

# Pinball Machine Maker

GUMBALL RALLY



## ASSEMBLY VIDEO!

Scan this QR code to view a step-by-step assembly video and tips on how to build and use your pinball machine.

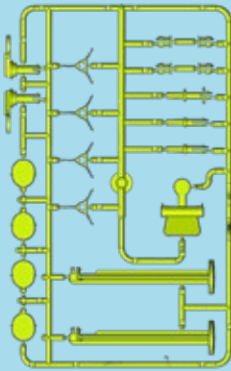


# KIT CONTENTS

*Good to know!*

Do you have any questions or are you missing any parts? Our tech support team will be happy to help you!  
 support@thamesandkosmos.com  
 or 1-800-587-2872

What's inside your experiment kit:



A



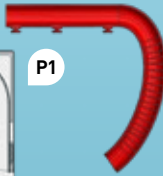
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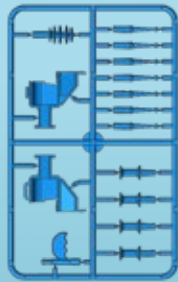
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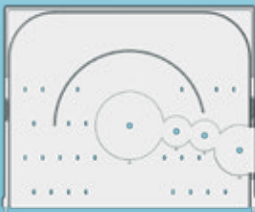
P5



P6



B



P1



P2



P7



P8



P9



P10



P11



P12



P13



P14



P15



P16



P17



P18



P19



P20



P21



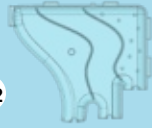
P22



P23



P24



P25



P26



P27



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 **TIP**

**YOU WILL FIND  
 ADDITIONAL INFORMATION IN  
 THE CHECK IT OUT SECTIONS  
 ON PAGES 18 AND 19.**



## Checklist:

 **YOU WILL ALSO NEED:**  
*Diagonal cutter or scissors and a nail file.*

✓ No.	Description	Qty.	✓ No.	Description	Qty.	✓ No.	Description	Qty.
○ A	Frame with parts A1–A9	1	○ P13	Gear with wall	1	○ P27	Chaos tray	1
○ B	Frame with parts B1–B6	1	○ P14	Gear	1	○ P28	Screw cover	1
○ P1	Base top	1	○ P15	Leg, back left	1	○ P29	Screw base	1
○ P2	Base bottom	1	○ P16	Leg, back right	1	○ P30	Screw	1
○ P3	Slide, split	1	○ P17	Leg, middle	2	○ P31	Slide support, narrow	1
○ P4	Slide, winner's circle	1	○ P18	Base connector	2	○ P32	Slide support, wide	1
○ P5	Slide, short corner	1	○ P19	Spinner post	1	○ P33	Winner's circle support	1
○ P6	Slide, long corner	1	○ P20	Launcher peg	1	○ P34	Gate support	1
○ P7	Thumb gear	1	○ P21	Flipper spring	2	○ P35	Rubber band, narrow	2
○ P8	Ramp	1	○ P22	Launcher spring, large	1	○ P36	Rubber band, wide	2
○ P9	Flipper	2	○ P23	Launcher spring, small	1	○ P37	Bell	1
○ P10	Launcher cap	1	○ P24	Base wall	1	○ P38	Cardboard back	1
○ P11	Ball catcher	1	○ P25	Upper deck, right	1	○ P39	Rubber foot, circular	4
○ P12	Screw wheel	1	○ P26	Upper deck, left	1	○ P40	Rubber foot, rectangular	2
						○ P41	Bag of gumballs	1
						○ P42	Sticker sheet	1

## SAFETY INFORMATION



### WARNING

Not suitable for children under 3 years. Choking hazard — small parts may be swallowed or inhaled. Store the experiment material and assembled model out of the reach of small children.

Keep packaging and instructions as they contain important information.

Clean the plastic parts before first use and regularly in lukewarm water.

Refer to the packaging for the nutritional information and the ingredients list for the candies.

### Dear parents and supervising adults,

Children as young as six years of age can enjoy experimenting with the built pinball machine, but most younger children will need some help building it. Regardless of their age, please support your child with advice and a helping hand, especially during tricky assembly steps. Before beginning, read the instructions together and discuss the safety instructions.

To prevent damage to the work surface on which your child is building, provide them with a mat or other surface protection.

When cutting the plastic parts out of the frames with the diagonal cutter or scissors, special care must be taken, not just because of the sharp edges on the tools, but also because the plastic parts can yield sharp edges or burrs. These can be removed with the help of the diagonal cutter or a nail file. Supervise your child when they are using the sharp tools until you trust that they can handle the tools independently.

We hope you and your child have a lot of fun building and playing with your Pinball Machine Maker.

### THE RIGHT TOOL

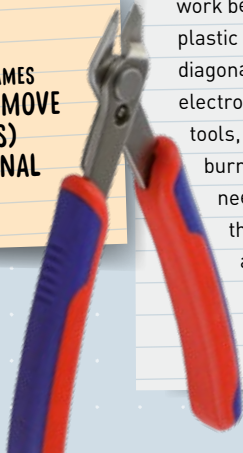
The right tool can make assembling your model much easier and it can also make your model work better in the end. It is best to cut the plastic parts out of their frames with a small diagonal cutter (such as those used for electronics work) or model pliers. Using these tools, the parts can be precisely cut so that no burrs remain on the parts and there is no need to file them down. If you don't have these pliers at home, you can use scissors and a nail file. Normal scissors do not cut as precisely as a diagonal cutter, so you may have to file some of the rough edges down with the nail file.



### TIP

#### IMPORTANT:

REMOVE THE PARTS FROM THE FRAMES ONLY WHEN THEY ARE NEEDED. REMOVE EXCESS MATERIAL (BURRS) BEFORE ASSEMBLY USING A DIAGONAL CUTTER OR A NAIL FILE.





