DESIGN ZONE

BEHIND THE SCENES

Teachers' Guide

OMSI

OREGON MUSEUM OF SCIENCE AND INDUSTRY

Teachers' Guide

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How to Use This Teachers' Guide

These materials have been developed as a supplementary resource for educators bringing their students to the ***Design Zone*** exhibit. Included are background information, connections to standards, strategies for working with students in the exhibit, classroom activities that tie to the exhibit, and the Active Learning Log—an open-ended worksheet for students to fill out while exploring the exhibit. The various materials can be used independently, combined to ensure a rich experience for classes visiting ***Design Zone***, or adapted to meet your classroom goals.

Exhibition Overview

What does it take to create a video game, line up rhythms like the best DJs, or design a roller coaster that produces the biggest thrills? In *Design Zone,* students can go behind the scenes and see how video game developers, music producers, roller coaster designers, and other creative problem solvers use math to do the amazing things they do.

Design Zone explores mathematical concepts like patterns, variables, scale, slope, and ratios used by artists, architects, engineers, musicians, and other innovators.

Design Zone is:

- A nontraditional, experiential approach to math, focusing on math concepts as a tool to create and invent everything from hip-hop to skate parks.
- A means to promote innovation and build math literacy—essential for careers in the twenty-first century—by directly connecting mathematical concepts to real-life experiences.
- A substantial professional development program for host museums, designed to leave a lasting impact on interpretive and education staff.

Design Zone is organized into three highly interactive thematic areas, highlighting the relationship between mathematical thinking and the creative process in art, music, and engineering. Each thematic area draws students into compelling scenes of music production, videogame development, and extreme sports that directly and experientially relate mathematical concepts to environments and activities attractive to youth. Students can design their own experience and, in some cases, e-mail their creations to family and friends. They'll solve real-world challenges and discover that math isn't just a subject in school but a fundamental, creative tool that can be used to design and invent!

Goals

Design Zone exhibits are about functions, patterns, and predicting; when one quantity changes, another changes in a predictable way. The exhibit and complementary materials were developed with the following goals for student experience:

- Students will have **enjoyable and social experiences** with algebra/math.
- Groups of students will **feel comfortable engaging** in algebra/math activities together.
- Students will use **algebraic thinking skills** and engage in **mathematical exploration**.

The exhibition's primary educational goal is for students to use algebraic thinking, a form of mathematical exploration, as they engage in creative problem solving. Like scientific inquiry, mathematical exploration is a powerful tool for understanding the world around us. *Design Zone* offers students an engaging and stimulating experience where they solve challenges, use creative thinking and problem-solving strategies, and consider problems from different perspectives. Students will use algebraic thinking in the exhibit by:

- Finding and exploring mathematical patterns and relationships between quantities.
- Representing mathematical relationships in a variety of ways, including images, words, models, graphs, and symbols.
- Using mathematical relationships to describe, analyze, predict, and create.

Mathematical exploration is a process similar to scientific inquiry that:

- Identifies variables
- Identifies patterns and relationships between those variables
- Asks questions like:
    - What is changing?
    - How is it changing?
    - Can I measure it?
    - How does a change in one variable affect another?

Exhibit Components

Design Zone's three thematic areas and exhibit components are described in depth below.

<u>ART—See It!</u>

Creative inspiration may come from anywhere, but whether it's digital design, architecture, or video games, visual designers use mathematical thinking to turn ideas into reality. In this area, students design their own 2-D and 3-D art and explore the math behind visual creativity. Math concepts include: visual patterns, scale and proportional reasoning, coordinate grids, equality, rate of change, and slope.

Exhibit clusters: Digital Design Domain, Architecture Studio, Video Game Design Lab

Digital Design Domain

Explore the math of visual patterns

Drawing in Motion
Coordinate grids help Web designers organize visual information, architects create scale drawings, and video game designers plot the movement of objects across a screen. In this full body iconic experience, two students become the designers as they move large sliders along number lines to manipulate a digital "pen" and draw on a monitor display. As they work together to create images, students will discover the math behind the concept of slope.

Mirror Multiplier
Many visual designs depict reflectional, rotational, or translational symmetry. In this exhibit students can explore reflectional symmetry using colorful geometric pieces and a hinged pair of mirrors. Students try to match several challenge images or create their own designs, while discovering the relationship between mirror angle and number of images.

Picture Calculator
Students take a picture of themselves and manipulate the values of the pixels to transform their photo. They can highlight a part of the image and then use a calculator-like interface to create simple functions that transform the highlighted section of the gray scale image. Students can choose a project from a gallery and create certain visual effects, such as heightened contrast or a negative image, or come up with their own transformations in Free Draw. Creations can be e-mailed home.

Architecture Studio

Use math to design and build in three dimensions

Balancing Art
Mobiles balance because of a relationship between the weights on each side of the balancing rod and their distance from the center of the fulcrum of the rod. Students discover the math behind mobiles as they create their own balancing art from colorful pieces.

Build a Wall, Build a Plaza, Build a Tower
Students test their abilities to continue a pattern in three dimensions as they try building a wall, a plaza, or a tower from custom printed architectural blocks.

Videogame Design Lab

Discover the algebra designers use to model virtual worlds and create on-screen action

Marble Maze
Video game designers use algebra to create games with the right feel and level of challenge. Students start with a simple marble maze game controlled by a giant tilt table. The goal of the game is to navigate the maze, avoid the black holes, and roll over stars to collect points. A simple equation relates the size of the holes, the bounciness of the marble, and the number of points per star. Students can adjust the variables and design a game that gives them the highest score.

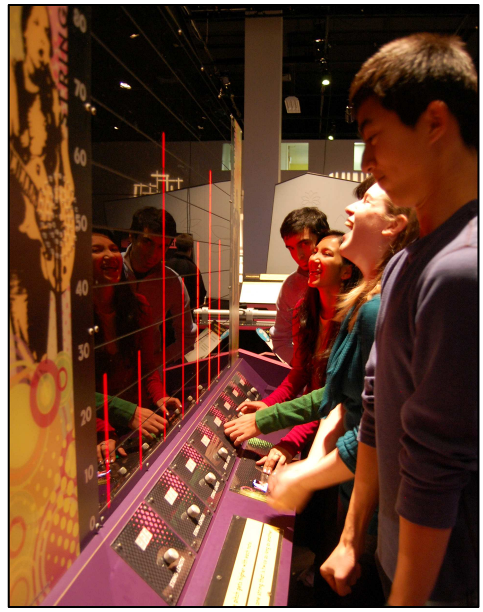
Jump on It
For a video game designer, creating motion in a virtual world involves knowing how variables like jump power and gravity interact. This game is similar to many classic arcade games. Students choose a character, select a scene, and adjust the jump power and gravity to find out how these variables affect their character's jump height as they land on platforms, collect stars, and try to complete all four jump challenges.

Hit the Target
Video game designers have to model real world motion—like balls flying through the air—to make their games more realistic and fun. Graphs and equations help them do that. In this full-body experience, students can launch a ball in the air and attempt to hit a target while learning more about the relationship between release angle and distance traveled by adjusting the release angle of a ball and trying to hit a series of lighted targets.

MUSIC—Hear It!

Students go behind the scenes and put together music tracks at a DJ recording studio, design and play instruments that reflect the mathematical relationships between length and pitch, and create a laser light show to get their friends dancing. Math concepts include: rhythmic patterns, ratios, and proportional thinking.

Exhibit clusters: DJ Recording Studio, On Stage!, Dance Party



DJ Recording Studio

Explore the math behind rhythm and music

Sound Graph

What does sound look like? Students can talk, sing, or whistle into a microphone and see the sound displayed on a colorful, real-time graph of pitch over time. They are challenged to try making sounds to match specific graph shapes.

Drum Machine

When mixing a new song, DJs have to think about the number of beats in each music track and how they line up with each other. Students pick the sounds and the number of repeats for a two-beat track, a three-beat track, and a four-beat track and see if they can get all three tracks to end on the same beat.

Music Mix

Students try out their music production skills by putting together actual music samples. They choose samples, select the number of repeats for each, and try to match the total number of beats to a pre-recorded rhythm track. Creations can be e-mailed home.

Turntables

How does a DJ move seamlessly between two songs on the turntables? It takes math. DJs can only mix songs together if they have the same beats per minute, slowing down or speeding up songs to make the beats match. Students practice their DJ skills on simulated turntables. They'll hear one song through the speakers and the next song through a mono headphone and use a graph of beats per minute to adjust the tempos up or down until they match and make the transition as smoothly as a professional.

On Stage!

Wow the audience with these wacky instruments

Digital Strings

This electronic instrument uses the relationship between string length and pitch to create music: the longer the string, the lower the note. Students can adjust the lengths of eight virtual strings and then push a button to hear their musical pattern. Lighting effects make the strings seem to vibrate as they play.

Whack-a-Phone

By whacking tubes of different lengths, students can make music. The length of the tube determines the pitch. Students can try playing one of the mystery songs—the only catch is the notes are represented as a graph showing the corresponding tube lengths.

Slide-a-Phone

Here's another twist on a tube instrument. This time, students adjust the overall length of the tube—and thus the pitch of the sound. While one person beats on the drumhead, the other slides the tube to play different notes. Students can try playing one of the mystery songs represented by a graph of tube lengths, then press the applause button and take a bow.

Dance Party

Create a mathematical light show that pumps up the crowd

Laser Light Show

Students discover how laser light show technicians create mesmerizing patterns with just two rotating mirrors and a single laser. Using a real laser, students can change the ratio of how fast one mirror moves relative to the other to create Lissajous patterns—the basis for many laser light show effects.

Light Show DJ

Once they've had some training at the *Laser Light Show*, students can put their skills to the test in the control booth at a virtual concert. Their challenge: put together laser light patterns to match the music and get their friends dancing. Like a popular dance video game, challenge patterns appear on screen moving towards you. Creating the right patterns at the right time makes the virtual crowd go wild.

ACTION—Move it!

Things that move are subject to laws of physics. The way we understand those laws is through math. In this area, students explore the algebra behind movement and speed as they build a custom digital roller coaster, design their own skate park, and race their bike to the finish line. Math concepts include: mathematical relationships describing movement, representing change over time, ratios and proportional thinking, slope, and linear equations.

Exhibit clusters: Theme Park, Action Sports Arena

Theme Park

Get the ball rolling and find out what it takes to create roller coaster thrills!

Fast Tracks

Variety is an important element of a thrill ride. Roller coaster designers try to create tracks so that the coaster travels at different speeds during different points in the ride. This giant magnet wall lets students create and test their own roller coaster course. Their challenge is to construct a course that will send the coaster through a series of speed gates at specific speeds.

Roller Coaster Hills

All roller coasters start with a hill, and the first step in roller coaster design is to understand the relationship between hill height and distance traveled. Students start a ball rolling down a ramp from a certain height and see how far it flies off the end of the ramp.

Design a Roller Coaster

In this computer graphing simulation, students can design and test virtual roller coaster tracks and discover how hill height affects speed. They take on the role of a roller coaster designer and test one of the company’s latest designs. But wait a minute, there's something wrong! The coaster doesn’t work as designed. The students’ job is to redesign each track to get the coaster safely through a series of hills at specified speeds—with maximum thrills.

Action Sports Arena

Explore the math behind bike, snowboard, and skateboard design!

Designing for Speed

Students discover the effect of weight distribution on the speed of a rotating wheel as they test a series of wheels on a downhill course of two parallel tracks. Some wheels have the weight distributed near the hub, others near the rim. Students measure how much time it takes each wheel to get to the bottom of the tracks to determine which wheel is fastest. Wheels can be weighed on the scale provided to confirm that it is mass distribution, and not total mass, that influences rolling time.

Bike Race

Students compete in a full-body bike race by choosing from three bike stations, including one of two recumbent bicycles or a hand crank. Once the race starts, students watch their progress on a graph of distance over time. Who will cross the finish line first? The race continues until each player has finished. At the end of the race, students have the option to try another course.

Testing Gears

How many wheel turns does it take to go the distance? Students feel the difference between the forces needed to perform work with three different gear combinations on two hand cranks. Students can compete with a friend and find out who can go farthest in a 20-second time trial! Just like on a bike, some gear ratios require more work than others.

Design a Skate Park

Skate parks can be modeled as a series of mathematical lines and curves. In this computer simulation, students manipulate slope to create essential skate park features. They test their design with a virtual skater who rides the course! Depending on the design, the skater might make it all the way through or crash against a ramp that’s too steep. If the skater successfully completes the course, congratulations!, the next challenge level appears. If not, students will get hints for improving the design next time.

Correlation to Educational Standards

Design Zone is intended to provide strong connections to mathematics content, focusing on algebra. *Design Zone* exhibits are about functions, patterns, and predicting; when one quantity changes, another changes in a predictable way. Throughout the exhibition, students engage in mathematical exploration through creative problem solving. In addition, by looking at math as a tool in the creative processes of art, music, and engineering, the exhibit provides further connections to science and fine arts educational standards.

Each *Design Zone* exhibit is presented with a series of progressively difficult challenges to promote engagement and learning. All of these challenges build problem-solving skills, demand creativity, build on prior knowledge, and encourage lateral thinking.

MATHEMATICS

Design Zone activities support the following standards from the National Council of Teachers of Mathematics' (NCTM) *Principles and Standards for School Mathematics* (2000). Those in italic are particularly emphasized in the exhibition.

