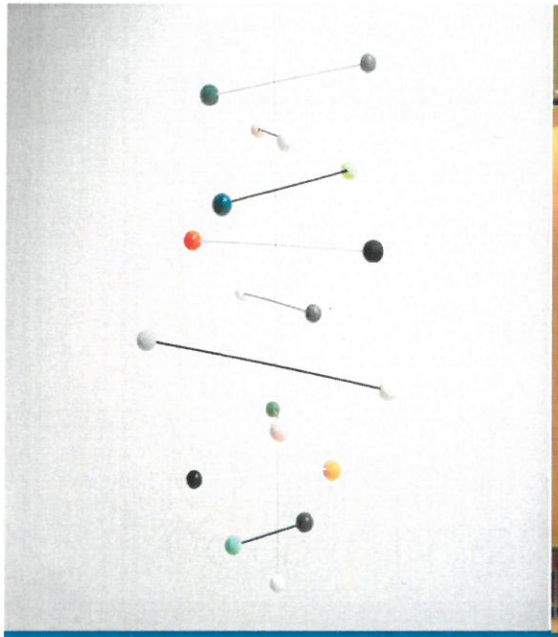


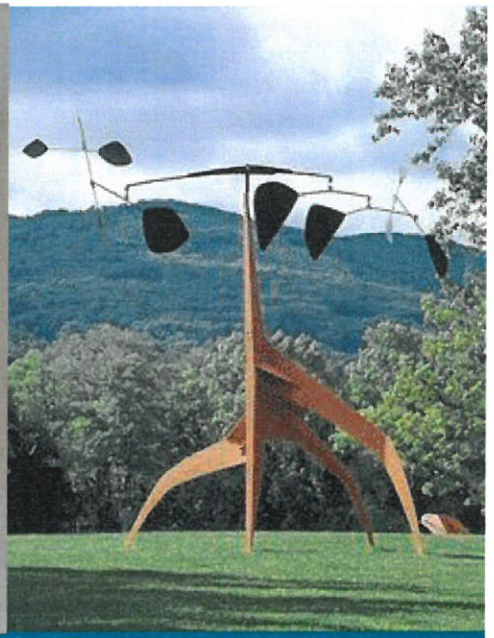

Rotational Equilibrium

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IEEE Try Engineering
NJIT, Newark
October 17, 2018

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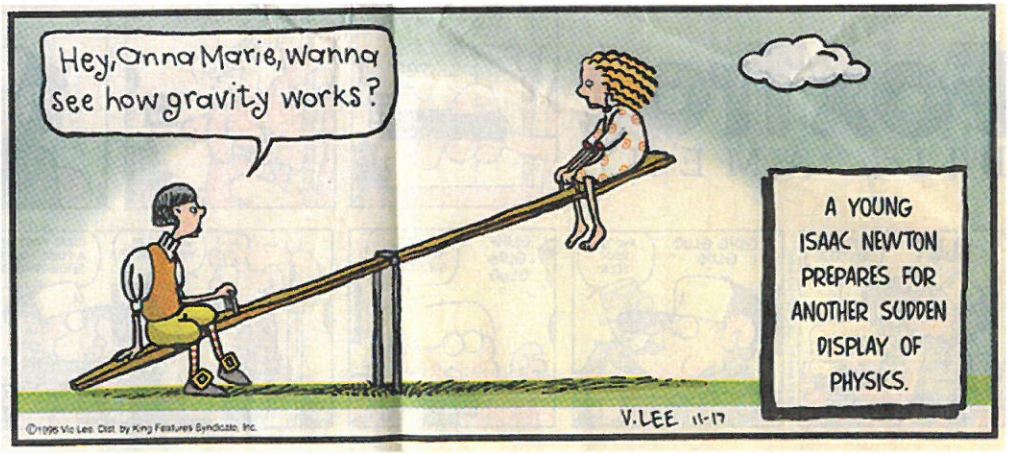
What is a Rotational Equilibrium?

