Power Up! The Physics of Finishing First

TEACHER NOTES

Objectives

- Students will learn work, energy, and power.
- Students will apply their understanding of work, energy, and power in a simulation.
- Students will learn about triathlons and how work, energy, and power relate to them.
- Students will learn about the STEM career – Engineering

Vocabulary

- work
- joule
- energy
- power
- watt
- electrical engineering
- displacement
- triathlon
- effort
- efficient
- potential energy
- kinetic energy
- mechanical energy

About the Lesson

- The lesson tells the story of Kelly Kutach, an electrical engineer who also competes in triathlons
- Throughout the story, students will learn about how work, energy, and power relate to helping Kelly compete more efficiently.
- Students will be required to make informed decisions during a virtual triathlon as the conditions during the race constantly change.
- Teaching time: one to two 45-minute class period(s)

TI-Nspire™ Navigator™

- Send out the *Power_Up!.tns* file.
- Monitor student progress using Class Capture.
- Use Live Presenter to spotlight student answers.

Activity Materials

- Compatible TI Technologies: TI- Nspire™ CX Handhelds, TI-Nspire™ Apps for iPad®, TI-Nspire™ Software

Tech Tips:

- This activity includes screen captures taken from the TI-Nspire CX handheld. It is also appropriate for use with the TI-Nspire family of products including TI-Nspire software and TI-Nspire App. Slight variations to these directions may be required if using other technologies besides the handheld.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials.

Lesson Files:

Student Activity

- Power_Up!_student.pdf

TI-Nspire document

- Power_ Up!.tns

Background

STEM CAREER - This activity presents a conversation between an interviewer and Kelly Kutach who has an advanced degree in electrical engineering and also competes in triathlons. Kelly explains why she became interested in engineering and triathlons and how math and science are important for both. Students will see that a decision to go into engineering requires math and science but also other courses such as language arts and government.

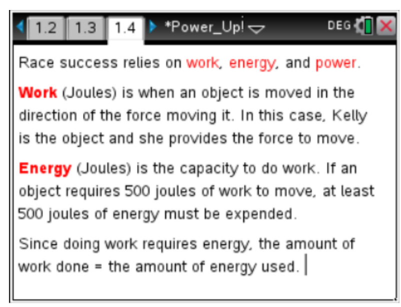
OVERVIEW – Students will use simulations to participate in a virtual triathlon where they will need to make decisions about how to approach changing course conditions. For example, when running uphill, shortening the stride will help to more efficiently get up the hill. Swimming against a current and with the current requires different approaches to maintain a steady effort during the race. A balance between effort, energy, and time is important when taking on a long race like a half ironman. Students will see that work, energy, and power can be determined based on several parameters such as direction of an applied force (pulling your body against the water, pushing your body forward on the pavement, or turning the pedals to turn the wheel to push against the terrain.

Move to pages 1.2–1.3.

1. Pages 1.2 to 1.3 give students an introduction to triathlons and Kelly Kutach. Kelly is an electrical engineer and triathlete.

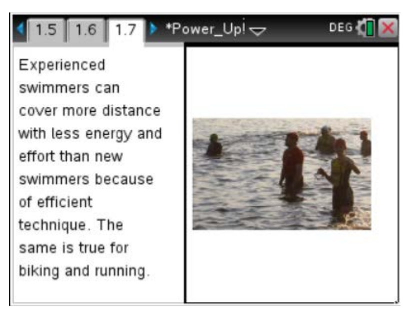
Move to pages 1.4—1.6.

2. Pages 1.4 to 1.6 offer students definitions of work, energy, and power. Students are also given the mathematical equations for each topic.



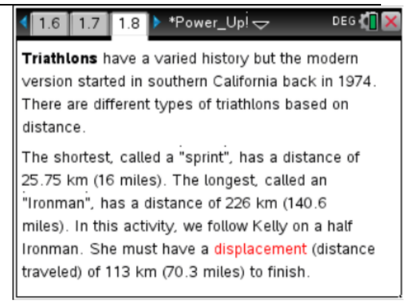
Move to page 1.7.

