Fun With Machines (Level 3)

Description	Learners will learn how force, pressure, and friction work in the real world and unleash their inner engineer by creating their own Rube Goldberg machine!
Leading question	Can you build a machine that will be useful and fun?
Subjects covered	Science, Art and Design, English, Math
Total time required	40-60 minutes a day for 5 days
Resources required	Pencil, cardboard, thread, tissue/ cloth, a ball/ a pen/ any cylindrical or spherical object that rolls, balloons, a needle/ sharp object (*to be used under adult supervision*), a plastic or a glass tube, a water bottle *Alternative*: Make your own ball or cylindrical object by rolling a piece of paper and taping it securely. (See **Appendix 1**)
Learning outcomes:	By the end of this project, learners will be able to: Knowledge-Based Outcomes: 1. Distinguish between simple and compound machines. 2. Identify and differentiate between different types of force (contact, non-contact). 3. Perform various activities to demonstrate force and its effect. 4. Perform necessary tests to identify factors affecting friction. 5. Explain the ways to decrease and increase friction. 6. Explain friction as a necessary evil. 7. Explain the relationship between pressure and force. 8. Explain how liquids and gases exert pressure. 21st Century Skill Outcomes: 1. Critically think about the effect of friction on materials and how to set up a machine. 2. Creatively build a Rube Goldberg machine. 3. Communicate ideas and present the workings of the machine to an audience. 4. Collaborate will adults/ peers to improve the design and overall structure of the machine.
Previous Learning	Force and its effects on objects
Supervision required	Medium

Day 1 -

Today, you will learn about force and see an example of a Rube Goldberg machine.

Time	Activity and Description

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10 minutes

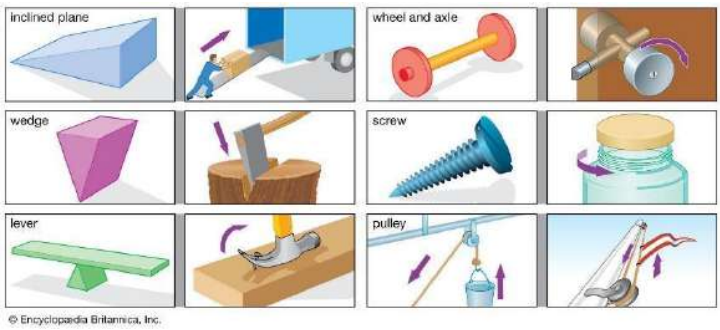
This week we are going to learn about machines.Do you know what a machine is?

A machine is something that is designed to make our work easier. Not all machines are complicated and run on batteries or power. There are different types of machines.

- They can be classified as simple machines and more complex ones called compound machines.
- Can you think of examples of each type?

- Simple machines have few or no moving parts. The moving parts are used to change the direction of movement and the amount of force required to perform a task.
- There are 6 types of simple machines: levers, pulleys, wheels and axles, screws, wedges, and inclined planes. What are two examples of these that you see in your daily life?

Note: *Explain each simple machine with examples using the images shown below.*



Compound machines are made up of two or more simple machines. Can you think of two examples of these machines that combine simple machines? (*Examples of compound machines include bicycles, wheelbarrows, scissors etc.*)

Let's take 5 minutes to explore our surroundings and identify 2 simple machines and 2 compound machines each and share what we find!

Create the table below in your notebooks and fill it out. As you observe your surroundings, think about the following:

- What is the name of the machine?
- How does it make our work easier?
- How many parts does it have? Do the parts move?
- How does it work? Does it use batteries?
- Is it a simple or compound machine?

Item	Number of parts	Type of machine

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<table>
<tr><td></td><td><table>
<tr><td>e.g. a screw/nail</td><td>2 (body and head)</td><td>Simple</td></tr>
<tr><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>10 minutes</td><td>Let’s try to create a machine using these objects – two round cuts of cardboard paper and a pencil. What do you think we can create with these items?

We can use these to create a wheel!
- What state of motion is the wheel when we do not move it? How can we make it move? (Ask a learner to move the wheel)
- What kind of action was taken to move the wheel? Can you think of another way to make it move?
- Can something move on its own? Can you think of an example?
- What makes an object move?

