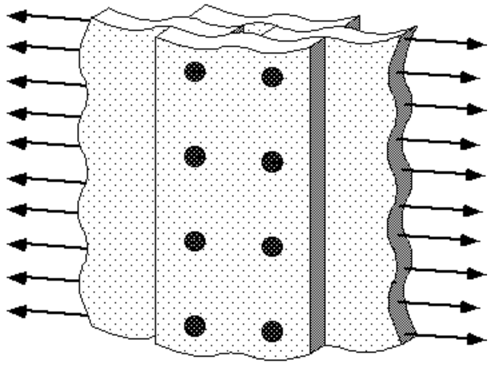
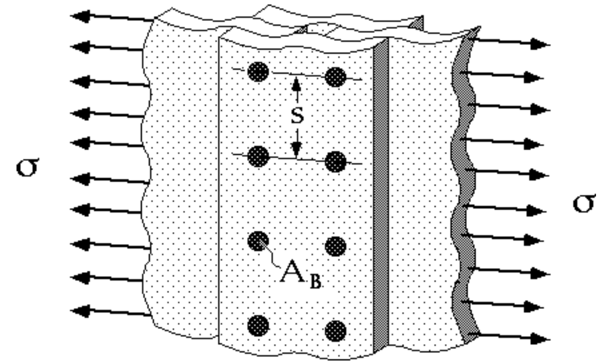
The Double Lap Joint

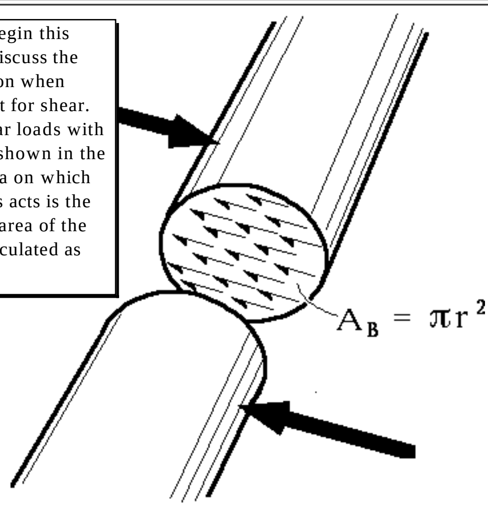


The double lap joint shown below is connecting two plates in uniaxial tension. The stress in the plates is σ. The spacing of the bolts is s, and the shear area of each bolt is A_B.

What is the shear stress in each bolt?

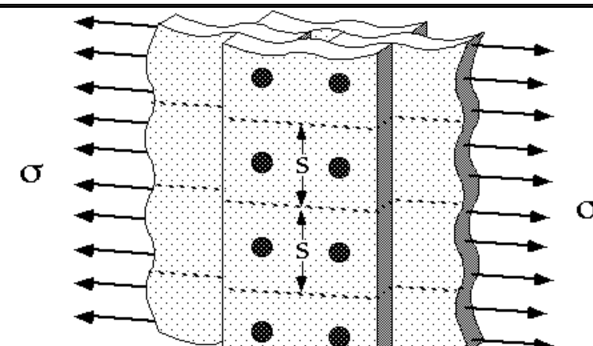


Before we begin this problem, let's discuss the critical dimension when designing a bolt for shear. Bolts resist shear loads with shear stress as shown in the figure. The area on which this shear stress acts is the cross-sectional area of the bolt, usually calculated as πr^2.



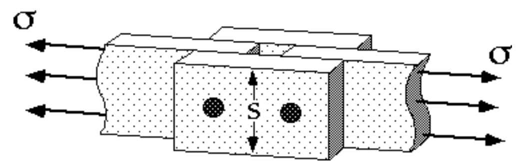
Notice that we have only drawn a typical section of this lap joint. The joint could be of any length and not effect the following analysis.

In order to continue, we assume that each pair of bolts bear the stress from only a portion of the connection, and that length of the portion is equal to the spacing of the bolts.

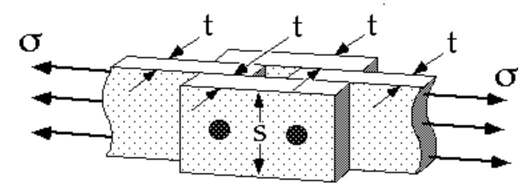


Therefore, to analyze any pair of bolts we need only to consider that section of the joint which contributes stress to the bolts.

