

Draft

Balance Investigations

Designing an Inquiry Workshop with Balance

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The following is a description and rationale for an inquiry experience that we designed for an Exploratorium Institute for Inquiry workshop. Although it describes a particular workshop, it can serve as an example of the elements to consider in the design of any short-term inquiry experience. The times listed in the attached schedule indicate a plan for a particular workshop, but you can create whatever schedule best fits your teachers, goals, needs and constraints.

Context

This workshop is designed to give participants a quick, intensive experience of inquiry so that they would have both a feel for what inquiry is and a vision of the process. We want them to see that movement toward conceptual understanding can be achieved through a self-directed inquiry in a particular content area.

If you have experienced the Institute for Inquiry Pinhole Investigation, you will notice that the balance inquiry experience has many differences in its design. In the work developing this inquiry experience, we found that the subject matter lends itself to investigations that are more incremental in nature --- where work on one little question leads to another and so forth --- rather than generating broader questions that carry you through an entire investigation. The design of the inquiry experience reflects this difference.

Workshop Design Inquiry Starting Points (Inquiry Initiators)---Four Balance Stations

We start by dividing the participants into four groups and rotating them through a brief (8 to 10 minutes) exploration at four stations. This is an introductory period where people just explore or "mess about". It is designed to introduce participants to the topic and materials and has the purposes of:

- arousing interest with intriguing phenomena
- defining a domain (a range of ideas and phenomena) for investigation
- generating questions which could lead to further investigation
- providing tools for investigations (e.g. odd shaped boards to balance on tennis ball fulcrums, "tinker toy" balances, etc.)

Soliciting Observations and Questions --- Sharing Experience

At this point we bring the group back together and ask them to share their experience. In particular, we ask for interesting observations and questions that were raised. We record these questions on chart paper to:

- make the inquiry a group process. People get ideas and inspirations from each other's experience which help them find their own path into the investigation

and they share information toward the building of individual and group conceptual understandings.

- identify people with similar interests.
- generate ideas and questions which lead to more focused investigation.

We have found it useful to point out during this time that many of the questions that they were raising during their explorations of the materials at the four stations were not verbalized but were illustrated by their actions. For example, if someone keeps building higher and trying to balance with the blocks on the balance board, they may be asking, "How high can I build and still keep the board balanced?" or "How does building high effect the balance?" We identify these types of unarticulated questions as "action-questions". We keep our eyes open for a number of examples of these from the groups' explorations and share these examples with the group during this time. This is done, in part, to make it clear that questions are driving the explorations and investigations. **Return to a Station for More Exploration**

After sharing observations and questions, we ask people to return to a station that caught their interest to continue exploring for 1/2 hour. During that exploration time their goal is to find a more focused path of investigation and to find one or two other people with similar interests to be their investigation partners. During this period people may also move between investigation stations or, with the recommendation of the facilitator, start to work with some of the supplementary materials.

The initial brief encounter at each station is just adequate to acquaint people with the materials and introduce some simple balance phenomena. Additional exploration time is necessary to get sufficient background to form a more focused question for investigations. The structural design here does this in a very natural manner, giving people more time to "mess around", to find something that intrigues them or puzzles them, and to find someone with whom to investigate.

Brief Sharing Out

Sharing observations and thoughts with the group is particularly important in this balance inquiry. After the exploration, the facilitator asks for a brief sharing of interesting observations and questions that came up during the exploration. The facilitator should prompt the sharing out by suggesting that certain broad areas be addressed. A good general prompt is to ask what kinds of things did they find that effected the balance. The effect of weight, the position of the weight and its distance from the fulcrum are important ideas to elicit here. Since the same concepts underlay much of the phenomena illustrated by these materials, findings from all investigations help build the concepts and influence the path of investigations for all in the group. **A Thinking Tool --- Pack on the arm demonstration (Torque and lever-arm)**

