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Connecting Math to Our World:

Solving Problems with Math

Student Reader

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Solving Problems with Math

Student Reader

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Solving Problems with Math

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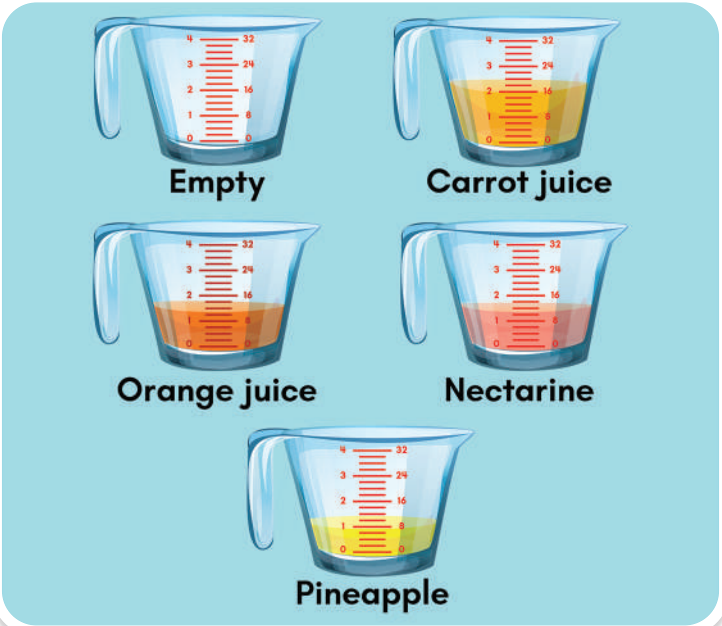


Math is everywhere, even when making a winning batch of fruit juice.

It helps us understand . . .

how masons use math in their work.

It helps us design. . . the seating area for an event.

It helps us answer questions like . . .

how do scientists classify wildlife?

What else can math do?

Adventures Around Town

Chapter 1

Charlie is staying with his grandparents for the week. He wakes up to the smell of his favorite breakfast—pancakes. “Good morning, Granny,” says Charlie. “It sure smells good in here!”

“Good morning, Charlie! When you are finished with your pancakes, we need to run some errands,” says Granny.

Charlie doesn’t mind running errands with Granny. But he knows that Granny is a stickler for planning and keeping to a schedule. He’d better not waste time.

The first stop is the mechanic's garage. Granny says, "Hi, Don! Do you have time to check my car? A yellow light on my dashboard came on yesterday."

Don replies, "Sure. Let me get my gear. Pop the hood for me."

Don hooks a device to the car's engine. Charlie thinks it looks like a game controller. After a few minutes, Don says, "The scan is done. This is giong to take some time to fix. I can have the car ready for you tomorrow morning."

As Charlie leaves the garage, he spots a cabinet with a drawer open. In the drawer there are many wrenches. "Look at all of the different sizes of wrenches! How do you know which one to use?"

Don says, "Each wrench has a measurement on the handle. These have fractions, so they are sized in inches. This shows how wide the jaw opening of the wrench is. Bolts come in different sizes so we need different wrenches."

Charlies says, "I never knew that!"

"Thanks for looking at the car so quickly!" Granny says. "We will see you tomorrow. Next stop—the frame shop."

Granny and Charlie walk to the Master Framer. Granny greets the owner, "Hi, Sami! I have this drawing by my grandson Charlie that I'd like to get framed."

"I'd be happy to frame Charlie's drawing," Sami replies. "Charlie, did you know that in framing, the most important skill is math?" Sami motions Charlie into the studio. "Let's pick out a frame."

Charlie asks Sami, "Is there a way to narrow down the selection?"

Sami shares, "We will measure the drawing. That will help us eliminate frames that are too large or too small." Sami measures and writes "4 inches by 6 inches" in her notebook.

Sami points to one of the studio walls. "Charlie, look at the frames over there." Charlie points out a gold frame that he likes. Sami exclaims, "Nice choice! I can use the measurements that I took and have this framed and ready by next week."

Next on Granny's list is Anchor Barbershop. Chris the barber asks, "What number guard did I use on you last time, Charlie?"

"What do you mean?" asks Charlie.

Chris hands Charlie a few guards. "See the numbers on the guards? They tell me how close the clippers cut your hair. The lower the number, the shorter the hair on your head and the longer the length of hair being cut off." Chris hands Charlie a ruler to help him visualize how long he wants his hair in the back.

Charlie asks, "If we start with a high number and my hair is too long, can we cut it again with a lower number?"

"Absolutely," Chris replies, "but we can't start with a low number and go longer!" Chris starts with a 4 guard. It leaves Charlie's hair about half an inch long. It's just right.

Granny thinks Chris did a really good job.

Bluejay Bakery is next on the list. Granny and Charlie go straight to the counter. They know exactly what they want!

Toby, the owner, greets them. “Hi, Lillian! Hi, Charlie! Let me guess: a loaf of sourdough bread and half a dozen blueberry scones.”

“Toby, you know us way too well,” Granny says with a smile.

While their order is wrapped, Charlie looks at the different breads in the bakery. “Look, Granny! The breads are different shapes! Some breads are crescent shaped, and some are long and thin. Some are round and flat like a hockey puck; others are domes like half a ball. A few are rectangular, and the scones are triangular. I never noticed all these shapes before.”

Granny replies, “The breads are different shapes for different purposes.”

Just then, Toby hands them their order. “Thanks, Toby,” says Granny. “Now, Charlie, let’s walk home and have lunch.”

A few short blocks away and a few minutes later, Granny and Charlie are home and wash up. Granny starts making sandwiches for Charlie, Grandpa, and herself.

"Granny, you are using the sourdough bread, right? It's rectangular, so it will make great sandwiches," says Charlie.

Granny laughs. "I wouldn't eat a sandwich with any other type of bread! Think how hard it would be to eat a sandwich on a triangular scone!" Granny cuts each sandwich in half and puts them on plates. "Two halves for each of us!"

Main Idea

Math is used in many careers.

More Adventures Around Town

Chapter 2

The next morning, Granny says, "Good morning, Charlie. Today, we are taking Rex to the veterinarian to get his allergy medication. Then, we have your orthodontist appointment." Charlie quickly gets ready for the adventures of the day.

Charlie and both his grandparents walk Rex to Parks Pets for his appointment. "Hi, Rex and family!" says the veterinarian technician. "I see that Rex is coming in to get a prescription refill."

Granny replies, "Yes, he has been sneezing up a storm."

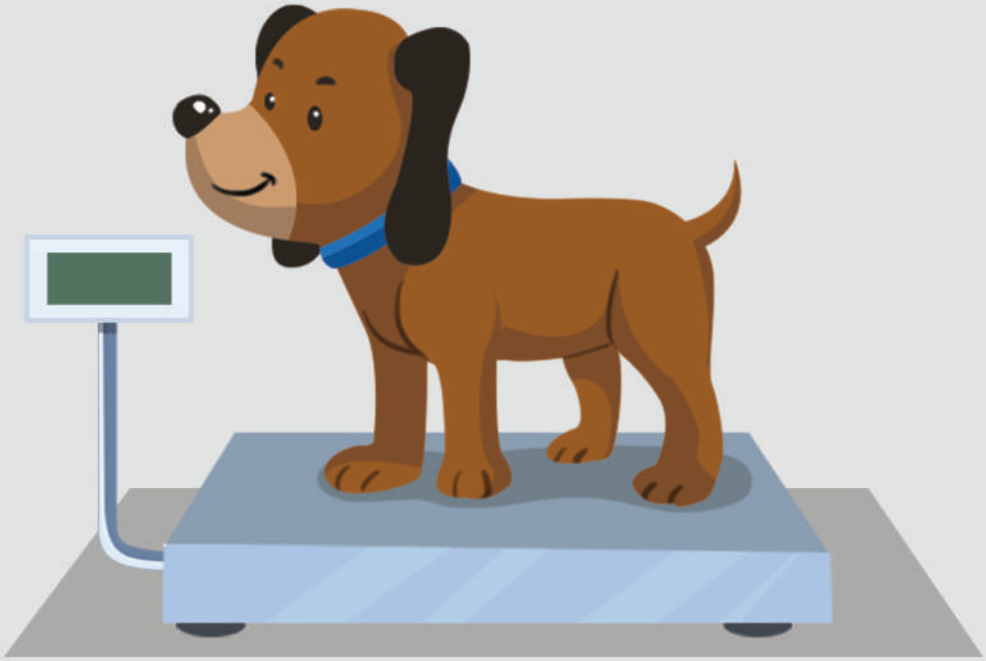
The vet tech takes Rex and walks him up on the scale. “Rex has gained a little weight,” she says.

Charlie wonders why Rex needs to be weighed. He asks, “If Rex just needs a prescription refill, why did he need to be weighed?”

“That’s an excellent question, Charlie! Rex’s weight might be higher or lower than when we gave him his last prescription. After we measure Rex’s weight today, we calculate how much medicine he should be taking now,” explains the vet tech. “To do this, we need to convert measurements, and multiply and divide fractions. This makes sure Rex has the exact dose of medicine he needs.”

Charlie thinks about the math that goes into making sure Rex has the right amount of medicine. “I am glad you know how to do all of that math!” says Charlie.

After they get the prescription, Grandpa walks Rex home. Granny and Charlie have more errands in town.



Next on the list is Charlie's orthodontist appointment. Soon Charlie will be getting braces. Dr. Watson wants to take x-rays and make molds of Charlie's mouth.

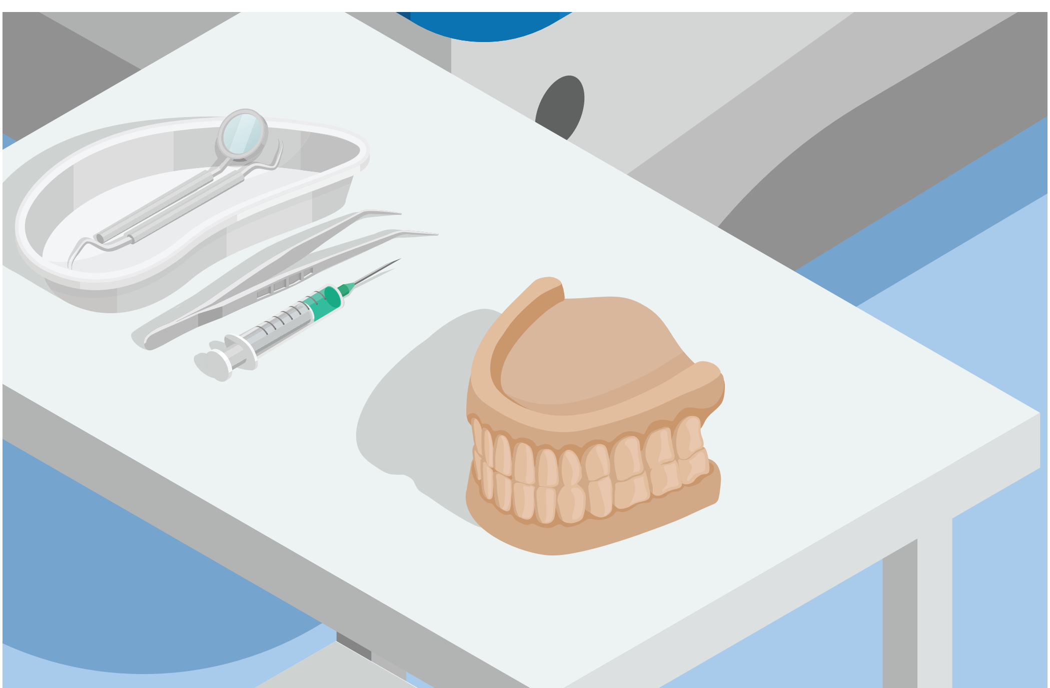
The dental assistant takes Charlie to the x-ray area. "Charlie, you need to stay as still as possible. We need to take x-rays of your full mouth. This will take a few minutes. These x-rays will show us your teeth and your jaw bones. With these x-rays, we can measure how much space we have to work with. This will help Dr. Watson make a plan for your braces."

Charlie replies, "I will try my best."

Next, Charlie moves to the exam chair. Dr. Watson is looking at the x-rays as he walks into the exam room. Dr. Watson explains, "Today, we are going to press a metal tray with putty against your teeth. Once the putty is set, we'll have a mold of your teeth. We will fill the mold with plaster to make a cast. This cast and the x-rays let me study your teeth without you having to sit here for hours with your mouth open wide!"

Dr. Watson explains. "Having the cast of your teeth helps me know exactly how your teeth are aligned now. I can figure out which teeth need to be moved by your braces and in which direction and how far. We use all different sizes of brackets and wires to move your teeth a very tiny amount at a time."

After Charlie's orthodontist appointment, Granny and Charlie go to the flower shop.



“Hi, Alan. You look busy,” Granny says as they enter the flower shop.

“Yes, I have three wedding orders. I’m trying to combine orders for the flowers to get the best price,” Alan says. “All three orders have white roses and pink tulips. One company gives a discount of 25% for white roses, but the tulips cost more than at other companies. Another company gives a 10% discount for all types of flowers, but that discount isn’t much.”

Charlie knew there would be math in here! He thinks about how in his math class they compared discounts.

“Charlie, my work paper probably looks like your math homework!” says Alan.

Granny comes to the register with a dozen white daisies and half a dozen purple carnations. Alan says, “Speaking of discounts, when you buy a dozen of any flower, you get one more for free. Grab another daisy.”

Granny and Charlie leave the flower shop and head out for their last stop of the day.

Granny and Charlie walk into Don's Auto Shop. "Hi, Lillian," Don says. "Let me pull your car around."

Next, Don explains the volumes of fluids he added to the car and the air pressure in the tires in pounds per square inch. He reminds Granny about how many months and miles she has before she'll need to have the car serviced again.

Math really is everywhere!

Main Idea

Measurement, multiplication and division of fractions, and comparing percentages are just a few of the math skills needed in some careers.

For Your Amusement

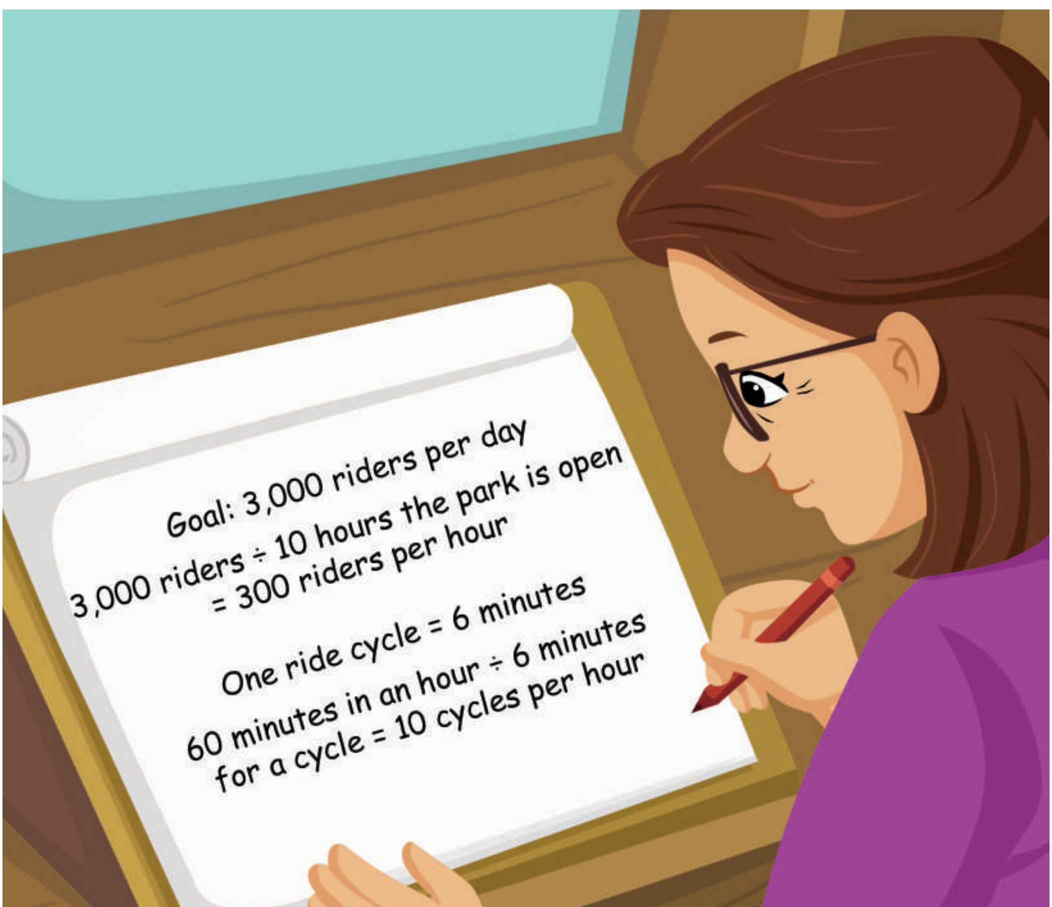
Chapter 3

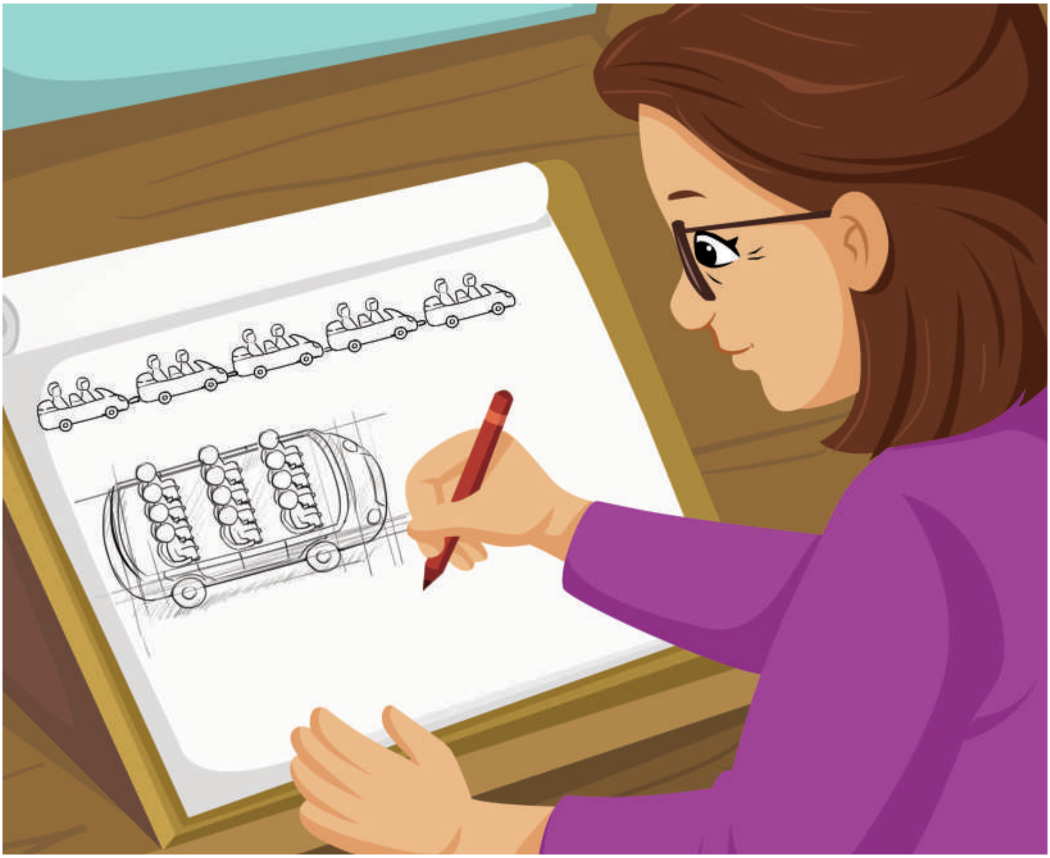
Hi. I'm Mabel, and I have the coolest job! I'm an amusement park designer. Like most engineering jobs, my work involves solving one problem after another.

I'm designing a new ride named Peter Rabbit's Hare-Raising Adventure. I want to develop a design that cycles at least 3,000 riders through every day. I need to know the kind of cars the ride will use so that we can meet that goal.

Here's an example of problem-solving that I must do. First, I gather the information that I have. I know that the park is open from 10:00 a.m. to 8:00 p.m. every day. That's 10 hours. Our team has determined that the experience should be 6 minutes long, including time for people to board and exit the ride.

After doing some math, I know we can run 10 cycles each hour. I'll start by figuring out how many riders we need each hour to meet our goal. I divide 3,000 riders per day by 10 hours per day. That equals 300 riders per hour. 300 riders per hour isn't a big demand for us. We can do that.





We want at least 300 people to go through the ride in an hour. So we should have at least 30 people going through the ride during each cycle.

Now I need to decide what type of car we should use. Hmm, how about separate cars that are linked together? We could have 15 cars that each hold 2 people, and 30 people could ride in 1 trip.

Or we could use a larger car with 3 rows of 4 people. That would send 12 people in each car. If we had 3 cars, we could move 36 people on each trip. That's more than the 30 we need!

When I'm designing solutions, I never generate just one idea and run with it. We engineers always sketch up various ways to solve a problem and then evaluate the pros and cons of each option.

