Kinetic Sculpture

A Do-It-Yourself Guide to Promote STEM Skills and Awareness

Summary:
Students are introduced to key concepts and skills of kinetic sculpture, including balance, gearing, energy sources and design-oriented chain-reaction-type artwork.

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Dear Educator,

Welcome to the course Kinetic Sculpture. Over five days you will have the opportunity to assist students as they explore familiar materials in new and whimsical ways. Through the manipulation of traditional art supplies, recycled materials, hardware, and food, students will build a variety of kinetic elements. In the process they will experiment with concepts such as center of balance, potential and kinetic energy, gear mechanisms, and harnessing wind-generated power. They will also explore how to optimize the visual and auditory aesthetics of their works and be exposed to the work of some masters of kinetic sculpture.

The overall challenge of this week will be for students, working in groups, to create a sculpture that incorporates movement, other visual stimuli, and sound, and that is designed as a whole to evoke emotions such as calm, anticipation, and surprise. There are secondary challenges throughout the week that will introduce students to concepts and components that they will be able to incorporate into their final sculpture. It is
important that students be reminded throughout the process that their kinetic sculpture can involve many different elements. It need not be strictly a marble run, for instance, nor include a marble run as an element at all. You will be exposing them to several kinds of kinetic art that they may choose to use to express themselves.

You may find that some students will be ready to jump right in. Others may find they need to test the waters before they are comfortable exploring. As a mentor you can help both kinds of students by helping to create a supportive environment where the journey is at least as important as the goal.

Create a welcoming space for the students:

- Hang mobiles around the room.
- Have various balancing toys available for them to handle.
- Place pinwheels, windsocks, and similar objects near an open window or fan.

We highly recommend reading through the whole curriculum prior to the start of the week, trying out the activities yourself and taking the time to glance through the links to the articles and videos we have selected to include in the introduction. These are items we found to be insightful, helpful, or exciting (sometimes all three). You may find you’d like to share some of them with your students. These are only a fraction of the worthwhile resources out there; once you start digging you might find it hard to stop.

We hope you have fun with this. We certainly have!

Happy building,

Joan and Ari
# Kinetic Sculpture Teachers Guide

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Appendix (in separate files)

PDFs:
- Acrobat template; one per student
- Gear-ratio sheets; one per team (figure two–four students per team)
- “Getting into Gear” challenge sheets; one set per team
- CamCards; printed on heavy stock and cut; one card per team
- Cam-parts diagram

Bill of Materials
General Lab Safety
Notebooks
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*Introduction to the Course*

**Part 1: Desired Results**

*Enduring Understanding:* Students will gain an understanding of connections among art, science, and engineering. They will develop an appreciation for the aesthetics of large and small movements, sounds, and other elements within kinetic sculptures. They will view themselves as creators, problem solvers, and collaborators.

**Goals for the Course**

Goals include exposing students to areas of STEM they have not already seen at school, different possible careers in STEM they had not previously considered, and the overall nature of engineering (collaboration, reiteration, troubleshooting, communication, etc.).

- Introduce students to connections between science and art
- Introduce students to basic principles of physics, and show students unexpected applications of principles they already know
- Give students the sense that they are creators, designers, artists, engineers
- Teach students useful life skills such as collaboration, problem solving, and revision

**Students will be able to:**

- Apply physical principles to achieve aesthetic effects
- Sketch design ideas
- Communicate ideas with team members and peers
- Incorporate feedback
- Build working models of their ideas
- Modify components and compare results

**Students will understand:**

- Center of balance
- Balanced and unbalanced systems
- Gear ratios
- Relationships between kinetic and potential energy
- How to incorporate wind power into mechanical devices
- How contemporary artists have used physical principles in designing kinetic sculpture

**Part 2: What Evidence Will Show That Students Understand?**

- Evidence of understanding will be shown when students are able to design and create their own working kinetic sculptures.
- Students will harness the power of gravity and wind.
- Students will be able to plan, connect and explain their ideas.
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- Students will revise their work to accommodate new information.
- Students will keep a journal (see “i2 Camp Notebooks” in the appendix) to record their ideas and sketches for elements of a kinetic sculpture.

Note that while this document contains specific instructions for kinetic sculpture, it should also be viewed as a guide, which can (and should) be modified at the instructor’s discretion according to the needs and situations in individual classrooms.

Part 3: The Learning Plan

Classroom Requirements
- Big, flat tables rather than desks. Typically found in chem-labs or phys-labs. Example dimensions for table: 100 cm × 182 cm.
- Open floor spaces
- Several electrical outlets for each table

Equipment Needs
- Whiteboard or chalkboard
- Equipment for sharing online videos
- Internet access for linking to online videos
- LCD projector

Materials List

Suggested Field Trip(s)
No field trips planned

Safety Concerns

Note: See “General Lab Safety” in the appendix.

While the glue guns provided are low-temp guns, they still get hot enough to burn, as does the heated glue. Remind students to use caution when they are in use.

Students will also be using cutting blades. These should be used with care and safely stored when not in use. Provision should be made for a “sharps” container to store used blades. An empty jar or soda can is good for this. Used blades should not be discarded in the trash.

The food used in the course is not to be eaten. It is likely to have been handled by others and to have come into close contact with inedible substances. In addition, students should develop the fundamental instinct that objects associated with laboratory activities should not be viewed as edible.
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Additional Resources for Instructors

Note: It is quite common for K–12 schools, for the safety of the students, to block access to YouTube resources. The instructor may want to check with the site manager at their school to make sure YouTube is available. Very often, the IT manager for the school can temporarily allow YouTube access. Some of these resources may also be available on TeacherTube. CHECK AHEAD!

Calder:

http://www.theartstory.org/artist-calder-alexander.htm
http://www.calder.org/
https://www.artsy.net/artist/alexander-calder
Video: http://video.wttw.com/video/1614701629 (5:09)

Creating mobiles:

http://www.marcomahler.com/how-to-make-mobiles/
Video: https://youtu.be/b5GTUM-Q2g0
Video: https://youtu.be/Cw4BHfuA7ws
Video: https://youtu.be/O0VKpmsj1nA
Video: https://youtu.be/n9VaylREiAQ

Kinetic-art videos:

https://youtu.be/8QiOAg_Caig
https://youtu.be/mDlqe3s09sE
https://youtu.be/1CNU3DQclGs

Interesting articles, links, and videos about automata and toys:

http://cardinalreader.weebly.com/woodshop.html
http://dugnorth.com/

Wind turbines:

http://www.dw.de/the-wind-turbine-that-looks-like-a-tree/a-18344921

Gears:

https://youtu.be/odpsm3ybPsA
# Suggested Timeline

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Classroom Requirements/Setup

A large classroom is best. This classroom needs to be thought of as a “workshop” and set up accordingly. Work space is the primary function, both tabletop space and floor space. Gathering space will also be important. A whiteboard/blackboard would be helpful for instructors and students to share concepts with one another. Wifi and equipment for sharing online videos is also required. The distribution of power outlets in the classroom is very important. Depending on the classrooms available, there may or may not be power outlets near each worktable. If the power outlets are restricted to the perimeter of the classroom, then extension cords will need to be used and these should be taped down and visibly marked to reduce the risk of a students tripping over them. Tables or desks should be positioned to allow instructors and students to walk freely around each table.

Tables
Tables should be set up as four- or six-person work spaces, depending on the size of the available tables; each student needs to have ample personal work space. Good dimensions for tables are 100 cm × 182 cm.

Cords should be taped down—brightly colored tape will help make the cords visible to students. Each student may also have metal trays or small sheets of chipboard to work on when using the glue guns. This will help protect the tables from any possible burns or scratches.

Classroom Organization
Safety is very important and a first-aid kit should be stored at the front of the classroom. A sink would be beneficial to have in the room so that students might wash their hands before snack time, and so that any burns can be dealt with immediately by immersion in cold water.

Safety Concerns
Keep a first-aid kit in the classroom. The first-aid kit should have cold packs, burn cream, and band-aids. Make sure each student and instructor has safety glasses but also keep several extra pairs. See “General Lab Safety” in the appendix.

Remember that any injured student should be sent to the nurse.

Course Goals/Objectives

- Instill a notion that art and science are intertwined
- Expose students to various artists
- Give students exposure to different kinds of kinetic sculpture
- Work with students to provide experiences of moving from ideas to sketches to creating objects
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- Provide students with skills to tinker with materials on their own and encourage students to tinker and think about creating sculptures beyond the course
- Foster collaboration and communication skills (students will work on some activities in teams of two or more)
- Give students exposure to the design process
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Day #1: Balance

Preparation

• Gather wooden dowels used in activity #8. Bend dowels slightly. This is most easily done by first soaking the dowels in water. Then bend them into a shallow bow shape by weaving them through the back of chair or by resting them over a rolling pin with books weighing down the ends. Leave them in these molds to dry overnight so they will maintain a slight curve when removed.
• Reproduce needed printouts: acrobat template
• Create sample for activity #3
• Create demo balance for activity #7
• Create sample ramp walker for activity #9

Materials

Jenga set
Markers; several
Craft sticks; 1 per student
Chenille stem (pipe cleaner); 1 per student
Washers, 5/16”; several per student
Beads; several per student
Chipboard, 8.5” × 11”; 3 per student
Pencils
T-pins; 1 per pair
String, yellow; 12” per pair
Colored pencils
Scissors; 1 per student
Magnets, 3/4”; 7 per student
Single-hole paper punch; several
Index cards, two-tone
Yellow string
Blue string
Red string
Print-out of acrobat on heavy card stock (PDF in appendix); 1 per student
Needle-nose pliers with wire cutters; 1 per student
Wooden dowel, 12” × 3/16”; 1 per team plus 1 per student
Wooden dowels, 12” × 3/16”; 7 per student, bent
20 gauge wire, 3” segments; 10 per student
Corrugated cardboard strips, 3” × 12”; 1 per team

Additional materials are listed with each activity.
Goals and Objectives

*Students will engage in a number of tasks to help them learn about center of balance.*

Overview

| Activity #1: Meet the Team | Students will learn one another’s names while engaging in a balancing task. | 15 min |
| Activity #2: Balancing Sweet Spot | Students will balance craft sticks on their fingers. | 25 min |
| Activity #3: Mass Distinction | Students will learn how to locate the center of mass of irregular objects. | 25 min |
| Activity #4: Balancing Acrobat | Students will build a balancing toy. | 40 min |
| Activity #5: Introduction to Mobiles and Calder | Students will explore the definition of mobiles and be introduced to the work of Alexander Calder. | 15 min |
| Activity #6: It All Balances Out | Students will explore restoring balance when center of mass shifts. | 30 min |
| Activity #7: Branch Mobile | Students will create a simple branch mobile. | 40 min |
| Activity #8: Asymmetric Calder-Style Mobiles | Students will create asymmetric mobiles. | 55 min |
| Activity #9: Off Balance | Students will design and build a ramp-walking toy. | 40 min |

Introduction to Day #1

Welcome the students to Kinetic Sculptures. Ask for a show of hands from those who have seen a kinetic sculpture (a sculpture that incorporates movement of some kind) ever before. Call on a few of them to describe the sculptures they have seen. As a group, generate a list of elements a kinetic sculpture might have (things that spin, twirl, roll, flip, etc.).

