South Dakota State University Extension

South Dakota 4-H STEM Challenge

2025 Challenge Packet

Photos courtesy of SDSU Department of Ag and Biosystems Engineering

Table of Contents

Challenge Overview

The South Dakota 4-H STEM Challenge is an opportunity for youth to apply their knowledge of science, technology, engineering and math to build a complex machine designed to perform a simple task, similar to a Rube Goldberg™ type machine. The challenge encourages creativity, collaboration, communication and critical thinking in young people.

Event Location

The event will be held Friday August 29, 2025, on the South Dakota State Fairgrounds, Huron, SD. The challenge will be held in the Nordby Exhibit Hall on the State Fair Grounds.

Eligibility

1. Team registration is taken on a first-come-first-serve basis through **August 12, 2025**. This registration deadline will be strictly enforced.
2. Teams **must have at least two** members with a **max of 3**.
3. Teams may consist of youth from different counties.
4. All participants must be actively enrolled in 4-H and at least 8 years of age by January 1, 2024, but not have turned 19 years old prior to January 1, 2024.

Schedule

Schedule is tentative and subject to change

10:30 a.m.-12:00 p.m. Teams will check in and begin set up and testing of their machines. Teams can arrive at any time during this period and are not required to remain at their machines the whole time. However, machine set up should be completed by the youth and not coaches or parents.

1:00-4:00 p.m. Team judging*

*Teams will be present at their projects for the entirety of this time. This will allow them to share their projects with the public while waiting for the judges.