Numbers and Operations
- Understand numbers, ways of representing numbers, relationships among numbers, and number systems
- Understand meanings of operations and how they relate to one another
- Compute fluently and make reasonable estimates

Algebra
- *Understand patterns, relations, and functions*
- Represent and analyze mathematical situations and structures using algebraic symbols
- Use mathematical models to represent and understand quantitative relationships
- *Analyze change in various contexts*

Geometry
- Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships
- *Specify locations and describe spatial relationships using coordinate geometry and other representational systems*
- Apply transformations and use symmetry to analyze mathematical situations
- Use visualization, spatial reasoning, and geometric modeling to solve problems

Measurement
- *Understand measurable attributes of objects and the units, systems, and processes of measurement*

- Apply appropriate techniques, tools, and formulas to determine measurements

Data Analysis and Probability

- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them
- *Develop and evaluate inferences and predictions that are based on data*

Problem Solving

- *Build new mathematical knowledge through problem solving*
- *Solve problems that arise in mathematics and in other contexts*
- Apply and adapt a variety of appropriate strategies to solve problems

Reasoning and Proof

- *Make and investigate mathematical conjectures*

Communication

- Organize and consolidate their mathematical thinking through communication
- Communicate their mathematical thinking coherently and clearly to peers, teachers, and others
- Analyze and evaluate the mathematical thinking and strategies of others
- Use the language of math to express mathematical ideas precisely

Connections

- Recognize and use connections among mathematical ideas
- *Recognize and apply mathematics in contexts outside of mathematics*

Representation

- Create and use representations to organize, record, and communicate mathematical ideas
- Select, apply, and translate among mathematical representations to solve problems
- *Use representations to model and interpret physical, social, and mathematical phenomena*

SCIENCE

Design Zone activities support the following content standards from the National Research Council's (NRC) *National Science Education Standards* (1996). *Design Zone* also supports Program Standard C—coordination of science and mathematics programs.

Unifying concepts and processes in science

- Evidence, models, and explanation
- Change, constancy, and measurement

Science as inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Physical Science
- Properties of objects and materials
- Motions and forces
- Transfer of energy

Science and technology
- Abilities of technological design
- Understanding about science and technology

Science in personal and social perspectives
- Science and technology in society

History and nature of science
- Science as a human endeavor
- Nature of science

FINE ART

Design Zone activities support the following content standards from the Consortium of National Arts Education Associations' (CNAEA) *National Standards for Arts Education* (1994).

Visual Arts
- Understanding and applying media, techniques, and processes
- Using knowledge of structures and functions
- Making connections between visual arts and other disciplines

Music
- Performing on instruments, alone and with others, a varied repertoire of music
- Improvising melodies, variations, and accompaniments
- Listening to, analyzing, and describing music
- Understanding relationships between music, the other arts, and disciplines outside the arts

TOPICS BY COMPONENT	Balancing Art	Build a …	Drawing in Motion	Hit the Target	Jump On It	Marble Maze	Mirror Multiplier	Picture Calculator	Digital Strings	Drum Machine	Laser Light Show	Light Show DJ	Music Mix	Slide-a-Phone	Sound Graph	Turntables	Whack-a-Phone	Bike Race	Design a Roller Coaster	Design a Skate Park	Designing for Speed	Fast Tracks	Roller Coaster Hills	Testing Gears
Mathematics																								
Data				X		X	X	X	X						X	X		X	X		X	X	X	X
Equality	X									X	X	X	X			X								
Equations	X				X	X		X		X			X											X
Functions	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Graphs			X	X					X					X	X	X	X	X	X					
Inverse							X	X	X					X			X							X
Operations	X					X		X		X			X										X	X
Patterns	X	X					X	X	X	X	X	X	X		X									
Proportion/Ratio									X	X	X	X	X											X
Scale		X																						
Slope			X															X	X	X				
Tables							X														X			X
Science																								
Acceleration																			X		X	X	X	
Force	X			X	X																X	X	X	
Gear Ratio																								X
Gravity				X	X	X													X		X	X	X	
Inertia						X													X		X			
Levers	X																							
Lissajous											X	X												
Mapping			X																					
Mass	X																				X			
Projectiles				X																			X	
Sound									X					X	X	X	X							
Speed																		X	X		X	X	X	X
Structures	X	X																				X		
Visual Art																								
Balance	X	X					X																	
Contrast		X						X																
Patterns	X	X	X				X	X			X	X												
Scale		X	X																					
Shape	X	X	X				X	X			X	X			X					X				
Symmetry	X		X				X				X	X												
Music																								
Instruments									X	X			X	X	X		X							
Octaves									X						X									
Pitch									X					X	X		X							
Rhythm									X	X			X	X	X		X							
Tempo									X	X			X		X	X								
Process Skills																								
Classifying	X	X					X	X	X						X	X					X			X
Communicating			X																					
Inferring	X	X	X	X			X		X		X	X			X	X			X	X	X	X	X	X
Measuring	X		X	X	X		X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X
Observing	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X	X	X	X
Predicting	X	X	X	X	X		X		X	X	X	X	X	X	X		X		X	X	X	X	X	X

Active Learning Log

The active learning log on the following pages is a tool designed to help students get engaged during a field trip. It features inquiry based questions about the exhibits students will experience in *Design Zone*.

An answer key is provided for teacher use, though many questions are open ended. Exhibit descriptions and likely answers are provided when questions do not have a single correct answer.

DESIGN ZONE
BEHIND THE SCENES

Active Learning Log

Name____________________

Build a Wall, **Build a Tower**, or **Build a Plaza**

Which did you build? ❑ Wall ❑ Tower ❑ Plaza

Describe or draw how you would build the next step (Step 4) in the pattern:

Drawing in Motion

Do one of the challenges (you will need a partner).

Draw the challenge shape:

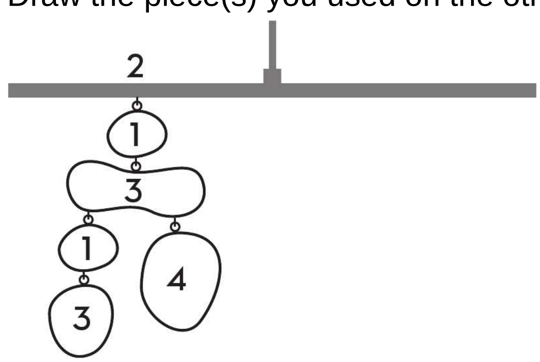
Did you both move at the same speed? Why or why not?

Draw a new shape:

Try to draw your shape in free draw mode. How difficult was it? How did you and your partner have to move to make the shape?

Balancing Art

Alexander Calder was a famous artist who made sculptures by balancing metal, wood, and other objects hanging from wires—he invented the mobile (pronounced moh-beel). Can you balance this mobile? Draw the piece(s) you used on the other side:



Designing for Speed

Record your data:

Wheel	Time (sec.)
1 (Yellow)	
2 (Green)	
3 (Blue)	
4 (Red)	

Which wheel gets the fastest time?

❑ 1 (Yellow) ❑ 2 (Green) ❑ 3 (Blue) ❑ 4 (Red)

Why do you think that wheel is the fastest?

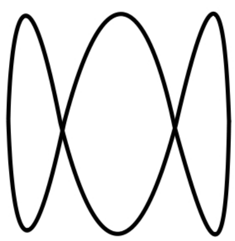
Design a Roller Coaster or Design a Skate Park

Which did you design? ❑ Roller Coaster ❑ Skate Park

What did you change to make it work? Why?

Laser Light Show or Light Show DJ

Find two sets of mirror speeds that produce this Lissajous (pronounced liss-uh-jew) pattern:



________ : ________

Mirror 1 Speed Mirror 2 Speed

________ : ________

Mirror 1 Speed Mirror 2 Speed

Bonus: How are the two sets of speeds alike?

Whack-a-Phone, Slide-a-Phone, or Digital Strings

Some people say that you use the same part of your brain for both music and math. Try playing one of the musical instruments. How are musical notes related to math?

Additional Questions

What are two jobs featured in *Design Zone* that use math?

1. ____________________ 2. ____________________

Which exhibit was your favorite? What did you like about it?

Write a trivia question about a *Design Zone* exhibit that will stump your classmates:

Question:

Answer:

![Design Zone Behind the Scenes]

Active Learning Log

Name Answer Key

Build a Wall, **Build a Tower**, or **Build a Plaza**

Which did you build? ❑ Wall ❑ Tower ❑ Plaza Note: there are two possible challenges for each

Describe or draw how you would build the next step (Step 4) in the pattern:

Challenge	Pattern Rule	# of blocks for Step 4
Wall 1	Add 3 blocks to make a new column, alternate colors	Add 2 orange, 1 gray
Wall 2	Add an arch of orange and an arch of gray, each arch has 4 more blocks than the previous arch of the same color	Add 13 orange, 15 gray
Tower 1	Cover each block with a block of the same color, add 1 gray block to the end of each branch	Add 16 gray, 1 brown
Tower 2	Cover each with 1 one of the same color, add two blocks of the same to the end of each branch	Add 16 gray, 16 brown
Plaza 1	Add blocks around the previous step, each step has 8 more blocks than the step before, alternate the color in each step	Add 28 brown
Plaza 2	Add the same color and number of blocks to each side from the previous step plus 1 more, arrange the blocks to form growing triangles of each color	Add 8 orange, 8 brown

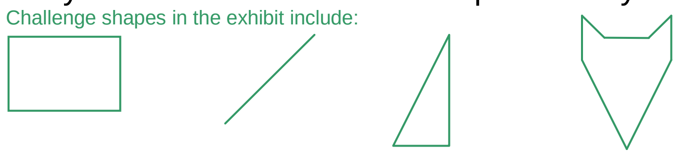
Drawing in Motion

Do one of the challenges (you will need a partner).

Draw the challenge shape:

Did you both move at the same speed? Why or why not?

Challenge shapes in the exhibit include:



Speed will depend on the slope, or steepness, of the line. For horizontal lines only the X person moves. For vertical lines only the Y person moves. For lines with a slope of 1 or -1 both move at the same speed. For steeper lines the Y person moves faster, and for less steep lines the X person moves faster.

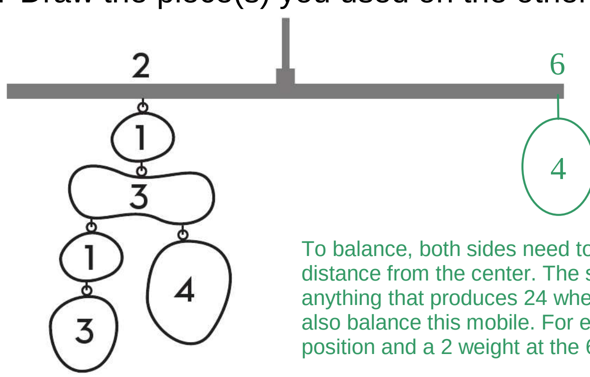
Draw a new shape:

Try to draw your shape in free draw mode. How difficult was it? How did you and your partner have to move to make the shape?

Curved lines and complex shapes will be more difficult.

Balancing Art

Alexander Calder was a famous artist who made sculptures by balancing metal, wood, and other objects hanging from wires—he invented the mobile (pronounced moh-beel). Can you balance this mobile? Draw the piece(s) you used on the other side:



To balance, both sides need to be equal when weight is multiplied by distance from the center. The simplest solution is shown here, but anything that produces 24 when weight is multiplied by distance will also balance this mobile. For example, placing a 4 weight at the 3 position and a 2 weight at the 6 position would also work (4x3+2x6=24).

Designing for Speed

Record your data:

Wheel	Time (sec.)
1 (Yellow)	11.7 ±0.5
2 (Green)	12.4 ±0.5
3 (Blue)	14.0 ±0.5
4 (Red)	15.1 ±0.5

Which wheel gets the fastest time?

☑ 1 (Yellow) ❑ 2 (Green) ❑ 3 (Blue) ❑ 4 (Red)

Why do you think that wheel is the fastest?

Yellow is fastest, followed in order by green, blue, and red. All of the wheels weigh the same, but the small metal weights in the yellow wheel are placed closest to its center axle (the red's weights are closest to the rim). The closer the weights are to the center, the faster the wheel speeds up (accelerates). *This happens because the weights must move in a circular path and the circle is smaller if they are closer in. Since they have less distance to travel around the circle, the wheel can move more easily.*

Design a Roller Coaster or **Design a Skate Park**

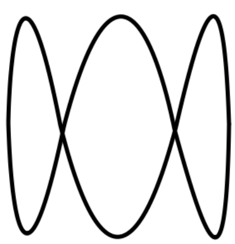
Which did you design? ❑ Roller Coaster ❑ Skate Park

What did you change to make it work? Why?

The challenges in Design a Roller Coaster require the user to adjust the height of roller coaster track hills so that the coaster's speed stays in a prescribed range throughout the ride, which is depicted on a graph of speed over time. The challenges in Design a Skate Park have the user control the location of ramp ends (which changes the length and slope of the ramps) in order to achieve target slopes and avoid obstacles. The exact changes that need to be made in both exhibits vary from challenge to challenge.

Laser Light Show or **Light Show DJ**

Find two sets of mirror speeds that produce this Lissajous (pronounced liss-uh-jew) pattern:



________ : ________

Mirror 1 Speed Mirror 2 Speed

________ : ________

Mirror 1 Speed Mirror 2 Speed

Bonus: How are the two sets of speeds alike?

They are equivalent ratios. Any 1:3 ratio will produce this pattern (i.e., Mirror 2 Speed needs to be 3x Mirror 1 Speed). Values of 10 through 60* are available (*on Laser Light Show this range may vary slightly depending on the tuning of the laser).

Whack-a-Phone, **Slide-a-Phone**, or **Digital Strings**

Some people say that you use the same part of your brain for both music and math. Try playing one of the musical instruments. How are musical notes related to math?

Whack-a-Phone, Slide-a-Phone, and Digital Strings all demonstrate the relationship between length and pitch: the longer the tube or string, the lower the note. A tube or string that is double the length of another produces a note that is an octave lower. Whack-a-Phone and Slide-a-Phone also use graphs of tube length as a unique form of musical notation and Digital Strings resembles a bar graph. All three components are labeled with numeric lengths rather than note names (e.g., A-B-Bflat, Do-Re-Mi).

Additional Questions

What are two jobs featured in *Design Zone* that use math?

Design Zone features architects, digital designers, videogame designers, musicians, DJs, laser engineers, roller coaster engineers, bike engineers, and skate park engineers.

Which exhibit was your favorite? What did you like about it?

Descriptions of all *Design Zone* exhibits can be found in the Teachers Guide.

Write a trivia question about a *Design Zone* exhibit that will stump your classmates:

Question:

Descriptions of all *Design Zone* exhibits can be found in the Teachers Guide.