When I am considering a design, I need to determine how long it will take for the riders to enter and exit the cars. I wonder if it will take longer to load a car that holds 2 people or a car that holds 12. The size of the car will also affect the size of the track that the car travels on. There are many things to think about before I decide which car we will use.

Both car designs require materials to build them. And the materials cost money. I make lists of materials and their costs to compare. How many seats do I need for each car design? How many wheels? It seems like the bigger car would be less expensive to build than a train of smaller cars, but I won't know for sure until I do the math.

And above all, I have to consider safety. A single car that carries a dozen people at once must be extremely sturdy. Would the load of the 36 riders in a train of 3 cars be heavier overall than the load of 30 riders in a train of 15 smaller, lighter cars?

The heavier load will be harder to move. This means that the motor used to move the cars must be very powerful.

I'm constantly comparing numbers. Sometimes I am looking for the most of something, and sometimes I am looking for the least of something. Often I'm searching for a solution that pairs a "most" and a "least" together.

It's a good thing I like figuring out solutions to problems!

Main Idea

Amusement park design engineers rely on math to design rides.

Beautiful Trade

Chapter 4

Masons build structures using stone, bricks, and similar blocks. If built correctly, they can produce strong buildings that last for centuries. High-quality masonry stands up to time. It provides beauty as well as function.

Learning how to become a mason takes dedication. It involves both classroom learning and hands-on experience. Masons get their hands-on experience by working as apprentices. Apprenticeship means working with and learning from an expert—while getting paid! Apprenticeships are common in the building trades, so people who want to become carpenters, plumbers, or electricians will follow a similar path.

Masons approach their work as art. They create designs that are pleasing to the eye. Taking math, science, and drawing classes in school can help you prepare to be a mason. This occupation requires precision, so if anyone has ever told you that you're a perfectionist, you might make a great mason!

Masonry can be hard physical work. Masons need to be in shape to lift heavy bricks, stand for long hours, and work outside, even when it's very hot or cold. If you're physically fit and like being active, that's a big plus.

To become a mason, you must join an apprenticeship program. Many brick masons belong to trade unions, like the International Union of Bricklayers and Allied Craftworkers (BAC). These unions often have apprenticeship programs.

It's a good idea to research different programs and talk to people who have gone through them. That can help you find the program that is the best fit for you.

The value of an apprenticeship is that you learn by doing. You will work with experienced masons, called journeymen, who teach you the job. At first, you will learn the basics, like how to mix mortar, lay bricks in a straight line, and use the tools of the trade.

As you get better at the basics, you will learn more advanced skills. These might include building arches or corners or making decorative patterns with bricks.

As you gain experience, you will start working on more complicated projects. Even though you'll be working more independently, you will still have a journeyman guiding you and checking your work.

Safety is very important in masonry work, so you will get a lot of training on how to stay safe on the job. This includes learning how to handle materials, operate machines, and work safely at heights.

In addition to learning on the job, you will also spend some training time in classrooms. This part of the apprenticeship is called related technical instruction, or RTI. In the classroom, you will learn the math skills you need for masonry. Masons use quite a bit of math. They must be able to add and subtract using fractions and decimals, especially when they are measuring. It is important to accurately measure before they cut the materials. Masons need a good understanding of geometric concepts. They measure angles, find the area of a space, and work with volume to mix the grout they'll need. And they must be able to estimate how much material they need to do a job.

Imagine what could happen if they didn't have math skills!

In the classroom, you will also learn about the different materials you will use and how to choose them. You will learn how to read blueprints and understand building codes as part of the classroom work. Building codes are the laws that make sure buildings are safe and strong.

The combination of hands-on work and classroom learning makes sure you have both the practical skills and the knowledge needed to be a good mason.

After completing your apprenticeship, you will be considered a journeyman mason. This means you are fully qualified to work on your own. Typically you will get a certificate or license that shows you have completed your apprenticeship.

Being a journeyman doesn't mean you stop learning. Masons can continue to learn and improve their skills. Some might specialize to become experts in restoring old buildings or using environmentally friendly building methods. Becoming a brick mason is just the beginning of an interesting, rewarding career!

Main Idea

Masonry involves measuring, calculating area and amount of materials, and estimating the cost of a job.

Lining Up a Plan

Chapter 5

Avett, Bianca, Zeke, and Bianca's mom, Mrs. Jackson, are at their local library today. Mrs. Jackson has asked them to join her and help set up for this year's opening ceremony of the book festival.

"Hi, kids! Thank you so much for helping us get ready for today's ceremony! I have a feeling this will be our best book festival yet," says Mrs. Jackson.

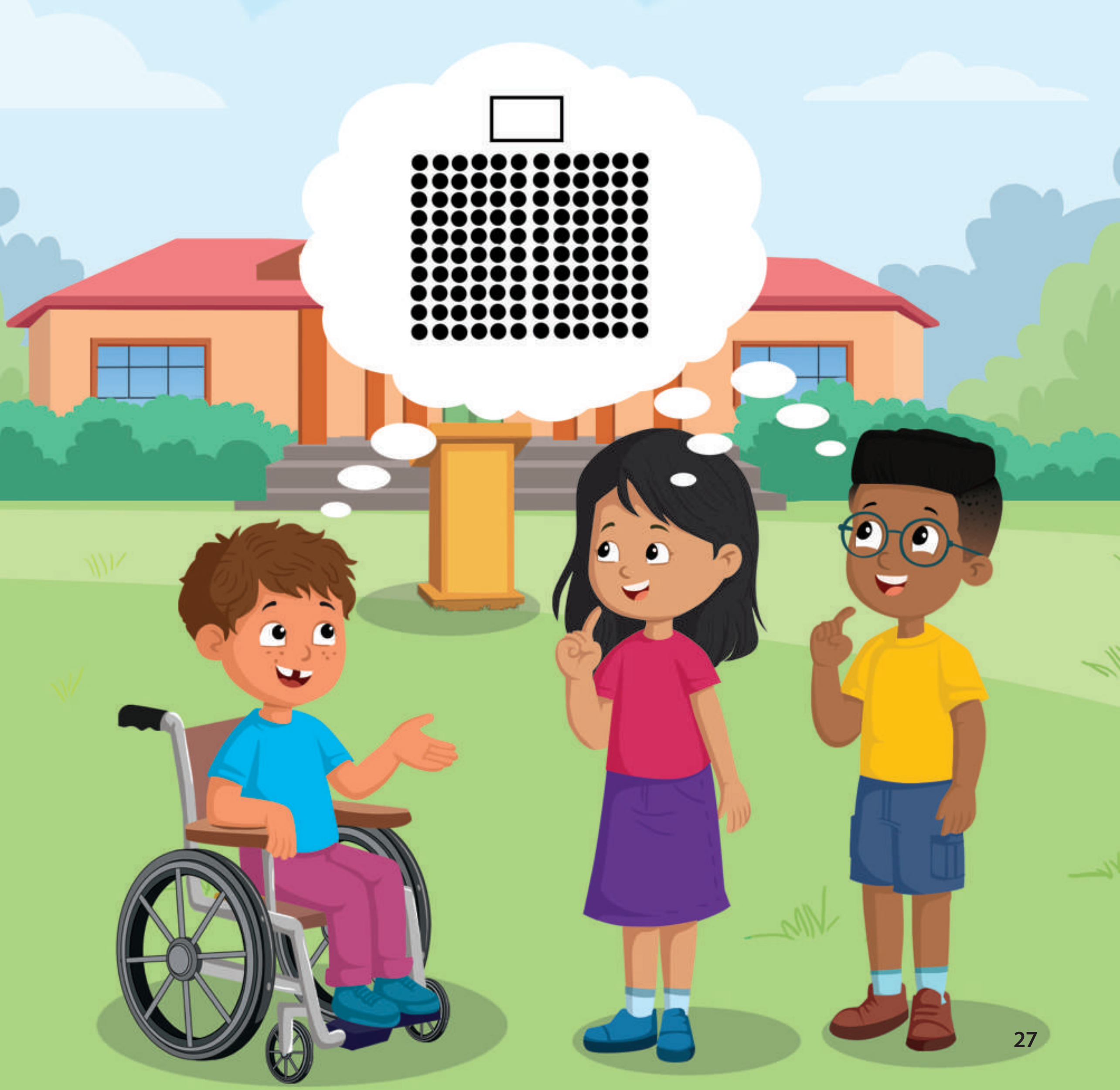
"How can we help, Mom?" Bianca asks.

"We have chairs for 120 special guests. Can you please set up the chairs? I'd like the rows to have the same number of chairs. Other than that, the arrangement is up to you."

Avett has already done the division in his head. He was able to do it quickly because 120 is a multiple of 10. He says, “Let’s see. We could do 12 rows of 10 chairs *or* 10 rows of 12 chairs.” The friends picture the 10 long rows he is describing.

“Yeah, but what if somebody has to get up during the ceremony?” asks Bianca.

“It’s awkward trying to scoot past a bunch of people,” adds Zeke. “That’s why I like to sit close to the aisle.”

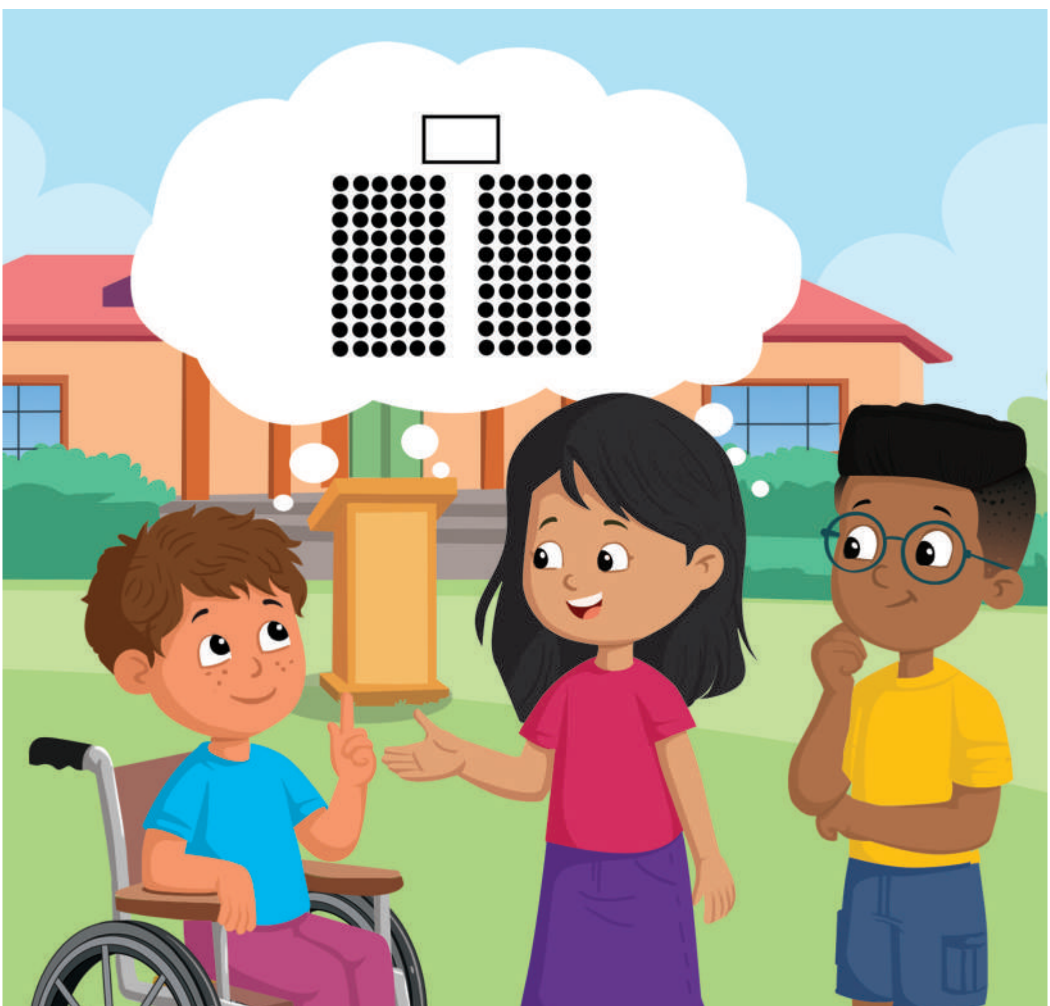


“Here’s an idea,” says Bianca. “If we divide the chairs with an aisle, everyone is in a shorter row and closer to one aisle or another.”

“The aisle would divide our seats into 2 sections. Each section will seat 60 people,” says Avett.

“We could arrange the chairs in each section into 10 rows of 6 chairs,” continues Zeke.

Avett chimes in, “Don’t forget that we need to plan for 120 seats but won’t need to place 120 chairs. I need one of the 120 spots, but I have my own chair.”



The kids keep thinking about how the chair setup will work in real life. “If we divide the audience in half with an aisle, the aisle will be right in front of Bianca’s mom at the podium,” Avett continues.

“Well, that doesn’t seem ideal!” says Zeke. “People could be distracting if they get up and use the aisle.”

Bianca has an idea. “Maybe we should have 2 aisles?”

Avett thinks through the multiplication and division of seats as he pictures Bianca's suggestion. "Two aisles would split our seats into 3 sections. 120 seats divided by 3 is 40 chairs per section."

"We can make 8 rows with 5 seats each for each section. The center section of chairs can line up in front of the podium," adds Bianca. "Let's reserve the front row of one section for wheelchair spaces."

Zeke envisions that the seats in the outside sections are not looking toward the podium. The people there may not be able to see well. "We should angle the outer 2 sections so that they're facing the podium, too," he says.

"Great idea, Zeke!" say Bianca and Avett.

"Bianca, how wide do you think the aisles should be?" Zeke asks.

She turns to Avett. "Avett, how wide is your wheelchair?"

"Mine's pretty small," he answers, "because I'm a kid. I think a three-foot-wide aisle will be good. That's how wide the accessibility laws say public hallways have to be."

"Hi! I'm back!" says Mrs. Jackson. "The chairs are on their way! Did you run into any problems?"

"Nothing a little planning couldn't fix!" replies Avett.

Main Idea

A visual arrangement of chairs into equally spaced rows and columns can be useful for planning events.

Profile: A Printmaker Plans

Chapter 6

A Newspaper Article by Misty Warner

Local artist Molly McKenna is preparing to show her screen-printed posters at the new Main Street Gallery in just three days. She was notified by the gallery of a last-minute opening in the show when another artist unexpectedly dropped out. This left McKenna, an art student at a local college, with a huge opportunity—but not much time to prepare for it. She has 5 days to get everything ready.

Main Street Gallery

Even though McKenna is working on a tight deadline, she agreed to an interview. She sat down with us at her studio, which she shares with one other artist. As she opened the door, her fingers were stained with green ink, and her face was beaming with excitement. Empty frames, framed prints, bottles of ink, and other screen-printing equipment covered nearly every surface.

When asked about her feelings about the upcoming show, McKenna expressed both gratitude and nervousness. “This is a huge honor for me,” she said. “I want everything to be perfect, but I’m feeling overwhelmed by how much work I still have to do.”

Printmaker Molly McKenna in her studio

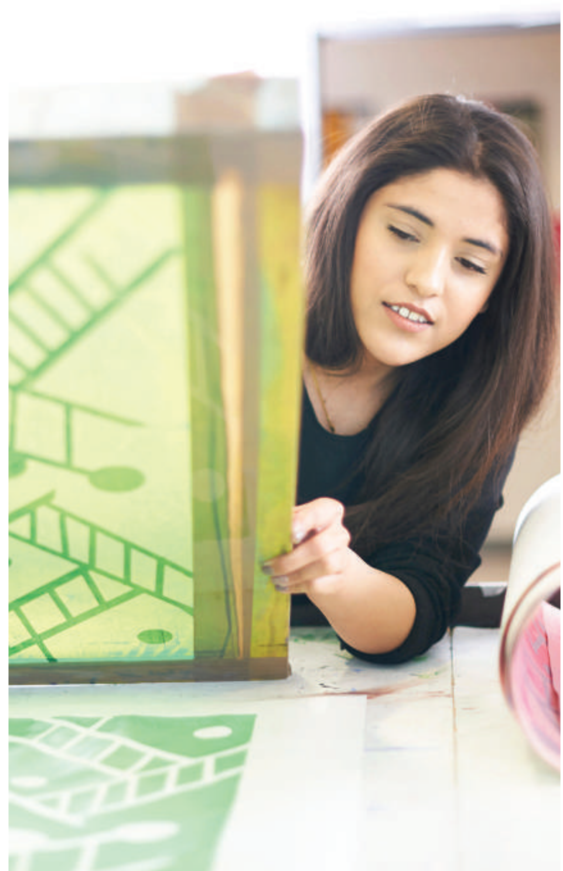
McKenna noted that she'll be showing all-new prints. "I looked at some of my old work, but it just didn't feel right for this show," she explained. "I decided to print new pieces, even though I worry about getting it all done in time. I estimated that I have all of the supplies I need to make new prints."

McKenna then walked me through the screen-printing process. First, she creates her design digitally and prints it on transparency film at a copy shop. The next step is covering a screen with an emulsion. The emulsion is a liquid that is sensitive to light. After that, the transparency film is placed over the prepared screen. It's exposed to a special light for a few minutes. This hardens the emulsion, except where the design is covering it. The wet emulsion is then washed away, leaving the design ready for printing.

When asked how she planned to be ready for the opening, McKenna laughed. “I made a schedule that I must follow, and I know how long each step takes. Putting on the emulsion takes about 10 minutes for each screen. That’s followed by 2 hours of drying time, 15 minutes for the light exposure, 10 minutes for washing, and another hour for drying. And that all happens *after* I create a design and get it printed at the copy shop.”

“I won’t lie. There was some serious math going on in my head when I started planning out my time! When I added up the time it takes for each batch of screens, I realized it takes about 350 minutes, which is about 6 hours. I am planning for about 5 batches, which is fine if I don’t need to sleep or eat! And that does not include the printing!”

McKenna preparing the transparency

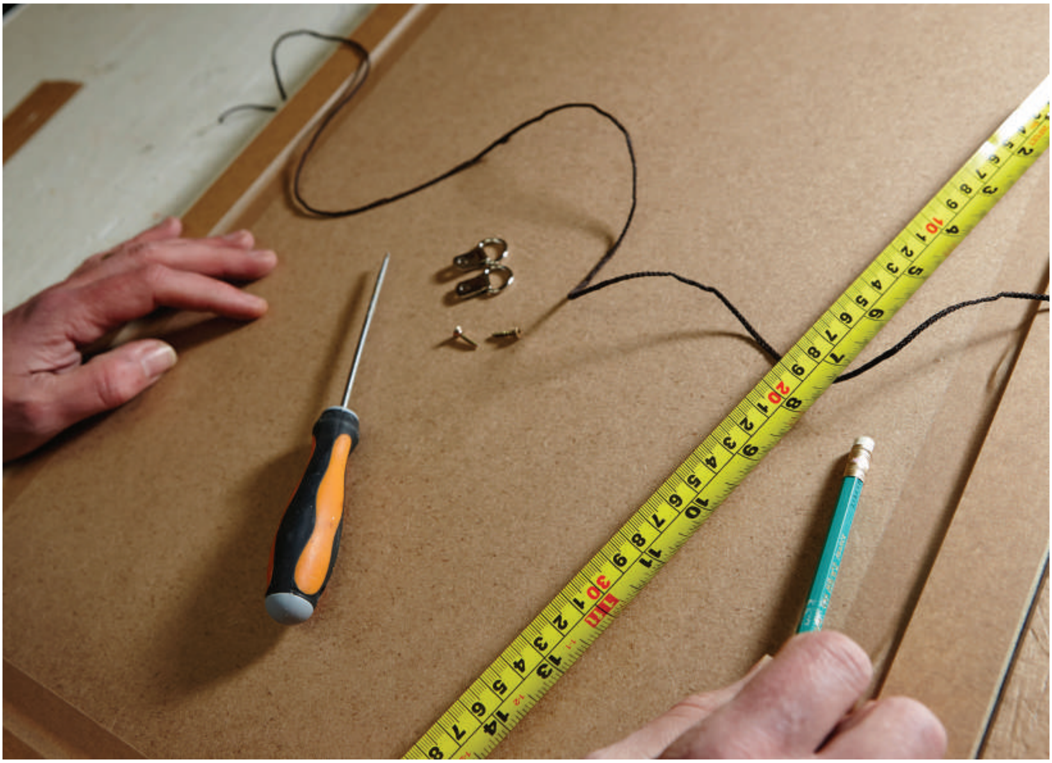


McKenna printing a poster

Once all of this preparation is done, McKenna prints her designs on paper. She pushes ink through the screen onto the paper, which transfers the design quickly. "For me, that's the easy part," she explained. "It takes less than five minutes. But of course, some of my designs have more than one color. Which means I create them in layers, and each layer is printed separately!"

McKenna's work tends to be geometric patterns, some of them monochromatic, or just one color. Other designs use 3 or 4 colors, and these take longer to print because the ink has to dry between applications.

All of her designs have a boldness and energy despite using simple shapes and lines. "My designs are really related to my mood and frame of mind when I'm creating them. Some days I'm feeling quiet and in the mood for simplicity. Other days I throw open the windows, put some music on, and create more complex designs."



McKenna adding a hanger to a framed print

While many artists use professional framing services, McKenna does her own framing. “I like to see how different frame styles affect the overall look of the print, and I don’t trust anyone else to get it just right!” she explained. “Sometimes I’ll try out 6 or 7 different frames before I find one I like.”