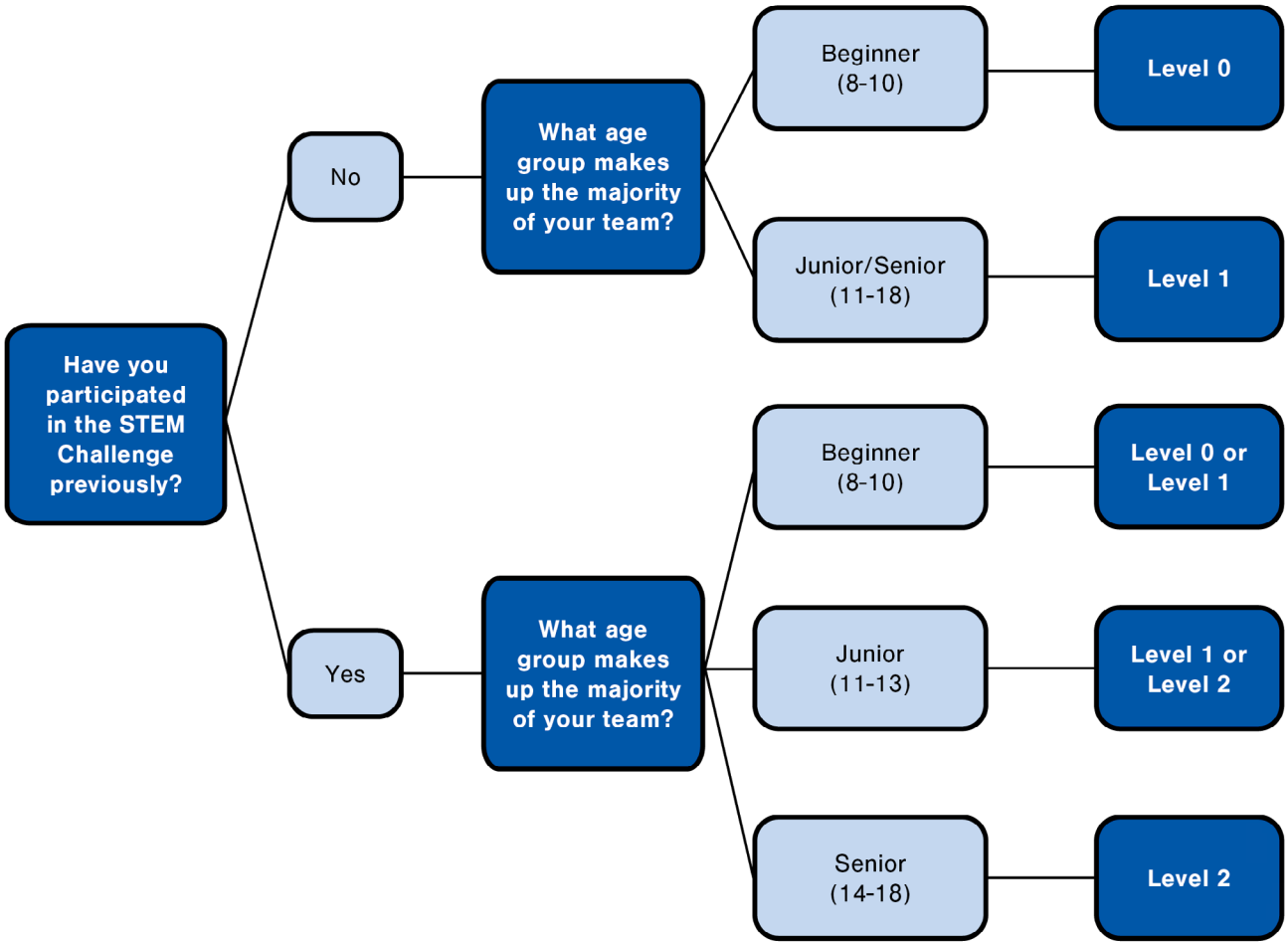
Challenge Task Guidelines

The theme of the 2025 South Dakota 4-H STEM Challenge is Aerospace Engineering

Teams will:

- Develop a machine meeting given specifications using the Engineering Design process.
  - Teams building a Level 0 Machine will employ physics, engineering, and storytelling to create a machine that can accomplish a task.
  - Teams building both Level 1 and Level 2 Machines will employ physics, engineering, and storytelling to create a Rube Goldberg™ type machine.
    - A Rube Goldberg™ machine is an overly complex contraption that does a simple task and uses everyday items in a fun or amusing way. The machine uses a series of chain-reaction steps that culminate in accomplishing a task. This requires understanding simple machines and the use of motion to transfer energy from one step to the next.
- Record the development process in an engineering notebook (Appendix A).
- Create a story that fits their machine and the overall theme of the challenge (Appendix B).
- Develop a presentation (2-3 min) to share their design process and their machine's story (Appendix B).

Choosing appropriate challenge level



*Note: While the above graphic can provide guidance on selecting the level at which to enter, teams may choose to enter any level.

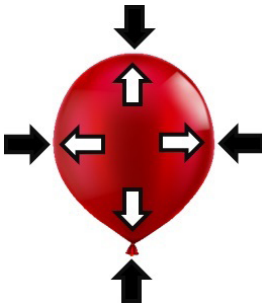
Level 0 Machine

The Level 0 Machine introduces youth to STEM principles and engineering design concepts as they act as Aerospace Engineers to accomplish a designated task.

STEM Concepts to Understand

- **Newton's First Law of Motion:** an object at rest will stay at rest unless acted upon by an unbalanced force.
- **Newton's Second Law of Motion:** acceleration is produced when unbalanced forces act upon an object.
- **Newton's Third Law of Motion:** for every action there is an equal and opposite reaction.

To demonstrate these laws, let's think about a balloon!

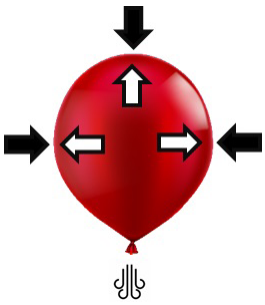


This balloon demonstrates the First and Third Laws of Motion. In order to hold its shape, the air pressure on the outside must be equal to that on the inside; these are the action and reaction pairs. Since the action and reaction pairs are equal, they keep the balloon at rest. These balanced forces are indicated by the force vectors (arrows).

If you were to untie the balloon, how would that change the forces inside and outside the balloon? Would they still be balanced?

Can you draw force vectors to indicate what would happen if you untied the balloon?

Let's see what will happen in real life. Take two balloons. Blow one up and have a team-mate blow up another. Tie one but leave the other untied. At the same time, release both balloons. What happened? Is it what you predicted would happen?



When the balloon is opened, the forces become unbalanced. There is no longer a force holding the air inside the balloon. The release of air causes the balloon to accelerate, demonstrating the Second Law of Motion.

These unbalanced forces are similar to those that make a rocket ship move. Gas in the rocket pushes up on the rocket and the rocket pushes the gas down and out. It is the job of aerospace engineers to design the best size and shape of rocket to produce the desired unbalanced forces.