Answer:

Facilitation Strategies

During the exhibit's development, several components of ***Design Zone*** underwent extensive testing to develop strategies for museum education staff supporting visitors in the exhibit. Many of these strategies can also be used by classroom teachers to support students as they engage with the exhibit and mathematical exploration. Strategies are intended to aid educators in:

- ***Orienting*** students to the exhibit's activity by showing students how to use the exhibit, highlighting the primary goal of the activity, or pointing out important features (often the variables or quantities important to the math).
- ***Supporting Student Interactions*** by recognizing that students are often effective at facilitating their own learning and supporting rather than superseding any facilitation that is already going on within student groups.
- ***Promoting Mathematical Exploration*** by carefully encouraging discussion through the posing of questions and challenges.

General strategies that have proven successful for many *Design Zone* components are outlined below. The "facilitation sheets" on the following pages describe six individual exhibit components in greater depth. This includes the educational goals for each component, a summary of the students' experience, exhibit layout, suggested facilitation strategies, and important vocabulary.

Challenges to pose
- Challenges that highlight the goal of the activity or simply restate the initial challenges from copy panels
- Challenges that simplify the activity for groups who are struggling
- Encourage and support students who create their own challenges

Things to *say*
- Describe the activity using every day, non-technical, mathematical language (e.g., faster, smaller, double) that students can borrow.
- Explicitly prompt student facilitation (e.g., suggesting that a student explain the activity to a newly arrived group member)
- Ask open ended questions (e.g., "Tell me about your wheel.")
- Ask past tense questions that prompt students to explain their thinking when successful (e.g., "What did you do, I didn't get to see?")
- Explicitly encourage communication among students
- Ask questions that prompt students to make predictions

Things to *do*
- Give students time to explore independently
- Model/highlight mathematical vocabulary and features
- Connect to students' prior knowledge and experience
- Watch for student cues and opportunities to ask questions, such as when students seem surprised by a result

Balancing Art Facilitation

DESCRIPTION: *Students construct a large mobile using whimsical colored shapes and a balance bar marked with numbers.*

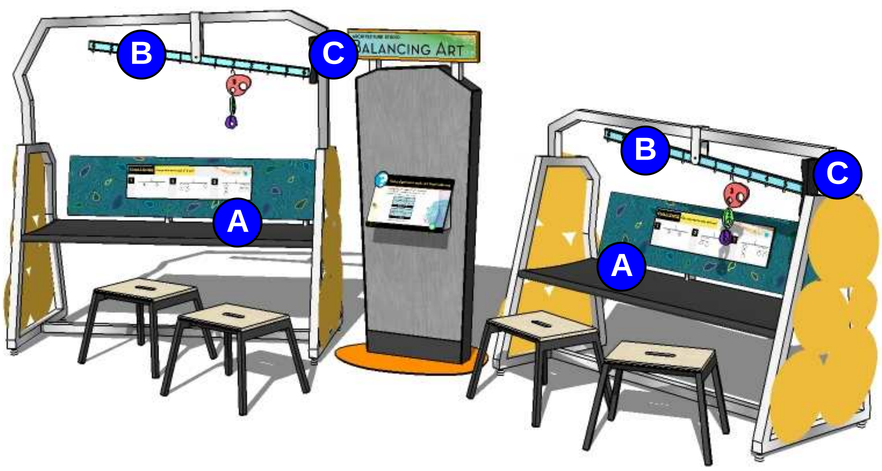
LEARNING OBJECTIVES: *Students will explore equality, weighing as a means of measuring and comparing, and the relationship between weight and distance in a mobile.*

MATH TOPICS	SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Equality	Force	Observing	K–12
Equations	Levers	Classifying	
Functions	Mass	Inferring	
Operations	Structures	Measuring	
Patterns		Predicting	

EXHIBIT DESCRIPTION

- Students choose weighted pieces, labeled numerically, from a bin and suspend them from points along a fixed hanging rod, also numbered numerically to make a mobile.
- Pieces can also be suspended from other pieces, creating more complex mobiles.
- Pieces are weighted in units of 1, 2, 3, and 4 (i.e., 2 is twice as heavy as 1) and pieces of the same weight are all one color, but may be different abstract shapes.
- Students can build freely or try posted challenges, with the goal being to have their mobile balance.
- Balance is indicated by a colored scale.
- Two stations of different heights are available.

EXHIBIT LAYOUT



A. Weight bin
B. Balance bar
C. Balance scale

EXPLANATION

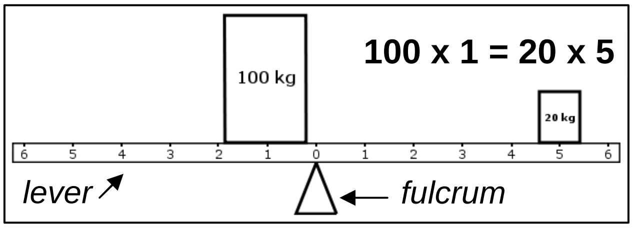
Design Zone exhibits are about functions, patterns, and predicting; when one quantity changes, another changes in a predictable way.

Teachers and students can talk about math using everyday words.

MATHEMATICAL RELATIONSHIPS

To **balance**, both sides have to be **equal**, but both **weight** and **position** matter. The overall force on each side is a function of **weight multiplied** by **distance**.

SCIENTIFIC PRINCIPLES



To balance, the forces on both sides have to be **equal**. A lever and fulcrum is a simple machine that **multiplies** the force exerted by an object on another object. The force applied with a lever is proportional to the **ratio** of the **lengths** of the lever arm between the fulcrum and each application point. Turning force (a.k.a. moment or torque) on each side can be calculated as applied force (the weight in this case) multiplied by distance between the force and the fulcrum.

FACILITATION STRATEGIES

Facilitation strategies are intended to help teachers orient students to the exhibit activity, support students' interactions with one another, and promote mathematical exploration.

∗Strategies which are particularly useful for helping a student get started at the exhibit are marked with an asterisk.

CHALLENGES TO POSE

- ∗ Start by making it **balance** with 1s on each side, then get more complex.
- Balance symmetrically (e.g., both sides 3 on 4) or inversely (e.g., 3 on 4, 4 on 3).
- ∗ Isolate a section when a student is frustrated, e.g., "You have 25 here, how can you get the same over there?"
- Encourage students to challenge each other by building one side and seeing how many ways to **balance** on the other side.

THINGS TO SAY

- ∗ "There are lots of ways to **balance** this bar using different blocks—try it out!"
- ∗ "Let's look at why this one worked before we start another challenge."
- ∗ "If you have 2 and 3 here, you can do a 3 and 2 there—**reverse** the **numbers**."
- "I'm going to let go now—what do you think will happen?"
- ∗ "6 **on the** 5 is the **same** as 5 **on the** 6" and other "**on the**" language.

THINGS TO DO

- Encourage groups to work together toward the common goal of a **balanced** bar.
- ∗ Raise awareness that "**position** matters."
- ∗ Help students focus on each side of the equation, e.g., "what do you have on this **side**?"
- Give everyone a role to ensure their involvement. Example: have someone hold the bar until ready to test.

GLOSSARY

Force:	An influence that causes an object to change speed, direction, or shape. A push or a pull.
Fulcrum:	The support about which a lever pivots.
Equation:	A mathematical expression stating that two opposite sides are equal.
Torque:	A specific kind of force, also known as **moment**. A force that rotates an object around an axis, fulcrum, or pivot point. Where a force can be thought of as a push or pull, a torque can be thought of as a twist.

Important Everyday Words

Balance	Distance	Even	Equal
Weight	Multiply	Uneven	

RESOURCES

http://www.nga.gov/exhibitions/calder/realsp/roomenter-foyer.htm
A virtual tour of the National Gallery of Art's *Alexander Calder* exhibition. Calder is considered the inventor of the mobile.

http://www.nga.gov/kids/zone/mobile.htm
An Adobe Shockwave application from the National Gallery of Art that allows you to create your own virtual mobile.

http://nlvm.usu.edu/en/nav/frames_asid_201_g_3_t_2.html
Algebraic equations represented using a virtual balance beam from Utah State University's National Library of Virtual Manipulatives (Java).

Drawing in Motion Facilitation

***DESCRIPTION**: Two students work together to draw a picture on a coordinate grid by moving large sliders representing the X and Y axes.*

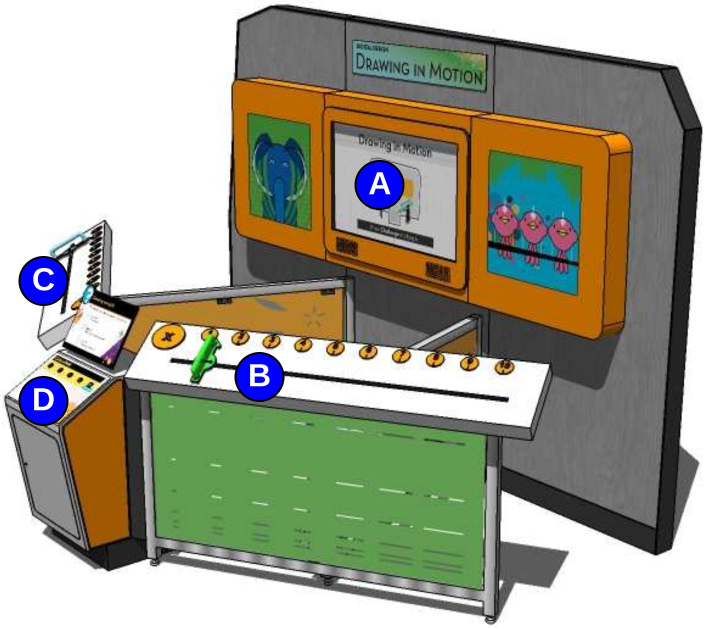
***LEARNING OBJECTIVES**: Students will use their own movement to explore graphical representations of slope and how position and slope are represented on a coordinate grid.*

MATH TOPICS	SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Functions Graphs Slope	Mapping	Observing Communicating Inferring Measuring Predicting	K–12

EXHIBIT DESCRIPTION

- Two students work together to draw pictures on an X-Y coordinate grid, which is displayed on a screen.
- One student moves a slider on a number line that represents the X-axis while another student moves a slider on a number line representing the Y-axis.
- The students' combined movements are translated into a real-time drawing on the on-screen coordinate grid.
- Students use buttons to select from four challenges in which they follow on-screen paths to connect a series of dots and create a shape. They can also create their own shapes in free draw mode.

EXHIBIT LAYOUT



A. Screen
B. X-axis slider
C. Y-axis slider
D. Challenge buttons

EXPLANATION

Design Zone exhibits are about functions, patterns, and predicting; when one quantity changes, another changes in a predictable way.

Teachers and students can talk about math using everyday words.
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MATHEMATICAL RELATIONSHIPS

Position on the screen is a **function** of the **position** of both sliders. The X-axis is left and right, and the Y-axis is up and down. The **slope** of a line is a **function** of how **fast** each person moves in relationship to the other. If the Y person moves a lot **faster** than the X person, you get a **steeper** slope.

For **horizontal** lines, only the X person moves. For **vertical** lines, only the Y person moves. For lines with a **slope** of 1 or -1, both move at the same speed. For **steeper** lines, the Y person moves faster, and for **less steep** lines, the X person moves faster.

SCIENTIFIC PRINCIPLES

The X slider controls how far left or right the pen is while the Y slider controls how far up or down. To make sloped lines both axes need to move at the same time, but not necessarily at the same **speed**. The **speed** each person should move depends on the **slope** of the line.

FACILITATION STRATEGIES

Facilitation strategies are intended to help teachers orient students to the exhibit activity, support students' interactions with one another, and promote mathematical exploration.

∗Strategies which are particularly useful for helping a student get started at the exhibit are marked with an asterisk.

CHALLENGES TO POSE

- ∗ Try same shape again, but make it neater.
- Try to make the same shape but wider, taller, etc.
- ∗ Switch axes and try again.
- Have a third student think of a shape and instruct the others how to move without telling the others the shape.

THINGS TO SAY

- ∗ "At this exhibit you work together to make **shapes**. It helps to take turns getting familiar with how **moving** each of your bars impacts the screen."
- ∗ "Who do you think controls **left** and **right** movement? **Up** and **down**?"
- ∗ "When you are working together to make an **angle/slope**, **speed** matters."
- "What did you do differently?" after a second attempt.
- "How did you make that _____?"
- "Why do you think the slope is **steeper**/**flatter**?"

THINGS TO DO

- ∗ Point out the goal of the challenges: get to the blue dot by tracing the line.
- ∗ Guide the more expert student to control the (more challenging) Y-axis.
- ∗ Remind students they are working together.
- Encourage group to have planning conversations about how they are going to move and give each other clear directions.
- Operate one station and have a lone student tell you what to do.

GLOSSARY

Axis:	One of two perpendicular lines of reference in a coordinate system.
Origin:	The point where the X-axis and Y-axis intersect.
Coordinates:	A set of numbers used to reference a point's location on a grid.
Slope:	The steepness, incline, or grade of a line.

Important Everyday Words

Straight	Left	Up	Curve
Steep	Right	Down	Speed
Angle			

RESOURCES

http://entertainment.howstuffworks.com/question317.htm
An article explaining how an Etch A Sketch works.

http://www.mathopenref.com/coordpoint.html
An interactive that allows you to move a point around a two-dimensional grid and discover its coordinates.

