

Structural Concepts of a Hole Punch

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The hole punch, pictured below, is an important everyday item which makes use of several fundamental structural concepts in order to punch holes in sheets of paper. The main concept discussed will be the use of moments to apply a load on the punch rod, which causes it to move downwards and create a hole in the paper. Other concepts include the shearing effect of the punch rods in order to create the hole, as well as the use of springs in order to force the rod upwards and return the hole punch arm to its original position.

Figure 2 shows a labelled diagram of the main components of a hole punch, while Figure 3 shows the associated free body diagram. The pivot at which the hole punch arm rotates about the base is assumed to act as a pin joint as it allows rotation of the arm but no horizontal or vertical movement. Also, the spring inside which the rod moves is fixed at the base and at the arm and ensures that the rod and arm return to their original positions.



Figure 1 - Hole Punch

A force, F , is required to rotate the hole punch arm about the pivot in the clockwise direction, as shown in Figure 3. This creates a moment in the arm, as follows:

$$M = F_1 \times L_1$$

The arm then applies a force, F_{rod} , on the punch rod due to M :

$$F_{\text{rod}} = M \div L_2$$

Since the moment created by the applied force is the same as that applying a force on the punch rod, there is an inverse relationship between the force on the rod and the distance between the rod and the pivot – the smaller the distance L_2 , the greater the force that will be applied on the rod due to the applied moment. This is the reason for the punch rod being positioned so close to the pivot.

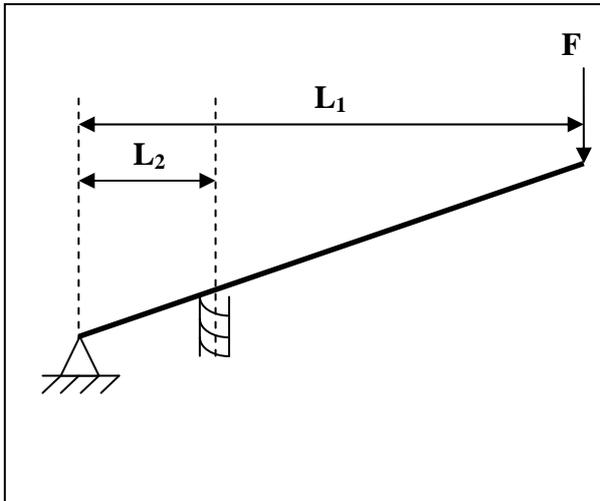


Figure 2 - Free-Body Diagram of a Hole Punch

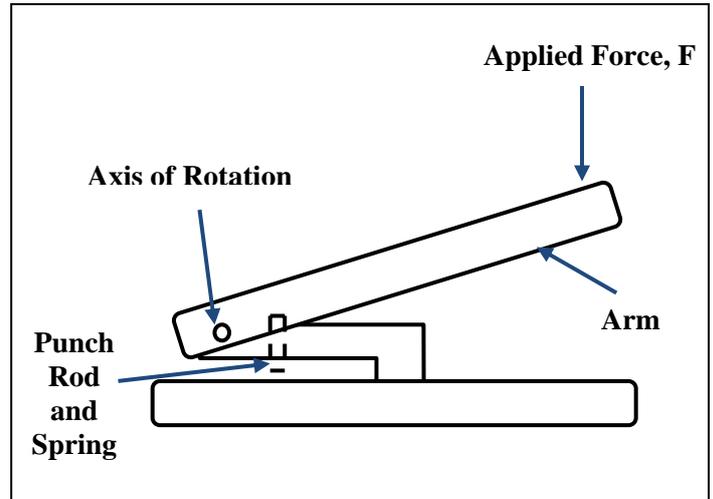
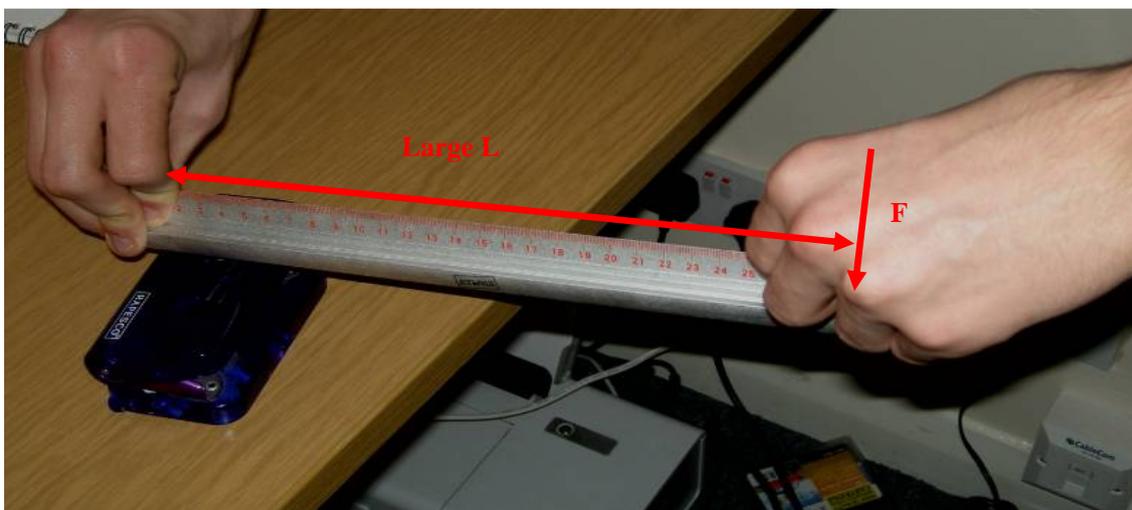


Figure 3 - Diagram of Hole Punch

It follows that a greater moment acting on the arm due to the applied force will cause the arm to apply a greater force on the punch rod. Assuming the same force is applied, the moment can be increased by applying the load at a further distance from the pivot.

In order to see the effect of increasing the distance between the force and the pivot, a simple practical example can be used. It involves firmly holding a long ruler in place on the hole punch at the position of the pivot, as shown in the picture below. Apply a force to the other end of the ruler and compare this with the force needed to be applied to the hole punch without the ruler – it should be seen that it is easier to rotate the arm by applying the force to the ruler. This is due to the fact that the increase in length creates a greater moment which, in turn, applies a greater force to the rod.



Conclusion:

- The moment generated due to the force applied on the arm increases as the distance between the force and the pivot increases.
- The force applied to the rod due to the moment in the arm increases as the distance between the rod and the pivot decreases.