Science Objectives

- Students will describe how different forces can be balanced.
- Students will relate the balance of a lever to torque on a wrench.
- Students will develop an understanding of torques as they relate to force applied at different angles.

Vocabulary

- balance
- eccentric
- equilibrium torque
- force
- force perpendicular
- fulcrum
- gravity
- lever
- lever arm
- rotational motion
- torque

About the Lesson

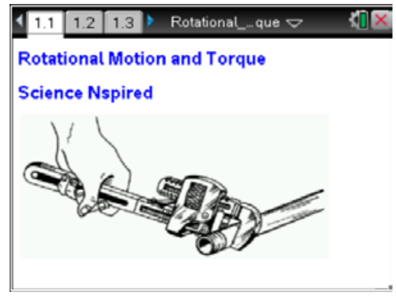
- This lesson has students create situations where a simple lever is in balance.
- As a result, students will:
  - Understand that a lever is balanced by the product of the lever arm and the force.
  - Compare a first class lever to a third class lever and explore the concept of torque.
  - Develop equations for the relationship of perpendicular force and torque.

TI-Nspire™ Navigator™

- Send out the *Rotational_Motion_and_Torque.tns* file.
- Monitor student progress using Screen Capture.
- Use Live Presenter to spotlight student answers.

Activity Materials

- *Rotational_Motion_and_Torque.tns* document
- TI-Nspire™ Technology



TI-Nspire™ Technology Skills:

- Download a TI-Nspire document
- Open a document
- Move between pages
- Use minimized sliders

Tech Tips:

Make sure students understand how to grab and drag points. They should also understand how to change sliders.

Lesson Materials:

Student Activity

- Rotational_Motion_and _Torque_Student.doc
- Rotational_Motion_and _Torque _Student.pdf

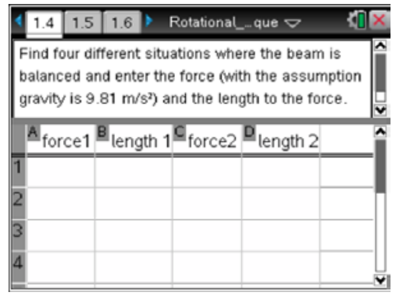
TI-Nspire document

- Rotational_Motion_and _Torque.tns

Discussion Points and Possible Answers

Move to pages 1.3 and 1.4.

1. Discuss with students about gathering 4 different situations where the lever balances on page 1.3. They should enter the data on page 1.4. Discuss with the students about relationships between force and length of situation one and force and length of situation two.



Tech Tip: Students can calculate forces in the cells by typing **=** then the mass times 9.81 and pressing enter. Have them title column C “torque.”

Move to pages 1.5–1.8.

Have students answer the questions on either the handheld, on the activity sheet, or both.

Q1. If the applied forces are not equal, what else has to be considered to get them in balance?

Answer: the length1 needs to be adjusted

Q2. When are Force 1 (F_1) and Force 2 (F_2) in balance?

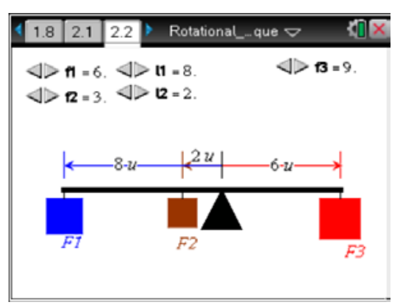
Answer: C. $F_1 * L_1 = F_2 * L_2$

Q3. If a force of 50.0 N is placed at a distance of 3.00m from the fulcrum, what would the length of the lever arm need to be for a force of 30.0 N to balance this beam?

Answer: 50.0 N * 3.00m/30.0 N = 5.00 m

Move to pages 2.1–2.3.

Balancing Multiple Forces



2. On the following page the idea is to balance the forces on both sides of the beam by adjusting the forces (F_1 and F_1) and the distances (L_1 and L_2) from the fulcrum. Find multiple situations where the beam is balanced.
3. Students will enter forces and lengths that balance the lever on page 2.3. Again discuss the idea of what creates this balance.

Tech Tip: Students will need to work a little to get things in balance. They should discover the concept and be able to create multiple situations fairly quickly. Suggest using their own weight and a friend's weight as an initial frame of reference. Also, a quick review of basic dimensional analysis would support unit cancellation.

Move to pages 2.4–2.7.

Have students answer the questions on either the handheld, on the activity sheet, or both.

Q4. What must be true of the conditions required for the beam to balance? Explain how this relates to the other situations where the beam was balanced.