Digital Strings Facilitation

***DESCRIPTION**: Students create music by adjusting the length of illuminated virtual strings.*

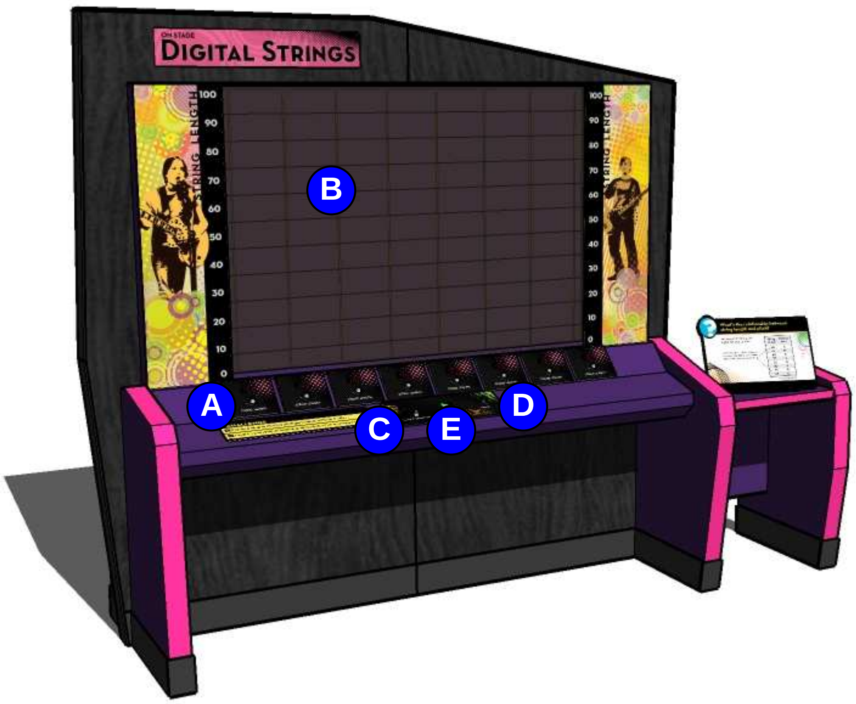
***LEARNING OBJECTIVES**: Students will explore the mathematical relationship between string length and pitch.*

MATH TOPICS	SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Data Functions Graphs Inverse Patterns Proportion/Ratio	Sound	Observing Classifying Inferring Measuring Predicting	K–12

EXHIBIT DESCRIPTION

- Students turn knobs to adjust the length of eight columns of LEDs representing "strings."
- Students can also use additional knobs to choose an instrument and adjust the tempo.
- When students press the play button, the LED strings are played through three times from left to right.

EXHIBIT LAYOUT



A. String knobs
B. Strings
C. Instrument knob
D. Tempo knob
E. Play button

EXPLANATION

Design Zone exhibits are about functions, patterns, and predicting; when one quantity changes, another changes in a predictable way.

Teachers and students can talk about math using everyday words.

MATHEMATICAL RELATIONSHIPS

Pitch is a **function** of string **length**. The **longer** the string, the **lower** the note. A string that is **twice** as long as another is an octave lower. A string that is **half** as long as another is an octave **higher**.

SCIENTIFIC PRINCIPLES

The **length** of an object controls the wavelength and, consequently, the frequency (frequency is inversely proportional to wavelength) of the sound waves produced when it vibrates. **Longer** objects vibrate at longer wavelengths and **lower** frequencies (lower notes), **shorter** objects vibrate at shorter wavelengths and **higher** frequency (higher notes). An object that is **twice** as long as another (of the same material) will produce sounds of twice the wavelength and **half** the frequency, i.e., an octave lower.

FACILITATION STRATEGIES

Facilitation strategies are intended to help teachers orient students to the exhibit activity, support students' interactions with one another, and promote mathematical exploration.

∗Strategies which are particularly useful for helping a student get started at the exhibit are marked with an asterisk.

CHALLENGES TO POSE

∗ Make a mountain, start and end on the same note.
- Figure out the missing note in a real song.
- Figure out a song of their own choice without music. Encourage students to challenge each other this way.

∗ Set up a scale (for students familiar with music).
∗ Avoid "name that tune" challenges. Rhythmic limitations cause confusion.

THINGS TO SAY

∗ "We're making **music notes** by making these **longer** or **shorter**."
∗ "Do you play **music**?"
∗ "When you press play, it will play three times and stop."
- "What happens if we **double** that one?"

∗ "Which one is flashing when you hear the **high/low** notes?"
- "What kind of **song** are you making?"
- "What do you think it's going to **sound** like?"

∗ "Does it remind you of any **musical instruments**?"

THINGS TO DO

∗ Use piano for cleanest sound. Slow down the tempo to hear better.
∗ Listen for student talk that references notes or other music words.
∗ Suggest humming if they don't know the actual notes to figure out a song.
∗ Highlight **low** and **high** by setting strings to extremes and putting the same together (e.g., 100, 100, 25, 25).
- Assign specific strings to specific students in a large group so that they can create a collaborative song.

GLOSSARY

Pitch: The perceived frequency of a sound, as in high or low.

Note: A musical pitch with a specific frequency.

Frequency: The rate of vibration of sound.

Octave: The interval between one musical pitch and another with half or double its frequency—it sounds like the same note, only higher or lower. A scale covers one octave.

Important Everyday Words

Strings	Short	Low	Half
Long	High	Double	

RESOURCES

http://entertainment.howstuffworks.com/guitar.htm
An in-depth article on how guitars work.

http://www.physicsclassroom.com/Class/sound/u11l2a.cfm
A detailed explanation of frequency and pitch.

Laser Light Show Facilitation

DESCRIPTION: *Students manipulate the speeds of rotating mirrors to control a laser light show.*

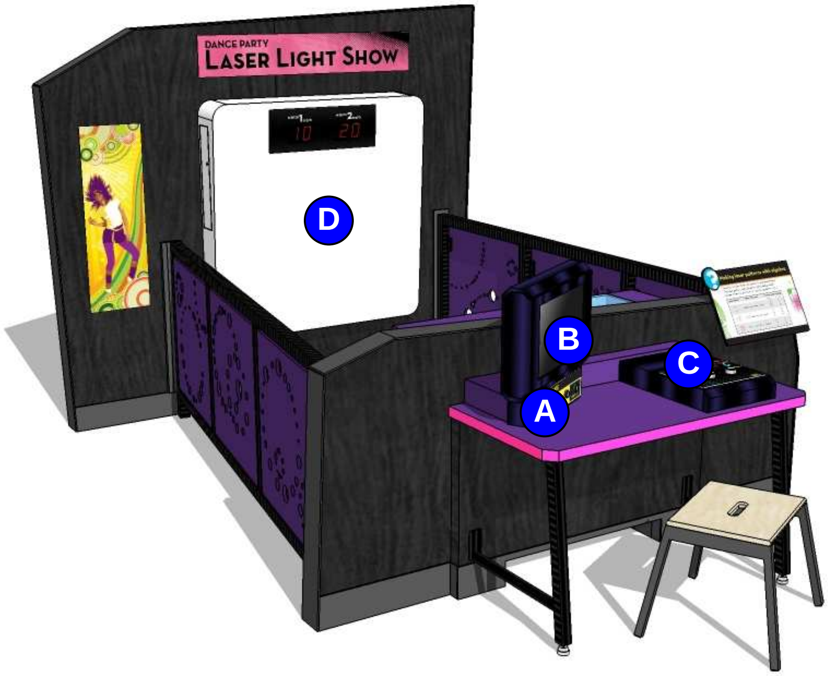
LEARNING OBJECTIVES: *Students will explore the mathematical rules behind Lissajous patterns.*

MATH TOPICS	SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Equality Functions Patterns Proportion/Ratio	Lissajous patterns	Observing Predicting Inferring	K–12

EXHIBIT DESCRIPTION

- Two oscillating mirrors control the position of a real laser on a screen.
- Students press a challenge button to begin and a screen displays the challenge.
- Students adjust two frequency knobs that control the speed of each mirror and manipulate the Lissajous patterns produced on the wall by the laser.
- Hints appear on-screen after a few seconds that help students find the right ratios to complete the challenge.
- Students may also select free-play mode.

EXHIBIT LAYOUT



A. Challenge buttons
B. Challenge screen
C. Frequency knobs
D. Laser screen

EXPLANATION

Design Zone exhibits are about functions, patterns, and predicting; when one quantity changes, another changes in a predictable way.

Teachers and students can talk about math using everyday words.

MATHEMATICAL RELATIONSHIPS

Changing the **ratio** of the mirror **speeds** produces different **patterns**. **Equivalent ratios** (e.g., 10:20, 20:40) produce the same **patterns**. The **number** of curves in the pattern is a visual representation of the **ratio**. For example, ratios **equivalent** to 1:2 (e.g., 10:20, 20:40) produce a **pattern** with one vertical curve and two horizontal curves.

SCIENTIFIC PRINCIPLES

The laser's **position** on the screen is controlled by two spinning mirrors that reflect its beam The mirrors are close to, but not quite flat while spinning, so each causes the laser's path to vary just slightly. If only one mirror were spinning, a **circular** pattern would be produced on the screen. With both spinning, the pattern becomes related to the **ratio** of the two mirrors' speeds.

FACILITATION STRATEGIES

Facilitation strategies are intended to help teachers orient students to the exhibit activity, support students' interactions with one another, and promote mathematical exploration.

∗Strategies which are particularly useful for helping a student get started at the exhibit are marked with an asterisk.

CHALLENGES TO POSE

∗ Create a pattern and then challenge students to create the same pattern using different mirror speeds (any equivalent **ratio** will work).

- Try to flip the pattern on its side (use the opposite ratio).
- Give mirror speeds (e.g., 10 and 20) and have them guess what the image will look like.

THINGS TO SAY

∗ "The numbers (or speeds) you select will directly impact the shapes created on the screen. Changing the **ratio** between those numbers is especially important for creating specific patterns."

∗ Use words like **double**, **half**, **fraction**, etc. for students unfamiliar with the concept of **ratio**.

- "Equivalent ratios, like 10:20 and 20:40, produce the same patterns."
- "The ratio gives you a clue to the pattern. For example a 1:2 **ratio** (like 10:20 or 20:40) will produce one vertical curve and two horizontal curves."
- "The number of curves in the pattern is a visual representation of the **ratio**."

THINGS TO DO

∗ Draw attention to the parent panel as a "cheat sheet" for mirror speed **ratios**.

- Emphasize the concept of **ratios** as the key to solving challenges.
- For a group, have one person control each mirror speed and have them work together to solve challenges.

GLOSSARY

Lissajous pattern: A pattern of crisscross lines that results from the ratio of two frequencies.

Ratio: A set of pairs of numbers that have the same multiplicative relationship between them. For example, 10:20, 20:40, and 1:2 are all examples of the ratio 1:2.

Important Everyday Words

Double Half Fraction

RESOURCES

http://www.math.com/students/wonders/lissajous/lissajous.html
Lissajous Lab, an online Lissajous pattern generator.

http://www.ngsir.netfirms.com/englishhtm/Lissajous.htm
Another online Lissajous pattern generator, which animates the motion of the laser.

Sound Graph Facilitation

***DESCRIPTION**: Students create sounds that are displayed in a graph of frequency over time.*

***LEARNING OBJECTIVES**: Students will explore how graphs can visually represent the frequency of sound.*

MATH TOPICS	SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Data Functions Graphs Patterns	Sound	Observing Classifying Inferring Measuring Predicting	K–12

EXHIBIT DESCRIPTION

- Students speak into a microphone or control the frequency of a whistle and see the graph of the sound that they create.
- Students can try to make sounds that match challenge patterns including an upward slope, a stair step pattern, and a wavy line.

EXHIBIT LAYOUT

A. Microphone
B. Whistle controls
C. Graph

EXPLANATION

Design Zone exhibits are about functions, patterns, and predicting; when one quantity changes, another changes in a predictable way.

Teachers and students can talk about math using everyday words.

MATHEMATICAL RELATIONSHIPS

Frequency and pitch are related. The **lower** the note, the **lower** its frequency.

SCIENTIFIC PRINCIPLES

Frequency is the **rate** of vibration of sound, and pitch is the perceived fundamental frequency of a particular sound. **Higher** notes are **higher** frequency. **Lower** notes are **lower** frequency.

FACILITATION STRATEGIES

Facilitation strategies are intended to help teachers orient students to the exhibit activity, support students' interactions with one another, and promote mathematical exploration.

∗Strategies which are particularly useful for helping a student get started at the exhibit are marked with an asterisk.

CHALLENGES TO POSE

- ∗ Create a steep or shallow slope, arch, flat line, etc.
- ∗ Make a staircase pattern.
- "How would you make a curved line?"
- Have each group member try to make the same shape.
- Try playing a single note with the whistle and singing the same note. What differences do you see?

THINGS TO SAY

- ∗ "This exhibit visually tracks the pitch of sounds."
- ∗ "Try humming a note into the microphone or playing different notes with the whistle."
- ∗ "What do you think your voice will look like?"
- ∗ "What happens when you talk in a **high**/**low** voice?"
- ∗ "What happens to the image on the screen when you **change** the pitch of _____?" (insert noise used).
- ∗ Describe pitches as **high**, **low**, **higher**, **lower**, etc.
- "How is this one different from how _____ looked?" (when trying a different noise).
- "Frequency is a **measure** of the speed of vibrations made by sound. Pitch is how we perceive that frequency. Musicians use it as a tool to make music."
- "Visual graphs like this help scientists study sounds." (e.g., echolocation, seismic sonar).

THINGS TO DO

- ∗ Have extra students help by holding buttons.
- ∗ Point out that sound is shown as a visual graph.
- ∗ Compare different sounds.

GLOSSARY

Pitch: The perceived frequency of a sound, as in high or low.

Note: A musical pitch with a specific frequency.

Frequency: The rate of vibration of sound.

Octave: The interval between one musical pitch and another with half or double its frequency—it sounds like the same note, only higher or lower. A scale covers one octave.

Important Everyday Words

High Low

RESOURCES

http://en.wikipedia.org/wiki/Audio_frequency
The Wikipedia page on audio frequency gives several playable examples of specific frequencies (notes).

http://cnx.org/content/m11060/latest/
A simple explanation of frequency.

http://spectrogram.software.informer.com/
Spectrogram by Visualization Software LLC is the freeware audio spectrum analysis software program for Windows used in the "Sound Graph" exhibit component.

http://www.exploratorium.edu/snacks/slinkyinhand/index.html
http://www.smm.org/sound/activity/2b.htm
http://www.physicsclassroom.com/class/sound/u11l1a.cfm
A long spring, such as a Slinky, makes a great tool for demonstrating sound waves (these are just a few takes on the classic demo). With some practice you can show several waves moving down the spring and distinguish between higher (more waves per unit of time) and lower (fewer waves per unit of time) frequencies.