Note: Explain the following conceptual points to the learners:
- The wheel is initially stationary. Wheels like all machines work when force is applied.
- To move the wheel we can apply force by pushing it. We can also move it by pulling it. This push or pull that makes the wheel move or change its state of motion is called force.
- When force is applied by two different objects coming in contact, it is called as contact force. When we push the wheel on a surface, the contact from our hands pushing it creates the force that moves it.
- There are different types of contact forces including muscular force and friction. Muscular force is applied when we use our muscles to to push or pull something (like pushing a wheel). We will learn about friction tomorrow.
- Sometimes things appear to be moving on their own. Such things move because of non-contact forces. Non-contact forces occurs due to either attraction or repulsion between two objects without any contact between them. Magnetic force (attract and repel) and gravity (attract) are examples of this.
- When we drop something, it falls to the ground on its own, without any apparent push or pull. This is because of the force of gravity, which is a non-contact force.</td></tr>
<tr><td>10 minutes</td><td>Let’s create a Rube Goldberg machine. A Rube Goldberg machine is a compound machine that is designed to do something simple or silly. First, I will draw an example on the board:</td></tr>
</table>

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	Think and answer:
	- What do you think the purpose of this machine is?
	- What kind of machine is it - simple or compound?
	- A Rube Goldberg machine is a chain-reaction type of compound machine that is intentionally designed to solve a simple problem (*such as pressing a button, closing a door, dropping a bottle in a garbage bin etc*).
	- It is made up of several simple and compound machines that are connected to each other.
	- When we apply force on the first part of the machine to "start" it, the machine transfers to the next part and so on until the last part is pushed or pulled and the task is accomplished.
	- Where do we see force being applied in this machine?
	  - What is its direction?
	  - Is it a push or a pull?
	  - Is it a contact or a non-contact force?

10 minutes	Now let's create our own mini Rube Goldberg machine! - We have the following items: a small ball, a few books, cardboard, tape/ glue. You can also use the wheel we created earlier today. - What can we make with these? What would the purpose of our machine be? ***Note:*** *Allow students to attempt arranging the items to create the machine. If they are unable to, walk them through the process:* 1. *You will create a basic machine that throws items in the garbage bin for us.* 2. *Stack and place the books on a table.* 3. *Tape/ glue the cardboard to the side of the stack of books so that it forms an incline as shown in the figure below.* 4. *Place the item you want to discard in front of this setup.* 5. *When you are ready to "start" the machine, roll the ball or wheel you made down the incline so that it knocks off the item into the garbage bin below.*

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	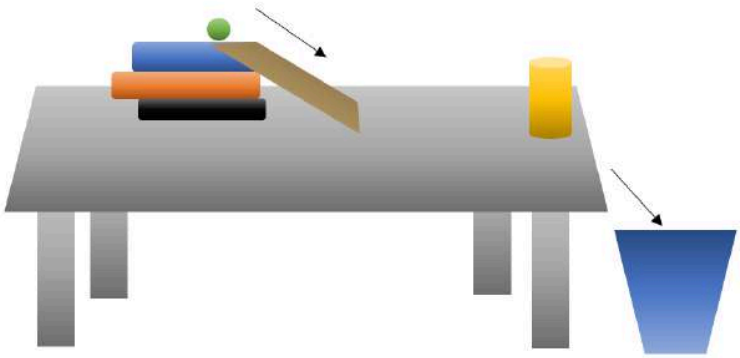 ***Note:*** *you can see another example of a Rube Goldberg machine in* ***Appendix 2****.*
At-home activities	Reflect on what you learned in class by answering the following questions: - What types of simple machines did you notice? - What kinds of force did you notice? - What went well with the machine? - What did you find challenging? - If you were creating your own machine, what would you do differently?

Optional Literacy/ Numeracy Activity	- Read the following story and discuss in groups: https://storyweaver.org.in/stories/11024-ammachi-kee-gazab-masheenein?mode=read
	- You can also listen to a read-along here: https://www.youtube.com/watch?v=-b3QhyUX2C0
	  - What did Sooraj want Ammachi to make?
	  - What are the steps involved in making this dessert?
	  - What machines did Ammachi and Sooraj use to make it?
	  - Can you draw the steps and machines side by side?

