3.2 - Work & Power Unit, Packet 2

Score
□ Above & Beyond
□ Meets Expectations
□ Near Expectations
□ Incomplete – *fix the following pages:*

First & Last Name: ______________________________ Period/Hour:______

NOTE: Packets are due after completing Part 5. Check each page to be sure all blanks are completed.

Driving Question: How does energy relate to motion and work?

Anchoring Phenomenon: Often, people associate the terms work and power with physical strength or machinery, envisioning the raw force exerted by a horse or the efficiency of an engine. What determines how powerful something is? And how does this relate to the amount of work it can do?

Deeper Questions
1. What is the difference between energy, force, and motion?
2. What determines the amount of work done?
3. How are work and power measured?

Schedule

Part 1: Introduction
- Initial Ideas & Data Dive
- Discussion & Developing Explanations

Part 2: Core Ideas
- Core Ideas & Revisions of Part 1 Explanations

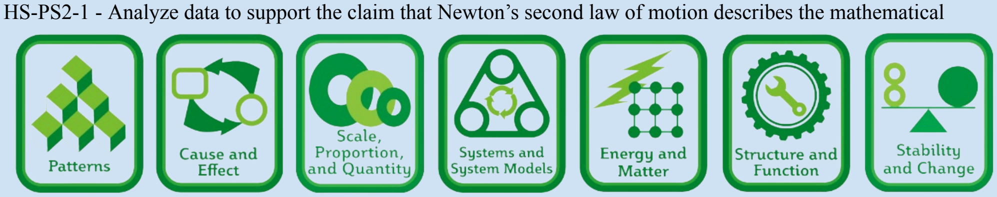
Part 3: Investigation
- 3A: Conservation of Energy
- 3B: Burning Calories

Part 4: Review & Assessment
- Ranking Your Readiness & Practice Problems
- Formative Assessment & Mastery Check

Part 5: Life Connections
- Life Connections - Skate Park Physics

NGSS Standards (*PEs & CCCs are summarized below. SEPs are noted throughout the packet*).

HS-PS2-1 - Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.



HS-PS2-4 - Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects

Semester Schedule

1. Motion
1.1: How and why does something move?
1.2: How fast do objects fall?
1.3: Why do thrown objects follow a predictable path?
1.4: Unit Assessment

2. Forces
2.1: What causes acceleration?
2.2: What slows down acceleration?
2.3: Why do objects stay in orbit in space?
2.4: Unit Assessment

3. Work & Power
3.1: What determines the power generated by an object
3.2: How does energy relate to motion and work?
3.3: Can we decrease the force needed for work?
3.4: How can the force of a collision be reduced?
3.5: Unit Assessment

4. Trebuchet Project
4.1: How can we design a tool to hit a precise target?

These materials were partly developed with assistance from artificial intelligence.

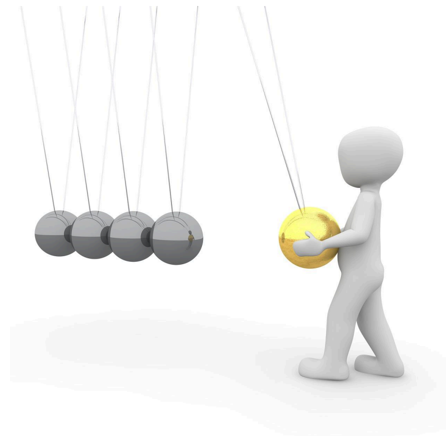
Resource Links: Class Website; Core Ideas; Quizlet;

Part 1: Introduction (3.2.1)

Overview: In this activity, you will begin by discussing your initial ideas about the conservation of energy. You will then analyze data and work in teams to develop your initial explanations.

Initial Ideas - *Record your ideas separately (e.g., on a white board or scratch paper).*
SEP: Engaging in Argument from Evidence

A Newton's Cradle shows how energy transfers through a series of swinging spheres. If you lift one sphere, it crashes into the others and causes a sphere on the opposite site to move. Eventually, all motion stops. Three students debate why this occurs.



- **Do you agree or disagree with each student's claim**?
  - Mike: "You put energy into this object, but eventually the energy runs out." Agree/ Disagree
  - Lucia: "The energy doesn't run out; it is just absorbed by each of the metal spheres." Agree/ Disagree
  - Oscar: "The energy doesn't run out. It just gets transferred to air particles." Agree/ Disagree
- **Work in your small groups to discuss your ideas.** How are your ideas similar or different? Decide as a group whether each statement is correct (and why). Be prepared to present your ideas to the class.