The Challenge

You have been hired by NASA to design and construct a rocket that is capable of carrying important cargo to the international space station. It is critical that your rocket is able to make it to the space station, but not go past it as it cannot be retrieved beyond the space station. Not only will your design be evaluated on its ability to arrive at the space station, but it will also be evaluated on its complexity (use at least 5 different materials, not counting the balloon). Use the following worksheet to keep track of your design process and what materials used.

Suggested Materials: Various sizes and shapes of balloons, cardboard rolls, paper clips, binder clips, straws, rubber bands, construction paper, glue sticks, scotch tape

Set Up Needed: Attach two, 8 ft pieces of fishing line horizontally between two sturdy surfaces. Indicate the space station location 6 ft from starting point (Earth) using a paper plate or something similar (see Figure 1).

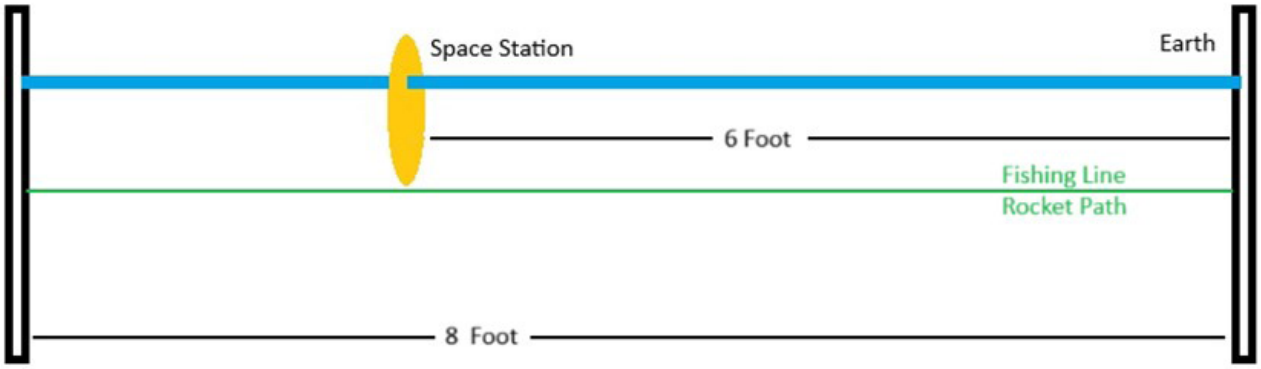


Figure 1: Level 0 Aerospace Engineer Challenge Set Up

South Dakota 4-H STEM Challenge – Level 0 Worksheet

Team Members: _____

Identify – The challenge is to use a balloon to move a rocket along an 8 ft string. The rocket needs to be made of at least 5 different parts. What might be some things that will make this challenge hard?

_____

_____

_____

_____

Explore – What are some supplies that could be helpful in building your balloon rocket?

_____

_____

_____

_____

Design – Use the space below to sketch what your rocket will look like.

Create – Attach a picture of your rocket

Test – Test and record the results of your design. Some information you might want to record includes: Did it stay on the fishing line? How far did it fly? Did it make it to the space station? If not, did it get stuck before the station or fly past it? Did the rocket stay in one piece, or did it break? How big did you blow up the balloon?

Improvements – Brainstorm what improvements you would like to make to the rocket and what you think should stay the same. Write them down below and use them when you restart the Engineering Design Method the next time you meet to design and create your rocket!

*The Level 0 Machine serves as the basis for the Level 1 and Level 2 Machines.

Level 1 Machine

Before building the Level 1 Machine, teams must build the Level 0 Machine. The Level 0 Machine should be utilized as the first step of the Level 1 Machine.

The Level 1 machine is a 5 step Rube GoldbergTM type of machine that pushes a button. The button type and purpose are part of the team's design and story and therefore will vary from team to team.

- Completion of the task is NOT a step. There should be a minimum of 5 steps leading up to this task. (see Appendix C for information on steps).
  - The first step must be the Level 0 Machine.
  - One step must be a mechanical engineering (simple machine) step.
- Completion is scored based on how well the machine operates under specific constraints as well as human interventions. Human interventions include any assistance the machine requires (not including its start) to complete the task. For example, if a step does not trigger the next step youth can step in to start the next step.

