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About this Guide

This curriculum is provided as a day-by-day guide to the course. The activities and resources that are included are designed to fulfill the goals of the course over the week, and provide an environment for the campers to experiment and broaden their understanding of science. It shouldn’t, however, restrict you (the instructor) from taking some creative license with the course. Like any good class, this is and will always be a work in progress. Feel free to add, subtract, and modify activities in order to help the campers succeed and to fit within the time allotted.

As this curriculum will be used to teach 5th and 6th grade classes, as well as 7th and 8th grade, there may be campers/classes for which the material needs to move more slowly or more quickly. Included in this guide are ideas for explorations that campers who finish early can test. Instructors should feel free to adjust the pace of the course and adapt it to fit the needs of the particular class. Bear in mind that there are no requirements in this curriculum, and no need to finish any particular activity. Allow the campers time to grasp and enjoy each activity fully, even at the expense of material.

This curriculum is designed to be a guide, rather than an instruction manual. This is intentional, as we find that student-driven learning is far more powerful. And from the campers’ point of view, this should allow them to feel empowered to explore on their own and create a sense of ownership in their experiments and results.
**Goals for the Course**

In this class, the campers will explore Sound, Music, and Motion, and how they relate to and affect each other. They will build and understand the workings of a speaker and a motor. They will use these as tools to explore how we observe the world both from the naked eye and through video recording and the use of strobe light systems.

Through experimentation, the campers will understand the basics of sound waves and begin to explore ways of moving air. They will also be introduced to electromagnetism, and how a speaker functions. The campers will continue throughout the week to explore sound creation and, through the iterative process, continue to improve both their products and their understanding.

The campers will also explore ideas of motion by building and modifying sculptures and other objects to put on top of their speakers. They will then expand this idea into visuals and video through the use of strobe lights.

Peer learning is emphasized through the final small-group project. Students will bring different levels of experience and knowledge into the course, and they can be encouraged to combine and match these skills for their group.
Overview of the Week

Day 1: What is sound?
- Overview of how sound works
- Using magnets and electromagnets to move air
- Build a paper speaker
- Build paper sculptures
- Introduction to strobe lights
- Flipbook animation

Day 2: What is music? (How do we make a better sounding speaker?)
- Compare sound from an instrument to the sound of instrument through a speaker
  - Discuss how music is made from a broad range of sounds from low to high pitches
- Build a sealed-box speaker
  - Why does it sound better in a box?
- Build your own box speaker

Day 3: How does music inspire motion?
- Explore the strobe effect
- Build sculptures to dance to music
- Explore video of sculptures – get familiar with the iPad App
- Begin planning for Day 4 videos

Day 4: Make your music video
- Team activity
- Prep for showcase

Day 5: What is a motor and how does it work?
- Build a motor
- What is animation?
- Test pre-made animation disks
- Create your own animation disks
Course Basics

Classroom Requirements
The arrangement of the classroom for this course is flexible, although the more desk space for building, the better. Tables may also be preferable to desks in order to create a more freeform work environment. Some sort of large computer display (projector or large screen monitor with audio playback capability) connected to an internet enabled computer will be required for showing several short instructional videos and explanatory video clips that will be available on the web at build.bose.com.

Equipment Needs
One iPad will be needed for every 4 students, for music playback and video capture and editing of the campers’ projects. All other materials will be included in the kit or directly from Bose.

Materials List
The materials list can be found separately in BOSE-Science of Sound.xlsx

Environment Preparation
Campers will be working primarily individually, but transition to teams of 4 towards the end of the week. They should be encouraged to sit at larger tables with other students. Sufficient room for building will be important. As the week progresses into group activities, campers may need not only building space but also recording space. Consider setting aside a corner or a section of the room for this purpose.

Field Trips
There will be no field trips in this course.
Lesson Plans

DAY 1

Preparation
✓ Make sure all relevant templates are printed/prepared
✓ Test all Blue boxes for functionality
✓ Make sure you have a music ready to play on the iPad for activities requiring music
✓ Remove unrelated games and apps from the iPads before handing them out.

Materials

Included in BOSEbuild kit:
• Magnet
• Wire coil
• Blue box and power supply
• Control cable
• Speaker adapter
• Audio cable
• Alligator clip cables (2)
• BOSEbuild paper speaker template

Additional materials:
• Tape (regular scotch tape is fine)
• Scissors
• Paper (colored and plain)
• Sticky note pads

Goals & Objectives

Day 1 is about introducing the campers to ideas that will be explicitly explored in greater depth later in the week. As a teacher, this is a perfect way to encourage curiosity and experimentation in the campers. Push them to find their own answers rather than asking for them.

As this day is particularly focused on camper exploration, be prepared for this day to take much more or less time than expected. Ideas for further exploration will be included in each activity to be included at the teacher’s discretion.

The concepts they will be introduced to will include: how a speaker works (sound discussion), and how periodic motion works (experimentation with sculptures).
Day 1 Overview

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>I – Ice-Breaker(s)</td>
<td>Introduce Class, Fellow Campers</td>
<td>15 minutes</td>
</tr>
<tr>
<td>II – What is sound?</td>
<td>Explain (with video and activities) how sound is about moving air.</td>
<td>30 minutes</td>
</tr>
<tr>
<td>III – Magnet and Electromagnet</td>
<td>Using magnets and electromagnets to move air</td>
<td>30 minutes</td>
</tr>
<tr>
<td>IV – Build a Paper Speaker</td>
<td>Build first speaker from template</td>
<td>45 minutes</td>
</tr>
<tr>
<td>V – Build a Paper Sculpture</td>
<td>Start with a simple loop, then experiment</td>
<td>1 hour</td>
</tr>
<tr>
<td>VI – Introduce the Strobe</td>
<td>Use to view motion in new way</td>
<td>1 hour</td>
</tr>
<tr>
<td>VII – Flipbook Animation</td>
<td>Make flip books as a way to understand the strobe effect</td>
<td>1 hour</td>
</tr>
</tbody>
</table>

Safety Concerns

Safety of the campers should be unaffected by any of today’s activities. A small comment should be made about strobe lights and ask campers if any of them are sensitive to flashing lights.

Activity I – Ice-Breaker (15 minutes)

At the teacher’s discretion, this time should be used to introduce the teachers to the campers, and the campers to one another. Because of the size of most of the campsites and the number of classes, it should be stressed to all members of the teaching staff to learn the names of the campers as quickly as possible. You should also take this opportunity to begin reading the personalities of the campers to predict how to best help individual campers during the remainder of the week.

As a way to get started, ask each camper to say their name, and the name of a song they like. The teacher or assistant teacher should make a note of each kid’s song, as later in the week those songs will be purchased and downloaded onto the iPads that the kids will be working with.

Another example ice-breaker could be playing the “Sound and Motion” game:

1. Everyone stands in a circle, and the teacher starts by making a sound and motion. (Could be anything; simple is usually better to start out.) The next person in the circle repeats the sound and motion, and the next, and so on, until the circle is complete. Now the teacher makes a new sound and motion, and passes it around the circle.

2. In this variation, when the teacher makes a sound and motion, the next person must repeat it, and then immediately make up a new one. Each person repeats the last sound and motion, and then invents a new one to pass on.