McKenna’s prints will be exhibited at the Main Street Gallery for a month. The opening is this Friday at 7:00. Tickets to the opening are $20 and can be purchased online. McKenna’s works and those of the other artists will be for sale, so get there early!

Main Idea

It is important to estimate time when making a plan to accomplish a task.

It Adds Up

Chapter 7

Mrs. Gillig is planning the upcoming field trip to the zoo. She asks Grant, Chloe, and Liam to help her. “The first thing we need to do is to raise some money for our trip. It will cost about $1,000 to take the whole fourth grade and have a special meet-and-greet with the penguins. Any ideas for a fundraiser?” Mrs. Gillig asks the group.

“I know what we can do! And it doesn’t take a lot of materials. We can set up a penny war!” exclaims Liam.

Liam explains that a penny war is a contest in which students vote for their favorite animals by putting pennies in jars. Each jar represents an animal that they might see at the zoo. The animal with the most pennies at the end of 2 weeks wins.

"How many jars should we set up?" asks Mrs. Gillig.

"Enough to keep things exciting!" says Chloe.

Liam scratches his head. "I think that if we need to raise $1,000, 8 jars would work best."

On Wednesday, the jars are set out, and students start to vote. That afternoon, the students gather in Mrs. Gillig's classroom to check their progress. They count the pennies by putting them in stacks of 10. So far, they have collected $38.17.

"That's a lot of coins for only $38.17," Chloe grumbles. "There are 3,817 pennies!"

"We aren't anywhere close to $1,000. At this rate, we won't raise what we need," says Grant.

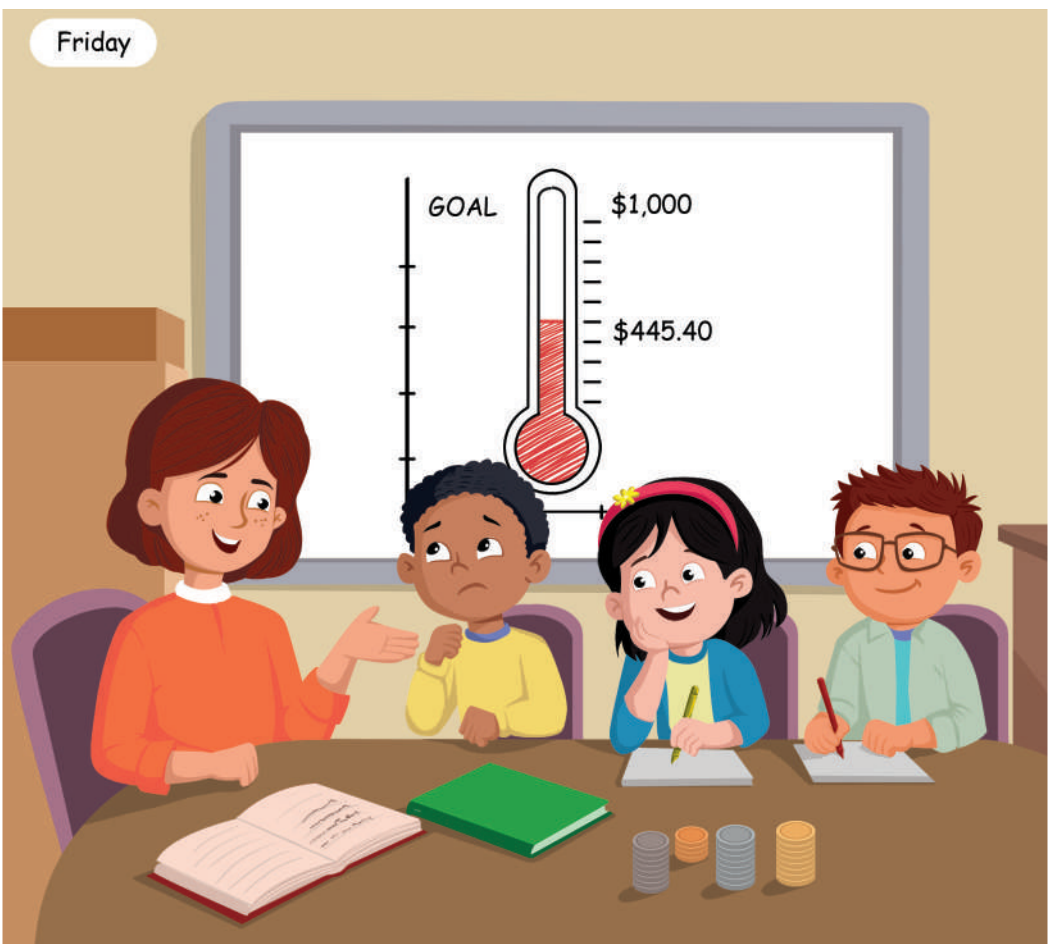
"I have another idea!" says Liam. He thinks they can raise money faster if they encourage students to vote with coins of higher value than pennies. They change the name of their fundraiser from "penny war" to "animal election" and let students know they can cast votes 5 at a time for a nickel, 10 at a time for a dime, and so on.

“OK, team,” Chloe begins at the progress meeting on Friday. “Our decision to change ‘penny wars’ to ‘animal election’ is really helping. Now kids are bringing in all kinds of coins—pennies, nickels, dimes, quarters—and that is adding up a lot faster!”

“How much do we have so far? How much do we still need to raise?” asks Grant. “We only have a week left.”

“We’ve collected $445.30 this week from the animal election,” says Chloe. “Let’s record the amount we’ve collected onto a thermometer goal chart. This makes our progress easy to see.”

“So we need another $554.70,” says Grant.



It’s the last meeting for the fundraising team.

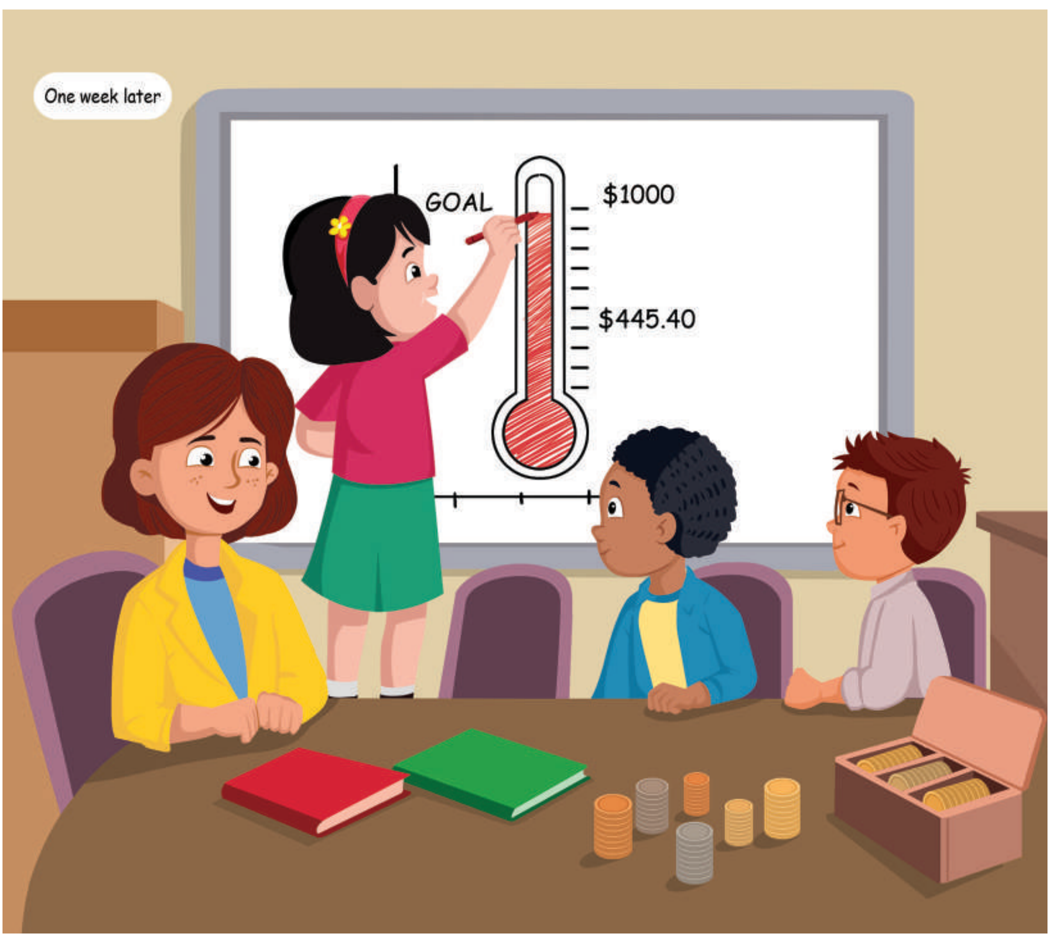
“. . . 21, 22, 23. Add $23.60 to the tally, please,” says Chloe, pointing to Liam’s notebook.

“How much? Did we make it?” Grant asks. “Don’t keep me in suspense!”

“Well, this week’s total is . . . drumroll, please . . . $553.20,” says Chloe.

“So it’s not enough?” asks Grant. “We needed more than that, right?”

“Yeah, we needed $554.70, but we’re only a little short,” says Chloe.



"Mrs. Gillig!" Liam shouts, running into the classroom.

"What's the news?" asks Mrs. Gillig.

"Well, there's bad news and good news," says Liam. "The bad news is that we didn't quite make our goal. The good news is that we're only a tiny amount short! We've raised $998.50!"

"I have some good news," says Chloe.

Chloe reaches into her pocket and pulls out a dollar bill and two quarters. "I earned some money doing extra chores at home," she says. "I'm donating it to the zoo trip!"

Everyone looks at her with smiles on their faces. "See," says Grant, "we didn't need parent donations! We did it ourselves!"

There is a pause.

"Wait, who won the animal election?" asks Mrs. Gillig.

"Oh! Well, the penguin, of course!" says Liam.

Main Idea

Progress towards a goal can be tracked by a goal chart.

Beavers: Nature's Incredible Engineers

Chapter 8

Have you ever seen a beaver dam? A beaver dam is a barrier that beavers build across streams and rivers. The dam creates a pond, which helps provide a safe place for their home.

A beaver dam may look like a random pile of logs and branches. But don't judge too quickly. This incredible structure provides an example of important math and engineering concepts. A beaver dam shows that beavers are the engineers of the animal world!

Why Do Beavers Build Dams?

Sometimes people think beavers build dams in order to live in them. That's not quite the case. Beavers build dams to create a pond. By blocking the flow of water in a stream or river, the dam causes water to build up behind the dam and form a pond.

The water in the pond doesn't flow at a fast pace the way water in a stream does. A pond is calmer. So the pond makes a safe spot for beavers to build their lodge. A beaver lodge forms a small island in the pond. This is the beavers' home, where they live and raise their young.

The pond formed by the dam helps keep beavers safe from predators. Wolves and coyotes who might see beavers as a tasty meal think twice before swimming through deep water to the lodge. Beavers also form underwater entrances to their lodges so they can go in and out safely.

> Beavers can hold their breath for about 15 minutes! So underwater entrances to their homes make a lot of sense.

How Do Beavers Build Dams?

Beavers have to consider a lot of factors as they find a good place for a dam. Then they must carefully build it so it will be strong enough and snug enough to change the flow of the stream.

First, they choose a spot. They usually build at a narrower part of a stream. Then, they gather materials. They use their teeth to gnaw on trees until the trees fall down. Beavers have extremely strong teeth that can cut through wood! The animals also collect branches, twigs, mud, and rocks.

Beavers have orange teeth because they contain iron! Iron is a strong metal, giving beavers their super-strong teeth.

Next, it's time to build! Beavers begin by placing the largest branches and logs across the stream. Then, they use mud and rocks to fill in the spaces between the branches, making the dam watertight. They keep adding layers of branches and mud until the dam is high and strong enough to hold back the water.

Beavers are good builders and natural engineers, and they use some basic engineering when building their dams. People can learn a lot from observing beavers!

For example, beavers place the largest logs in the dam first to form a strong foundation to build around. Then, they use other logs and branches at a specific angle to build up the sides. This is similar to how people use large stones or concrete at the base of buildings, then use steel beams to frame the building.

Beavers also know a thing or two about geometry. They often build their dams in a curved shape, like a crescent or semicircle. This creates more surface area. The force of the flowing water against the dam is spread out over a larger area. This relates to the reason people use arches in constructing large buildings because arches are so strong.

Beavers also know how to transport materials easily. If they chew down a tree far from home, they may dig a canal from the tree to their lodge and float their tree home!

Beavers seem to have instincts related to mathematical ideas. Beavers seem to know how the length of their dam will affect the size of the pond that forms. And the size of the pond is important because it determines how big a lodge they can build. In general, beavers build their dams about 100 feet in length for every 10 feet of a lodge's width.

Beaver dams can get pretty large. Sometimes several beaver families live in an area, each with its own dam. Over time, some of their beaver dams may join up with each other, forming one giant dam. One of the largest in the world is in Alberta, Canada. It is already over 500 meters long and could get longer since there are other dams nearby!

Using their skills, beavers build dams and lodges that can last many years. Often several generations of beavers will live in the same lodge. They all help to keep it in good repair. If water levels rise, they add more layers. If the dam springs a leak, they know how to plug it.

Beavers are amazing animals that use their natural instincts and skills to build structures that function in important ways. Their dams and lodges are not just simple piles of sticks and mud! They show innate understanding of ideas that people use engineering and math concepts to understand.

Main Idea

Beavers seem to have a built-in sense of math and engineering, and this helps them build and repair their lodges and dams.

Maya Calendars

Chapter 9

The ancient Maya lived between 2000 BCE and the 1500s CE in the place that is now Central America. The Maya civilization was made up of several city-states in what is now the North American countries of Guatemala, Belize, El Salvador, Honduras, and Mexico. Today descendants of the ancient Maya still live in this area. Their civilization was at its largest and most powerful from 250 to 900 CE.

The Maya were a mathematically advanced society. Some of their discoveries about astronomy, architecture, and engineering are still used today. The ancient Maya used a base-20 number system, or a system based on the number 20. Their knowledge of astronomy and math helped them produce some of the most detailed and accurate calendars the world has ever known.

The Maya used 3 main calendars. They were the Haab, the Tzolk'in, and the Long Count calendar. Some Maya descendants still use these calendars.

The Haab calendar

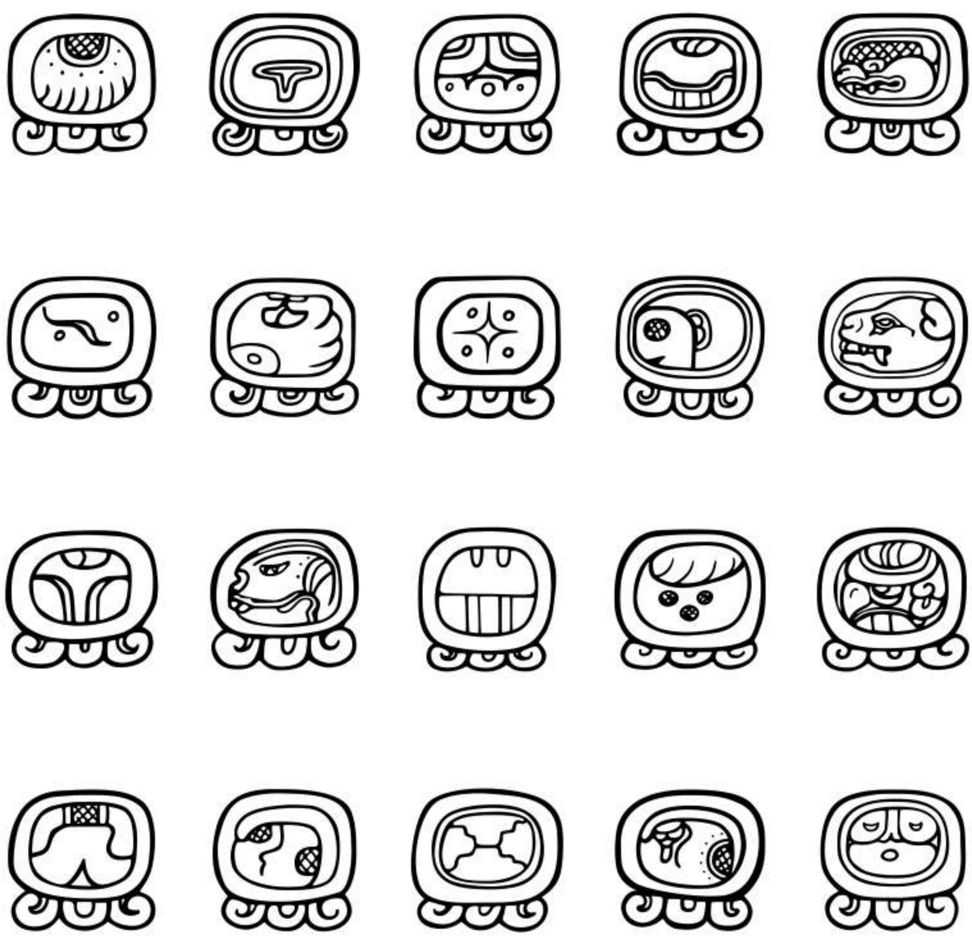
Why do we need a calendar? A calendar helps us keep track of the seasons. It tells us when it is the best time to plant and harvest food. It is used to mark religious celebrations. The calendar tells you when your birthday is and when the school year starts and ends. What else does a calendar tell you?

The calendar we use today, called the Gregorian calendar, is a solar calendar. That means it's based on the time it takes for Earth to completely orbit the sun. The Haab calendar is also a solar calendar.

These two solar calendars have the same number of days: 365. It takes 365 days for Earth to travel around the sun. The Gregorian calendar divides those 365 days into 12 months. The Haab calendar has 19 months. Eighteen of those months have 20 days, most likely because the Maya's number system was based on the number 20. The last month, called Wayeb, has only 5 days.

The Tzolk'in calendar is a 260-day calendar. It is a sacred calendar used to identify the timing of religious and agricultural events. It is not divided into months. Instead, each day is assigned a combination of a glyph, or picture, and a number. There are 20 glyphs and 13 numbers, which produces 260 different combinations of unique days.

An important number in Maya culture is 260. It's related to the zenith, or the point where the sun is directly overhead. If you live in the tropics, the sun will pass through this point twice within 260 days. That number is also the number of days in 9 moon cycles.



This plate is similar to, but not exactly like, the Calendar Round.

The Calendar Round combines the Haab and Tzolk'in calendars. Remember, the Haab calendar has 365 days. The Tzolk'in calendar has 260. It takes 52 years of the Haab (365-day) calendar before any unique combination of a Haab date and a Tzolk'in date is repeated.

This is why reaching the age of 52 is considered an important rite of passage in Mayan culture. Once a person has experienced all the possible combinations of days, they are considered to have the wisdom of an elder.

The Calendar Round is presented as a series of 4 rings. The outer ring shows the 19 months of the Haab calendar. The next ring shows the numbers 1–20 for each of the days in a month. The next 2 rings represent the Tzolk'in Calendar. The 3rd ring shows the 20 Tzolk'in glyphs, followed by the center ring of numbers 1–13.

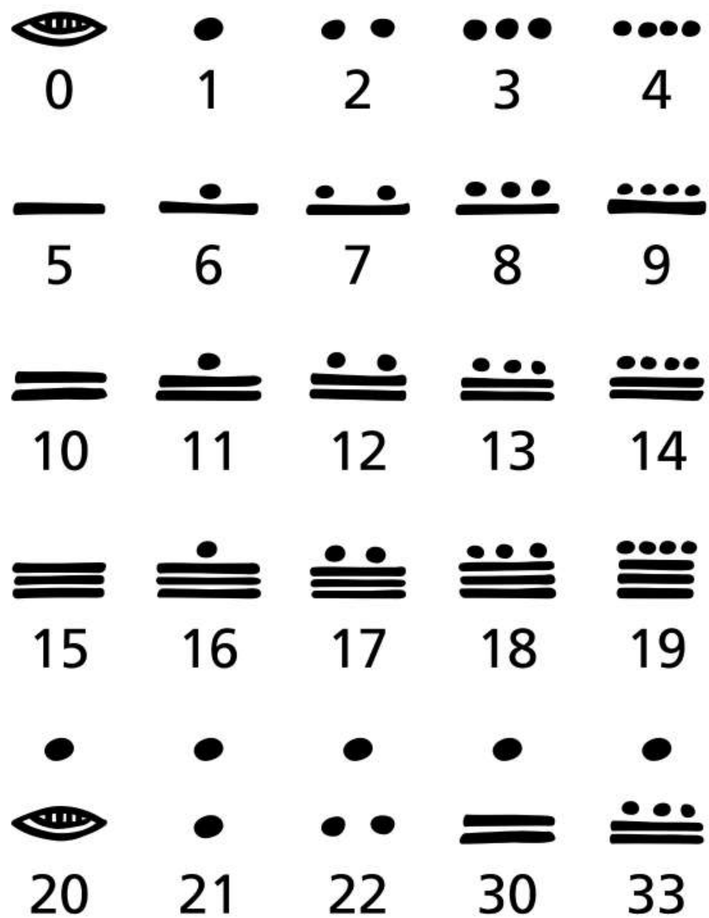
The Long Count calendar was used by the ancient Maya to track events that lasted longer than 52 years. It recorded events that had already happened and future events. This includes events that are real and events based on myths. An example of an event that can be found on the Long Count calendar is the reign of a ruler. It was noted to be very accurate in the tracking of events in the sky, such as solar eclipses and the movement of Venus.

