Lesson Plan:
Critical Load
Real-World Application
What do Civil Engineers Do?

• An inside look at how 3 Civil Engineers are changing the world. (Video 6:22)

Source: ASCE YouTube Channel: https://www.youtube.com/watch?v=cJaRij7K-Lw
Finding the Strongest Shape

- Learn how different shapes relate to the strength of a structure. *(Video 3:34)*

Source: PBS Learning Media, Zoom:
https://nj.pbslearningmedia.org/resource/phy03.sci.phys.mfe.zcolumns/columns-finding-the-strongest-shape/
Earthquake Proof Buildings?

• Explore ideas for earthquake proofing buildings with hands-on design challenges. *(Video 5:57)*

Source: QuadSquad YouTube Channel: https://www.youtube.com/watch?v=9N8iQ9Ch8nw
Engineers designing buildings in areas which experience heavy snows must factor in the weight of a massive snowstorm into designing the strength of the roof. The weight at which a building or structure fails is called the "critical load."
The Design Challenge
The Design Challenge

You are a team of engineers all working together, using the engineering design process, to design a structure using 12 index cards and tape to hold a minimum of 4 pounds of weight without collapsing.
Defining the Challenge: Criteria & Constraints

Criteria

- Hold a minimum 4 pounds of weight

Constraints

- Use 12 cards or fewer
- Cards may not be cut or torn
Material

Required for Build
• 12 index cards
• 1 roll of tape

Alternative Materials
• Game cards (i.e. Uno), playing cards, pieces of cardstock
Testing

Testing materials

• Plastic container to put the weight in
• Weight to test structure: coins, marbles, Legos, sand, etc.

Alternative materials

• Flat surface to stack weight (i.e. folder, cardboard, notebook, etc.)
• Weight to test structure: books, stacks of magazines, cans of food, etc.
Testing Process

• Each team should first predict the “critical load” of their structure and document it.

• Test each team’s structure by adding measurable weight (minimum of 4 pounds) to determine at what weight the team's structure will collapse. This is each structure's "critical load“ or amount just prior to failure.
Teams then compare their predictions to their testing results.

After determining the “critical load” of each team’s design, it’s time to have some fun! Keep stacking weight on the designs until they are as flat as a pancake.
Before you get started brainstorming and sketching your design...consider the following...

- What shapes are strong?
- Will your weights stack well or do you need a container to hold them?
- How big is the container to hold the weight and will it fit on top of your design?
Reflect & Debrief
Reflection

• What was your structure's "critical load?“
• How close were you to your prediction?
• What aspects of your design do you think helped its ability to hold more weight? What hindered it from holding more weight?
• What human factors do you think a civil/structural engineer needs to take into consideration when planning an office building? (weight of people and furnishings, need for water, fresh air, escape routes)
Engineering Design Process
The Engineering Design Process

Learn about the engineering design process (EDP). The process engineers use to solve problems.

(Video 1:47)

Source: TeachEngineering YouTube Channel http://www.youtube.com/watch?v=b0ISWaNoz-c
Engineering Design Process

- Divide into teams of two or three
- Review the challenge and criteria & constraints
- Brainstorm possible solutions (sketch while you brainstorm!)
- Choose best solution and build a prototype
- Test then redesign until solution is optimized
- Reflect as a team and debrief as a class
Productive Failure

- The engineering design process involves productive failure: test, fail, redesign. Iterate again and again until you have the best possible solution.

- It is important to document iterations to keep track of each redesign. Use the engineering notebook to sketch ideas, document iterations and any measurement and/or calculations.

- It’s also important to showcase the fact that there can be multiple solutions to the same problem. There’s no one “right” solution.
Vocabulary
Vocabulary

• Civil Engineers: Problem solvers, meeting the challenges of pollution, traffic congestion, drinking water and energy needs, urban redevelopment, and community planning.

• Constraints: Limitations with material, time, size of team, etc.

• Criteria: Conditions that the design must satisfy like its overall size, etc.

• Critical Load: The weight at which a building or structure fails.

• Efficiency Rating: Measures the weight that will cause a structure to fail divided by the weight of the structure itself.
Engineers: Inventors and problem-solvers of the world. Twenty-five major specialties are recognized in engineering (see infographic).

Engineering Design Process: Process engineers use to solve problems.

Engineering Habits of Mind (EHM): Six unique ways that engineers think.

Iteration: Test & redesign is one iteration. Repeat (multiple iterations).

Prototype: A working model of the solution to be tested.

Structural Engineers: Face the challenge of designing structures that support their own weight and the loads they carry, and that resist wind, temperature, earthquake, and many other forces.
Dig Deeper
Dig Deeper into the Topic

Internet Connections
- Bryan Burg Cardstacker
- Tallest Buildings and Structures

Recommended Reading
- Why Buildings Stand Up: The Strength of Architecture by Mario Salvadori
- Why Buildings Fall Down: How Structures Fail Architecture by Mario Salvadori

Writing Activity
Write an essay or a paragraph describing a recognizable building in your town. Include the history, interesting challenges to the building's engineering, and challenges that the engineers faced in design and construction.
Engineering Fields
What is Engineering?

Learn about engineering and how engineers are creative problem solvers and innovators who work to make the world a better place.

(Video 3:43)

Source: TeachEngineering YouTube Channel - http://www.youtube.com/watch?v=H9VDkgGmVo
Related Engineering Fields

• There are several types of engineering fields that are involved with buildings and structures. Here are just some of the related engineering fields.
  • Civil Engineering
  • Structural Engineering*
  • Architectural Engineering

• Download the Engineering Fields Infographic
How will YOU change the world?

*Structural Engineering Basics website [https://structuralengineeringbasics.com](https://structuralengineeringbasics.com)
Engineering Habits of Mind is about how engineers think everyday. The Core Engineering Mind is about making things that work and making them work better.

Source: 
https://online-journals.org/index.php/i-jep/article/view/5366
Engineering Habits of Mind Checklist

- Systems thinking
- Problem-finding
- Visualising
- Improving
- Creative problem-solving
- Adapting
Learning Habits of Mind Checklist

- Open-mindedness
- Resilience
- Resourcefulness
- Collaboration
- Reflection
- Ethical Consideration
- Curiosity
Greatest Engineering Achievements of the 20th Century

Welcome!
How many of the 20th century's greatest engineering achievements will you use today? A car? Computer? Telephone? Explore our list of the top 20 achievements and learn how engineering shaped a century and changed the world.

1. Electrification
2. Automobile
3. Airplane
4. Water Supply and Distribution
5. Electronics
6. Radio and Television
7. Agricultural Mechanization
8. Computers
9. Telephone
10. Air Conditioning and Refrigeration
11. Highways
12. Spacecraft
13. Internet
14. Imaging
15. Household Appliances
16. Health Technologies
17. Petroleum and Petrochemical Technologies
18. Laser and Fiber Optics
19. Nuclear Technologies
20. High-performance Materials

Source: http://www.greatachievements.org/
Learn more about how engineers make the world a better place

Provide energy from fusion

Human-engineered fusion has been demonstrated on a small scale. The challenge is to scale up the process to commercial proportions, in an efficient, economical, and environmentally benign way.
For more engineering lesson plans and resources like games, engineering careers, and STEM opportunities visit IEEE’s TryEngineering.org.