- An object is in rotational equilibrium if its rotational acceleration is zero
- Rotational equilibrium implies that the sum of all external torques applied to the object is zero
- For example, if an object such as a see-saw is not rotating, you know the torque on each side is balanced



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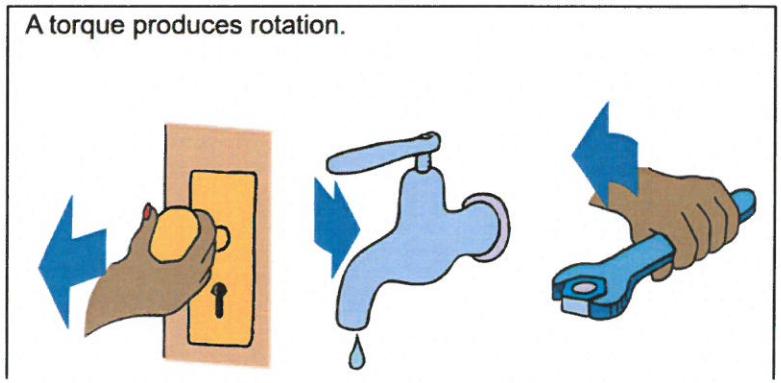
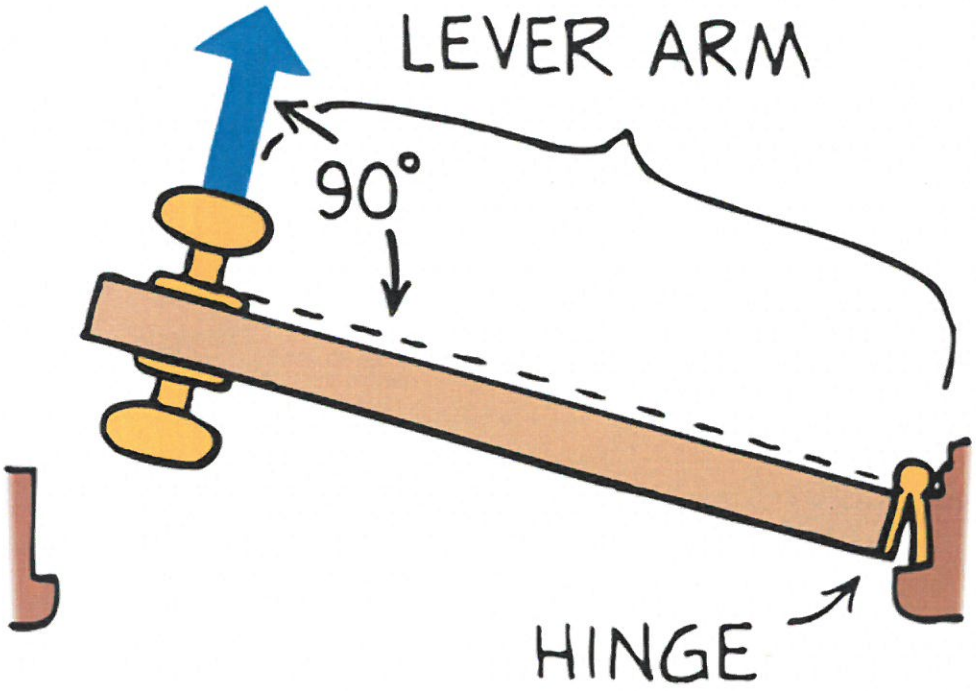
Torque

- Every time you open a door, turn on a water faucet, or tighten a nut with a wrench, you exert a turning force
- Torque is produced by this turning force and tends to produce rotational acceleration.
- Torque is different from force
- • Forces tend to make objects accelerate
- • Torques produce rotation



When a perpendicular force is applied, the lever arm is the distance between the doorknob and the edge with the hinges.



