BRIDGE UP!
ENGINEERING

LESSON 10 – GRADES 9-12

LESSON 10 – GRADES 9-12: Fundamental Forces

Big Idea

Students will examine the fundamental forces that impact the construction of bridges.

Essential Questions

What are the forces that need to be considered when building a bridge?

Background Information

Bridges are designed for specific purposes and loads. They are designed to have service lives and maximum load capacities. Some can be modified over time, others need to be replaced. Engineers consider several factors when deciding on bridge designs, including location (cold climates) and the different kinds of loads it will carry – people, cars, trucks, or trains.

Standards & Benchmarks

Minnesota Science Standards

9.1.2.1 Addressing Human Need

Engineering is a way of addressing human needs by applying science concepts and mathematical techniques to develop new products, tools, processes and systems.

Benchmark 9.1.2.1.1 Refinement of Designs

Understand that engineering designs and products are often continually checked and critiqued for alternatives, risks, costs and benefits, so that subsequent designs are refined and improved.

9.2.2.2 Motion

An object's mass and the forces on it affect the motion of an object.

Benchmark 9.2.2.2.3 Action/Reaction

Demonstrate that whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted by the second object back on the first object.

9P.2.2.1 Forces

Forces and inertia determine the motion of objects.

Benchmark 9P.2.2.1.3 Gravity & Motions

Use gravitational force to explain the motion of objects near Earth and in the universe.

9.1.2.2 Practice of Engineering

Engineering design is an analytical and creative process of devising a solution to meet a need or solve a specific problem.

Benchmark 9.1.2.2.2 Using Models in Designing

Develop possible solutions to an engineering problem and evaluate them using conceptual, physical and mathematical models to determine the extent to which the solutions meet the design specifications.

9.1.3.4 Knowledge & Understanding
Science, technology, engineering and mathematics rely on each other to enhance knowledge and understanding.

Benchmark 9.1.3.4.6 Analysis of Models
Analyze the strengths and limitations of physical, conceptual, mathematical and computer models used by scientists and engineers.

9P.2.2.1 Forces
Forces and inertia determine the motion of objects.

Benchmark 9P.2.2.1.1
Vectors Use vectors and free-body diagrams to describe force, position, velocity and acceleration of objects in two-dimensional space.

Connections with Multimedia Program

Bridge Up! Fundamental Forces

Activity Description

Students will explore, virtually, the forces that bridges experience. They will apply what they learn in a computer design challenge to build the least expensive bridge that will support a standard moving load. Several days are needed to complete this lesson.

Vocabulary

Force terms

Compression – Pushing forces aligned along the axis of a member.

Tension – Pulling forces aligned along the axis of a member.

Shear – Pushing or pulling forces aligned perpendicular to the axis of a member.

Balanced – Sum of net forces = zero.

Unbalanced - Sum of net forces NOT = zero.

Load terms

Static – Load that is not moving, may be the bridge itself.

Dynamic – Load that is moving, as in a truck crossing a bridge.

Mechanical equilibrium - Sum of net force = zero.

Truss terms

Member – A component part of a bridge or other structure, complete in itself.

Node – The steel joint on a bridge where multiple members of a truss connect, typically held together by two gusset plates.

Gusset plate – Sheets of steel that are used to connect beams and girders to columns or to connect truss members.

Materials

- Textbook
  - Chapters that cover basic forces
- Physicsclassroom.com
- Access to computers with Java technology. Java is a browser plug-in that may need to be downloaded in order to play the West Point Bridge Designer program. Java is free to download at **https://www.java.com/en/**.
- Johns Hopkins Truss design
- West Point Bridge Designer

Procedure

This lesson is content – focused on teaching students about forces. Resources are listed that can be used to illustrate how forces are applied in bridges.

A basic introduction of forces should be provided using the resources you currently use. The rest of this procedure will focus on web-based activities to help students develop an understanding of truss and bridge design.

Johns Hopkins Truss Builder (1 day) – Computer-aided design system that helps students design trusses by showing how compression and tension forces interact in a truss system. The website will calculate forces based on loads applied. It also shows which forces are in compression and which are in tension.

Use this site to have students build a simple truss as illustrated in the site instructions. This will allow students to grasp the basics of truss design. From there, have students experiment with different designs. This helps them see that, as they are designing, some members have little or no impact on the strength of a truss, while others are crucial. As students plan a truss design, have them predict the types of forces in each member as a result of the applied load. Values and force types will be displayed when the simulation is run.

West Point Bridge Builder (2 days) – Computer-aided design system that has students build a virtual bridge to meet certain design challenges. This is an actual annual competition, but the competition makes previous years' competition software available for educational use.

https://bridgecontest.org/resources/previous-versions-of-the-software/

Use the previous years' software versions to issue student challenges. Attached is a sample activity where students need to design a bridge that has the lowest cost, yet is able to sustain a load as the load crosses the bridge. This activity assumes that the students have had an opportunity to work with the Bridge designer software before attempting the activity.

Assessment

- Computer results (have students show screen when assignment is complete)
- Science journal entries
- Student notes

Extensions

- Have students actually compete in the West Point Competition. Scholarships and prizes are available.
- Have students build trusses out of spaghetti, balsa wood, toothpicks, straws, or any other supplies that would simulate truss members. Test with hanging masses.

West Point Bridge Designer Competition

Name of team:

Members of team (2 max: $100,000 added to bridge cost for each additional)

Your team has been tasked with solving the problem of building a bridge to transport cargo across a river. You will use the West Point Bridge designer software to complete this task. You have 20 minutes to design the lowest cost bridge to achieve the goal. You may start with a predesigned bridge or you may build from scratch. Once your design is complete, you will set the simulation to loop so that we can watch the truck safely cross your bridge. The definition of safe that will be used is that your truck does not fall through the bridge into the water.

At the completion of this activity, we will discuss how the designs varied and decide if the above definition of safe is truly enough and how these definitions cause design plans to account for more than just the minimum safe load.

Make a drawing of your bridge. Make sure that you include the land on each side of the bridge, showing any excavation that has been done.

Starting cost of bridge:

Ending cost of bridge:

Describe one aspect of your design that caused you significant challenges and how you were able to solve it. This description should use complete sentences and fully develop your ideas.