The Long Count calendar counts 5 different cycles of time. It counts *k'in* (1 day), *uinal*, (20 days), *tun* (360 days), *katun* (7,200 days), and *baktun* (144,000 days). Notice that everything after *k'in* is a multiple of 20. That relates to the Maya's numbering system, in which the number 20 is very important. *Tun* is 360, which is close to 365—the number of days in a Haab year. There are 365 days in the Gregorian calendar that we use as well.

Maya Numbers

In our base-10 number system, we use the numbers 0, 1, 2, 3,4, 5, 6, 7, 8, and 9. The placement of each digit in a number shows its value. The Maya numbering system was totally different from what we use today. They had symbols for 0, 1, and 5 that combined to make the numbers up to 20.

Mayan words and phrases were written as glyphs. This chart shows the Maya numbering system. Zero is meant to look like a shell. Can you find a pattern in the rest of the numbers?



Main Idea

Maya calendars are based on cycles of different lengths.

Juice on the Loose

Chapter 10

Flint: And we're back with Round 2 of the 6th Annual Juice on the Loose Junior Flavor Combo Competition sponsored by Julie's Jams and Juices. My name's Flint Farrelly, and I'm your eyes and ears on our junior kitchen competition floor.

During Round 1, our pint-sized contestants were asked to produce three identical $\frac{1}{2}$ of a liter jars of a seasonal fruit-based jam or jelly. Mary W. from Spokane, Washington, took first place with her orange marmalade. Dawson Hornswabber came in second with his spicy gooseberry red pepper jam.

Here's Dawson now. Dawson, what's your strategy for Round 2?

Dawson: For me it's all about proportions, Flint. I have to find the right percentage of each ingredient to produce the balance I'm looking for.

Flint: A hush falls over the audience as the secret ingredient of Round 2, Juices, is unveiled. Could it be . . . ? Yes! This year's secret juice is carrot juice! What a surprise! I believe this is the first non-fruit juice that's been named the secret ingredient in the Juice on the Loose Junior Flavor Combo Competition. Let's go to Karen up in the booth for this round's rules.

Karen: Thanks, Flint. Our junior chefs must prepare a juice mixture using carrot juice and any other juices of their choice. They must prepare at least 2 quarts of their mixture to present to the judges before the sound of the buzzer.

Flint: Let's head back to the floor to see how preparation is going. Dawson Hornswabber, what juice combination will you be presenting today?

Dawson: I call this one the "Crazy Bunny."

Flint: Ah, because of all the carrots?

Dawson: I guess you could say that. But Bunny is actually my dog's name. She loves carrots. They're her favorite food, next to lettuce. When she hears the bag of carrots come out of the fridge, she goes wild!

Flint: Will there be lettuce in your juice today?

Dawson: Uh, no. I don't think lettuce would make very good juice. It would mostly be water, right?

Flint: I think that's correct, yes.

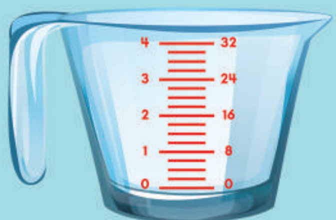
Dawson: Bunny spends most of her day sleeping in sunbeams around the house, so I've picked fruits that remind me of the sun: oranges, pineapples, nectarines, and lemons.

Flint: Ooo, that lemon will pack a powerful punch. How are you going to make sure you won't have the judges puckering up too much?

Dawson: I only use $\frac{1}{12}$ of a quart of lemon juice.

Flint: Can you share the rest of your recipe with us as you work?

Dawson: Sure. First, I put in my $\frac{1}{2}$ of a quart of carrot juice. Then I add $\frac{1}{3}$ of a quart of orange juice and $\frac{1}{3}$ of a quart of nectarine juice. That's followed with $\frac{1}{4}$ of a quart of pineapple juice.



Empty

Carrot juice

Orange juice

Nectarine

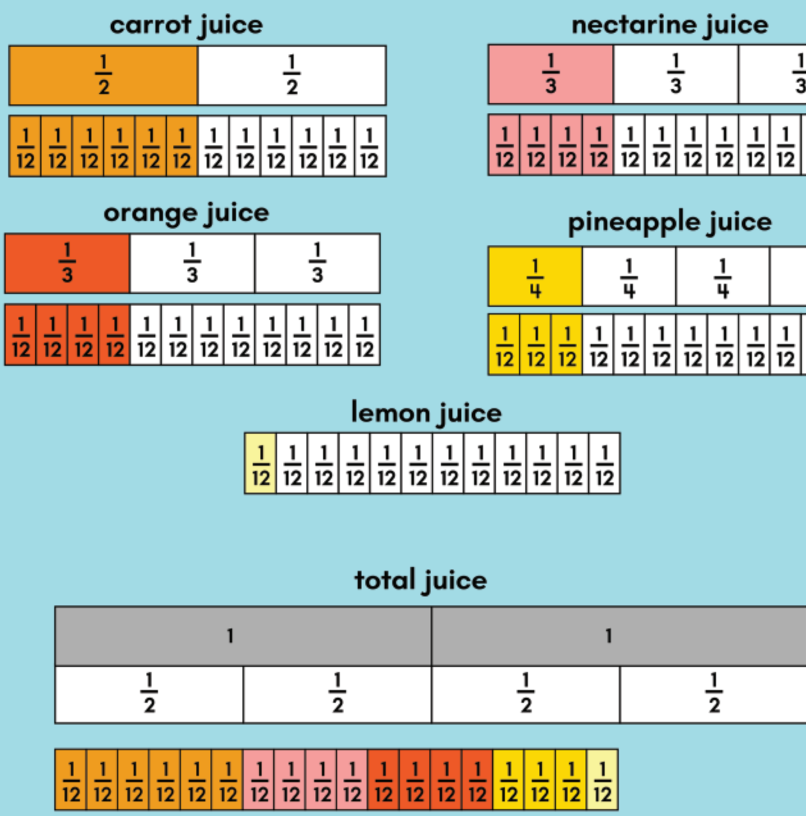
Pineapple

Flint: How much juice do you have in total?

Dawson: To add my fractions together, I have to make sure they have the same denominator. The lowest denominator they have in common is 12. I have $\frac{1}{12}$ of a quart of lemon juice, $\frac{6}{12}$ of a quart of carrot juice, $\frac{4}{12}$ of a quart of orange juice, $\frac{4}{12}$ of a quart of nectarine juice, and $\frac{3}{12}$ of a quart of pineapple juice. Altogether, that's . . . $\frac{18}{12}$, or $1\frac{1}{2}$ of a quarts of juice.

Aw man, I need to present the judges with at least 2 quarts of juice! Sorry, Flint, but I need to concentrate while I make another batch. Carrot, orange, nectarine . . .

Flint: I'll leave you to it while we show viewers at home your amounts.



(*minutes later*)

Flint: Now the judges will do their taste test of the juices. Remember that they don't know which contestant made which juice.

Judge #1: (*tasting Dawson's juice*) This juice has a lovely orange color and a pleasant taste, but something about it feels rather flat.

Judge #2: It borders on the slightly-too-sweet side for me. I wish there were more noticeable lemon to balance and brighten the flavor.

Dawson: (*whispering*) Oh no! I forgot the lemon juice in my second batch!

(*minutes later*)

Judge #1: And the honorable mention for best color goes to Dawson for his Crazy Bunny juice. Well done, Dawson. It was very close between you and Mary for first place.

Dawson: Thank you. Next time, I promise not to forget any of the ingredients!

Main Idea

You need a common denominator when adding, subtracting, or comparing fractions.

Mind Your Own Beehive

Chapter 11

Raising livestock isn't just for folks who live on country roads anymore. Today, it's possible to find a chicken coop in a suburban neighborhood, too! You might also find honeybee hives. The bees nuzzling into front yard flowers aren't visitors from far away; they live right next door!

Urban and suburban beekeeping is growing in popularity across the United States and other countries. All it takes is patience, some special equipment, and a willingness to learn. With those investments, beekeepers provide a safe and healthy home for the insects that pollinate $\frac{9}{10}$ of the world's plants. That includes $\frac{3}{10}$ of the world's crops, which humans and many animals need to survive.

Bees will build their nests almost anywhere. Wild bees nest in the ground, in wood, and in open cavities, or spaces, in cliffs and trees. Some wild bees build their own nests out of mud, stones, plants, and animal fur.

Human-raised honeybees build their hives in rectangular wooden boxes stacked atop one another. The boxes aren't very big. Depending on how tall you stack them, they can resemble an office filing cabinet.

The base layer of the hive is the bottom board. That's where the bees enter and exit the hive. A super, short for *superstructure*, is put on top of the bottom board. Supers are the individual boxes that make up a human-kept hive.

Each super holds 10 frames, which are also made of wood. The frames will hold honeycomb. Some beekeepers supply their bees with premade wax honeycomb. Others let their bees build their own.

Beekeepers have different supers for different purposes. The lowest super is for the brood, or baby bees. The queen bee of the hive will lay her eggs in the honeycomb of the lowest super. If the brood doesn't use all the frames, the bees will also use this super for storing the pollen collected by worker bees. It will be combined with nectar, honey, and saliva to make "bee bread," which is easy for bees to digest.

Any supers above the brood super are used for storing honey. The honey is used by the bees to make their bee bread, but it’s also collected by beekeepers to go on top of their toast or in their tea or to share with friends. Some beekeepers sell the honey they collect.

Bee boxes have two covers. The inner cover is put on top of the highest box. It has a small gap in it that acts as a second bee doorway when the top cover is off. The top cover is the cap of the bee box. It protects the hive from rain, snow, and other wet weather.

Healthy honeybee colonies can grow quickly. New beekeepers aren't always sure when they should add another super to their hive. Experienced beekeepers offer this advice: Don't expand your hive until $\frac{7}{10}$ of a super's frames are full.

That's because being a honeybee is a lot of work. Bees don't just fill their honeycombs with honey. They also take care of baby bees, clean the hive, maintain the honeycombs, and guard the hive from intruders. More space means more to clean, care for, and guard. If the hive doesn't have enough workers to handle all those jobs, the bees will get stressed. They won't produce much honey, which means they won't have enough food to eat.

When beekeepers collect their last honey harvest of the year, they need to remember to leave enough for the bees to survive the winter. In cold climates, honeybees need between 60 and 70 pounds of honey per hive. In climates that don't have very much cold weather, 20 to 30 pounds of honey should be enough for the colony's survival.

The amount of honey a frame can hold depends on the frame's size. A deep frame can hold 6 pounds of honey. A medium frame can hold 4 pounds of honey, and a small frame can hold about 3 pounds of honey. Expert beekeepers recommend waiting until a frame is $\frac{8}{10}$ full before harvesting the honey.

Main Idea

Beekepers use fractions to maintain their hives and know how much honey to harvest.

Subtracted Seconds Add Up

Chapter 12

In the sport of swimming, races are often won or lost by just a tiny portion of a second. Every part of swimmers' training is aimed at reducing time. Even a fraction of a second can make the difference between winning and losing.

Swimming competitions are called meets. Swim meets include different races. Like track meets, races can be different lengths. During a swim meet, different races require the swimmers to use specific strokes. A stroke is the certain way you move your arms and legs to travel through the water.

There are 4 main types of strokes—freestyle, backstroke, breaststroke, and butterfly. Each stroke has its own style and uses different muscles. Freestyle is the fastest stroke. The butterfly is considered the hardest. It requires good coordination between arm and leg movements and a lot of body strength.

There are a couple ways the swimmers can be timed during a meet. In some cases, there are touchpads that the swimmer touches at the end of a race. This records that swimmer's time for the race. But in case the touchpads don't work, there are also people called timers who use stopwatches to time the swimmers. These times are recorded and are a backup for the touchpads.

There are several things that a swimmer can do to improve their race time.

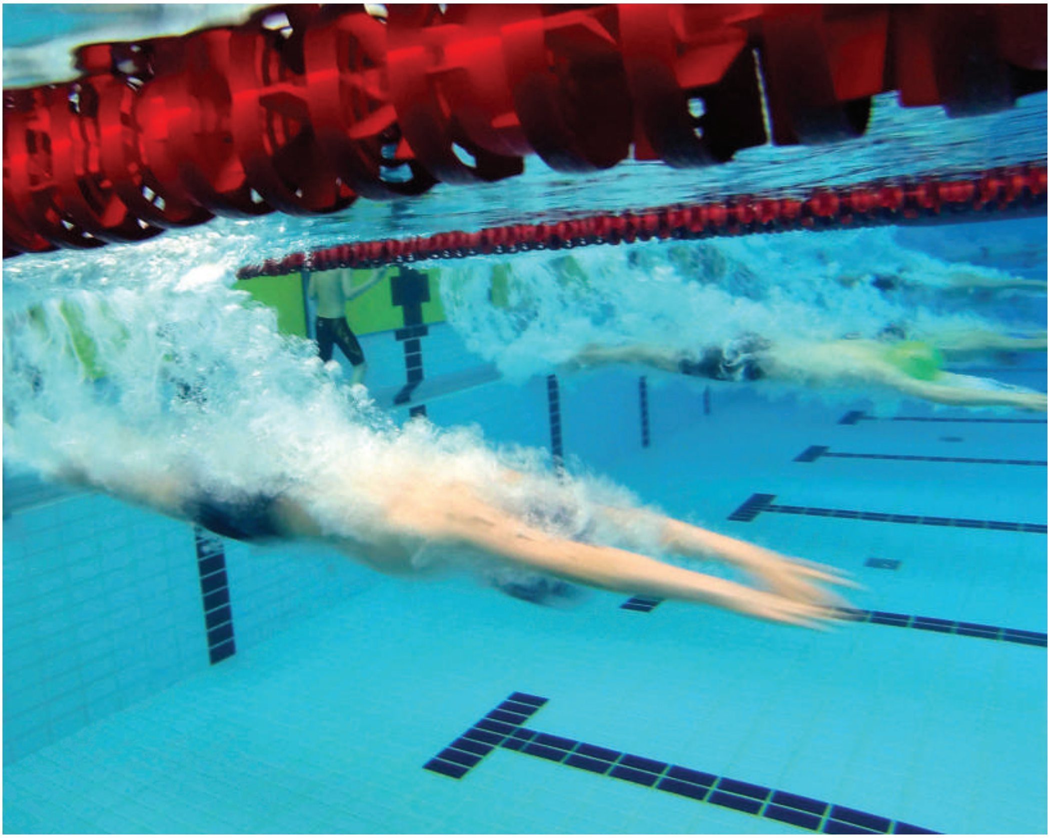
Start and Reaction Time: Being ready to dive into the pool at the starting signal is a good start. The time between when a race starts to when the swimmer hits the water from the starting block typically takes around 0.5 seconds to 1 second.

How you enter the water is important, too. For the fastest speed, a swimmer's body should be in a streamlined shape, or one that can cut through the water easily. This lowers water resistance, which slows you down. A powerful start helps set a fast pace for the race.

Stroke Technique: Technique means the way you do something. Perfecting your stroke technique takes a lot of practice, but it pays off. It can help you swim faster and reduce the amount of energy you need. No matter the stroke, how long your stroke is and how often you take a stroke can change your time. In freestyle, keeping your body as close to the water's surface as possible is one technique that helps you swim faster.

Breathing Technique: Proper breathing technique—timing the breath with the stroke and keeping the head low in the water—reduces water resistance and helps you swim faster. A well-timed breath can ensure that you maintain your rhythm without disrupting your stroke. Breathing every 2 or 3 strokes can help keep the body in a streamlined position. Every time you move your head to breathe, it can slow you down. It is like putting the brakes on. For the best time, you want to keep a steady speed.

Kick Efficiency: A strong, steady kick helps maintain speed. Kicks should be powerful and well controlled. This helps drive the swimmer forward without causing them to get as tired.



Turns: A good turn can save time. A swimmer wants to maintain speed through the turn. It is important to know when to start turning. Being too close or too far from the wall will slow you down. A good swimmer maximizes their speed when they kick off of the wall in a turn.

Underwater Techniques: After making a turn, staying underwater as long as possible allows swimmers to maximize their speed. This is because underwater dolphin kicks are more efficient than surface strokes. A good swimmer will take several dolphin kicks before they surface. Swimmers spend a lot of time working on their turns and dolphin kicks.

Understanding how math can help a swimmer get a faster time is important to winning the race. How often a swimmer takes a stroke, how long their strokes are, and how much time they take for each stroke can all affect their time. Knowing when to take a breath and how to keep the best body position can take time off their score. A good swimmer is always evaluating how they are doing so that they can be as efficient and as fast as possible. After all, you can win a race by just a fraction of a second.

Main Idea

Swimmers can use math to look for ways to improve their time when they race.

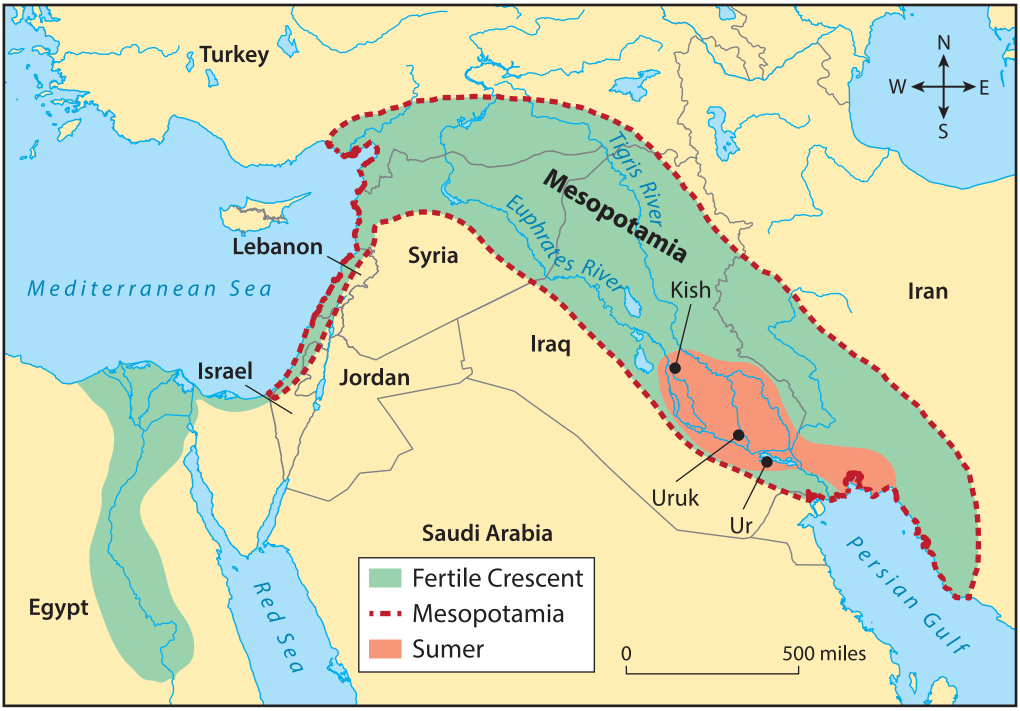
Math Over Time

Chapter 13

Why do we do math the way we do it today?

The answer is that math developed over time. People have always done some form of math, but as their needs changed, they needed better math skills. We don't know the details about how the earliest math was done because the first people who would have used math lived before historic records were kept, but we do have records showing how math skills developed.

Archaeologists have found evidence of math on clay tablets and papyrus texts from ancient Sumer, Mesopotamia, and Egypt. They think that math must have been used to produce the architecture of the past. Experts have evidence that for a long time, different ancient civilizations had their own ways of doing math.



How did we get from many different ways of doing math all around the world to the widely-used system of math that we use today? A simple answer is that people found ways to read each other's work and to learn from each other. They found written materials by earlier people who studied math from different cultures and translated their work. That meant it could be read and studied by people in their own time and language. Ideas could be shared, debated, and discussed.

Trade played an important role in the development of modern math. Traders traveled around buying and selling goods. Some of these traders were Muslims. Muslims practice the Islamic religion. Islam began in the Arabian Peninsula and spread into parts of Asia, North Africa, and Europe.

Muslim traders traveled far and wide during the Islamic Golden Age, from the 700s to the 1400s CE. As they traveled, traders and explorers exchanged goods—and they also encountered ideas and books. They brought these ideas and books back home with them, where scholars eagerly studied them.

People shared knowledge all over the world. Muslim teachers and thinkers translated books about math, science, and philosophy into Arabic. These books originally came from places like Greece and India. Some Muslim learners read the translated books about math and came up with their own new ideas.

One of those people was Muḥammad ibn Mūsā al-Khwārizmī (780–850 CE), who studied math and the night sky. He was a scholar at the House of Wisdom, a school for research and study in present-day Iraq. He invented a mathematical process called "al-jabr." Today it is known as "algebra." Al-Khwārizmī also made popular the use of Hindu-Arabic numbers, which are the numbers we use today.