Other ice-breaker activities could include asking the campers to line up in some order (last name, birthday, etc.) without being allowed to speak; playing a memory game in a circle; etc. Whatever the game, bear in mind that these are bright kids – be aware of what rules you layout and how they could be potentially bent. Not that this should be discouraged, just anticipated.
Activity II – What is sound? (30 minutes)

What is sound? 3 key concepts:

• Sound starts as a motion – a vibration in the air.
• Those vibrations can travel through the air as a sound wave.
• When a sound wave reaches your ear, it shakes your eardrum back and forth, and you hear it.

Ask everybody to make a sound, first one at a time and then all together. Ask the kids: How did that sound get made? Some kids will clap, some will talk, and some will bang something together. And in each case, show how the thing they did to make a sound caused air to move.

Watch video: “How Does Sound Work?” (2:00) on build.bose.com/discover

Sound is about moving the air. So today, we are going to build a machine that can move air to make sound. It’s called a speaker.

Activity III – Magnet and Electromagnet (30 minutes)

Campers will connect the Wire coil to the Blue box, and experiment with the coil and magnet to see how the two magnetic fields interact. They will use the Motion slider to send different signals to the coil, and they will connect the iPad to the Blue box to hear how music sounds when played through a bare coil.

How do Magnets and Electromagnets work? 3 key concepts:

• A permanent magnet has an invisible magnetic field around it. It can attract or repel other magnets.
• When you pass a current through a wire, it makes a magnetic field around the wire: an electromagnet.
• An electromagnet is like a magnet that can be switched on or off.
CREATE

Follow these steps to set up the activity

1. Connect the power supply to the Blue box and plug it into an outlet.

2. Connect one end of the control cable to the Blue box. Connect the other end to the Speaker adapter.

3. Connect two alligator clip cables to the Speaker adapter.

4. Connect the other end of the alligator clip cables to the Wire coil.
5. Place the **Magnet** on the table with the blue flange facing down.
6. Hold the **Wire coil** by the yellow flange, and position it over the **Magnet**.

**EXPLORE**

*Things to try, questions to ask*

*Turn on the BOSEbuild Blue box using the Volume knob. The Blue box should light up pink. (If you see a different color, check the troubleshooting section at the end of this document.)*

*If possible, keep the Strobe arm closed for this activity. It can be a nice surprise for the campers when you reveal the strobe light later in the day.*

- Use the controls to adjust the signal. Start by turning the **Volume knob** about half-way up, so that the dot is in the 12:00 position. What happens? Can you feel the **Wire coil** being pushed and pulled by the **Magnet**?
- Try turning the **Volume knob** up a little. Can you hear a sound coming from the coil?
- With the coil still positioned over the magnet, try adjusting the **Motion slider**. What happens to the sound? How does it change when you move the slider up or down?
- Try moving the **Wire coil** around. Where does the **Magnet** push and pull hardest? How far away can you hold the coil and still feel the tug of the magnet?
- What happens if you turn the coil upside down? Does it make a difference?
- Use the black audio cable to connect the iPad to the **Blue box**, and try playing a song. Can you feel the coil getting pushed and pulled by the magnet? Can you hear the music coming faintly from the coil?
- Try taping the **Wire coil** to the center of a sheet of letter-sized paper. How does the paper affect the sound?

**DISCOVER**  
*Concepts for deeper understanding*

Watch video: “How Do Magnets Work?” (2:00) on build.bose.com/discover

**Electromagnetism**

On its own, the **Wire coil** is not affected by the magnet. (You can demonstrate this yourself by disconnecting the alligator clips from the coil.) But when you pass an electric current through the coil, it becomes magnetized, which means it can pull or push against the magnet. When you change the direction of the current moving through the coil, you change its polarity: a push becomes a pull, and a pull becomes a push. This is an electromagnet.

**About theBOSEbuild Blue box**

In the beginning of this activity, the **Blue box** acts as a tone generator. It can change the direction of the electric current that flows through the **Wire coil**, and it does this very quickly: many times a second. The **Motion slider** changes how frequently the current alternates back and forth. Higher frequencies make the coil move back and forth more quickly, which results in a higher pitch. The **Volume knob** changes how much current flows through the coil. More current means the magnet and coil will interact with more force, resulting in a louder sound.

When you connect the iPad to the **Blue box**, the **Blue box** acts as an audio amplifier. It still alternates the flow of current through the **Wire coil** causing the magnet and coil to push and pull against each other, but now it’s the song that determines the pattern of pushes and pulls.

For a complete list of **Blue box** modes, please refer to the **Troubleshooting** section at the end of this document.
Activity IV – Build a Paper Speaker (45 min)

Using the template and materials provided, the campers will build a simple speaker. Be sure the campers are careful with their paper. If the paper is not bent on the creases, it can affect the performance of the speaker. Extra templates will be included, and can be given out if necessary.

The speakers will then be hooked up to the provided control boxes to produce sounds.

NOTE: Many of the following activities involve all the campers playing music or tones out loud at the same time. Establish a clear rule or signal early on for all campers to turn off their Blue boxes.

After construction is complete, allow the students to explore their speakers largely on their own. Then encourage them to share their findings with other campers. For example, the speaker will create more sound if it is taped down to the table/desk. However, the vibrations created by the speaker can also make the speaker dance across the table if not taped down.

How Does the Paper Speaker Work? 3 key concepts:
• To make sound, we need to move the air.
• In the paper speaker, we are using a permanent magnet and an electromagnet to get that movement.
• The shape of the paper helps keep the coil in position over the magnet.

CREATE

Follow these steps to set up the activity

(If you’ve already completed Activity III, you can skip ahead to step 4.)

1. Connect the power supply to the Blue box and plug it into an outlet.
2. Connect one end of the control cable to the Blue box. Connect the other end to the Speaker adapter.
3. Connect two alligator clip cables to the Speaker adapter.
4. Leave the Wire coil disconnected for now. (If it’s already connected from the previous activity, disconnect the alligator clip cables from the wire coil now.)
5. Cut out the paper speaker template.
6. Fold up carefully along the dotted lines. (Don’t tape anything yet.) FOLD IN toward the colored outlines.

7. Place the Magnet on the template with the blue flange facing down, and tape it in place.

8. Place the Wire coil on the template with the yellow flange facing down, and tape it in place.

9. Fold the paper over so that the Wire coil slides around and over the Magnet.
10. Tape the three tabs in place. (Try to be precise with this step – if the tabs aren’t centered, the speaker won’t work as well when you’re done.)

11. Connect the alligator clip cables to the Wire coil. (It doesn’t matter which cable connects to which wire – it will work either way.)

EXPLORE
Things to try, questions to ask

Unplug the iPad for now, and use the Blue box to play some sounds through your new paper speaker.

• Play around with the Motion slider and Volume knob. Can you make different tones? How do you make the tone louder or quieter? Higher or lower?
• Plug in the iPad and play a song. Listen carefully, and compare the sound of just the coil and magnet to the sound of the paper speaker.
• Does it sound different? Which one sounds better? Which one gets louder? Which one lets you hear more of the music?
• What happens when you hold it up in the air while it’s playing? What about holding the base firmly on the table? Does that change the sound?