Day 2

Today, you will design your machines and understand the concepts of force and friction.

Time	Activity and Description
15 minutes	Today you will design your own Rube Goldberg machine! The Rube Goldberg machine must meet the following criteria: - It must include at least 3 types of simple machines: levers, pulleys, wheels, inclined planes etc. - It must have at least 10 parts. - It must solve a problem at the end – like ringing a bell, pushing a button etc. Think about the type and purpose of the machine you want to make and draw it in your notebooks or on a piece of paper using a pencil. Examples:

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	- A machine to put sugar in tea is made up of a small ball, a few wooden sticks, a packet containing sugar and a cup with tea at the bottom. - A machine to pop a balloon made of a small ball, a toy car with a pin attached, wooden sticks and a balloon at the end. ***Note:*** *After drawing the machine, discuss:* - What is the purpose of your machine? - What is making it easier for you to do? What problem is it solving? - What items will you need to create your Rube Goldberg machine you have drawn?
15 minutes	So, when you designed your Rube Goldberg machine, did you keep in mind how the speed of the object in motion gradually decreases as it comes to a halt? - What causes a change in their state of motion? - The force responsible for changing the state of motion in this case is **friction**. Let's see this in action! Take a ball/ tube/ pen/ water bottle or any cylindrical or spherical object and play the following game: 1. Mark the starting point where you will push the object with a pencil as X. 2. Push it gently on a table to roll it then mark where it stops as Y 3. Now roll it gently using the same force on a different surface (*e.g. cloth, tissue etc.*) but make sure you hold this surface down so it doesn't move. 4. Now mark where the object lands. On which surface did it travel the fastest? On which surface did it travel the farthest? Why do you think this is the case? - **Friction** is what causes the object to stop moving after a while. - Which surface resisted the motion of the ball more? - The ball experienced more resistance or friction when it was rolled on a rough surface. - We can increase friction acting on objects when we use rough surfaces or decrease friction when we use smoother surfaces. Now play a game again and try to get the object from point X to Y the fastest on both surfaces. - Do you notice that you use more muscular force when pushing the object on the rougher surface? - Does it take more effort to move a moving object or an object that isn't moving? Try it with your ball/ pen/ cylindrical object and share! *(depends on the direction of the motion and the force applied)* You should notice that it takes more effort to move an object when it is not moving. The friction that acts on stationery objects by the surface they are placed on is called **static friction**.

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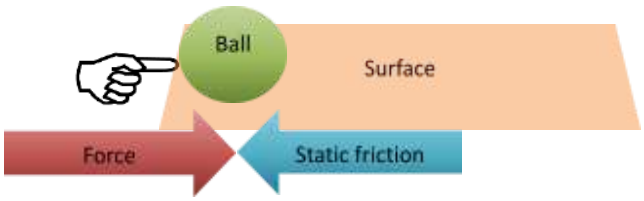
	When we slide an object over a surface, **sliding friction** comes into play. Can you think of any examples where sliding friction is acting? Another type of friction is **rolling friction**. The activity you did just now is an example of rolling friction. What do you think is the direction of friction? If I push a ball to the right, the contact force moves it to the right, but friction moves in the opposite direction to the left. Friction always acts in the direction opposite to the direction of the overall force acting on an object.
10 minutes	In the drawing of your machine that you made at the beginning of the class, mark the following: - Contact force - Non-contact force - Muscular force - Types of friction - Arrows indicating the direction in which force and friction are moving. For example in our ball activity, we would draw them like this:  After marking the force and friction, reflect on the following questions: - Do you feel confident about your drawing? - Do you think your machine will work as designed?
At-home activities	Collect items you will need for the machine from your house and bring them to class to assemble your Rube Goldberg Machine!
Optional Literacy Activity	Friction is helpful because it helps us walk and do many things. If there wasn't any friction, we would just be gliding very fast on any surface! We can also warm ourselves when we rub our hands together because of friction. Imagine a world without friction. What would this world look like? Write a paragraph about it. Be creative!

Day 3 –

Today, you will assemble your machines, learn the concept of pressure, and apply it to your machine.

Time	Activity and Description
10 minutes	Today we will assemble our machines! - First, let's write down the steps involved in putting our machine together. - Gather all the objects you brought from your house and write down what type of machine it is and what part it plays in your machine.