Arabic-Language Numbers	Hindu-Arabic Numbers	Roman Numbers
٠	0	(no zero)
١	1	I
٢	2	II
٣	3	III
٤	4	IV
٥	5	V
٦	6	VI
٧	7	VII
٨	8	VIII
٩	9	IX

Central Asian Al-Khwārizmī read about the positional base-10 numeral system developed by Indian mathematicians centuries earlier. This number system uses the numbers 0–9 and the value of the numbers depend upon their position within a larger number. He is thought to have introduced the concept of the positional base-10 number system to the Arab world. Abu'l-Hasan al-Uqlidisi (920–980 CE) was another scholar who studied math. Some historians think al-Uqlidisi was the first person to use decimal fractions, which means the denominator was a power of 10. His book, published in 952–953, is the first written evidence of using a decimal to separate the whole part of a number and the fractional part. Al-Uqlidisi's version of the decimal looked like a comma, but it worked like the period (dot) we use today. Many countries still use the comma.

Many other people studied math and shared their work with other scholars, who then tested those ideas and came up with new ones. At one time or another, all these people (and more) have been said to have contributed to the development of the decimal.

780–850 CE: Al-Khwārizmī introduces the positional base-10 number system to the Arab world.

952–953 CE: Al-Uqlidisi shows how the decimal can be used to express a fraction in his book *The Book of Chapters* on Hindu arithmetic.

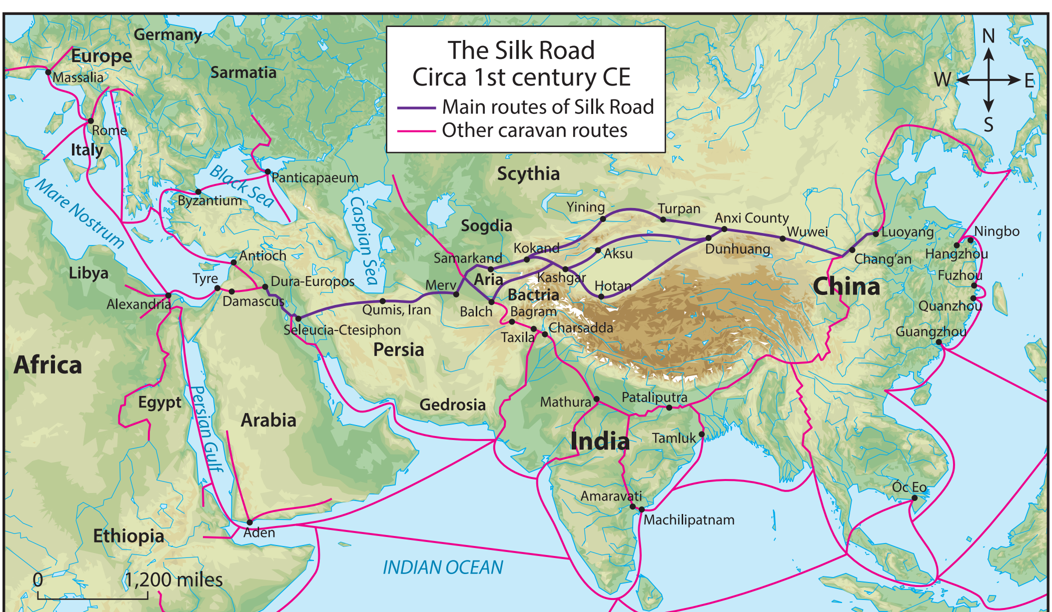
1440s CE: Italian mathematician Giovanni Bianchini uses a decimal point in his astronomy tables to separate whole numbers from fractions—one of the earliest known uses in Europe.

1585 CE: Flemish (Belgian) mathematician Simon Stevin publishes a booklet that explains how to use decimals to express fractions.

So how did mathematical concepts travel between Europe, Africa, and Asia? They followed the Silk Road, which was a series of trading routes that connected China to the Roman Empire. The routes were meant for trading goods, but also allowed people of different cultures to exchange ideas.

In 1202 CE, an Italian mathematician known as Fibonacci—his real name was Leonardo de Pisa—wrote a book called *Liber abaci*, which means "Book of Calculations." It was the first book about Indian and Arabian math to be published in Europe. De Pisa's father was a merchant, and de Pisa spent a lot of his childhood in North Africa, where he studied math using Hindu-Arabic numbers. The Hindu-Arabic number system uses the numbers 0–9.

European scholars read de Pisa's book. At the time, Europeans used Roman numerals. Scholars who spent their days doing math problems quickly discovered that Hindu-Arabic numbers were much easier to work with.

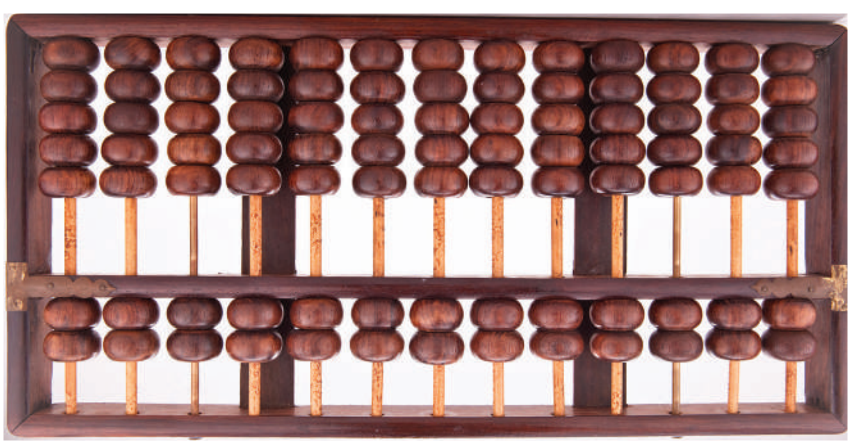


The Silk Road carried goods, religion, philosophy, and culture between Europe, Africa, and Asia.

The rest of the population didn't adopt the new numbering system as quickly. Merchants used the abacus, which was a series of wires mounted on a frame. Each wire had beads or disks strung on it, which were used for adding, subtracting, multiplying, and dividing. Using an abacus was fast, and it didn't require writing materials, which were expensive.

Still, European scholars continued to study de Pisa's work. When a new era of learning and creativity began in the 14th century, universities began teaching this "new" type of math, including algebra, to their students. It then spread to the wider population.

The development of mathematics is a tale of discovery and cooperation that spans many cultures and centuries. From ancient civilizations to modern classrooms, people have built upon each other's ideas to produce the math we use today. By sharing knowledge and learning from one another, we have developed a powerful tool that helps us understand and explore the world around us!



Main Idea

The way we write numbers, including the decimal point, is based on a system developed by mathematicians over a thousand years ago.

Gaining from Training

Chapter 14

Track and field is an exciting sport. It combines speed, strength, and strategy. Math plays an important role in track and field. One important aspect of track and field is the use of the metric system. This is how distances are measured in most parts of the world. Even though we usually don't use the metric system in the United States, track and field events are measured in meters. This allows athletes to compete internationally and compare their times with others. For example, races like the 100-meter dash, 200-meter dash, and 400-meter run are all measured in meters, no matter where in the world they are run.

Understanding Performance

In track and field, athletes and coaches use math to track their performance. They can use key performance indicators, or KPIs. KPIs measure how well an athlete is doing and identifies areas where they can improve. For example, a KPI could include a runner's best time for a specific distance. By studying this information, a runner can make a plan for training.

Say a runner completes the 100-meter dash in 22 seconds one day and 21.5 seconds another day. They can subtract the two times to find out how much faster they ran: 22 seconds–21.5 seconds = 0.5 seconds. This calculation helps the runner understand their progress and set goals for future races. Tracking these times over weeks or months allows the runner to see trends in their performance. This can help the runner stay motivated and focused on their training.

The Importance of Timing

Timing is another part of track and field that uses math. Races are timed using stopwatches or electronic timing systems. These record how long it takes each athlete to complete their race. Timing data is important for comparing performances. For instance, if two runners compete in the 200-meter dash, their times can be compared to determine who performed better, even if they ran on different days.

To calculate speed and pace, athletes use the following formula:

Speed = Distance ÷ Time

Here's how a runner who completes a 400-meter race in 50 seconds calculates their speed:

Speed = 400 meters ÷ 50 seconds = 8 meters per second

Understanding speed helps athletes determine how fast they need to run to meet their goals. Pace is also important. Pace refers to the time it takes to cover a specific distance. It is often expressed in minutes per kilometer. For example, if a runner completes a 5-kilometer race in 25 minutes, their pace would be

25 minutes ÷ 5 kilometers = 5 minutes per kilometer

Knowing their pace helps runners manage their energy during a race. This keeps them from starting too fast and tiring out before the finish line.

In track and field, there are several types of running events. Each type requires different strategies and training methods. Two types of running events are sprints and relays.

Sprint Races

Sprints are short-distance races in which athletes run as fast as they can. There are three main sprint events. They are the 100-meter dash, the 200-meter dash, and the 400-meter run.

100-Meter Dash

This is the shortest of the sprints. If someone runs the 100-meter dash, they'd run hard for all 100 meters. This race typically takes less than 20 seconds to complete! To train for this race, runners often do drills such as running 100 meters quickly, walking back, and doing this again 10 times. This is known as a 10 by 100.

One meter is about 3.28 feet. So the 100-meter dash is about same as running 328 feet, or a little longer than a football field.

200-Meter Dash

The 200-meter dash is a longer sprint that requires both speed and a bit of endurance. This race begins on the curve of the track and ends on the straight side. To prepare for the 200-meter dash, athletes often practice with a “7 by 200” workout. This is when they run 200 meters 7 times, taking walking breaks in between each sprint. This helps the athlete develop the ability to maintain speed while navigating the curve of the track, which can be tricky.

A 200-meter dash is twice as long as the 100-meter dash. That’s about 650 feet. That run is as long as 200 Amsterdam Avenue, a 203-meter tall skyscraper on the Upper West Side of New York City.

400-Meter Run

The 400-meter run is one full lap around the track and is known for being fast and exhausting. Runners need a combination of speed and endurance to succeed in this event. A typical training drill for the 400-meter run is a "4 by 400," in which athletes run 4 laps with walking breaks in between. This helps them build endurance while also practicing their speed.

A 400-meter race is 4 times as long as the 100-meter sprint. So it's 328 feet times 4, which is about 1,312 feet! That is the same length as this ship.

Relay Races

In relay races, teams of 4 runners take turns running parts of the race. The runner passes a baton when it's the next runner's turn. The total time for the relay is calculated by adding up the times of each runner. For example, in a 4 by 100-meter relay, each runner sprints 100 meters. In a 4 by 400-meter relay, each runner runs 400 meters (one lap).

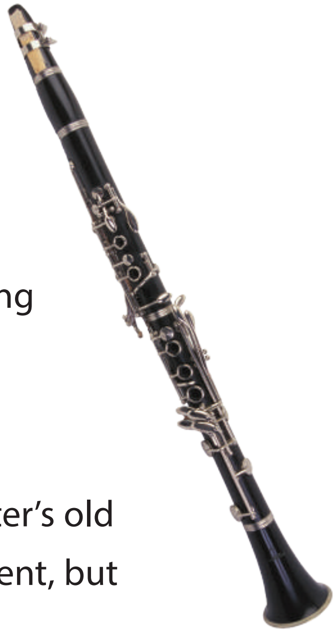
Coaches use math to determine the best placement for each runner based on their strengths. The first runner is usually the best starter. They need to be quick at accelerating from the starting blocks. The second leg is often the fastest overall runner on the team. The third leg may be a strong curve runner. The last runner is typically the one who can finish the fastest under pressure.

Main Idea

Measurements of time, distance, and speed help athletes evaluate and improve their performance.

Eye on the Prize

Chapter 15



One March afternoon, Evan runs into the kitchen. He's excited to share some news with his mom.

"Mom, I did it!" Evan exclaims. "I picked the tuba for next year to play in band!"

"Oh?" says his mom. "I thought you were going to play the clarinet."

"Nope, I'm playing the tuba!" Evan says.

His mom sighs. "But we already have your sister's old clarinet. It might not be your favorite instrument, but it's free."

“Please, Mom?” Evan pleads. “Grandpa played the tuba. Remember how he used to play in all those tuba holiday concerts? I was born to do that!” He adds a charming smile to win her over.

His mom considers this point. She seems lost in a memory. “Well . . . okay,” she says. “But you’re going to help pay for the tuba *and* your summer lessons.”

Evan stands up and cheers. “Yes! Thank you! I’ll do extra chores, whatever it takes!”

The next day, Evan tells his friend Hana about his plan.

“So how much money do you need to earn?” Hana asks.

“$387.75 in all,” replies Evan.

“How did you figure that out?” asks Hana.

“My mom said if I practice all summer and decide to keep playing, they’ll pay for the tuba during the school year,” explains Evan. “So I just had to figure out how much I needed to earn for the summer, which is 3 months long.”

“You need money for both the rental *and* the lessons. Did you figure out all that?” asks Hana.

“Yep, I did the math,” says Evan. “It’s $25.25 a month to rent and $104 for a month of lessons. I wrote it all down in a notebook at home. I added that up for one month. Then I multiplied it by 3 months. $387.75!”

“It sounds like a lot,” says Hana. “But I know you can do it!”

A few weeks later, Evan sits at the kitchen table with a notebook in front of him. He is trying to make a plan to make money, but every idea he has becomes a wadded-up ball of paper.

“Ugh, why is it so hard for kids to make money? I’m too young to babysit or mow lawns. I’m never going to be able to afford a tuba.”

His mom calls to him from outside the house.

“Hey, Evan, will you help me out in the yard?”

“Be right there, Mom!” Evan replies.

They work side by side for the afternoon, pulling weeds and moving rocks.

“Thanks for your help, sweetie,” says his mom. “Who knew you were so great at moving rocks and pulling weeds?”

She opens her wallet and hands him a $20 bill and 3 quarters. “This is to pay you for your hard work.”

“Wow!” Evan exclaims. “$20.75? For a few hours of garden work? That gives me an idea . . .”

In May, Hana sees Evan working in his neighbor's yard.

"How are your tuba plans coming along?" she asks.

"So far, so good," he replies. "These weeds will keep growing all summer long! I have 5 customers on this block who are paying me $20 each time I weed their gardens."

"Wow," Hana replies. "My neighbor is going on vacation. They could use someone to feed their cat. I'll bet they'll pay you to do that for them."

"I'll head right over there today and ask if I can help," says Evan. "And I have posters I can put up to see if people need a dog walker."

"Maybe you'll earn enough money for the tuba after all," Hana says with a smile.

Evan flashes his cheerful grin. "Tuba summer, here I come!"

Main Idea

Using math skills helps you monitor progress toward your money goals.

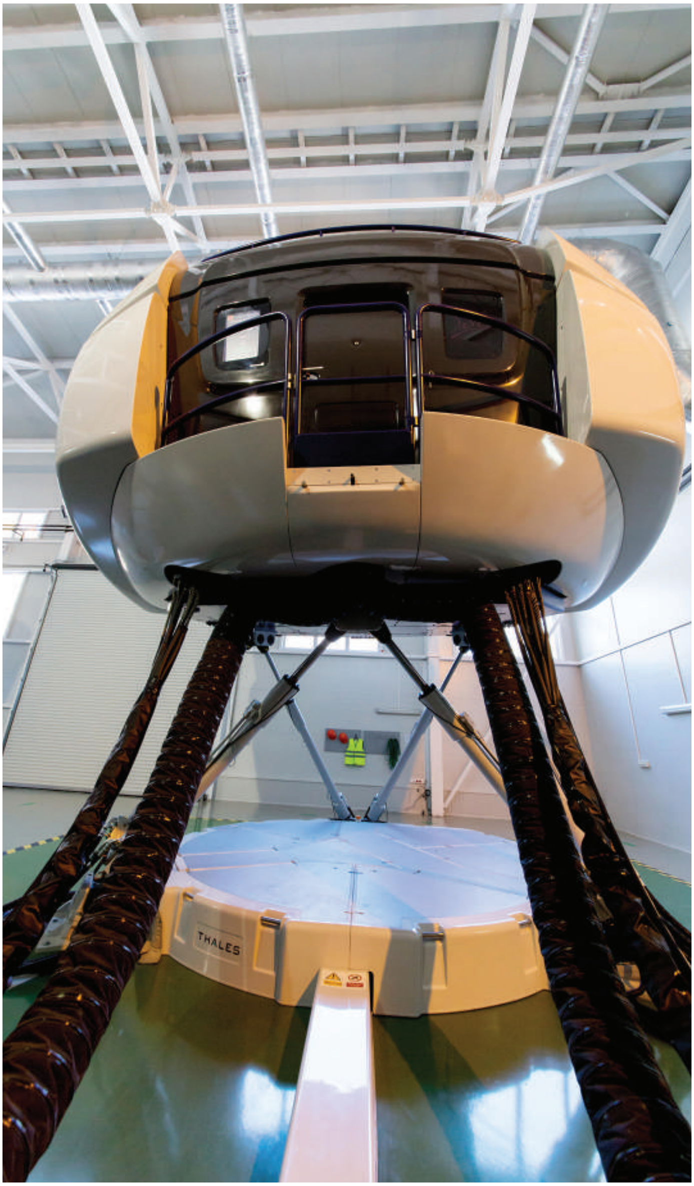
Figuring for Flight

Chapter

16

During our family trip to visit Grandma, we stop by the airport. I see Aunt Nia as we pull up. She is in the open doorway of the airplane hangar. She is taking classes to get her commercial pilot license.

After we all hug, Aunt Nia leads us farther into the airplane hangar. It is like a big warehouse, except there isn't much in it.



I point to what looks like a round room on stilts in the middle of the hangar. It is wrapped in windows, but they are all blacked out. "What's that?" I ask.

"That's my airplane!" Aunt Nia says. "Come on. I'll show you."

Aunt Nia leads us up a steep flight of stairs and into the little room. It's an airplane cockpit!

"This is a simulator," Aunt Nia explains. "It simulates, or acts like, the cockpit of a real airplane." She points to the 4 windows that wrap around the front of the little room. They sit above a control panel crowded with buttons, switches, dials, and tiny screens. "Those are video screens," she continues. "When the simulator is turned on, the screens show what it would look like if you were actually flying an airplane."

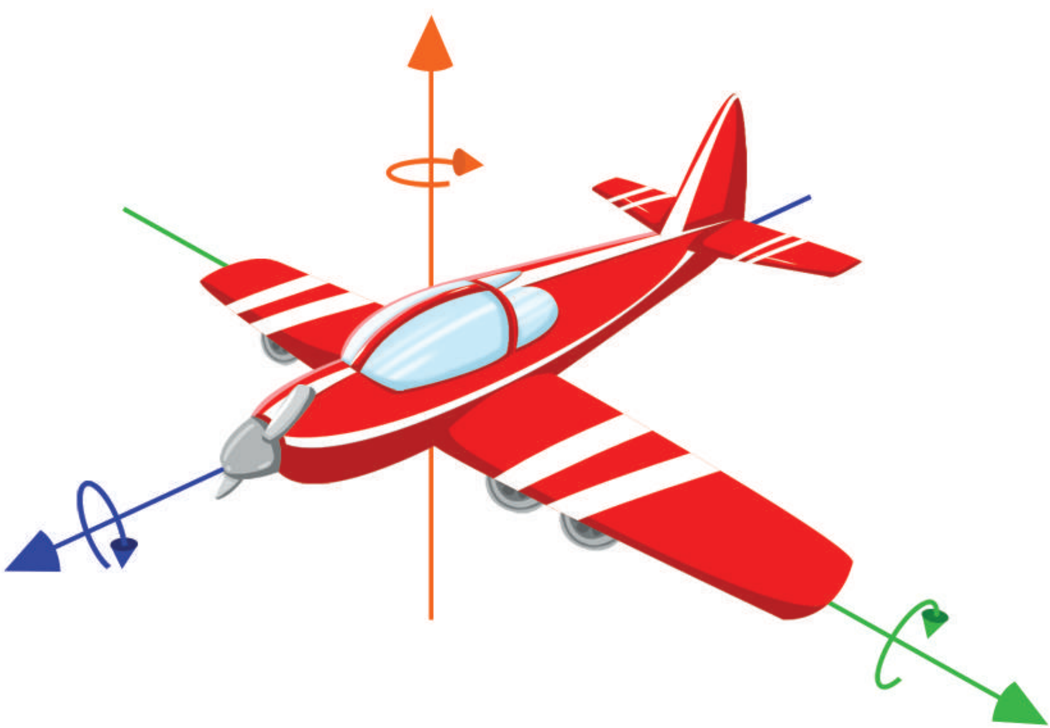
I can't believe my Aunt Nia knows what all those controls are for. There are even buttons and knobs on the ceiling!

“Flying a plane seems really complicated,” I say. “How do you remember what all this stuff is for?”

Aunt Nia settles me into the copilot’s seat and gives me a quick lesson about how airplanes work.

Unlike cars, which go forward, backward, and can turn left or right, planes can move in three dimensions. They go forward, move left and right, and move up and down in the air. Four parts of the airplane are responsible for these movements: the engine, the ailerons, the rudder, and the elevators.

An airplane’s engine is what makes it go. In the cockpit, it’s controlled by the throttle lever. The engine’s power provides thrust, which is what makes vehicles move forward.



