Biomechanical Jumping Machine

Engineering Design Challenge

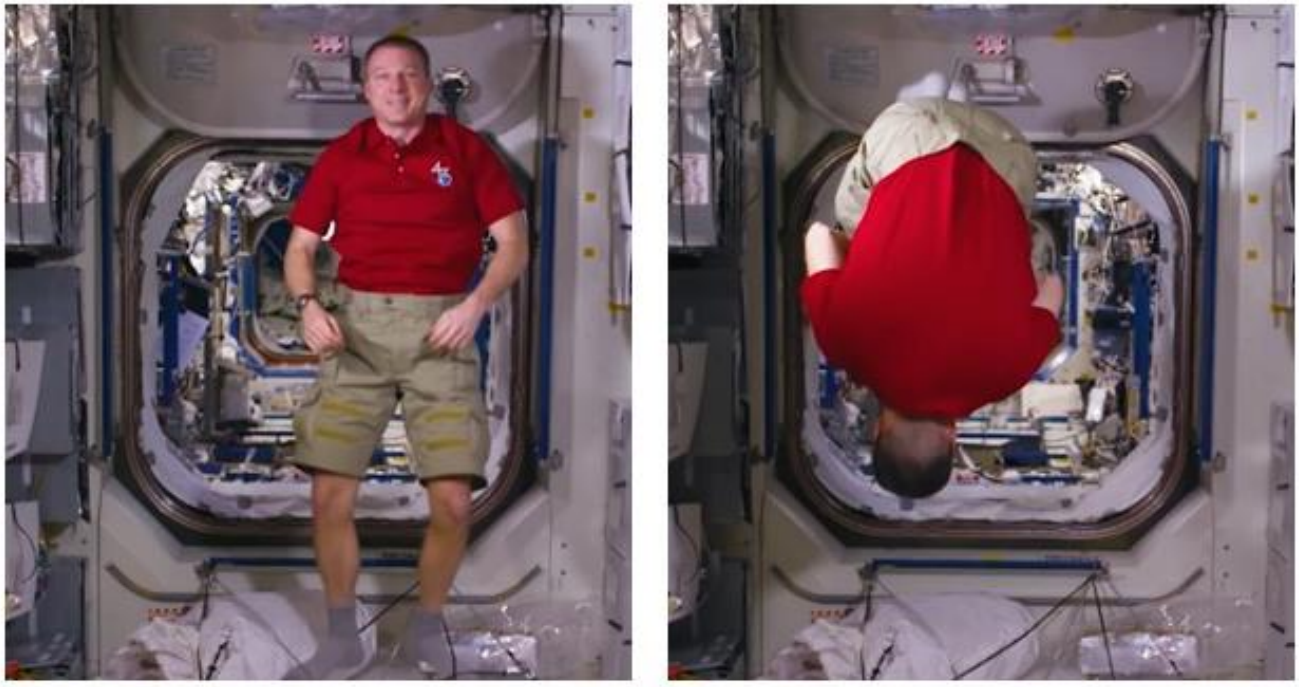

Image Credit: NASA Explorers - Terry Virts, former International Space Station Commander, Space missions: Expedition 42, Expedition 43, STS-130, Soyuz TMA-15M

Lesson Overview:

Being physically fit is important for everyone, but it is especially important for astronauts living and traveling in space. Being in space for extended periods of time put extra stress on their bodies. To counteract the stresses of living in space, astronauts must exercise a lot to maintain the health and function of their muscles and bones.

The Biomechanical Jumping Machine challenges learners to explore how muscles and bones work together to help people move. Learners are challenged to design and build a model that simulates a jumping motion. The biomechanical jumping machine must travel vertically a specific distance.

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Instructional Objectives

- Learners explore how muscles and bones work together to allow movement.
- Learners design a biomechanical jumping machine to simulate jumping.

Next Generation Science Standards (NGSS)

4-LS1-1. Construct an argument that plants, and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

LS1.A: Structure and Function
Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction.