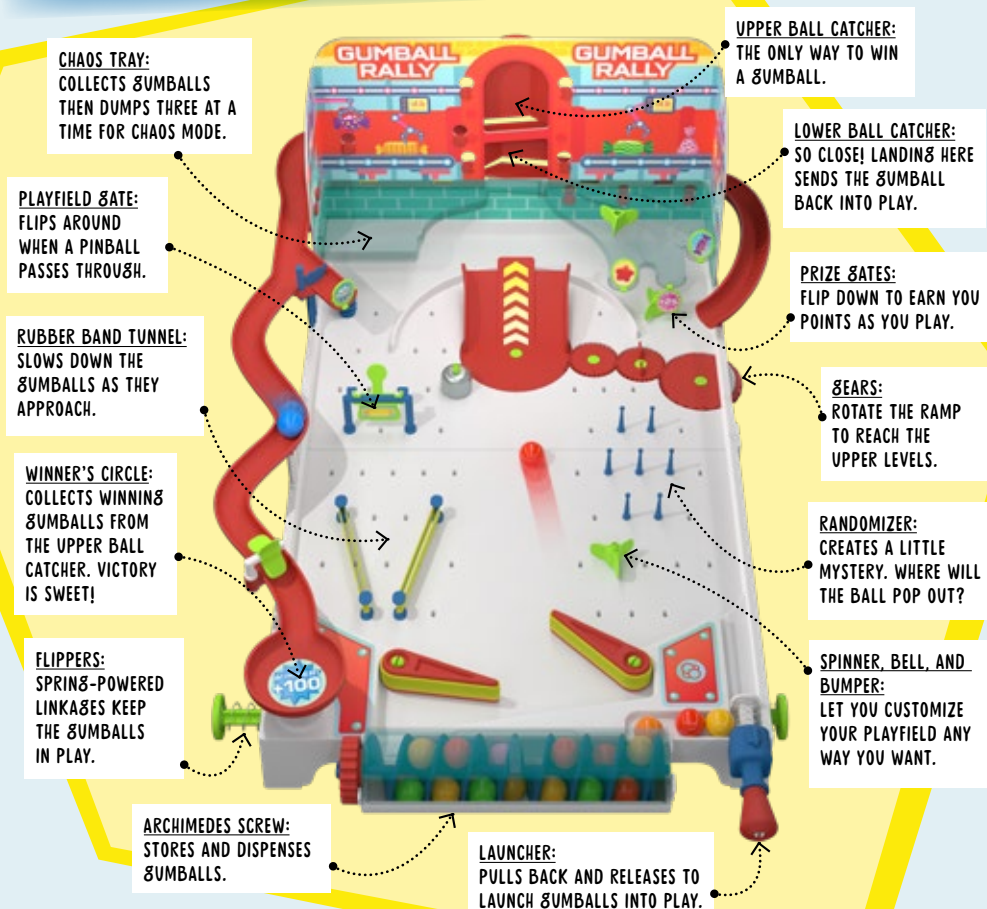
## INTRODUCTION

*Ready?*  
Let's get  
building!

# Pinball Machine

Arcades, pizza shops ... even museums! Pinball machines entice players with their signature side flippers — one for each hand — and ball launcher. Playing means defying gravity to keep the balls in play for as long as possible. Pinball machine themes vary wildly, from super heroes to sports to movies to outer space. This machine is a candy factory!

With this kit, you can build a **mechanical** pinball machine where you play with yummy gumballs. Your machine requires no electricity or coins — just simple machines and the power of your hands. Set up the gates with stickers to collect points as you play. Can you wait to eat a gumball until you get one in the winner's circle? Change up the pegboard to create endless combinations for your playfield. And learn cool engineering and physics concepts along the way.

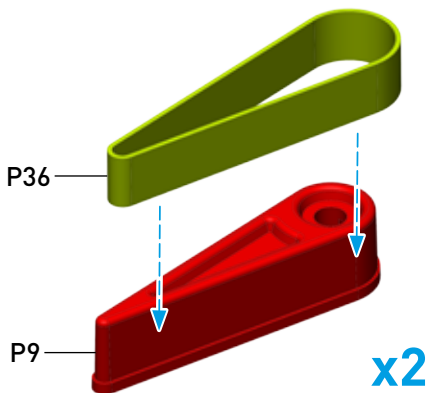


# PINBALL MACHINE ASSEMBLY

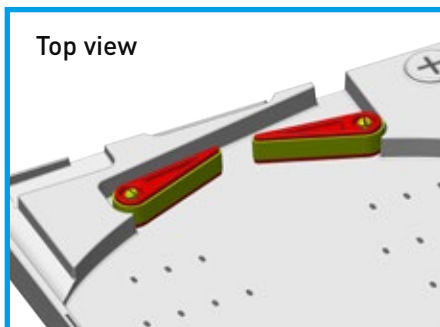
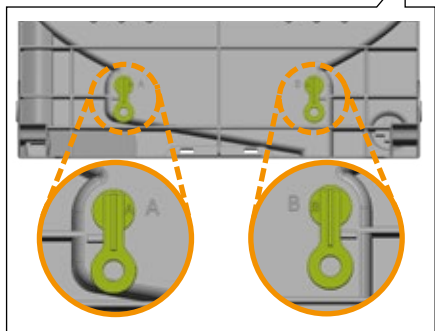
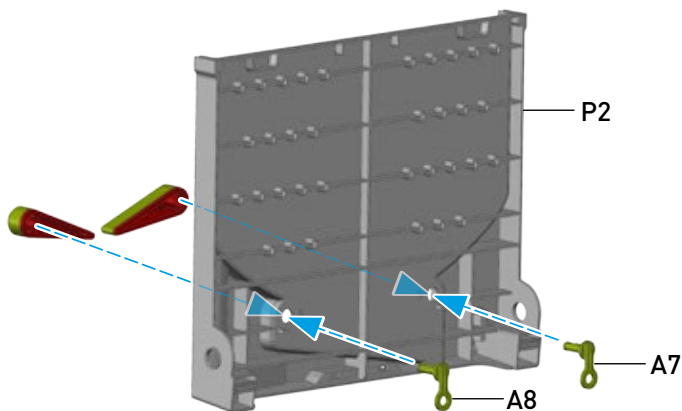


## ASSEMBLY VIDEO!

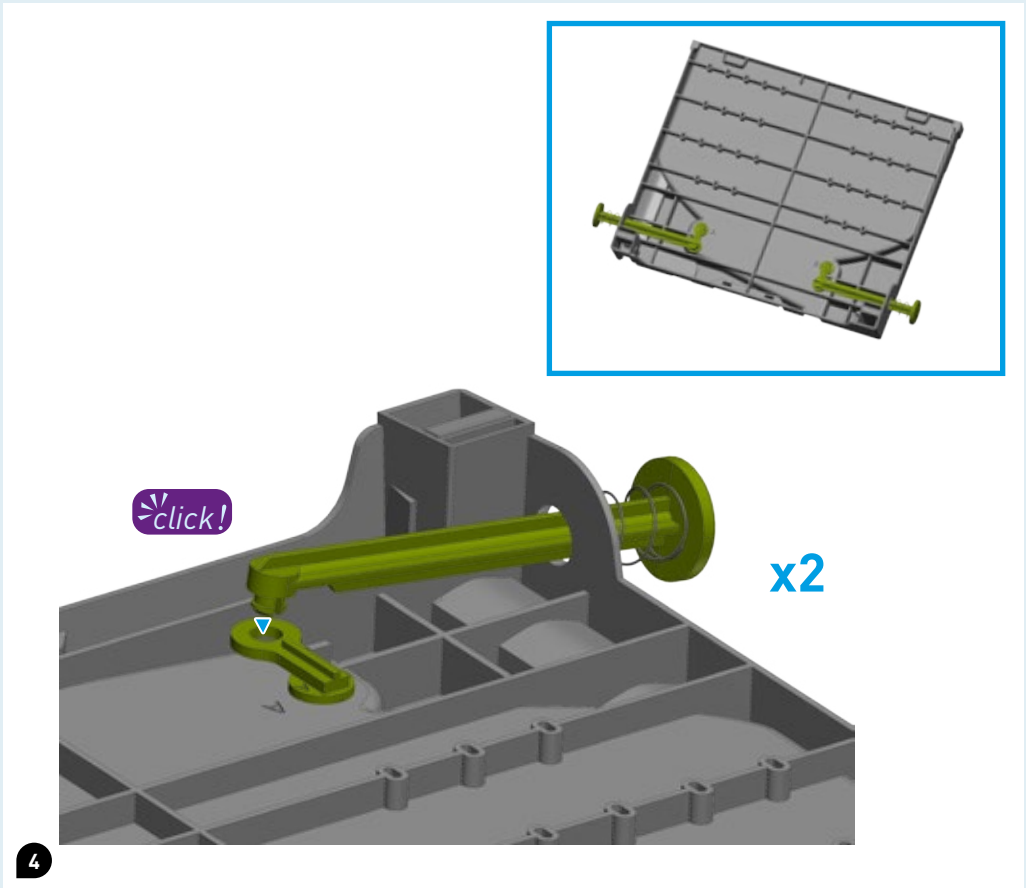
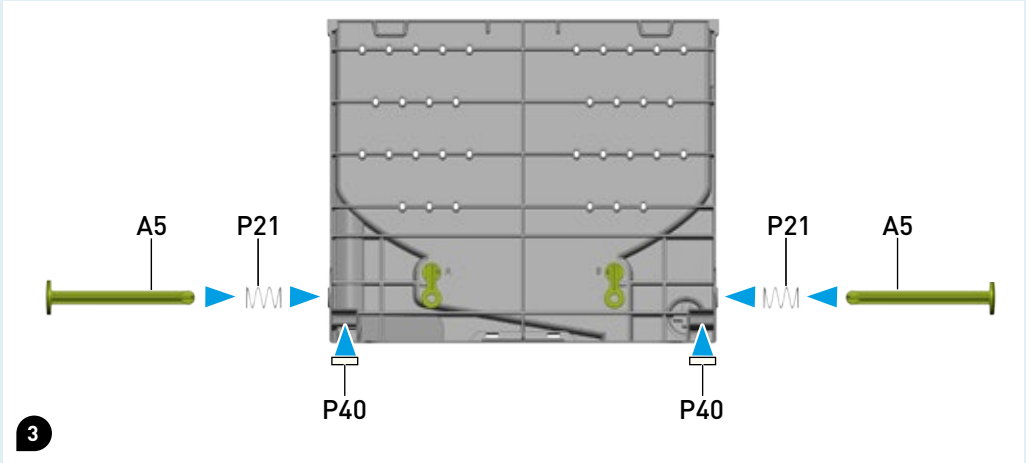
Scan this QR code to view a step-by-step assembly video and tips on how to use your pinball machine.