3. Page 1.7 gives students an example of how, in a triathlon, conserving energy and effort with good technique can improve performance.



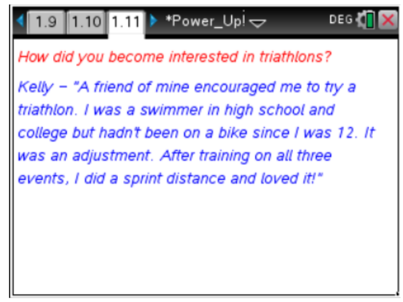
Move to page 1.8.

4. Page 1.8 explains where triathlons came from and the different types. It also introduces the concept of displacement which will be used several times in this activity.



Move to pages 1.9--1.15.

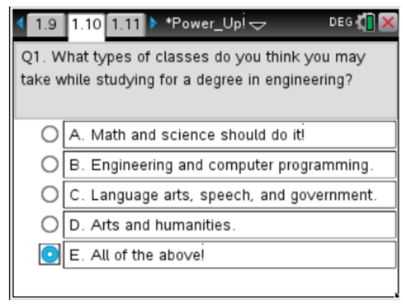
5. Pages 1.9 to 1.15 present a conversation with Kelly Kutach about her interest in engineering and triathlons. Encourage students to read this dialog as it can help them compete in the virtual triathlon later in the activity.



Move to page 1.10.

Q1. What types of classes do you think you may take while studying for a degree in engineering?

Answer: E. All of the above!



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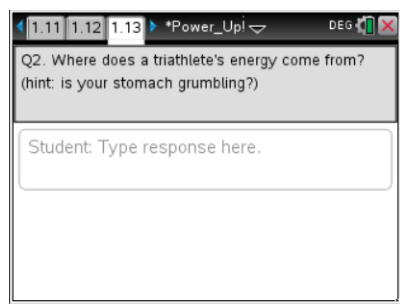
Q2. Where does a triathlete's energy come from? (hint: is your stomach grumbling?)

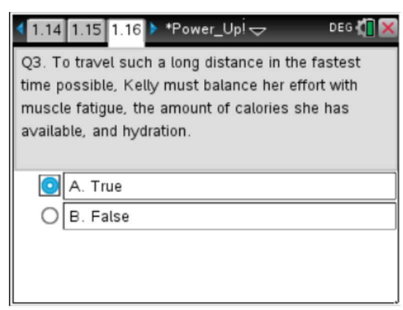
Suggested Answer: Food or Calories



Move to page 1.16.

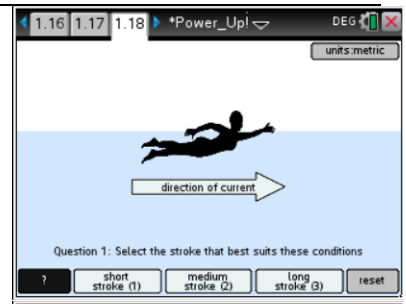
Q3. To travel such a long distance in the fastest time possible, Kelly must balance her effort with muscle fatigue, the amount of calories she has available, and hydration.

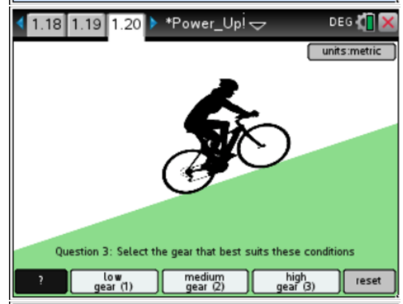
Answer: A. True

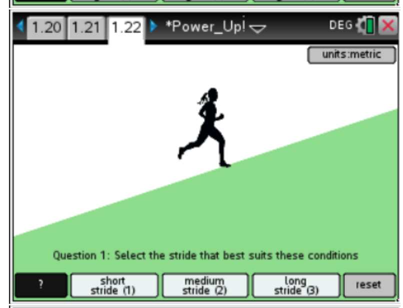


Move to pages 1.17--1.23.