- All organisms have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water and air.
- Body systems, including the skeletal and muscular systems, are made up of interacting subsystems that perform specific functions.

Crosscutting Concepts - Systems and System Models

- A system can be described in terms of its components and their interactions.

Science and Engineering Practices

- Developing and Using Models, Constructing Explanations and Designing Solutions
- Construct an argument with evidence, data, and/or a model.

3-5-ETS1-1, 2, & 3 Engineering Design

- Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

MS-ETS1-1, 2, 3, & 4 Engineering Design

- Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, considering relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Biomechanical Jumping Machine
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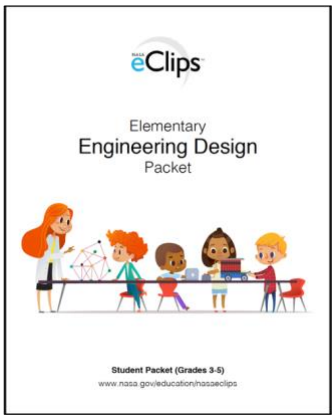
National Health Education Standards

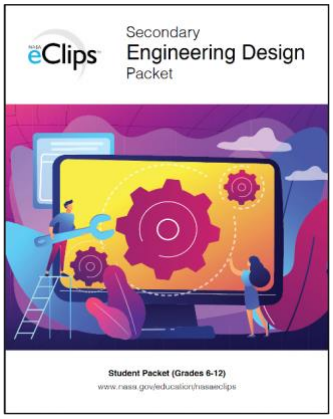
Relevant Standards for Grades 5–8

1. **Standard 1: Core Concepts**
   - Understand the relationship between physical activity, nutrition, and the health of muscles and bones.
   - Recognize the importance of exercise in maintaining strong bones and muscles.
2. **Standard 3: Accessing Information**
   - Identify resources to understand how bones and muscles function and how to maintain their health.
3. **Standard 5: Decision-Making**
   - Make informed decisions about exercise, posture, and nutrition to support musculoskeletal health.
4. **Standard 7: Practicing Health-Enhancing Behaviors**
   - Practice habits like proper body mechanics, stretching, and regular physical activity to prevent injury and promote musculoskeletal health.

International Technology and Engineering Educators Association (ITEEA) Standards for Technological and Engineering Literacy (STEL)

- **STEL 7 Design in Technology and Engineering Education**
- **STEL 8 Applying, Maintaining, and Assessing Technological Products and Systems**





NASA eClips has developed an open-ended design packet to introduce learners to a formal design process. This open-ended packet can be applied to any design challenge and can be used to enhance existing curriculum. Use this link to access the NASA eClips Engineering Design Packets.

https://nasaeclips.arc.nasa.gov/resources/guides#Engineering_Design_Packet

Biomechanical Jumping Machine
Engineering Design Challenge

Materials and Tools List

Biomechanical Jumping Machine

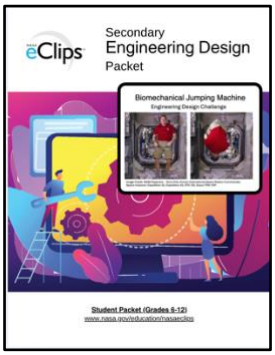
- paper and plastic disposable cups of different sizes
- rubber bands of different sizes and strengths (elasticity)
- scissors
- tape
- yardstick or meterstick
- safety goggles

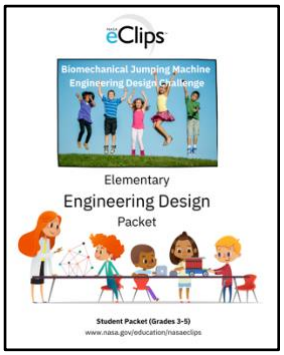
Customized learner Engineering Design Packets for the Biomechanical Jumping Machine can be found at the NASA eClips website.
https://nasaeclips.arc.nasa.gov/

