

TURING TUMBLE™

Educator Guide

Version 2.8 - Covers challenges 1 to 30



Welcome Educators!

We are excited that you're using Turing Tumble in your classroom! This kit is easy to use. There are no batteries to charge, no apps to install or update, and no cords needed...just show the students how to follow the puzzle book, and your class will be ready to go. You can use it as part of math stations, unit studies, learning engineering concepts, independent study, introducing computer science principles, free choice time, or in a library learning center.



This educator guide is a companion to Turing Tumble. Everything is black and white to make it easy for you to print or copy. This version of the guide covers the first 30 challenges in the book.

What's in this guide?

Inside are two types of resources:

1. Lesson curricula: As students progress through the puzzles, there are certain times where you can take a break for a lesson. The lessons anchor the concepts learned through Turing Tumble to real life applications. You'll find materials for each of these lessons spread out among the puzzles.
2. Help with individual puzzles: We show the puzzle, the solution, an explanation of the solution, common pitfalls, and the underlying concept that the puzzle is intended to teach.

As you walk around a classroom, you can glance at this guide to quickly learn how to coach a student trying to solve a puzzle and help them understand the underlying concepts.

What is Turing Tumble?

Turing Tumble is a game where players build mechanical computers powered by marbles to solve logic puzzles. While they play, they learn key computer science concepts and build skills essential to coding. It also helps students learn how computers work at a basic level: how simple switches, connected together in clever ways, can do incredibly smart things. It can be used as a standalone tool to teach how computers work, as a precursor or supplement to coding lessons, or as a helpful manipulative to reinforce programming and mathematical concepts.

What does Turing Tumble teach?

Turing Tumble teaches a number of concepts and skills that are fundamental to computers, programming, and digital electronics. It builds skills in computational thinking, logic, algorithm design, critical thinking, debugging/troubleshooting, fine motor, spatial reasoning, and persistence. It also teaches concepts including logic gates, truth tables, conditionals, binary, binary operations, and digital circuit design.

Is this guide useful to you?

Please tell us what you think! We're always looking for ways to make our games better and improve our educator resources. If you find something that works well, that you think others could use, please reach out to us! Send us an email at hello@upperstory.com, or head to our Turing Tumble Community page (community.turingtumble.com) to share your ideas and ask questions.



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Recommended Age

We recommend Turing Tumble for ages 8 and up. The puzzle book is laid out so that a student can independently get started and progress at his/her own pace. We find that kids 8-12 are able to get through the first 20-30 puzzles. University students and adults get addicted by puzzle 27, and they are amazed by what a mechanical computer can do by puzzle 35. Younger kids enjoy the first ten and building their own computers.

Single Player or Partners

We recommend only one to two students per board. With this game, true understanding happens when students are physically working through the puzzle. You will see your students add pieces and then drag their finger down the board to test their prediction of where the marbles will fall. When you see this happening, you will know they are getting it, but this kind of hands-on learning can't happen very well in a group of three or more.

Puzzle Timing

In an hour-long class introducing the game, setting up, playing, and cleaning up, most students will have time to solve 4-5 puzzles.

Puzzles 1-10:	5-15 minutes each to solve
Puzzles 11-20:	10-15 minutes each to solve
Puzzles 21-30:	10-20 minutes each to solve
The remaining puzzles vary greatly from person to person	

Independent Learning and Intentional Scaffolding

Students must keep track of their own progress - it is *crucial* that they understand each puzzle and don't try to skip ahead, even if the first puzzles are too easy for them. Each puzzle introduces a new concept, rule, or trick and they'll find themselves quickly lost if they don't complete each of the puzzles in turn. We often see students try the first three puzzles, flip to the last puzzle, and think they've solved it immediately because they don't yet know all the rules.

Classroom Videos

Getting Started with Turing Tumble video:

<https://bit.ly/getting-started-with-turing-tumble>

Students describe how to get started with Turing Tumble, some helpful hints for setting up the game, how to play, and troubleshooting.



How Turing Tumble is a Computer:

<https://bit.ly/like-a-computer>

This video explains how Turing Tumble is a mechanical computer and the differences between mechanical computers and their electronic counterparts that most people are familiar with. It shows the inside of an electronic computer and zooms in on the microscopic switches inside the processor that can only be seen with an electron tunneling microscope. Turing Tumble has mechanical switches that players can connect together in clever ways to do smart things. If Turing Tumble were big enough, it could do anything your desktop computer, laptop or cell phone can do.



Looking inside a computer processor:

<https://bit.ly/computer-processor>

This video zooms into a computer processor all the way until you can see the individual switches (called “transistors”) inside and the tiny copper wires connecting them together. As it zooms further and further in, you’ll notice the images change from color to black and white. That’s when the creators of the video had to switch from taking pictures with light to taking pictures with electrons, because they’re so much smaller.



Promotional Educator Video:

<https://bit.ly/turing-tumble-edu-video>

This video can be used to promote Turing Tumble within your school, district, and community.



Practice Guide

Don't forget about the Turing Tumble Practice Guide! You can download it for free at upperstory.com/turingtumble/edu/resources. Besides offering all the puzzles in an easy-to-print/copy black and white form, it also contains 30 extra “practice puzzles” placed in between the regular ones. The practice puzzles lower the learning curve by easing players into new concepts more gradually.

Turing Tumble on a Screen

Online Turing Tumble simulators are great for demonstrating how to use Turing Tumble to a class. You can project a simulator on a screen, build machines on it quickly, and run it right there on screen for your class to watch. Currently we recommend using the following simulators.

Simulator 1 by Rich Twilton:

<https://bit.ly/tumble-together-simulator>

This simulator looks very similar to the actual game and has the first 30 challenges loaded in the menu for immediate play. It also allows students to share their work remotely as they solve challenges via shared rooms.



Simulator 2 by Jesse Crossen:

<https://bit.ly/tt-sim>

This simulator looks very similar in appearance to the actual game. It animates marbles falling through it with physics that look just like the real Turing Tumble. You can even make the board larger if you want to make more complicated machines.

Simulator 3 by Lode Vandevenne:

<https://bit.ly/js-tumble>

This simulator is easy to learn. You'll be creating little machines in minutes.

Tips and Tricks

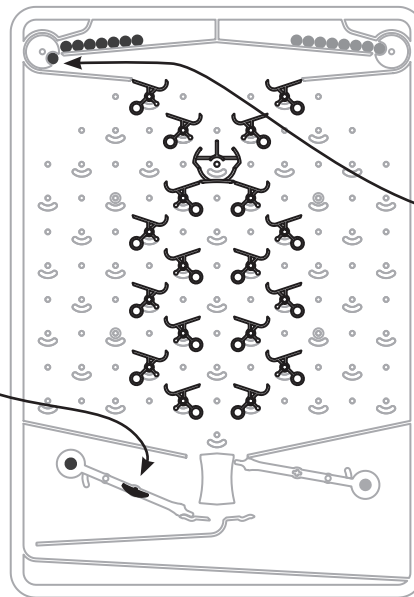
- The legs on the stand can be assembled two ways, but only one way holds the board. If the stand doesn't hold the board, pull the stand apart, flip one part around and try it in the new configuration.
- Put the stand and the board **INSIDE** the box top to keep all the parts and marbles corralled.
- Wait to load the marbles until **AFTER** game pieces have been added to the board. The process of solving the challenge can cause the board to jostle or the bottom lever to be triggered which can result in the marbles getting released too soon and bouncing all over.
- Do not load all of the marbles! Load only what the challenge calls for (typically about 8 on each side).
- Trace the path of the marble with a finger to find out where the pieces should go. If the finger path runs into one of the white pegs on the board, add another piece.
- Marbles should never free-fall. If they do, place the parts on the board to guide them all the way down.
- Use the “emergency stop” by holding up the levers at the bottom of the board to catch the marbles from triggering more.
- The black tray that holds the legs may be placed under the box to preserve space.
- Clean-up Tips:
 - Make sure each piece is returned to its spot.
 - Insert the book on top of the game pieces with the binding in the wedge.
 - Place the legs in the tray and set this on top of the pieces and book.
 - Place the white board on the very top.