Level 1 Machine Specifications

Specification	Requirement/limitation
Complete the Official Task	Required
Safe for participants and observers	Required
Written list of all steps in your machine	Required
Number of steps	Minimum: 5 Maximum: 15
Machine must follow the theme and solve the task	Required
Physical size of the machine	Maximum: 4 ft x 8 ft x 6 ft; width x length x height
Single run time to complete the task	Minimum: None; Maximum: 5 minutes
Reset time (time required to set your machine up again)	Maximum: 15 minutes
Objects flying beyond machine boundaries	Not allowed
Corporate logos	Allowed with written permission from the logo owner. (Ensure the 4-H clover is present on the machine)
Use of: • live animals • Hazardous (toxic, noxious, dangerous) materials, explosives, or flames • Combustion engines • Use of profane, indecent, or lewd expressions, offensive symbols or graphics • Use of air compressors • Use of AC or DC power cords running to the machine	Not allowed

Level 2 Machine

Before building the Level 2 Machine, teams must build the Level 0 Machine. The Level 0 Machine should be utilized as the first step of the Level 2 Machine.

The Level 2 machine is a 7 step Rube Goldberg™ type of machine that pushes a button. The button type and purpose is part of the team's design and story and therefore will vary from team to team.

- Completion of the task is NOT a step. There should be a minimum of 7 steps leading up to this task (see Appendix C for information on steps).
  - The first step must be the Level 0 Machine.
  - Two steps must be a mechanical engineering (simple machine) step.
  - One of the steps must be an electrical engineering step.
- Completion is scored based on how well the machine operates under specific constraints as well as human interventions. Human interventions include any assistance the machine requires (not including its start) to complete the task. For example, if a step does not trigger the next stem youth can step in to start the next step.

Level 2 Machine Specifications

Specification	Requirement/limitation
Complete the Official Task	Required
Safe for participants and observers	Required
Written list of all steps in your machine	Required
Number of steps	Minimum: 7; Maximum: 17
Machine must follow the theme and solve the task	Required
Physical size of the machine	Maximum: 4 ft x 8 ft x 6 ft; width x length x height
Single run time to complete the task	Minimum: None; Maximum: 5 minutes
Reset time (time required to set your machine up again)	Maximum: 15 minutes
Objects flying beyond machine boundaries	Not allowed
Corporate logos	Allowed with written permission from the logo owner. (Ensure the 4-H clover is present on the machine)
Use of: • live animals • Hazardous (toxic, noxious, dangerous) materials, explosives, or flames • Combustion engines • Use of profane, indecent, or lewd expressions, offensive symbols or graphics • Use of air compressors • Use of AC or DC power cords running to the machine	Not allowed