There are many videos online showing how to build a knee joint. Below is a link to one example
https://youtu.be/pCGd513-Jac?feature=shared

Knee Joint

- popsicle sticks, plastic spoons
- cardboard tubes
- foam or lightweight plastic ball (ping pong)
- rubber bands
- string or yarn
- straws
- paper fasteners, paper clips
- pipe cleaners
- tape, glue





Safety First

Always stress safety protocols for all science experimentation and engineering design. To learn more about safety protocols, see NSTA's Safety Resources.
https://www.nsta.org/topics/safety

NSTA Safety Acknowledgment Forms (PDF)

Elementary School

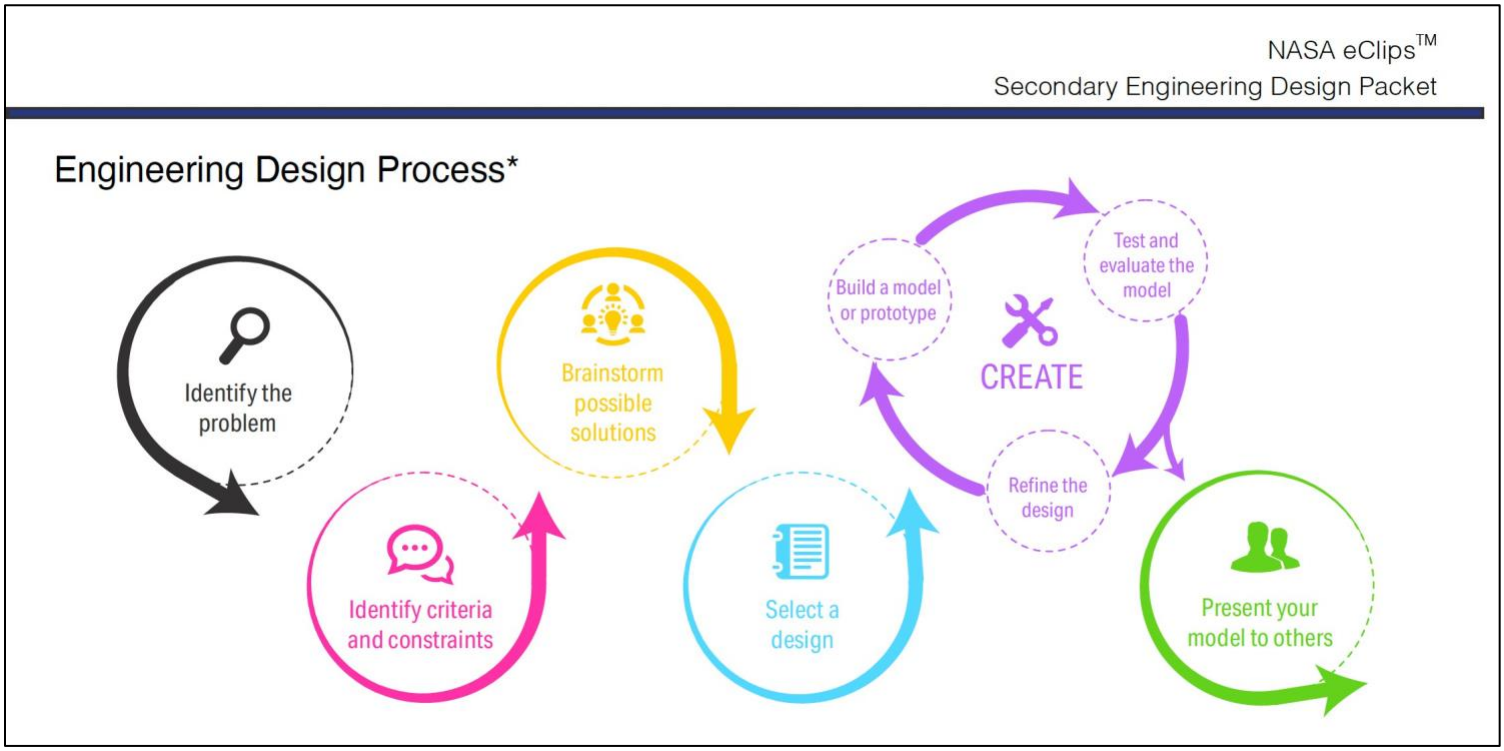
Middle School

High School

Biomechanical Jumping Machine
Engineering Design Challenge

Engineering Design Lesson Development
Engineering Design Process and Biomechanical Jumping Machine Introduction (5-10 minutes)