Let students know that this week they will work together to design and build kinetic sculptures. The final sculptures will use wind, gravity, or viewer interaction (or a mix of the three) to power their movements. Students may decide to make the movements slow or quick, small or grand. Some may choose to make the sculpture one that is continuous or resets itself, while other groups may design one that needs to be reset by the viewer. Regardless of the path teams take in their design, they will create a sculpture in which the movement will add to the experience of the viewer. Throughout the session they will be working on projects that will help prepare them to tackle that challenge, as well as viewing a variety of kinetic sculptures to provide inspiration.
Activity #1: Meet the Team  15 minutes

Goals and Objectives
Students will introduce themselves to one another while engaging in a balancing task. They will begin to collaborate on a project and practice communicating their ideas with one another as they strive to build the tallest tower they can.

Materials
Jenga set
Markers

Procedure
1. Pass out a block from the game Jenga to each student.

2. Each student should write his/her name on the block with a marker.

3. Everyone in the group should sit in a circle around the area where the game will be played.

4. Have each student introduce him/herself to the group as you collect his/her signed Jenga block.

5. You do not need to use all the blocks in the game but will want the number of blocks in use to be a multiple of three. You should add blank ones to the mix to achieve this.

6. Set up the game on the floor or a table, as instructed in the game rules. The game will be played by the original rules with some additions (see below).

7. The instructor should go first. Introduce yourself again. Choose a block to make your move and remove it from the stack. Before placing it on the top read the name written on the block and point to that person. If you cannot remember who that person is, ask for him/her to identify him/herself.

8. Continue around the circle having each student share his/her name and introducing the person whose name is on the chosen block at each turn.

9. Continue until all the students have introduced themselves or until the tower falls.

*If* the tower falls prior to each student having a turn, shuffle and restack the blocks in the starting position. Resume play with the last person having gone going first. Continue around until each has had at least one turn.

**Note:** Depending on how many students there are there may be some blocks with no names on them. If a student pulls a blank block she/he should take a second turn.
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Activity #2: Balancing Sweet Spot  25 minutes

Goals and Objectives
Students will experiment with balancing principles and apply knowledge gained to balance a craft stick on its end.

Materials
Craft stick; 1 per student
Chenille stem (pipe cleaner); 1 per student
Washers; 2 per student

Sample created as follows:

1. Take a chenille stem (pipe cleaner) and fold it in half.
2. Open the stem and place a craft stick on the fold such that the stem is about 1/4 of the way down the craft stick.
3. Wrap each arm of the stem around the craft stick one complete wrap.
4. Attach a washer to the end of each arm.
5. Place the craft stick on the end of your finger and bend the chenille arms until you can balance the unit there.

Procedure
1. Give each student a craft stick.
2. Ask students to balance the craft stick on one end on their fingertips.
3. Ask students for feedback. Have any succeeded?
4. Show them that it is possible by sharing your sample.
5. Distribute a chenille stem and two washers to each student and have each of them experiment to make the craft stick balance.

Questions
What sort of adjustments did students need to make to get it to work? (Attaching the chenille stem lower on the stick; bending the chenille stem.)

What adjustments would be necessary to get it to balance more horizontally instead of vertically? (Bend the chenille stems to hang at about a 45-degree angle from the vertical.)

Ask students why this works. Don’t give any answers yet—that will have to wait until the next activity. Leave the question open, but do gather and record their suggestions.
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**Activity #3: Mass Distinction**

**35 minutes**

**Goals and Objectives**
Students will learn what the center of mass of an object is and how to locate the center of mass of an irregular object.

**Materials**
- Chipboard sheets for demos
  - 8.5” × 11” full sheet
  - 8.5” × 11” sheet cut into an irregular shape
  - 8.5” × 11” sheet cut into the irregular shape with a piece cut out of the center
- Chipboard sheet; 1 per student with spares
- Magnets; 6 per pair of students
- Pencils; 1 per pair of students
- 12” yellow string with a small loop tied at one end and a bead suspended from the other; 1 per pair of students
- T-pins; 1 per pair of students

**Procedure**

1. Explain that the center of mass of an object is the average position of all the object’s mass. When the object moves just under the influence of gravity (for example, when it is thrown or dropped), the object moves as if its entire mass were located at its center of mass. For example, if you throw an irregular object, the object itself may spin and tumble, but its center of mass follows a smooth parabola. Show this video: [https://youtu.be/DY3LYQv22qY](https://youtu.be/DY3LYQv22qY) and perhaps also this one: [https://youtu.be/M-XOB0640zY](https://youtu.be/M-XOB0640zY). Present a sheet of chipboard.

2. Solicit ideas about where students think the center of mass is.

3. Demonstrate the procedure for how to find out:
   - Stick a T-pin through the loop on one end of the string, and then stick the pin into the sheet of chipboard. Hold just the T-pin and let the chipboard and string swing freely until both are at rest.
   - With the other hand grasp the bottom edge of the chipboard and the string where it crosses the edge.
   - Have a helper mark where the string crosses the edge of the chipboard and then, using a ruler, carefully draw the line from the T-pin to that point.
   - Repeat this two more times, sticking the T-pin into a different point on the chipboard each time.

4. Have students note where these lines cross. This point is the center of mass. The chipboard should hang from this point in a relatively stable way.
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- To show this, insert a T-pin at some other point and hold just the pin; the chipboard will rotate rapidly until the center of mass is directly below the pin.
- Now insert the pin at the center of mass, and the chipboard will not rotate. (Or, since the location you identified for the center of mass is not perfect, the chipboard will rotate a bit, but not nearly as rapidly as when the pin was inserted far from the center of mass.)
- If you insert the pin at points far from the center of mass the chipboard will be unstable, and if you insert the pin at points near the center of mass the chipboard won't "care" as much about its orientation, because no matter how it is oriented the center of mass can't be moved much lower by the object's changing orientation. (You can try moving the pin's location around a bit to find a location where the object is stable; that will be the true center of mass. But you may not want to take the time to do this, since it involves a lot of very minor adjustments.)
- Wherever you insert the pin, the object will rotate so that it rests with the center of mass directly below the pin.

Where gravity is concerned, the object will act as if all its mass is at the center of mass. This means that the object's most stable position will be one in which the center of mass is as low as possible. If you rotate the object in a way that raises the center of mass, the object will "want" to rotate back in order to lower the center of mass; ultimately, that will mean that the center of mass will lie directly below the suspension point, no matter where that is. That is why this system for finding the center of mass works.

5. Repeat steps 2–4 using the irregularly shaped chipboard sheet.

6. Present a different irregularly shaped sheet with a hole cut out of it—prepare the sheet in advance such that the center of mass is in the section where you have cut the hole, so that the part of the object where its center of mass lies is "missing." Have students predict where they think the center of mass will be.

7. Repeat the process to determine where the center of mass is for that shape. This will be tricky, because the lines will cross in empty space. The idea in this case is not to find the exact center of mass, but to show that the center of mass can lie someplace where there is no mass at all—it's just the "average" position of the object's mass.

8. Each group should gather a chipboard sheet, six magnets, a piece of yellow string with a loop on one end and a heavy bead on the other, a T-pin, and a pencil. Show the students how to attach pairs of magnets to the chipboard by placing one magnet on each side, oriented so that they attract one another through the chipboard, staying in place via friction.
9. Students should attach each of the pairs of magnets somewhere on their chipboard creating a system with uneven mass distribution and therefore a shifted center of mass.

10. Using the method demonstrated earlier they should find the center of mass for their new system.

11. Then they should try to come up with an arrangement (shifting or removing the magnets, cutting away some of the chipboard, etc.) that moves the center of mass to an area outside of the sheet of chipboard or contained in an opening they created in it.

12. Now is the time to discuss why the pipe-cleaner-and-craft-stick device worked. Using your device as an example, ask students where the center of mass of the device is (if you draw an imaginary line between the washers, the center of mass will be just above the center of that line, directly below the point on which the stick balances). Now tilt the device and hold it at the new angle, and ask what has happened to the location of the center of mass. (Since the center of mass originally hung below the balancing point, when you tilt the device the center of mass will rotate to the side and up a bit.) Tilting the object has raised the center of mass. Remember that where gravity is concerned, the object acts as if all of its mass is at the center of mass; raising the center of mass is like raising the mass of the whole object. Under the influence of gravity, the center of mass will move as low as it can go in order to be stable. In your device, the lowest the center of mass can go is when the washers are both hanging down, with the center of mass between them and below your finger.

Next students will use this set of ideas to create a slightly more complex balancing toy.
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Activity #4: Balancing Acrobat  

40 minutes

Goals and Objectives
Students will use their knowledge of how the center of mass of a balanced object affects the object’s balance to build a more complex balancing toy.

Materials
Printout of acrobat on card stock (PDF provided in appendix); 1 per student
Chipboard sheet, 8.5” × 11”; 1 per student
Colored pencils
Scissors; 1 pair per student
Stapler; several
Staples
Wooden dowel; 1 per student
Magnets; 4 per student
One-hole punch; several

Procedure
1. Hand out acrobat printout and have students cut out the figure and the arch to create templates.
2. Using these templates students should trace the design onto chipboard and cut out the pieces.
3. Give students a few minutes to color and decorate the acrobat and balancing bar.
4. Students should use the hole punch to punch a hole in the bottom of each foot as indicated by the X on the original template.
5. Legs should be gently separated, one pulled forward and one pressed back to create a forward split.
6. Staple the arch to the acrobat such that the arch is hanging like an upside-down horseshoe (as if the acrobat is holding the arch at hip level).
7. Insert the dowel through the holes in the acrobat’s feet, being sure to maintain the forward split. The split is necessary so that the acrobat doesn’t “bend” forward or backward.
8. Hold the dowel horizontally.
9. Place each end of the arch between two attracting magnets.
10. Have one student hold the dowel as the other teammate adjusts the magnets along the arch to obtain a good balancing act. The acrobat should be able to gently rock upright on the dowel. (Note: be sure to maintain the acrobat’s split stance. Otherwise it will bend and flip upside down!)
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Optional Extension
Have students experiment with different arches. Can they design a shape/size that improves the acrobat’s balance?
Activity #5: Introduction to Mobiles and Calder  

15 minutes

Goals and Objectives
Students will be given a brief introduction to the artist Alexander Calder and his work as well as the art form of the mobile.