Appendix A: Team Notebook

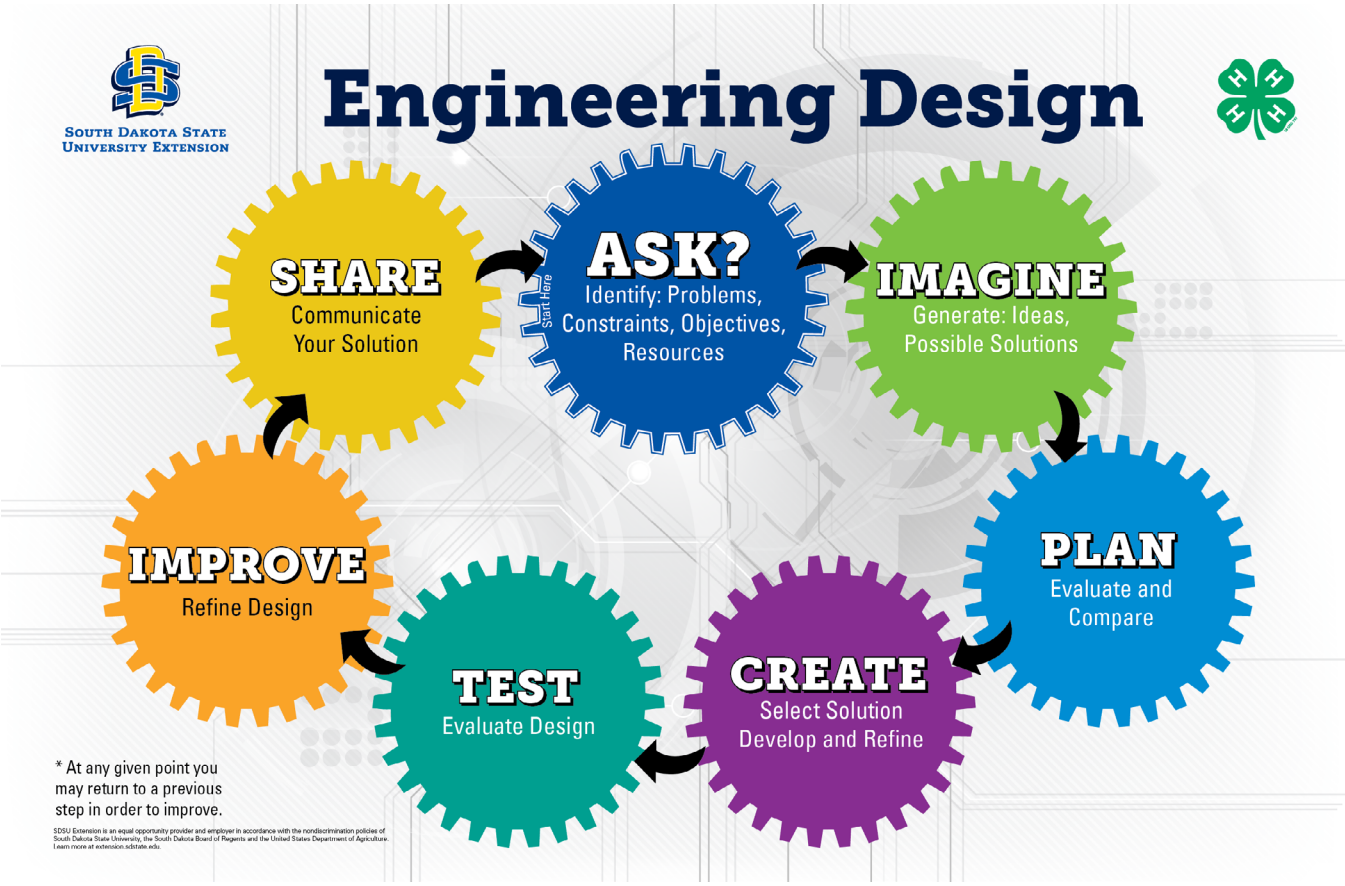
As teams work to design and build their machine, they should be diligently documenting their progress in a **Team Notebook.**

- Each team needs to keep a written team notebook to document the team's work, including research, successes, setbacks and progress.
- It serves as a record of the team's ideas and accomplishments throughout the process of designing and building the machine.
- The notebook is a means of reflecting on what they learned and accomplished each time they met, and how the engineering design process guided the team's work.

Engineering Design Process

Teams are required to use this process to help guide the machine planning and creation. **Teams are required to use the Design Process throughout creating their machine and be able to explain how they did so.**

1. **Ask:** Define the challenge objectives, constraints, and resources.
2. **Imagine:** Information gathering/idea generation.
3. **Plan:** Make a plan.
4. **Create:** Begin constructing and refining design.
5. **Test:** What works and what needs improved.
6. **Improve:** Redesign.
7. **Share:** Participate in the State 4-H STEM Challenge.



Notebook Tips and Suggestions

- The notebook can be a spiral-bound school notebook, a three-ring binder with loose-leaf sheets, a bound book with blank pages or an electronic notebook in a computer file.
- Should be accessible to all the team members and everyone should have the opportunity to make entries and record information.
- A useful notebook contains both writing and drawings as a way of capturing ideas and figuring out how to make the machine work. If an idea is not used or if something does not work, make a note next to the drawing or writing explaining why the idea was not used or why it did not work.
- We recommend that each time the team meets, use the last 10 minutes of the meeting to discuss and add an entry to the team notebook.
- The best notebooks are used consistently throughout the process of building the machine.

For examples of what your notebook can look like, visit Minnesota 4-H's Engineering Design Challenge for Teams section: https://extension.umn.edu/projects-and-more/4-h-engineering-design-challenge#for-teams-1397213

Appendix B: Presentation

To foster creativity and communication skills, teams are asked to develop a story for their machine and a presentation.

Story

While developing the design for the machine, think about narrative that can describe what is happening. The story should explain what is happening for each step. For example, your first step is the Level 0 machine. The story of the Level 0 machine is partially given to you within the challenge:

'A rocket is launched from Earth headed to the international space station carrying important cargo.'