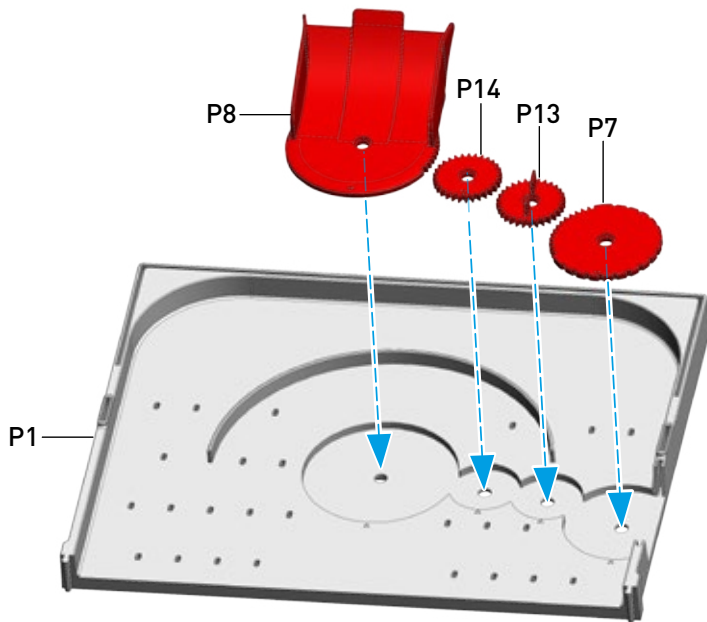


1



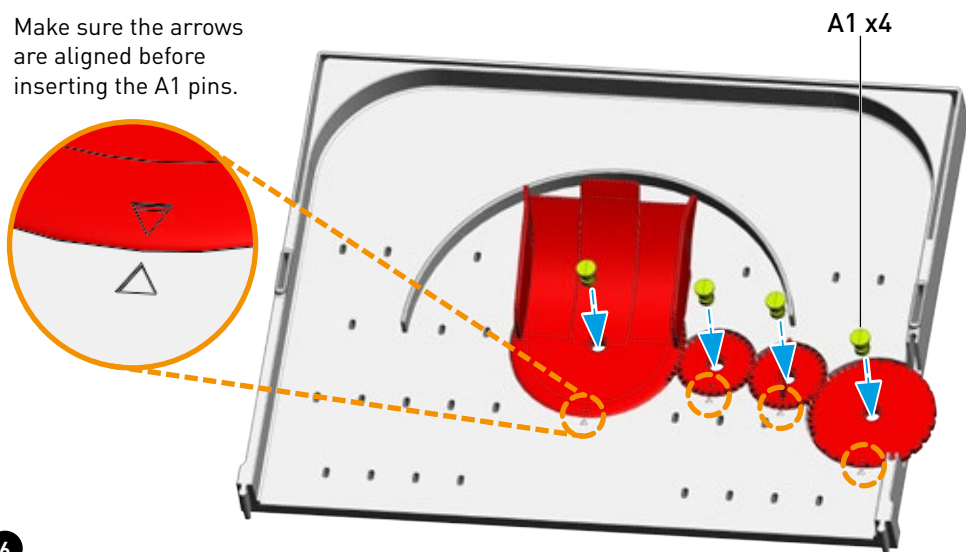
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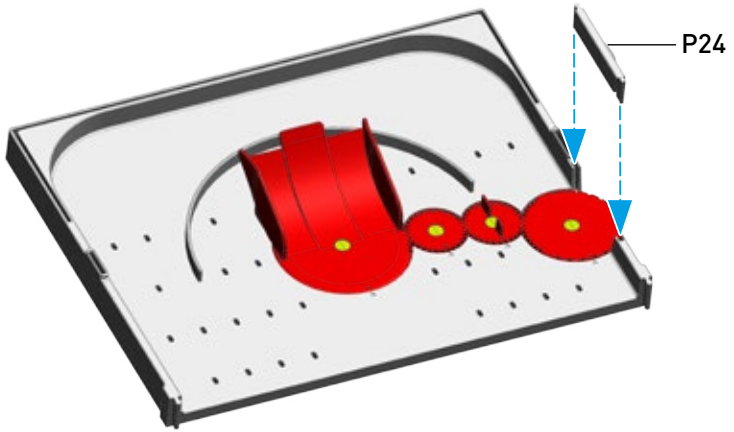


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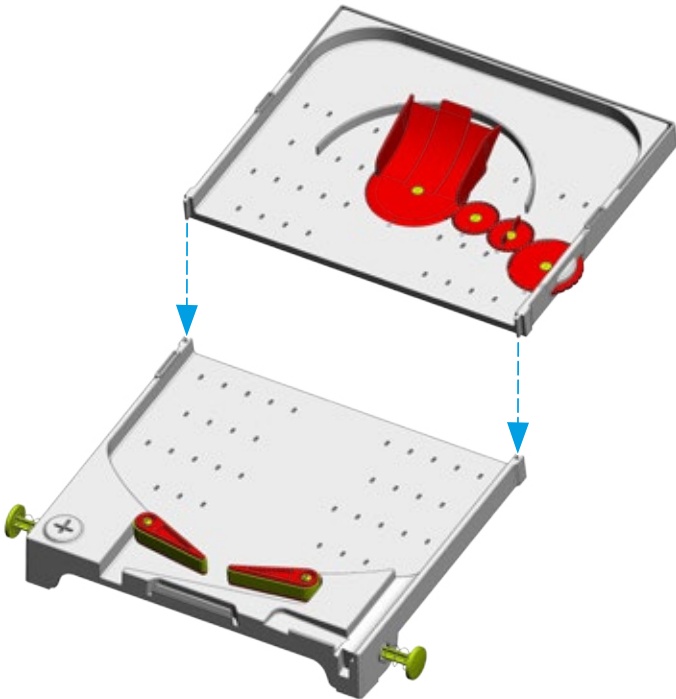
Make sure the arrows are aligned before inserting the A1 pins.