After sharing out, we give a demonstration where we hang a heavy pack or purse on someone's outstretched arm. When the pack is close to shoulder, it does not feel too heavy. When it is out near the fingers, it feels much heavier. But the weight has not changed. We tell them that this combination of weight and distance that effects how the extent to which the arm feels forced to twist around the shoulder is called torque. The shoulder is like the fulcrum of the balance and the arm is like the balance board. We also show how this torque actually depends on the weight and the horizontal distance from the fulcrum (lever-arm [see "Pack On The Arm Demonstration]). This demonstration serves the purpose of:

- giving some language to a phenomena that people noticed during their explorations

- providing a "thinking tool" (a way of thinking about phenomena) which helps people to organize and make sense of their experience and experimental results

Plan With Partner -- Organizing and Initiating Investigations

At this point we ask the groups that have formed to do some planning and writing about what they will focus on for their investigation. If some people are without partners, we either help them to join a group or determine that they can do a solo investigation. Most groups at this point will have already started down a more focused path of investigation. Others will need to choose a focus.

We ask the groups to determine and write down the answers to the following questions:

- What will you focus on and pursue?
- What questions will you try to answer?

The balance investigations tends to be driven by a progressive set of small questions rather than large, overarching questions. Often the balance questions that drive people's work are hidden within their actions. For the purpose of illustrating that inquiry is driven by questions, it is important to have people reflect and bring their questions to the surface. Facilitators can help by catching people's questions that are inherent in their actions (the things they try while they are exploring) and feeding those questions back to those people. For instance, if someone is trying to get the balance board to balance with a tall pile of blocks on either side, the facilitator could say, "You seem to be asking, 'What makes it hard to balance with the blocks piled that high?' " In order to help point out the questions driving the inquiry, the groups should post their written responses to the questions above for all to see. **During the Investigation**

The process of inquiry, like most creative processes, is often a path with peaks and valleys, moments of triumph and moments of frustration, and times when you think that you know less than when you started. If the investigation time is long enough, many groups run into places where they feel "stuck", not knowing what to do next. We find it useful to alert people to these aspects of investigation ahead of time to tell them to seek the assistance of a facilitator if they get stuck.

Groups may be engaged in more focused investigation from as little as an hour to as much as 3 or 4 hours. (At least two hours is preferred.) During this time staff facilitates investigation while the groups are:

- planning and carrying out investigations
- interacting with materials
- making observations
- asking questions
- talking to each other to share observations and ideas
- proposing explanations
- making predictions and testing them
- revising questions and explanations in light of new observations
- recording and representing thinking through writing and drawing

Facilitating Investigations

The style, intensity, and staff-to-participant ratio for facilitation during investigations depends on a number of elements. These include your goals for the group, the group's experience with the inquiry process, and the amount of time that have for investigation.

Facilitation requires an artful balance of knowing how to "read" the group, and knowing when and when not to intervene. It is a complex skill that develops over time. While there is no prescription, here is a brief description of some things to consider.

- **soliciting information** --- we solicit information to determine whether and how to intervene through looking at what groups are doing, asking them what they are doing, asking for explanations of what they are doing or trying to find out, asking them how they did something, etc.
- **Intervening** --- an intervention can be anything that the facilitator does with a group to enhance their inquiry. If a group is already on a productive path, encouragement and validation may be the only kinds of interactions that are needed to help a group continue working meaningfully and enthusiastically. However, in many cases there are various reasons that groups may need some guidance, such as when groups are "stuck", sidetracked, could benefit from thinking more broadly or in a more focused way about the phenomena, or could benefit from connecting together ideas and experiences related to the phenomena. Some examples of possible interventions include: pointing out something that people haven't seen, suggesting that they look at someone else's work, suggesting that they draw or represent what they think is going on, suggesting that they try something again, suggesting a path they might pursue, or asking them to consider a thinking tool.

Periodic, Focused Sharing

By soliciting sharing of their work among the various groups, we help to build a community of inquiry. They can gain from each other's findings to help clarify ideas. They also use the ideas of others to help suggest where they might go next with their own investigations.