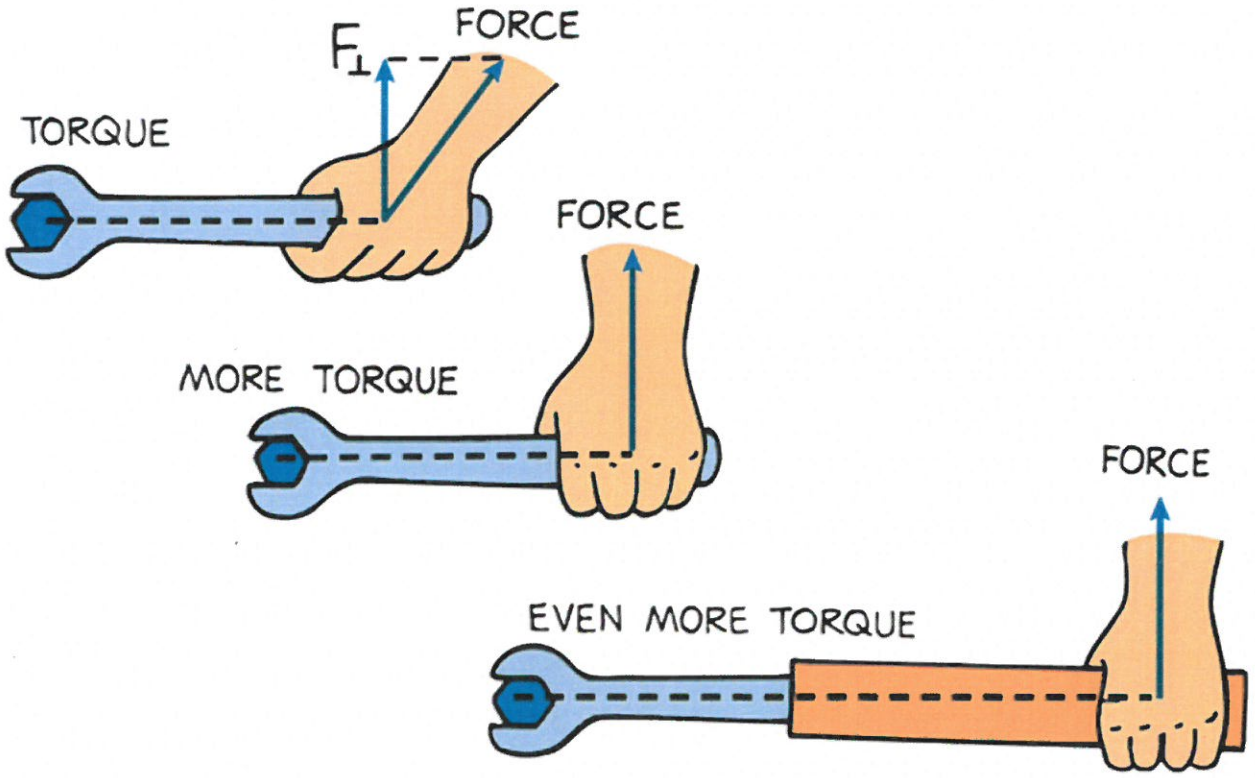
Torque - definition

When the force is perpendicular, the distance from the turning axis to the point of contact is called the **lever arm.**

If the force is not at right angle to the lever arm, then only the perpendicular component of the force will contribute to the torque.

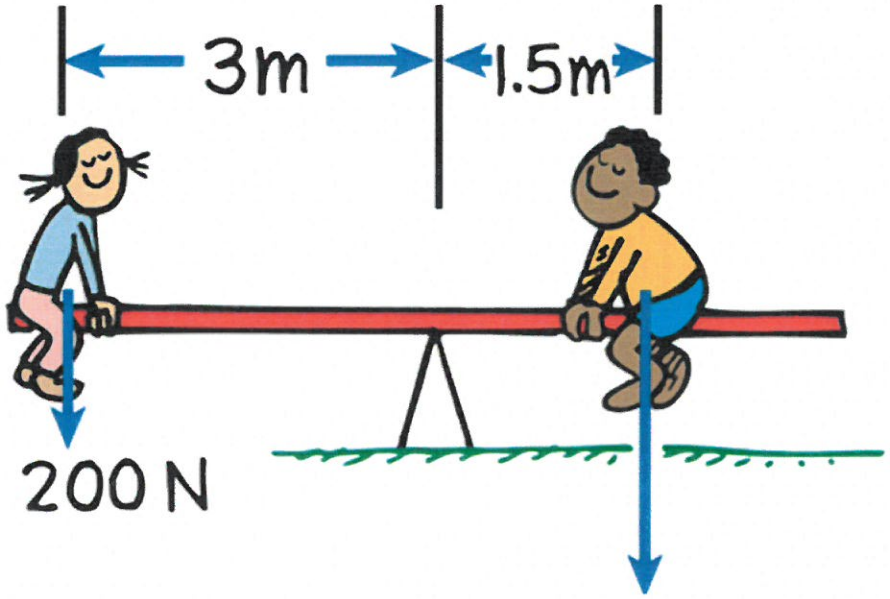
$$\text{torque} = \text{force}_{\perp} \times \text{lever arm}$$

Although the magnitudes of the applied forces are the same in each case, the torques are different.



