33024 Torque About It

Purpose:

The notion of Torque or Moment is used to explore the change of the balance point of a simple apparatus as it is assembled from common objects. Accepted values emerge from the classroom process for randomly assembled sets of apparatus.

Background:

Since the tubes, the rods, and the dowels are of uniform composition, it is safe to assume that the center of gravity or center of mass or balance point of each (after this referred to here as the centroid) will be at the geometrical center. Since the mass and overall length of each element is easily taken, sufficient data are available to calculate the results of assembling the pieces in different ways. Once all results have been calculated, then a physical trial can confirm the findings.

Since each trial will involve balancing an assembly on a finger tip, the apparatus will be in equilibrium with respect to translation and also rotation when it balances. An object in equilibrium with respect to rotation about a **particular** point, say the finger tip, is also in equilibrium with respect to rotation about **any** point, say one end of the tube. This greatly simplifies calculating the torques to solve the problem. This laboratory activity has two parts.

Part One. If a steel rod is placed inside of the tube so that one end is flush, calculate the new position of the centroid for the combination of parts.

Part Two. If a dowel is then added so that it just touches the end of the steel rod, calculate by how much the centroid is displaced. This first requires calculating the position of the centroid for the new combination of parts before comparing it with the results of Part One.

Three different versions of an activity sheet allow the calculations to proceed, with support appropriate for the level of the investigators. The first sheet defines the tasks and includes a data table for each part. The second sheet does not provide an explicit data table, while the third sheet
provides a conceptual scaffold for the computations.

The investigators need to be familiar with the following ideas:

1. The centroid of each component piece is at its midpoint, that is a distance of L/2 from either end
2. The weight vector for each component piece is acting at its respective centroid.
3. The arm (or Moment Arm) is the distance from the particular centroid to the point about which rotation is being considered, in this case, the common end where the tube and rod are flush with each other. These are labeled in the diagrams. For instance, A4 is half the length of the dowel added to the full length of the rod. A1 is half the length of the rod. A2 is half the length of the tube.
4. All the component pieces provide a torque in the same direction about the chosen point.
5. The force to be provided by the finger, equal to the sum of the component weight vectors, provides a single contrary torque to establish equilibrium. The moment arm for this torque answers the question in each part about locating the final centroid for the combination of parts.

Procedure:

Since five sets of apparatus can be assembled by randomly picking a tube, a rod, and a dowel, each of these component parts should be first labeled in some convenient way using colors or letters or numbers. This will facilitate the classroom management of the activity, the compilation of accepted values, and discourage student teams from simply copying one another's data. A key idea in the design of this apparatus is that student teams are free to share ideas while sharing answers will not be worthwhile. Next, each student team should agree on the mass, the length, the moment arm, and the torque contributed by each component. Team members should resist the temptation to balance things first and calculate them later. It is more fun the other way, and years of classroom trials suggest a very high ratio of success.

Using the notation from the diagrams, and calling the tube length LT, the tube mass, MT, the rod length LR, the rod mass MR,

the dowel length LD, the dowel mass, MD --- A1 must be LR/2, A2 must be LT/2, the following assertions are made:

A3, the first centroid position must be [(MR times A1) plus (MT times A2)] all divided by the sum of MR and MT.

Since A4 is LR plus half of LD, the second or final position of the centroid, called A5, is the sum of MR times A1 plus MT times A2 plus MD times A4 all divided by the sum of MR plus MT plus MD. The final centroid is displaced from the first one by the difference between A5 and A3.

Proper answers can be calculated in advance by those responsible for classroom management using a calculator or computer after the fashion of the format below, or accepted values can emerge from the class process in the same way that they emerge in the scientific community.

LETS TORQUE ABOUT IT

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!    This program is written in TrueBASIC

PRINT
PRINT"CALCULATIONS FOR THE ONE-DIMENSIONAL
          BALANCE POINT LAB ACTIVITY"
PRINT
PRINT"TUBE LENGTH";
INPUT LT
PRINT"TUBE MASS";
INPUT MT
PRINT"ROD LENGTH";
INPUT LR
PRINT"ROD MASS";
INPUT MR
PRINT"DOWEL LENGTH";
INPUT LD
PRINT"DOWEL MASS";
INPUT MD
LET A1=LR/2
LET A2=LT/2
LET A3=[(MR*A1)+(MT*A2)]/(MR+MT)
PRINT "FIRST BALANCE POINT= ";
PRINT A3
LET A4=LR+(LD/2)
LET A5=[(MR*A1)+(MT*A2)+(MD*A4)]/(MR+MT+MD)
PRINT"SECOND BALANCE POINT WAS DISPLACED ";
PRINT(A5-A3)
END
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Time Allocation:

No prior assembly is required for this product. Individual experiment times will vary depending on methods of instruction, but normally will not exceed one class period.

Feedback:

If you have a question, a comment, or a suggestion that would improve this product, you may call our toll free number.