1. Explain to your learners that they are being challenged to design, build, and test a ***Biomechanical Jumping Machine.*** To do this, they will work through the engineering design process (EDP) as a team. Share the EDP image and probe to discover learners' prior knowledge of the EDP.



Steps of the engineering design process:

- Identify the problem.
- Identify criteria and constraints.
- Brainstorm possible solutions.
- Select a design.
- Build a model or prototype.
- Test and evaluate the model.
- Refine the design.
- Share the design.

2. Share the scenario and problem statement with learners. These are included in the customized Elementary and Secondary Engineering Design Packets.

Scenario:
Being physically fit is important for everyone in our world, but it is especially important for astronauts living and traveling in space. Being in space can cause bones and muscles to become weaker. It is important for astronauts exercise a lot to stay physically fit.

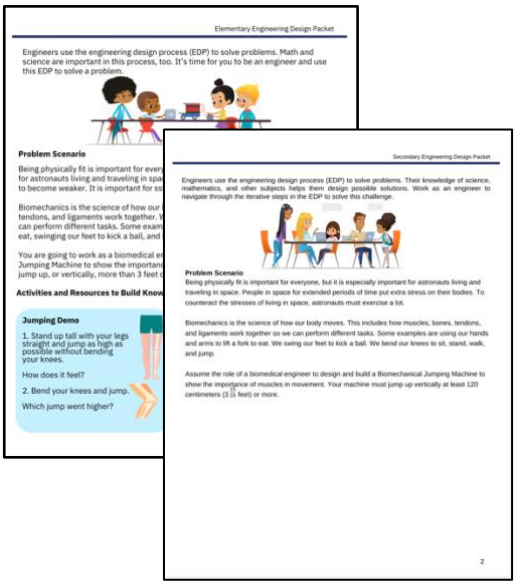
Biomechanical Jumping Machine

Engineering Design Challenge

Biomechanics is the science of how our body moves. It studies how our muscles, bones, tendons, and ligaments work together. When all of these body parts work together, we can perform different tasks. Some examples are using our hands and arms to lift a fork to eat, swinging our feet to kick a ball, and bending our knees to jump.

Problem:
You are going to work as a biomedical engineer. Design and build a Biomechanical Jumping Machine to show the importance of muscles in movement. Your machine must jump up vertically more than 3 feet or 91.44 centimeters.

3. Ask learner teams to review and discuss the scenario, problem statement, and criteria and constraints. Facilitate discussions and questioning around the essential components of the challenge as a large group.



Criteria are conditions that must be met to solve the problem.

Constraints are things limiting a solution, like cost, safety, materials...

Criteria & Constraints:
For this challenge, you will perform the same steps as NASA scientists and engineers.

Challenge 1		Challenge 2
Jump	Show	Carry
The biomechanical jumping machine must jump 120 centimeters (3 feet) or more vertically.	You must use the potential and kinetic energy stored in the elastics or the rubber bands as a force.	The jumping machine must carry a weight of 8 grams or more.

Biomechanical Jumping Machine

Engineering Design Challenge

Some questions learners might ask include:

a. What are biomechanics?
b. How can physics help athletes become better?
c. How do muscles work with bones to create movement?
d. What types of forces are used when someone bends or jumps?
e. What materials are available?
f. How do the different types of rubber bands behave or move when launched at a target?
g. What are the characteristics or properties of the different types of cups?
h. Which materials can be used to represent bones? muscles? connecting parts?