The ailerons are flaps on the back of the airplane's wings. They determine how much the plane rolls, or rotates, along an imaginary horizontal line in the air. The ailerons are controlled by a wheel on the control panel. When the pilot turns the wheel clockwise, the right aileron raises into the air while the left one drops downward. The change in the ailerons' angles makes the airplane roll to the right.

The rudder is a vertical fin on the tail of the airplane. It helps pilots keep the plane flying straight. It's controlled with foot pedals. When the pilot pushes the right pedal, the rudder moves to the right. Air now hits the rudder at a different angle, which pushes the airplane to the left.

Ailerons and rudders are used together to turn airplanes in flight.

Angles of Turns

Airplanes generally make three types of turns: shallow turns, in which the angle is less than 20 degrees; medium turns, in which the angle is between 20 and 45 degrees; and steep turns, in which the angle is greater than 45 degrees. Pilots and people riding in a plane can feel the steep turns more than the medium turns.

The last major parts of an airplane are its elevators. They're also on the tail. Like ailerons, elevators are horizontal flaps that move up and down with the help of a control wheel. Unlike ailerons, the 2 elevators move in the same direction. They control the airplane's pitch, which is the level of its nose. Raising the elevators makes the plane's nose go up into the air, which allows the plane to go higher. Lowering the elevators makes the plane's nose go down, which allows it to descend.

"So you would have your elevators up during takeoff?" I ask.

"Yep!" says Aunt Nia. "My plane's nose has to be pointed into the air to get the angle I need to achieve for takeoff."

"What angle is that?" I ask.

Angles of Takeoff

Large passenger planes, such as the Boeing 747, slowly angle up during takeoff at about 2 to 3 degrees per second. The average passenger plane has a maximum takeoff angle of about 10 to 15 degrees. Other planes, such as the Boeing 787-9 Dreamliner, have the ability to go almost straight up, at a 90-degree angle. However, takeoff angles are usually kept moderate to make passengers feel comfortable, save on fuel, and be as safe as possible.

"It depends on the airplane," Aunt Nia says. "There are a lot of things to consider: the plane's weight, its length, how many engines it has, and even where the airport is located." She smiles at the look on my face. "Don't worry. Pilots learn how to calculate all those things in pilot school. There's an app that will figure it out for us, of course, but I like this."

She hands me a thick, rectangular card inserted into a sturdy paper circle. The circle slides up and down the rectangle, and it has a dial that spins. "What is it?" I ask.

Aunt Nia grins. "It's a flight computer! I find my numbers and line them up, and it shows me the information I need. Pretty handy, huh?"

From a paper computer to a flight simulator, I've seen a lot of new things today!

Main Idea

Pilots use their understanding of dimensions and angles to take off, steer, and land planes safely.

Wassily Kandinsky

Chapter 17

For most of human history, artists have drawn and painted pictures that show objects mostly as they are. Lines, colors, and textures combine to create recognizable faces, flowers, and places.

But we also have art that looks like nothing we've ever seen in the real world. Some works of art look like the shapes we learned in preschool. Some look like splatters of paint on paper. Some are so simple that we can duplicate them ourselves. Others are so complicated that our eyes don't know where to rest.

Many paintings in these bold, unusual styles are in a category known as abstract art. One leading abstract artist was Wassily Kandinsky, a Russian law professor who couldn't stop thinking about color.

This painting by Wassily Kandinsky is titled *Black Lines*.

Wassily Kandinsky was born in Moscow, Russia, in 1866. He came from a family that had both money and interest in the arts. As a student, young Kandinsky studied the piano and cello. He also took painting lessons. Later in life, he recalled that as a child, he thought that each color was a living thing with its own personality.

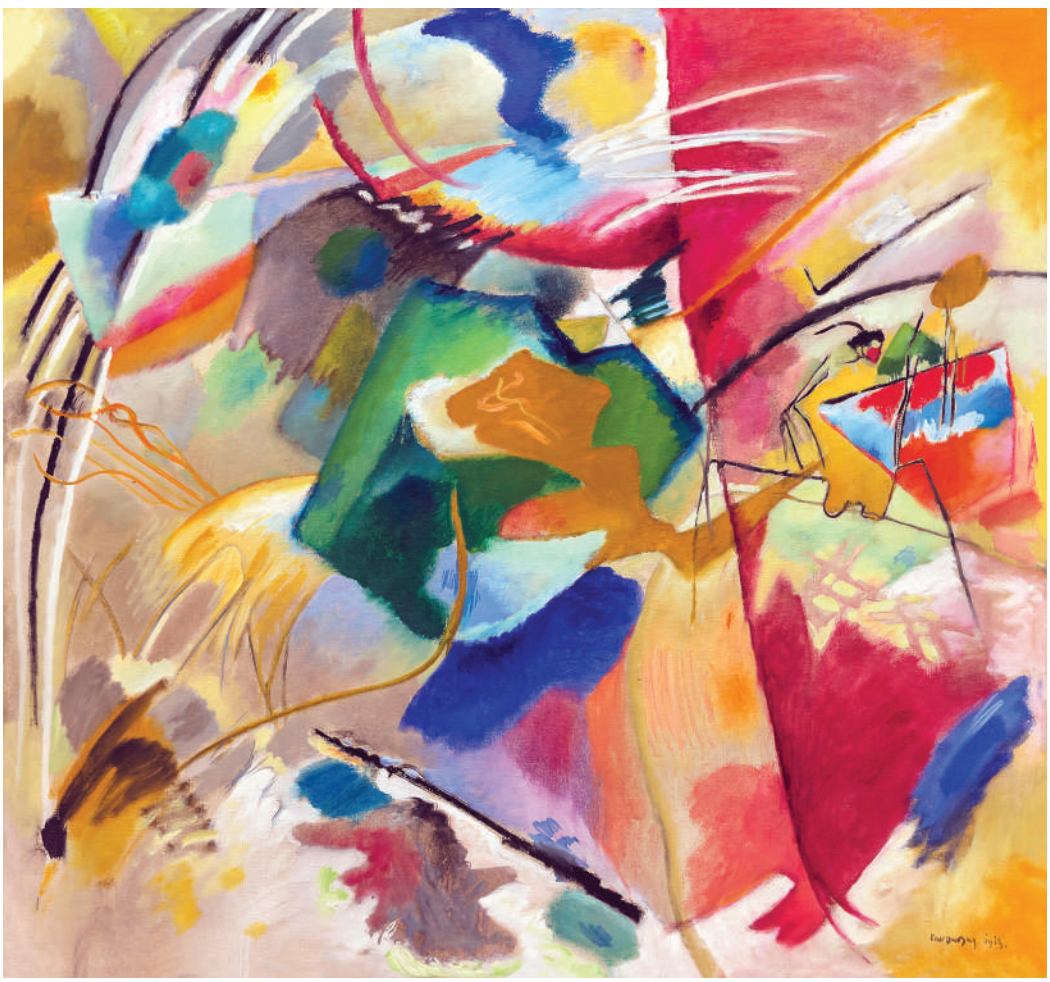
In 1886, Kandinsky began studying law and economics at the University of Moscow. In 1889, the school sent him to study the people and culture in Vologda, a city in northern Russia. While he was there, he took an interest in a style of traditional Russian paintings that weren't very realistic.

Wassily Kandinsky

Kandinsky's passionate interest in colors can also be seen in this painting, *The Bear*.

Kandinsky graduated from college in 1893, but he wasn't really interested in a law or economics career. He wanted to be an artist. Unfortunately, he felt that being an artist was "a luxury forbidden to a Russian." So he taught law for a few years in Moscow and then took a job at a print shop.

A single choice in 1896 changed Kandinsky's life forever. He was offered a job teaching law in the region of Estonia, to the west of Moscow. Instead of accepting the offer, Kandinsky hopped on a train to Germany and enrolled in art school. Just before his thirtieth birthday, he decided to follow his dream of becoming a painter.



Kandinsky began his art studies like most other artists: He painted things from real life. But as he was exposed to different styles and techniques, his work began to change. When he graduated from art school in 1900, he was using dots, blotches, and bold colors to create recognizable figures. By 1909, his paintings were fully abstract. That means they didn't look like anything from real life.

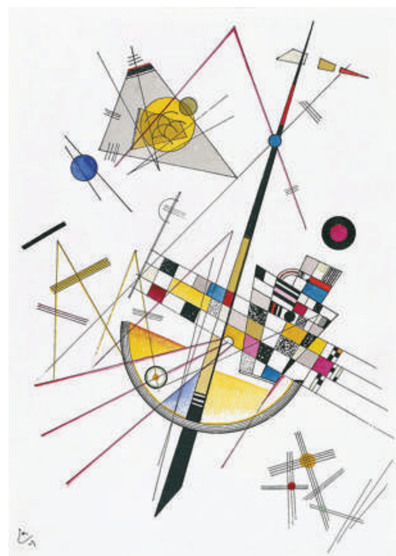
That was on purpose. Kandinsky didn't want people to look at his work and see the same thing as everyone else. He wanted his lines, shapes, and colors to express big ideas and deep emotions. He believed that colors and lines communicate in much the same way music communicates—by making the audience feel something.

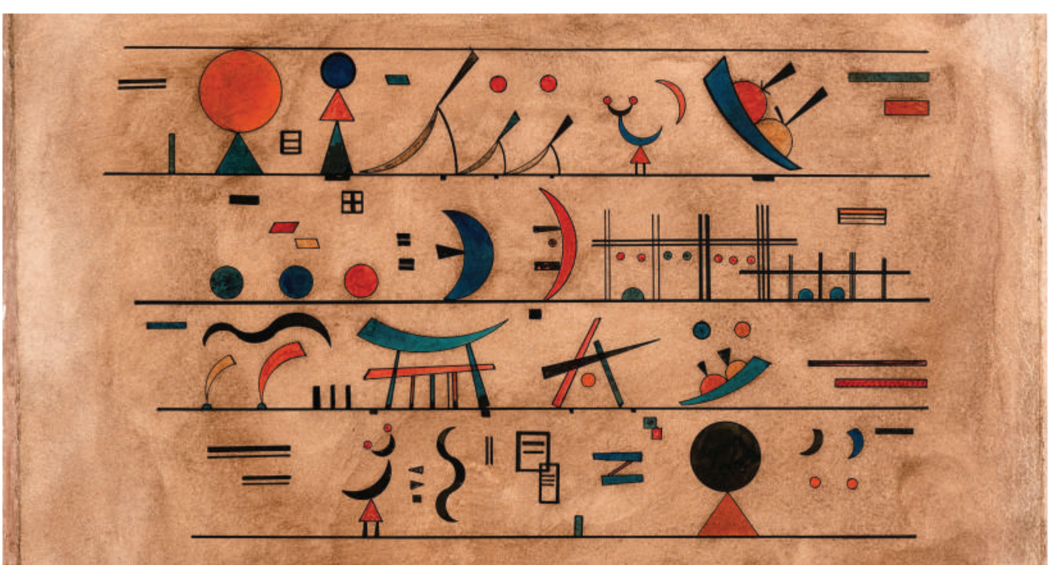
Kandinsky never lost his fascination with color and its many "personalities." As his work became more geometric, he started assigning shapes different characteristics, too. For example, he thought horizontal lines were cold. Vertical lines were hot.

Arcs

An arc is a portion of a circle—but you can also just think of it as a curve joining two points. As you can see in the two paintings on this page, Kandinsky often painted arcs close to angular shapes, like triangles and rectangles.

Geometric shapes became more and more common in Kandinsky's later work. He began introducing them in the early 1920s. As the decade closed, his lines, squares, triangles, circles, and arcs had become finely detailed elements of each painting. In the 1930s, those shapes had turned into something of a visual language, somewhat like the hieroglyphs carved by ancient peoples.





During the last years of his life, Kandinsky's geometric forms turned into more flowing shapes.

Wassily Kandinsky died in 1944 at the age of 77. Today, he is remembered as one of the pioneers of the abstract art movement of the early 20th century. He is described as the first artist who purposefully painted something that didn't resemble anything else. His bold use of color—especially red, yellow, and blue—has influenced dozens of other artists.

Kandinsky's influence is also seen outside of the art world. His paintings have been printed on posters, postage stamps, and mugs. In 2008, a town in northern Bavaria, Germany, made its own version of a Kandinsky painting on the stones of the town square. It was a copy of a painting Kandinsky made of the town in 1909!

Main Idea

Abstract art uses geometric shapes and lines to create images that can express emotions.

Race to the Treasure

Chapter 18

Mateo and his family are visiting the city for the week. Mateo's parents tell him that he can choose an adventure for one of the days they are here. While looking through some brochures, Mateo sees an advertisement that sparks his interest: "Do you like boat rides? Do you like using your math skills? Do you like races? Do you like treasures? If you thought 'YES,' then come boat with us to Beaver Island."

Mateo rushes to his parents, "I know what I want to do on my adventure day!" Mateo hands his parents the brochure. "Doesn't this sound fun? We will have an experienced guide, and we race against other boats to get to Beaver Island the fastest," explains Mateo.

His parents both look at the brochure. "This seems like the escape room race we did back home. Sounds like a fun day. Let's call and get a reservation for tomorrow." Mateo's mom calls the number and schedules the trip.

The next morning, the family arrives at the boat dock. They meet their guide, Sailor Jackie. Jackie greets Mateo and his parents. "Ahoy, mateys! Are you ready to learn some navigation and beat the other two boats to Beaver Island?" asks Jackie.

"YES!" Mateo exclaims with excitement.

"Excellent!" says Jackie. "First, we need to get your equipment on the boat. Everybody will have a part in getting us to Beaver Island, and each part is important. I hope you all are good with angles and measurements."

Mateo and his dad each take a side handle on the chest and bring it on the boat. Mateo's mom grabs life vests from the dock for each of the boat passengers.

Jackie explains that even though phones are not banned from the boat because they might be needed in an emergency, they absolutely cannot be used for navigation during the competition. To win the race fairly, every participant uses math skills and logic to get the boat over to Beaver Island.

Jackie grabs a pair of binoculars from the chest and hands them to Mateo. "Mateo, you are the boat's lookout. You will do a 360-degree view through the binoculars every 10 minutes for any obstacles. You also will let us know when you see Beaver Island. Record what you see in the boat log."

Mateo is up for the challenge. He thinks to himself, "I'm glad I listened in math class. I didn't even have to ask Jackie what she means by 360 degrees."

Next, she hands Mateo's dad a compass. His instructions are to determine if the boat is going in the correct direction. The compass shows the cardinal directions—north, south, east, and west. Each of these directions are separated by 90 degrees. The compass uses Earth's magnetic field and always points north. Mateo's dad will use the compass to keep them headed to Beaver Island.

Angles on a Compass

A compass is a circle, which means it is 360 degrees around. It shows the four directions: north, south, east, and west. Each direction represents 90 degrees, which means directions form right angles to one another.

To test Mateo's dad on his angles, Jackie asks, "If I say we need to be going right 45 degrees from north, what direction do we need to be going?"

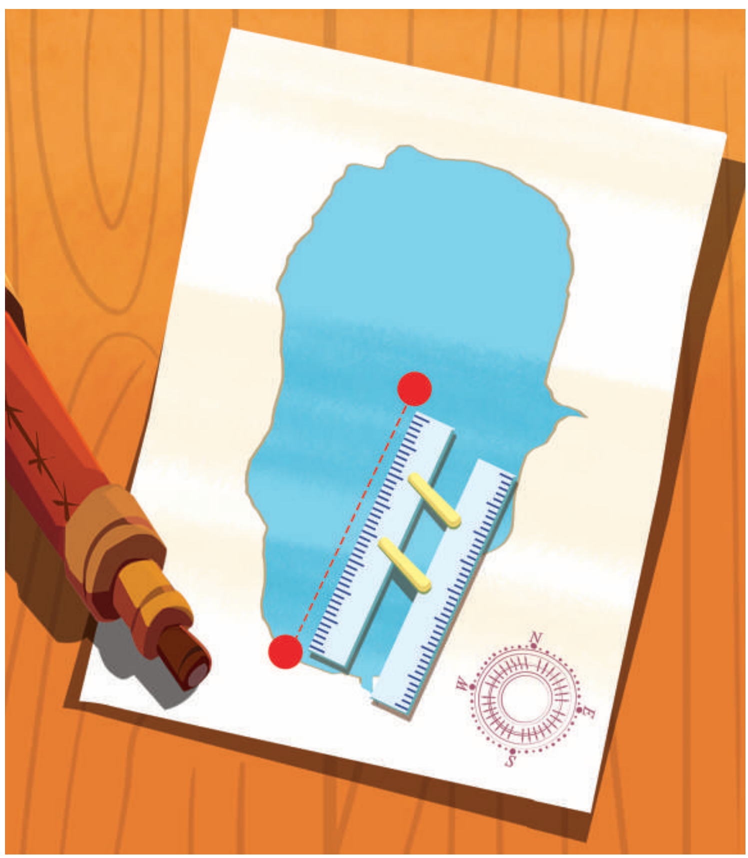
Mateo's dad looks at the compass. "I know that going right from north is toward the east. There is a 90-degree angle between north and east. So half of that is 45 degrees. That means we need to go northeast." "Gold coin for Dad!" says Jackie.

Jackie hands Mateo's mom a map, a nautical chart, and a parallel ruler. "You are going to help me with navigation," says Jackie.

Mateo's mom asks, "I understand the importance of the map. But how do this ruler and chart help us?"

"I'm glad you asked that! The nautical chart is a tool that every sailor should not leave the dock without. It gives us the depths of water, the outline of the shoreline, and any locations of dangers we need to avoid. The parallel ruler helps us plot our course," Jackie explains.

Mateo's dad notices the compass rose on the map. "That looks like the compass," he says.



"Yes! See the dot at the bottom left? That is the city. The other dot is Beaver Island," replies Jackie.

Mateo notices and says, "So we will be going almost due north."

"Gold coin for you, Mateo," says Jackie. The family chuckles!

The navigators are all busy with their roles. Mateo gives updates from the front of the boat every 10 minutes. Mateo's dad shares the cardinal directions, and his mom continues to watch out for any dangers based on the nautical chart.

After about 2 hours, Mateo suddenly yells out, "LAND!"

Mateo's dad responds, "Still on the northern path." Mateo's mom indicates that there are no shallow dangers in the water.

"Well done, crew! It seems we are the first boat to arrive!" Jackie says with enthusiasm.

Mateo does one more 360-degree observational scan. "I see the other two boats way behind us."

The group pulls up to the island, and Jackie secures the boat by tying dock lines. This will prevent the boat from floating back out into the water. Mateo, his parents, and Jackie jump off the boat to the dock. They rush to the treasure on Beaver Island.

“WOW! A pirate cookout!” Mateo says. The group crosses the finish line. Each person receives treasure—a first-place medal that looks like a gold coin. “We finally get our REAL gold coins!” Mateo says to Jackie. Everyone laughs.

Main Idea

Sailors use lines, angles, cardinal directions, and charts to safely get their boats from one location to another.

Zapatar and Squee

Chapter 19

It had been a slow, quiet day at the public library. Kate, a reference librarian, is surprised but welcoming when two aliens approach where she is sitting at the information desk. The creatures tap and poke her desk repeatedly then look at her.

“Greetings, Mistress of Books!” the first creature says. “I am Zapatar, and this is my companion, Squee. Could you help us communicate with this desk? It is not giving us information!”

Kate nods. “Hello and welcome to the library! I’m Kate, one of the library’s information specialists. What are you researching today?”

Zapatar wiggles in what Kate understands to be excitement. “We are curious about Earth cities. We have noticed that some cities follow a pattern. Why do the streets stay in such straight lines? And why are they always the same distance apart?”

Kate smiles. “Oh, you must mean the grid system!” she says.

Kate opens a drawer and pulls out a map. She unfolds it on top of the desk so that Zapatar and Squee can examine it.

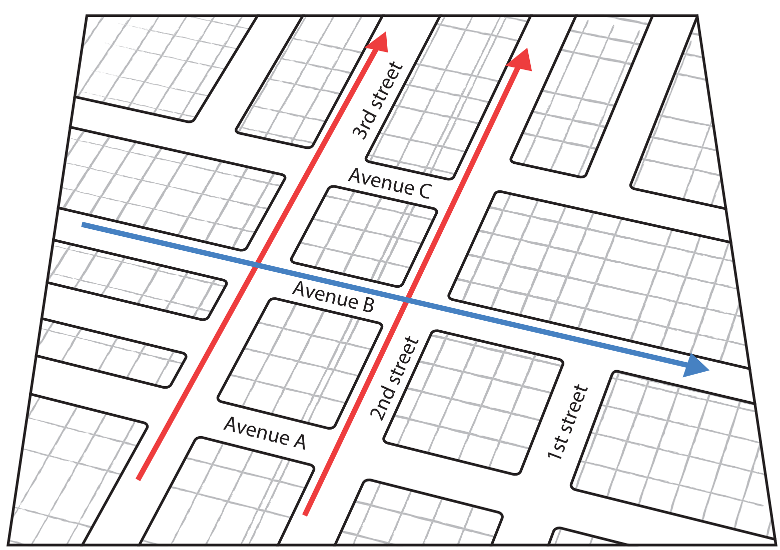
“Many Earth cities are built on a grid system of streets. The streets run parallel and perpendicular to one another,” she explains.

Kate picks up a red marker and draws two arrows on the map to identify some parallel streets in the city. Then she uses a blue marker to draw another arrow to identify a perpendicular street.