How it Works



The game board releases one marble at a time from the top:

Press here to start the machine...

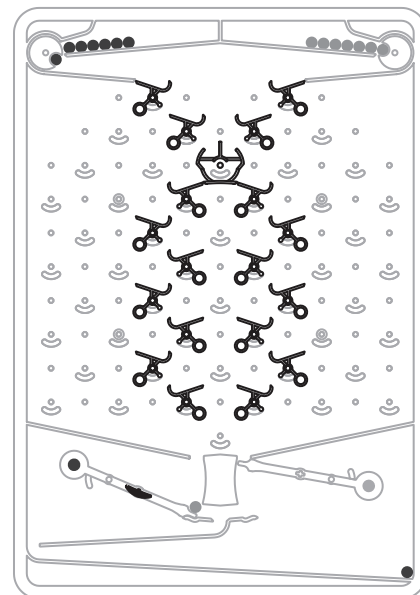
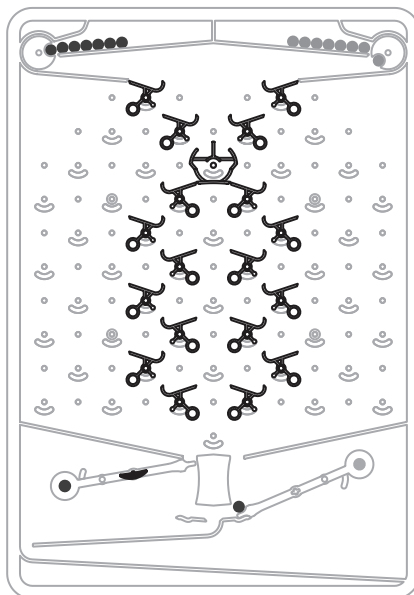


...and a marble is released from the top.

Each marble falls down the board and when it reaches the bottom, it pushes down one of two black flippers at the bottom that release another marble.

If it pushes down the **right** flipper, a **red** marble is released.

If it pushes down the **left** flipper, a **blue** marble is released.

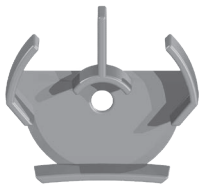


Players add logic by putting **six different types of parts** onto the board:



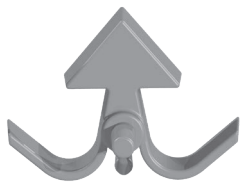
RAMP

The **ramp** directs marbles to the right or to the left, depending on how you place it on the board. They are reversible pieces, but once you've put them on the board, the counterweights turn them to their original position after a marble goes through them. The ramps are like electrical wires in a computer and the marbles are like electricity.



CROSSOVER

The **crossover** acts like two wires crossing over each other without touching each other, sort of like how overpasses allow cars to drive over other roads.



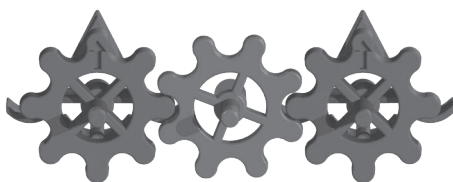
BIT

The **bit** adds logic. It stores information by pointing to the right or to the left. These two states (left or right) can represent the statements False or True, or 0 or 1 like is often used in computer science. A marble passing through a bit changes its direction and therefore changes the information it stores. The bit becomes more and more important as the puzzles progress.



INTERCEPTOR

When the computer's objective is complete, the **interceptor** can be used to stop the computer from releasing any more marbles.



GEARS AND GEAR BITS

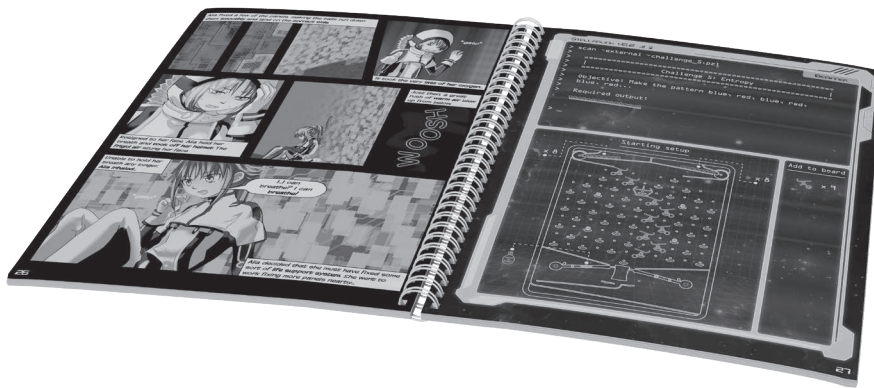
Like the bit, the **gear bit** stores information by pointing right or left, but when a gear bit is flipped, it can also flip other gear bits connected to it by **gears**.

The gears and gear bits are mind-bending, but they add a whole new level of functionality to the board. They also make the computer "Turing-complete," which means that if the board was big enough, it could do anything an electronic computer could do!

Every kit comes with a small bag of black washers. These should be added behind the gear bits when only two gear bits are connected together to increase friction. However, if *more* than two gear bits are connected, the washers shouldn't be used.

Turing Tumble comes with a book of 60 puzzles. They start out easy and become steadily more challenging. As you move through the puzzle book, new types of parts are unlocked. For example, you start by just using the ramp pieces, but after four puzzles, the crossover is unlocked. Each puzzle leads the player to discover new concepts that can be applied to more complicated puzzles later on.

There is also a story woven into the puzzles to give them context and to hopefully make them more interesting for some students. Each puzzle brings Alia the space engineer closer to rescue from a seemingly deserted planet.





Each challenge is listed with the page number for quick reference. The puzzle page is shown at the top with the solution next to it. Some players' questions can be answered with a quick glance at the solution.

Computer logic lessons

In this guide, “Computer Logic Lessons” are positioned before students begin using a new part or before they learn a new concept. It is organized this way so that educators can anticipate what will be learned. However, you may find it easier to teach the lesson after the students have had some practice with the parts.

Puzzle-specific educator resources

Each challenge has its own teaching and learning concepts listed below the visuals of the challenge and solution. An educator can flip to any challenge and find guidance for helping students with the specific skills and hang-ups that might be encountered.

You'll quickly notice that there is repetition in the educator resources for each puzzle. For example, challenges five, six, and seven all teach students how to use the crossover. Therefore, in the educator resources for each challenge, you'll see many of the same points discussed. This allows you, as a teacher, to consult only the educator resources for the relevant puzzle, without having to look back at the educator resources for previous puzzles to understand it.

- **What players learn about computer logic**

In this section, you'll find quick bullets about the connection between the puzzle and what's going on inside a computer. The Computer Logic Lessons give a more thorough description of the connection.

- **What players learn about the game**

This section shows what players learn about the game through this puzzle. It could be a functional aspect of the game (like how the board or parts work), something to notice about the puzzle book or the challenges themselves, or a

trick the player is learning that will need to be reused later on.

- **Possible hang-ups**

In this section, hints and tricks are included to help students complete the challenges. These are not exhaustive, but highlight the logic steps we've seen players struggle with.

As you use this Educator Guide, we would appreciate your input so that we can improve this guide and add content for future use.

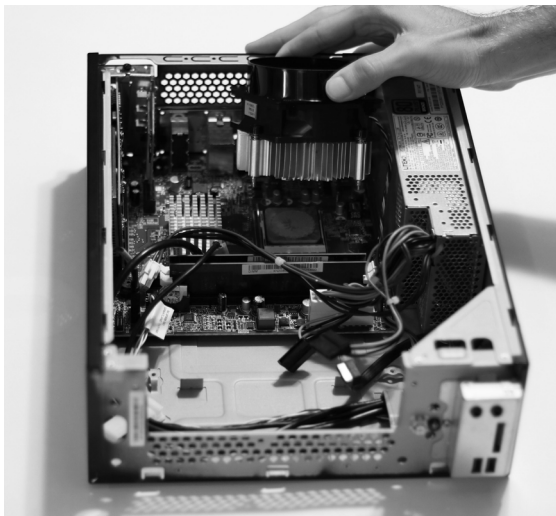
Computer Logic Lesson #1: How is Turing Tumble a Computer?