DISCOVER
Concepts for deeper understanding

Making a speaker sound ‘better’
You should be able to hear a pretty obvious difference between the sound of your paper speaker and the sound of the bare coil and magnet. There are two main reasons for this: position and surface area.

Position
The shape of the paper speaker helps keep the coil positioned in just the right spot, where the push and pull of the magnet is strongest. It also keeps the coil centered so it doesn’t rub against the magnet as it moves back and forth. (If you hear a lot of buzzing from your speaker, the position of the coil might be part of the problem.)

Surface Area
The surface area helps, too. By itself, the coil and flange don’t have much surface area, so they can’t move very much air. Just as a swimmer can use flippers to move through the water more efficiently, the larger area of the paper speaker allows it to move more air and make more sound.
Activity V – See Motion in a New Way (1 hour)

This activity is a good way to introduce campers to the concept of periodic motion and the strobe effect. Campers will make paper sculptures and mount them to their speakers to make them move. They will then use the included strobe lights to view this motion in a new way.

The speaker will be moving up and down in order to create sound, but the effect is relatively small. The paper sculptures will allow the campers to more clearly see the motion that is present and allow them to explore ideas on harnessing it.

Be aware of the strobe light on the Blue box and potential problems this could cause. Check for sensitivity to flashing lights amongst the students and lay out rules regarding misuse.

How Does Periodic Motion Work? – 3 key concepts:

- Any motion that is repeated over a set amount of time can be called periodic motion.
- A few good examples of periodic motion are: swinging on a swing, jumping on a trampoline, the pendulum on a grandfather clock.
- Strobe lights give us a different way of seeing periodic motion.

CREATE

Follow these steps to set up the activity

1. Start with the paper speaker connected to the Blue box from the previous activity. (Leave the iPad unplugged for now.)
2. Cut out a strip of paper, about 1 inch wide by 11 inches long.
3. Tape the strip into a loop.
4. Tape the loop to the top of the paper speaker.

EXPLORE

Things to try, questions to ask

- On the Blue box, use the Motion slider and Volume knob to play different tones though the paper speaker. How does the loop react?
- Once you get the loop moving, try to find the combination of motion and volume settings that results in the biggest movements.
- Now lift the Strobe arm and shine the strobe light on the loop. What do you see? (If possible, dim the classroom lights to let campers see the strobe more clearly.)
- Play around with the Strobe slider. Can you make the loop look like it’s moving in slow motion? Can you freeze it in place?
- Experiment with all three controls: Volume, Motion, and Strobe.
- When you find a strobe effect you like, try closing the Strobe arm to see how the snowman looks in natural light, and then open the Strobe arm again. Why does it look so different?
DISCOVER

Concepts for deeper understanding

Watch video: “How Do Strobe Lights Work?” (2:00) on build.bose.com/discover

Strobes and Periodic Motion
When you play a tone through your paper speaker, the speaker goes through periodic motion: it moves forward and then back again in a set amount of time, then the cycle repeats. In this case, the paper speaker is moving back and forth hundreds or even thousands of times per second.

The Motion slider determines how many times per second the speaker goes through one back and forth cycle, and the Strobe slider determines how many times per second the strobe light flashes. When the strobe light flashes at exactly the same frequency as the speaker, it always shows you the same point in the cycle. Since the speaker is in the same position each time, it looks frozen. If the strobe frequency is slightly higher or lower than the speaker frequency, each flash of the strobe comes at a slightly earlier or later point in the cycle, and it will look like the speaker is moving in slow motion.

So even though the paper loop might be moving so quickly that it looks like a blur in normal light, you can use the strobe light to make it look like it’s moving in slow-motion, or even standing still.

Activity VI – Improvise and Experiment (1 hour)
Let the campers experiment with new paper sculpture designs. Particularly flexible paper works best in order to get the most movement. The loop is a great place to start, as it is simple to build and easy to modify. Campers can add more loops of different sizes, change the order of the loops, (smallest to largest, largest to smallest, etc.) and can even play with where the sculpture is on the speaker. You can challenge the campers in various ways – how do you get the most movement? The least? Etc.

Ideas for kinetic paper sculptures

• Make a cone-shaped bowl of paper and attach it to the motion platform. Cut small bits of colored paper to make “confetti” that will dance around inside the bowl.
• Cut two long, narrow strips of paper. Hold them at 90° to each other, and repeatedly fold one over the other to make a long, springy, accordion-like chain.
• Try building sculptures that go between 2 (or even more) speakers. A simple flat piece of paper between two speakers at a distance can have interesting results.
• Long, slender, tapered shapes tend to result in interesting motion.
• Parts that stand rigidly vertical will tend to stay in lockstep with the platform; parts that hang out horizontally will move more.

Steps in Review:
1. Flash strobe light over moving sculptures.
2. Campers explore/redesign sculptures with strobe effect in mind.
3. Encourage them to look around the room and see what their fellow campers are creating, share ideas, and inspire each other.
Activity VII – Flipbook Animation (1 hour)

This activity is a good way to help campers think about the strobe light effect they have been working with. Since we’ve used the analogy that “each flash of the strobe shows you a single image, like pages in a flip book,” having the campers make their own flipbooks can help them internalize this concept. The flipbook activity also connects well with the Animation Disc project in Day 5.

CREATE

Follow these steps to set up the activity

1. On a sheet of plain, white paper, draw 9 rectangles in a 3-by-3 grid. Use these 9 panels to sketch out your flipbook idea.

2. Start by sketching the first and last frames, then fill in the remaining frames.

3. Use your sketch as a storyboard to create the final pages of your flipbook.
A few flipbook tips:

- You’ll have a lot more than 9 pages in your finished flipbook. Aim for about 20 pages or more.
- For slower, smoother motion, make each image move only a little bit from one page to the next.
- Try to keep your drawings confined to the lower part of the page, away from the binding. If you draw something up close to the binding, it will be hard to see it as you flip through the pages.

DISCOVER
Concepts for deeper understanding

**Flipbooks and Strobes: What’s the connection?**

When we make a flipbook, we take a series of still images and view them in rapid succession to create the illusion of motion. With a strobe light, we can take motion and split it up into a series of images – one image for each flash of the strobe. When we see those images in rapid succession, we can see the motion, but now we can control how fast the motion looks to our eyes by making the strobe faster or slower.
DAY 2

Preparation

✓ Test Bose transducers
✓ Gather construction materials (cardboard, box cutters, etc.)
✓ Check iPods for musical instrument samples

Materials

• BOSEbuild Blue box and power supply
• Control cable
• Speaker adapter
• BOSEbuild transducer
• Transducer mounting plate
• Screws and nuts (4 each)
• 1 Philips screwdriver
• Audio cable
• Cardboard box
• Strong packing tape
• Box cutter or X-Acto knife
• Drawing and craft supplies (pens, pencils, crayons, markers, colored paper)
• iPad with songs and apps loaded

Goals & Objectives

Day 2 is about further exploring sound, and how to make speakers sound louder and clearer. Campers will use transducers made by Bose and build speaker enclosures. They will experiment with the sound quality with and without the enclosure.