Designing for Speed Facilitation

***DESCRIPTION**: Students compare the speeds of wheels with different weight distributions on a downhill track.*

***LEARNING OBJECTIVES**: Students will explore the relationships among mass, mass distribution, and acceleration for a wheel rolling downhill.*

MATH TOPICS	SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Data Functions Tables	Acceleration Force Gravity Inertia Mass Speed	Observing Classifying Inferring Measuring Predicting	K–12

EXHIBIT DESCRIPTION

- Students send wheels with different mass distributions down a track (two tracks are available).
- A button releases each wheel from the release gate and starts a timer, which stops when the wheel reaches the bottom of the track.
- For each track, a data table displays the most recent times recorded for each of four different wheels.
- A scale is available to confirm the equal weight of all wheels.
- Wheels with adjustable mass distribution are available for facilitated use.

EXHIBIT LAYOUT

A. Wheels
B. Release button
C. Clear button
D. Data tables
E. Scale (free standing—museums may place differently than shown)

EXPLANATION

Design Zone exhibits are about functions, patterns, and predicting; when one quantity changes, another changes in a predictable way.

Teachers and students can talk about math using everyday words.

MATHEMATICAL RELATIONSHIPS

Acceleration is a **function** of the mass distribution in a wheel if the wheels are otherwise identical. The **closer** the mass is to the center, the more **quickly** the wheel speeds up.

SCIENTIFIC PRINCIPLES

Mass that is **farther** out from the center must, for a given rate of rotation, move more **quickly** than mass closer in because it has farther to travel (the circular shape of its path is **larger**, so the **length** of the path—the circumference of the circle—is longer). As gravity is the only force acting on the wheel, it will take **longer** for mass to accelerate to that **faster** speed, so wheels with more mass located at the center accelerate **faster** than wheels with more mass located near the rim.

Misconception alert: Many students will confuse mass and weight, but since this activity takes place under constant gravity, the terms can be used interchangeably. You may choose to make the distinction if students have a clear understanding of gravity.

FACILITATION STRATEGIES

Facilitation strategies are intended to help teachers orient students to the exhibit activity, support students' interactions with one another, and promote mathematical exploration.

∗Strategies which are particularly useful for helping a student get started at the exhibit are marked with an asterisk.

CHALLENGES TO POSE

- ∗ Compare two wheels, predict which is **faster**.
- Race wheels using both tracks.
- Use all four wheels and try to get them to spread out as they roll.

THINGS TO SAY

- ∗ "These wheels all roll at **different speeds**. Can you find the fastest?"
- "Tell me about your wheel."
- "Do you think it will go **faster or slower** than ____?" or "Why do you think it went **faster/slower**?"
- "If you could adjust the wheel, how would you beat its time?"

THINGS TO DO

- ∗ Demonstrate how to get good data, i.e., just use release gate, don't push.
- ∗ Point out the scale.
- ∗ Encourage students to explain what they are doing to new comers.
- Use a spinning figure skater as an example for explanations: arms held in → spins fast, arms extended → slows down.

GLOSSARY

Inertia: The resistance of any physical object to a change in its state of motion or rest.

Mass: A measurement of the amount of matter in a body.

Matter: Anything that occupies a space.

Weight: A measure of the gravitational pull on an object (dependant on mass).

Moment of inertia: A measure of an object's resistance to changes in its rotation, also known as **rotational inertia**.

Acceleration: The rate at which something speeds up or slows down.

Rotation: Spinning of an object around itself.

Angular momentum: A conserved quantity describing how something moves around a fixed point.

Important Everyday Words

Distance	Outer	Faster	Spin
Inner	Speed	Slower	Roll

RESOURCES

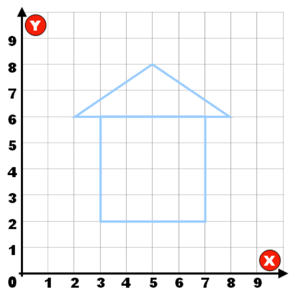
http://library.thinkquest.org/3042/angular.html
An explanation of angular momentum in simple terms.

http://www.youtube.com/watch?v=yAWLLo5cyfE
A YouTube video of a physics teacher demonstrating rotational inertia/conservation of angular momentum.

Classroom Activities

The activities outlined on the following pages are based on two exhibits in *Design Zone*. These activities can be used to connect classroom curriculum to a *Design Zone* field trip, pre- or post-visit, or can be used independently.

Drawing with Math

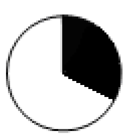
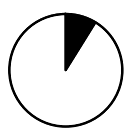
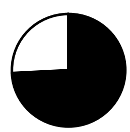
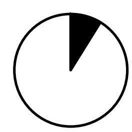


***DESCRIPTION**: Students work together to draw different shapes using an Etch A Sketch.*

***LEARNING OBJECTIVES**: Students will use movement to explore graphical representations of slope and position on a coordinate grid.*

MATH TOPICS	SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Functions Graphs Slope	Mapping	Observing Communicating Inferring Measuring Predicting	Grades 5–9

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
			
20 minutes	**5 minutes**	**45 minutes**	**5 minutes**

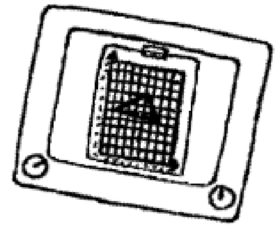
SUPPLIES

Item	Amount Needed
Etch A Sketch toys	1 per student pair*
Challenge overlays (Master A)	1 set per table group
Blank grid overlays (Master B)	1 per student pair*
Challenge ideas (Master C)	1 per student pair*
Clear tape	1 roll per table group
Dry erase markers	1 per student pair*
Graph paper	A few sheets per table group
Permanent marker	1

*Pairs are ideal, but if students take turns they could work in larger groups.

ADVANCE PREPARATION

- ❑ Draw a line like a clock hand on each Etch A Sketch knob and label the horizontal knob "X" and the vertical knob "Y" using a permanent marker.



> *Note*: If asking students to bring Etch A Sketches from home, skip the above step or carefully use removable tape on the knobs.

- ❑ Copy or print Master A (challenge overlays) onto transparencies and cut out the individual grids, creating one complete set per table group.
- ❑ Copy or print Master B (blank grid overlays) onto transparencies and cut out the individual grids, creating one grid per student pair.
- ❑ Copy Master C (challenge ideas) on regular paper, one per student pair.

SET UP

<u>For each student pair:</u>

- ❑ 1 Etch A Sketch
- ❑ 1 blank grid overlay
- ❑ 1 dry erase marker
- ❑ 1 Challenge Ideas sheet

<u>For each table group:</u>

- ❑ 1 set of challenge overlays
- ❑ 1 roll clear tape
- ❑ A few sheets of graph paper

INTRODUCING THE ACTIVITY

Let students speculate before offering answers to any questions. The answers at the right are provided primarily for the teacher's benefit.

Choose questions that are appropriate for your classroom.

Ask students if they've ever played with an Etch A Sketch and wondered how it works. Explain that students will be working together to draw pictures and "slope" will help them draw (older students who are studying algebra are likely to be more familiar with mathematical representations and equations, which can be emphasized throughout this activity).

What is slope?

In every day terms, slopes can be "downhill" or "uphill," "gentle" or "steep." Slope is a way of thinking about how far up and how far over something goes. Slopes are always lines in mathematics, but they may be bumpier in real life!

How do we describe slopes?

Slopes can go up faster or slower—we often say they are more or less steep. To describe a slope mathematically, you figure out how high the slope goes and how far over it goes. The higher it goes in relation to how far over it goes, the steeper it is. Sometimes, we call this "rise over run."

But what's rise and what's run?

Rise is distance along the Y-axis and run is distance along the X-axis. You can think of rise as "how far up" and run as "how far over."

If you wanted to draw a line with a slope of 3, what would you do?

Make one dot, then go up three and over one and make another. Then draw a line to connect the dots.

CLASSROOM ACTIVITY

When prompting students, choose language and a level of detail that are appropriate for your classroom. The base activity is suitable for a range of grade levels.

First, encourage students to experiment with their Etch A Sketch.

- One partner should control each knob.
- Allow them some time to try doodling on their own to get a feel for the knobs.

Ask the students to choose a challenge overlay and place it on the Etch A Sketch screen.

- A square or rectangle will be easiest to start.
- They can use a small piece of clear tape to hold the overlay in place if needed.

Encourage students to work together to draw their shape.

- If they want to start with a clean screen they should move to a point on the shape before inverting the Etch A Sketch and shaking it to erase.
- Call students attention to the “clock hand” lines on the knobs—these will help them track how far they are turning their knob.
- Ask students to think about which partner needs to move their knob for which parts of the picture. When does the X student move? When does the Y student move? When do they both move?
- Remind students to communicate with their partner. Counting out loud as they move can help them keep pace with each other.

Encourage students to try additional challenges.

- As they try the more difficult ones (triangles with slopes greater than or less than 1), ask them to think about the speed they are moving their knob relative to their partner. Who is moving faster? How much faster?

Finally, encourage students to create their own challenges.

- Use the blank grid overlay and a dry erase marker.
- They can use the Challenge Ideas sheet for inspiration or create their own.
- They may want to sketch on graph paper before drawing on the overlay.
- Pairs of students can challenge other pairs by trading.

CLASS DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

Discuss the challenges and how students accomplished them.

How did you need to work together to finish the shapes? What strategies did you use?
You need both knobs to control the position of the pen in an Etch A Sketch. The X student is controlling its horizontal (left or right) position and the Y student is controlling its vertical (up or down) position. It's important for the two to communicate—counting out loud can be particularly helpful.

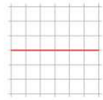
Did you move at the same speed or different speeds? When did one person have to move faster?
Speed depends on the slope, or steepness, of the line. For horizontal lines, only the X student moves. For vertical lines, only the Y student moves. For lines with a slope of 1 or -1, both move at the same speed. For steeper lines the Y student moves faster, and for less steep lines the X student moves faster.

Which shapes were easiest? Which were hardest?
Typically, shapes where only one student moves at a time, like squares and rectangles, are easiest. Slopes of 1 or -1 are fairly easy, but require communication so that both students move at the same speed. Other slopes are more difficult as they require the two students to move at different speeds. Communication is the key! Curved lines are usually extremely difficult.

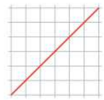
How do you think the Etch A Sketch works?
An Etch A Sketch uses a simple two-axis system of pulleys to control its stylus "pen," which scrapes aluminum powder off of the screen. Shaking the Etch A Sketch allows the powder to recoat the screen—small beads help to smooth it.

MATH BACKGROUND

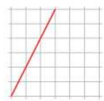
Position on the screen is a function of the position on both axes. The X-axis is left and right and the Y-axis is up and down. The slope of a line is a function of how fast each person moves in relationship to the other. For horizontal lines, only the X person moves. For vertical lines, only the Y person moves. For lines with a slope of 1 or -1, both move at the same speed. For steeper lines the Y person moves faster, and for less steep lines the X person moves faster.



Slope = **0**
Only X moves.



Slope = **1**
X and Y move at the same speed.



Slope = **2**
Y moves twice as fast as X.

OPTIONAL EXTENSIONS

Extension A: Coordinate Positions
With a blank grid overlay on the screen, have students draw "dot-to-dot" drawings by giving them the sequence. For example:

- Start at (1, 1).
- Draw to (1, 4).
- Now draw to (4, 4).
- Then draw to (4, 1).
- Finally go back to (1, 1).
- What did you draw? (*a 3x3 square*)

For added challenge, give a third student a challenge image and ask them to determine what instructions to give students controlling an Etch A Sketch while keeping the image hidden.

Extension B: Equations
Have students draw (graph) the equation for a line or multiple lines. Provide multiple equations, each with a range, to draw an image. For example:

- Draw:

X = 2	between	Y = 4	and	Y = 7
Y = -X + 9	between	X = 2	and	X = 3
Y = 6	between	X = 3	and	X = 5
Y = X + 1	between	X = 5	and	X = 6
X = 6	between	Y = 4	and	Y = 7
Y = 3/2X - 5	between	X = 4	and	X = 6
Y = -3/2X + 7	between	X = 2	and	X = 4

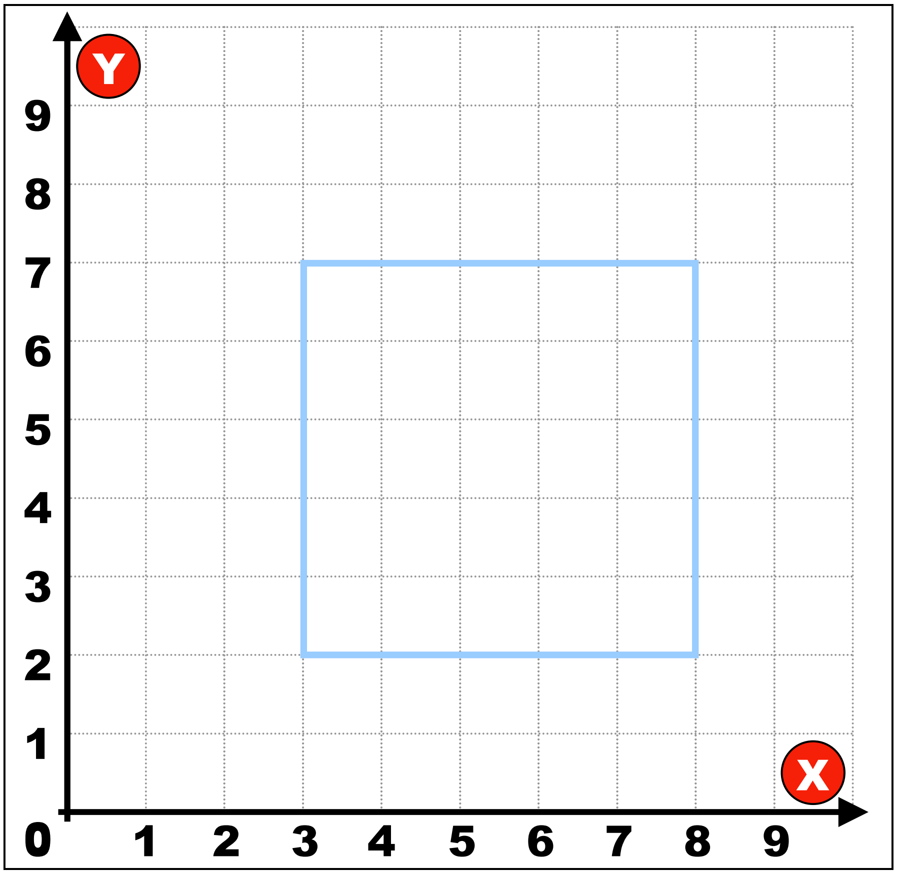
- What did you draw? (*a fox or cat*)