- Teams can be creative as they define what that important cargo is. They should then carry on the story indicating what happens after the cargo arrives at the space station up until the button is pushed. Team should also indicate what pushing the button signifies within their narrative. Does it launch something, does it turn something off/on, what does the button do?
- The story should be a fun part of creating a machine, not an obstacle. Some teams start with a story first and develop their machines from there.
- Presentations should be from 2-3 minutes in length and each member of the team needs to participate in sharing the information.

Presentation

A big part of sharing the story of the machine and the experience of creating the machine is being able to share that information in a **summary**.

  - The purpose of the summary is to help teams share their experience. It should include:
  - Youth introductions
  - Machine design elements (challenges and victories)
  - Machine story – what is happening?
- While the notebook helps the team think about what they've learned in each small step, the presentation highlights the "aha moments," the fun, and maybe also some of the frustrations the team had from the time they first began to plan their machine to the day they decided it was finished.

Appendix C: Machine Steps

Each machine has to include a minimum number of "steps." A step in the machine is a transfer of energy from one action to another action.

- Example 1: A ball rolls down a ramp. This equals one transfer-of-energy or one step (ball rolling along a surface).
- Example 2: A ball rolls down a ramp and causes a row of dominoes to fall over. This is two transfers of energy or two steps (ball rolling along a surface and dominoes falling over).
- Example 3: A ball rolls down a ramp, hits a row of dominoes, the dominoes trigger a mousetrap. This is three transfers of energy or three steps (ball rolling along a surface, dominoes falling over, and a mousetrap being triggered).

Identical transfers of energy in succession are only counted as one-step. For example, a line of dominos hitting each other only counts as one-step. Counting 100 dominoes as 100 steps does not meet the guidelines.

Steps will be scored based on precision. Youth are allowed to provide assistance if steps are not precise enough to start the next step. However, points will be docked for these human assists (see score sheet).

Step Ideas

There is an infinite number of actions that can be utilized as a step including simple machines. For some visualization, check out these YouTube videos:

- 50 Rube GoldbergTM Machine Ideas (https://www.youtube.com/watch?v=WiHn5_RfKjE)
- 75 Rube GoldbergTM Ideas and Inventions (https://www.youtube.com/watch?v=cv5WLLYo-fk)
- A Minnesota 4-H Engineering Design Challenge team in action (https://www.youtube.com/watch?v=UIC5ViQFPnU)

Mechanical Engineering

Teams are required to include a Mechanical Engineering step. This can be done by building and utilizing a simple machine. A simple machine is a mechanical device that changes the direction or magnitude of a force. They are a tool used to accomplish a task and make work faster or easier.

Simple Machines

There are 6 basic simple machines:

- Lever
- Wheel and axle
- Inclined plane
- Wedge
- Pulley
- Screw

Using simple machines to create your machine

- Simple machines can be found anywhere. Look around your house, at school, in your garage, ask a friend, teacher or neighbor for items to use.
- To visualize your machine, think about the Challenge two-step task and how simple machines can play a role in completing the Challenge task. Think about the six different simple machines and how you can apply them to your engineer design machine.
- Team members should be able to name the three simple machines used in their machine and how each of them function.

Learn more about Mechanical Engineering/Simple Machines

- Simple machines for kids (video) (https://www.youtube.com/watch?v=fvOmaf2GfCY)
- Simple machines explained (video) (https://www.neok12.com/video/Simple-Machines/zX5879664d767e550f536d73.htm)

Electrical Engineering

Teams are required to contain at least one electrical engineering step in their machine. Teams are encouraged to use any type of power (with the exception of wall outlets), such as batteries, circuits and controls using electricity. The electrical reaction should be simple and safe.

Electricity

Electricity is the presence and flow of electrical charges. While certain aspects of electricity had been observed for centuries, like lightning and static electricity, it wasn't until the 1600s that people tried to harness this energy.

Electrical Safety

Water is an excellent conductor. It is important to keep all electrical items away from water, and make sure your hands are dry, and you are not standing in water when you touch anything electrical.