If you're like most people, you're probably wondering how on earth this marble contraption could possibly be a computer. It has no screen, no keyboard, and no electronics. How is it anything like a computer?

To start, let's look at what's inside a regular desktop computer.

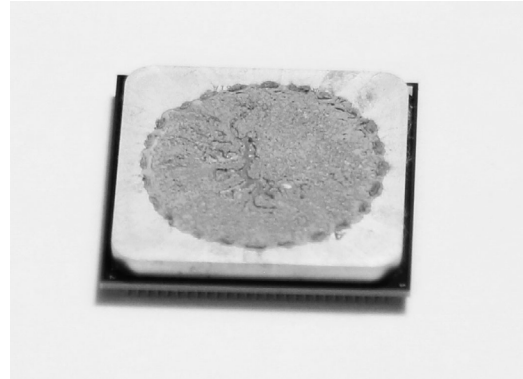
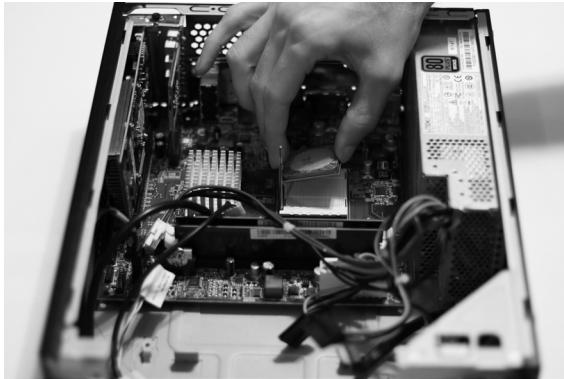


There are all sorts of things in there like circuit boards, fans, lights, and motors, but those aren't the smart parts of a computer. In fact, they're only there to support the computer's processor - a little rectangular chip under a big fan that cools it down.

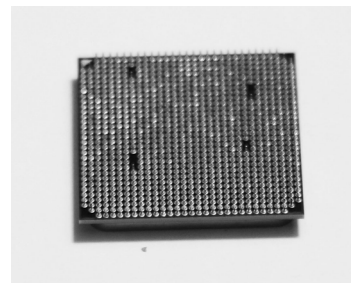


The computer processor (or central processing unit - CPU) is where all the “smarts” in a computer happen. It’s the part that runs programs and does math and logic. The processor does a lot of hard work when the computer is running and it generates a lot of heat in the process. The fan on top of it is there to cool it down so that it doesn’t overheat.

This is what this computer’s processor looks like when it’s taken out:



The goopy stuff on top of the processor is thermal paste. It makes it easier for heat to transfer out of the chip. If we clean off the thermal paste, it looks like this on top and bottom:



On the bottom of the processor, you can see over a thousand little pins sticking out. The pins connect the inside of the processor to things on the outside. Some pins are inputs - they send information into the processor or simply provide it power. Other pins are outputs - the processor uses the outputs to send information to the rest of the computer. For example, the computer’s keyboard would provide *input* to a processor while a screen would show information coming from the *output* of a processor.

What’s inside a computer processor?

Switches. Lots and lots of switches. *Billions* of switches. The switches are so small that you can’t even see them with your eye. In fact, they’re so small that you couldn’t even see them through a microscope because the wavelength of visible light itself is too big. These days, the switches

in a computer processor are about a thousand times smaller than the thickness of a human hair.

The following video zooms into a computer processor all the way until you can see the individual switches (called “transistors”) inside and the tiny copper wires connecting them together. As it zooms further and further in, you’ll notice the images change from color to black and white. That’s when the creators of the video had to switch from taking pictures with light to taking pictures with electrons, because they’re so much smaller. You can see the video here:

<https://bit.ly/computer-processor>

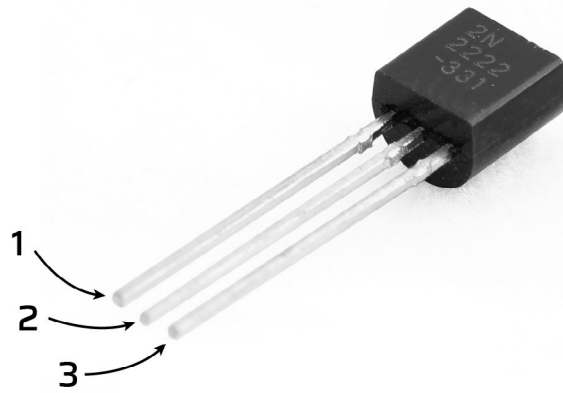
How do switches do *anything* smart?

When you hear “switch” you probably think about the switch on your wall that turns the light on and off, and it seems impossible to think that switches like that could do anything other than turn stuff on and off.



And you’d be right about your light switch. It can’t do anything smart. Switches in computers, however, are not limited to “on” or “off” like light switches; their state (on or off) also effects the way other switches in their neighborhood behave. In other words, computer switches can do smart stuff because they are able to flip other switches. In order for switches to be able to do smart things, **the key is that they must be able to be flipped by the same type of energy that they control.** A light switch can’t flip other switches because it takes *mechanical* energy to flip it, but it controls *electrical* energy. You can’t connect the output of one light switch to the input of another.

In Turing Tumble, the switches (that is, the blue and purple parts we call “bits” and “gear bits”) are flipped by *mechanical* energy, and they also control *mechanical* energy: They’re flipped by a marble rolling over them, and they control whether a marble rolls off their left or right side.



Switches in a computer (transistors) are flipped by *electrical* energy and also control *electrical* energy. The image above is of a relatively large, individual transistor that's about the size of the nail on your pinky finger. This is how it works: pin 1 controls the flow of electricity from pin 2 to pin 3. If electricity is being pushed into pin 1, electricity can flow from pin 2 to pin 3. Otherwise, it can't.

Since the switches in computer processors and in Turing Tumble are flipped by the same type of energy as they control, it's possible for one switch to cause another switch to flip. As you work through the puzzles in Turing Tumble, you'll discover how this one, simple property makes it possible to build machines of limitless capability!

How Turing Tumble is a Computer Video:
<https://bit.ly/like-a-computer>

Computer Logic Lesson #2: Ramps

In these first challenges, the only part used is the “ramp.” It looks like this:



The purpose of the ramp is to make marbles always go in a certain direction. If you put it on the board pointing to the left, the marbles will go left. If you put it on the board pointing to the right, the marbles will go to the right.

What do electronic ramps look like in an electronic computer?

In an electronic computer, like a laptop, desktop, or smart phone, wires are used for the same purpose as ramps. Wires direct electricity where it should go, sort of like a pipe for electrons. Sometimes wires direct electricity to a switch or another electrical component, or sometimes they just lead to more wires that branch off.

There are even tiny wires in microchips like this one:



Photo of a Motorola 68040 processor taken by Konstantin Lanzet. Shared under CC BY-SA 3.0 license at https://en.wikipedia.org/wiki/Motorola_68040.

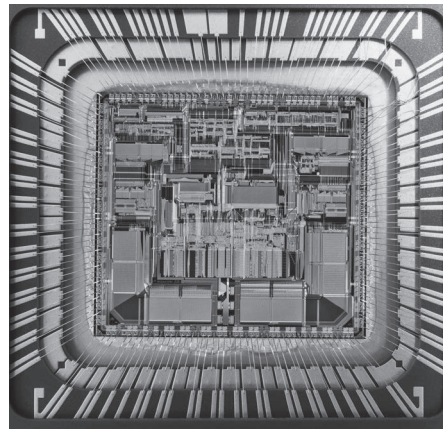


Photo of a decapped Motorola 68040 processor taken by Gregg M. Erickson. Shared under CC BY 3.0 license at https://en.wikipedia.org/wiki/Motorola_68040.