Perpendicular and Parallel

When a line, like a street, runs perpendicular to another line, it forms a right angle of 90 degrees with that other line. This means the lines intersect one another. Parallel lines—and streets—run in the same direction and never intersect.

As Zapatar and Squee lean closer to look at the map, Kate continues her explanation. “In our city, the streets that are numbered run parallel to one another from east to west. They intersect with streets that have letter names, which run from north to south.”



Zapatar jiggles a little as he tries to understand the city map. Then he asks, "And the streets, they do not get up and move when they are bored? They do not swirl and dance?"

Kate shakes her head, a bit confused. "No, they definitely do not," she replies.

"Squee!" exclaims Squee.

Kate realizes she needs to explain why the grid system is so helpful. "Grids make life in the city a lot easier. Finding new places is pretty simple as long as you have an address," she says. "Public transportation is easy to navigate. And as long as you can find a street sign, you always know where you are. It's tough to get lost in a gridded city!"

Zapatar bounces as he thinks of something else. “Another question,” he says. “Your city has many open green spaces. Why?”

Kate smiles again and explains, “Those are parks. They’re places people can go when they want to get outside and enjoy some fresh air.” She moves to the window to point to a nearby park. “That’s another nice thing about the grid system. Parks are easy to find in between the spaces with buildings.”

Zapatar looks worried at this discovery.

“Squee,” says Squee softly.

Kate understands that perhaps the creatures can’t actually enjoy fresh air.

Then Zapatar asks, “What would you recommend for a civilization where the outdoors is dangerous to one’s life?”

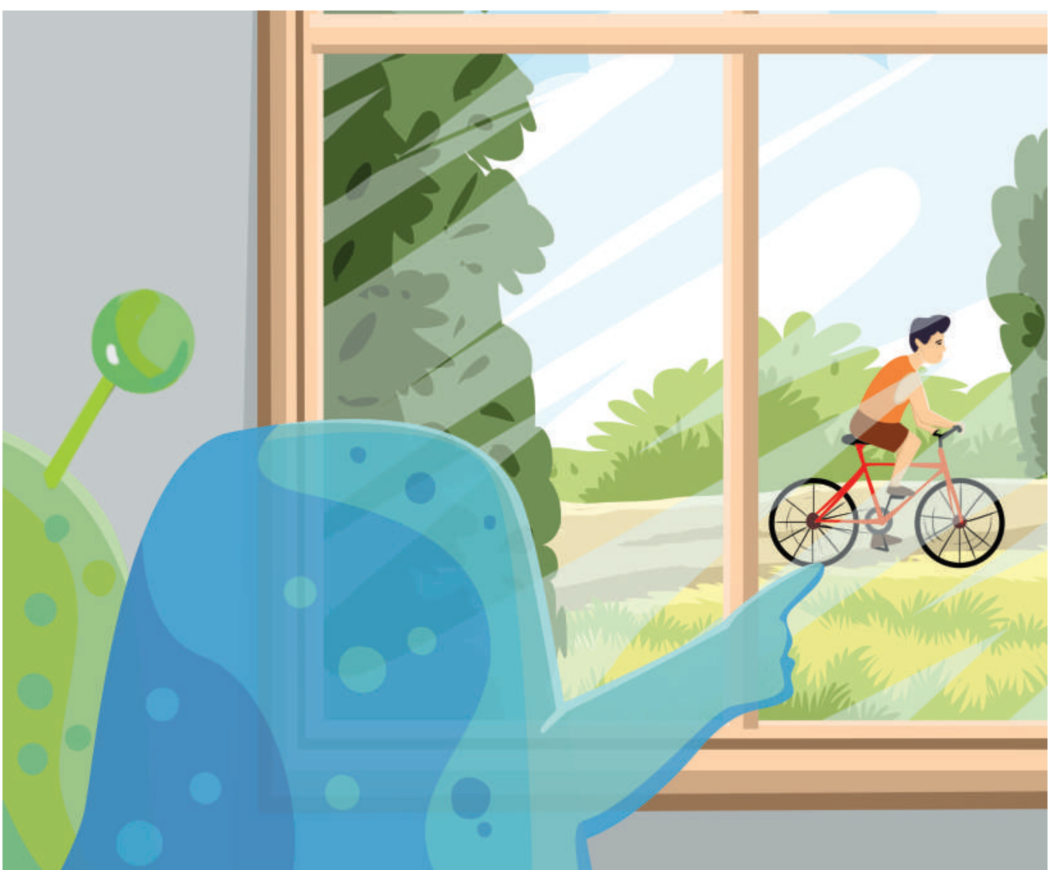
Kate thinks quickly. “Oh! Well, indoor parks would be a good choice in that case. We call those botanical gardens,” she says. “Museums are a good way to pass time. There are always movies and plays and libraries, of course.”

"We have one last question," Zapatar says to Kate. "We notice that some of your recreational walkways cross the grid at unusual angles. These walkways are narrower than your streets."

Kate nods. "You mean the bike paths. Yes, many of our bike paths actually cut across the grid to help our cyclists avoid cars and buses," she replies.

"Ah, for safety! Yes, I see," says Zapatar, bouncing again. "But where are your recreational travel tubes? Do they follow the grid structure, or do they have their own separate pathway?"

Kate wrinkles her forehead in confusion. "Recreational travel tubes? I'm sorry. I don't quite understand what you mean. What are those?"



Zapatar gurgles in what Kate thinks might be a chuckle. “My apologies!” he exclaims. “On our planet, recreational travel tubes are used when we change to our more liquid form, like this!”

Squee adds, “Squee!”

Kate rolls up the city map as she looks at the two globs of colorful goo. “You know,” she says, “this isn’t even the strangest conversation I’ve had today.”

Main Idea

Many cities are built on a grid design, making them easy to navigate.

Trust the Truss

Chapter 20

A bridge is a structure that carries a path, road, or railroad track across something else, like a river, another road, or a ravine. Bridges come in all shapes, heights, and lengths. Some are made of wood. Others are made of iron and steel.

Some bridges are simple. A log that has fallen across a stream can function as a bridge. Others are much more complex. They may have cables or other kinds of supports that crisscross in every direction.

Humans have been building bridges longer than they've been writing! Experts think that the first bridges were made of wooden logs and planks. Ancient peoples eventually built bridges with stones that were held up by wooden supports. There were some bridges made out of vines woven together that supported the weight of the bridge.

There are several different types of bridges. Beam, arch, and suspension bridges have been used since ancient times, and they're still used today. Their forms have inspired other types of bridges, including the truss bridge.

Beam bridge

Arch bridge

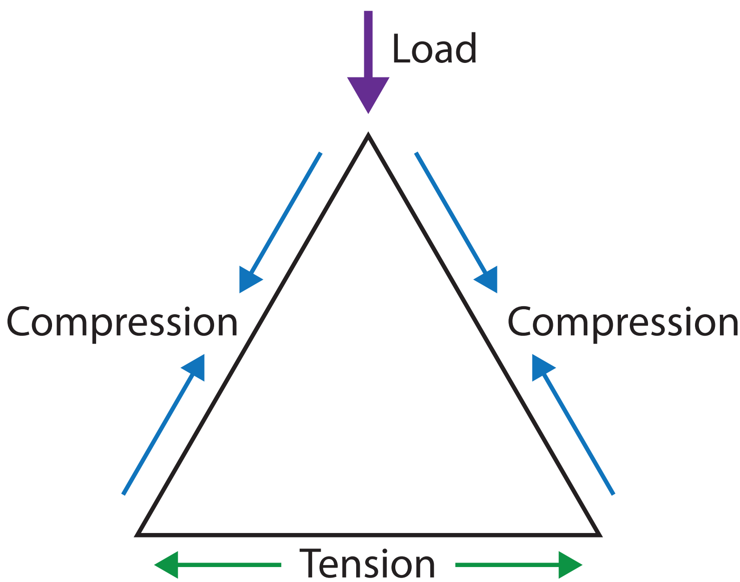
Suspension bridge

A truss bridge has supports that are shaped like triangles. The triangle is a very strong shape. It can’t be distorted, or pulled out of shape, by stress. Bridges experience a lot of stress from all the weight and motion of loads that cross them over and over. Because the triangular trusses keep their shape, they are able to keep bridges steady and rigid.

The first truss bridges appeared sometime between the 12th and 14th centuries in Europe. Early truss bridges were usually short and enclosed, or covered. That’s because they were made of wood, and wood doesn’t remain very strong when it is exposed to rain and snow. Enclosing the bridges helped them last longer.

For centuries, engineers designed and built truss bridges without really knowing why they worked so well. American engineer Squire Whipple finally described the principle in the late 1860s. He figured out how triangles act under weight or pressure, or what engineers and scientists call load.

Look at the diagram. When a load is placed on one corner of a triangle, the two sides that touch that corner are squeezed. Another word for that is compression.



The third side of the triangle—the one opposite from the corner bearing the load—is stretched sideways so the other two sides can squeeze together. That's called tension. The triangle balances itself to take on the stress of the load. Other shapes don't do that.

Whipple's discovery helped engineers figure out new and better ways to build truss bridges. At the time, wood and stone were already being replaced with iron and steel. The new designs required fewer materials than before.

This combination of newer and fewer materials was important. The railroad was quickly becoming the fastest form of cross-country transportation in the United States. Train cars are heavy and move at high speeds. The building of many steel truss railroad bridges allowed trains to transport goods and people over bodies of water and dangerous terrain.

Pratt truss

Two popular truss bridge designs of the 1800s are the Pratt truss and the Warren truss. Both are still used today. The Pratt truss uses diagonal beams that meet and form upside-down isosceles triangles. The Warren truss also has diagonal beams, but they form equilateral triangles.

Triangle Types

An isosceles triangle has two sides that are the same length. An equilateral triangle has sides that are all the same length.

Warren truss

Truss bridges are still used around the world today. The longest continuous-truss is the Ikitsuki Bridge in Japan. It was built from 1983 to 1991 and connects two islands in southern Japan. It is 1,300 feet (400 meters) long and doesn't have any hinges or joints supporting it.

In the United States, the Astoria Bridge that goes between Oregon and Washington is 21,474 feet (6,545 meters) long. One of its sections is 1,232 feet (376 meters) long without any hinges or joints, which makes it the second longest continuous-truss bridge in the world. Altogether, the Astoria spans 4.1 miles across the Columbia River. More than 6 million vehicles cross it each year!

Ikitsuki Bridge

Astoria Bridge

Main Idea

Triangles have properties that make them ideal for building strong, rigid structures such as truss bridges.

The Art of Shaping Clay

Chapter 21

If You Attend

What: Greta Burke's ceramics show, "Here Be Dragons"

Where: Harmon Studios, 1216 Richards Avenue, St. Paul

When: Friday, March 24, 7:00 p.m.

Attendees are invited to roll up their sleeves and get dirty in the interactive part of Burke's exhibit. She will guide visitors through the process of making a pinch or coil pot out of air-dry clay. Burke advises gallery-goers to dress appropriately. Children 5 and older are welcome to participate.

Greta Burke hopes everyone who attends her new ceramics show leaves an absolute mess.

The local artist's show, which opens this Friday at 7:00 p.m. at Harmon Studios in downtown St. Paul, Minnesota, has been on the calendar for months. But Burke, 63, has been unofficially planning her debut gallery opening for years. And in every version of her ideal show, people don't just want to buy her work. They want to make their own. And that will only happen if they get to experience working with clay for themselves.

“Clay is a very hands-on form of expression,” Burke says. “There’s something about it that connects you to your surroundings. It brings you back to nature and back to the earth. I think you lose some of that when you only see the final product.”

Burke’s “final products” range from the practical to the fantastical. After 35 years as an elementary school art teacher, she began her retirement making things that would be useful in any home: mugs, platters, and vases, all in shades of white.

“I think my brain needed a break after the constant noise and mess of teaching,” she says.

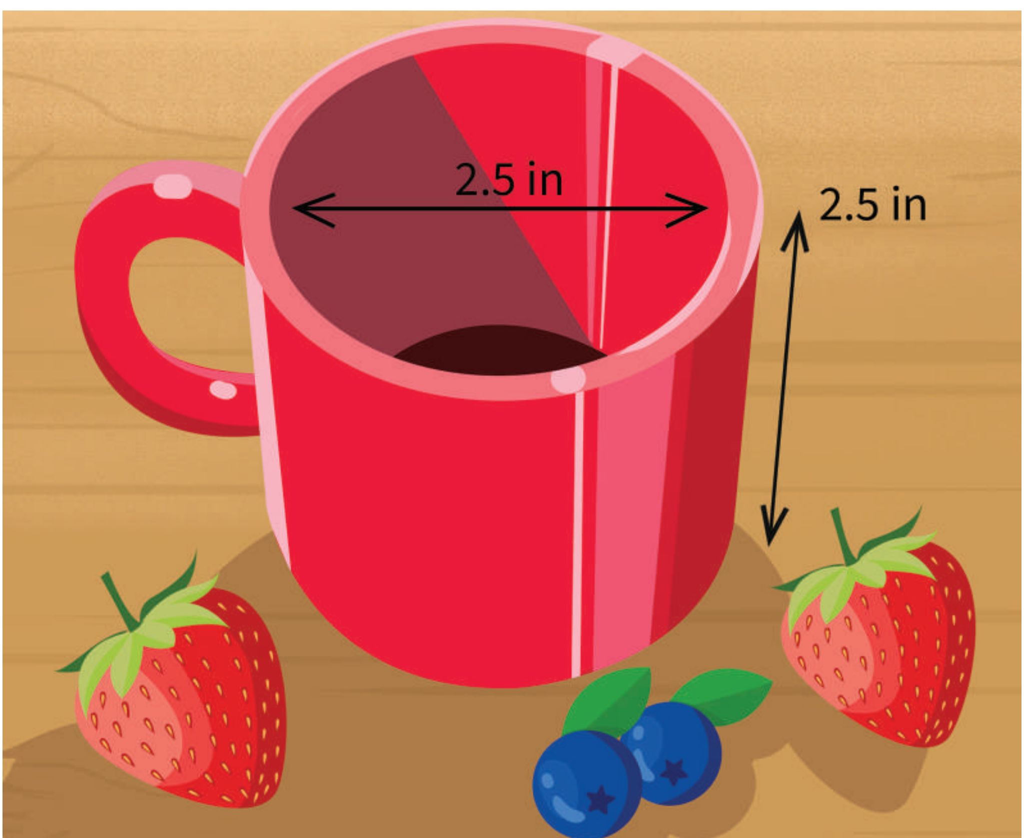
Burke’s process requires some mathematical planning, especially when she is making several uniform objects. Her after-dinner mugs are formed on a potter’s wheel out of 14 ounces of clay. Her clay comes in 10-pound bags, which means she can get 11 mugs out of 1 batch of clay. Never one to waste perfectly good art materials, she once tried using the potter’s wheel to throw, or make, a smaller mug out of the bag’s remaining 6 ounces.

Her first attempts at using the wheel didn't work, so Burke turned to a technique she taught in the elementary classroom: handbuilding. She rolled her 6 ounces of clay into a slab of uniform thickness of about 0.2 inches. She then cut a circular base; a long, thin rectangle; and a long, 3-inch-wide rectangle. The wide rectangle became the body of the mug. The thin rectangle became the handle.

The little mug, which Burke painted cherry red, finished at about 2.5 inches by 2.5 inches. She says that's "just the right size for a tea party with your cat."

A Diameter Reminder

The small red mug's dimensions, or measurements, are its height and its diameter. Remember that the diameter of a circle is the distance from one side to the other as it passes through the center. With a mug, this would be the distance from one side of its circular top to the other.



Burke continued making and selling her traditional tableware, but she found herself setting aside an additional 6 ounces of clay for experimentation with every new batch. Within just a few weeks, she was no longer making items for everyday use.

“I rediscovered the joy of play,” she says.

Burke hasn’t stopped playing since. From tea sets fit for a royal mouse to fragile “dragon’s eggs,” Burke’s work is now limited only by her imagination and the size of the kiln she uses to fire her pieces.

“The biggest thing I’ve ever done was a giant hot dog. It was about 3 feet long. I had to have help loading it into the kiln!” she says. The hot dog and its bun reportedly required 5 10-pound bags of clay.

Main Idea

Artists measure quantities of materials and dimensions of objects to plan their work.

What a Hoot!

Chapter 22

There are about 250 different species of owls in the world, but only 19 of them are found in the United States. Although they present a wide variety of traits, all owls have a few characteristics in common.

The first is the shape of their face. Owls generally have flat faces with hooked beaks and large, forward-facing eyes. Owls are nocturnal animals. That means they're awake at night. Their big eyes enable them to see in the dark.

Owls have remarkable flexibility that helps them see what's around them. They can turn their necks 270 degrees from a front-facing position. That means they turn their head over one shoulder, then beyond their back, to over the other shoulder! A human facing front can only turn their neck about 90 degrees.

When we think of owls, we think of a sound—*hoot*. That's the call of the great horned owl, which is also known as the hoot owl. This owl doesn't really have horns, though. It *does* have tufts of feathers along the side of its head that are called plumicorns. Scientists think those feathers may help this large owl camouflage itself in its dark forest habitat.

Great horned owls live all across North America. They are fierce predators that will hunt insects, reptiles, mammals, birds, and even other owls. They're not picky eaters, so some great horned owls are able to successfully make their homes in cities.

Once a great horned owl chooses a home, it stays there all year long. Great horned owls don't migrate. When they're ready to nest, they reuse nesting spots built by other large birds, such as hawks.

How Is Wingspan Measured?

A bird's wingspan is the measurement of the distance between the tip of one wing and the tip of the other. As you will see from the data in this chapter, this measurement can vary from several inches to several feet!

Great Horned Owl	
Height	16–24 inches
Wingspan	4–5 feet (48–60 inches)
Weight	3–4 pounds (48–64 ounces)
Location	North America, Central America, parts of South America

Barn owls are easy to tell apart from other owls. Barn owls have heart-shaped faces that are usually white. So are the undersides of their gold and gray wings.

Barn owls are found on every continent except Antarctica. They live in a wide range of habitats, including marshes, grasslands, and open areas where they can hunt small mammals.

Barn owls have been known to raise their families in barns, silos, and abandoned buildings. In years when hunting is good, a female barn owl can lay as many as 12 eggs up to twice a year.

Barn Owl	
Height	13–16 inches
Wingspan	39–42 inches
Weight	0.88–1.54 pounds (14.1–24.7 ounces)
Location	Every continent except Antarctica

Most owls nest in high places, but the burrowing owl prefers to be lower to the ground—a lot lower! This little owl is about the size of a robin. It lives in holes dug in soft or sandy soil. Sometimes it will dig its own burrow, but it's just as happy living in a hole made by a prairie dog or tortoise.

Burrowing owls have adapted to life on and in the ground. They can safely nest underground because they are able to survive with less fresh air than other owls. And even though they can fly, burrowing owls will often run after their prey. They store what they catch in their burrows so they have enough to eat during nesting season. Burrowing owls eat lizards, snakes, mice, songbirds, and even frogs.

Burrowing Owl	
Height	8–10 inches
Wingspan	22 inches
Weight	0.31 pounds (5 ounces)
Location	western North America, southern South America

The heaviest species of owl in North America is the snowy owl. It can weigh anywhere between 3 and 5 pounds. It likes to eat small mammals like voles and lemmings. On a good hunting day, a snowy owl can eat 5 lemmings.

Snowy owls live in the evergreen forests of the Arctic tundra in Canada and parts of Alaska. These forests get a lot of precipitation and endure long winters. But the snowy owl doesn't mind. Its white feathers, which are dotted with dark brown or black on females, help it blend into the snowscape. These feathers are thicker than those on other owls, and they keep the snowy owl warm on cold winter nights. They're also the feature that makes the snowy owl so heavy.

Snowy Owl	
Height	up to 27 inches
Wingspan	49–51 inches
Weight	3–5 pounds (48–80 ounces)
Location	Arctic tundra

Don't be fooled by the northern pygmy-owl's size. Although it is a little smaller than a robin, it is a ferocious hunter that has been known to prey on full-grown chickens!

This fluffy little owl keeps a different schedule than most other owls. It prefers to hunt during the day, when songbirds are visiting bird feeders. Size doesn't seem to matter to the northern pygmy-owl. Although it weighs only 2 to 3 ounces and is a maximum of 7 inches tall, the pygmy-owl will easily take on a northern flicker woodpecker that weighs up to 6 ounces and is 12 inches tall.

Word gets around quickly when there's a northern pygmy-owl in the neighborhood. Groups of songbirds defend themselves and their territory by "mobbing" the owl and forcing it to fly away.

Northern Pygmy Owl	
Height	6–7 inches
Wingspan	12 inches
Weight	0.13 pounds (2–3 ounces)
Location	western North America

Main Idea

Measurements are used to classify wildlife.

Survey the World

Chapter 23

Have you ever seen someone standing along the side of the road with what looks like a large camera on a tall tripod? They were probably wearing a bright-orange or neon-yellow safety vest or jacket. And they may have been with someone else who was standing farther down the road with a similar tripod.

That person was a land surveyor. Land surveying is the science of identifying points on Earth's surface and measuring the distances, angles, and elevations—or height differences—between those points. Architects, engineers, and construction workers rely on land surveyors to make sure they're building in exactly the right place and the design is right for the space.