Biomechanical Jumping Machine

Engineering Design Challenge

Biomechanical Jumping Machine - Research, Brainstorm, Plan and Create (20-40 minutes)

1. Brainstorm ideas and help learners find resources to learn about bones, muscles, and biomechanics. Show one of the following NASA eClips™ video segments to learners.

Our World: Exercise Equipment
https://nasaeclips.arc.nasa.gov/videosingular/ourworld/our-world-exercise-equipment

Our World: Exercise in Space
https://nasaeclips.arc.nasa.gov/videosingular/ourworld/our-world-exercise-in-space

Ask SME “Astronaut Strength and Conditioning Specialist - Corey Twine”
https://nasaeclips.arc.nasa.gov/videosingular/asksme/astronaut-strength-and-conditioning-specialist-corey-twine

2. Have learners complete the jumping demo and guide them as they test rubber bands.

Resources and Activities to Build Knowledge

Jumping Demo

1. Stand up tall with your legs straight and jump as high as possible without bending your knees.

How does it feel?

2. Bend your knees and jump.

Which jump went higher?

Rubber Band Testing

1. Collect rubber bands of different sizes and thickness.

2. Put on safety goggles.

3. Stand behind the line.

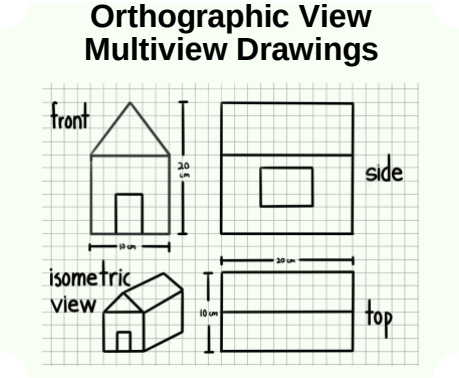
4. Shoot the rubber bands at the target on the wall.

Why do some bands go further than others?

Biomechanical Jumping Machine
Engineering Design Challenge

Several resources are already added to the customized Engineering Design Packets. You may add others, if you choose.

3. Once learners have had the opportunity to explore more about biomechanics, ask them to brainstorm possible solutions to the challenge. Encourage learners to make detailed drawings of their solutions in their EDP packet.



4. Continue to use the EDP packet to guide learners through the next steps of the design process.

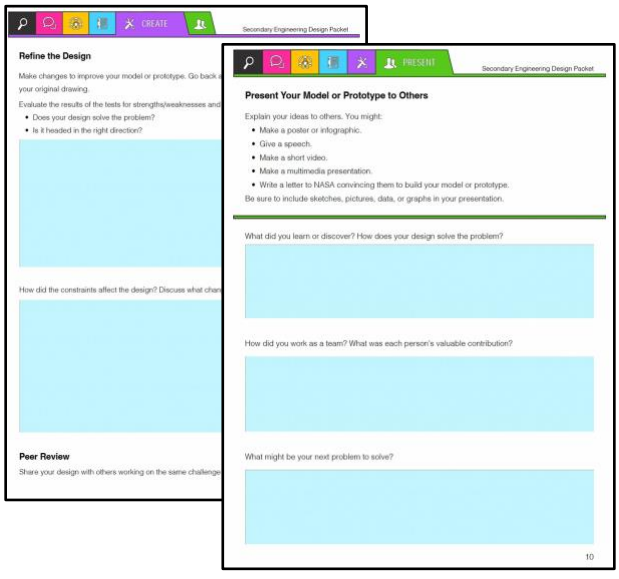
- Select a design
- Build a model or prototype
- Test and evaluate the model or prototype
- Refine the design

Biomechanical Jumping Machine - Review and Explain (10-20 minutes)

1. Run a Preliminary Design Review where teams share their innovations with one another, verifying that their designs work.