The picture on the left shows a microchip like you might see inside your computer. Microchips are just tiny electrical circuits, covered in plastic or ceramic to keep them safe. On the right is the same microchip, but without

Challenge #1: Gravity




(page 15 in puzzle book)

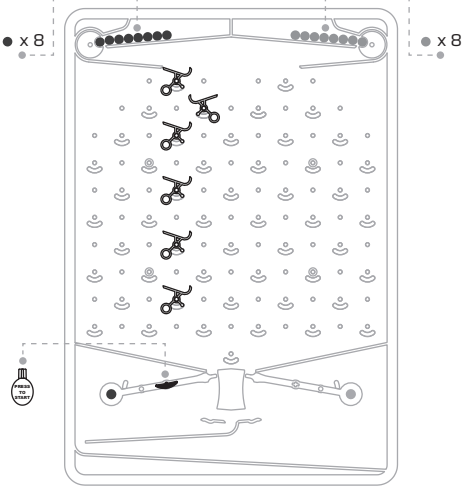
Challenge 1: Gravity

Objective: Make all of the blue marbles (and only the blue marbles) reach the end.


Required output:



Starting setup



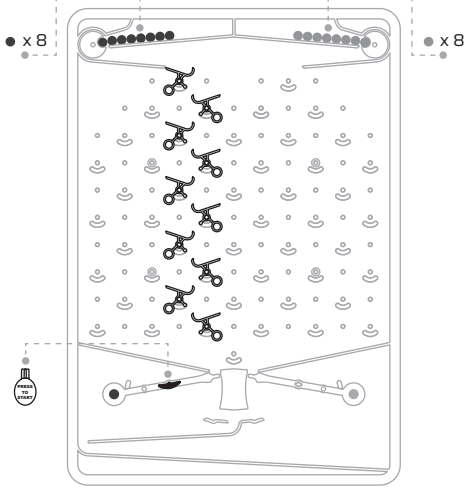
Available parts



Challenge 1 Solution

Explanation: The four ramps complete the path from the top of the board to the bottom of the board.

Remember that it's against the rules to allow marbles to fall freely for any distance! When a marble rolls off a part, it must immediately land on the next part.



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What players learn about computer logic:

- The only part used in this challenge is the ramp. Ramps are just like wires in an electrical circuit and the marbles are like electricity. When players place ramps on the board, they are setting up paths that marbles can travel through, just like how wires set up paths that electricity can follow.

What players learn about the game:

- Familiarity with the layout of the puzzles: required output, starting setup and available parts.
- The levers on the bottom are connected to the marble release on top.
- Practice putting the ramps on the board. Players will discover that the ramps are **reversible** and can go on the board in either direction, depending on where they want to route the marbles.

Possible hang-ups:

- Player's machines cannot let marbles drop freely for any distance. Marbles might be bouncing unpredictably because there aren't parts leading all the way down or the ramps are facing the wrong direction.
- Starting the machine: Once the machine is in motion, players cannot touch it or otherwise interfere with its operation. Press the start button down once to start the machine. Once a marble reaches the bottom, it will push a lever to trigger the next marble.
- Putting the ramps on the board: the ramps are reversible! Note which direction they face before putting them on the board.

Challenge #2: Re-entry


(page 16 in puzzle book)



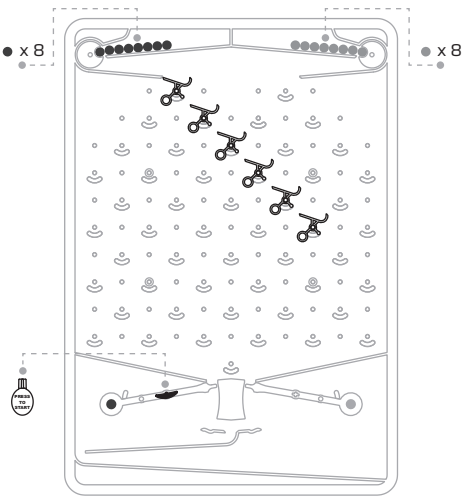
Challenge 2: Re-entry

Objective: Make all of the blue marbles (and only the blue marbles) reach the end.


Required output:



Starting setup



Available parts



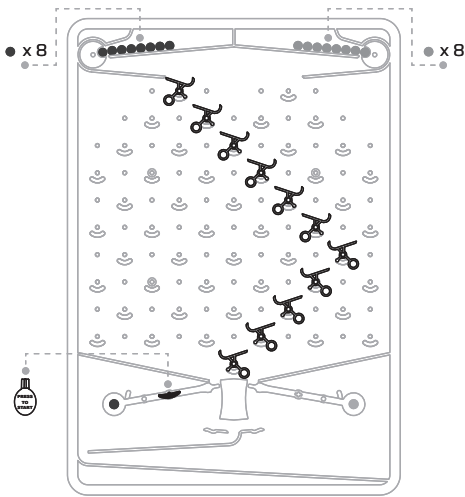
x 5

23

Challenge 2 Solution

Explanation: The starting setup leads the marbles over onto the right side. That's a problem! If the marbles hit the right lever, they'd release red marbles, but you're only supposed to let the blue marbles get to the bottom.

To solve this puzzle, you have to use the 5 ramps to lead marbles back over to the left lever.



23

What players learn about computer logic:

- The only part used in this challenge is the ramp. Ramps are just like wires in an electrical circuit and the marbles are like electricity. When players place ramps on the board, they are setting up paths that marbles can travel through, just like how wires set up paths that electricity can follow.

What players learn about the game:

- Familiarity with the layout of the puzzles: required output, starting setup and available parts.
- The levers on the bottom are connected to the marble release on top.
- Practice putting the ramps on the board. They will discover that the ramps are **reversible** and can go on the board in either direction, depending on where players want to route the marbles.

Possible hang-ups:

- Players might initially place ramps so that the marble triggers the right lever. This will be a good time to be sure they've looked at the back of the board to see how the lever on the bottom is connected to the marble release on top. Encourage them to place the ramps so that the marbles are guided back over to the blue side.

Challenge #3: Ignition



(page 17 in puzzle book)

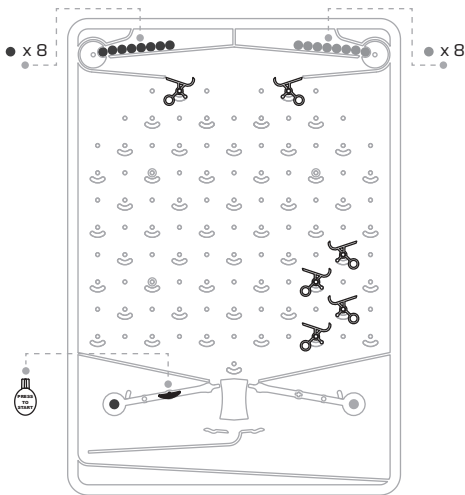
Challenge 3: Ignition

Objective: Release one blue marble and then all of the red marbles.

Required output:



Starting setup



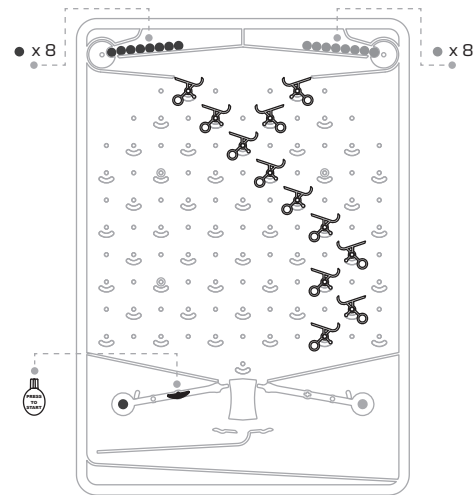
Available parts



x6

Challenge 3 Solution

Explanation: The ramps bring the paths of the red and blue marbles into one path that leads to the right lever. After the first blue marble, all the rest are red.