MASTERS

Master A—Challenge Overlays

Master B—Blank Grid Overlays

Master C—Challenge Ideas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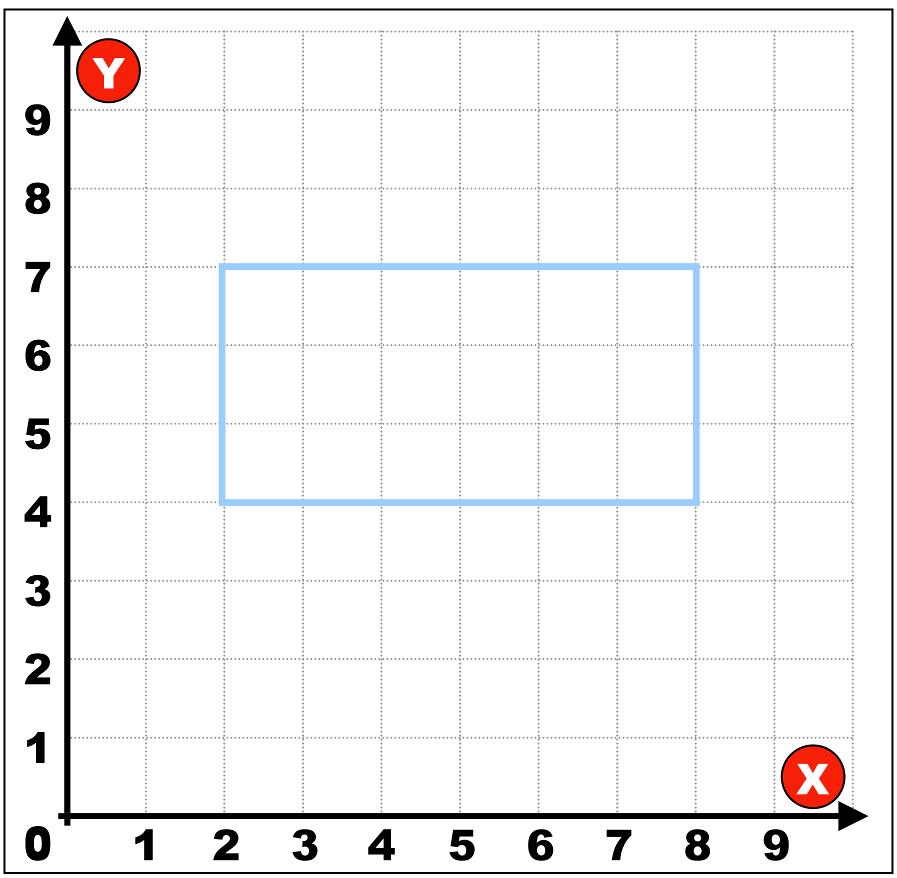
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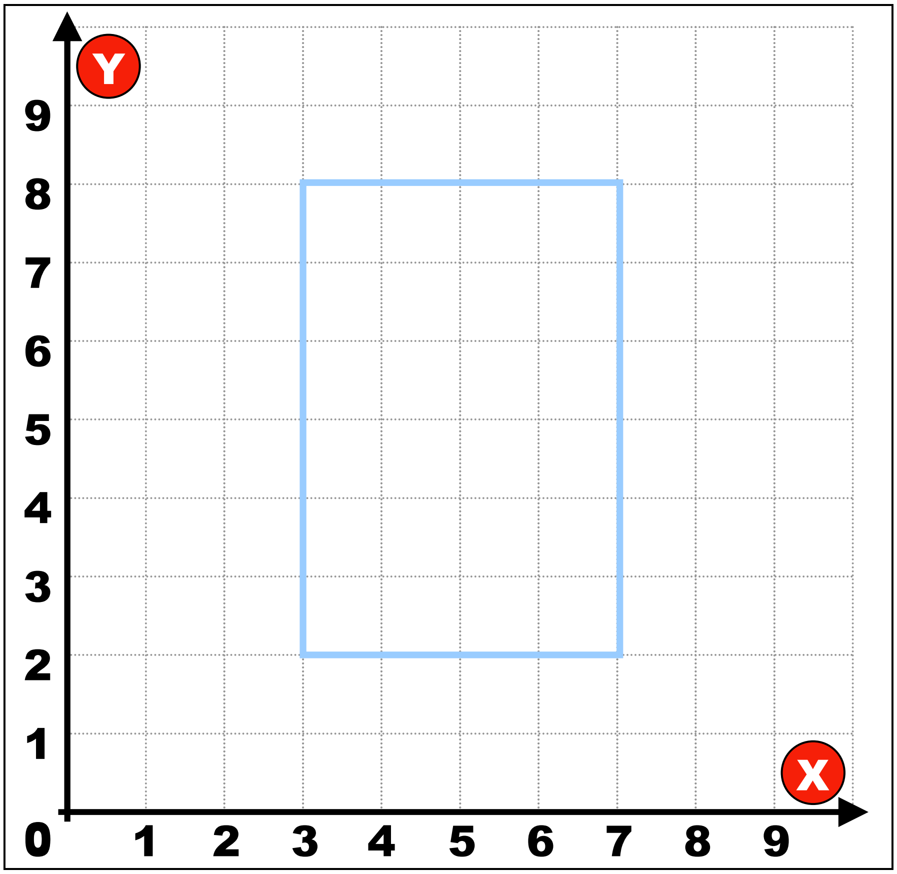
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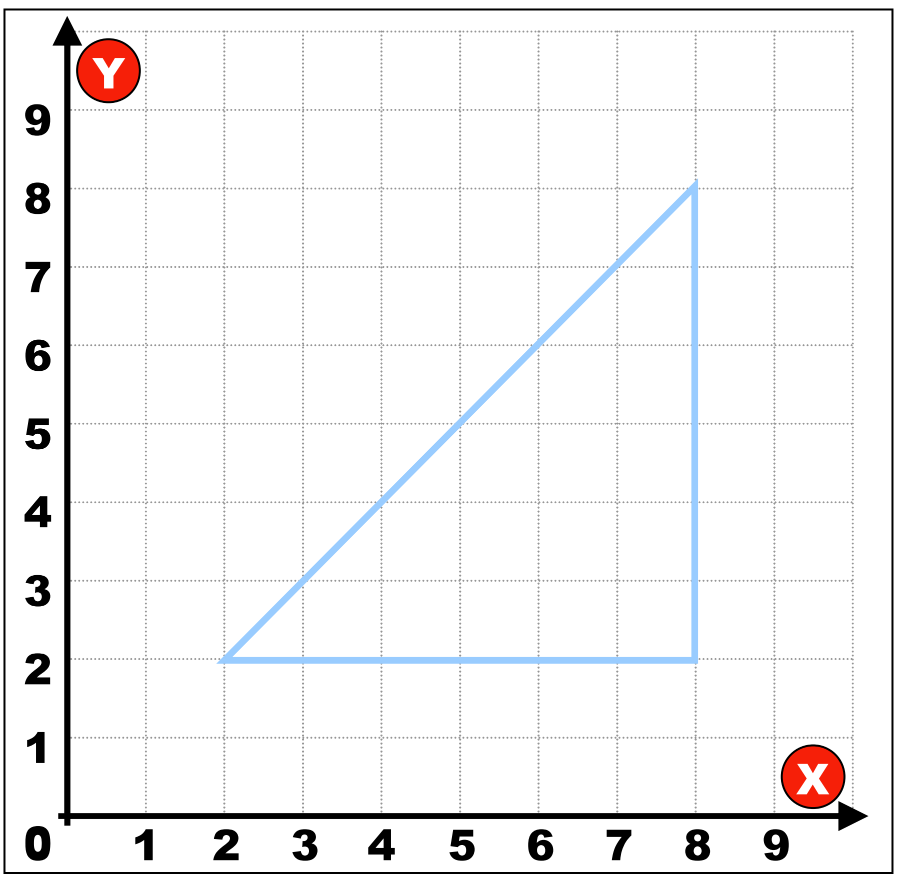
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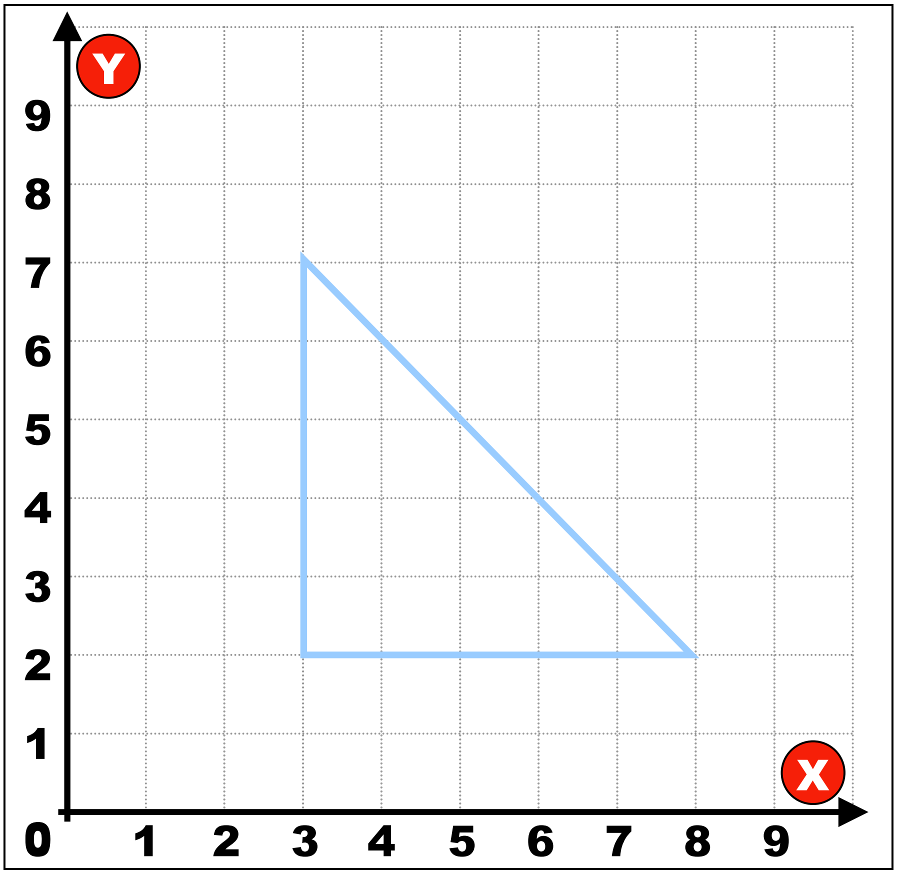
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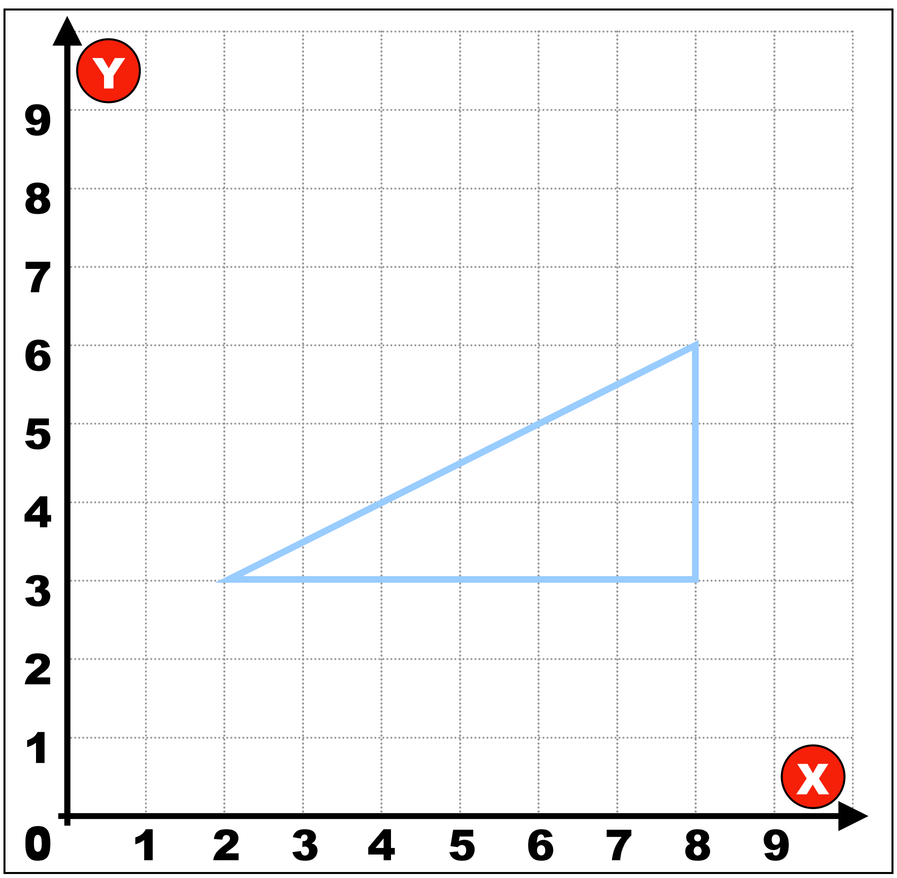