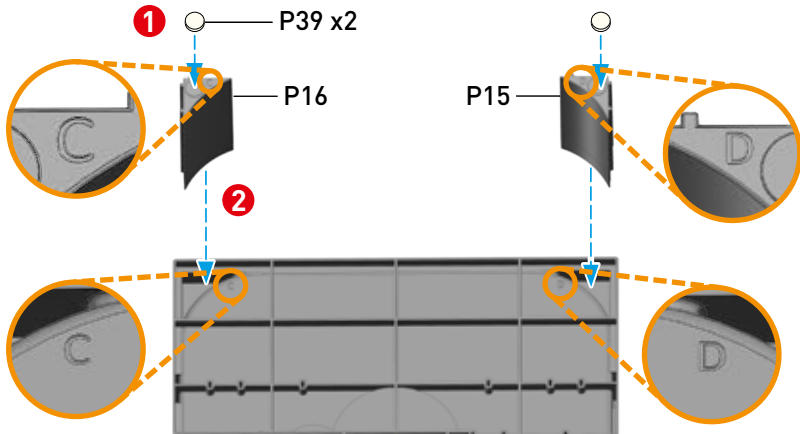
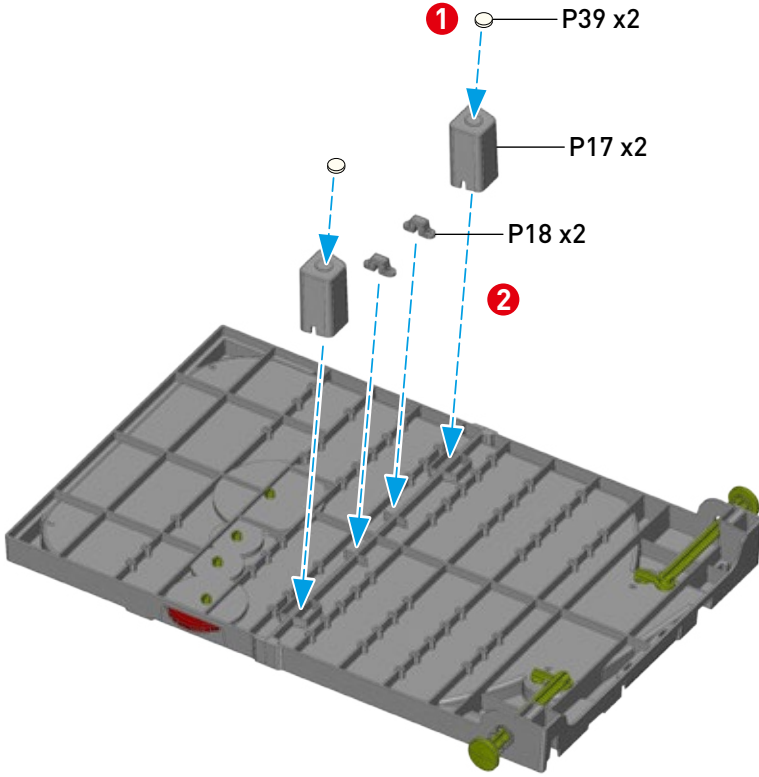
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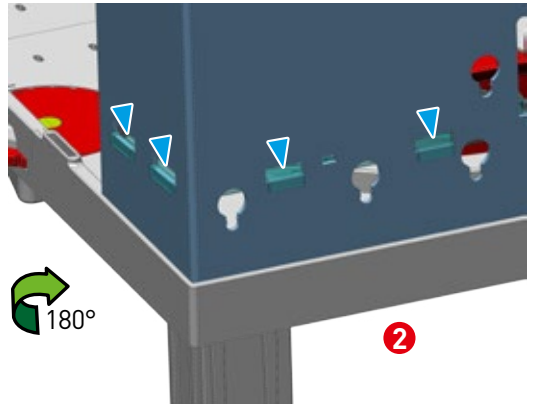
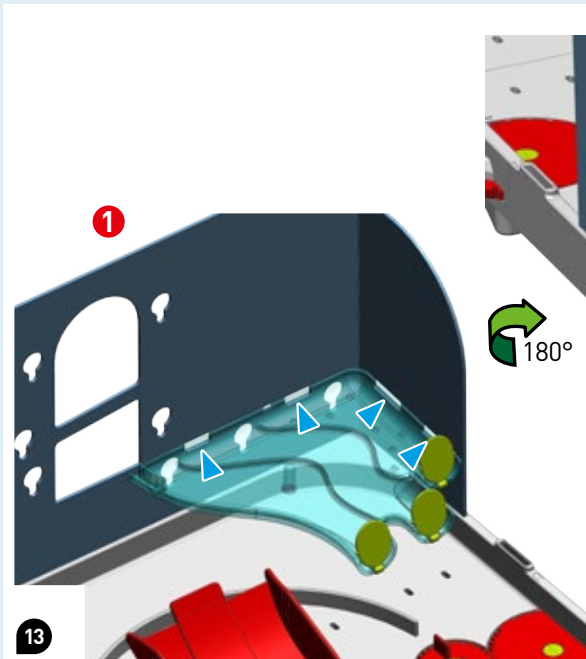
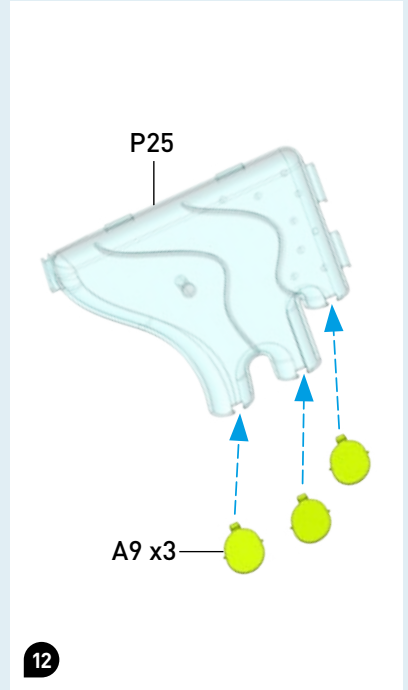
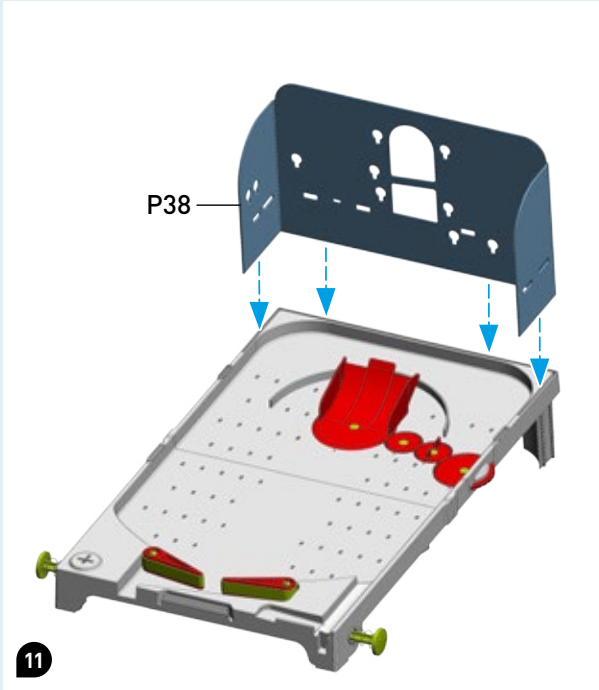
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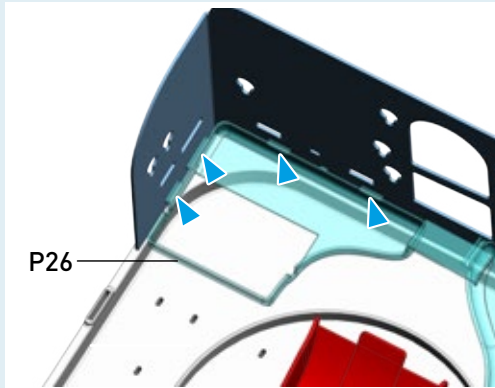
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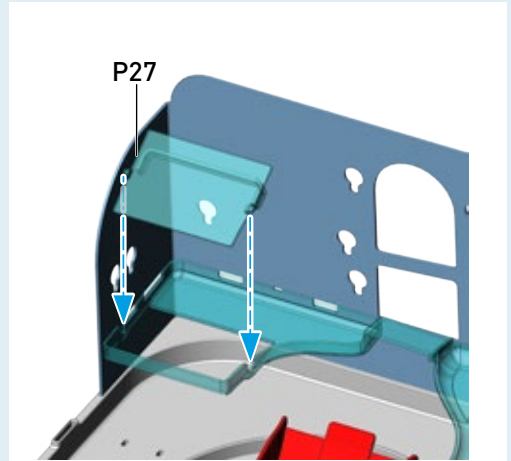
1. Insert the tabs of P25 into the cardboard backing.
2. From behind, push the tabs downward to secure the part.