Materials
A picture of Alexander Calder (optional)
Several pictures of Calder’s mobiles (optional)
Video links (see “Resources” in the appendix)
Equipment to view videos

Procedure
Ask students and collect their ideas:

What is a mobile? What does a piece of art have to have to make it a mobile?

(A mobile is “a type of kinetic sculpture in which an ensemble of balanced parts capable of motion are hung freely in space but... never come into contact with each other.” From Wikipedia: Mobiles, accessed 2/6/15.)

Introduce Calder and share photos of him and some of his works.

Brief bio: Alexander “Sandy” Calder was an American artist born in 1898. He designed toys, tapestries, jewelry, and sculptures as well as other forms of art. He is perhaps best known by the general public for his mobiles and has been referred to as the father of mobiles.

Originally Calder’s mobiles were motor-driven. Then he began building mobiles for which movement was the result of air currents or direct contact from the viewer. He tended to use organic colorful shapes in his mobiles.

View video about Calder:


Option 2: http://video.wttw.com/video/1614701629 (5:09)
Activity #6: It All Balances Out  

Goals and Objectives
Students will experiment with balancing similar weights attached to a single object and learn that dissimilar weights can balance one another by altering their distance from the point from which the object is balanced.

Materials
Corrugated cardboard, in strips about 3 inches wide and a foot long; 1 strip for every pair of students
Strings with beads attached, from previous activities
T-pins, from previous activities
Magnets, from previous activities

Procedure
1. Take one strip of cardboard, and attach a pair of magnets in one corner. Now attach another pair of magnets at the corner that shares a long edge with the original corner. Stick a T-pin in the center of the strip and show that it balances.

2. Now move one of the magnet pairs in toward the T-pin (keeping the magnets at the long edge of the cardboard strip), but hold the cardboard in place (i.e., do not let it rotate freely around the T-pin). Ask the students what the cardboard will do when you let it go. Now let it go, and show that it tilts to come back into balance.

3. Using the system from activity #3 for finding the center of mass, find the center of mass of the strip-and-magnet setup; you will see that the strip rotated so that the center of mass of the setup would be directly below the suspension point.

4. Ask students what you should do in order to make the cardboard balance horizontally again, without moving the pair of magnets that you just moved. Some may suggest moving the other pair, others may suggest adding pairs of magnets elsewhere on the strip. Try both of these things, but when you add the magnets, be sure that they are on the same long edge that the other pairs of magnets share.

5. Now find the center of mass of this arrangement; again you will see that it is directly below the suspension point. Repeat steps 2–4, perhaps a few times; to avoid confusion, each time you find the center of mass of a new arrangement, use a different color of pencil to mark the lines.

6. Let students do the same, working in pairs, with their own strips, pins, and magnets, being sure that they use different colors of pencil for each arrangement.
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Students will now see how the principles demonstrated in this activity apply to construction of balanced mobiles.
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Activity #7: Branch Mobile

40 minutes

Goals and Objectives
Students will create branch mobiles and use them to explore concepts in physical and aesthetic balance.

Materials
12” wooden dowels; 1 per team
6” wooden dowels; 2 per team
3” × 5” index cards (ideally colored, two-tone index cards); 2 per team
Scissors; 1 per team
Lengths of string
   12” yellow
   6” blue; 2 per team
   6” red; 4 per team
T-pin; 1 per team
Paper clips; 8 per team
Zots (dots of double-sided tape)
Ruler; 1 per team
Pencil

Procedure (will include photos)
1. Divide students into teams of two or three.
2. Have students find and mark the center of each dowel.
3. Tie the 12” yellow string to the center of the 12” dowel.
4. Slide it until the stick hangs from it horizontally.
5. Secure string location with a glue dot.
6. Attach a blue string to the center of one of the 6” dowels and slide it until it hangs horizontally when suspended by the string.
7. Repeat for the other 6” dowel and string.
8. Tie one of the blue strings to one end of the 12” dowel and the other blue string to the other end of the dowel.
9. Have one student hold the unit up by the yellow string.
10. Slide the blue strings until all dowels are hanging horizontally and secure the strings with Zots.
11. Cut each index card in half parallel to the short side.
12. Using a pencil draw a vertical line down the center of one of the cards (perpendicular to the printed lines).

13. Stack all four cards, placing the drawn-on one on top.

14. Using the T-pin poke a hole where the pencil line intersects the top printed line (be sure to poke the T-pin through all four cards).

15. Attach a paper clip through the hole of each card. The paper clip may need to be unbent a bit to get it through.

16. Attach the cards to the short dowels by tying one end of the red string to the paper clip and the other to an end of one of the 6″ dowels. Repeat until each of the four cards is attached to an end of one of the 6″ dowels.

17. Hang by the yellow string.

18. Slide the red strings along the dowels until each dowel hangs horizontally.

19. Secure strings to dowels with Zots.

Questions
Does shape of the elements affect the balance of a mobile?

What would happen if one were to cut a shape out of the center of one of the cards and make the cutout piece into a new element hanging beneath the card from which it was cut?

Let’s try it!

1. Add a paper clip to the bottom of each of the hanging cards. Note that it should all still be in balance since you have added an equal amount to each element.

2. Remove the paper clip from one of the cards on your mobile. Carefully cut a diamond (or some other shape) out of the index card.

3. Using the T-pin, poke a hole near the top edge of the new shape and the bottom edge of the card from which it was cut.

4. Using the paper clip attach these two shapes by slipping a paper clip into one hole and then the other.

Did this change the balance? Why or why not?

Does the new element change the visual appeal of the piece? If yes, in what way does it do so?

Breaking symmetry, such as changing the shapes as above, is one way to alter the visual aesthetics of a mobile. Another way to break the symmetry is through the
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elevation of the elements. Hanging the elements in different planes adds visual texture to the piece.

Wrap one of the red strings around the end of its dowel three times to raise the hanging element.

Does this change the physical balance?

Does this change the visual appeal of the piece?
Activity #8: Asymmetric Calder-Style Mobiles  

60 minutes

Goals and Objectives
Students will create mobiles in Calder’s style, implementing principles of physical and aesthetic balance.

Materials
Sample of dowel-and-swivel assemblage
“How to Build a Mobile” diagram by Marco Mahler (poster provided; also found at http://www.marcomahler.com/how-to-make-mobiles/)
Polyform Model Air clay; 0.5 lb per student
3” segments of 20-gauge bare copper artistic wire; 10 per mobile
12” wooden dowels, bent; 5–7 per mobile
Swivels; 5–7 per mobile
Round-needle-nose pliers; 1 per student
Command Party ceiling hook; 1 per student
Key ring; 1 per student
Pencils; 1 per student
Colored markers
Ruler

Procedure
Present and explain Marco Mahler poster.

Show example of project prepared up through step 10 (below).

The result doesn’t work very well as the elements can’t swing freely. Adding a sense of balance will reduce the chaos and change the aesthetics.

Give a quick overview of how you built the sample before having them build their own. Be sure to include the technique you used to attach the wires to the swivels and the dowels.

Directions (photos to be included):

1. Line up all curved dowels (5 or 7 depending on how big you would like it to be).
2. Using a pencil, mark dowels approximately 4” from one end.
3. Color the end nearest this mark with the marker.
4. Take a swivel and two wires. Attach a wire to each side of the swivel. Crimp with pliers.
5. Repeat for each swivel (5 or 7, equal to the number of dowels you have chosen).
6. Attach a key ring to one of each swivel’s wires.
7. Wrap the wire from the other side of that swivel tightly around a dowel at the 4” mark. Crimp with pliers. This will be dowel #1 (or the top dowel of the mobile).

8. Use another swivel to attach the colored end of dowel #1 to the 4” mark of a new dowel (dowel #2).

9. Use the next swivel to attach the colored end of dowel #2 to the 4” mark on another new dowel (dowel #3).

10. Repeat until all dowels are connected.

11. Hang mobile from key ring.

12. Put a clump of clay on both the ends of the bottom-most dowel.

13. Adjust the amounts until the dowel hangs horizontal.

14. Now move up to the next dowel from the bottom and add clay to the free-floating end until that dowel hangs horizontally.

15. Continue upward until all dowels have clay and are hanging horizontally.

Check to make sure each of the elements can freely spin about.

Remove from hanger and place on desk surface.

Maintaining the amount of clay and approximate location on each dowel, reshape the blob into a shape you find pleasing.

Hang the mobile and check for balance and free rotation of the elements.

Make any necessary adjustments.

Let it remain hanging until the clay dries (about 24 hours).
Activity #9: Off Balance: More Fun with Gravity  

35 minutes

Goals and Objectives
Students will create a ramp-walking toy powered by gravity.

Materials
Ability to view online video [http://tinyurl.com/nptpnoy](http://tinyurl.com/nptpnoy) (Dr. Dave Billiard’s “Toy Physics – Part 3: Waddling Duck”)
Pencils
Dowels, 12” × 3/16”
Traction tape
Double-stick tape
Plank to use for ramp
Beads (with holes big enough for dowels)
Washers
Rubber bands
Corrugated cardboard, scraps

Procedure
1. Show students a sample ramp walker made out of the materials available.
2. Discuss how balance and lack of balance underlie the ramp walker’s function, as it falls forward, catches itself, and falls forward again.
3. Challenge students to use the supplies to create a ramp walker of their own.
4. Gather students to share their walkers.
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**Day #2: Gears and Wind Power**

**Preparation**

- Create work spaces for the food-automata activity (activity #3) such that students will have access to power for the hot-glue guns.
- Reproduce gear-ratio sheets and "Getting into Gear" challenge sheets (PDFs provided in appendix)
- Create sample of food automaton
- Watch videos at [http://www.cabaret.co.uk/education/making-automata-with-food/](http://www.cabaret.co.uk/education/making-automata-with-food/)
- View [http://www.clohemovingtoys.eu/www/Home_EN/Automata_Gallery_Mechanisms.htm](http://www.clohemovingtoys.eu/www/Home_EN/Automata_Gallery_Mechanisms.htm) and familiarize yourself with some of the possible mechanisms
- Cut 6″ × 6″ × 6″ boxes in half. Teams will use 6″ × 3″ × 6″ boxes for the cams activity (activity #2).