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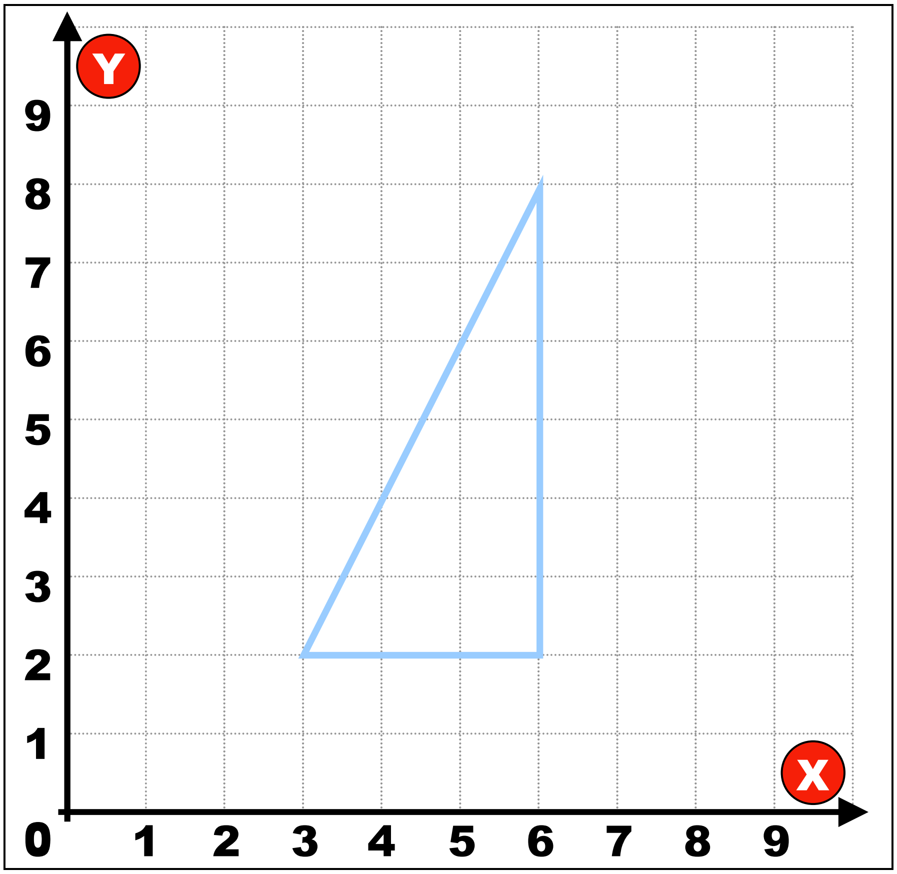
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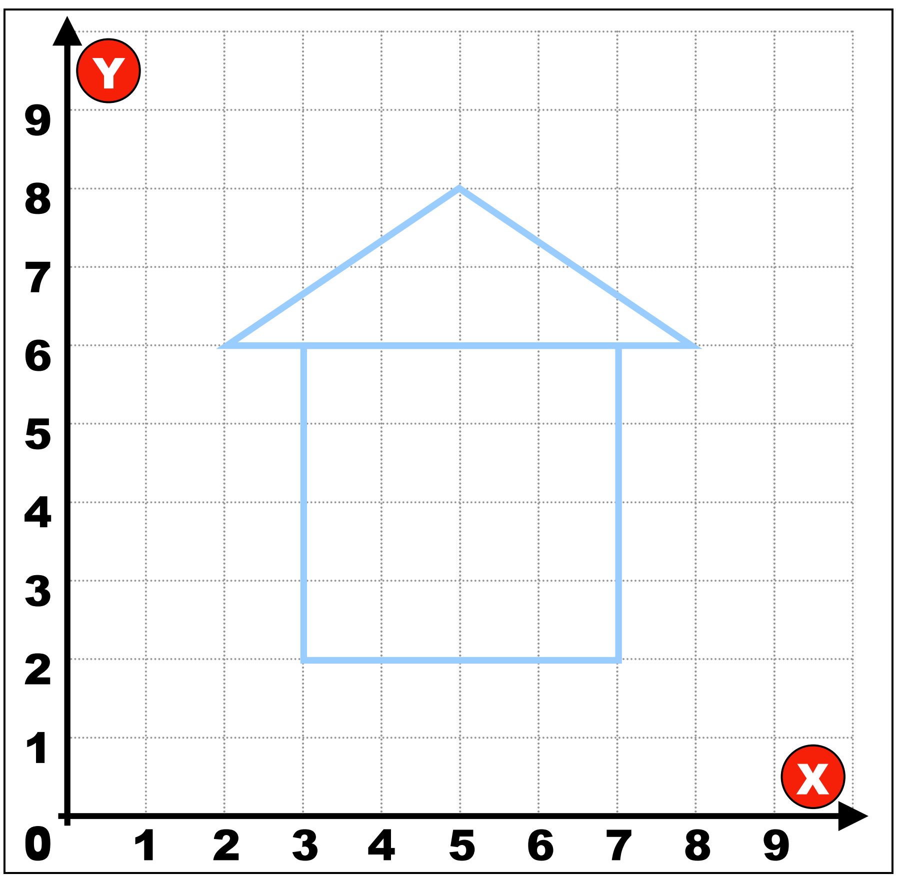
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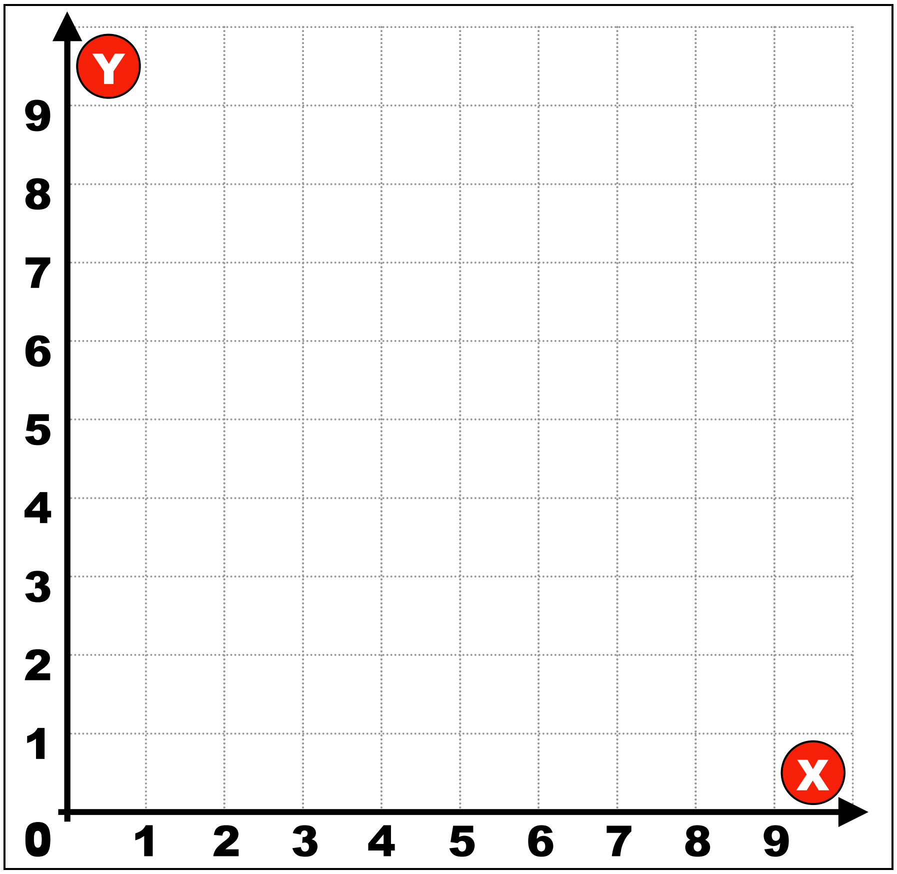
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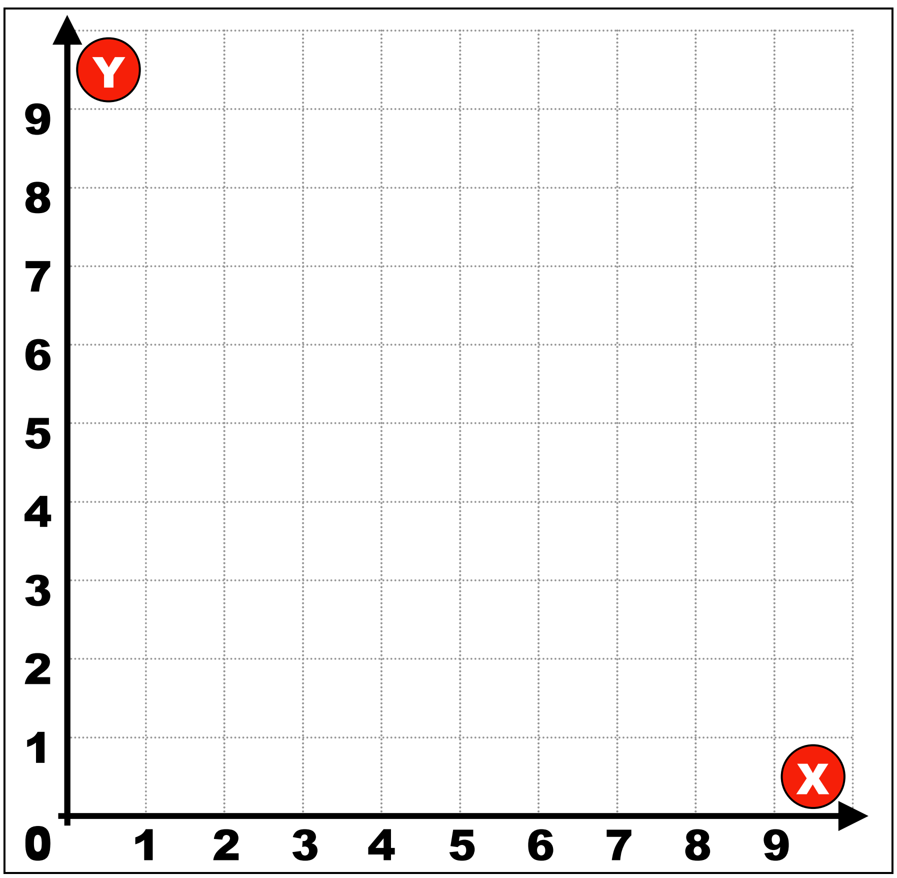
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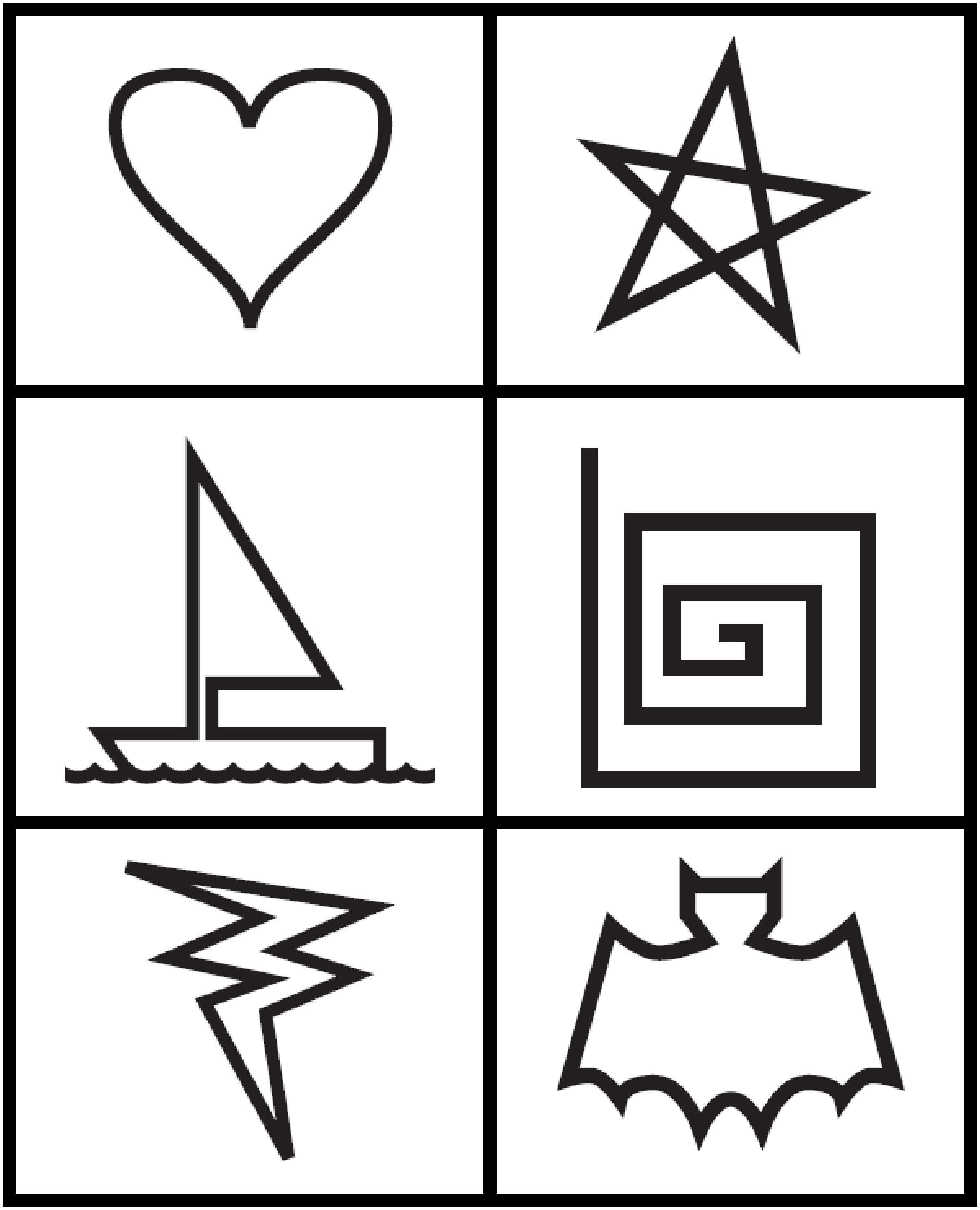
Challenge Ideas

Try drawing these shapes and patterns with a partner.