In the balance inquiry, relatively frequent short periods of sharing have proven very useful. These brief times for group sharing can be focused by prompting the sharing with a focusing question suggested by what the facilitator has seen happening in the groups. For instance, in one workshop several groups started talking about the apparent existence of some sort of "balance center". When they stopped for sharing the facilitator said, "I have heard a number of people talking about there being some sort of 'center' in their balance. Could you share your group's experience of seeing some sort of 'center'?" **Final Sharing of Results**

At the end of the investigation period, groups share information about both their investigation process and what they learn. This serves several purposes:

- **consolidation of learning** ---no knowledge is complete. There are always questions to pose and more understanding to gain. Because of this, inquiry often ends with as many questions as it starts out with (albeit, they are new questions). In that sense there is no final closure. However, there are "resting points" or places where you can consolidate your progress and leave off further investigation until another time. It is important to provide help with this period of consolidation so that inquiry learners realize that they have made progress toward understanding by doing their investigations.
- **developing group understanding** ---during the sharing of information we encourage group interaction, their asking questions of each other and continued dialogue. We also elicit and point out discoveries that we had noticed them make. Active facilitation can help the group come to a conceptual understanding based on the combined findings from the whole group's work.

Synthesis of Conceptual Understanding

After the group sharing we present a brief synthesis of the major concepts underlying the topic of balance (see attached "Balance - What's Happening Here"). Inevitably, these concepts will have been touched on to a greater or lesser extent in the presentations done by the groups. We prepare the presentation of these concepts ahead of time often making up charts to support our talk. However, all of the example and amplification of the ideas are taken from the group presentations just completed.

This presentation of the balance concepts is another element in helping the group to consolidate their learning. It helps individuals connect the ideas that they have been forming with the standard way of talking about the concepts and with the standard vocabulary. By having some part of this presentation written ahead of time, it shows that there are definite content learning goals for this experience. The fact that, during the inquiry, the groups touched on most if not all of these concepts, reinforces the idea that inquiry can be used to teach specific content.

Debriefing the Inquiry Experience

While involved in the inquiry experience we ask that the participants stay in the role of the learner. Although we have them talk about both what they learned and their process and path through that learning, we have them do it from the perspective of learner.

After completing the inquiry experience, we ask the participants to switch to their role of educator and reflect on that experience. Sometimes, we will start this reflection by giving them 10 to 15 minutes to write in journals. We follow that with small group (12 or fewer people), facilitated discussions lasting from 25 to 45 minutes. Both journal writing and the group discussion are prompted with, "Describe what you learned about the process of investigation based on your personal experience." Additional prompts given during the discussion depend on who your group is and what you are trying to achieve with that group. For instance, with a group of administrators, we ask, "Given your district responsibilities, what issues have come up for you regarding supporting doing inquiry investigations?"

The discussion of the inquiry experience initiates the process of translation from workshop participant's personal learning experience to their thinking about implications for classroom teaching and hence a critical element of this professional development experience.

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Balance Inquiry Schedule for Inquiry Leadership Seminar

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- 9:00 - 9:10 Introduction (Set context for the inquiry experience)
- 9:10 - 9:20 Pre-assessment activity
- 9:20 - 10:05 Rotate through 4 stations (8 minutes per station)
- 3-D balance (tinker toys)
 - 2-D balance
 - balance board
 - Pegboard beam
- 10:05 - 10:10 Written reflection (Surprises, observations, question)
- 10:10 - 10:35 Share surprises, observations. and questions with the whole group.
- 10:35 - 10:50 - Have people write questions on sentence strips.
- 10:50 - 11:00 Break
- 11:00 - 11:20 Return to area of interest and explore further (find another person or two to partner with in your area of interest)
- 11:20 - 11:35 Focused Sharing
- 11:35 - 11:50 Thinking Tool - Pack on arm demonstration
- 11:50 - 12:00 Plan with a partner
- 12:00 - 12:10 What will you focus on and pursue?
- 12:10 - 12:20 What questions will you try to answer?
- 12:20 - 12:30 - Write these on a piece of paper
- 12:30 - 12:40 LUNCH
- 12:40 - 1:00
- 1:00 - 1:10 Setting the Stage for the investigation
- This short investigation will allow you enough time to look at the peaks and valleys of inquiry, share the process - a sort of inquiry into inquiry. Indicate contact person for each group. If you feel you are getting nowhere or are stuck, check in with your facilitator. We're here to help. We'll have groups share their experiences .
- 1:10 - 1:40 Small group focused investigations
- 1:40 - 1:50 Center of Mass Thinking Tool
- 1:50 - 3:50 More investigation time (Incorporate break)
- 3:50 - 4:20 Whole group sharing by group - Tell a little about where you started, your process, where you might go from here
- 4:20 - 4:35 Synthesis
- 4:35 - 4:40 Post-activity assessment
- 4:40 - 4:50 Clean-up