In addition to experimentation, the campers should also be led towards optimization. The challenge is not only to make something that is interesting, but also something that sounds good.

The concepts they will be introduced to will include: How does the speaker make sound? Why is it important for a speaker to produce a range of sounds from lower tones to higher tones? Why does the speaker sound better when it is in a box versus outside a box?
Day 2 Overview

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>I – Talk about Music vs. Sound</td>
<td>Discuss the range of sounds produced by different instruments.</td>
<td>30 minutes</td>
</tr>
<tr>
<td>II – Introduce the BOSEbuild Transducer</td>
<td>Explore similarities and differences with the paper speaker</td>
<td>30 minutes</td>
</tr>
<tr>
<td>III – Build a Better Speaker</td>
<td>Using Bose transducer, increase sound by building a simple box enclosure.</td>
<td>1 hour</td>
</tr>
<tr>
<td>IV – Build a Better Box</td>
<td>Optimize and customize your enclosure</td>
<td>30 minutes</td>
</tr>
<tr>
<td>V – Team Up for Stereo Sound</td>
<td>Team up in pairs to hear your speakers in stereo</td>
<td>30 minutes</td>
</tr>
<tr>
<td>VI – Turn a Speaker Into a Microphone</td>
<td>Use one speaker to send sounds and coded messages to another</td>
<td>1 hour</td>
</tr>
<tr>
<td>VII – Exploratorium: Sound Uncovered</td>
<td>Sound-related apps and demos</td>
<td>30 minutes</td>
</tr>
<tr>
<td>VIII – Music vs. Sound Demos</td>
<td>Additional demos and activities</td>
<td>30 minutes</td>
</tr>
</tbody>
</table>

Safety Concerns

Safety of the campers should be unaffected by any of today’s activities.

Activity I – Talk about Music vs. Sound (30 minutes)

Since Day 2’s activities will focus on making a better-sounding speaker, start by getting the campers to think about why better sound is necessary. Some good questions for leading the conversation:

- What is music? How are sound and music similar or different?
- Play some samples of musical instruments, and talk about the different sounds.
- Point out that even though two different instruments might play the same note, they sound very different.
- Talk about the fact that music includes a wide range of sounds, from very low notes to very high notes.
- How would you describe the sound of music played through the paper speaker? What was missing?
- If you were to design a new speaker system specifically for playing music, how would it differ from the paper speaker? How would you want the new speaker to sound?

Activity II – Introduce the BOSEbuild Transducer (30 minutes)

What’s a Transducer? 3 key concepts:

- A transducer changes energy from one form to another.
- The paper speaker and the Bose transducer are both machines that convert electrical energy into mechanical energy.
- The paper speaker and the Bose transducer have these three key components in common: voice coil, magnet, and cone.
CREATE
Follow these steps to set up the activity

1. Connect the power supply to the Blue box and plug it into an outlet.

2. Connect one end of the control cable to the Blue box. Connect the other end to the Speaker adapter.

3. Connect two alligator clip cables to the Speaker adapter.

4. Connect the other end of the alligator clip cables to the wire terminals on the BOSEbuild transducer. (It doesn’t matter which cable connects to which terminal – it will work either
5. Use the black audio cable to connect the iPad to the Blue box.

EXPLORE
Things to try, questions to ask

- Use the iPad to play some music through the BOSEbuild transducer. How does the sound compare to the paper speaker?
- Look closely at the transducer. See if you can identify these basic parts: Magnet, voice coil, and cone.
- How do these parts compare to the corresponding parts on your paper speaker?

DISCOVER
Concepts for deeper understanding

What’s a transducer?
A transducer is something that converts energy from one form into another. When your ear takes the back-and-forth motion of your eardrum and converts it into nerve impulses, it’s acting as a transducer: it’s converting mechanical energy into electrical energy. A microphone works the same way, picking up vibrations in the air and converting that mechanical energy into an electrical signal. In the same way, a speaker is a transducer, but in this case it converts electrical energy (the signal from the Blue box) into mechanical
energy (the motion of the speaker cone).

In some ways, the BOSEbuild transducer is very similar to the paper speaker. Both have the same basic parts (magnet, voice coil, and cone). But the BOSEbuild transducer has some important differences:

- Its magnet is more powerful, so it can push and pull the coil with more force, which translates to more sound.
- The “cone” of the paper speaker is simply the flat square of paper at the top. In the BOSEbuild transducer, the cone is shaped to help it move more air and make more sound. It’s also made of a special paper that is very stiff and strong, but still very light.
- The BOSEbuild transducer has a special part called a “spider” (the wavy, yellow fabric at the bottom of the voice coil) and a stronger, sturdier “surround”, (the round, flexible roll at the edge of the cone.)
- Together, the spider and surround help keep the coil centered over the magnet more precisely. They move the coil and cone quickly back into place after they’ve been pushed or pulled by the magnet, and they help keep the cone from wobbling, which can cause bad-sounding audio.

Watch video: “Manufacturing the Superdome Transducer” on build.bose.com/discover
Activity III – Build a Speaker Enclosure (1 hour)

CREATE
Follow these steps to set up the activity

(If the Blue box is still set up from the previous activity, you can skip to step 5.)

1. Before assembling the cardboard box, decorate the sides with whatever patterns and designs you like. (It’s much easier to draw on the cardboard before the tape gets applied.) Keep in mind that one side of the box will be cut out for the speaker.
2. Connect the power supply to the Blue box and plug it into an outlet.
3. Connect one end of the control cable to the Blue box. Connect the other end to the Speaker adapter.
4. Connect two alligator clip cables to the Speaker adapter.
5. Leave the BOSEbuild transducer unplugged for now. (If it’s still plugged in from the previous activity, unplug it now.)
6. Assemble the cardboard box by folding it into shape and taping it closed with the packing tape. Try to seal all the seams and corners: The more airtight your box is, the better your speaker will sound in the end.

7. Hold the BOSEbuild transducer face down, centered on one of the blank sides of the box. (Make sure to use one of the sides of the box that doesn’t have a seam.)
8. Use a marker to trace the outline of the transducer on the box.
9. Set the transducer aside, and use the box-cutter to cut out the square you outlined.

10. Attach the mounting plate to the transducer using the 4 screws and nuts.

11. Connect the free end of the alligator clips to the two wire terminals on the BOSEbuild transducer. (It doesn’t matter which wire connects to which terminal; it will work either way.)

EXPLORE
Things to try, questions to ask

Before you play any music through the transducer, make a prediction: Will it be louder or quieter when it’s mounted in the box? Why?

Now hold the BOSEbuild transducer in free air, away from the box, and use the iPad to play a song. As the music plays, put the speaker in the hole in the box, and hold the mounting plate firmly against the side of the box.
• Compare the sound of the speaker in free air to the speaker in an enclosure. Does it sound different? Louder or quieter? Was your prediction correct? What do you think causes the difference?
• Play a song that has deep bass notes. Can you hear those notes better with the enclosure or without it?
• Try turning the speaker so it faces in toward the enclosure. Does it matter which way the speaker faces?