Further, if the geometry and the load conditions are constant for the length of the connection, we need to analyze only one pair of bolts, knowing that the stress in all the bolts will be equal.

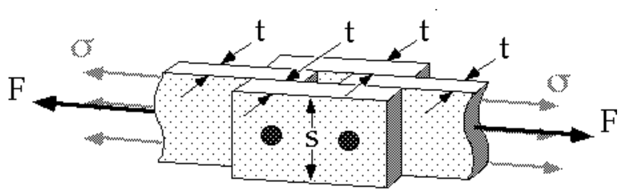


For this example we will consider that all of the plates used in the lap joint are of the same thickness, t.

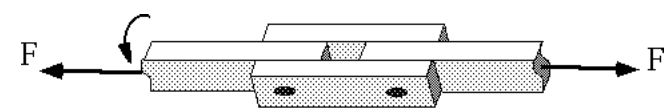


The force exerted by the normal stresses in the outer plates on the pair of bolts can be calculated as shown below.

At this point we are going to move to a birds-eye view of the connection.

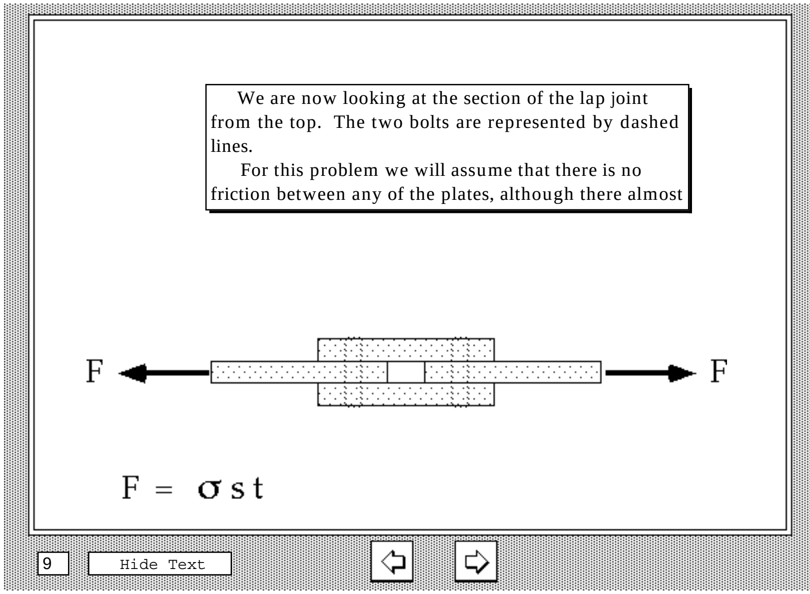


$$F = \sigma A = \sigma s t$$



$$F = \sigma s t$$

Lap Joints: 3



We are now looking at the section of the lap joint from the top. The two bolts are represented by dashed lines.
For this problem we will assume that there is no friction between any of the plates, although there almost
F
F
F = σ s t
9
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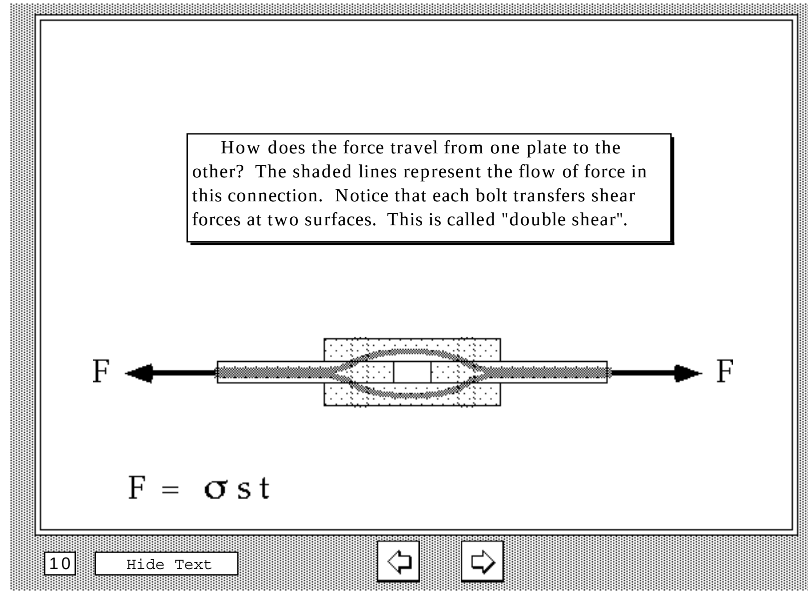