What **CAN** and **CANNOT** be used for Electrical equipment in a machine

- Items teams **ALLOWED** to use:
  - Up to four batteries (nothing larger than a 6 volt or 12 amp sealed dry cell battery)
  - Light bulbs
  - Power switches
  - Wire
  - Or any other item that will help you with completing this step
- Items teams **NOT ALLOWED** to use:
  - Wall outlets
  - Air compressor
  - More than two power strips
  - Broken, taped (repaired) and or modified power cords
  - Any dry cell batteries larger than a 6 volt.
  - Any cords connected to a wall outlet

Learn More About Electricity

- Try Engineering (handout)
- Electricity Connect (Website, materials for students and teachers)
- Introduction to electricity (video)
- Explaining an Electrical Circuit (Power Bytz video)
- Introduction to circuits (video)
- Ohm's Law and Power (tutorial)

Appendix D Resources

Education Resources

An effective Engineering Design team will have a thorough understanding of simple machines and a basic understanding of physics. To further knowledge in these areas consider these education resources:

- Engineering Explorers Challenge 1: Wind Powered Vehicle (https://docs.google.com/document/d/1xAj-WQeg_u6wb6Z7fplNQJaqPpt6r7elbx666ADfCNs/edit)
- Engineering Explorers Challenge 2: Catapult (https://docs.google.com/document/d/1yli4_yKkmLwFUFibINXPPuy55X39SZkK9FKvLhu307I/edit)
- Engineering Explorers Challenge 3: Pulley Power (https://docs.google.com/document/d/1mXcDfrkiyoj6Ls7QJEipzUBLRR-SJQlFHzoeXFpRnrM/edit)
- Engineering Explorers Challenge 4: Energy on the Move (https://docs.google.com/document/d/1mXcDfrkiyoj6Ls7QJEipzUBLRR-SJQlFHzoeXFpRnrM/edit)
- Engineering Challenge 5: Build that Machine (https://docs.google.com/document/d/19HO5SIeeclZ9jNcs5DdqP3JbddSTkv4qxTzU88kEC6o/edit)

4-H STEM Challenge Contact Information

Christine Wood
Robotics Committee Advisor
SDSU Extension 4-H Science Technology Engineering and Math (STEM) Field Specialist
605-782-3290
Christine.Wood@sdstate.edu

Nathan Skadsen
Robotics Committee Co-Chair
SDSU Extension 4-H Educator - Minnehaha County
Nathan.Skadsen@sdstate.edu

Please contact us with any questions or concerns.

Acknowledgements

The South Dakota 4-H STEM Challenge is adapted from the Minnesota 4-H Engineering Design Challenge. We would like to thank the Minnesota 4-H STEM Team for their guidance and resources.

Frequently Asked Questions

Q: What is a step?
A: A step in the machine is a transfer of energy from one action to another action; identical transfers of energy in succession should be counted as one-step.

Example: A sequence of dominos hitting each other counts as one-step. Counting 100 dominoes as 100 steps is repetitive and not in the spirit of the Engineering Design Challenge.

Q: What do we mean by “machine”?
A: A Rube Goldberg™ machine is an overly complex contraption that does a simple task and uses everyday items in a fun or amusing way. The machine uses a series of chain-reaction steps that culminate in accomplishing a task.

Q: What does human intervention mean?
A: Once the first step in your machine takes place (e.g. someone pushes a ball onto a ramp), the machine should function all the way to the end without a person touching it. However, sometimes the machine may fail to reach the last steps to accomplish the task. If a machine fails before it completes the task, it may be necessary for a person to start it again from the point where it failed. That is human intervention.

Q: Can I enter a machine that has been previously built and posted online?
A: No. All entries must be new machines created for the current challenge year and theme.

Q: Does our machine have to fill the whole 4’ x 8’ x 6’ space?
A: No, your machine can be smaller than the maximum allowed dimensions, it just can’t be larger.

Q: What sources can we use for research?
A: Information gathering is a key step in the design process. Some of the information may be what you and your teammates already knew before you started to think about your machine. In that case, your source is your other teammates or maybe the class in school where you learned the information, or maybe a parent or relative or a 4-H volunteer who taught it to you. But you probably won’t know everything before you start. The library, your teachers, the Internet, your family and friends are all good sources for helping you figure out how to solve a problem.

Q: Can a team be made up of youth from different school grades?
A: Yes. Adult leaders should carefully consider the benefits and challenges of widely varying age/grade groups. Youth in different grades vary greatly, not only in their attention span and ability to stay on task, but also in the amount and type of planning they are capable of, the guidance and recognition they require, and the types of personal development they seek.