4:50 -5:00 Journal (Reflect on inquiry experience) and end of day closure

Next Day

9:00 - 9:20 Analysis of assessment

9:20 - Debrief of the inquiry experience discussion 4 groups -

10:00 1) describe what you learned about the process of investigation
based on your personal experience;

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Balance Investigations

Starting Point / Inquiry Initiators --- Four balance stations

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A quick rotations through four stations provides an introduction to the phenomena of balance and the tools provided to investigate these phenomena. This stage of inquiry is called "messaging about", or the exploratory stage. It is designed to engage peoples' interest and generate questions.

Time

45 minutes

Grouping

1/4 of the group is at each station

Materials

See materials list.

Stations

- Pegboard beam
This stations has a length of pegboard (3 holes by 21 holes) hanging from a nail on a stand. Metal washer weights are hung from this using bent paper clip hooks. This is a good station for exploring quantitative relationships of weight and distance.
- Balancing board
At this stations 4 foot long 1x4 boards are balanced on fulcrums. Rounded fulcrums made with cut mailing tubes provide fairly stable balances. Half-round wooden molding provide a slightly less stable fulcrum. A pointy edge fulcrum is almost impossible to balance. Uniform wooden blocks are available to pile on the boards. Piling blocks high on the balance beam provides of the intriguing phenomena. For a different scale, small balance beams made of yardsticks cut in half with sugar cubes for weights are also provided.
- Two-dimensional balance
Odd shaped pieces of pegboard are balanced on tennis ball fulcrum at this station. Weights made of film canisters filled with sand are used to explore this balance. One of the pegboard pieces is cut so that it can't be balanced without weights added to it.
- Three-dimensional balance
At this station, people are challenged to build onto a "Fiddle-stix" (tinker toys) piece with a small dowel with a point sticking out so that it will balance on that point. After balancing it, they explore what effects the balance.

People are told to explore the materials at each station. At each station, we put a sheet with suggested things to try. (See following pages for copies of these.)

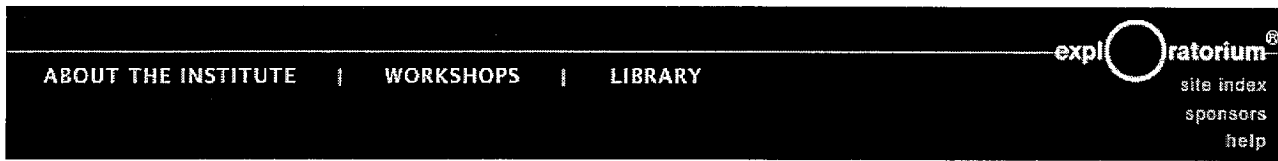
Rotations

People are told that they will get eight minutes at each stations. They will necessarily be cut off on what they are doing. The idea is to give them a chance to experience all of the tools that we have set out before they focus in on a particular direction. They will be given the opportunity to return to their interest after rotating through the stations.

Discussion

After the rotations people are asked to share observations and questions.

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Balance Boards

Explore the large and small balancing boards

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Suggestions:

- Is it possible to build up on the boards and keep both ends off the table without propping it up?
- Can you balance the board off center?
- Try balancing the board with three blocks of equal weight. Is there more than one arrangement that works?
- Try to move blocks on a balanced board and maintain the balance.

Challenge:

- Can you balance the board on a pointy fulcrum? You may add anything you like to try to make it balance.

