LESSON TITLE: FORCES

TOTAL TIME: ONE 60-MINUTE PERIOD

BRIEF DESCRIPTION

In this *The House That STEM Built* lesson plan, students will identify examples of static and dynamic equilibrium on the construction site as well as in examples around them. This lesson will cover the differences between static and dynamic equilibrium, what conditions are needed to create both, and net force.

Students will watch *The House That STEM Built: Forces* video before putting on their engineering caps and tackling their very own construction project.

CURRICULUM OUTCOMES

Taken from the New Brunswick Grade 12 Physics curriculum.

GENERAL CURRICULUM OUTCOMES

Knowledge: Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

SPECIFIC CURRICULUM OUTCOMES

SCO ACP-1: Use vector analysis in two dimensions for systems involving two or more masses, relative motions, static equilibrium, and static torques.

NEW BRUNSWICK GLOBAL COMPETENCIES ACHIEVED[1]

- Critical Thinking and Problem-Solving
    - Learners engage in an inquiry process to solve problems, as well as acquire, process, interpret, synthesize, and critically analyze information to make informed decisions.
    - Learners construct, relate and apply knowledge to all domains of life, such as school, home, work, friends, and community
    - Learners formulate and express questions to further their understanding, thinking, and problem-solving
- Innovation, Creativity, and Entrepreneurship
    - Learners take risks in their thinking and creating; they discover through inquiry research, hypothesizing, and experimenting with new strategies or techniques.
- Collaboration
    - Learners participate in teams by establishing positive and respectful relationships, developing trust, and acting interdependently and with integrity.
    - Learners learn from and contribute to the learning of others by co-constructing knowledge, meaning, and content.

LEARNING OBJECTIVES

Learners will

- identify how multiple forces act on an object,
- define static and dynamic equilibrium,
- define net force,
- differentiate between examples of static and dynamic

1 https://www2.gnb.ca/content/dam/gnb/Departments/ed/pdf/K12/curric/competencies/NBCompetencies.pdf?fbclid=IwAR1ldrZs1gFgiNm8rC4oz7Fmx6mSn-6t_QJkenev0eD33rZ-foYYn6bmdmc *also available at* https://tinyurl.com/nb-competencies

equilibrium, and

- provide unique examples of dynamic and static equilibrium found in everyday life.

MATERIALS:

- Video: *The House That STEM Built: Forces*.
- Stationary object to use during the introductory demonstration.
- Technology that can support *The Bridge Designer* program. This program needs to be downloaded prior to class and each group will require access to it. It can be found at https://bridgedesigner.org/download/.

or

- Technology that can support the *Construct a Bridge* game, which can be found at https://www.crazygames.com/game/construct-a-bridge/.

or

- Popsicle sticks, hot glue guns, and glue.

MINDS ON: 5 MINUTES

GROUPING: ENTIRE CLASS

Before introducing today's topic and video, get students thinking by walking through this simple demonstration.

- Set an object on a desk or table at the front of the class. Ask students to name some of the forces that are acting on the object.

What is the net force of this object?

- Slowly push the object across the desk at a constant speed. What types of forces are now acting on the object? Are they different than the ones acting on the stationary object? What is the net force of the moving object?

WARM UP: 20 MINUTES

GROUPING: ENTIRE CLASS

Watch *The House That STEM Built* video. Feel free to pause the video and ask some or all of the following questions to prompt discussions.

- 0:47 – If a force is "a push or pull upon an object resulting from the interaction with another object" how many different types of forces can you think of? Which types of forces have we dealt with previously in different lessons or classes? Feel free to create a list as a class.
- 1:42 – If we were to look at the example of the box sitting on the incline. What forces are acting on the box? Are there any other factors that influence whether or not the box will move or remain stationary?
- 2:26 – What forces are acting on the car as it accelerates?
- 2:38 – Are there any terms that come to mind when you think of equilibrium? What does that mean to you?
- 2:50 – Are there any examples that you can think of in your own life where dynamic equilibrium is at play?
- 3:50 – How can we bring the system into one of static equilibrium without changing the mass of the box, the angle of the incline, or the coefficient of friction?
- 4.16 – Feel free to walk through this question together as a class. The solution can be found at the end of this lesson plan.
- 4:56 – What forces are acting on the nail as it is being driven into the wood? Should gravity be considered important in this

example?