What players learn about computer logic:

- The only part used in this challenge is the ramp. Ramps are just like wires in an electrical circuit and the marbles are like electricity. When players place ramps on the board, they are setting up paths that marbles can travel through, just like how wires set up paths that electricity can follow.

What players learn about the game:

- Players don't need to press the right lever to get red marbles to the bottom. A blue marble can trigger the marble release on the red side, allowing a red marble to fall.

Possible hang-ups:

- It can be tricky for players to figure out how to release one blue marble and all the rest red. Remind them that the blue will release when they press the start button, and they can determine what color marble comes next based on how they direct the marbles with the ramps.

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Challenge #4: Fusion

(page 18 in puzzle book)



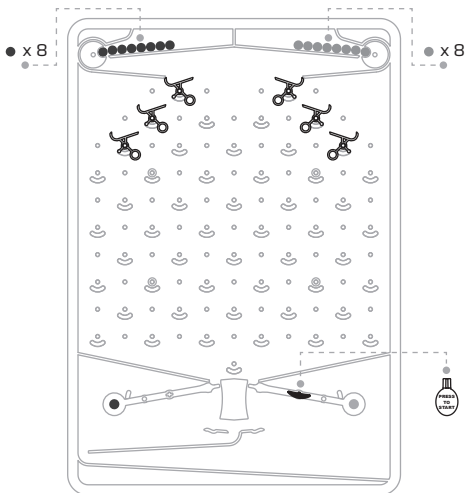
Challenge 4: Fusion

Objective: Release one red marble and then all of the blue marbles.

Required output:



Starting setup



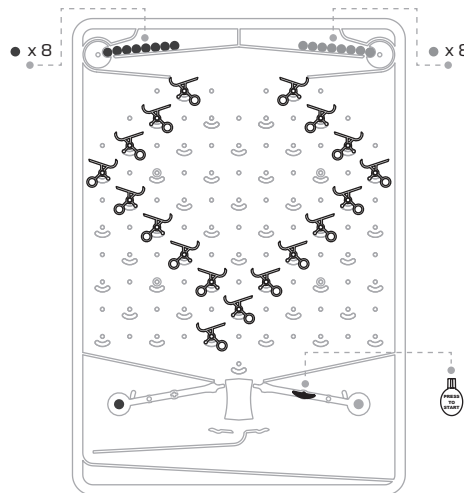
Available parts



x 13

Challenge 4 Solution

Explanation: The paths need to come together, but they start far apart! Use the ramps to bring the paths together and lead all of the marbles to the left side.



What players learn about computer logic:

- The only part used in this challenge is the ramp. Ramps are just like wires in an electrical circuit and the marbles are like electricity. When players place ramps on the board, they are setting up paths that marbles can travel through, just like how wires set up paths that electricity can follow.

What players learn about the game:

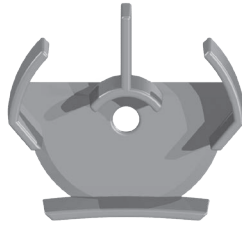
- The start button can be placed on either lever. In this challenge, it needs to go on the right side so that a red marble is released first.
- As noted in the talk bubble, players can sometimes solve challenges with fewer parts than are listed in the “Available parts” section. You can challenge students who are finding the introductory puzzles easy to create the most elegant and simple solution.

Possible hang-ups:

- It can be tricky for players to figure out how to release one red marble and all the rest blue. Remind them that the red will release when they press the start button, and they can determine what color marble comes next based on how they direct the marbles with the ramps.
- There are many ways a player can lay out the ramps to solve this challenge. The example on the top is just one solution.

Computer Logic Lesson #3: Crossovers

In puzzle 5, the “crossover” part is introduced. It looks like this:



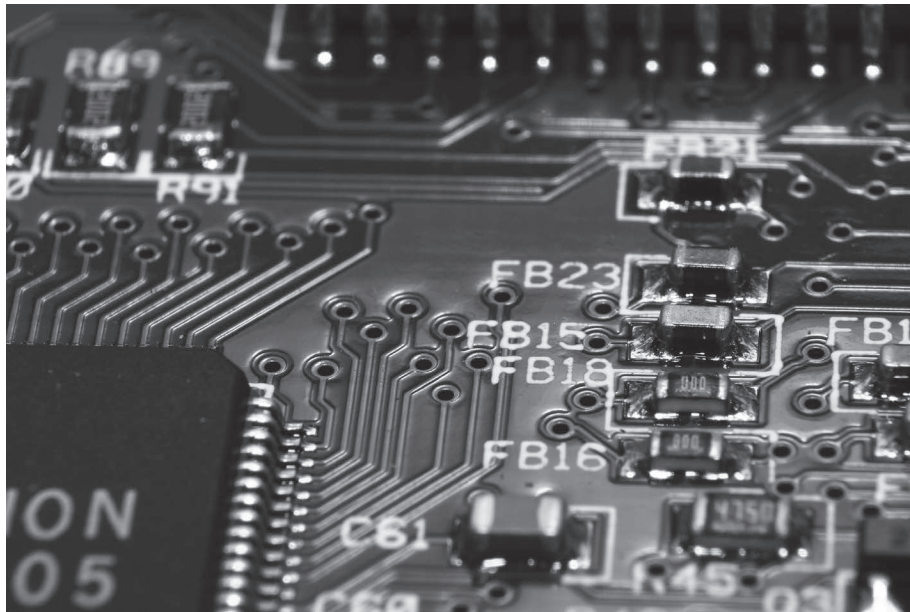
The purpose of the crossover is to let the paths of the marbles cross over each other. A marble coming in the left side exits on the right. A marble coming in the right side exits on the left.

What do crossovers look like in an electronic computer?

The crossover acts like two wires crossing over each other, but *not* touching each other, sort of like how overpasses allow cars to drive over other roads. Electricity can move along each of the wires, but the crossing paths don't interfere with each other. It would be impossible to create complicated circuits without wires that cross. Because the crossover allows the paths of the marbles to cross over each other without interfering with the path of the next marble, they are performing one small component of what happens in a circuit board.



Circuit boards are used in electronic computers to keep all the wire connections sturdy, safe, and fixed in place. A circuit board is made of a hard, flat material. On the surface is a thin layer of copper, etched into a carefully designed pattern of wires that connect the electronic components on the board. A circuit board is comprised of many more elements than just crossing wires. Circuit boards house transistors, CPUs, and much more. Below is an example of a circuit board. You can see the copper wires in between all the electronic parts:



If the wires on a circuit board are all on a flat surface, how do they cross over each other without touching? Most circuit boards actually have multiple layers of copper wires sandwiched between insulators. Little holes, called “vias,” connect wires in the various layers of copper. In the picture above, you can see lots of little vias connecting the various layers of the circuit board, allowing the copper wires to cross over and under each other without touching. Even on a one layer circuit board, wires can cross using "jumper wires." A jumper wire is a wire that is soldered on top of a circuit board to hop over other wires on the circuit board.

In computer chips, there are also multiple layers of tiny wires that cross over and under each other.

Challenge #5: Entropy



(page 21 in puzzle book)

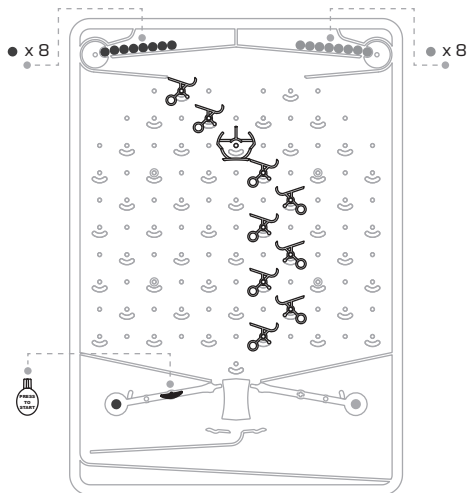
Challenge 5: Entropy

Objective: Make the pattern blue, red, blue, red, blue, red...

