Pantograph

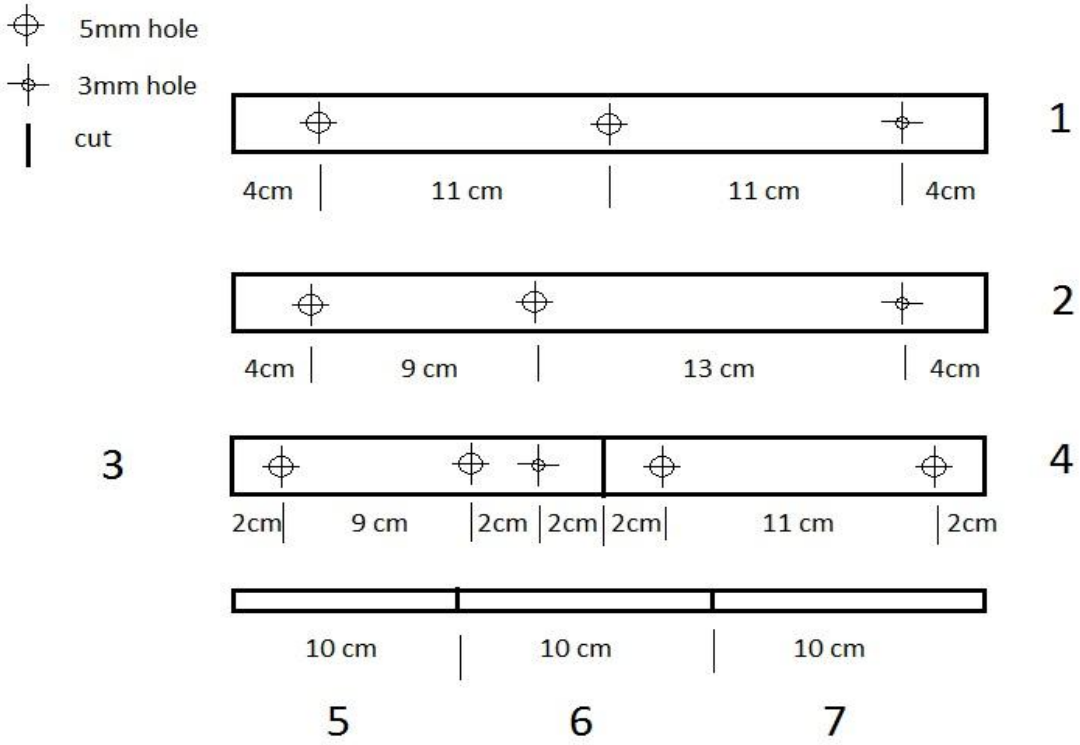
The Pantograph is a mechanical divice used for making enarged or miniaturized copies of a drawing. The first pantograph was constructed in 1603 by Christoph Scheiner and a tri dimensional version was developed later by the steam pioneer James Watt. The later versions were used by milling machines to make copies of an original object (called master model).

Materials

3 wooden dowels, diameter 9mm, length 30 cm
1 wooden dowel, diameter 3mm, length 30 cm
4 screws and nuts, diameter 5mm, length 30mm
2 ruber bands

Tools:

working surface
C-clamp
measuring tape and pencil
mini handsaw
sharp nail and hammer
drilling machine with 3mm and 5mm drill bits.
file (conical or rat tail shape)
hot glue gun

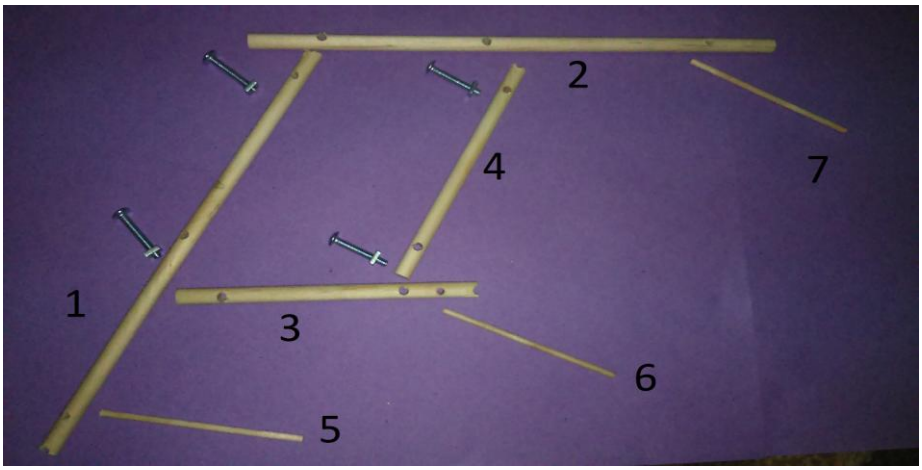


Construction steps

The pieces 1,2,3 and 4 are cut from 9mm diameter dowels
The pieces 5,6 and 7 are cut from the 3mm dowel