**Materials**

<table>
<thead>
<tr>
<th>Power strips</th>
<th>Foil pans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gear sets</td>
<td>110 lb paper</td>
</tr>
<tr>
<td>Foam trays</td>
<td>Tape</td>
</tr>
<tr>
<td>Mini wooden dowels</td>
<td>Fans</td>
</tr>
<tr>
<td>Markers</td>
<td>Video (online)</td>
</tr>
<tr>
<td>Pencils</td>
<td>Equipment to play video</td>
</tr>
<tr>
<td>Food for automata</td>
<td>Foamie sheets, 6 mm</td>
</tr>
<tr>
<td>Low-temp glue guns; 1 per student</td>
<td>Straws</td>
</tr>
<tr>
<td>Low-temp melt glue</td>
<td>Boxes</td>
</tr>
<tr>
<td>Scissors; several</td>
<td>Dowels</td>
</tr>
<tr>
<td>KidWind MacGyver kits</td>
<td></td>
</tr>
<tr>
<td>Gear-ratio sheets; 1 per team (PDF provided in appendix)</td>
<td></td>
</tr>
<tr>
<td>“Getting into Gear” challenge sheets; 1 set per team (PDF provided in appendix)</td>
<td></td>
</tr>
</tbody>
</table>

*Additional materials are listed with each activity.*

**Goals and Objectives**

*Goals and objectives are listed with each activity.*

**Overview**

| Activity #1: Getting into Gear | Students explore gear ratios. | 45 min |
| Activity #2: Cam-eo | Students create and explore cams and how they are used. | 40 min |
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<th>Activity #3: Do Play with Your Food</th>
<th>Students create food automata.</th>
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<tbody>
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<td>Activity #4: Video Session 1</td>
<td>Students watch video for inspiration and begin notebook for final creation.</td>
<td>15 min</td>
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<tr>
<td>Activity #5: Wind Catcher</td>
<td>Students build a wind catcher out of a bottle.</td>
<td>30 min</td>
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<tr>
<td>Activity #6: Blowing in the Wind</td>
<td>Students design and build a wind turbine.</td>
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<td>Activity #7: Good, Better, Best</td>
<td>Students test blade variations.</td>
<td>55 min</td>
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<td>Students watch video for inspiration and add to notebook for final creation.</td>
<td>10 min</td>
</tr>
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</table>

### Introduction to Day #2

Today, students will continue their exploration of movement. They will work with gears and familiarize themselves with how gears work together to change direction and speed of rotation. They will learn how to calculate gear ratios and apply them to complete various challenges. Students will build wind catchers and experiment with variations to determine how a change in blade design alters their effectiveness. Students will also create a system in which they harness the wind to power a machine.
Activity #1: Getting into Gear 45 minutes

Goals and Objectives
Students will manipulate gears and familiarize themselves with how gears are used to change direction of motion and speed.

Materials
- Gears, assorted; 15–30 per team
- Pencils
- Foam trays; 2 per team
- Mini wooden dowels
- Markers
- Printed-out “Getting into Gear” challenge sheet (PDF provided); 1 per student
- Printed-out gear-ratio sheet (PDF provided); 1 per team

Procedure
1. Create teams of two or three students.
2. Have teams mount two identical gears on their foam boards so that they mesh with one another using the mini wooden dowels as mounting posts.
3. Using the markers, they should draw a line connecting the centers of the gears.
4. Turn the left-hand gear (the drive gear) clockwise and describe the motion of the second one (the follow gear).
5. Turn the drive gear counterclockwise and describe the motion of the follow gear.
6. Remount those gears with a third gear between them (this gear is called an idle gear).
7. Turn the drive gear and describe the motion of the follow gear.
8. What would happen if two gears were between the two original gears?
9. Choose two different-sized gears and mount them so they mesh. Turn the left-hand gear clockwise.
10. Does the change in size affect the motion from what was observed earlier?
11. If so, how?

(The direction of the rotation will remain the same as before but the speed of rotation will change when the gears are different sizes.)

Now let’s explore the relationship between the number of teeth each gear has and the number of rotations each gear makes.

12. If you mesh two gears with the same number of teeth and rotate one a full revolution, how many times does the other go around? Again, it may be helpful
to draw a line on the gears connecting their centers. It will make it easier to count the number of times the gear makes a complete revolution by watching the line.

13. If you mesh two gears with differing number of teeth and rotate the larger one a full revolution how many times does the smaller one go around?

14. How many teeth does the large gear have? How many teeth does the smaller gear have?

15. What is the relationship between the number of teeth the gears have and the number of rotations the gears make when meshed together? (Note: it is important to make it clear that you are discussing relative numbers of teeth, not relative diameters of gears; in some cases these may not correspond.)

(If you use a 40-toothed gear and a 20-toothed gear the larger one will rotate once for every two times the smaller gear revolves. The diameter of one gear is twice that of the other, therefore the gear ratio is 2:1. The 40-toothed gear and the 30-toothed gear have a gear ratio of 4:3; the larger gear will rotate 3/4 of a rotation for each rotation of the smaller gear.)

16. Try the challenge cards: set up your gear boards with the starting gear (drive gear) and ending gear (follow gear) as shown on the cards. Then follow the directions on the card and add gears such that turning the drive gear clockwise ends up with the desired movement of the follow gear stated on the card (such as turning clockwise or making three rotations for every one rotation of the drive gear).

Create a challenge card for another team and trade cards.
Activity #2: Cam-eo

Goals and Objectives
Students will explore the ways cams can be used to translate rotary motion into reciprocating motion.

Materials
- Example CamBox
- Foam sheets (6 mm)
- Glue guns
- Cutting tools
- Boxes; 1 per team
- Straws; 1 per team
- Paper
- Cutting board
- Pencil
- CamCards; PDFs provided
- Glue sticks
- Mini dowels
- Foam boards
- Washers; 1 per team
- 12″ dowels; 1 per team

Procedure
Describe the parts of a system that includes a cam (cam, shaft, follower, slide) using the PDF and example CamBox to show the parts.

Demonstrate how a circular cam does not introduce movement to the follower. Ask students to predict what movement will be created using a different-sized cam. Now have them investigate what movement a different-shaped cam creates.

Create teams of two or three students.

Distribute a CamCard to each team. Students should examine the shape of the cam on their card and predict what the motion of the follower will be if this cam is used. Teams should cut their cam shape out of a foam sheet and then try it in a Cam Test Box to test their predictions.

Bring the teams together and have each team share the shape of their cam and demonstrate the movement it causes.

Advanced version:
1. Have each team install their cam shape inside the test box so that no one can see the shape of the cam.
2. Have other teams analyze the movement of the follower to determine the shape of the cam and draw what they think it is.
3. Compare the drawings to the actual cam.
4. If there is time you can use the drawings as templates for creating new cams to compare the motion to the motion created by the cam that inspired it.
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Activity #3: Do Play with Your Food 50 minutes

Goals and Objectives
Students will build automata using familiar materials (food) while experimenting with creating gear and cam systems.

Materials
- Low-temp hot-glue gun
- Glue sticks
- Celery
- Pasta
- Radishes
- Crackers
- Cookies
- Gumdrops
- Trays
- Knives
- Paper
- Pencils
- Automata samples (actual or online)
- Sample food automaton (see http://youtu.be/tvjCWIOFYLU for instructions for one version)

Procedure
Show students some examples of automata: http://youtu.be/iRJ4tWbijDA.

Elaborate ones can be found at http://www.dugnorth.com.

Tell them that they will be making their own automata using food as the materials. Remind them that this food is for building, not eating. It has been touched by numerous people and should no longer be considered edible.

Show them your example of the food automaton you have made.

Encourage students to work in pairs.

1. Have students tour the food on the supply table.

2. Give students ten minutes to brainstorm how these items might be able to be used to create gears, cams, or other items to aid in creating movements. Teams should be prepared to make rough sketches of at least one idea to present to the group. (Gears made from pieces of spaghetti stuck in gumdrops, cams from ginger cookies, etc.)

3. Have them share their ideas by making sketches for the group on the presentation paper. Leave these ideas up throughout the build in case students wish to use them as inspiration.

4. Teams will go to the food supply table and gather supplies to take back to their stations. (Let students know that they will be able to return to the supply table throughout the build to gather more items or return items they no longer wish to use.)
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5. Before beginning to build teams should make sketches of their design. While they are working on their design they should plug in their glue gun so it can heat up.

6. When time is up have students unplug the glue guns and place them in a designated safe zone until they cool down.

7. Have students demonstrate their creations to the larger group.
Activity #4: Video Session 1

15 minutes

Goals and Objectives
Students will view examples of several kinetic sculptures and begin to imagine possible elements for their culminating project.

Materials
http://youtu.be/D5lueA7mam8 (5:19)
http://youtu.be/8Qi0Ag_Caig (2:08)
Equipment for showing the video
Composition books with graph-paper pages
Pencils

Procedure
1. Show the video.
2. Remind students that they will be building a kinetic sculpture later in the week. Now would be a good time to give them a detailed description of what the parameters of their project will be. Be sure to note any size restrictions, display considerations (will sculptures be set up on a table or the floor, or will there a space to suspend some?), and other necessary guidelines that may be set by the site. Also let them know that the sculptures should be designed to be easily transported as they will be displayed in the end-of-the-week showcase that may take place in a different room.
4. Give them 10 minutes to start compiling lists and sketching ideas for elements they may wish to include in the final project. Each student should work in his/her own notebook.
5. Remind students that while not every idea they come up with will end up in their final sculptures, any ideas can make it into the notebooks. Now is not the time to edit!
Activity #5: Wind Catcher  

30 minutes

Goals and Objectives
Students will create a fun and colorful wind-c Catching device.

Materials
- Cutting blade
- Plastic bottles (20 oz bottles work well)
- Markers
- Hammer
- Glue sticks
- Large nail (8d, or “eight-penny” size)
- Block of scrap wood
- Glue gun
- Scissors
- Fan
- Wire hangers
- Wire cutters
- Pliers
- Rubber band

Procedure
(Pictures will be provided.)

1. Using a cutting knife, students should carefully cut the plastic bottle about 2″ from the bottom.

2. Smooth out the cut with scissors. Set aside.

3. Draw lines from the shoulder of the bottle to the new edge dividing the bottle into four equal sections. These will be the blades of the wind catcher.

4. Using scissors cut along the lines and round the ends of the blades.

5. Fold blades to the outside of the bottle using the pliers to twist/crimp the blades to the left.

6. Set bottom piece on the block of scrap wood. Use the hammer and nail to poke a hole in the center of the bottom piece. *(This is surprisingly difficult and may be best done by the teachers, perhaps in advance. A drill might be easier.)*

7. Poke a hole in the center of the cap using the same block, nail, and hammer setup.

8. Screw the cap back onto the bottle.

9. Insert the bottom into the top portion of the bottle. (You may need to make some cuts in the sides of the bottom to help it fit into the top.)