How does the force travel from one plate to the other? The shaded lines represent the flow of force in this connection. Notice that each bolt transfers shear forces at two surfaces. This is called "double shear".
F
F
F = σ s t
10
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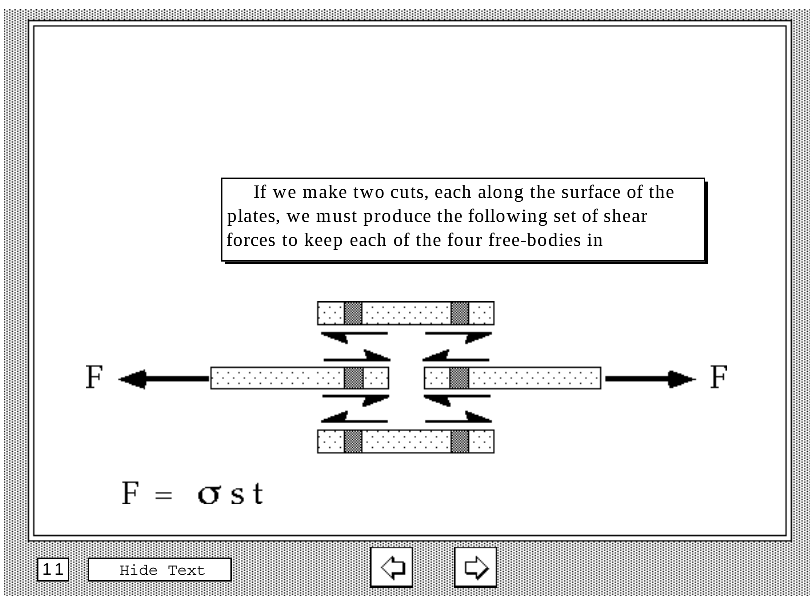

If we make two cuts, each along the surface of the plates, we must produce the following set of shear forces to keep each of the four free-bodies in
F
F
F = σ s t
11
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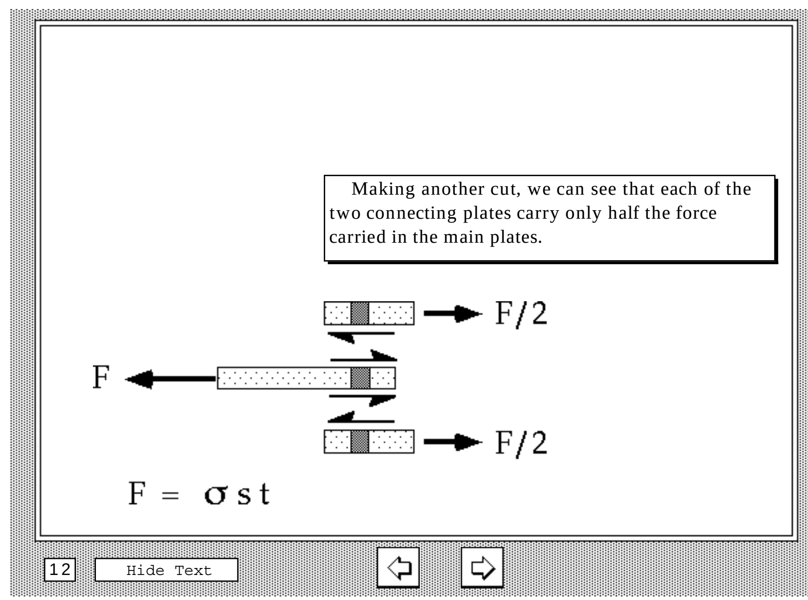

