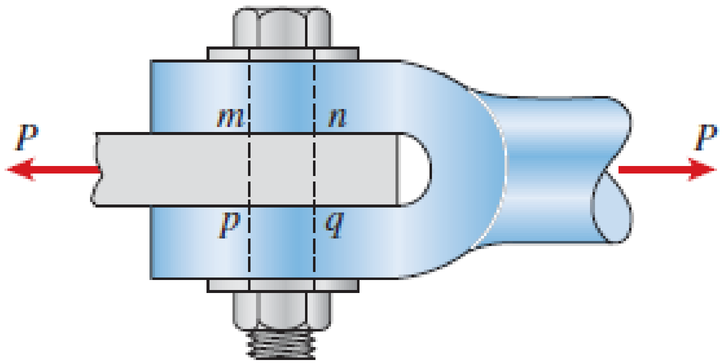
- The minus sign is inserted in the equation to compensate for the fact that the lateral and axial strains normally have opposite signs.
- Poisson's ratio lies in the range 0.25 to 0.35 for most metals and many other materials.
- Materials with an extremely low value of Poisson's ratio include cork, for which ν is practically zero, and concrete, for which ν is about 0.1 or 0.2.
- A theoretical upper limit for Poisson's ratio is 0.5. Rubber comes close to this limiting value.

SHEAR STRESS AND SHEAR STRAIN

- Consider the bolted connection shown in Figure. This connection consists of a flat bar A, a clevis C, and a bolt B that passes through holes in the bar and clevis.

- Under the action of the tensile loads P, the bar and clevis tend to shear the bolt, that is, cut through it.





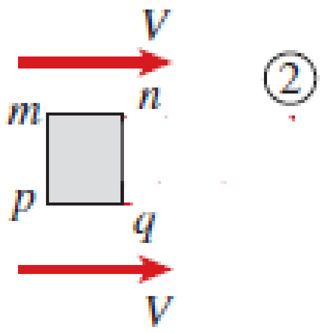
SHEAR STRESS AND SHEAR STRAIN

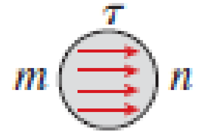
- The free-body diagram of Figure shows that there is a tendency to shear the bolt along cross sections mn and pq. From a free-body diagram of the portion mnpq of the bolt, we see that shear forces V act over the cut surfaces of the bolt.

- The shear forces V are the resultants of the shear stresses distributed over the cross-sectional area of the bolt. ***These stresses act parallel to the cut surface.***

- The average shear stress on the cross section of a bolt is obtained by dividing the total shear force V by the area A of the cross section on which it acts, as follows:

$$\tau_{aver} = \frac{V}{A}$$



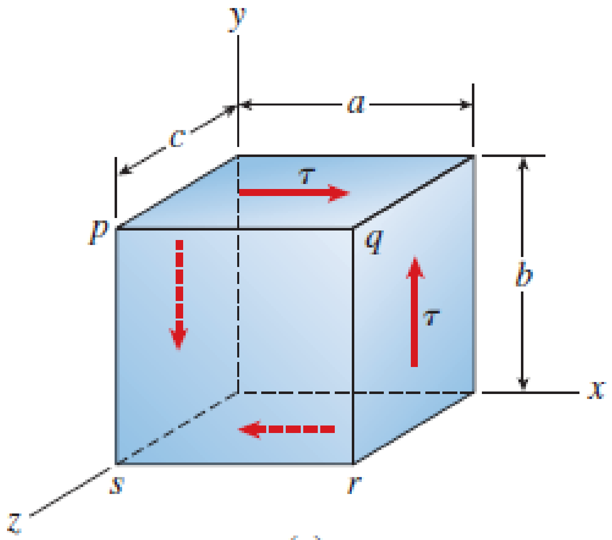


SHEAR STRESS AND SHEAR STRAIN

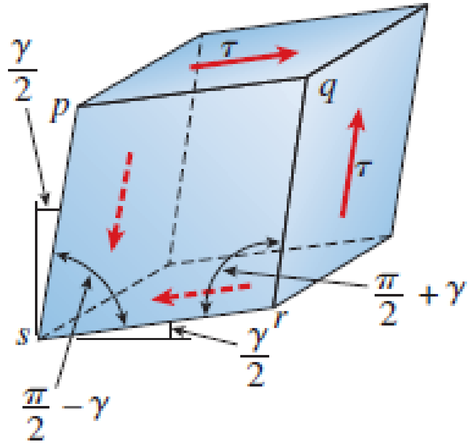
- Shear stresses acting on an element of material are accompanied by shear strains.