<table>
<tr><td></td><td>
- You can use any of these items or you can create some objects out of paper if needed as alternatives.
- List out the items and what they should do.

Note: *Provide learners with a format, such as the one shown below, to help them* organise *their thoughts:*

<table>
<tr><th>Item</th><th>Machine type</th><th>What does it do?</th></tr>
<tr><td>1. Ruler</td><td>Inclined plane</td><td>Taped to a book so it can be used to roll the ball</td></tr>
<tr><td>2. Toy car, coin or pencil</td><td>Wheel</td><td>Roll down the ruler and hit the playing cards</td></tr>
<tr><td>3. Playing cards, dominoes or blocks</td><td>(not a machine)</td><td>Fall one by one and hit the next object etc.</td></tr>
</table>
</td></tr>
<tr><td>15 minutes</td><td>Now that you know all the steps involved, assemble your machine.

Tip: Support learners if they need any help while assembling the machine.</td></tr>
<tr><td>15 minutes</td><td>Now that our machine is ready, let us learn the concept of pressure and apply it to our machine.
- What is the meaning of the word ‘pressure’?
- Will I burst a balloon if I poke it with my finger?
- Will I burst a balloon if I poke it with a needle?
- Why do you think this happens?

When a balloon is poked by a needle, more pressure is exerted by the needle than my finger and it will deflate.

Pressure is the force applied per unit area.
Which object do you think exerts more force – the needle or my finger?

The strength of force applied is called the **magnitude of force**.
- The more force we apply to an area, the greater the pressure created.
- Let us try this out with our machine and note down our observations in the table given below.

Note: *Ask learners to create the table. They can then experiment with force and note their observation in the table.*

<table>
<tr><td>Event</td><td>Force (type)</td><td>Magnitude of force (high/low)</td><td>Friction (type)</td><td>Pressure (high/low)</td></tr>
</table>
</td></tr>
</table>

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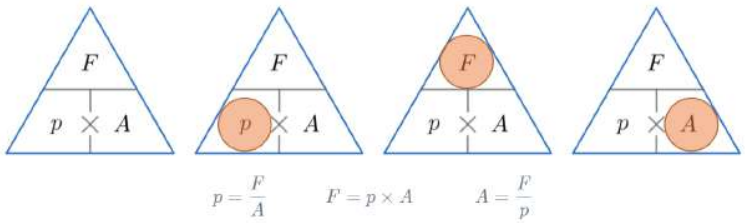
	<table><tr><td>E.g. the ball rolls down the ruler</td><td>Contact force</td><td>Low</td><td>Rolling friction</td><td>Low</td></tr><tr><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td></tr></table>
At-home activities	- Identify 3 examples of pressure in everyday life. E.g. hitting a nail with a hammer. - Ask family or friends to share feedback on the machine you create. - Make changes suggested (if any).
Optional Literacy/Numeracy Activity	Literacy activity: - We know that in science, pressure is when force is applied to an area, but pressure also has other meanings. Have you ever felt pressured to do something by someone? Or felt pressured by exams or any challenges you are facing? Write an essay about 3 things that make you feel pressured and 3 ways you can cope with this. Exchange your essay with your partner in class and discuss how you can use these tips next time you feel that way. Numeracy activities: - The formula for pressure is as follows: pressure = force ÷ area on which the force acts. Based on this formula, what are two ways we can increase pressure? (Hint: what should we do to the number in the numerator – force – and the number in the denominator – area?)  $p = \frac{F}{A}$ $F = p \times A$ $A = \frac{F}{p}$ - How can we calculate force from this equation? (Answer: force = pressure x area) - If a force of 200 Newtons or N (the unit for measuring force) is applied on an area of 5 square meters (m^2), can you calculate how much pressure is applied on the area? - The unit for measuring pressure is Newton per square meter or (N/m^2). A child is applying pressure of 90 N/m^2 on a ball with his hand. The area of his hand is 0.01 m^2. How much force is the child applying?

Day 4 –

Today, you will learn how liquids and gases exert pressure and use them to improve your machine.

Time	Activity and Description

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<table>
<tr>
<td>10 minutes</td>
<td>
We learned about pressure from contact force. Do you think liquids and gasses also exert pressure? Why or why not?
Let’s do some experiments to investigate this.