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Balance Investigations

Pegboard Beam

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Explore balancing the pegboard beam on the nail.

Try hanging washers on bent paper clip hooks from the holes in the beam.

Suggestions:

- Try the middle row, top row and bottom row of holes on the nail.
- Try hanging washers one below the other.
- Try balancing one washer against two or three.
- Try other combinations.

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Balance Investigations

Two-Dimensional Balance

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Explore the irregularly shaped boards on the tennis ball fulcrums.

Suggestions:

- Try balancing an irregularly shaped board on a ball. You may need to add weights to make some of them balance.
- Try adding and moving around weights.
- Try balancing it in both level and tipped positions.
- Find different combinations and positions of weights that balance.
- Try adding more weights once you get it balanced.

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Three-Dimensional Balance

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Find a way to balance "tinker-toys" on a point.

Once you get it balanced -

Suggestions:

- What additions or changes make it more stable? What makes it less stable?
- Try making it more or less symmetrical.
- Try to make it taller.
- How does adding or moving pieces effect the way it moves or sways?

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Balance Investigations

The Pack on the Arm Demonstration¹ Focusing on Torque and Lever-Arm

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After a short time of exploring balance phenomena, people usually realize that it is not just the weight but also the location of the weight that effects balance. In order to focus this idea the facilitator does a demonstration that helps define the concept of torque and lever-arm. The following is a description of that demonstration.

We start the demonstration by having people choose a partner. Partner one stands with one arm held straight out to their side. Partner two takes a heavy purse, bag, or pack and hangs it by the strap on the outstretched arm near the shoulder.

- Facilitator: "Take note of how heavy the pack feels now. O.K. Partner two; now hang the pack out to near your partners fingers. Does the pack now feel heavier or lighter?"

It is quit clear that the pack feels heavier. Some people can barely hold their arms out and all recognize the difference.

- Facilitator: "So what is going on here? Has the Earth's gravity suddenly gotten stronger? Did the weight of the pack suddenly increase as it was moved out near your fingers? Clearly neither of these answers seems to be the case. **The strength which the pack exerts to twist your arm about your shoulder depends both on its weight and how far out the weight is from your shoulder.** The further out, the more twist you feel. Closer in, you feel less twist. Your shoulder acts as a fulcrum or pivot point. Just as with the balances that you have been working with, the effect of the weight depends on its distance out from the fulcrum. **This combination of weight and distance is call torque.** [Write the word out for all to see.] In general, torque is the combination (product) of any force and distance from a pivot that tends to twist the object about the pivot."

Partner one is now asked to stand with one arm outstretched while partner two pushes horizontally on the arm, first close to the shoulder and then close to the hand. Partner one should try to resist the push.

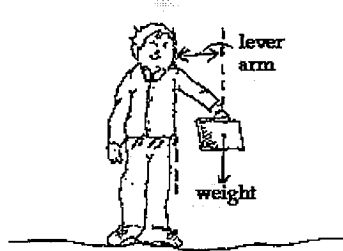
- Facilitator: "You noticed that this was similar to the pack in that the push that was further from the shoulder felt stronger. The concept of torque, the combination of force and distance from a pivot, works for any type of force . In balance, the force that we work with is always weight pulling downward."

To look at one additional refinement of the concept of torque the partners are asked to try one additional demonstration.

- "Hold the pack out at arms length and notice how strongly it twists the arm about your shoulder. Next, hold the pack by your side with your arm down.

Even though the pack is the same distance from your shoulder, you do not feel it trying to twist your arm. There is zero torque.

Now, holding your arm rigid, slowly lift the pack until your arm is horizontal. You probably notice that the further the pack gets from your side, the heavier the pack feels; the larger the torque becomes. The torque is actually determined by the combination of the weight and the horizontal distance out from the pivot-point or fulcrum." (see illustration)



"This horizontal distance from the fulcrum to the force is called the lever-arm. Therefore, in balances, the torque for each weight is the combination (product) of the weight and lever-arm for that weight. You are balanced when the torques twisting you to the right (or clockwise) equal the torques twisting to the left (or counterclockwise.)