- As an aid in visualizing these strains, we note that the shear stresses have no tendency to elongate or shorten the element in the x, y, and z directions—in other words, the lengths of the sides of the element do not change.

- Instead, the shear stresses produce a change in the shape of the element. The original element, which is a rectangular parallelepiped, is deformed into an oblique parallelepiped, and the front and rear faces become rhomboids.

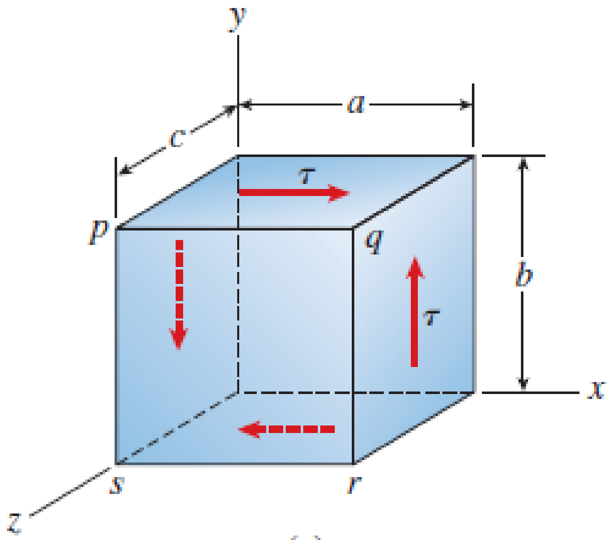


(a)



SHEAR STRESS AND SHEAR STRAIN

- Because of this deformation, the angles between the side faces change.
- For instance, the angles at points q and s, which were $\pi/2$ before deformation, are reduced by a small angle γ to $\pi/2 - \gamma$.
- At the same time, the angles at points p and r are increased to $\pi/2+\gamma$. The angle γ is a measure of the distortion, or change in shape, of the element and is called the **shear strain**.
- Because shear strain is an angle, it is usually measured in degrees or radians.



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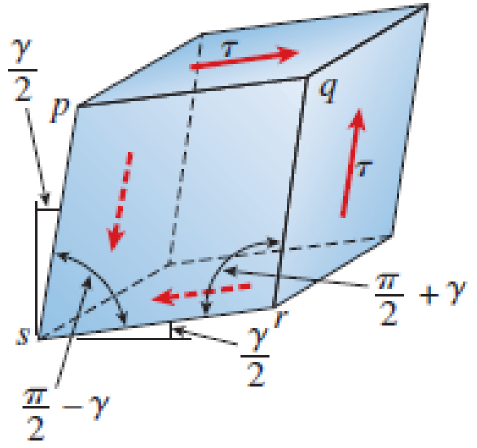

HOOKE'S LAW IN SHEAR

- The properties of a material in shear can be determined experimentally from direct-shear tests or from torsion tests.

- From the results of these tests, we can plot shear stress-strain diagrams (that is, diagrams of shear stress τ versus shear strain γ). These diagrams are similar in shape to tension-test diagrams (σ versus ε) for the same materials, although they differ in magnitudes.

- For many materials, the initial part of the shear stress-strain diagram is a straight line through the origin, just as it is in tension. For this linearly elastic region, the shear stress and shear strain are proportional, and therefore we have the following equation for Hooke's law in shear:

$$\tau = G\gamma$$

in which G is the shear modulus of elasticity (also called the modulus of rigidity).

HOOKE'S LAW IN SHEAR

- The moduli of elasticity in tension and shear are related by the following equation:

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

FACTOR OF SAFETY

- The maximum load that a structural member or a machine component will be allowed to carry under normal conditions is considerably smaller than the ultimate load.

- This smaller load is called the allowable load or working or design load. Thus, only a fraction of the ultimate load capacity of the member is used when the allowable load is applied.

- The remaining portion of the load-carrying capacity of the member is kept in reserve to assure its safe performance. ***The ratio of the ultimate load to the allowable load is used to define the factor of safety:***

$$\text{Factor of safety} = F.S. = \frac{\text{ultimate load}}{\text{allowable load}}$$

- An alternative definition of the factor of safety is based on the use of stresses:

$$\text{Factor of safety} = F.S. = \frac{\text{ultimate stress}}{\text{allowable stress}}$$

THANK YOU

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