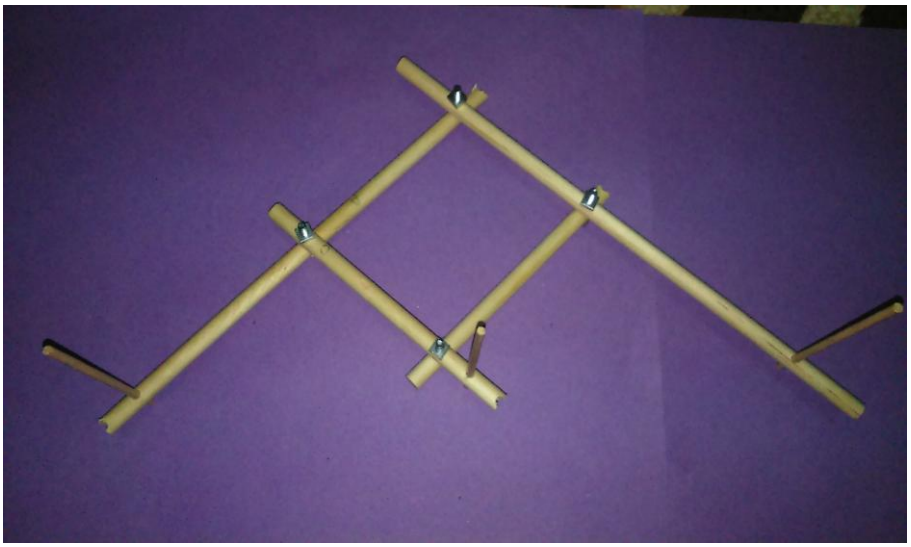
1. Cut and drill the dowels. For each dowel:
    1.1 Fix the dowel in a C-clamp
    1.2 Measure and mark the wooded dowels as in the schematic above
    1.3 Use a nail and hammer to mark the center of the holes to be drilled. This will prevent the drill bit from slipping away during the drill process
    1.4 Cut and drill the dowels as per schematic

2. Insert the 5,6 and 7 dowel pieces into the 3mm holes of dowels 1,2 and 3
    2.1 Use a rat tail file to enlage the 3mm holes. Enlarge the hole from both ends
    2.2 Insert the dowel into the hole. Lightly hammer it if needed. The tip of the small dowel must protude 5mm on the other side for the piece 1, and 14mm for the pieces 2 and 3.

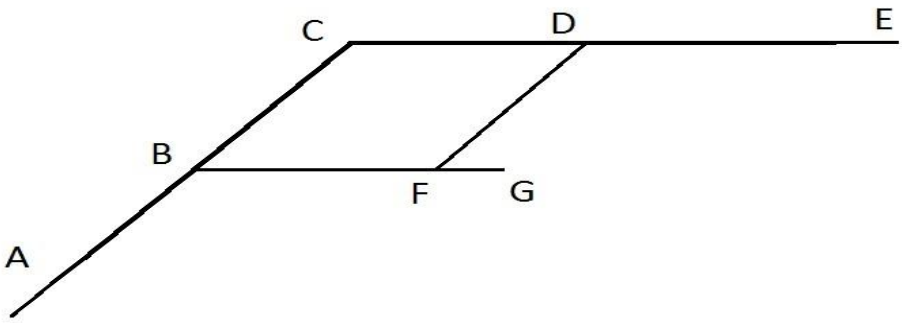


3. Assemble the pieces using the 5mm screw and bolts
    3.1 The pieces 2 and 3 must be placed on top of the pieces 1 and 4
    3.2 The screws must be inserted from below, the nut must be at the top. Do not overtighted the nuts as they will prevent the pieces from moving freely.
    3.3 Secure the nut in place with hot glue.

4. Attach a marker or a pen to the 3mm vertical dowel using rubber bands.
    4.1 If the marker is attached to the middle dowel, the pantograph can be used for miniaturized copies.
    4.2 If the marker is attached to one of the side dowels, the pantograph can be used for enlarged copies



Mathematical principles behind the pantograph



1. BF =CD and BC = FD (from construction) => BCDF is a paralelogram => BF || CD
2. AB || AC and BF || CE => angles ABG = ACE
3. ABG = ACE and (AC / AB) = (CE / BG) => triagles are simlilar ABG ~ ACE
4. => angles BAG = CAE
5. => points A, G, E are on the same line and (AC /AB) = (CE / BG) = (AE / AG)