DISCOVER
Concepts for deeper understanding

Why does it sound better in a box?
There should be a pretty dramatic difference between the sound of the transducer in free air and the transducer in the enclosure. The main reason for this is that the enclosure seals off the back of the speaker cone, leaving only the front to push and pull on the air.

When the transducer is outside the box in free air, the cone moves back and forth, which pushes and pulls the air to make sound. But as the cone pushes forward to squeeze the air in front of it, the backside of the cone is pulling back, stretching the air. And when the front of the cone pulls, the back pushes. This means that the two sides of the cone are always making the opposite sound wave: when one side pushes, the other side pulls. And when you can hear the combined sound waves from both the front and the back, they tend to cancel each other out. Not completely, but enough to make it noticeably quieter.

When you mount the transducer in the enclosure, you’re basically sealing off the back side of the cone, so it can’t cancel out the sound waves from the front. The result is louder sound, with deeper bass notes.

Watch video “How Do Speaker Enclosures Work?” (2:00) on build.bose.com/discover

Activity IV – Optimize Your Speaker (30 minutes)

1. Insert the BOSEbuild transducer into the opening in the cardboard box. Make sure the wires feed out through the notch, and the flange sits smoothly against the side of the box.

2. Tape the wires to the front of the flange to keep them from getting pulled out of place.
3. Tape the mounting flange securely in place. Use strong packing tape, and make sure there are no air gaps. A good, airtight seal will give you a better-sounding speaker.

4. Use the Signal Gen app, or any tone generator, and play a 150 Hz tone through the speaker.
5. Check all the seams on the box for leaks or gaps. If you can feel air blowing out of the box, seal up the leak with tape.
6. If desired, use the drawing and craft supplies to further decorate and customize your speaker.

Activity V – Team Up for Stereo Sound (30 minutes)

1. Pair up with a partner, and use two Control cables to connect both of your cardboard speakers to a single Blue box.
2. Connect an iPad to the Blue box and play some music through your speakers. You’ve created a stereo system!

- While the music plays, take turns placing your head exactly between the two speakers. See if you can find a song that has a voice or instrument that sounds like it’s floating between the two speakers.
- With everybody teamed up in stereo pairs, try queuing up the same song on everybody’s iPad. See if you can all press Play at the same time to hear the song through all 10 systems at once.
Activity VI – Turn a Speaker Into a Microphone (1 hour)

This activity also uses two speakers connected to a single Blue box, but this time one speaker will be connected to the Audio Input and will act as a microphone.

How does a microphone work? Key concepts:

- A transducer takes one kind of energy and converts it to another.
- A speaker converts electrical energy into motion energy, which shakes the air to make sound.
- A microphone is like a backwards speaker: sound waves in the air shake the microphone back and forth, and the microphone converts that motion energy into an electrical signal.

CREATE
Follow these steps to set up the activity

1. With your partner, use a Control cable to connect one of your cardboard speakers to the Blue box.
   NOTE: Be sure to connect to the jack on the RIGHT.
2. Connect the black Audio cable to the Blue box.
3. Use two alligator clips to connect the second speaker to the audio cable. Attach one clip to TIP, and the other to SLEEVE, as shown.

   ![Image of speaker and Blue box connections]

4. Turn the Blue box volume all the way up.
EXPLORE
Things to try, questions to ask

- The speaker that’s connected to the Audio cable is now acting as a microphone. Try tapping lightly on its cone. What happens to the other speaker?
- What happens when you speak or sing into the microphone? Can your partner hear it at the other speaker?
- Try sending coded messages to each other using the Tap code shown below.

THE TAP CODE

<table>
<thead>
<tr>
<th>TAPS</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>B</td>
<td>C/K</td>
<td>D</td>
<td>E</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>G</td>
<td>H</td>
<td>I</td>
<td>J</td>
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<td>3</td>
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<td>5</td>
<td>V</td>
<td>W</td>
<td>X</td>
<td>Y</td>
<td>Z</td>
</tr>
</tbody>
</table>

Tap the row, then the column.
(For example, H = 2,3 and I = 2,4)

- Try teaming up in 4-person groups to set up a two-way communication system, with a sender and a receiver at both ends.

DISCOVER
Concepts for deeper understanding

Think about how the sound of a drum is recorded and played back: when a musician hits the drum, the drum head shakes back and forth, which shakes the air to make a sound wave. When the sound wave gets to the microphone, it shakes the microphone, and the microphone converts that motion into an electrical signal. We can then send that same electrical signal to a speaker, which will make the speaker shake in the same pattern as the drum, and we hear the sound of the drum.
Activity VII – Exploratorium: Sound Uncovered (30 minutes)

This app, developed by the Exploratorium in San Francisco, includes a series of sound-related demos and experiments. We recommend loading this app on the teacher’s iPad, and presenting them as teacher-led group activities.

These five demos are well suited to the course:

**How old are your ears?**
Discuss what sounds we can and can’t hear, range of human hearing, and hearing loss.

**Find the Highest Note**
What sounds like a single note is actually made of lots of different tones combined together.

**Eyes vs. Ears**
Sometimes, what we see can affect what we hear. Have half the kids **hear and see** the video, and the other half **only hear** it. Then have each group write down on a chalkboard or piece of paper what they heard.

**Ten Queue Berry Mulch**
How much information do we need to hear to be able to understand? How much sound can be removed from speech before it becomes unintelligible?

**Play it Backward**
Experiment with audio palindromes.

Activity VIII – Music vs. Sound Demos (30 minutes)

These optional demos and activities can help reinforce the idea that music is made up of a combination of many different sounds — high, low, and in between. Part of the challenge of making a speaker sound good is making sure it can reproduce the whole range of musical sounds.

Have the iPad connected to a cardboard speaker for these demos.

**Take Out the Highs**
1. Use the **EQ Player** app on the iPad to remove the high frequencies from a piece of music. (Pull the sliders all the way down for 6K and higher.)
2. Have the kids listen for a few seconds, and ask them how it sounds.
3. Now add back in the high frequencies. (Push the sliders back up to 0 dB, or just press “Normal”.)
   Notice that, without the high frequencies, you can still hear all the voices and instruments, but it sounds dull. What’s missing are sounds called “overtones”. These are very high sounds that give a lot of character to the sound of different musical instruments. These overtones are a big part of the reason we can tell the difference between Middle C on a piano and Middle C on a guitar.

**Instrument Sounds**
Have the campers experiment with **Real Guitar, Tiny Piano**, or other musical instrument apps. Consider that two instruments can play the same note, yet sound very different.
DAY 3

Preparation

✓ Make sure iPads have the campers’ songs loaded
✓ Make sure iPads have the VideoStar app loaded

Materials

• BOSEbuild motion platform
• String – approximately 3 feet long
• Drawing and craft supplies (glue sticks, pens, pencils, crayons, markers, craft paper)
• Decoration supplies (Craft feathers, ribbons, pipe cleaners)
• BOSEbuild papercraft templates
• iPad with songs and video app loaded
• Cardboard speaker from day 2

Goals & Objectives

Day 3 is about applying the ideas of motion to music. The campers will further explore the strobe light and create patterns that will make the sculptures appear to be moving with the music. The teachers should lead the initial tests, and the staff should be prepared to answer questions regarding why the result looks the way it does.