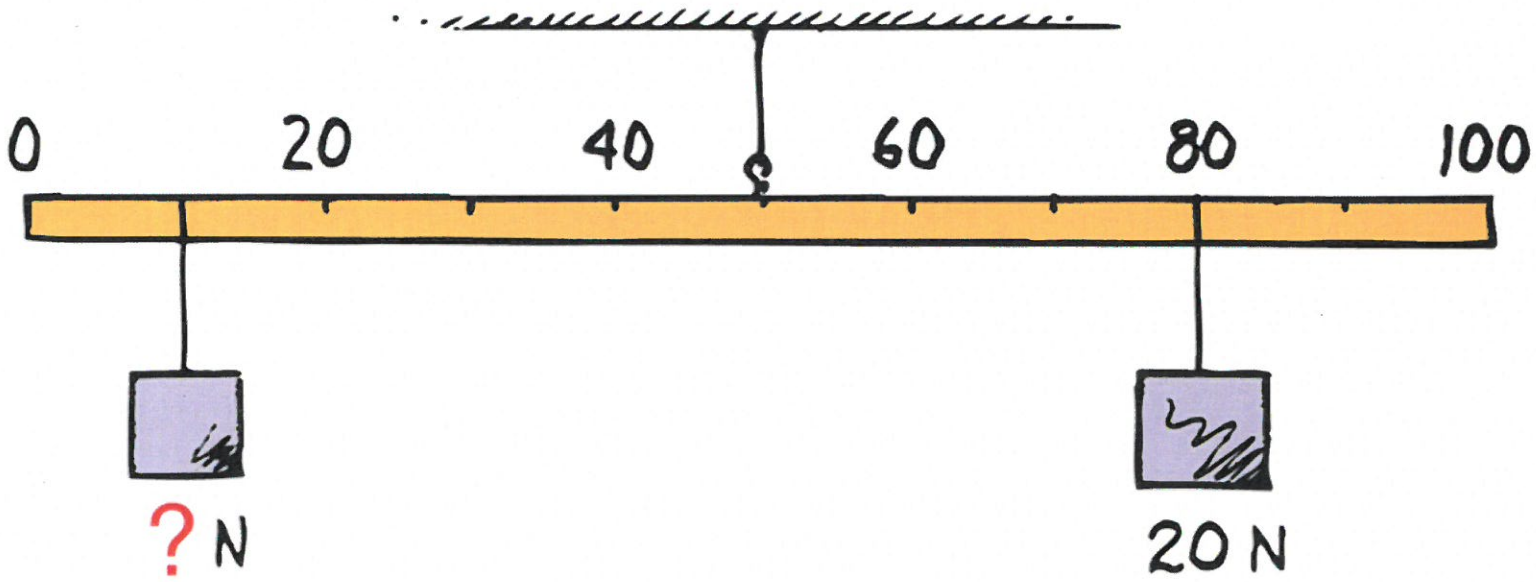
Balanced Torques

A pair of torques can balance each other. Balance is achieved if the torque that tends to produce clockwise rotation by the boy equals the torque that tends to produce counterclockwise rotation by the girl.



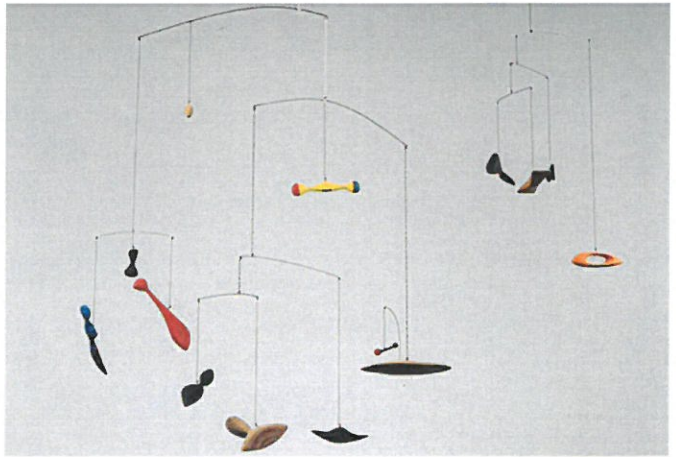
Balanced Torques: do the math!