6. Pages 1.17 to 1.23 take students through a virtual triathlon. They must make decisions several times during each of the three legs of the race. Their decisions will save them time or cost them time depending on their choices. At the end, students should be encouraged to compare their times.



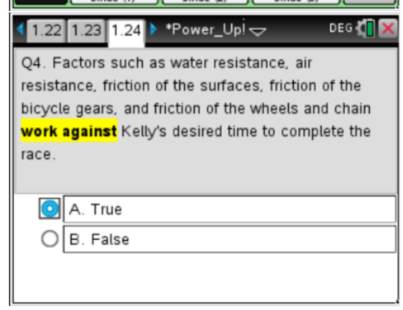




Move to pages 1.24-1.28

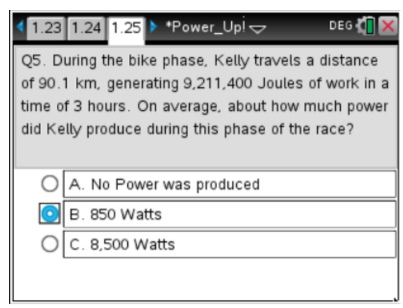
Q4. Factors such as water resistance, air resistance, friction of the surfaces, friction of the bicycle gears, and friction of the wheels and chain work against Kelly's desired time to complete the race.

Answer: A. True



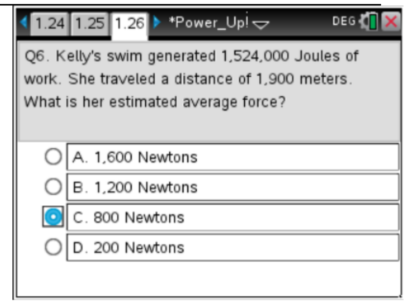
Q5. During the bike phase, Kelly travels a distance of 90.1 km, generating 9,211,400 Joules of work in a time of 3 hours. On average, about how much power did Kelly produce during this phase of the race?

Answer: B. 850 Watts



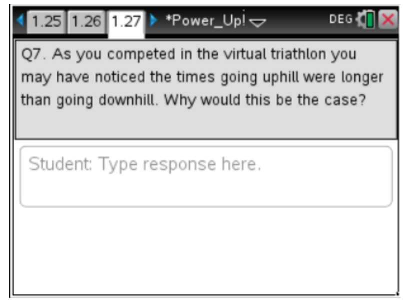
Q6. Kelly's swim generated 1,524,000 Joules of work. She traveled a distance of 1,900 meters. What is her estimated average force (per stroke)?

Answer: C. 800 Newtons



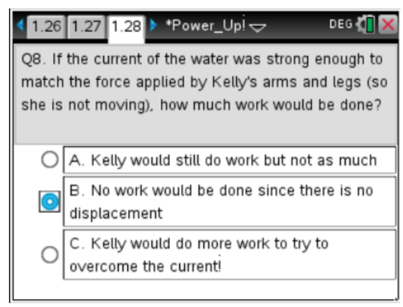
Q7. As you competed in the virtual triathlon, you might have noticed the times going uphill were longer than going downhill. Why would this be the case?

Suggested Answer: Although Kelly's times uphill are longer than going downhill, she tries to maintain an equal effort. Because of gravity, uphills are much more difficult than running downhill. Going uphill, gravity works AGAINST you, requiring shorter steps and more energy. Going downhill, gravity works with you, allowing longer steps and less energy.