Note: In the case of only 1 learner, the learner can pick any one experiment to do in class and the second one can be done as homework.

Let’s divide the class into two groups – one group will do the balloon experiment and the other will do the water bottle experiment.

Note: Before experimenting, ask learners to write down their hypothesis (what you think will happen) in the table below and after the experiment, ask them to write down the observations and inferences.

<table>
<tr><td>Hypothesis:</td><td></td></tr>
<tr><td>Materials Needed:</td><td></td></tr>
<tr><td>Method:</td><td></td></tr>
<tr><td>Observations:</td><td></td></tr>
<tr><td>Inferences:</td><td></td></tr>
</table>

Experiment 1: Balloon experiment:
1. Place a balloon at the bottom of a tube or any hollow cylindrical object.
2. Write down your hypothesis for what you think will happen when we fill the glass tube with water.
3. Fill it with water and observe. What happens to the balloon when we reduce and increase the amount of water in the tube?
4. Write down your observation and conclusion.

Experiment 2: Water bottle experiment:
1. Take a plastic water bottle and poke four holes around a few centimetres from the bottom of the bottle using a needle or sharp object.
2. Measure the length of the holes to make sure that all holes are the same distance from the bottom.
3. Place a tray or bowl underneath the bottle.
4. Write down your hypothesis for what you think will happen when we fill it with water.
5. Fill the bottle with water and write down your observations and conclusions
</td>
</tr>
<tr>
<td>10 minutes</td>
<td>
Discussion
- What have you concluded about liquids and pressure?
</td>
</tr>
</table>

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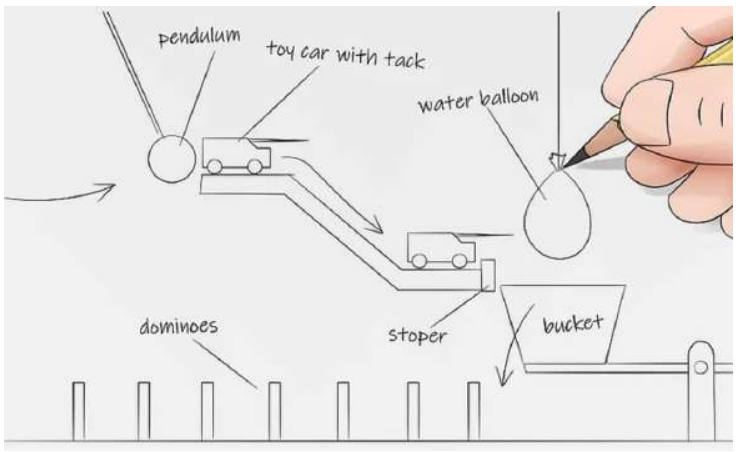
	- We see that in the balloon experiment, liquid applies pressure that causes the balloon to expand. The more water we use the more pressure that is exerted on the balloon. - Do you think gas also exerts pressure? - When we blow air into the balloon, it expands, which shows that gas also exerts pressure. - Try it by blowing air into the balloon! - What would happen if the balloon had holes in it? - Many gasses exert pressure. The gasses in our atmosphere also exert pressure called **atmospheric pressure.** - In the water bottle experiment, we see that when we create holes that are at the same depth, water pours out of the bottle in an equal force through all the holes. Did you notice that the water came out at an equal distance on the tray through each hole? - What is the area on which liquids and gasses exert pressure? Liquids and gasses exert pressure on the **walls of their containers** (i.e. inner wall of water bottles, balloons, tubes etc.)
20 minutes	Now that you know how liquids and gases can apply force and exert pressure on objects, think about how you can incorporate them in your machine. You can have an outcome related to air or water (for example, the purpose of the machine can be to pour water into a glass) or they can help move objects along the machine to achieve the final result. An example of how water can be used is shown below:  You can spend the rest of your time working on finalizing and testing your machine for your presentation! Make sure to test it a few times so that it works properly tomorrow when you are presenting it.
At-home activities	Try to create a Rube Goldberg machine to do something in your home. It can be something useful in the kitchen or something useful to help elders at home.