Discussion - *Record your ideas in the spaces below. SEP: Asking Questions & Defining Problems*

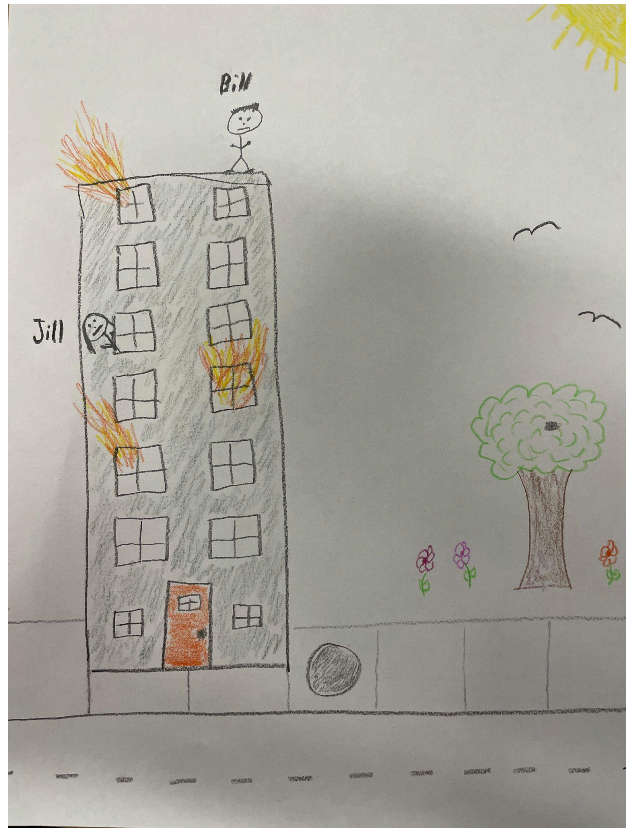
As a class, discuss your ideas about these statements. What are the ideas that most agreed on? Where did your ideas differ as a class? Record your ideas in the spaces below.

We generally agree that…	***We disagreed or were unsure if…***

Data Dive - *Read the directions below. SEP: Engaging in Argument from Evidence*

Bill and Jill are in an apartment building that is on fire in multiple places. **Look at the picture provided and answer the questions.**

1. Who is higher off the ground?
2. Who would get hurt more if they jumped off the building (assuming they are the same size)?
3. If more hurt = more energy, who had more energy before they jumped?
4. What, specifically, gave them more energy?



The more you know: Potential energy is "stored energy" Bill and Jill both had potential energy before they jumped off the building. But once they jump, some of that stored energy is turned into "energy of motion" or kinetic energy.

5. Who has more energy to convert to kinetic energy?
6. If Bill had 50J of potential energy before he jumped, how much kinetic energy would he have right before he hits the ground?
7. Once he hits the ground, how much potential energy does he have?

If you said zero, you may or may not be correct. Did you see the manhole cover missing on the sidewalk? What if Bill rolls into this and down into the sewer?

Initial Explanations - *Record your ideas in the spaces below. SEP: Constructing Explanations & Designing Solutions*

Describe the relationship between potential and kinetic energy. Don't worry if you aren't completely sure about this. You will come back and revise this explanation as you gain more information.

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Part 2: Core Ideas (3.2.2)

Overview: In this activity, you will begin with a short presentation to provide you with information that will help you improve and revise your initial ideas. Your instructor will decide on how to implement this portion. You will then work in small teams to address the questions listed below.

Driving Questions - *Record your ideas separately (e.g., on a white board or scratch paper).*
SEP: Developing & Using Models

1. Energy is conserved. What does this mean?
2. What is kinetic energy, and how is it calculated?
3. A big car & a small car each move at 60 mph. Does their kinetic energy differ? Explain.
4. How is kinetic energy related to work?
5. What is potential energy, and how is it calculated?
6. How is a swinging pendulum an example of a) transformation of potential energy and kinetic energy, and b) conservation of energy?
7. If energy is conserved why does a pendulum eventually stop moving?
8. What is negative work? What are examples of this?
9. What is an elastic force, and how is it an example of potential energy?
10. How is the elastic potential energy of a spring calculated?
11. What is the difference between a conservative and a nonconservative force?
12. What is a restoring force?