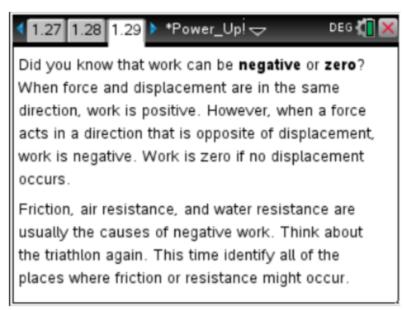
Q8. If the current of the water was strong enough to match the force applied by Kelly's arms and legs (so she is not moving), how much work would be done?

Answer: B. No work would be done since there is no displacement



Move to page 1.29.

7. Page 1.29 discusses the possibility of work being positive, negative, or zero. A discussion about scalar vs. vector quantities may be appropriate here depending if this lesson is being used in a physics class or physical science class and local standards.



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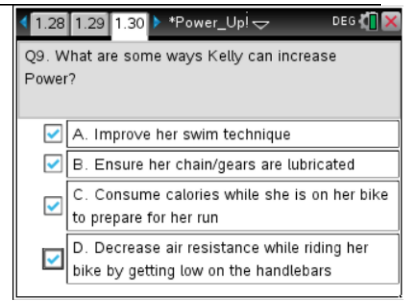
Q9. What are some ways Kelly can increase Power?



Answer:

A. Improve her swim technique

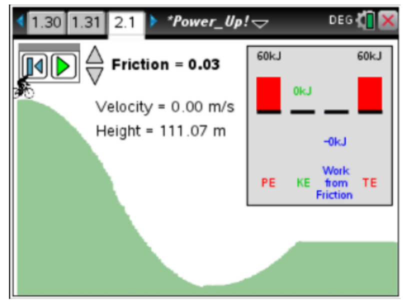
B. Ensure her chain/gears are lubricated

C. Consume calories while she is on her bike to prepare for her run

D. Decrease air resistance while riding her bike by getting low on the handlebars

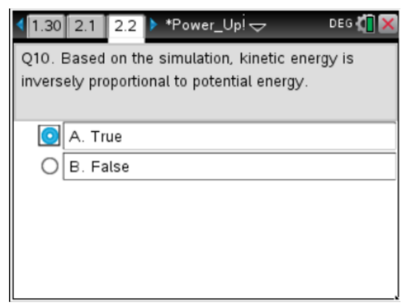
Move to pages 1.31—2.1.

8. Pages 1.31 to 2.1 enable students to experiment with changing the friction of Kelly's bike to observe the changes in potential, kinetic, and total energy. They can also see negative work produced which is the work from friction. Ask the students where possible sources of friction may come from.



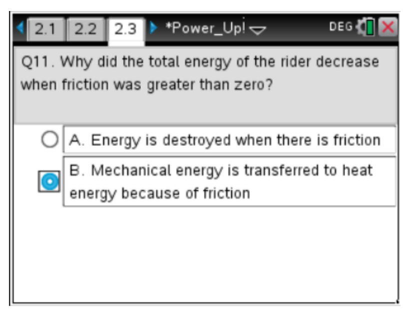
Move to pages 2.2—2.8.

Q10. Based on the simulation, kinetic energy is inversely proportional to potential energy.



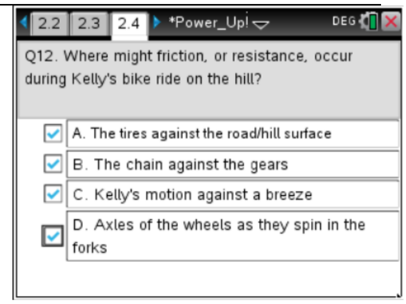
Answer: A. True

Q11. Why did the total energy of the rider decrease when friction was greater than zero?



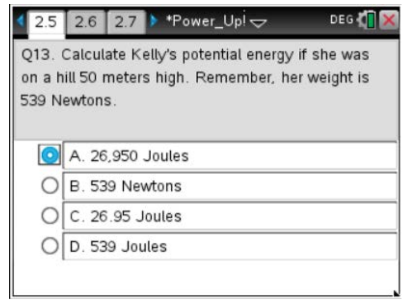
Answer: B. Mechanical energy is transferred to heat energy because of friction

Q12. Where might friction, or resistance, occur during Kelly's bike ride on the hill?