¹If desired, the facilitator can give additional examples of torque from everyday experience. These could include screwdrivers, torque wrenches, automobile engines and bicycle gears.

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Balance --- What's Happening Here?

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There are a number of fundamental concepts which lie at the heart of the balance phenomena experienced in this investigations. These concept include:

- Equilibrium
- Torque
- Center of Mass
- Stability
- "Self-reactive" systems (feedback).

Equilibrium

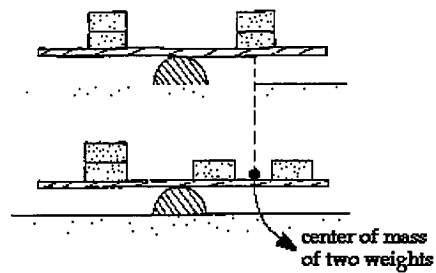
Equilibrium is actually just a more expressive word for balance. A balance board is balanced or in equilibrium when the forces pushing up equal the forces pushing down and the torques tending to twist it clockwise equal the torques trying to twist it counterclockwise. This definition can be expanded to balances that are not just along a line by requiring opposing forces and torques in all dimensions (i.e. left and right, up and down, forward and backward) to be equal in order to be in balance.

Torque

Torque the combination (product) of force and distance that twists a balance about its fulcrum. For balances, the force is the weight and the distance is the horizontal distance of that weight from the fulcrum (called lever-arm). See [The Pack on the Arm Demonstration](#) for more on torque.

Center of Mass

The center of mass of a system of masses or weights is the point about which all forces and torques are in equilibrium. If you could put a fulcrum at that center of mass, the system would be in balance. The center or mass is a particularly useful way of thinking about a system of weights since you can treat the system as if all the weight is concentrated at that point. For instance, the balance board shown below has four equal weights on it. Two in the middle of the left side are balanced by two on the right each moved an equal distance away from the middle of that side. The center of mass of the two weights on the right is shown. Their combined weight acts as if it were at that point.



For a uniform, symmetric material the weight is spread throughout the material but the center of mass is at the geometric center. For instance, the center of mass of a uniform meter stick is at the 50 cm. mark. If the material is not symmetric the center of mass may be harder to find. In some cases the center of mass is not even physically within the material.

Stability

People find that the lower the weight, the more stable the balance. By stable, we mean that the balance finds a resting point easily and returns to the resting point if disturbed slightly. If you look at the center of mass for the entire system, the system is balanced (in equilibrium) if the center of mass is directly above or below the fulcrum. However, if the center of mass is above the fulcrum it tends to fall over and the balance is unstable. If the center of mass is below the fulcrum, it acts like a pendulum weight which always returns to the bottom and is stable.

Self-reactive System (feedback)

The stability and instability described above can be understood in terms of a balance reacting back on itself. In a stable balance, when the balance is tilted out of equilibrium, say clockwise for example, it moves in a way that increases the torque twisting it counterclockwise and decreases the torque moving clockwise. As it moves back toward the equilibrium position the counterclockwise torque begins moving back down and the clockwise back up until they are equal again. Unstable balances do just the opposite. When they are tilted out of equilibrium they move in a way that increases the torque tending to move it even further out of equilibrium. These kind of "self-reactions" are called feedback.

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Materials List for Balance Inquiry

Materials Needed (for 36 participants)

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Fiddlestix Balance

(Formerly Tinker Toys)

- 10 fulcrums.
Fulcrums can be made by sharpening the end of a 3/8" dowel (1/4" for tinker toys) with a pencil-sharpener and cutting it off at about 1-1/2" - 2".
- Four 90 piece Fiddlestix Sets or four Tinker Toy construction sets
- 8 - 10 stands . You can use a 12" -24" 1x2 nailed to a scrap 2x4 or larger base. Another simple stand is a 3/4" dowel or a piece of 1x2 in a coffee can full of sand. Bottles filled with sand or water closed with a cork also work.