Required output:



Starting setup



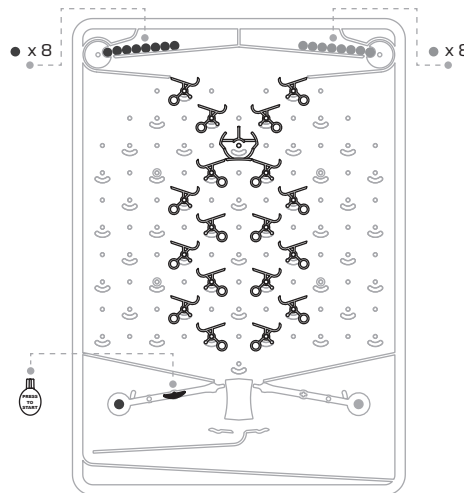
Available parts



x 9

Challenge 5 Solution

Explanation: This time, you have to create your own path for the red marbles to get over to the left lever! You must use the crossover where your path crosses the path of the blue marbles.



What players learn about computer logic:

- The crossover is a mechanical version of two wires crossing over each other (but not touching). In electrical circuits wires are used to connect parts throughout the circuit board. Wires weave around, over, and under each other to route electricity where it needs to go.
- Circuit boards are usually made of several layers of wires. Wires can cross each other if they are on separate layers. Even on a one-layer circuit board, wires can cross using “jumper wires.” A jumper wire is a wire that is soldered on top of a circuit board to hop over other wires on the circuit board.

What players learn about the game:

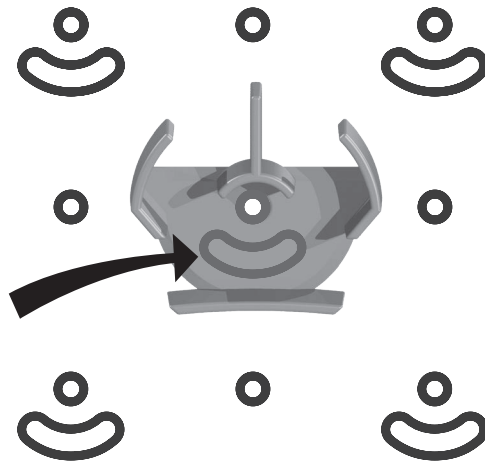
- Practice putting the new crossover pieces on the board.
- How the crossovers work: a marble that goes in on the left side will cross over and exit out the right. A marble that goes in on the right side will cross

over and exit out the left.

- Solidifies their understanding of the levers at the bottom and marble releases at the top.

Possible hang-ups:

- In this puzzle, the start button goes back on the left lever.
- When putting the crossover pieces on the board, the smile on the crossover fits a bit snugly into the open smile on the board. It needs to be pushed all the way onto the board.



- Since this is a mechanical computer, it makes a difference if the parts are placed correctly. Players will start to notice if they didn't slide the parts all the way onto the board because the marbles will be a little less predictable.

Challenge #6: Total Internal Reflection



(page 22 in puzzle book)

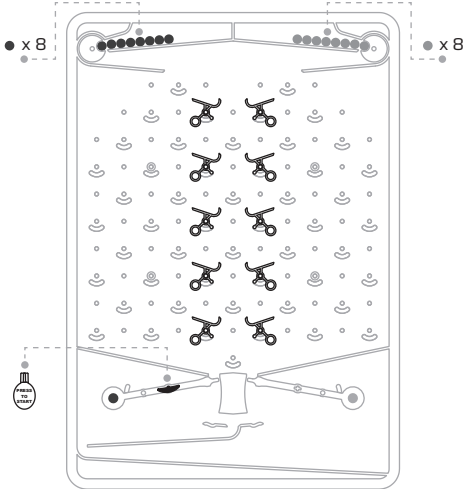
Challenge 6: Total Internal Reflection

Objective: Make the pattern blue, red, blue, red, blue, red...

Required output:



Starting setup



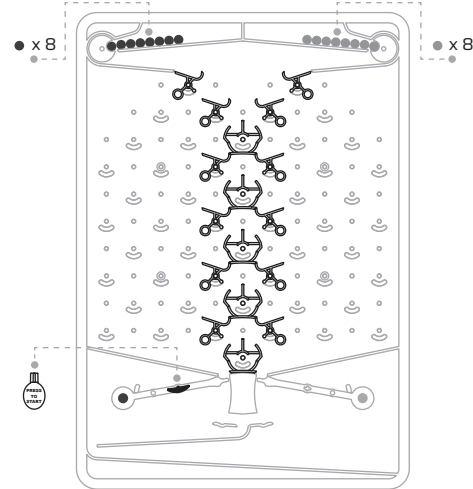
Available parts



Challenge 6 Solution

Explanation: The paths for the red and blue marbles cross over each other five times. Crossovers must be placed at each point where they cross.

In the last two puzzles, the paths crossed each other one and three times. One, three, and five are all odd numbers. What would happen if the paths crossed over each other an even number of times?



What players learn about computer logic:

- The crossover is a mechanical version of two wires crossing over each other (but not touching). In electrical circuits wires are used to connect parts throughout the circuit board. Wires weave around, over, and under each other to route electricity where it needs to go.
- Circuit boards are usually made of several layers of wires. Wires can cross each other if they are on separate layers. Even on a one layer circuit board, wires can cross using “jumper wires.” A jumper wire is a wire that is soldered on top of a circuit board to hop over other wires on the circuit board.

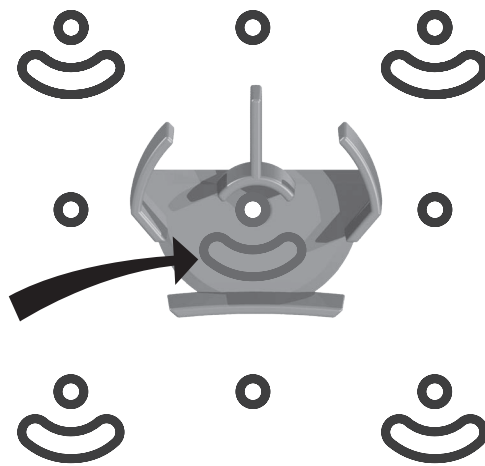
What players learn about the game:

- This challenge requires the same output as challenge five, but it is a more simple and elegant solution.
- Practice putting the crossover pieces on the board.

- Solidifies their understanding of the levers at the bottom and marble releases at the top.

Possible hang-ups:

- When putting the crossover pieces on the board, the smile on the crossover fits a bit snugly into the open smile on the board. It needs to be pushed all the way onto the board.
- Since this is a mechanical computer, it makes a difference if the parts are placed correctly. Players will start to notice if they didn't slide the parts all the way onto the board because the marbles will be a little less predictable.



Challenge #7: Path of Least Resistance



(page 23 in puzzle book)

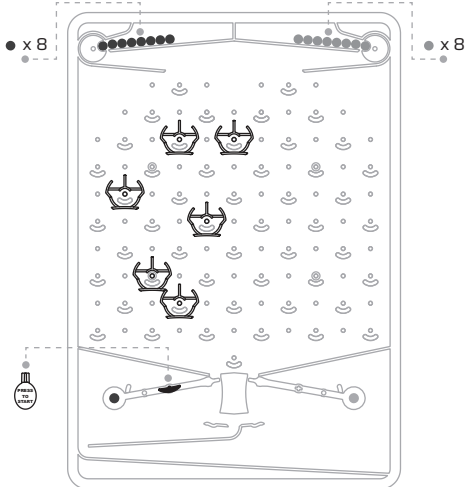
Challenge 7: Path of Least Resistance

Objective: Create a path for the blue marbles to reach the output with only 6 ramps.