P26

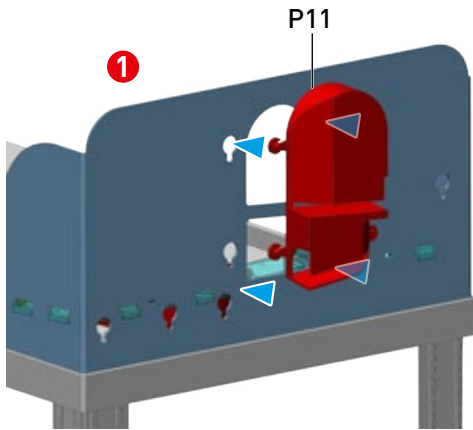
14

Insert the tabs. Then from behind, push the tabs downward to secure the part.



P27

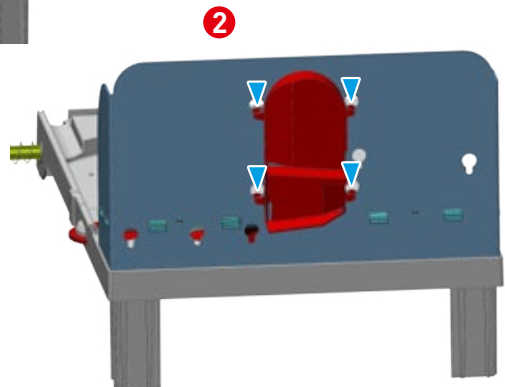
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P11

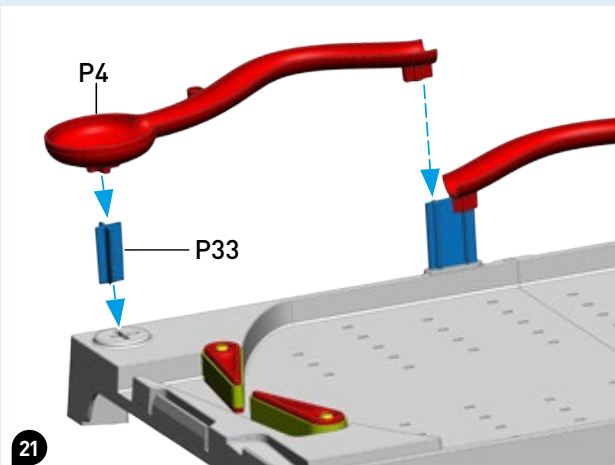
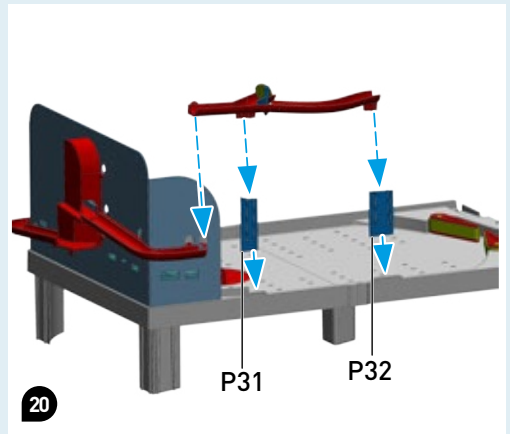
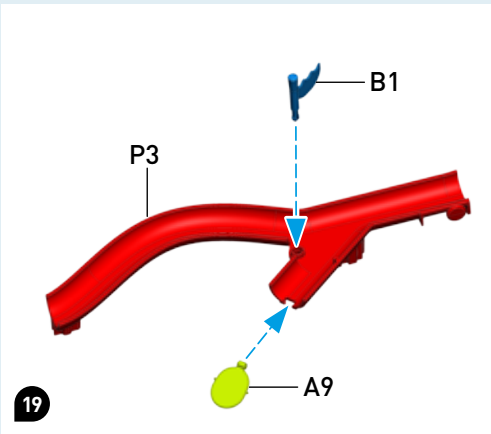
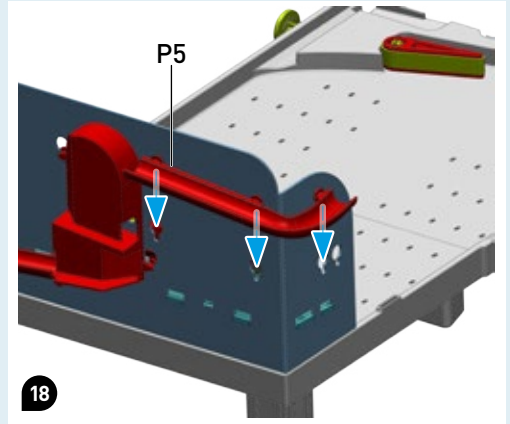
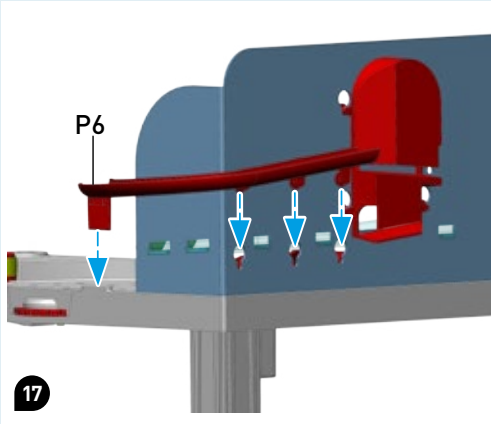
1