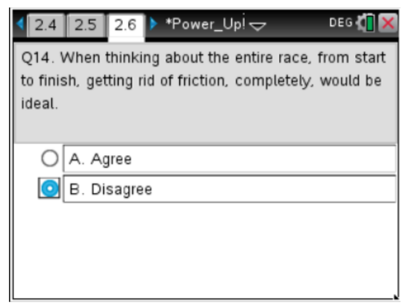
Answer:
A. The tires against the road/hill surfaces
B. The chain against the gears
C. Kelly's motion against a breeze
D. Axles of the wheels as they spin in the forks

Q13. Calculate Kelly's potential energy if she was on a hill 50 meters high. Remember, her weight is 539 N.



Answer: A. 26,950 Joules

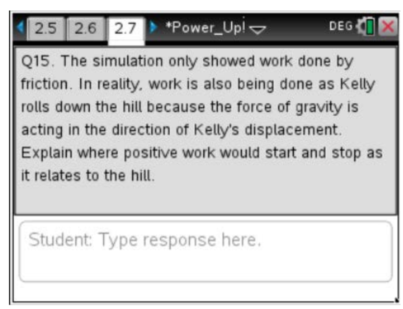
Q14. When thinking about the entire race, from start to finish, getting rid of friction, completely, would be ideal.



Answer: B. Disagree

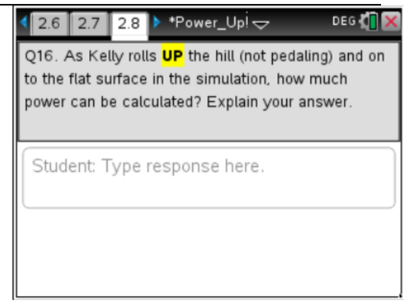
(This may be a great discussion topic. Students may suggest that without friction, Kelly could go through the course using very little energy. A large force at the beginning would be all she would need. But remind them that to get started, she also needs friction)

Q15. The simulation only showed work done by friction. In reality, work is also being done as Kelly rolls down the hill because the force of gravity is acting in the direction of Kelly's displacement. Explain where positive work would start and stop as it relates to the hill.



Suggested Answer: Positive work would happen during the downhill part of the hill because gravity is acting in the direction of Kelly's motion. Positive work is also being done in the direction of the uphill due to Kelly pushing her pedals. She must exert more force than gravity is pushing against her to make it to the top. Therefore, work will be positive going uphill as well. There are different forces.

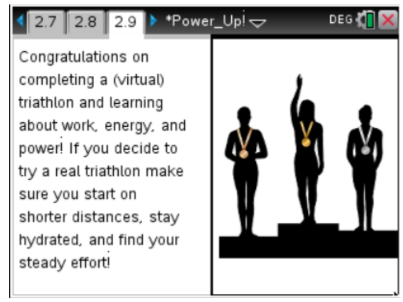
Q16. As Kelly rolls UP the hill (not pedaling) and on to the flat surface in the simulation, how much power can be calculated? Explain your answer.



Suggested Answer: No power can be calculated in this scenario because there is no work being done due to Kelly not pedaling. Although her momentum takes her to the flat portion of the hill, there was no force causing her to accelerate in the direction of her displacement; therefore, work was not done. If there is no work, power will be zero.

Move to page 2.9.

9. Page 2.9 concludes the activity with congratulations to the students and encouragement to try a triathlon!



TI-Nspire Navigator Opportunities

Make a student the Live Presenter to demonstrate his or her asteroid simulation graphs.

Assessment

- Students will answer questions throughout the lesson to ensure they understand the concepts of work, energy, and power and how these concepts relate to real-world scenarios such as triathlons!