Answer: The sum of the forces times their length is equal to the force time length on the other side. $F_1 * L_1 + F_2 * L_2 = F_3 * L_3$

Q5. What is the product of Force 3 and the lever arm of F_3?

Answer: 9 × 6 = 54 N-m

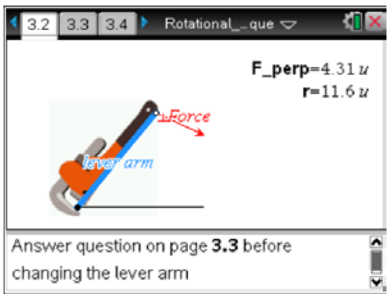
Q6. How does the product of Force 3 and F_3's lever arm compare to the other two forces and lever arms?

Answer: The sum of the two forces times their lever arms has to equal the product of Force 3 and L_3.

Move to pages 3.1 and 3.2.

4. Torque is defined as the product of the **perpendicular force** ($F_\perp$) applied times the length of the **lever arm** (r). The perpendicular force is the force that is applied at 90 degrees to the lever arm. On the following page determine the equilibrium Torque (τ_0). Equilibrium Torque is the maximum torque before rotation occurs.

F_perp represents the force perpendicular and **r** is the length of the lever arm.



Move to pages 3.3–3.5.

Have students answer the questions on either the handheld, on the activity sheet, or both.

Q7. Torque is defined as the product of the lever arm (r) and the perpendicular force ($F_\perp$). What is the equilibrium torque needed on the prior page?

<u>Answer</u>: 4.33 × 11.5 = 49.8 N.m

Q8. If the end point of the lever arm is moved does the product of r and $F_\perp$ change? Explain.

<u>Answer</u>: No the product remains the same but the force needed is inversely proportional to the length of the lever arm

Q9. How long does the lever arm need to be for a perpendicular force of 5.00 N to create a torque of 35.0 N·m?

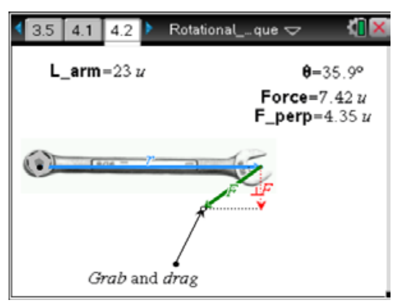
<u>Answer</u>: 35.0 / 5.00 = 7.00 m

Move to pages 4.1 and 4.2.

Torque without Perpendicular Forces

5. When a person is pulling or pushing on a wrench to loosen a nut they sometimes are not applying this force perpendicular to the wrench or lever arm. Explore the result of changing the force vector to a non- perpendicular position to the lever arm.

5.1. Students will grab the point and drag it left and right observing the force needed to stay at and equilibrium torque. The torques stays constant even though the angle changes therefore the Force perpendicular times the lever arm distance will equal the torque. The force perpendicular can be determined by multiplying the force times the sin of theta.



$F_\perp = F{\cdot}\sin(\theta)$ Therefore $\tau_0 = R{\cdot}F{\cdot}\sin(\theta)$

Move to pages 4.3–4.6.

Have students answer the questions on either the handheld, on the activity sheet, or both.

Q10. What angle between r and F requires the least amount of force?

<u>Answer</u>: 90 degrees

Q11. What is the torque for this diagram?

Answer: 4.35 × 23.0 = 100. N-m

Q12. Since the total torque of this system does not change, how can the force at any angle be calculated based on the angle?

Answer: $\tau / R * \sin(\theta) = F$

Q13. A force of 20.0 N is applied at a 70° angle to the lever arm with a length of 0.500 m, what is the torque?

Answer: $\tau = 0.500 \times 20.0 \times \sin(70) = 9.40$ N.m

TI-Nspire Navigator Opportunities

Use TI-Nspire Navigator to capture screen shots of student progress and to retrieve the file from each student at the end of the class period. The student questions can be electronically graded and added to the student portfolio.

Wrap Up

When students are finished with the activity, pull back the .tns file using TI-Nspire Navigator. Save grades to Portfolio. Discuss activity questions using Slide Show. Make sure the concept of balancing torques is firm in their understanding and not balancing forces.

Assessment

- Formative assessment will consist of questions embedded in the .tns file. The questions will be graded when the .tns file is retrieved. The Slide Show will be utilized to give students immediate feedback on their assessment.
- Summative assessment will consist of questions/problems on the chapter test.