1. From behind, insert the tabs of P11 into the cardboard backing.
2. Push P11 downward to secure the part.



2

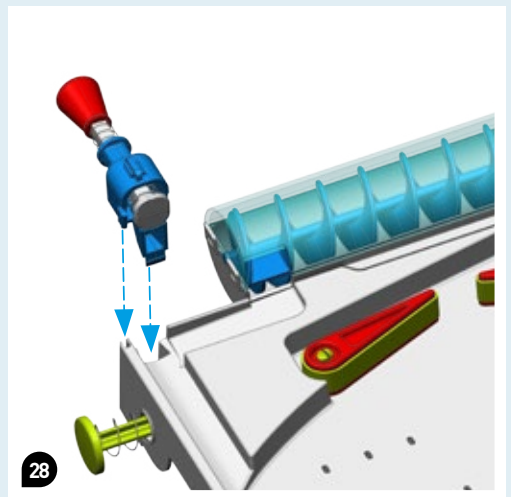
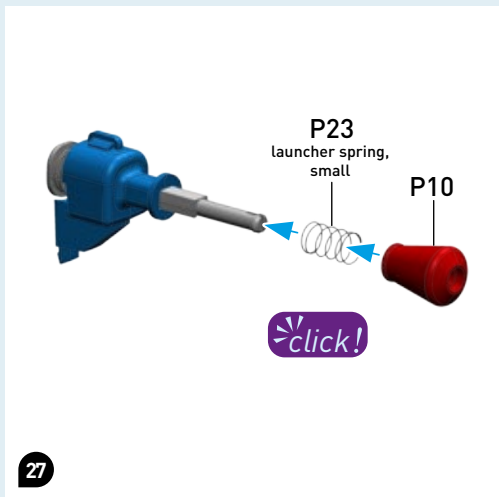
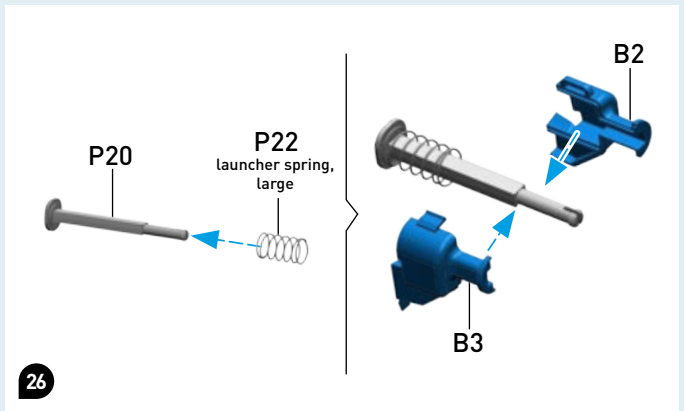
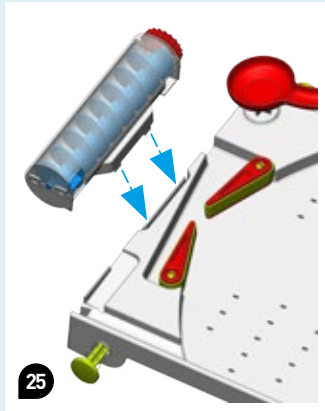
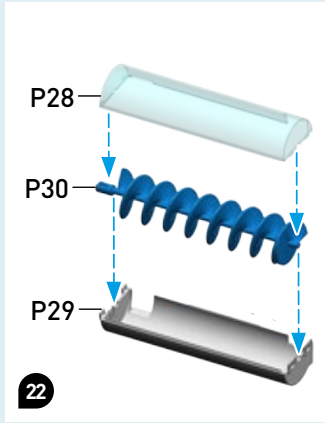
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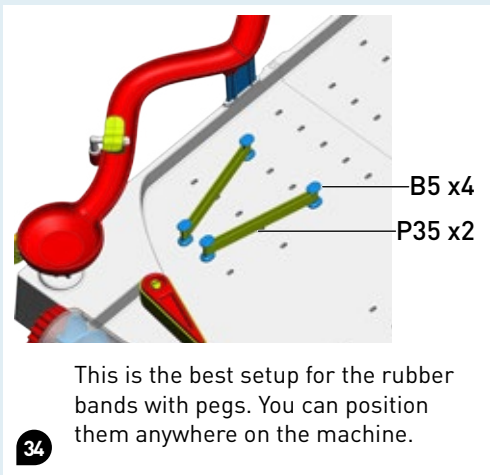
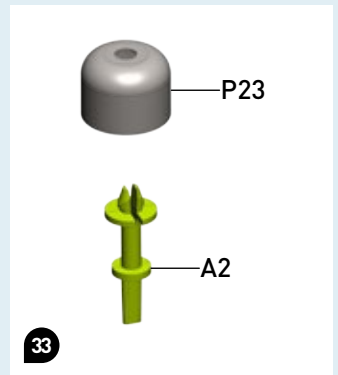
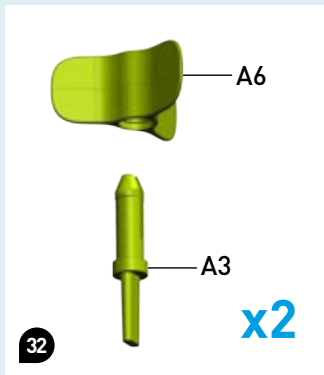
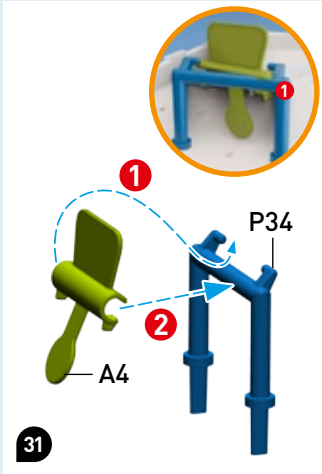
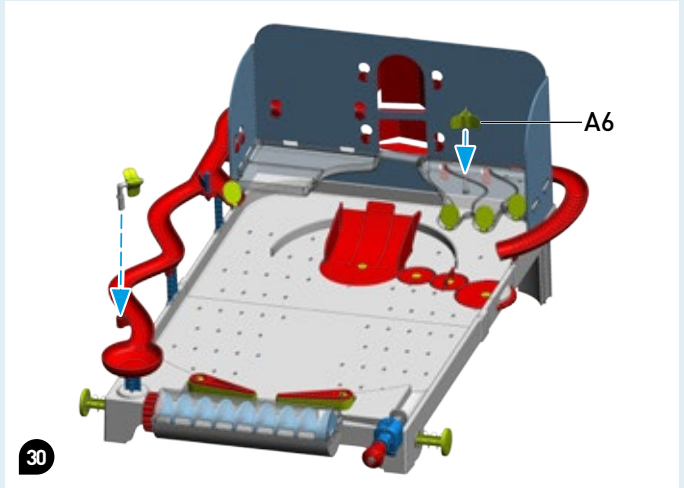
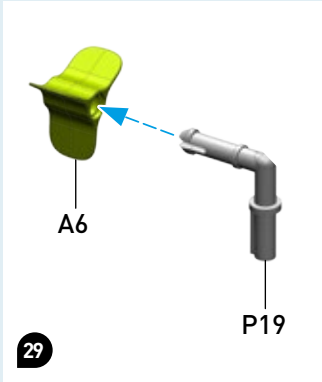


**!**

### CHECK THE TRACKS

Make sure the connections between the red tracks are smooth. After step 21, try placing a gumball by hand in the upper ball catcher area. It should roll smoothly to the winner's circle. Also place a gumball in the lower ball catcher area. It should roll smoothly and pop out onto the right side of the machine.