Making another cut, we can see that each of the two connecting plates carry only half the force carried in the main plates.
F/2
F
F/2
F = σ s t
12
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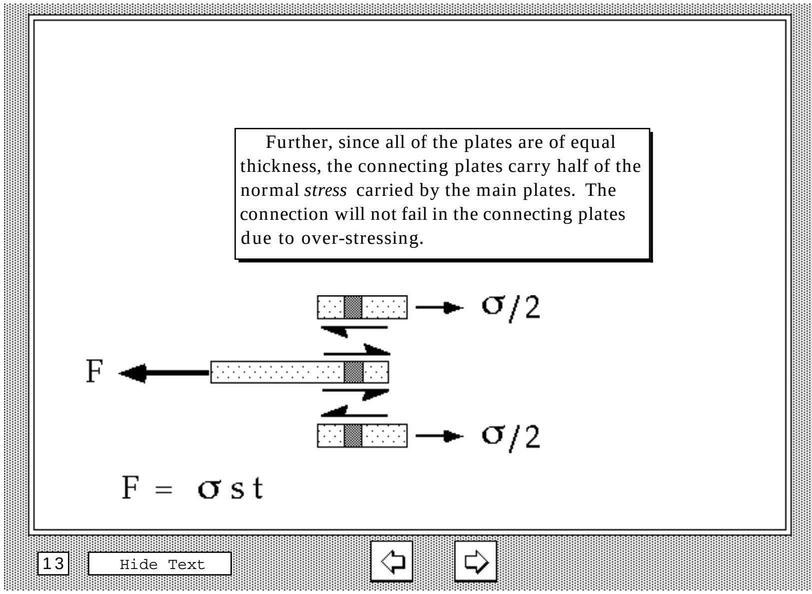
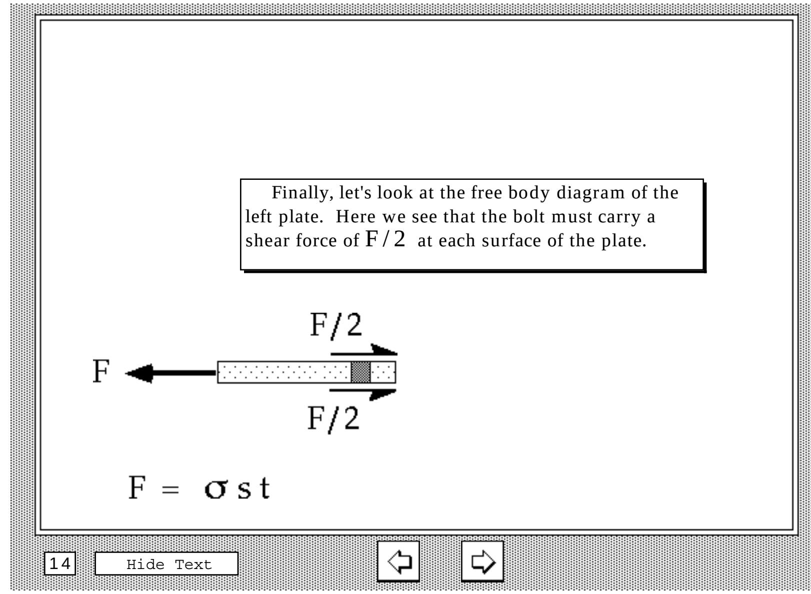

Further, since all of the plates are of equal thickness, the connecting plates carry half of the normal *stress* carried by the main plates. The connection will not fail in the connecting plates due to over-stressing.
σ/2
F
σ/2
F = σ s t
13
Hide Text