However, this is one of the main ideas the campers will be using in their showcase project, so be sure to leave plenty of time for experimentation. The campers will also join into groups after lunch for their final project, so encourage sharing throughout the class in the morning to see groups start to form amongst campers who may want to explore the same ideas.

Key goals for this day will be how does a strobe light produce that cool slow-motion effect, what are the basic elements of music (melody, rhythm) and how can we use them to inspire the motion of our paper characters (dance)

Day 3 Overview

| I – Teach a Snowman to Dance | Link strobe to music and make sculptures dance | 1 hours |
| II – Put a String Into Motion | Experiment with vibration modes | 1 hour |
| III – Plan for final video project | Gather groups and layout/test ideas for showcase | 2.5 hours |
| IV – Additional Motion Demos | Optional activities using the Motion Platform | 30 minutes |

Safety Concerns

Safety of the campers should be unaffected by any of today’s activities.
Activity I – Teach a Snowman to Dance (1.5 hours)

CREATE

Follow these steps to set up the activity

Note: for this activity, it’s important to connect the **Motion adapter** to the **RIGHT** control cable jack, and the **Speaker adapter** to the **LEFT** control cable jack.

1. Connect the power supply to the **Blue box** and plug it into an outlet.
2. Connect one end of the control cable to the **Blue box**. Make sure it’s connected to the **RIGHT** control cable jack.
3. Connect the other end to the **Motion adapter**.

4. Connect two alligator clips to the **Motion adapter**, and connect the other ends to the **Motion platform**.

5. Connect a second control cable to the **Blue box**, using the **LEFT** jack.

6. Connect the **Speaker adapter** to the other end of the **Control cable**.
7. Connect your cardboard speaker to the **Speaker adapter** using the alligator clips.

8. Assemble the paper snowman from the provided template, and tape it to the **Motion platform**.

9. Connect the iPad to the **Blue box**.

**EXPLORE**

*Things to try, questions to ask*

*Use the Volume knob and Motion slider to get your snowman moving. Open the Strobe arm and shine the strobe light on the snowman.*

- Using the **Strobe slider**, try getting the snowman to bounce at different speeds.
- Now use the iPod to play a song, and see if you can get the snowman to bounce in time to the music.

**DISCOVER**

*Concepts for deeper understanding*

**Dancing to the beat**

When you dance, you’re moving to the beat of the music. To get the snowman to look like it’s dancing, you have to listen carefully to the song, and try to match the beat. One simple way to do this is to just tap the table to the beat, and then see if you can use the **Strobe slider** to match the rhythm of your taps.

It might be challenging for some campers to get the motion of the loop to line up perfectly with the song. Depending on the song, they might need to bounce at half-time or double-
time to stay with the beat. Often, they might find that they get close, but then the loop seems to drift off the beat. This means the strobe is a little too fast or a little too slow. Encourage them to make small adjustments with the Strobe slider, then watch and listen closely for a few seconds to see what happens.

Activity II – Put a String Into Motion (1 hour)

CREATE
Follow these steps to set up the activity

(If the Blue box and Motion platform are still set up from the previous activity, you can skip to step 5.)

1. Connect the power supply to the Blue box and plug it into an outlet.
2. Connect one end of the control cable to the Blue box. Make sure it’s connected to the RIGHT control cable jack.
3. Connect the other end to the Motion adapter.
4. Connect two alligator clips to the Motion adapter, and connect the other ends to the Motion platform.
5. Take a piece of string, about 3 feet long, and tape one end to the motion platform.
6. Pull the string out straight, and tape the other end to the table.

EXPLORE
Things to try, questions to ask

• Use the Volume and Motion controls to get the string vibrating. See how many different vibration modes you can find.
• When your string settles into a stable vibration mode, open the Strobe arm to see how it looks under the strobe light.
• Try changing the position of the Motion platform to make the string tighter or looser.
• Pair up with a partner: try connecting two motion platforms to the same Blue box and tape the string from one platform to the other. See if you can reach more vibration modes using two platforms.
• Have a competition to see who can find the most vibration modes, or who can get the highest mode. Each time a camper finds a stable mode, give them a sticky note with the mode number written on it.
When the string vibrates, it doesn’t just shake back and forth. As you experiment with different speeds and different amounts of tension, you will start to see more complex motion, like the various vibration modes pictured above.

These are ways that the string naturally tends to move, and they vary depending on things like how long the string is, how heavy it is, and how quickly it’s vibrating. In these modes, there are parts of the string that move a lot, and other parts that are almost motionless. The points where the string seems to be standing still are called “nodes”. These can be seen clearly in normal light, but they also look very interesting under the strobe light.

On a string instrument, such as a violin or guitar, you can lightly rest your finger on one of the string’s nodes, and pluck or bow the string to hear the harmonic. As you get higher and higher in the harmonic series, the pitch sounds higher and higher to your ear.

Use the Harmonic Synthesizer app to demonstrate the sounds of the various harmonics.
Activity III – Make a Test Video (2.5 hours)

CREATE
Follow these steps to set up the activity

1. Open the VideoStar app on the iPad.
2. Press the + icon in the upper-right corner to make a new video.

3. Pick a song. The app will start playing a preview of the song – use this preview to synch up the strobe light to the beat.
4. When you’re ready to start filming, press Make Video.

5. Press Record to start filming. You get a 3-second countdown, and then the song begins.
6. Press Stop at any time to stop filming. The next time you press Record, it will give you a countdown and then start filming where you left off.

7. When you’re done, press Stop and then press the X in the upper-right corner.

Your video is saved in the VideoStar library.

EXPLORE
Things to try, questions to ask

The test video is a practice run for the showcase video project. This is a chance to get used to the VideoStar app, and to practice using the Strobe slider to match the beat of a song.

• Try a few different songs, and see what works best.
• Try cutting to different camera angles at interesting points in the song.
• Try moving the camera to the beat of the music.
• Experiment with different shapes and materials to see what gets the best motion.
• See if you can use different kinds of shots to tell a story. Are there parts of the song where the character is moving faster or slower, or not moving at all?
Activity IV – Additional Motion Demos (30 minutes)

Optional activities using the Motion platform.

Water droplets in slow motion
Sprinkle a few drops of water on the surface of the Motion platform, then turn it on and use the strobe light to see the motion of the water.

- Use only a few drops at a time.
- With the right combination of Volume and Motion settings, you can start to see small droplets rising up off the surface and falling back down again.
- Using the strobe light to match the motion of the platform (lowest Strobe setting) will make the drops appear to freeze.
- Moving the strobe slider slightly higher will make the drops appear to move in slow motion.

Paper Cone vs. Paper Sheet
Show that a sheet of paper is not very stiff, but if you shape the paper into a cone, the shape gives it more stiffness.