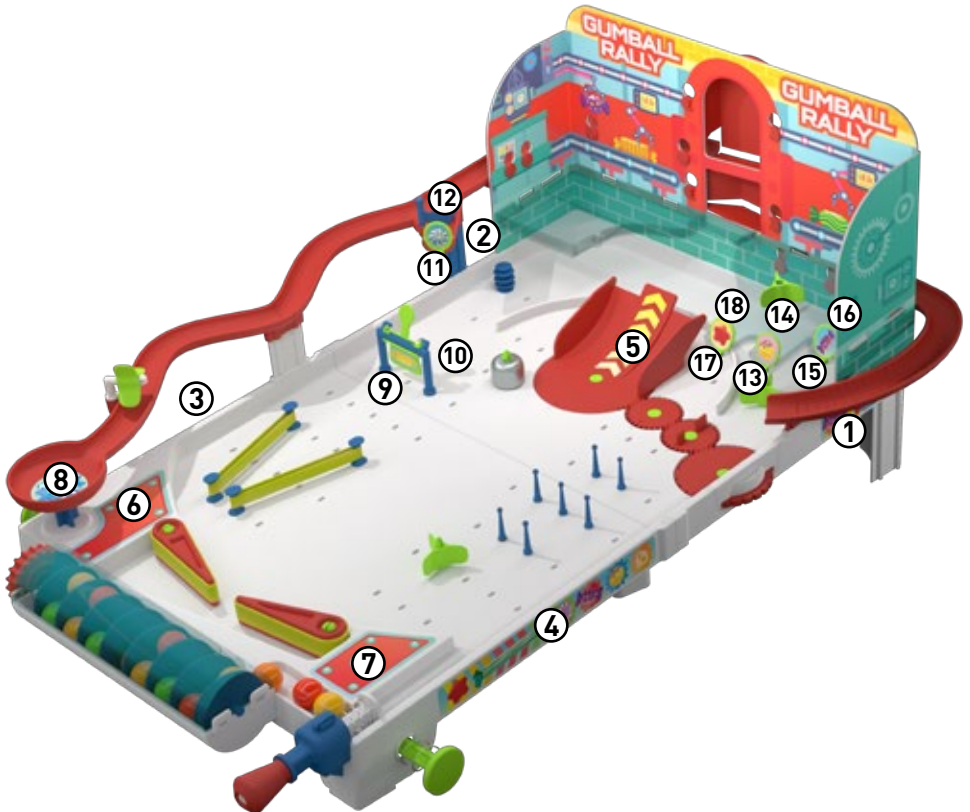
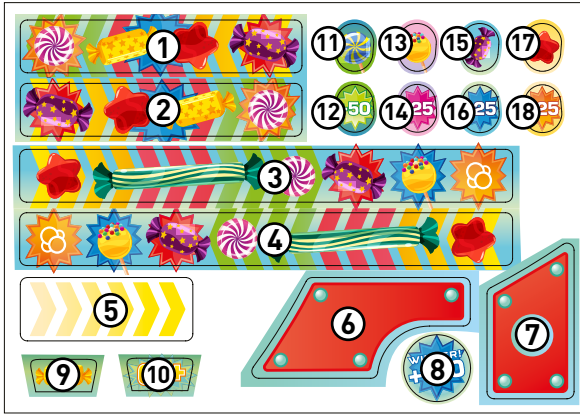


**!**

## INFINITE POSSIBILITIES

You can position the parts shown on this page anywhere on the pegboard to customize the playfield. Come up with something good? Parents: Tag us @thamesandkosmos on all social media platforms, and use the hashtag #TKpinballchamp.

# STICKER PLACEMENT





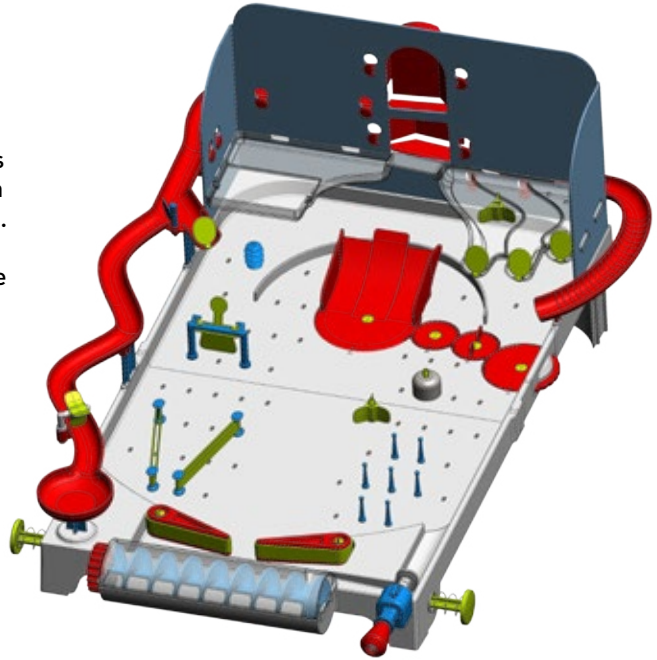


## PINBALL MACHINE SETUPS

### Experiment 1:

1. Set up the machine as shown.
2. Load some gumballs into the machine by dumping some gumballs behind the flippers, then turning the screw wheel.
3. Launch some gumballs into play, and experience the different features of the machine.

*Think about how you want to change the pegboard setup the next time you play.*



### Experiment 2:

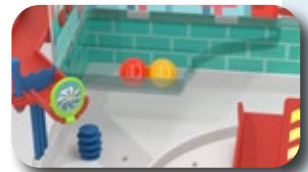
1. Set up the pieces in the playfield to slow down the gumballs as much as possible before they reach the paddles.
2. Use a stopwatch to measure your time and compete with your friends.

*Who can keep the gumballs in play the longest?*



### Experiment 3:

1. Position the ramp so it is pointing all the way to the left.
2. Try to send gumballs up the ramp onto the left upper deck.
3. After you get three gumballs onto the deck, the chaos tray will dump all three balls back onto the playfield.



*How many balls can you keep in play at the same time?*

# Pinball ENGINEERING

Your pinball machine is full of awesome mechanical elements that can help you learn different physics and engineering concepts.

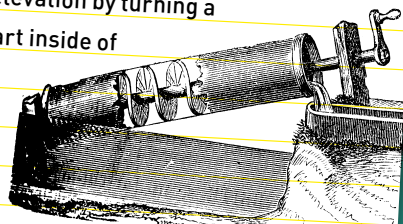


## EXPERIMENT 4

1. Put one gumball in the dispenser and turn the screw wheel slowly.
2. Put a small mark on the edge of one of the screw threads with a non-permanent marker or piece of tape and repeat step 1.
3. Turn the screw wheel slowly and watch the mark you made. While it may look like the screw is moving with the gumball, it is actually staying in place.

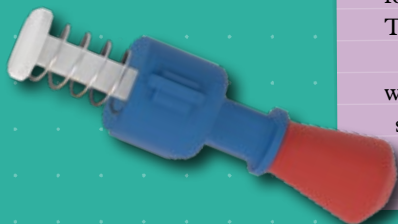
## ARCHIMEDES SCREW

The gumball dispenser is an Archimedes screw, also known as an Egyptian screw. It was invented in Egypt before the 3rd century BCE to lift water from the Nile River to irrigate crops. While it does not generate pressure like a pump, the device brought water to higher elevation by turning a screw-shaped part inside of a pipe.



## EXPERIMENT 5

1. Place a gumball in front of the launcher. Pull the cap back halfway, then release. How far and how fast did the gumball go?
2. Repeat step 1, but pull the cap back all the way then release. What do you notice?



## WHAT'S HAPPENING?

The distance that something elastic — like a spring — is stretched or compressed is **directly proportional** to the amount of force produced. This means that if the spring is compressed twice as much (for example, 2 cm instead of 1 cm) then the force produced would double.

This is commonly written as:

$$F = -kx$$

where  $F$  is the force,  $k$  is a constant specific to the particular elastic, and  $x$  is the distance of displacement.

**EXPERIMENT 6**

1. Use the flippers to send gumballs up the ramp, attempting to hit the upper ball catcher area. What do you need to do to send the gumballs higher?

**WHAT'S HAPPENING?**

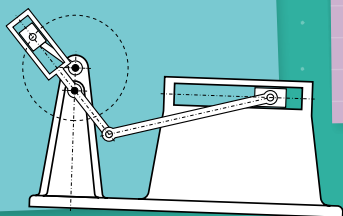
When the gumballs move up the ramp, they gain **potential energy**. That energy needs to come from somewhere, since energy is neither created or destroyed. In this case, it comes from the **kinetic energy** of the gumballs. The faster the gumballs are going at the base of the ramp, the higher they will be able to go.