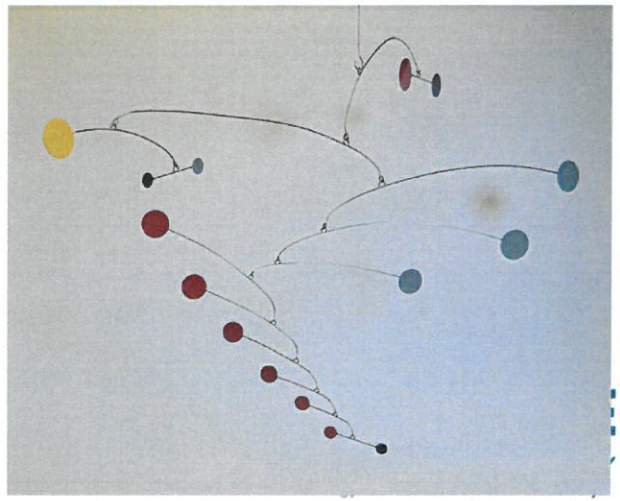
What is the weight of the block hung at the 10-cm mark?



Today's Challenge

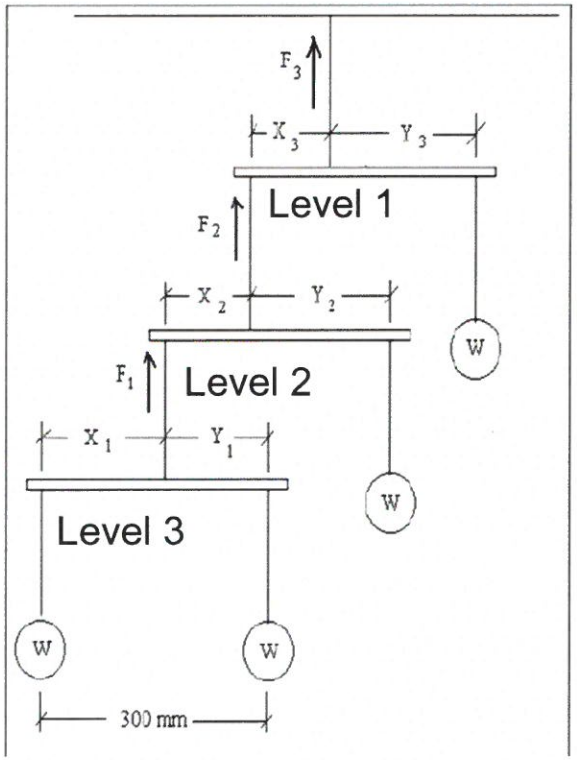
- Working in teams of 2, we will design 2 different mobiles using simple materials
- Mobile Design 1
  - Three-level mobile with four weights
    under specified constraints
- Mobile Design 2
  - An individual design under more general constraints





Mobile 1 Design

- Three-level mobile with four weights



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Materials

- Balsa wood sticks
  - 31 cm long
- Sewing thread
- Coins or washers
- Tape

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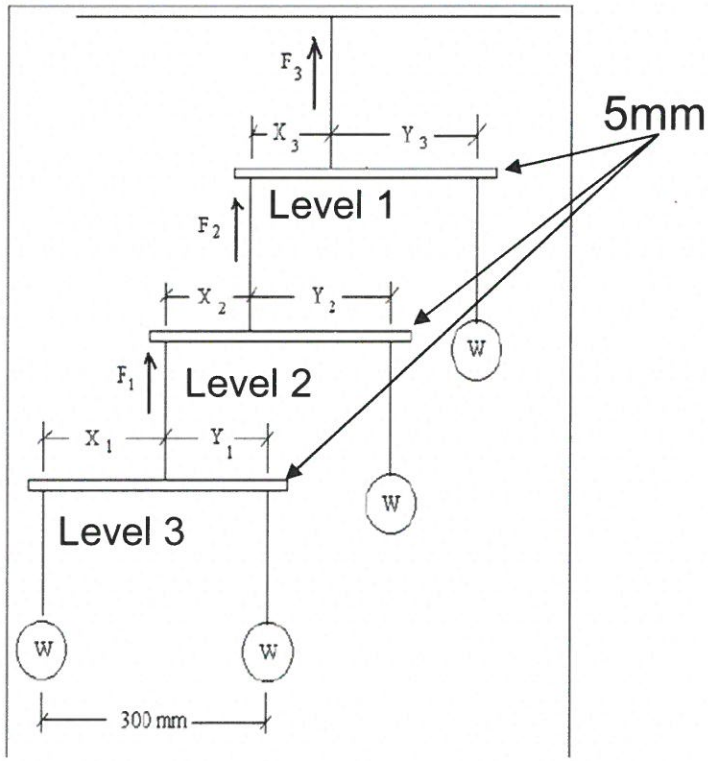
Procedure