- Demonstrate the lack of stiffness in a sheet of paper by holding it out horizontally, and pushing up on the middle with one finger. Point out that the middle moves with your finger, but the rest of the paper just flops around and doesn’t move the way you want.
- Now cut a circle out of the paper, and shape it into a cone:

![Diagram of a paper cone]

- Demonstrate the increased stiffness of the cone by pressing up with one finger, just as you did with the sheet of paper. Point out that the whole thing now moves together.
- Use a Magnet and Wire coil to demonstrate why stiffness is important to sound quality: tape the sheet of paper to a coil, hold it over the magnet, and play a song through it. The sound of the flapping paper will be obvious. Then, tape the paper cone to the coil and compare the sound quality. The stiffness of the cone should provide a noticeable improvement in sound quality.
• Tape the cone to the Motion platform, and cut small pieces of colored paper into the cone. The combination of regular, periodic motion in the cone, and random, chaotic motion of the confetti makes an interesting effect.
DAY 4

Preparation

✓ Double check iPads/tablets for functionality
✓ Make sure the VideoStar app is logged in to the BOSEbuild account on all iPads

Materials

• BOSEbuild Motion platform
• BOSEbuild Blue box and power supply
• BOSEbuild papercraft templates
• Storyboard Scaffold document
• Pencils
• Cardboard speaker from Day 2
• Characters from Day 3
• iPad with VideoStar and songs loaded

Goals & Objectives

Day 4 is all about the showcase video project. The campers should already be in groups and should have an idea of where they are going with their project.

It would be worthwhile to start the day with a pitch meeting to make sure both that the campers know where they are going and that it is attainable within the time given.

Day 4 Overview

<table>
<thead>
<tr>
<th>I – Video Storyboard</th>
<th>Plan out a story for your video</th>
<th>1 hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>II – Video Project Prep and Execution</td>
<td>Camper groups working on their final project</td>
<td>3–4 hours</td>
</tr>
</tbody>
</table>

Safety Concerns

Along with all of the standard safety concerns from the rest of the week, with the differing projects and the potentially rushed nature of the final day, be aware of what all the different groups are doing and how they may be at risk.
Activity I – Video Storyboard (1 hour)

1. Team up in groups of four to begin planning your video.
2. Look through the papercraft templates, and pick which characters you want to use in your final video. Or, design some characters of your own.
3. Fill out the provided **Storyboard Scaffold** document. Work with your team to plan out your video. Which characters will appear, and in what order? What shots will you try to get during different sections of the song? Keep in mind that you can use any part of the classroom as well as outdoor areas for different scenes.
Activity II – Make a Music Video (3–4 hours)

**Note:** Teachers should make sure the VideoStar app is logged in to the BOSEbuild account on all iPads before starting this activity.

To sign in, start the VideoStar app, press the **Upload** icon at the bottom of the screen, and select **Send to YouTube**.

This one-time setup needs to be performed on every iPad in order for students to be able to upload their videos.

**CREATE**

*Follow these steps to set up the activity*

1. Working with your team, assemble your characters and test them out on the **Motion platform**.
2. Make modifications to your characters to get the best dancing effects. Try adding things like feathers or pipe cleaners. Try for a combination of stiff, rigid parts and loose, floppy parts.
3. Pick the song you want to use, and find a good strobe frequency to go with it.
4. Once the characters and the song are ready, use the VideoStar app to make your music video.
5. When you’re done with your video, press the **Upload** icon at the bottom of the screen, and select **Send to YouTube**.
6. Add a Title and Description, and set the video to **Unlisted**.
7. Press **Upload Video**. Your video will be uploaded to the BOSEbuild YouTube account. Campers will receive an email link to their videos after camp is complete.
DAY 5

Preparation

✓ Double check strobe function on Blue box
✓ Check Motor adapters for proper function

Materials

• Magnet (with blue flange)
• Wire coil (with yellow flange)
• Insulated wire
• 9-volt battery
• Motor base plate
• Motor parts, labeled A through I
• Motor bearing
• Motor magnet
• Motor coil
• BOSEbuild Blue box and power supply
• Control cable
• Motor adapter plate
• Animation discs and blanks
• Drawing and craft supplies (pens, pencils, crayons, markers, craft paper)

Goals & Objectives

Day 5’s curriculum has been designed as an optional exploration of motors, strobes, and animation. If the group has needed more time to complete days 1–4, day 5 could be partially or completely dedicated to finishing the Make a Music Video project.

These activities are about taking the ideas of electromagnetism from the speakers and using that to power another form of motion. The rest of the day will focus on creating a motor, understanding how it works, concepts of animation and how our eyes perceive the individual frames. The strobe will be re-introduced and applied in a similar fashion to how the paper sculptures were observed. Bear in mind the alternate schedule on Showcase days.

Day 5 Overview

<table>
<thead>
<tr>
<th>I – Magnets and Electromagnets</th>
<th>Teacher-led demo</th>
<th>30 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>I - Build a Rotor</td>
<td>Build simple rotor from template</td>
<td>30 minutes</td>
</tr>
<tr>
<td>II – Build a Complete Motor</td>
<td>Complete motor and use strobe to create animation</td>
<td>45 minutes</td>
</tr>
<tr>
<td>III – Design Your Own Disks</td>
<td>Create animations of your own</td>
<td>1.5 hours</td>
</tr>
<tr>
<td>IV – Fill Out Camper Survey</td>
<td>Campers fill out survey (see below)</td>
<td>15 minutes</td>
</tr>
<tr>
<td>V – Showcase Prep</td>
<td>Clean up project space and prepare for Showcase</td>
<td>30 minutes</td>
</tr>
</tbody>
</table>
Safety Concerns

In addition to the concerns surrounding the electronics from previous days including epilepsy concerns with the strobe lights, the spinning motor and disk assembly can be a hazard to hands/fingers.

The wire & battery demo should be treated with caution, as the materials get hot after only a few seconds.

Activity I – Magnets and Electromagnets (30 minutes)

This teacher-led demonstration provides a review of magnets and electromagnets, how we’ve used them throughout the week, and how we will now use them in a new way to build a working motor.

1. Gather the magnet, battery, and wire.
2. Demonstrate that the wire is not affected by the magnet, since copper is a non-magnetic material.
3. Touch the ends of the wire to the battery terminals, and demonstrate that the wire now has a magnetic field, and can be attracted or repelled by the magnet.

CAUTION: don’t hold the wire in place for more than a few seconds at a time. The wire and battery both heat up quickly.

4. Show that switching the battery terminals reverses the direction of the current, and flips the polarity of the electromagnet. If the wire was attracted to the magnet before, now it will be repelled.

5. Now connect the wire coil to the battery and demonstrate how it interacts with the magnet.
6. Point out that we have been using a stationary magnet, and a moving electromagnet, to create linear, back-and-forth motion. In our next activity, we will keep the electromagnet stationary, and use it to move a permanent magnet.
Activity II – Build a Rotor (30 minutes)

CREATE
Follow these steps to set up the activity

1. Peel off the adhesive backing from the motor parts, and remove each part. (Set parts G, H, and I aside for now. We’ll use them in the next activity.)

2. Stack the two rotor plates (A and B) on top of one and other.

3. Insert the long legs of the magnet brackets (C and D) into the holes on the rotor plates (A and B).
4. Slide the motor magnet into the large holes in the magnet brackets.