Finally, let's look at the free body diagram of the left plate. Here we see that the bolt must carry a shear force of F/2 at each surface of the plate.
F/2
F
F/2
F = σ s t
14
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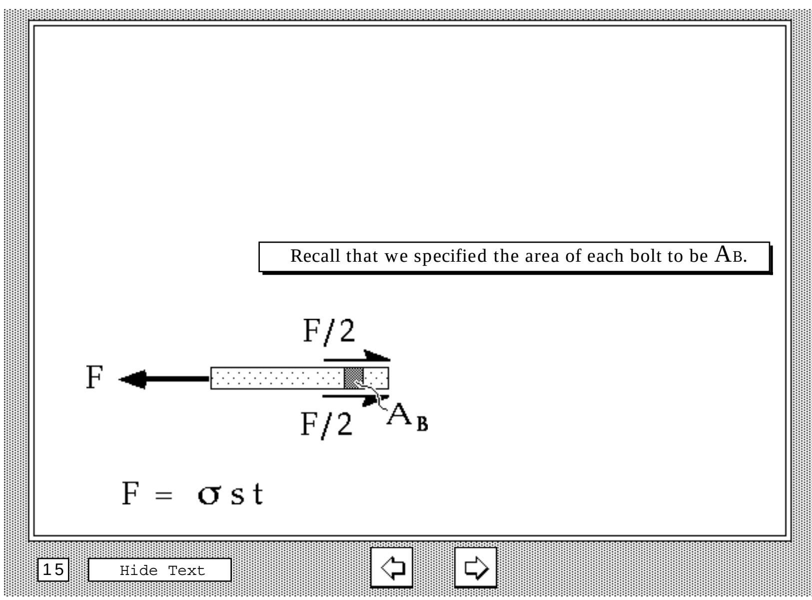
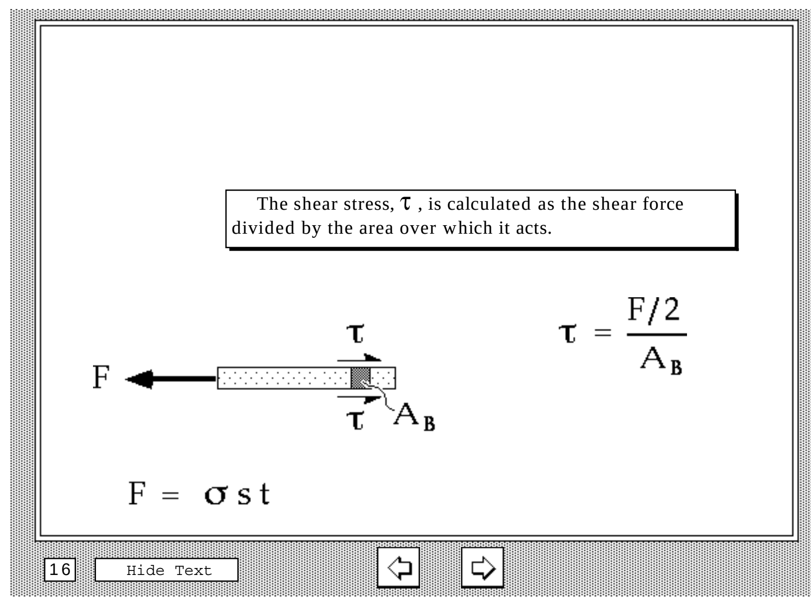
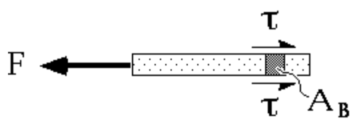

Recall that we specified the area of each bolt to be AB.
F/2
F
F/2
AB
F = σ s t
15
Hide Text


The shear stress, τ , is calculated as the shear force divided by the area over which it acts.
τ
F
τ
AB
τ = F/2 / AB
F = σ s t
16
Hide Text

Finally, we arrive at an expression for the shear stress in the bolt in terms of the stress in the plate, σ , the spacing of the bolts, s, the thickness of the plates, t, and the shear area of the bolts, A_B.
Because of the regularity in the geometery and loading of our connection the shear stress will be the same for each bolt in the joint.

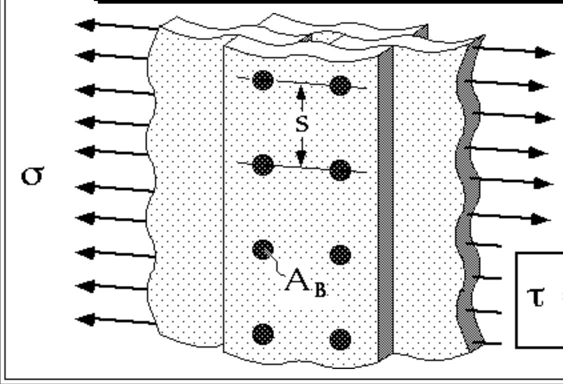


$$\tau = \frac{F/2}{A_B}$$

$$F = \sigma s t$$

$$\tau = \frac{\sigma s t}{2 A_B}$$

Although this result looks like some general formula to be memorized, it isn't. The process of the analysis is the important part of this tutorial. The equation below is not very general, so you must be able to perform this type of analysis yourself.



$$\tau = \frac{\sigma s t}{2 A_B}$$

The End