Land surveyors are hired for many different types of projects. They evaluate land where new buildings might soon be constructed. They locate the boundaries of existing properties. They also help settle disagreements about where property lines fall. The results of a land surveyor's work are published in a report with a drawing or a map of the land.

Surveyors use several different tools to gather all the information they need to create their reports, maps, and drawings. Some tools, like measuring tapes and safety gear, are simple to use. Others, like theodolites, are more complicated. What is a theodolite? Read on!

Remember the camera-like object that sits on the tripod? That's a theodolite. It measures horizontal and vertical angles. Angle measurements are important to surveyors, who use a lot of geometry and trigonometry in their work.

Trigonometry is the math of triangles. Triangles are formed by three points that are connected by three lines. If you know the distance between two of those points and you know all three angles of the triangle, then you can figure out the length of the other two lines. Surveyors use this basic idea from trigonometry to figure out the distances between objects.

Measuring Angles

Think of how you measure the angles of a triangle with a protractor and the sides of a triangle with a ruler. Have you noticed something consistent about the length of the side of a triangle when the angle it's opposite from gets bigger or smaller? Observations like these are some of the first steps in learning trigonometry—something you will study in future math classes.

This same idea was used long ago in mapmaking. Early mapmakers didn't have GPS or satellites to calculate the distance between cities. However, using angles and distances helped them make accurate maps.

The invention of the magnetic compass also helped early mapmakers make accurate star charts and sailing maps. In the 12th century, sailors in both China and Europe made an important discovery. They figured out that a type of magnetic rock called lodestone always points in the direction of the North Star when the rock is floated on a stick in water. Soon after, it was discovered that an iron or steel needle that had touched lodestone became magnetic. It would also align itself in a north-south direction.

Magnetic compasses work because Earth's core acts like a really big bar magnet. Freely moving magnets, like the magnetized steel needle in today's compasses, will move so they're aligned in the same direction as Earth's magnetic field.

Land surveyors use compasses, too, though they often use computers for much of their work. However, a compass is still helpful for determining the angle of survey lines in relation to north and south and east and west.

Sometimes land surveyors need to measure the angle of an elevation. Elevation is how high or low the ground is. The tool used for that is called a clinometer. Once you know the angle of the land, you can also figure out its height. Land surveyors need to know this kind of information so they can include it in their reports and maps.

Land surveyors don't just take measurements and calculate distances. They also note the natural and human-made features of the area they are surveying. For example, if they are working in a wildlife habitat, they will identify which animals live there and whether any are endangered. They can then give advice about how to move forward with a project while doing as little damage to the habitat as possible.

In areas with human-made features, surveyors note the existence of utilities. This can include power, sewer, and water lines. Knowing which utilities already exist in a place can help people plan for future utilities. It can also prevent the loss of current services that could be caused by damage during construction.

Main Idea

Land surveyors use measurement of distances and angles to document features of land.

Mirror, Mirror

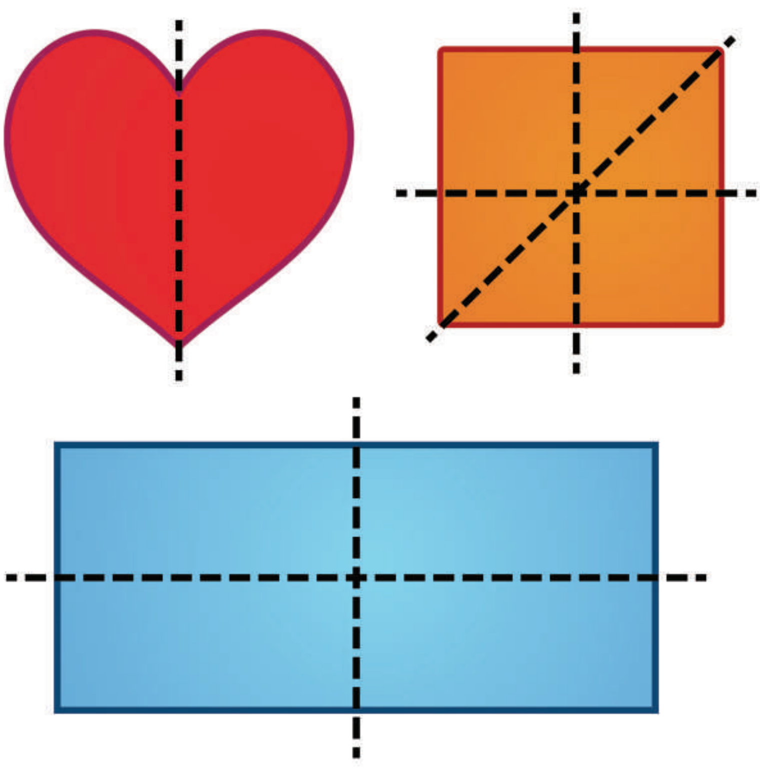
Chapter 24

Symmetry is the characteristic of an object that has two or more matching halves. For example, a heart has vertical symmetry because one side of the heart is the mirror image of the other side. Rectangles have vertical and horizontal symmetry. This means they can be folded in half from top to bottom or side to side and still result in mirror images. Squares have vertical, horizontal, *and* diagonal symmetry.

Symmetry is common in nature. Many flowers, leaves, and animal bodies are symmetrical.

Lines of Symmetry

When you imagine folding a shape in half, the "folding line" you picture is called a line of symmetry. Lines of symmetry mark the places where the symmetrical units come together.



Did you know that you can be almost as good as nature at making things symmetrical? Just follow this quick drawing tutorial, and you'll be matching halves in no time.

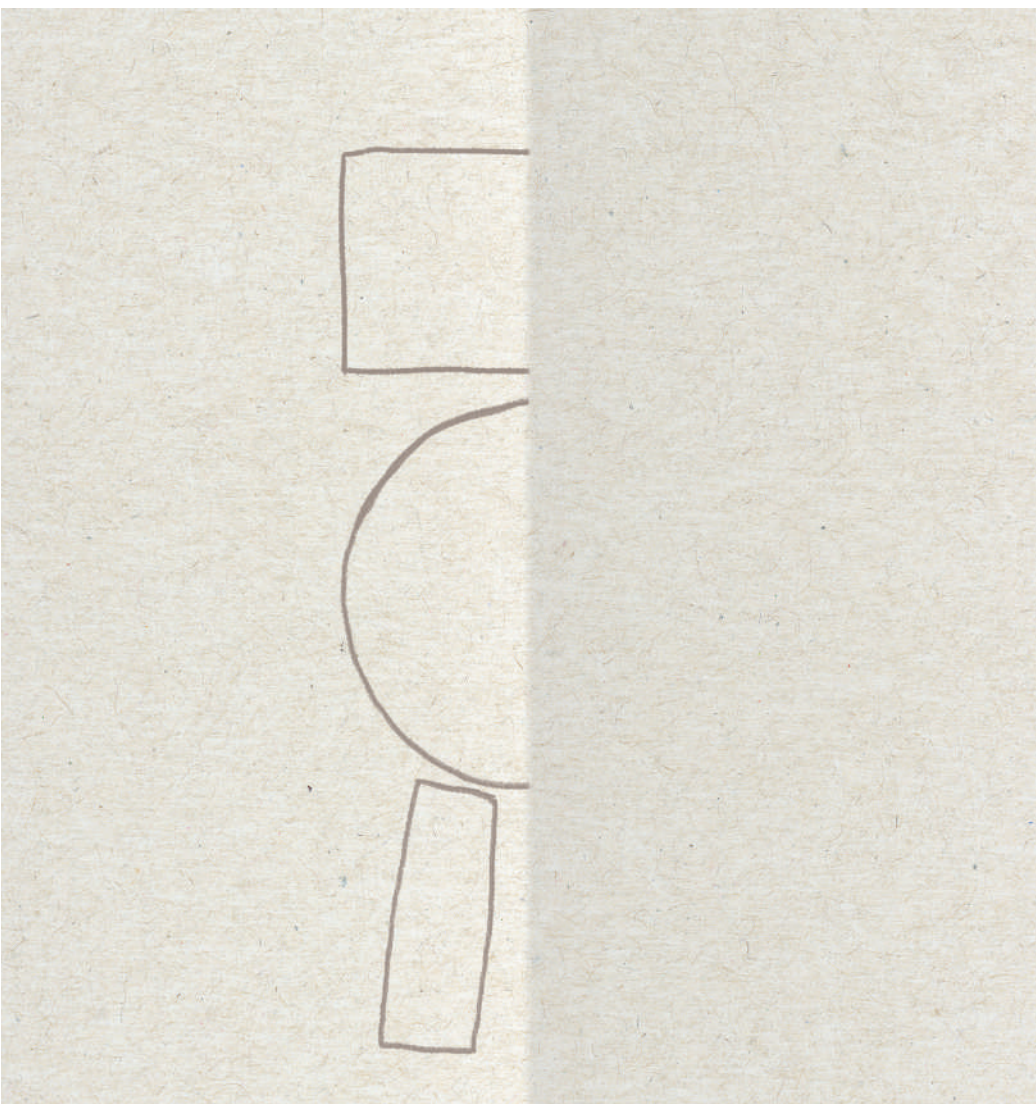
Step 1: Gather your materials. You'll need a sheet of paper, a pencil, and a dark-colored crayon.

Step 2: Place your paper horizontally in front of you. Then fold it in half. Use your fingers to crease the fold. Open the paper.

You're ready to draw your picture! You'll be drawing on only one side of the fold. Leave the other side blank.

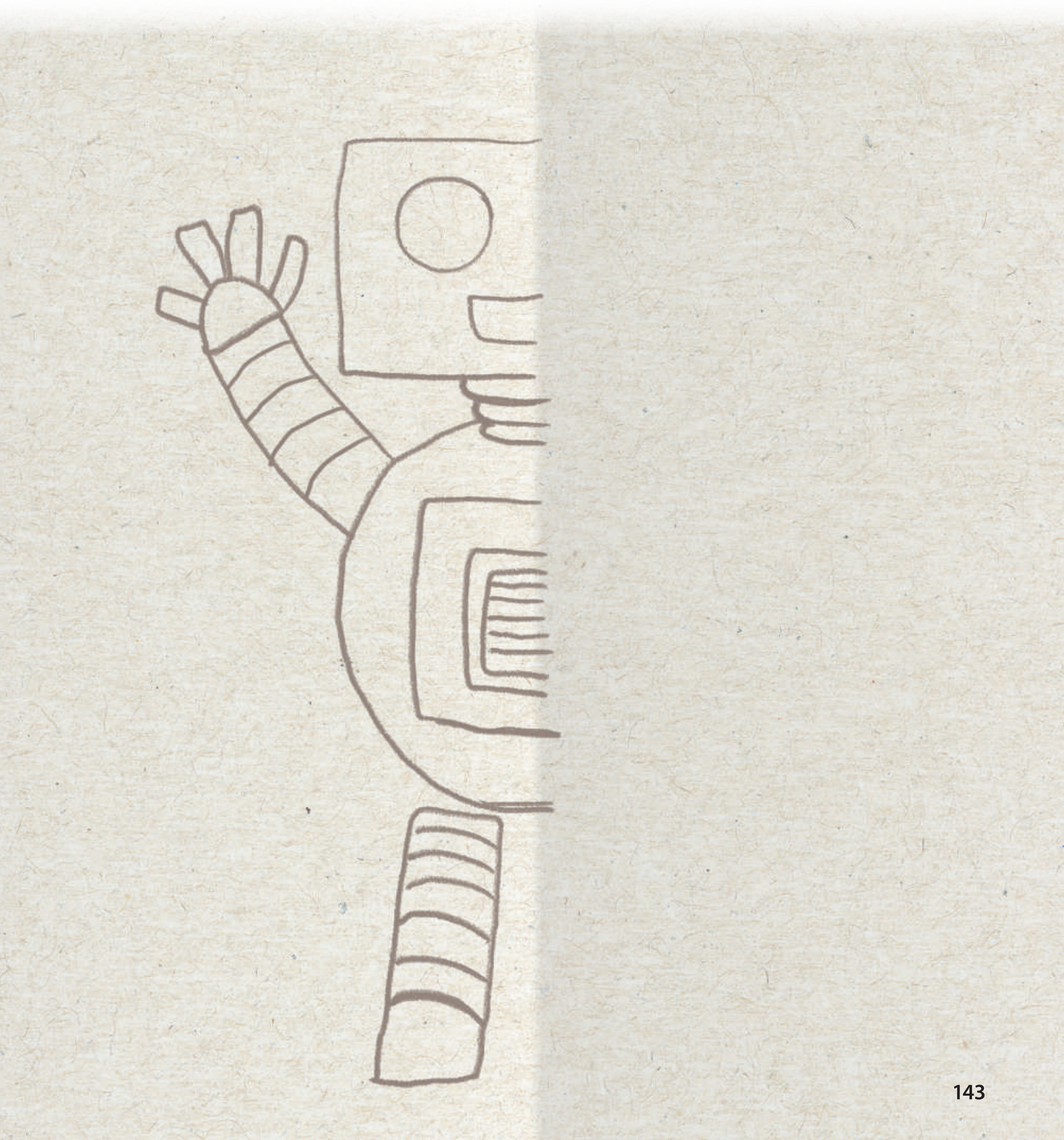
We're drawing a robot for this example, but the steps described next will work for any symmetrical picture.

Step 3: Using the pencil, draw halves of the robot's parts. We used a rectangle for the head, a half circle for the body, and a long rectangle for the legs. Remember that you are only drawing one side of the body.



Step 4: Add details to your robot. In our drawing here, we added the lines on the robot's neck, the lines on its leg, and its arm and hand. We also added a face and a panel on its body.

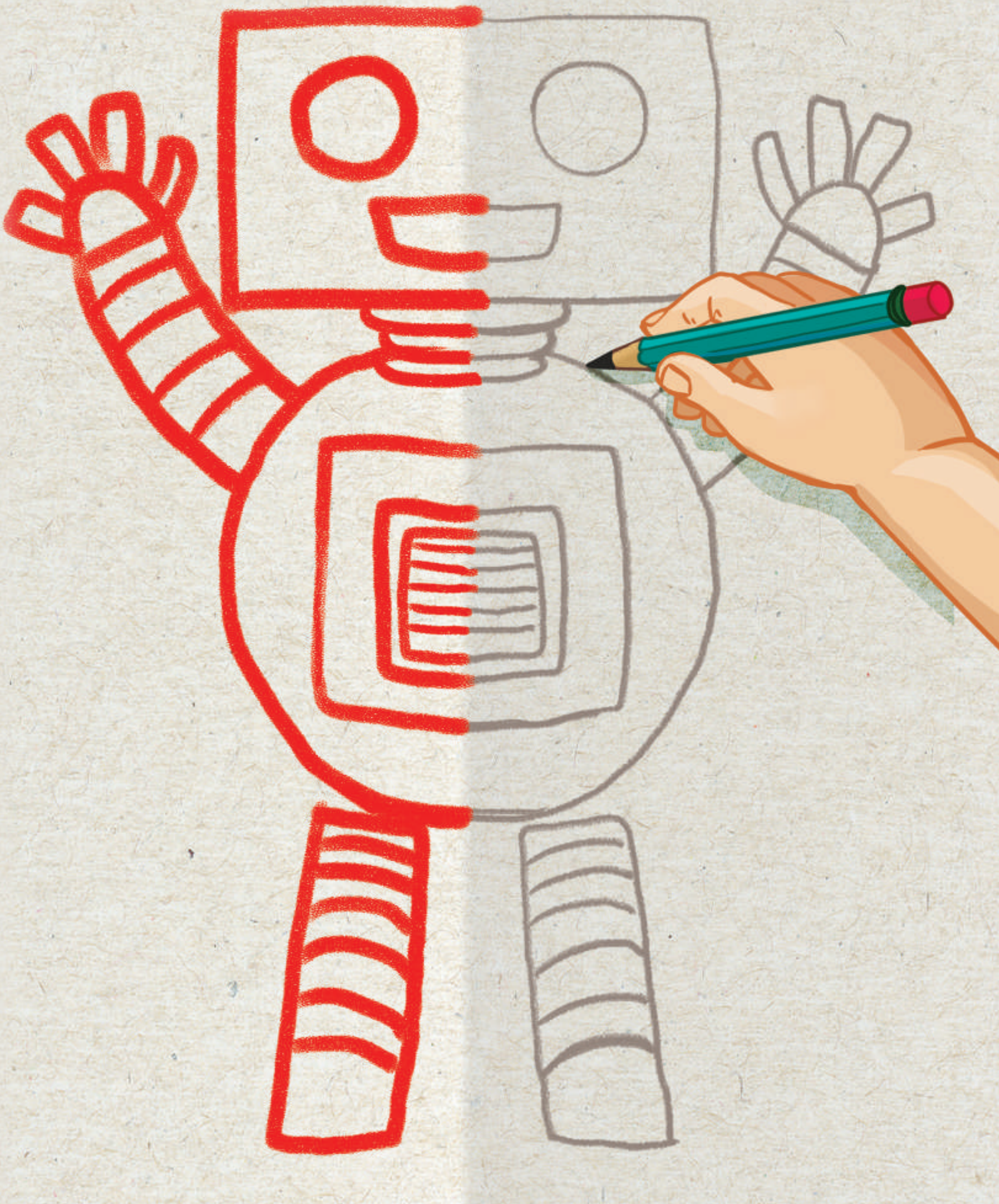
Tip: Don't get too detailed. You'll be tracing your design with crayon, which makes thick lines.



Step 5: Trace your drawing in dark-colored crayon. Use a fair amount of pressure as you trace.

Step 6: Close your paper along the fold so you can see your design through the back of the paper. Rub along the entire back of the paper with a pencil or your hand or fist. Press hard. You want to transfer your design to the other side of the paper.

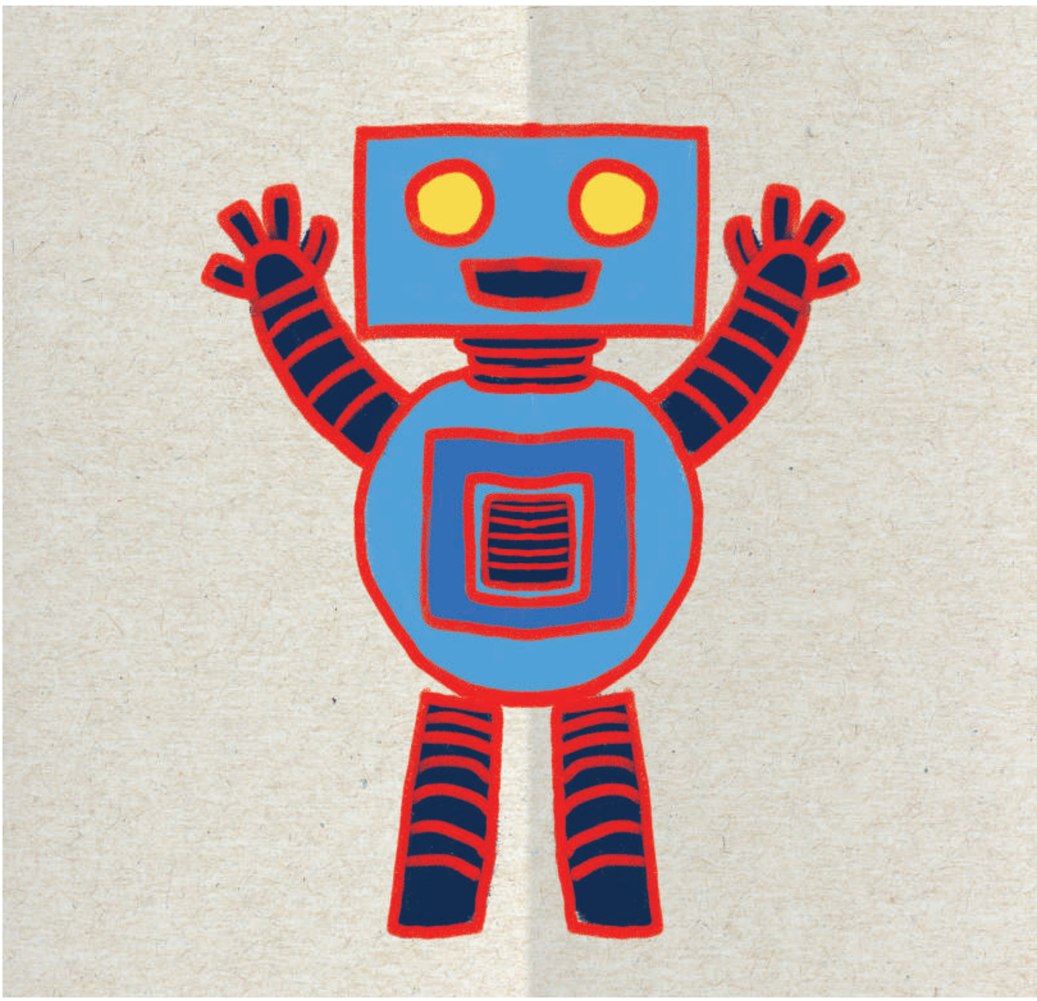
Step 7: Unfold the paper, and trace the design.



Step 8: You should now have a symmetrical outline of your design on the other side of the fold. If you don't, repeat Steps 5–7.

Step 9: Trace the new outline with crayon.

Step 10: Color and decorate your drawing any way you like.



Main Idea

Symmetrical objects have halves that match perfectly.

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