2. Ask learners to use and apply related vocabulary as they describe their designs.

3. In their engineering design packets, ask learners to reflect and sketch diagrams of possible improvements to their design. Share responses.



Biomechanical Jumping Machine
Engineering Design Challenge

Biomechanical Jumping Machine - Extend
(20 minutes)

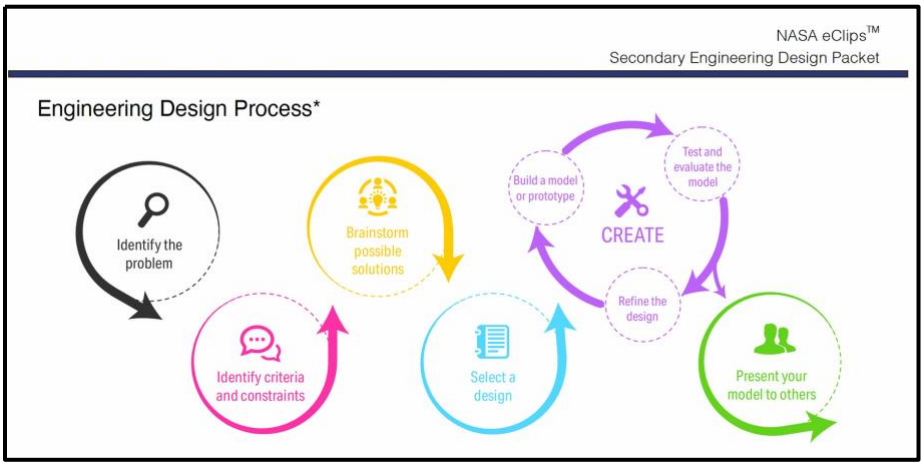
1. Guide learners through the design process for their second design challenge:

   Problem Scenario:

   Engineers and medical researchers often design artificial joints for people who have injuries or diseases affecting their movement.

   Design Challenge:

   In this challenge, you will design and create a model of a knee joint that mimics how it bends and flexes.



Ask (Identify the Problem):

- What are the main functions of a knee joint?
- How can you create a model that mimics bending and flexing?

Imagine (Brainstorm and Plan):

- Sketch possible designs of a knee joint model.
- Consider different materials for representing bones, muscles, and ligaments.

Plan:

- Select the best idea based on the criteria and constraints.
- Create a detailed sketch or diagram of your chosen design, labeling each part.

Create:

- Use the provided materials to build your knee joint model.

Biomechanical Jumping Machine

Engineering Design Challenge

Test:

- Test how well the model bends and flexes. Does it mimic a real knee joint's movement?
- Record observations about its strengths and weaknesses.

Improve:

- Modify your design to improve its function.
- Retest and refine until it meets all the criteria.

2. Learners can make an infographic or video describing their design(s). Have learners address the following prompt(s):
   - How could your **biomechanical jumping machine** design inspire new technologies to help people on Earth? Think about devices for rehabilitation, sports performance, or assisting individuals with physical disabilities. How might it also benefit astronauts to improve mobility and exercise in low-gravity environments?
   - How could your **knee joint** design improve the lives of people on Earth? Think about athletes, the elderly, or individuals recovering from injuries. How might this solution be adapted for specific challenges faced by astronauts in space, like low-gravity environments?

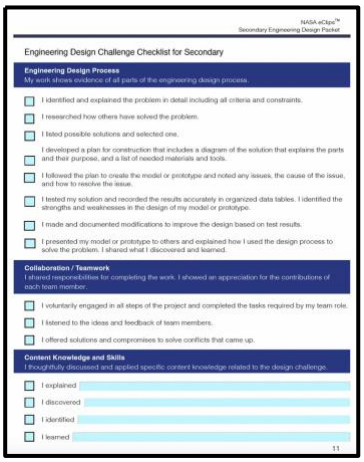
3. The infographic or video should include:
   - Purpose and use
   - Descriptions and drawings to highlight the benefits and identify any harmful components
   - Ease of use
   - Durability