Mirror Multiplier

***DESCRIPTION**: Students use colored tiles and folding mirrors placed at different angles to create patterns.*

***LEARNING OBJECTIVES**: Students will discover a mathematical relationship between two variables.*

MATH TOPICS	SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Data Functions Inverse Patterns Tables	Symmetry	Observing Predicting Inferring	Grades 5–9

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
20 minutes	5 minutes	20 minutes	5 minutes

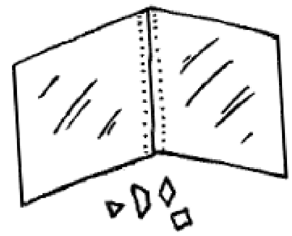
SUPPLIES

Item	Amount Needed
Mirrors (4” x 5” or larger)	2 per group*
Duct tape	1 roll
Pattern blocks or other geometric tiles	Several assorted per group*
Angle cards (Master A)	1 per group*
Challenge cards (Master B)	1 set per group*

*Groups of 2–4 are ideal

ADVANCE PREPARATION

- ❑ Create a "Mirror Multiplier" for each group by taping two mirrors together at one edge so that they open like a book with the reflective surface on the inside.



SAFETY NOTE: Cover any sharp edges on mirrors with tape.

- ❑ Copy Master A (angle card), one per group
- ❑ Copy Master B (challenge cards), one per group, and cut into individual cards

SET UP

<u>For each group</u>

- ❑ 1 mirror multiplier
- ❑ 1 angle card
- ❑ 1 set of challenge cards
- ❑ Assorted pattern blocks

INTRODUCING THE ACTIVITY

Let students speculate before offering answers to any questions. The answers at the right are provided primarily for the teacher's benefit.

Choose questions that are appropriate for your classroom.

Explain that students can change the angle of the Mirror Multiplier. The angle card will help them adjust it to a particular angle.

You may wish to remind students of various methods for measuring angles. This activity uses fractions, where ½ means half of a circle.

What is another way to measure angles?
Degrees

How many degrees is a whole circle?
360 degrees
Half of a circle?
180 degrees
¼ of a circle?
90 degrees
⅓ of a circle?
120 degrees

CLASSROOM ACTIVITY

When prompting students, choose language and a level of detail that are appropriate for your classroom. The base activity is suitable for a range of grade levels.

SAFETY NOTE: Remind students to handle the mirrors carefully.

First, encourage students to experiment.

- Have students set up the Mirror Multiplier so it is standing up, open like a book, with the reflective sides facing them.
- Blocks can be placed in the space between the two mirrors.
- Allow students time to make their own patterns using just the Mirror Multiplier and the blocks.

Ask students to try setting the mirrors at different angles, using the angle card, and make observations.

- Students should compare what they see at different angles using the same seed pattern of blocks.
- Ask students to write down their observations.
- Encourage students to consider the angle of the mirror and the number of images.

Ask students if they can predict what the image will look like at different angles.

- Suggest that students construct a data table and record the mirror angle and number of images.
- Ask students to draw a diagram of the patterns at different mirror angles.

Finally, ask students to recreate the challenge card images.

- Have students write down the pieces they used and the angle of the mirrors.
- Encourage students to use as few pieces as possible to make each challenge card image.

CLASS DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

Discuss the patterns in the reflections and how they are related to the mirror angles.

What happens when you change the angle of the mirrors? (If needed, prompt: **Does the reflection look the same?**)
Moving the mirrors changes the image that you see.

Does the reflection change in a predictable way?
Decreasing the mirror angle increases the number of images. For instance, with the mirror set at ⅓ of a circle, you get 3 images (1 original, 2 reflections). At ¼ of a circle, you get 4.

What type of relationship is this?
An inverse relationship—when one variable decreases, the other increases.

Encourage students to think about the exact angle the mirrors are set to and the number of reflections seen.

Could you predict the exact number of reflections you would get at any angle?
The number of images is the reciprocal of the angle fraction. At ½ of a circle you get 2 images, at ⅓ of a circle you get 3 images, etc.

How many images would you get if the mirrors were set to 1/16 of a circle?
At 1/16 of a circle you would have 16 images!

MATH BACKGROUND

There's a predictable relationship between the mirror angle and the number of images. Decreasing the mirror angle increases the number of images. For instance, when the mirror is set at ⅓ of a circle, you get three images—one original and two reflections. When the mirror is set at ¼ of a circle, you get four images. This is an inverse relationship—when one variable increases, the other decreases—and a particularly unique one. The number of images seen is actually the reciprocal of the angle fraction.

Mirror angle	Number of images
1/3	3
1/4	4
1/5	5
1/6	6
1/7	7
1/8	8

OPTIONAL EXTENSIONS

Extension A: Collecting and Analyzing Data
Have the students create a data table similar to the one in Math Background and plot a graph of the data. Encourage students to suggest reasons for the results, formulate testable questions, and conduct and share results of their own inquiries. Ask students to extrapolate: *How many images would you get if the mirrors were set to 1/16 of a circle?*

Extra Supplies:
- ❑ graph paper

Extension B: New Challenges
Have students create their own challenge cards and challenge other groups. To make a challenge card, have students:
- ❑ choose which tiles to use and arrange them into a seed pattern
- ❑ draw a picture of the pattern
- ❑ copy the picture the desired number of times and arrange in a circle
- ❑ check the image with a Mirror Multiplier before challenging others

Note: It is easiest to use seed patterns with reflectional symmetry. For non-symmetrical patterns, every other reflection is flipped in the circle.

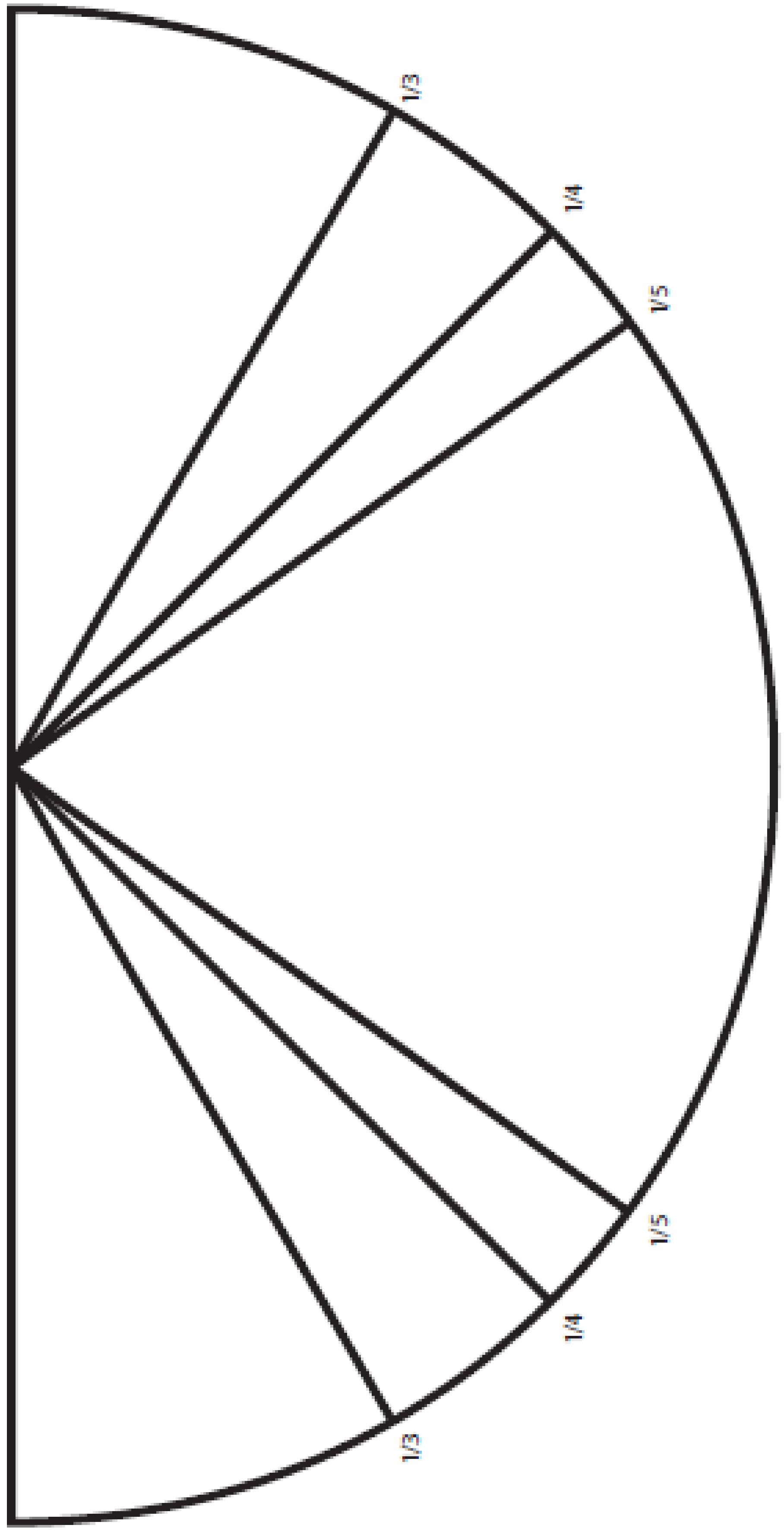
Extra Supplies:
- ❑ paper or blank index cards
- ❑ colored pencils or crayons

Extension C: Symmetry
Use the Mirror Multipliers to explore and discuss different types of symmetry with your students:
- *Reflectional Symmetry*—when one half of a pattern is a mirror image of the other half of the pattern, also called mirror symmetry. Do all of the Mirror Multiplier designs have reflectional symmetry? (*Yes, but some have only one axis of symmetry, others have multiple axes. This depends on whether there is an even or odd number of repetitions.)*
- *Rotational Symmetry*—when an object looks the same after a certain degree of rotation. Some of the images have rotational symmetry, some do not. Why? (*When the original pattern has reflectional symmetry, the Mirror Multiplier design will have rotational symmetry. A design without reflectional symmetry in the original pattern will only have rotational symmetry if reflected an even number of times!)*

MASTERS

Master A—Angle Card

Master B—Challenge Cards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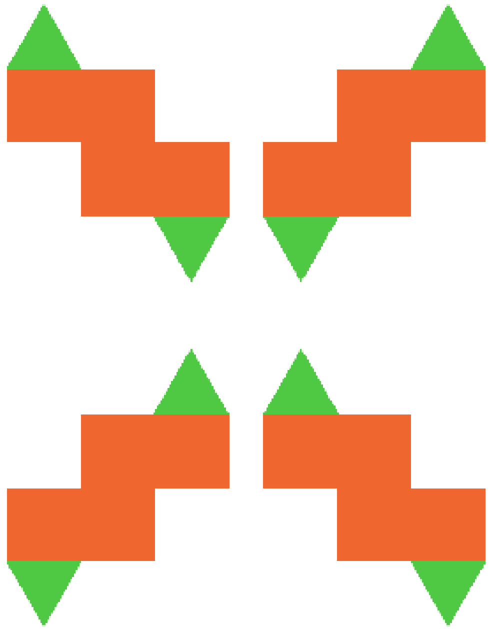
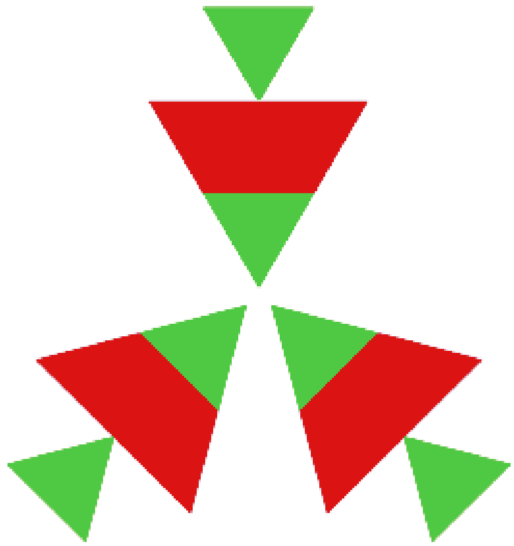
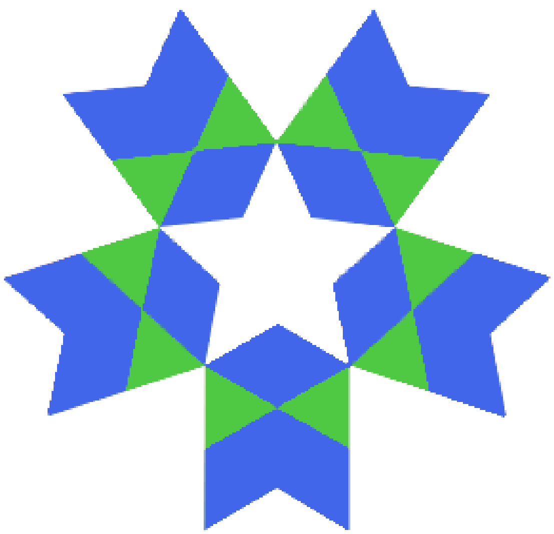


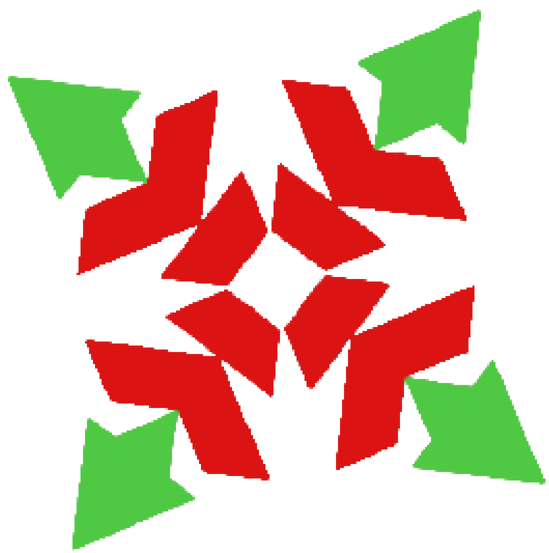
Challenge 1



Challenge 2



Challenge 3



Challenge 4

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