10. Cut the wire hanger to get a straight piece of wire about 17″ long.

11. Use the pliers to bend a small U on one end.
12. Insert straight end through the bottom of the bottle and out through the cap.

13. Push the assembly until it hits the U in the wire. Measure 3” from the cap and bend an L of slightly more than 90 degrees into the wire to make a handle.

14. If the bottom of the bottle is not staying in the top you can secure them together with a band of hot glue.

15. Decorate with markers.

16. Turn the fans on full. Bring group all together to test and share their wind catchers.
Activity #6: Blowing in the Wind  

**Goals and Objectives**
Students will problem-solve as they work together to design and build a wind catcher using limited resources.

**Materials**
- Pictures of wind turbines
- Equipment to show the pictures
- Box fans
- KidWind MacGyver kits
- Scissors
- Tape
- Rulers

**Procedure**
1. Show pictures of wind turbines. Options available on links below.
   


2. Create teams of four students and challenge each team to build a wind turbine using the MacGyver kits provided.

3. Once they have found a design that spins in the wind they should add a component that uses the wind energy to lift a weight-bearing cup.
**Activity #7: Good, Better, Best**  

### Goals and Objectives
Students will experiment with blade design to maximize the wind power harnessed.

### Materials
- Team turbines
- Tape
- Box fans
- Scissors
- Rulers
- MacGyver kits
- Additional materials for making new blades (foil tins, file folders, etc.)

### Procedure
1. As a group, brainstorm possible variations on blade design that might affect efficiency* (blade length, shape, material, pitch, number of blades).

   *Efficiency will be measured by how many washers each configuration can lift to the height of two feet.

2. Have each team choose a variable they would like to test. (It is not a problem if multiple groups choose the same variable.) Teams should design-test for their chosen variable being sure to include what will need to remain constant between tests.

3. Teams will carry out their tests, record their data, and determine which approach is the most efficient. They should make a chart to record their results as they work.

Teams will present their designs and results to the group as a whole.

If there is time you can try combining the “best of” the variations and creating a super blade.
Activity #8: Video Session 2

10 minutes

Goals and Objectives
Students will view several chain-reaction videos to further excite and inspire them as they prepare to design their final project.

Materials
http://vimeo.com/63907182
Equipment to show the videos

Procedure
Remind students that the culminating project for the week will be for them to design and build a kinetic sculpture.

Watch the videos.

Give them the remainder of the time to add ideas for elements to their composition books.
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Day #3: Marbles and Mayhem

Preparation

Using a box cutter, cut each section of pipe insulation in half lengthwise.

Materials

- George Rhoads video
- Equipment to show video
- Marbles; lots!
- 1/2” foam pipe insulation; 6’ per team
- Masking tape

Additional materials are listed with each activity.

Goals and Objectives

Goals and objectives are listed with each activity.

Overview

| Activity #1: Marble-Run Accuracy Challenge | Distance and accuracy. | 30 min |
| Activity #2: Marble-Lift Challenge | Marble lift. | 40 min |
| Activity #3: Introduction to George Rhoads | Video and discussion of works. | 30 min |
| Activity #4: Hear Ye! Hear Ye! | Create a run with an interesting soundscape. | 30 min |
| Activity #5: Brainstorming | Teams will begin to brainstorm ideas for the final project. | 20 min |
| Activity #6: Design Time | Teams will sketch one of the elements and present it to the group. | 30 min |
| Activity #7: First Draft | A first attempt at building one element for their final sculpture and presenting it to the group. | 70 min |
| Activity #8: Materials List | Generate initial supply list based on plan. | 30 min |

Introduction to Day #3

Students will begin the day exploring potential and kinetic energy through marble runs. They will view some works of George Rhoads and note the elements he uses in his sculptures. Students will begin designing their final project.
Kinetic Sculpture Teachers Guide

Activity #1: Marble-Run Accuracy Challenge  

30 minutes

Goals and Objectives
Students will create a marble run in which the marble lands in a bucket 12" from the end of the run.

Materials
Marbles
Pipe-insulation strips, cut in half lengthwise
Masking tape
Bucket
Ruler

Procedure
Have students work in teams of two to four.

1. Place the bucket on the floor and measure out 12" in front of it. Mark this line with a strip of masking tape.

2. The end of the marble-run apparatus cannot go beyond the masking tape.

3. Students must now create a marble run in which a marble released at the start of the run will end up in the bucket. They should feel free to use the walls, furniture, or other items in the room as supports for the marble run. Check with facility to see if they can use making tape to secure things to the walls. Zip ties might also be handy.

If teams manage this goal quickly, have them see how far away they can move from the bucket and still achieve accuracy.

Come together as a group, describe the marble runs, and discuss the challenges.

- What was the hardest part?  
  \textit{(Aim, distance, consistency)}
- What did groups try to address the difficulties?
- What worked well?
Activity #2: Marble-Lift Challenge  

**Goals and Objectives**
Students will use their ingenuity and a variety of items to create a marble lift capable of raising a marble above its starting point. Using a system of cams, gears, or other means, they will build a model of their idea.

**Materials**
Composition books  
Dowels  
Pencils  
Straws  
Marbles; 40  
Chenille stems  
Masking tape  
Recycle-bin items  
Foam-pipe-insulation strips  
Cardboard tubes  
Gears  
Scissors  
Foamies (6 mm)

**Procedure**
Present teams with the challenge of creating a mechanism to lift a marble to a level higher than its starting point.

Have teams begin by making drawings of their ideas. Once a team has created a coherent plan, give them access to a variety of supplies and have them build a prototype of their mechanism.

Bring all the teams together to share their ideas and their experiences trying to implement their ideas. Make it clear that it is okay if their ideas didn't work to lift the marble. It is still important to share their efforts. Allow time for comments and suggestions.
Activity #3: Introduction to George Rhoads 20 minutes

Goals and Objectives
Students will be introduced to one of the works of George Rhoads and will identify which elements are most powerful to them. They will begin to build a concept of their final structures.

Materials
Online videos of George Rhoads sculptures: http://www.georgerhoads.com/media/
Equipment for viewing video clips
Paper
Pencils

Procedure
View the George Rhoads video.

Discuss the various elements.

- Movement:
  How do the balls get from place to place?
  *(Rolling, dropping, bouncing, flying)*

- Sound:
  What sound does the sculpture make?
  *(Whir of the motor, rolling on ramps, spinning in funnel, plonking on blocks)*

- Timing:
  How is varied timing of movement achieved throughout the sculpture?
  *(By requiring more than one ball to overcome a counterbalance, funnel spiral, differing path lengths)*
Activity #4: Hear Ye! Hear Ye!  

30 minutes

Goals and Objectives
Groups will create a marble run that focuses on creating sounds.

Materials
<table>
<thead>
<tr>
<th>Marbles</th>
<th>Cans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe insulation</td>
<td>Index cards</td>
</tr>
<tr>
<td>Bells</td>
<td>Craft sticks</td>
</tr>
<tr>
<td>Wooden blocks</td>
<td>Other items to repurpose</td>
</tr>
</tbody>
</table>

Procedure
Same groups as earlier.

Ask students to explore the sounds the materials make.

How do things sound when marbles land on them? Brush past them? Roll over them? Knock them together?

Teams should create a quick marble run that produces interesting sounds.

Bring the large group together and have each team share their piece.
Activity #5: Brainstorming  

30 minutes

Goals and Objectives
Final groups will be formed and students will begin to formally work on their final sculptures.

Materials
Graph-paper composition books
Color pencils

Procedure
1. Assign students to teams of three to four for their final projects.

2. Teams should begin to discuss what type of kinetic sculpture they wish to build (wind catcher, automaton, chain reaction, etc.) and some of the elements they might like to include in their final construction. They will have 25 minutes to come up with a very rough initial plan.

3. Encourage sketching! Be sure to let them know that they will have about a day and a half to design and build their final sculpture.
Activity #6: Design Time

45 minutes

Goals and Objectives
Teams will choose one design element from their final sculpture to present to the group as a whole.

Materials
Presentation paper
Colored pencils

Procedure
1. Team members should make a drawing of their design for their final sculpture. Be sure students are aware that they will be building their sculpture in one space and presenting it during the final showcase, which may be in a different space; therefore it will need to be able to be transported. Alert them to any other constraints that are site-specific (such as if they must be shown on a table or if the floor is an option, if there are size restrictions, etc.).

2. One element should be drawn up for presentation to the larger group.

3. Teams will present the drawing and explain how it is going to fit into the larger sculpture.

4. Encourage feedback from the group.
Activity #7: First Draft  

**Goals and Objectives**
Students will build one element of their final sculpture, get feedback from other groups and refine their build.

**Materials**
Varied

**Procedure**
1. Each team should make one element of their sculpture.
2. Teams will present their piece to the larger group and report on how they made it.
3. Teams will receive feedback and suggestions from the larger group.
4. If there is time, teams should make notes about revisions they would like to try based on the group feedback.
Activity #8: Materials List

20 minutes

Goals and Objectives
Students will think through their designs step by step and figure out what items they wish to use for their build, being sure to identify any specialty items.

Materials
Their composition books
Pencils
Large presentation sheets
Markers

Procedure
1. Have groups look through their design and compile a list of items they think they will want to use for their build.

2. Any specialty items should be listed on large presentation sheets hung throughout the room.

3. Items on the presentation sheets should be read aloud to the group as a whole and individuals should be encouraged to bring in items from home that may be useful to their team or others.
Kinetic Sculpture Teachers Guide

Day #4: Build, Test, Redesign, Build Again

Preparation

Have a variety of items on hand for teams to incorporate into their sculptures.

Materials

*Materials are listed with each activity.*

Goals and Objectives

*Teams will spend the day working on their final sculpture.*

Overview

| Activity #1: Lessons Learned | Group discusses lessons learned from previous day's build. | 30 min |
| Activity #2: Revisions | Teams revise element from previous day. | 40 min |
| Activity #3: Presentations | Teams present revised element and highlight a challenge and a success. | 30 min |
| Activity #4: Build | Students continue their build. | 60 min |
| Activity #5: Evaluation | Teams pair up and evaluate their design and revise based on lessons learned. | 30 min |
| Activity #6: Build | Students continue their build. | 60 min |
| Activity #7: Progress | Quick check-in with teams and news about showcase. | 20 min |
| Activity #8: Build | Students continue their build. | 30 min |

Introduction to Day #4

Today students will be working with their teams to prototype and build their final sculpture. They will have the whole day to work on the build with various check-ins scheduled throughout the day. Plans for the Friday showcase will also be discussed.
Activity #1: Lessons Learned  

30 minutes

Goals and Objectives
Students will reflect on the feedback they received the previous day and on their build experience and share some of the things they learned, both things that worked well and things they would like to change.