5. Insert the long legs of the rotor clip (E) into the two holes in the rotor plates (C and D).

6. Attach the small disc (F) to the top of the rotor clip (E).

7. Insert the motor bearing into the center hole on the base plate, (make sure the shaft is pointing up,) and press the bearing firmly into place.

8. Slide the rotor assembly firmly down onto the bearing shaft.

9. Try spinning the rotor with your hand. It should spin freely. If it seems loose or off-center, check to make sure the bearing is seated firmly in the base plate.
EXPLORE
Things to try, questions to ask

• Hold a magnet in your hand, and move it gradually closer to the rotor. What happens to the rotor?
• Try moving the magnet in a circle around the rotor. Can you turn the rotor using only the magnet?
• Now hold the magnet in one place, and try flipping the magnet back and forth, alternating which pole faces the rotor. How does the rotor react?
• Try pairing up your rotor platform with your neighbor’s. Spin one rotor slowly and see what happens to the other.

DISCOVER
Concepts for deeper understanding

What is a Rotor?
The rotor is the part of a motor that rotates. When you bring another magnet close to the rotor, it will either attract or repel the rotor, depending on which way the poles are oriented. The bearing limits the rotor’s motion, so all it can do in response to the force from the magnet is spin.

When you flip the magnet back and forth, you alternate pushing and pulling on the rotor. If you time this just right, you can get the rotor to spin. When we build the complete motor, we will replace the magnet in your hand with an electromagnet, which means we can flip its polarity without having to physically move it.

Activity II – Build a Complete Motor (45 minutes)

CREATE
Follow these steps to set up the activity

1. Gather the three parts for the coil cradle, labeled G, H, and I.
2. Insert the short legs of part G into the holes on the base plate.

3. Insert the short legs of part H into the holes on the base plate so that it straddles part G.

4. Insert part I in the same way, at the other end of part G.

5. Place the motor coil into the coil cradle, with the wires feeding out and away from the rotor.

6. Connect the power supply to the Blue box and plug it into an outlet.
7. Connect one end of the control cable to the Blue box. Connect the other end to the Motor adapter.

8. Connect two alligator clip cables to the Motor adapter.
9. Connect the other end of the alligator clips to the Motor coil. (It doesn’t matter which clip connects to which wire; it will work either way.)

EXPLORE
Things to try, questions to ask

On the Blue box, turn the Volume knob all the way up. The Blue box LED should light up green. (If you see a different color, check the troubleshooting section at the end of this document.) Set the Motion slider to somewhere around the middle. You should see the rotor start to shake in response to the coil.

• See if you can get the motor to spin on its own. Sometimes it takes a little spin to get it started – just grab the top of the rotor between your thumb and forefinger and spin it like a top.
• Once the motor starts spinning, slowly move the Motion slider up to increase the motor speed.
• Now try adjusting the Motion slider to slow the motor down. How slow can you get it to spin before it stalls out?
• Can you start the motor spinning in either direction?
• With the motor running, open up the Strobe arm and shine the strobe light on the rotor, and use the Strobe slider to adjust the rate of the strobe. Can you make the motor appear to freeze? Can you make it look like it’s spinning in slow motion? Forwards? Backwards?
• With the motor stopped, try placing an animation disc on the disc mount at the top of the rotor.
• Shine the strobe on the spinning disc, and experiment with different strobe rates. See if you can get the animation to play forwards or backwards, or to freeze.
A working motor
The complete motor is made up of a rotor and a stator. The rotor is the part that rotates, (the magnet and bearing,) and the stator is the part that stays stationary, (the coil and cradle). Just as you could turn the rotor by moving or flipping a magnet with your hand, the coil can move it by alternating its polarity, attracting first one side of the rotor, then the other, over and over.

Types of motors
This is known as a synchronous AC motor. “AC” is for alternating current. (Remember, we are alternating the flow of current through the coil to switch the polarity of the electromagnet back and forth.) The term “synchronous” refers to the fact that the motor spins in lockstep with the current – the faster we alternate the current, the faster the motor spins.

Another common motor design is the DC motor. DC stands for direct current, like the current from a battery. DC motors typically have a permanent magnet on the stator and an electromagnet on the rotor. But practically every electric motor will have the same basic parts: a rotor and stator, made up of at least one permanent magnet and at least one electromagnet.

Activity III – Design Your Own Animation Disks (1.5 hours)
Use the provided animation disc templates to design your own animations and test them with the strobe light.

Some tips for making your own animation disc
• In order to loop smoothly, your motion sequence needs to end up in the same place it started.
• Bright, high-contrast colors will show up better under the strobe light.
• Start with a simple motion, like a bouncing ball.
• If you have twelve frames to make a ball bounce, the ball should be at its lowest point at frame 1, and at its highest point at frame 7.

• If you have six frames to make a horse gallop, it should be halfway through its stride by the third frame.
Activity IV – Fill Out Camper Survey (15 minutes)
Spend a few minutes having each camper fill out the questionnaire at the end of this document.

Activity IV – Cleanup/Showcase Prep (30 minutes)
Clean up project space and prepare for Showcase.
Resources

Troubleshooting

The BOSEbuild Blue box
When the Blue box is powered on and operating normally, its colored indicator LED lights up white. If one of the provided adapter plates is connected, the LED color changes to indicate the current mode.

<table>
<thead>
<tr>
<th>LED COLOR</th>
<th>MODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>On, nothing connected</td>
</tr>
<tr>
<td>Pink</td>
<td>Speaker adapter(s) connected – Tone mode</td>
</tr>
<tr>
<td>Blue</td>
<td>Speaker adapter(s) and audio device connected – Music mode</td>
</tr>
<tr>
<td>Yellow</td>
<td>Motion adapter connected – Motion platform mode</td>
</tr>
<tr>
<td>Orange</td>
<td>Motion adapter (R) and Speaker adapter (L) connected</td>
</tr>
<tr>
<td>Purple</td>
<td>Motion adapter (R), Speaker adapter (L), and audio device connected</td>
</tr>
<tr>
<td>Green</td>
<td>Motor adapter(s) connected – Motor mode</td>
</tr>
<tr>
<td>Blinking Red</td>
<td>ERROR – See below</td>
</tr>
<tr>
<td>Blinking White</td>
<td>ERROR – See below</td>
</tr>
</tbody>
</table>

If the LED is blinking white, that means there is an unsupported combination of devices connected. Make sure you are using one of the supported modes listed above. For example, the Motor adapter can’t be used with any other adapter type. Also note that when using the Motion and Speaker adapters together, the Motion adapter must be connected on the Right, and the Speaker adapter on the Left.

If the LED is blinking red, try the following troubleshooting steps:

1. Check to make sure there is not a short-circuit somewhere in your setup. If the metal tips of the alligator clips are touching, or if the wire leads from the voice coil or transducer are touching, that could trigger an error state. Fix the wiring and reset the Blue box by turning it off and on again.
2. If the LED is red and there is no apparent short-circuit, it’s possible that an adapter board is damaged or malfunctioning. To test this, swap it out for another adapter, and reset the Blue box by turning it off and on again. Test the suspect adapter on another Blue box.
3. If there is no short-circuit, and the adapter is determined to be functioning correctly, the Blue box could be damaged or malfunctioning. Replace it with another Blue box.