- Weights are made of two standard washers taped to a circular piece of cardboard
  - One washer on each side
    - If you wish to do it with only one washer it will be slightly harder to do
  - Each weight is tied to a piece of thread
    - The thread is connected to a wood rod at 5mm from the edge



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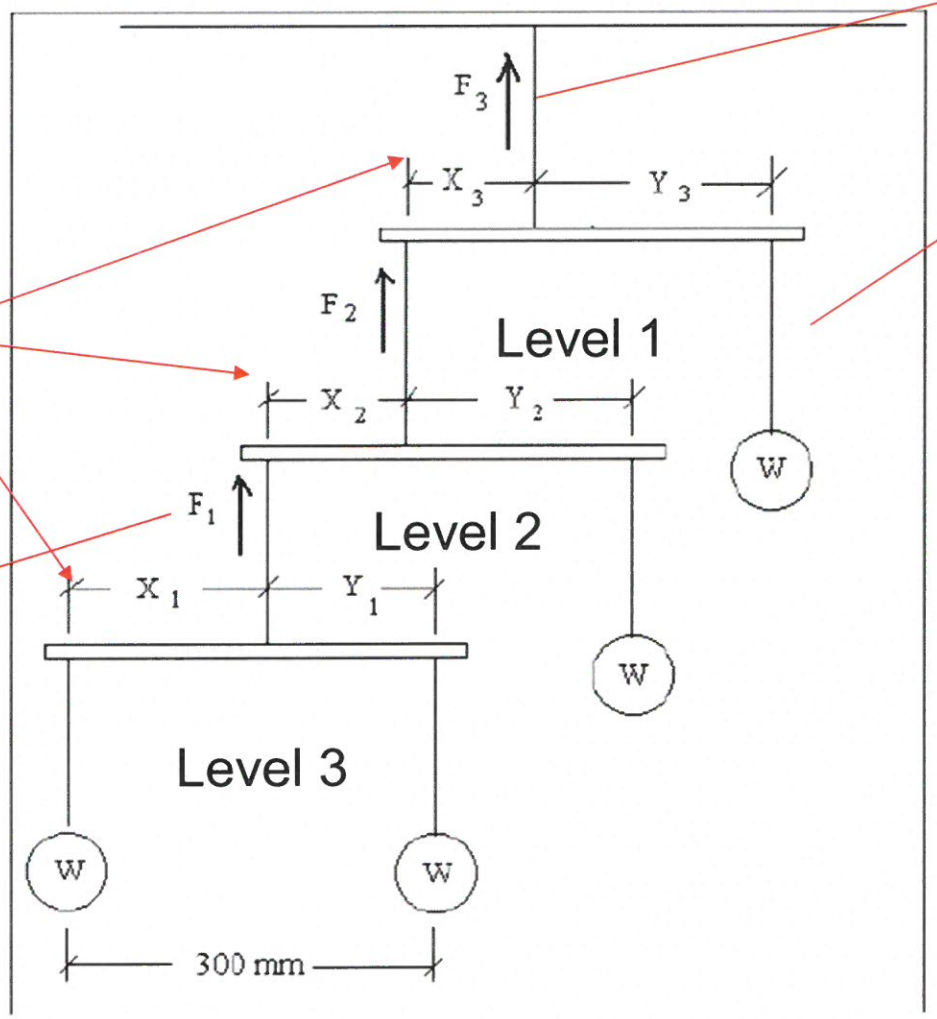
This is what you'll be building!



5 mm
from edge

> 22 cm

> 22 cm

> 22 cm

Minimum three levels

Rods of level 3 and 2 are tied to rods of level 2 and 1 respectively, at a distance of 5 mm from the edge of the lower level rod