Materials
Composition books
Pencils

Procedure
1. Gather the large group and facilitate a discussion about how the build worked the previous day. Touch on both the actual building techniques and the roles people played within the teams. What worked well? What didn’t?

2. This is also a good time to share any specialty items that were brought in and ideas about how they will be used.
Activity #2: Revisions

40 minutes

Goals and Objectives
Students will rebuild the element from the previous day incorporating the feedback they received from the group as a whole.

Materials
Varied

Procedure
Students will work within their teams to restructure their element based on the feedback they received from their fellow students.
Activity #3: Presentations  

30 minutes

Goals and Objectives
Teams learn from one another’s struggles and successes so they can apply that knowledge to their build.

Materials
Varied

Procedure
Teams present revised element and highlight a challenge and a success. Make some time here to discuss the role of “failure” in engineering design. A “failed” prototype is not really a failure—it is a success, in that it has shown the designers where they need to improve their design before moving to production. The iterative design process is essentially a series of such “failures,” each followed by redesign and testing.
Activity #4: Build

60 minutes

Goals and Objectives
Students will work together and make progress on the build of their kinetic sculptures.

Materials
Varied

Procedure
Let students know they will have an hour of build time.
Activity #5: Evaluation

Goals and Objectives
Students will receive feedback from another team and will be able to draw advice from them about any challenges they are facing.

Materials
Student projects in process
Additional items they may wish to incorporate

Procedure
Pair up teams and have them showcase their work thus far to one another. Have each team address any areas of difficulty and have the other team offer ideas for tackling the problem.
Activity #6: Build  

60 minutes

Goals and Objectives
Students will work together and make progress on the build of their kinetic sculptures.

Materials
Varied

Procedure
Let students know they will have an hour of build time.
Activity #7: Progress 20 minutes

Goals and Objectives
Check in with the group to make sure everyone is progressing in their projects. Share any information regarding the Friday showcase.

Materials
None

Procedure
Gather students away from their build stations so that you can be sure to have their attention. Check in with each team for a quick overview of where they are in their build phase. Let them know anything they will need to know about the Friday Showcase.
Activity #8: Build 30 minutes

Goals and Objectives
Students will work together and make progress on the build of their kinetic sculptures.

Materials
Varied

Procedure
Let students know they will have the remainder of the day for build time. To prepare them for the showcase, let them know:

1. What is expected of them prior to the presentations (anything they need to prepare, any cleanup for which they are responsible, etc.)

2. What is expected of them during the showcase (whether they will be asked to speak about the sculptures, if they are expected to stay by their sculptures, etc.)

3. What is expected of them after the showcase (how to de-install the sculptures, what parts of them are going home with whom, etc.)
Day #5: Showtime!

Preparation
Survey the area for the showcase and determine where each team will set up.

Materials
Any final materials needed to finish up sculptures
Markers
Poster board
*Additional materials are listed with each activity.*

Goals and Objectives
Today students will prepare their sculpture for the showcase and make an exhibit plaque to display alongside of it.

Overview

<table>
<thead>
<tr>
<th>Activity #1: Final Build</th>
<th>Students will complete the building phase.</th>
<th>80 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity #2: All in a Name</td>
<td>Students will create a plaque for the display.</td>
<td>20 min</td>
</tr>
<tr>
<td>Activity #3: Wrap It Up!</td>
<td>Quick final touches to sculptures.</td>
<td>20 min</td>
</tr>
<tr>
<td>Activity #4: Showcase Setup</td>
<td>Students install their creations.</td>
<td>30 min</td>
</tr>
<tr>
<td>Activity #5: Presentation</td>
<td>Students will participate in the camp showcase.</td>
<td>120 min</td>
</tr>
</tbody>
</table>

Introduction to Day #5
Remind students that today will be the day they get to share their sculptures with a larger community of other students, family and friends.

Again, remind them of:

1. What is expected of them *prior* to the presentations (anything they need to prepare, any cleanup for which they are responsible, etc.)

2. What is expected of them *during* the showcase (whether they will be asked to speak about the sculptures, if they are expected to stay by their sculptures, etc.)
3. What is expected of them after the showcase (how to de-install the sculptures, what parts of them are going home with whom, etc.)
Activity #1: Final Build 80 minutes

Goals and Objectives
Students will complete their sculptures in preparation for sharing them at the afternoon showcase.

Materials
Varied

Procedure
Let students know how much time they will have to complete their sculptures. Give them countdowns throughout that period letting them know how much time they have left. Announce this more frequently as they approach the end.
Activity #2: All in a Name 20 minutes

Goals and Objectives
Teams will decide on a name for their kinetic sculpture and create a “museum” plaque to display near it during the showcase.

Materials
Markers
Paper

Procedure
Have students brainstorm and choose a name for their sculpture. Using markers, teams should create a plaque to place on display near their sculpture during the showcase. The plaques should include the following information:

- Name of the piece
- Name of the artists
- Materials used
- A short sentence or two about the inspiration for the piece

Gather the groups and have them share their choice and why they chose it.
Activity #3: Wrap It Up!  

20 minutes

Goals and Objectives
Teams will make final adjustments to their kinetic sculptures and ready them for the showcase.

Materials
Varied

Procedure
Tell the students that they should make any final adjustments to their sculptures.

Have them prepare the sculptures for transport to the location of the showcase.
Activity #4: Showcase Setup

Goals and Objectives
Students will move their sculptures to the showcase venue, set them up, and run them through a test to make sure they are working properly.

Materials
Kinetic sculptures
Any display apparatus (supports, tape, hooks)
Plaques

Procedure
1. Move all kinetic sculptures to the location of the showcase.
2. Have each team set up and then test their setup.
3. Display each sculpture’s plaque near it.
Kinetic Sculpture Teachers Guide

Activity #5: Presentation

120 minutes

Goals and Objectives
Students will have the opportunity to share their kinetic sculptures with the larger i2 community and families and will get a chance to watch as viewers are influenced by their works.

Materials
None

Procedure
Make sure the students are clear about what they are expected to do during the showcase.
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Part A weighs the same as part B – Balance point is right in the middle.

Part A weighs more than part B – Balance point moves closer to part A, the heavier part.
The following illustration might look complex, but it’s really the exact same idea. All those lower parts count as just one part when it comes to the balance of the top part, it’s only about the balance between part A and part B.

And then it just goes on like that to the next level of the mobile:
### Kinetic Sculpture

This is the quantity that would be needed for **8** students, including consummables and durables

This is the quantity that would be needed for **4** students, including consummables and durables