**EXPERIMENT 7**

1. Push the flipper buttons inward.
2. Push the tips of the flippers up.
3. Turn the machine around so you can look closely at the linkage on the backside that activates the flippers. What do you notice?

**LINKAGES**

Linkages are important elements of many mechanical devices. They link levers together and are designed to change the direction of motion. The flippers on the pinball machine are controlled by a **three-bar linkage** with one fixed **pivot point**.

**EXPERIMENT 8**

1. Place one gumball on the chaos tray.
2. Place a second gumball on the tray.
3. Place a third gumball on the tray. What happens?

**WHAT'S HAPPENING?**

The chaos tray is designed so that the **center of gravity** is not aligned with the **fulcrum** — or pivot point. Only when there are three gumballs on the tray does the weight of the gumballs tip the tray.

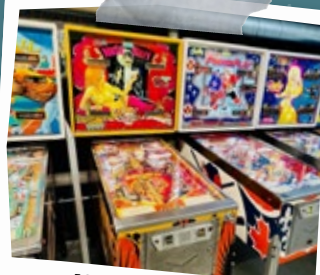




CHECK IT OUT

## Pinball Machine Technology

While new pinball machines made today use computer chips, electromagnetic pinball machines rely on the intersection between electricity and magnetism to operate. Steel balls roll on a non-conductive wooden surface. When the balls hit switches, different actions are activated. There are many types of switches, both electrical and mechanical.



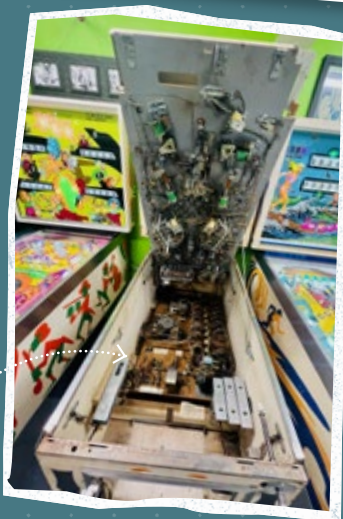
Machines in the  
Electromagnetic Pinball  
Museum in Pawtucket, RI.



### DON'T TILT!

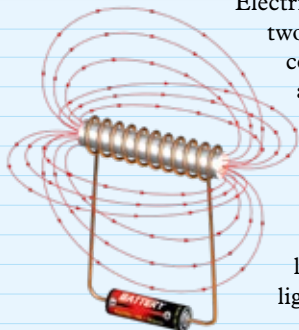
Pinball machines have built-in mechanisms that punish players who cheat by tilting the machine in their favor. The mechanism consists of a metal pendulum that hangs inside of a metal ring. If the pendulum touches the ring, it completes a circuit. Usually machines give a few warnings before shutting off power to the flipper controls.

The guts of an  
electromagnetic  
pinball machine



## What is Electromagnetism?

Electricity and magnetism are inextricably linked. They are like two sides of the same coin. Running electric current through a coil of wire — called a **solenoid** — creates a magnetic field around the coil. The reverse is also true: you can generate electricity by moving an **electromagnet** (a coil of wire around an iron core) inside of a larger magnet. In fact, that's how most of the world's electricity is generated!



In electromagnetic pinball machines, solenoids power actions like popping a ball out of a hole, ringing a bell, turning on lights, or giving more power to the flippers.



## ALL ABOUT FLIPPERS

When we think of pinball machines, we think of flippers, but the first pinball machine with flippers was not invented until 1947. The Humpty Dumpty pinball machine had six outward-facing flippers which players controlled. Flippers changed pinball from a game of chance into a game of skill, but it was too late. Pinball had been banned in the US just a year before the invention of flippers.



Flippers, along with other components of pinball machines, are powered by electromagnetic solenoids. These are meant to be activated only for a short time to avoid overheating. But since players control the flippers, what happens when they hold the flipper in the up position, like when they are trapping a ball, preparing for a targeted shot? A typical solenoid would get very hot and melt the plastic around it. So flipper solenoids are designed with two coils of wire wrapped around the same core, which create two modes: high power for sending the ball to the back of the machine, and low power for when the player holds it in the up position. The low power mode is activated at the end of the flipper's arc.



Many modern pinball machines have themes that relate to movies or other popular culture.



### Pinball banned!

Pinball was banned in the US from the late 1930s until the mid-1970s, because the machines were thought to encourage gambling. But despite raids on bars and arcades with pinball machines, the game remained popular. The ban was lifted in New York City in 1976 after a player proved in court that pinball is a game of skill by calling his shot, like Babe Ruth.

## EXPERIMENT 9

1. Vary the height of the pinball machine to change the difficulty level.
2. Remove the legs and use books to prop the back of the machine at different heights.

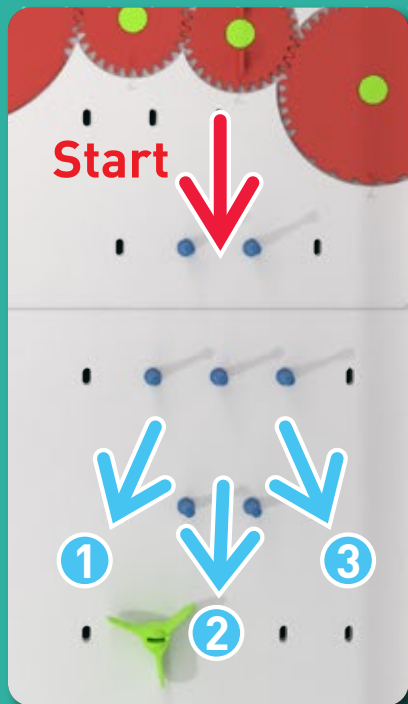


## WHAT'S HAPPENING?

Pinball machines work because of **gravity**. Typically pinball machines are inclined at a 6–7° incline toward the player. If the incline is slightly steeper, the balls will roll down faster toward the player, making it more difficult to keep the balls in play. If the incline is less steep, they will move slower and thus be a bit easier to handle.

## EXPERIMENT 10

1. Set up the blue pegs (B6) as shown on the right.
2. With your hand, place a gumball where the red arrow is.
3. Where does the ball exit (1, 2, or 3)?
4. Repeat steps 2–3 at least 10 times. Do you see a pattern emerge?



## WHAT'S HAPPENING?

The paths of the gumballs are not equally distributed between the three exits. The majority of the gumballs will pass through number 2. Fewer gumballs will pass through numbers 1 and 3. This is a miniature example of a Plinko board. Larger boards will follow a normal distribution — a bell curve with more balls falling in the middle and fewer at the edges.



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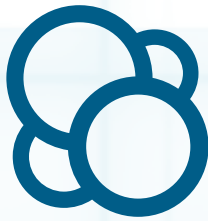
Invented by David Yakos, Streamline Design LLC  
Text and editing: Hannah Mintz and Ted McGuire  
Technical product development: Streamline Design LLC, Intex, Hong Kong  
Manual illustrations: Streamline Design LLC  
Manual photos: Jamie Duplass (all adhesive strips); Egyptian screw (p. 16), linkage and snowboarder (p. 17): Adobe Stock; tilt mechanism and electromagnetic illustration (p.18), Terminator 2 pinball, smashing pinball machine, and Humpty Dumpty (p.19): Wikipedia Commons, pinball machines (p. 18): courtesy of Electromagnetic Pinball Museum.  
Package design: Dan Freitas

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Printed in China / Imprimé en Chine



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