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Optional Literacy Activity	Do you remember the story of Ammachi we read a few days ago? Now that you know how a machine works, use the story to design your own machine to help you cook your favourite dish: - Re-read the story and go back to your notes to remind yourself of the steps Ammachi and Sooraj took to make the dish - Ask your parents or adults to find out the steps involved in making the dish and write them down - Think about the machines you will need to make this dish and draw them side by side with the steps - Now rewrite the story replacing the old dish with the new one and share it with your class and family

Day 5 -

Today, you will present your machine to your friends and family.

Time	Activity and Description
30 minutes	***Note:*** *Ask learners to set up their machines, turn them on, explain how they run and answer audience questions.* Each presentation must explain the following: - The purpose of the machine - How it works - The simple machines it contains - How force is applied during each part (type and magnitude of force) - How pressure is exerted and on what areas - The kinds of friction observed
10 minutes	***Note:*** *Celebrate the efforts put in by learners and ask them to reflect on the following questions:* - What went well? - What was challenging? Why? - What would you do differently? - Do you feel confident in building machines now? - Was it easy or difficult? - What did you enjoy the most about this project?

Additional enrichment activities:	- Learners can build a barometer to better understand atmospheric pressure:
	  - A barometer is a device that helps us measure air pressure which is useful in predicting the weather
	  - To create a barometer, we will need a glass jar or tin can, a balloon, scissors, a drinking straw, rubber bands
	  - Take the glass jar or tin can and place a balloon on its mouth. Make sure the balloon covers the mouth of the jar tightly using rubber bands so that no air escapes the jar or tin can

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	- Tape the straw on top of the balloon lid - Place a piece of paper on a wall or firm surface and tape it secure and place the barometer in front of it on the ground. Make sure that the barometer is placed outdoors in a place that receives wind but is away from direct sunlight  - Mark the area where the straw touches the paper - Come back the next day and see if the straw moved. Mark the new area where the straw touches the paper - Why do you think this happens? When the pressure of the air outside the jar is lower than the pressure inside the jar, the air inside the jar pushes the balloon up and pushes the straw down. When the outside air has more pressure than the air inside the jar, then the air outside the jar pushes down the balloon causing the straw to point down. - Changes in air pressure are critical to understanding and predicting weather changes
Modifications for simplification	- To simplify the project, focus on the main outcomes – types of force, types of friction, and pressure. Eliminate simple machines and additional numeracy activities (calculation of force and pressure). - Reduce the criteria for the final product (Rube Goldberg machine) to a basic machine that has a total of 6 parts and 2 simple machines.

ASSESSMENT CRITERIA

A majority of my learners were able to:

☐ Distinguish between simple and compound machines
☐ Identify and differentiate between different types of force (contact, non-contact).
☐ Explain the ways to reduce and increase friction and explain the importance of friction.
☐ Explain the relationship between pressure and force.
☐ Understand the pressure exerted by liquid and gas.
☐ Create a machine that:
- Included at least 3 types of simple machines

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- Has at least 10 parts
- Solves a problem at the end

APPENDIX 1

Create your own ball:

1. In a bowl, shred scrap paper into very small pieces and soak in water for 15 minutes
2. Add water-soluble glue or make your own paste using flour, sugar, salt and water
3. Mix the pieces of paper with glue and drain the water completely
4. Create a ball using the wet paper pieces after pressing hard to remove all water
5. Leave it for a few hours to dry or put it in a microwave or oven to speed up the process
6. You can use it as it is when it is dry or you can use sandpaper or any rough surface to smooth it out




Create your own cylinder:

1. Take a sheet of paper and place it on a surface like a table
2. Roll the bottom side into the sheet moving upwards as shown in the picture below to make a cylinder
3. Tape or glue it to make sure it doesn't unravel

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APPENDIX 2

Rube Goldberg example: A balloon popping machine: this machine features a ball that goes through several inclined planes hitting a fan and entering a funnel along the way to pop a balloon. The balloon is popped when the ball enters a cup attached to a spoon that is placed next to an object with a needle. When the ball enters the cup, the cup rattles and the spoon touches the object, prompting it to roll down the final inclined plane and pop the balloon that is placed at the end of the inclined plane.

Source: https://lcnme.com/school/jefferson-students-design-rube-goldberg-machines/

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