<table>
<thead>
<tr>
<th>ETA #</th>
<th>Item Name</th>
<th>Reusable/Consummable</th>
<th>Item Notes/Dimensions</th>
<th>Kit Quantity, Base</th>
<th>Kit Quantity, Additional</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12&quot; wooden dowels</td>
<td>C</td>
<td>12&quot; length, 3/16&quot; diameter</td>
<td>96 rods</td>
<td>48 rods</td>
</tr>
<tr>
<td></td>
<td>20 gauge wire</td>
<td>C</td>
<td>uncoated</td>
<td>104 3&quot; lengths</td>
<td>52 3&quot; lengths</td>
</tr>
<tr>
<td></td>
<td>6&quot; wooden dowels</td>
<td>C</td>
<td>6&quot; length, 1/4&quot; diameter</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Air dry clay</td>
<td>C</td>
<td>Polyform Air dry Clay</td>
<td>4 lbs</td>
<td>2lbs</td>
</tr>
<tr>
<td></td>
<td>Balance toys</td>
<td>R</td>
<td>1 or more</td>
<td>1 or more</td>
<td>1 or more</td>
</tr>
<tr>
<td></td>
<td>Beads</td>
<td>C</td>
<td>with holes 3/16&quot; holes'</td>
<td>24-48</td>
<td>13-25</td>
</tr>
<tr>
<td></td>
<td>Bells</td>
<td>C</td>
<td></td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Block of Scrap wood</td>
<td>R</td>
<td>scrap is fine, link if need to buy</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Box Fans</td>
<td>R</td>
<td></td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Boxes, 6&quot;x6&quot;</td>
<td>C</td>
<td>sold in pack of 15</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Buckets</td>
<td>R</td>
<td></td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Cans</td>
<td>R</td>
<td>recycle bin</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chenille stems</td>
<td>C</td>
<td>100/pack</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Chimes</td>
<td>C</td>
<td></td>
<td>4 packs</td>
<td>2 packs</td>
</tr>
<tr>
<td></td>
<td>Chipboard sheets</td>
<td>C</td>
<td>8.5x11</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Colored Pencils</td>
<td>C</td>
<td></td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Composition books</td>
<td>C</td>
<td>graph ruled</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Corrugated cardboard scraps</td>
<td>C</td>
<td>recycle bin</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Corrugated cardboard strips*</td>
<td>C</td>
<td>3&quot;x12&quot; strips NEEDED. Sold as 24&quot;x36&quot;</td>
<td>5 strips + 2 sheets</td>
<td>3 strips + 1 sheet</td>
</tr>
<tr>
<td></td>
<td>Craft sticks</td>
<td>C</td>
<td>1000/box</td>
<td>300</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Cutting mats/knife</td>
<td>R</td>
<td></td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Double stick tape</td>
<td>C</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Foam sheets (6mm)</td>
<td>C</td>
<td>sold in packs of 4 color doesn't matter</td>
<td>4 sheets</td>
<td>2 sheets</td>
</tr>
<tr>
<td>Item</td>
<td>Type</td>
<td>Description</td>
<td>Quantity</td>
<td>Notes</td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
<td>------</td>
<td>-------------------------------------------------</td>
<td>----------</td>
<td>----------------------------</td>
<td></td>
</tr>
<tr>
<td>Foam trays</td>
<td></td>
<td>sold in pack of 125</td>
<td>24</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Food items</td>
<td></td>
<td>must be bought locally</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foil tins</td>
<td></td>
<td>case = 12 /2 ct.</td>
<td>4</td>
<td>2 ct.</td>
<td></td>
</tr>
<tr>
<td>8d nail (8 penny)</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Glue gun glue</td>
<td></td>
<td>sold in packs of 100 sticks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glue gun (low temp)</td>
<td></td>
<td>must be low temp! 5/16&quot; diameter</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Gear Sets</td>
<td></td>
<td>set of 300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hammer</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Hole punch</td>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Index Cards</td>
<td></td>
<td>Oxford Colored cards</td>
<td>8</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Key ring</td>
<td></td>
<td></td>
<td>8</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>KidWind MacGyver kit</td>
<td></td>
<td>class set</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knives</td>
<td></td>
<td>sold in sets of 4</td>
<td>2 sets</td>
<td>1 set</td>
<td></td>
</tr>
<tr>
<td>Jenga</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Index Cards</td>
<td></td>
<td>Oxford Colored cards</td>
<td>8</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Kaleido Gears</td>
<td></td>
<td>Quercetti Georello</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Key ring</td>
<td></td>
<td></td>
<td>8</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Markers</td>
<td></td>
<td>1 case of 12</td>
<td>4 sets</td>
<td>2 sets</td>
<td></td>
</tr>
<tr>
<td>Marco Mahler poster</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Mini-wooden dowels; 3/16&quot;</td>
<td></td>
<td>MUST BE 3/16&quot;</td>
<td>40</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Mobiles</td>
<td></td>
<td>1 or more</td>
<td>1 or more</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Masking tape</td>
<td></td>
<td>20 rolls</td>
<td>10 rolls</td>
<td>3 rolls</td>
<td></td>
</tr>
<tr>
<td>Magnets</td>
<td></td>
<td>3/4&quot;</td>
<td>56</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Marbles</td>
<td></td>
<td>1&quot; marbles</td>
<td>32</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Mobiles</td>
<td></td>
<td></td>
<td>1 or more</td>
<td></td>
<td></td>
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<tr>
<td>Markers</td>
<td></td>
<td>1 case of 12</td>
<td>4 sets</td>
<td>2 sets</td>
<td></td>
</tr>
<tr>
<td>Masking tape</td>
<td></td>
<td>20 rolls</td>
<td>10 rolls</td>
<td>3 rolls</td>
<td></td>
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<tr>
<td>Mini-wooden dowels; 3/16&quot;</td>
<td></td>
<td>MUST BE 3/16&quot;</td>
<td>40</td>
<td>20</td>
<td></td>
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<tr>
<td>Mobiles</td>
<td></td>
<td>1 or more</td>
<td>1 or more</td>
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<tr>
<td>Item</td>
<td>Quantity</td>
<td>Case Size</td>
<td>Details</td>
<td>Units</td>
<td>Per Case</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>----------</td>
<td>-----------</td>
<td>----------------------------------</td>
<td>-------</td>
<td>----------</td>
</tr>
<tr>
<td>Needlenose pliers w/wire cutters</td>
<td>R</td>
<td></td>
<td>sold in cases of 12</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Paper</td>
<td>C</td>
<td>8 1/2x11</td>
<td>cardstock</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Paperclips</td>
<td>C</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Pencils</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Pipe insulation</td>
<td>C</td>
<td>sold in 6' segments</td>
<td></td>
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<tr>
<td>Plank*</td>
<td>R</td>
<td></td>
<td>use remaining corrugated sheets from strips as planks</td>
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<tr>
<td>Plastic bottles</td>
<td>C</td>
<td>20oz, liter or 2 liter</td>
<td>8</td>
<td>4</td>
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<tr>
<td>Power strips</td>
<td>R</td>
<td>8 foot cord or longer</td>
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<td>1</td>
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<tr>
<td>Presentation paper</td>
<td>C</td>
<td>1</td>
<td></td>
<td>1</td>
<td>1</td>
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<tr>
<td>Rubber bands</td>
<td>C</td>
<td>small diameter</td>
<td>48</td>
<td>24</td>
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<td>Rulers</td>
<td>R/C</td>
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<td>sold in cases of 12</td>
<td>8</td>
<td>4</td>
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<td>R</td>
<td>sold in cases of 12</td>
<td>4</td>
<td>2</td>
<td></td>
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<tr>
<td>Staplers</td>
<td>R</td>
<td>2</td>
<td></td>
<td>2</td>
<td>1</td>
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<tr>
<td>Staples</td>
<td>C</td>
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<tr>
<td>Steel marble</td>
<td>R</td>
<td></td>
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<td>Straws</td>
<td>C</td>
<td>pkg of 25 shake straws (wide diameter)</td>
<td>8</td>
<td>4</td>
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<tr>
<td>String</td>
<td>C</td>
<td>yellow</td>
<td>8 12&quot; strands</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>String</td>
<td>C</td>
<td>red</td>
<td>16 6&quot; strands</td>
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<td>3</td>
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<tr>
<td>String</td>
<td>C</td>
<td>blue</td>
<td>8 6&quot; strands</td>
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<td>Swivels</td>
<td>C</td>
<td>pkg of 144</td>
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<td>56</td>
<td>28</td>
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<td>T-pins</td>
<td>R</td>
<td>box of 100</td>
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<td>Trays</td>
<td>R</td>
<td>sold in case of 36</td>
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<td>4</td>
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<td>Washers, 5/16&quot;</td>
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<tr>
<td>Windcatcher</td>
<td>R</td>
<td>need 6 - sold in packs of 12</td>
<td>3</td>
<td>3</td>
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<td>Wire hangers</td>
<td>C</td>
<td>sold in lot of 100</td>
<td>8</td>
<td>4</td>
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<tr>
<td>Wooden marbles</td>
<td>R</td>
<td>sold in bags of 10</td>
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</tbody>
</table>

* package purchased for 3" corrugated strip will have enough sheets to also be used for planks.
Based on 20 students

If possible, indicate what day the item will likely be used (1-5).

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<tr>
<th>Total Quantity</th>
<th>Day</th>
<th>Vendor</th>
<th>Catalog #</th>
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<th>Unit Cost</th>
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<tr>
<td>224 rods (14/pkg)</td>
<td>1,2</td>
<td>craftamerica.com</td>
<td>9162-02</td>
<td><a href="http://craftamerica.com">http://craftamerica.com</a></td>
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<td>spools</td>
<td>1</td>
<td>jewelrytools.com</td>
<td>Product ID: BDC-804.23</td>
<td><a href="http://www.jewelrytools.com">http://www.jewelrytools.com</a></td>
<td>$3.75</td>
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<tr>
<td>20 (1 pkg)</td>
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<td>item# 11599669</td>
<td><a href="http://www.joann.com">http://www.joann.com</a></td>
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<td>1</td>
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<td>item AD2222W</td>
<td><a href="http://store.creative-wholesale.com">http://store.creative-wholesale.com</a></td>
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<td>item BE1080</td>
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<td>PS0500</td>
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<td>item # 430610</td>
<td><a href="http://www.staples.com">http://www.staples.com</a></td>
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<td>10 (case:24)</td>
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<td>SKU#:213039</td>
<td><a href="http://www.dollartree.com">http://www.dollartree.com</a></td>
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<td>several</td>
<td></td>
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<td>1 pkg of 100</td>
<td>1,4,5</td>
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<td>item 0500592(g)</td>
<td><a href="http://www.enasco.com">http://www.enasco.com</a></td>
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<td>10 packs</td>
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<td>factorydirectcraft.com</td>
<td>item # 162430</td>
<td><a href="http://factorydirectcraft.com">http://factorydirectcraft.com</a></td>
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<td>3 pkg of 25</td>
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<td>item # 2081958</td>
<td><a href="http://www.joann.com">http://www.joann.com</a></td>
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<td>6 sets of 10</td>
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<td>dollartree.com</td>
<td>sku# 21065</td>
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<td>item# 4308</td>
<td><a href="https://www.schoolsupplies4you.com">https://www.schoolsupplies4you.com</a></td>
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<td>trios + 4 sheets (1 pack)</td>
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<td>item: 948890 Model: SP24</td>
<td><a href="http://www.staples.com">http://www.staples.com</a></td>
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<td>1 box</td>
<td>1,4,5</td>
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<td># 0500462(a)</td>
<td><a href="https://www.enasco.com">https://www.enasco.com</a></td>
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<td>10</td>
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<td>item# 1204-36</td>
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<td>item DUC0021087</td>
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<td>item # F6RB4</td>
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<td>30</td>
<td>2</td>
<td>webstaurantstore.com</td>
<td>Item #: 99920S</td>
<td><a href="http://www">http://www</a></td>
<td>$9.49</td>
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<td>12</td>
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<td>SKU# 132166</td>
<td><a href="http://www">http://www</a></td>
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<td>item #202192876</td>
<td><a href="http://www">http://www</a></td>
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<td>300</td>
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<td>item SB26469M</td>
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<td>Item 9710682</td>
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<td>item 146308</td>
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<td>7 pkg of 3</td>
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<td>truevalue.com</td>
<td>item # 191440</td>
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<td>Classic Jenga</td>
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<td>w-ip-qa2341</td>
<td><a href="http://www">http://www</a></td>
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<td><a href="http://www">http://www</a></td>
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<td>1 class set</td>
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<td>kidwind.org</td>
<td>K-MACGX</td>
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<td>5 sets of 4</td>
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<td>mileskimball.com</td>
<td>item 347371</td>
<td><a href="http://www">http://www</a></td>
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<td>2 bags of 70</td>
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<td>item MTB075</td>
<td><a href="http://www">http://www</a></td>
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<td>bulk bag 125pieces</td>
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<td>megaglass.com</td>
<td>item 66267</td>
<td><a href="http://www">http://www</a></td>
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<td>12 sets of 8</td>
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<td>sku# 1818429</td>
<td><a href="http://dollar">http://dollar</a></td>
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<td>item JTSS1MASKCP106</td>
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<td>item UNV72210BX</td>
<td><a href="http://www.officesupplies.com/CLIP-1-GEM-SMOOTH-100BX/product_477829">http://www.officesupplies.com/CLIP-1-GEM-SMOOTH-100BX/product_477829</a></td>
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<td>1,2,3,4,5</td>
<td>schoolsupplies4you.com</td>
<td>item 4238</td>
<td><a href="https://www.schoolsupplies4you.com/sharpened-pencils-12pk-1.html">https://www.schoolsupplies4you.com/sharpened-pencils-12pk-1.html</a></td>
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<td>2,4,5</td>
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<td>Item IM1K85866</td>
<td><a href="http://www.staples.com/IM1K85866/directory_IM1K85866">http://www.staples.com/IM1K85866/directory_IM1K85866</a></td>
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<td>1 pad</td>
<td>1,2</td>
<td>amazon.com</td>
<td>Post-it Tabletop Easel Pad, 20 x 23-Inches</td>
<td><a href="http://www.amazon.com/Post--Tabletop-Easel-23-Inches-20-Sheets/dp/B00006IA99/ref=sr_1_1?ie=UTF8&amp;qid=1428337302&amp;sr=8-1&amp;keywords=Tabletop+Easel+Pad%2C+20+x+23-Inches">http://www.amazon.com/Post--Tabletop-Easel-23-Inches-20-Sheets/dp/B00006IA99/ref=sr_1_1?ie=UTF8&amp;qid=1428337302&amp;sr=8-1&amp;keywords=Tabletop+Easel+Pad%2C+20+x+23-Inches</a></td>
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<td>joann.com</td>
<td>item# 13147525</td>
<td><a href="http://www.joann.com/mini--stretch-band-bracelet-loops-1000-w%2F36-clips---multi/13147525.html">http://www.joann.com/mini--stretch-band-bracelet-loops-1000-w%2F36-clips---multi/13147525.html</a></td>
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<td>justartifacts.net</td>
<td>BTW090001</td>
<td><a href="http://www.justartifacts.net/eco-bakers-twine-54yd-9ply-solid-yellow-btw090001.html">http://www.justartifacts.net/eco-bakers-twine-54yd-9ply-solid-yellow-btw090001.html</a></td>
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General Lab Safety

MIT Stem workshops are intended to be fun and inspirational at the same time, allowing students to explore a variety of topics in an environment that encourages exploration, imagination and innovation. Since the workshop focuses on STEM (Science, Technology, Engineering, and Math), students may be using materials and procedures that require proper safety precautions. In order to provide exciting and safe experiences for students, the following safety specifications and prudent practices are highly recommended and in most cases required by regulatory agencies (OSHA, NFPA, ICC, etc.).