Score Sheet

County: _____ Team Name: _____

Participants Name: _____ Age: _____ Participants Name: _____ Age: _____

_____ _____ _____ _____

Presentation & Judge Interview

Criteria	Much improvement needed (1 point)	Some improvement needed (2-3 points)	Meets Expectations (4-5 points)
Theme or story about the machine.	There is no story OR The story does not match the theme or machine steps	X	The story told aligns well with the theme as well as the steps completed by the machine.
Worked as a team, the role of each team member is identified and described	No teamwork identified	Unequal distribution of workload or input	Each team member had a clearly defined role that was articulated or demonstrated to the evaluators in some method
Discovered ways problems were solved and described using examples; demonstrates perseverance	None identified	Problem solving was evident but not clearly described	Team was able to describe how one or more problems were solved using examples; demonstrated perseverance to get through problems
Elements of the Engineering Design process are evident	Youth lack knowledge of the Engineering Design process OR Youth are unable to describe utilization of the Engineering Design process.	Youth have some knowledge of the Engineering Design process or how it was utilized in the construction of the machine	Youth know the steps of the Engineering Design process and can identify how they are utilized in the construction of the machine
Sequence of steps are clear and described, energy transfer is described, simple machines are identified	Not discussion of the sequence of steps, energy transfer or simple machines	One of these criteria were not described clearly: • sequence of steps • energy transfer • simple machines	The sequence of steps are clearly described, energy transfer is described, simple machines are identified

Presentation and Interview Judging Total Points: _____

Machine Specifications

Criteria	Much improvement needed (1 point)	Some improvement needed (2-3 points)	Meets Expectations (4-5 points)
Task completed and Degree of human interaction	Task not completed OR Task completed with multiple interventions human outside of the specified time constraints	Task completed with multiple human interventions in the specified time constraints OR Task completed with 2 human interventions in the specified time constraints	Task completed with one human intervention in the specified time constraints OR Task completed with no human intervention in the specified time constraints
Number of steps completed: minimum of 7, max of 20	Less than 7 steps or more than 20 steps	X	7 to 20 steps
Degree of innovation, creative use of everyday items in new ways	None identified	Less than half of the steps demonstrate an innovative, different, creative use of tools	Over half of the steps demonstrate an innovative, different, creative use of tools (tools/machines are “re-purposed”)
Objects leaving the machine area	Objects left machine area	X	Objects didn’t leave machine area
Size Requirements	Not Met	X	Met
Safety Requirements	Not Met	X	Met
Machine Run Time	3+ min	2-3 min	Up to 2 min

Machine Specification Total Points: _____

Presentation and Interview Judging Total Points: _____

Purple (53-70) _____ Blue (35-53) _____ Red (17-34) _____ White(<17) _____

Comments:

Ribbon Colors and What They Mean

Purple. The exhibit meets all standards. The exhibitor has shown complete understanding of what, how, and why the exhibit was done, and has a thorough knowledge of the subject. The exhibit needs minimal to no improvement.

Blue. The exhibit meets most standards. The exhibitor can explain what, how, and why the exhibit was done and has a good knowledge of the subject. The exhibit is well organized and well done.

Red. The exhibit meets some standards. The exhibitor can somewhat explain what, how, and why the exhibit was done and has a fair knowledge of the subject. Some improvements may be needed on the exhibit.

White. The exhibit meets few standards and lacks the quality of other exhibits. The exhibitor cannot adequately explain what, how, and why of the exhibit. Possibly they have overlooked a safety flaw. Improvement is needed in either the exhibit, the knowledge of the subject, or both.

4-H STEM Challenge Registration

Due: August 12, 2025

Email Forms to: Christine Wood – christine.wood@sdstate.edu

County: _____

Team: _____

Coach: _____ Phone Number: _____

Email: _____

Team Member	Age
1.	
2.	
3.	
4.	
5.	

Please indicate your preference for where you will build your machine. *Note: This does not change the dimension requirements listed above, this is specifically to allow us to better plan for space set-up.*

_____ 8x4 tabletops (provided by event) Or _____ Floor space

Please indicate your machine type.

_____ Level 0

_____ Level 1

_____ Level 2

MC-03629