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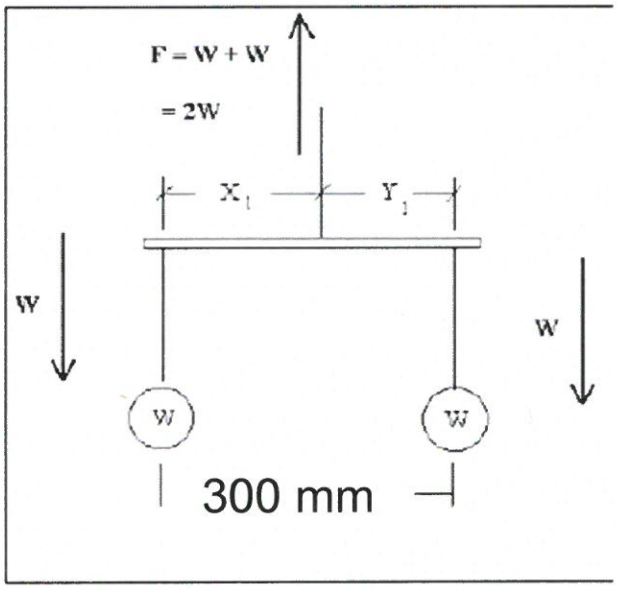
Designing the Mobile

Write and solve the equations for x_i And y_i (i=1,2,3)

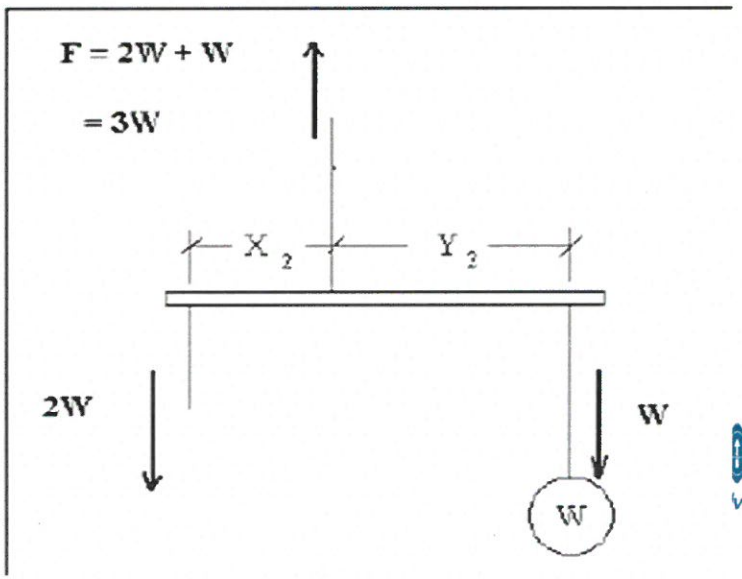
Level 3

- $W\ x_1 = W\ y_1$
- $x_1 + y_1 = 300$



Level 2

- $2W\ x_2 = W\ y_2$
- $x_2 + y_2 = 300$



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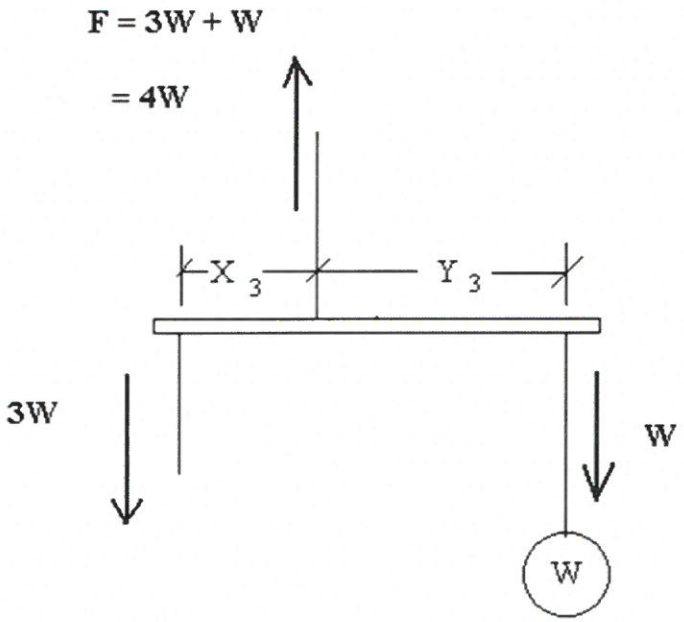
Level 1

$3W\ x_3 = W\ y_3$

$x_3 + y_3 = 300$



Calculations

- Write and solve the equations for X_1, X_2, and X_3
- Draw the equations for each level using coordinates Y_i vs. X_i for i=1,2,3 and find a graphical solution
- [rewrite the equations taking into account the weight of the rods, about 2.75g and recalculate]