Tips

- We prefer the old wooden tinker toys (for aesthetic reasons). However, they can now only be found in specialty catalogues and at garage sales. The brand Fiddlestix has replaced the Tinker Toy and can serve the same purpose.

Balance Board

Materials Needed:

- 8 - 10 four-foot 1x4 boards
- 10 rounded fulcrums (4" diameter mailing tubes, cut to 3" lengths and split to make a half-ring shapes)
- Several fulcrums with different diameters (e.g. 1" half-round wooden molding cut to 3" lengths; cardboard carpet tubes split and cut to 3" lengths.)
- 6 "pointy" fulcrums (triangle shaped wood molding cut to 3" lengths)
- 60 wood blocks. Cut 2"x4"x6" pieces or use sets of blocks of about uniform weight .

Little Balance Board

Materials Needed:

- 4 yardsticks cut in half
- 8 fulcrums (1" half-round wooden molding cut to 3" lengths)
- 1 2# box of sugar cubes

Two Dimensional Balance

Materials Needed:

- 6 odd shaped boards about 16" in largest dimension cut from 1/4" masonite pegboard. (Sample shapes shown below.)



- 100 Assorted weights such as large and small washer or film canisters full of sand
- 6 tennis ball in cup fulcrums
Fulcrums can be made by wedging a rubber ball or old tennis ball in a cup or juice can that has been cut to about half the height of the ball.
- Several extra 2' or larger super balls, marbles, etc. for alternative fucrums
- 1# box of sugar cubes (optional)

Pegboard Beam

Materials Needed:

- 8 pieces of 3/16" pegboard cut in strips 3 holes high by 21 holes wide
- box of 100 large paper clips used for hooks
- 100 - 150 1/2" metal washers for weights
- 8 stands (These can be made with a 1x2 nailed to a scrap 2x4 or larger base or supported in a coffee can full of sand. Near the top of the 1x2 hammer a small finishing nail on which to hang the pegboard beam. See below.)



Additional Materials

- 2 rolls 3/4" masking tape
- 1 pack 8" to 12" bamboo skewers
- 2 # oil based modeling clay
- 1 roll (50 - 100 feet) 16 gauge steel wire
- 2 - 3 wire cutters/pliers

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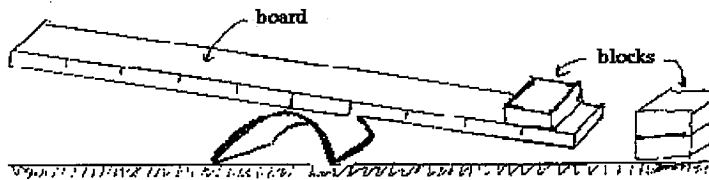
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MAKE IT BALANCE

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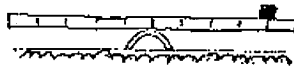
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Draw **below** where to add two identical blocks to each board to make it balance.
Draw at least one where the **blocks don't touch each other**.

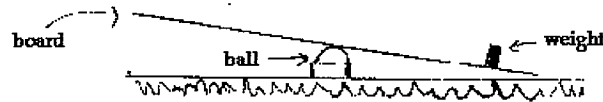
1)



2)



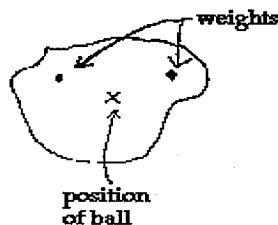
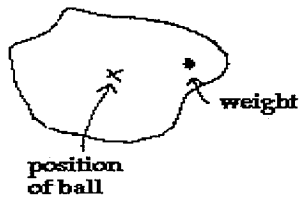
B)



Draw below where to add identical weights to make these unbalanced boards balance.

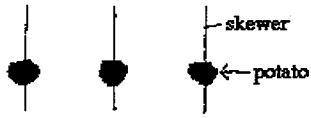
1) Add two weights.

2) Add one weight.



C) The drawing on the left represents three "identical" small potatoes, each with a skewer through it.

Draw how you could stick these together so that the tip of one of the skewers balances on the top of the stand.



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