A. Environmental Settings and Considerations

1. Laboratory Footprint
   • Furniture placement in laboratories should be designed in such a way as to facilitate easy movement, fast egress, direct observation/supervision and no trip/fall hazards.

2. Ventilation
   • Paints, chemicals, and soldering all can produce noxious or harmful fumes. Be sure that students have adequate ventilation: use a fume hood if necessary, paint outdoors, open windows.

3. Eyewash Stations
   • Be sure that students know the location of the eyewash station if one is indicated, and that they understand how to use it. Test the station on the first day of class to make sure it works and is charged with fresh water.

4. Eye Safety
   • Eye protection should be worn at all times in courses where there is the potential for eye injury from chemical splash or flying debris (e.g. snipping wires, soldering, cutting, drilling, etc.). Instructors should set the example by wearing eye protection at all times.

5. First Aid Kits
   • Instructors should make sure that a First Aid kit is available in their classrooms. Students should report any injury or accident, no matter how small, to the instructor immediately.

6. Fire Safety
   • Instructors should know the location of the fire extinguisher and be familiar with its operation. Use the following NFPA “PASS” approach when working with a first extinguisher:
     P – Pull the pin
     Most extinguishers use locking pin to prevent inadvertent operation. Pulling the pin unlocks the operating level to allow discharge operation.
     A - Aim low
     Point the extinguisher nozzle at the base of the fire.
S - Squeeze the lever
A lever below the handle or some other type of triggering device must be engaged to release the extinguishing agent.

S - Sweep from side to side
Using a sweeping motion across the base of the fire and continue discharging the extinguishing agent until the fire appears to be out. Be certain to watch the fire area; if the fire reignites, repeat the process.

B. Prudent Practices

1. Student Behavior:
   • Horseplay or other inappropriate behavior in the laboratory is not allowed.
   • Instruct students to never taste chemicals or other laboratory materials.
   • Instruct students never to inhale fumes produced during an activity or experiment.
   • Have students follow all instructions, both written and oral.
   • Have students report any accident or injury to the teacher immediately, no matter how simple it may appear.
   • Instruct students to never return unused chemicals to their original containers.
   • Remind students to never remove any materials from the laboratory unless approved by the teacher.
   • Remind students to never work in the laboratory without a teacher.

2. Clothing/Hair
   • Do not wear loose/baggy clothing or dangling jewelry. They are a safety hazard in the laboratory. Make sure long hair is tied back behind the ears.

3. Food and Drink
   • Eating, drinking and applying cosmetics are prohibited in areas where chemicals or biohazards are in use.

4. Housekeeping
   • Work areas should be kept clean at all times. Students should only use laboratory instructions, worksheets and necessary equipment in the work area. Other materials such as backpacks, books, purses and jackets should be stored in a separate area.

5. Material Safety Data Sheets (MSDSs)
   • MSDSs for any hazardous chemicals should be stored in the instructor’s notebook. Safe use procedures should be reviewed with students prior to the start of the activity. MSDSs can also be accessed on the Internet.

6. Personal Protective Equipment
   • In addition to safety glasses, other personal protective equipment such as gloves and aprons should be worn when appropriate.

7. Electricity
   • Know where the master switch is for electricity in the room in case of an emergency.
   • Make students aware of the appropriate use of electricity and dangers of misuse.
   • Discard batteries in an appropriate manner.
• Prevent trip and fall hazards by placing wires out of traffic areas.
• When storing batteries, never allow the terminals to touch.
• Never use water or have wet hands when dealing with cords, plugs or electrical equipment

8. Mechanical/Tool Use
• When using power tools, make sure that users are aware of the position of both hands at all times. Students should be briefed on the proper use of power tools and the safety considerations of same. They should know the location of the emergency shut-off switch.
• When drilling, sanding or milling materials, the item should be properly chucked or clamped to an appropriate work surface.
• Do not use tools that have a dull cutting surface.
• Use tools only for their intended purpose. A screwdriver is not the same as a pry bar.
Notebooks

As part of the MIT experience, students will be given notebooks in which to keep notes, picture, drawings, and handouts. These notebooks can be used to encourage reflection on their experience. They can also be used in a more formal way to keep track of ideas, concepts, and work accomplished. The emphasis given to the notebook is at the discretion of the instructor. It may be as simple as asking the students to write a few words to answer these questions each day:

- What is the best thing that happened to you today?
- Name one new thing you learned today.
- What are you looking forward to tomorrow?

For some courses, especially those involving engineering, students may wish to keep a more formal Engineers Notebook.

The Engineers Notebook
An engineer’s notebook, unlike a scientist’s notebook, is more of a diary than a record of science experiments and results. There are many similarities between the two: a scientist’s notebook contains the experimental procedure, materials, methods, data, results, and maybe conclusions. An engineer’s notebook contains these too, and so much more: ideas, designs, sketches, conversations, field notes, observations, pictures, contact information, problems encountered, printouts (taped in)-the list is exhaustive. Some notebooks are kept in incredible detail; others can be brief but still contain all the necessary information. Take a look at these two examples:
Fig. 1. A page from Thomas Edison’s notebook. Not nearly as neat or extensive as da Vinci’s, but note the dated signature and the different filament designs for light bulbs.

Fig. 2. A page from a da Vinci notebook describing a water pump. Note the detailed drawings and extensive notes.

A properly kept notebook will allow another engineer to not only reproduce your work, but to understand WHY you did what you did.
Engineering Design Notebook Guidelines

• On the front or on the inside cover, enter the project title, your name, and any other information that identifies where the work was done and how the notebook can be returned if it is found.
• Keep a table of contents for each entry in the front of the notebook.
• All entries must be done in (indelible) ink.
• Notebooks do not necessarily have to be neat, but they should be legible.
• Make your entries AT THE TIME YOU DO THE WORK. If you try to remember details later, you will not be successful.
• If you make an error, do not try to erase it or block it out. Draw a single line through the mistake and initial it.
• Never tear a page out of a notebook.
• All data must be in original form. Do not record data on a scrap of paper and later recopy it into your notebook.
• Make plenty of drawings—a picture is worth a thousand words. Make sure your drawings are clearly and thoroughly labeled.
• Loose pieces of paper (printouts, pictures, etc.) can be added to the notebook, securing with tape only.
• Sign and date each notebook page as you complete it.
• Do not skip pages.

Why is all this so important? As an engineer, you are an inventor and creator. You may invent the next Velcro or Sticky Note. If you do not sign and date your work and provide a complete record of it, someone else may steal your creation, and therefore your money. An engineering notebook can be and is a legal document, especially in proceedings involving patent filing. History is filled with examples of patents that were rescinded because notebooks were not properly kept.
**CamCard: Circular Cam**

Predicted motion:

Observed motion:

**CamCard: Circular Cam, off-set**

Predicted motion:

Observed motion:
**CamCard: Square Cam**
Predicted motion:

Observed motion:

**CamCard: Heart-shaped Cam**
Predicted motion:

Observed motion:
CamCard: Pear-shaped Cam

Predicted motion:

CamCard: Snail-shaped Cam

Predicted motion:

Observed motion:
**CamCard: Oval**

Predicted motion:

![Oval](image)

Observed motion:

**CamCard: Triangle**

Predicted motion:

![Triangle](image)

Observed motion:
4 Main Parts of a Cam Device

- Cam
- Slide
- Follower
- Shaft
Gear Ratios

Follow Gear
Drive Gear = Gear Ratio

Work out the following gear ratios using the formula above:

1) Drive gear Follow gear
   
   Gear Ratio = ________________

2) 
   
   Gear Ratio = ________________

3) 
   
   Gear Ratio = ________________

4) 
   
   Gear Ratio = ________________
If gear A makes 3 complete rotations each time gear B makes 2 complete rotations, then how many rotations will Gear A make if Gear B turns 10 times?

If gear A makes 7 complete rotations each time gear B makes 1.5 complete rotations then how many rotations will Gear A make if Gear B turns 3 times?

You have four different size gears (40, 30, 20, 12) Using any pair of these what is the greatest gear ratio you can get? Which gears did you use?

If you have a 42-toothed gear and wish to design something with a 7:3 gear ratio how many teeth would the coupling gear need to have? Would the 42-toothed gear be your drive gear or your follow gear?

How many times will gear B turn in the following cases?

A= 10; B=20 
If A turns one time, B will turn ____________________.

A= 10; B=40 
If A turns one time, B will turn ____________________.

A= 3; B=27 
If B turns one time, A will turn ____________________.

A= 10; B=200 
If B turns one time, A will turn ____________________.

A= 12; B=48 
If A turns one time, B will turn ____________________.

A= 26; B=130 
If A turns one time, B will turn ____________________.

A= 5; B=55 
If B turns one time, A will turn ____________________.
Getting Into Gear: Challenge #1

Using 6 gears create a gear train in which the drive gear goes around twice for each time the follow gear rotates three times.

Getting Into Gear: Challenge #2

Using the fewest gears possible create a gear train in which the drive gear rotates clockwise and the follow gear rotates counter-clockwise.
Getting Into Gear: Challenge #3

Using only 40-toothed and 20-toothed gears create a gear train in which both the drive gear and the follow gear turn clockwise.

Getting Into Gear: Challenge #4

Using one gear of each size create a gear train and determine the gear ratio.
Getting Into Gear: Challenge #5

Using an equal number of each type of gear you use create a gear train in which the drive gear and the follow gear rotate in the same direction.

Getting Into Gear Challenge #6

Using at least two different gear sizes create a gear train in which the drive gear and the follow gear rotate in a 1:1 gear ratio.