Optional Challenge - Design an Articulated Hand Model	
Learners investigate how to simulate articulate or jointed fingers on a hand to pick up a ball of paper. For younger learners, start with co-designing a finger that can wiggle. Then have teams work to put the fingers together so they can grab a ball of paper or ping pong ball. Older learners can be challenged to pick up heavier objects from a specific distance.	**Materials and Tools List** • drinking straws • cardboard • tape • scissors • nylon cord • centimeter ruler • pen • narrow rubber bands • zip ties, string
Check out NASA's "I Want to Hold Your Hand" lesson using the link below. https://www.nasa.gov/wp-content/uploads/2011/09/172353main_Hold_Your_Hand.pdf?emrc=19d9d2	

Biomechanical Jumping Machine
Engineering Design Challenge

Biomechanical Jumping Machine - Evaluate
(20 minutes)

- Guide learners to use the Evaluation Checklist in the Design Packet for self-evaluation of their understanding and use of the engineering design process in solving the challenge.


NASA eClips™
Secondary Engineering Design Packet

Engineering Design Challenge Checklist for Secondary

Engineering Design Process
My work shows evidence of all parts of the engineering design process.

- I identified and explained the problem in detail including all criteria and constraints.
- I researched how others have solved the problem.
- I listed possible solutions and selected one.
- I developed a plan for construction that includes a diagram of the solution that explains the parts and their purpose, and a list of needed materials and tools.
- I followed the plan to create the model or prototype and noted any issues, the cause of the issue, and how to resolve the issue.
- I tested my solution and recorded the results accurately in organized data tables. I identified the strengths and weaknesses in the design of my model or prototype.
- I made and documented modifications to improve the design based on test results.
- I presented my model or prototype to others and explained how I used the design process to solve the problem. I shared what I discovered and learned.

Collaboration / Teamwork
I shared responsibilities for completing the work. I showed an appreciation for the contributions of each team member.

- I voluntarily engaged in all steps of the project and completed the tasks required by my team role.
- I listened to the ideas and feedback of team members.
- I offered solutions and compromises to solve conflicts that came up.

Content Knowledge and Skills
I thoughtfully discussed and applied specific content knowledge related to the design challenge.

- I explained
- I discovered
- I identified
- I learned

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- Provide time for groups to share their designs during a Critical Design Review.

Biomechanical Jumping Machine

Engineering Design Challenge

Resources

Articles

Astronaut Exercise
Melissa L. Gaskill, MAY 20, 2024
https://www.nasa.gov/missions/station/iss-research/astronaut-exercise/

Anthropometry, Injury Biomechanics, & Ergonomics - Improving Living and Working Conditions in Space
Robert E. Lewis, March 16, 2023
https://www.nasa.gov/directorates/esdmd/hhp/anthropometry-and-biomechanics/

Counteracting Bone and Muscle Loss in Microgravity Space Station Research Integration Office,
December 1, 2023
https://www.nasa.gov/missions/station/iss-research/counteracting-bone-and-muscle-loss-in-microgravity/

Videos

What are Biomechanics? by Utah Valley University
https://youtu.be/FsOR2zALauo?si=sr-4XAYr2lLz-1nz

Biomechanics of Sports: Running, Jumping, and Hitting by Technovation
https://youtu.be/u6Ogy4JtRcY?si=2Jq579KZa96xfW_1

NASA eClips Our World: Exercise in Space
https://nasaeclips.arc.nasa.gov/video/ourworld/our-world-exercise-in-space
Find out why exercise is so important to the astronauts who travel into space.

NASA eClips Our World: Exercise Equipment
https://nasaeclips.arc.nasa.gov/video/ourworld/our-world-exercise-equipment
Learn about the exercise equipment used by the astronauts in space to keep astronauts fit and healthy.

NASA eClips Real World: Home Improvement - Space Station Style
https://nasaeclips.arc.nasa.gov/videosingular/realworld/real-world-home-improvement-space-station-style