Required output:



Starting setup

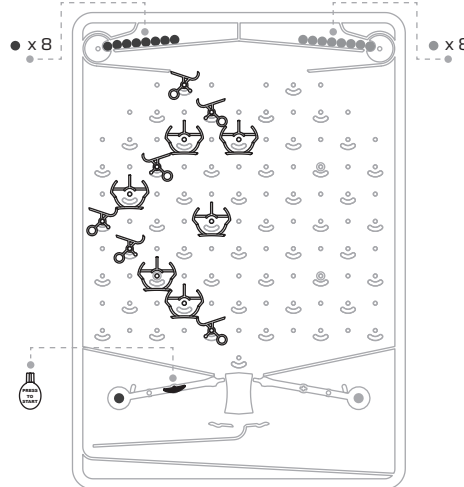


Available parts



Challenge 7 Solution

Explanation: This one is a little trickier than the last challenge. At the top, you must make a choice on whether to go to the left or to the right. You must go to the left this time.



What players learn about computer logic:

- The crossover is a mechanical version of two wires crossing over each other (but not touching). In electrical circuits wires are used to connect parts throughout the circuit board. Wires weave around, over, and under each other to route electricity where it needs to go.
- Circuit boards are usually made of several layers of wires. Wires can cross each other if they are on separate layers. Even on a one layer circuit board, wires can cross using “jumper wires.” A jumper wire is a wire that is soldered on top of a circuit board to hop over other wires on the circuit board.

What players learn about the game:

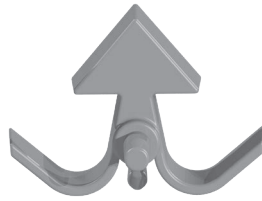
- Players don't have to make the marbles go through every part on the board. Once in a while, the challenges have parts in the starting setup that do not need to be used.

Possible hang-ups:

- This challenge has parts on the starting setup that are not meant to be used. Encourage the players to think of the route that takes advantage of as many of the crossovers on the board as possible.

Computer Logic Lesson #4: Bits

In puzzle 8, the “bit” part is introduced. It looks like this:



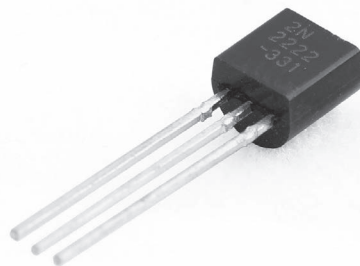
These bits are mechanical versions of the electronic switches inside computer chips. Electronic switches allow you to choose which way electricity will go based on how you set them. These mechanical switches allow you to choose which way the marble will roll off based on which direction they are pointed.

You often get to choose which direction the bits point when you start your machine: Should it point left or right? If you point the bit to the left, the next marble will fall to the right. If you point the bit to the right, the next marble will fall to the left.

You’ll notice that bits in Turing Tumble are a little trickier than electronic bits because a marble passing through them changes the direction of the bit for the next marble that falls. They don’t have a counterweight (like the ramps do) to put them back in their original position.

What do bits look like in an electronic computer?

The most basic type of electronic switch in a computer is called a “transistor.” Transistors are usually extremely tiny, but the one in the picture below is encased inside a relatively big, plastic package to make it easy to handle (it’s still only about the size of a pinky fingernail):



See how there are three wires coming out? One of the wires is a control wire. By changing the force of electricity applied to that wire (i.e., the “voltage”), it controls how much electricity can flow in through the second wire and out through the third wire.

That’s cool, but how can a switch like that store information? It turns out that if you take four of those transistors and connect them together in a certain way, you can create a little circuit that *remembers* if it’s been switched on or off, even when you stop pushing electricity into the control wire. That circuit is called a “flip-flop.” It’s one of the most important building blocks of a computer. Billions and billions of flip-flops are used to store information in computer memory.

What do bits look like in a programming language?

When bits are used to store information, they are like variables in a programming language. Of course, one bit doesn’t store much information, just a 1 or 0. But when you combine multiple bits into one variable, they can represent numbers, letters, or...anything else.

Bits also function as the most fundamental programming command of all: the ‘if’ statement. You could think of a single bit like this:

```
If (bit.direction = right) Then
    marble.send_left()
Else
    marble.send_right()
```

Challenge #8: Depolarization


(page 26 in puzzle book)



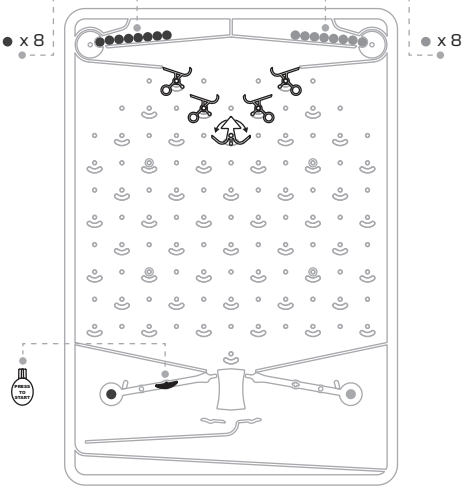
Challenge 8: Depolarization

Objective: Make the pattern blue, red, blue, red, blue, red...


Required output:



Starting setup

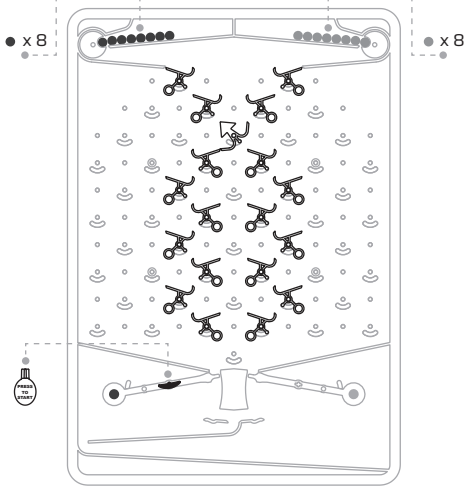


Available parts



Challenge 8 Solution

Explanation: A bit is used to alternate the color of the marbles released.



What players learn about computer logic:

- Bits are mechanical versions of the electrical switches inside computers. In computers, the electrical switches determine the path for electricity to flow. In Turing Tumble, the direction of a bit determines which way a marble will fall. If a bit is pointed to the left, the marble will fall to the right. If a bit is pointed to the right, the marble will fall to the left. However, the bits in Turing Tumble are a little more tricky than computer chip switches because they change direction every time a marble runs over them.

What players learn about the game:

- The starting position of the bit is very important. If a bit is pointed left, the marble will fall right. If the bit is pointed right, the marble will fall to the left. In this challenge, players must choose the starting position of the bit.
- When a marble goes through the bit, the bit stays pointed in the new direction. This is in contrast to the ramps which have a counterweight that

turns them back to their original position.

Possible hang-ups:

- The symbol of the bit in the “Starting setup” shows it pointing up, but with two curved arrows over it pointing to the left and right. That indicates that the player must *choose* the starting direction the bit points.
- Encourage players to run their finger down the parts and watch how the counterweight of the ramps work in contrast to the bit turning and staying pointed in the new direction.

Challenge #9: Dimers

(page 27 in puzzle book)



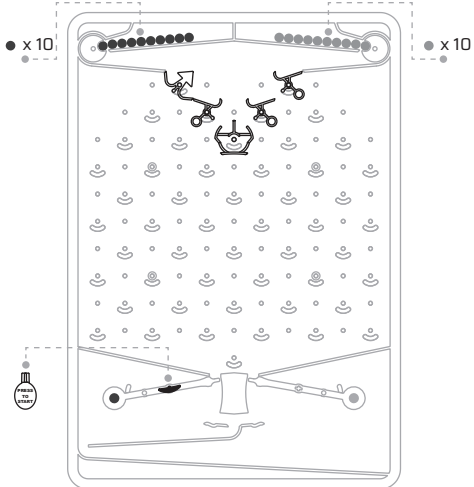
Challenge 9: Dimers

Objective: Make the pattern blue, blue, red, blue, blue, red...