- 5:32 – What are some types of systems that you could find on a construction site where the net force is not equal to 0?
- 6:40 – How could adding additional weight to the roof in the form of trusses help support and stabilize a roof better than a roof made without them?
- 7:53 – Why aren't trusses completely solid instead of being made up of many pieces? Are there any advantages to this? What about disadvantages?

ACTIVITY: 30 MINUTES

GROUPING: PAIRS OR GROUPS OF 3

- Static equilibrium is incredibly important for a lot of the infrastructure that we rely on every day. What sort of examples can you come up with that require static equilibrium in order to do its job?
- Like trusses, bridges are built with forces in mind. Today in groups it is your task to put on your engineering hat and build a bridge. It might be worth it to take the following questions into account.
  - What forces are acting on the bridge?
  - What is the bridge spanning? Will this have anything to do with the structural integrity of the bridge?
  - How many points of contact are there? Are the points of contact stable?

This activity can be done in a variety of ways. Here are 3 ways that this activity could be carried out.[2]

- In the event that technology permits, *The Bridge Designer* is a fantastic student engineering program that was created to help students learn about loads, forces, and engineering by constructing bridges of their own. The simulation presents

2 If time does not permit, this activity could be started in one period and completed at the beginning of another.

students with a realistic situation (they are tasked with building a two-lane highway bridge across a river valley) and the design tools and materials needed to design the bridge. You could ask students to successfully build a bridge and present it to you or their peers. This program is free to download for schools and can be found here: https://bridgedesigner.org/download/. It is required that you download the program in advance.

- Another option that is a little less detailed and does not require any downloading is called *Construct a Bridge*. This game has multiple levels that do increase in difficulty. As you progress, the span in which the bridge is required to cover increases as well as the load (truck). If the bridge does not have enough support it will fall apart. You could ask students to successfully build a bridge at a level that you determine. You can find that game at https://www.crazygames.com/game/construct-a-bridge/.
- If technology is not available, this activity can easily be done with popsicle sticks and hot glue. Ask students to create a bridge that can span between two desks or chairs and can hold weight as well. They can identify how many points of contact there are and what forces are acting upon the bridge. This activity could easily become a competition.

CONCLUSION: 5 MINUTES

GROUPING: ENTIRE CLASS

To wrap up the class, ask students to jot down 3 things that they either learned or found surprising about this activity and 2 questions they still have. These questions can help guide the rest of this unit.

DIFFERENTIATION

CONTENT

Use *The House That STEM Built* video to spark a conversation about

- dynamic equilibrium in moving objects that students are familiar with (for example, cars, aeroplanes, or trains),
- static equilibrium in the classroom (how many examples can you think of?), and
- calculating net force (what do you need to consider?).

PRACTICE

Are there any STEM or student engineering organizations in your area that might be a good resource? Are there any groups or professionals that might be available to do a demonstration for your class? Let's Talk Science[3] is a volunteer-supported Canadian organization that does demonstrations for classes and groups. If you are in New Brunswick, Science East[4] is another great place to find student resources and class demonstrations. If you are outside New Brunswick, inquire whether your local science centre may offer similar programs.

Do you have access to a school technology workshop where you might be able to find materials that could help you out with this topic? Is there an opportunity for any cross-subject learning?

Phet Interactive Simulations has a great introductory simulation to forces. Students can play around and change the parameters to see the effect they have on the net force. This simulation includes the option to show speed, sum of forces, and other values. It can be found at https://phet.colorado.edu/en/simulations/forces-and-motion-basics/.

PRODUCT

Ask students to create a project or presentation explaining why it is better for trusses to have multiple connected pieces instead of being

3 https://letstalkscience.ca/

4 https://scienceeast.nb.ca/schools-and-groups/school-programs/demonstrations/ *also available at* https://tinyurl.com/science-east

made up of one solid piece. They can analyze weight, force, and cost.

Students can create a booklet, podcast, or video comparing different bridge designs and explain the benefits as well as the drawbacks of each. Which bridge designs are the most stable? Which are the most cost-efficient? Historically, which designs were used in the area?

EXTENSION

EGG DROP LAB

Ask students in groups to design and create a container that will prevent an egg from cracking when dropped. Students will analyze factors that contribute to minimizing the force on the egg. Materials can include shoe boxes, cotton balls, bubble wrap, garbage bags, straws, etc.