Required output:



Starting setup



Available parts

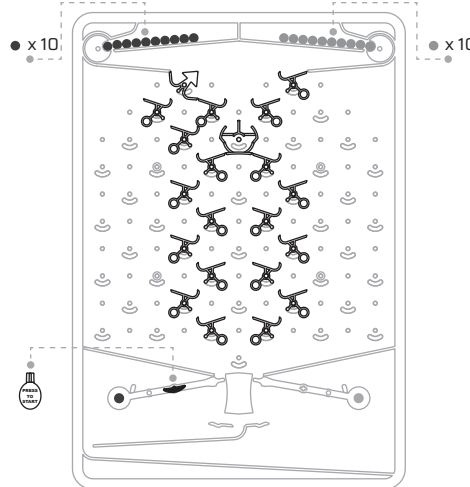


x 18

Challenge 9 Solution

Explanation: The bit makes every other blue marble release a red marble, but every red marble releases a blue marble.

Do you see how the bit splits the path of the blue marbles to go in two directions? This is very important in the coming puzzles!



What players learn about computer logic:

- Bits are mechanical versions of the electrical switches inside computers. In computers, the electrical switches determine the path for electricity to flow. In Turing Tumble, the direction of a bit determines which way a marble will fall. If a bit is pointed to the left, the marble will fall to the right. If a bit is pointed to the right, the marble will fall to the left. However, the bits in Turing Tumble are a little more tricky than computer chip switches because they change direction every time a marble runs over them.

What players learn about the game:

- The starting position of the bit is very important. In this challenge, the starting position of the bit is chosen for the player: it must point to the right. Since the bit is pointed right, the marble will fall to the left.
- When a marble goes through the bit, the bit stays pointed in the new direction. This is in contrast to the ramps which have a counterweight that

turns them back to their original position.

- The starting setup also indicates how many marbles should start on top. This is the first challenge that uses ten of each instead of eight.
- The bit and crossover, working together, allow for a more complicated pattern because you are able to route the marbles three different directions as they fall from the top.

Possible hang-ups:

- The symbol of the bit in the “Starting setup” shows it pointing to the right. Players do NOT get to choose the starting position of the bit in this challenge. It must be pointed right to start.
- This is the first time players are using the bit and crossover together. It might take a moment to think about the path the marble will go when the bit is pointed right (starting position) versus when it is pointing left. Encourage players to use their fingers to trace the path the marbles will take.

Challenge #10: Double Bond

(page 28 in puzzle book)



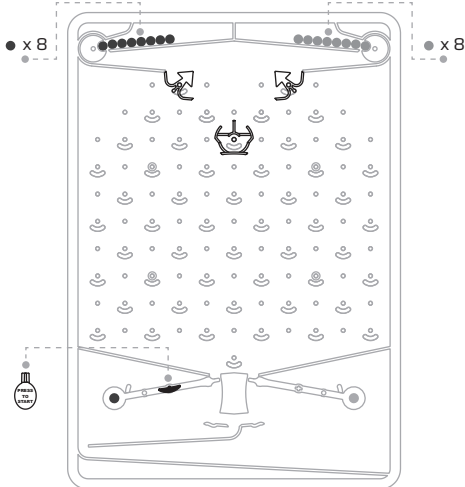
Challenge 10: Double Bond

Objective: Make the pattern blue, blue, red, red, blue, blue, red, red...

Required output:



Starting setup



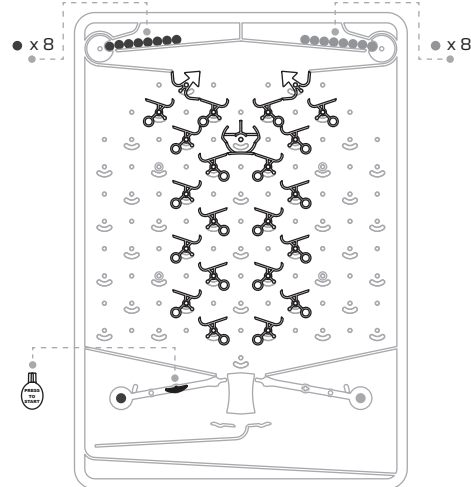
Available parts



x 22

Challenge 10 Solution

Explanation: This time, there are bits in the path of both the red and blue marbles. The bits cause only every other marble to cross to the other side of the board.



What players learn about computer logic:

- Bits are mechanical versions of the electrical switches inside computers. In computers, the electrical switches determine the path for electricity to flow. In Turing Tumble, the direction of a bit determines which way a marble will fall. If a bit is pointed to the left, the marble will fall to the right. If a bit is pointed to the right, the marble will fall to the left. However, the bits in Turing Tumble are a little more tricky than computer chip switches because they change direction every time a marble runs over them.

What players learn about the game:

- The starting position of the bit is very important. In this challenge, the starting positions of the bits are chosen for the player.
- When a marble goes through the bit, the bit stays pointed in the new direction. This is in contrast to the ramps which have a counterweight that turns them back to their original position.

- The starting setup also indicates how many marbles should start on top. This challenge has players go back to using eight of each.
- Two bits allow for a more complicated pattern because players are able to route the marbles four different directions as they fall from the top.

Possible hang-ups:

- The symbols of the bit in the “Starting setup” shows one pointing right and one pointing left. Players do NOT get to choose the starting position of the bit in this challenge.
- While there are four paths for marbles at the top, players only need two paths once they get to the bottom: one path to trigger the left (blue) lever and one path to trigger the right (red) lever.

Challenge #11: Selectivity

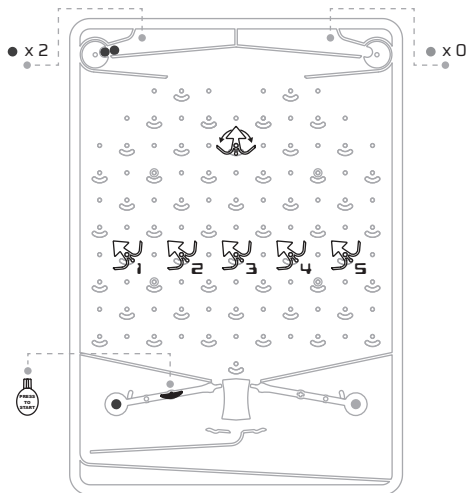
(page 29 in puzzle book)



Challenge 11: Selectivity

Objective: Flip bits 2 and 5 to the right.

Starting setup



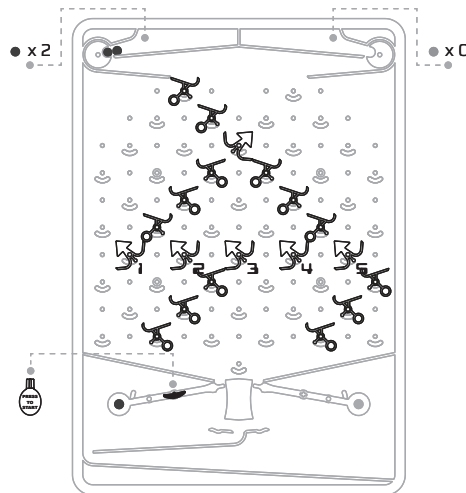
Available parts



x 15

Challenge 11 Solution

Explanation: The top bit splits the path of the blue marbles. One path leads to bit 2 and the other path leads to bit 5.



23

23

What players learn about computer logic:

- Bits are mechanical versions of the electrical switches inside computers. In computers, the electrical switches determine the path for electricity to flow. In Turing Tumble, the direction of a bit determines which way a marble will fall. If a bit is pointed to the left, the marble will fall to the right. If a bit is pointed to the right, the marble will fall to the left. However, the bits in Turing Tumble are a little more tricky than computer chip switches because they change direction every time a marble runs over them.

What players learn about the game:

- The starting setup also indicates how many marbles should start on top. This challenge has players only using two blue marbles.
- The starting position of the bit is very important. If a bit is pointed left, the marble will fall right. If the bit is pointed right, the marble will fall to the left. In this challenge, players choose the starting position of the top bit. The

starting position of bits 1 through 5 is left.

- Players don't have to make the marbles go through every part on the board.

Possible hang-ups:

- The starting setup also indicates how many marbles should start on top. This challenge has players only using two blue marbles.
- This challenge has parts in the starting setup that marbles will never go through.