Revising Explanations - *Record your ideas in the spaces below. SEP: Construction Explanations & Designing Solutions*

Describe the relationship between potential and kinetic energy. Based on this new information, how would you now respond to this question?

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Throughout this packet, you will be updating this explanation as you gain more information and more experience. When you complete this packet, compare your initial explanation to your final version. You should see clear improvement with each revision.

Part 3A Investigation: Conservation of Energy (3.2.3a)

Pre-Investigation Questions - *Prepare verbal responses as a group for these questions. Raise your hand when you're ready to present your explanations. Your instructor will provide feedback and decide if you can proceed to the investigation. SEP: Developing & Using Models*

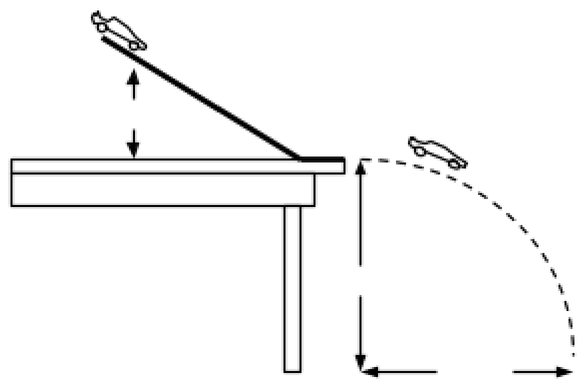
1. How would I measure the initial potential energy of an object?
2. How would I measure the final kinetic energy of an object?
3. What equation would we use to find the potential and kinetic energy of an object?
4. How would you verify that the initial potential energy is converted to kinetic energy?
5. What are some experimental errors you could encounter doing this experiment?

This activity was completed ____ (*instructor signature*)

Overview: You will demonstrate the conservation of energy through projectile motion. The amount of potential energy (PE) of a matchbox car at the top of the race track is equal to the total amount of kinetic energy (KE) at the bottom of the race track. By measuring the initial PE of the matchbox car, you can calculate the KE and the velocity of the matchbox car, and predict the range of the car using projectile motion equations:

Δ PE = Δ KE (Δ = *"change in"*)

m g h = 1/2 m v^2



Directions - *Carefully read the directions below before beginning. SEP: Planning & Carrying Out an Investigation*

1. ☐ Address the following as a class: *1) Question - what are we trying to figure out? 2) Hypothesis - what do we think will happen, and why? 3) Independent Variable - what will be changed and what needs to be kept constant? 4) Dependent Variable - what data is needed for our question & hypothesis?*
2. ☐ Using a matchbox track, set-up a ramp on a lab table (see image above).
   a. A matchbox car will be used as the projectile since its mass is large compared to the number of moving parts - this will reduce rotational inertia and friction and will give a more accurate prediction.
3. ☐ Mark a starting position at the top of the track using your pencil and measure the height of this position relative to the table top.
   a. This will be used to calculate the initial PE of your matchbox car and ultimately it will determine the velocity the car will travel off the table top.
   b. Be sure to position the track at a height where the matchbox car will not hit the cabinets, or position the track away from the cabinets.
4. ☐ Using the conservation of energy equation, we will calculate the velocity with which the matchbox car leaves the table top horizontally: Δ PE = Δ KE → m g h = 1/2 m v^2 → g h = 1/2 v^2
   10(h) = 1/2v^2 → 20(h) = v^2

Data & Results - *Record your data below.* *SEP: Analyzing & Interpreting Data*			
Height of car starting position h_i = ____________ m Velocity of car **v = _____________m/s**			
Measure the height of the table top: h_t = _____________ m			
Calculate the time of flight for your car using the projectile equation: **t = ________ s** ($h_t = 1/2\ g\ t^2$)			
Predict where the car will land on the floor using this equation: predicted **X = __________ m** (X = v t)			
Roll the matchbox car down the ramp 8 times and record the range values and average range below.			
Trial	**Range**	**Trial**	**Range**
1		**5**	
2		**6**	
3		**7**	
4		**8**	
Average Range =			

5) Do an error analysis to see how close you were to your predicted range.

$$\%\ \text{Error} = \frac{|(\text{actual} - \text{theoretical})|}{\text{theoretical}}$$

Concluding Questions:

1. How close were you to the actual range?

2. What were some of the factors that influenced the matchbox car and the outcome of the experiment?

3. Would the matchbox car ever have a range greater than what you predicted?

4. Given the experiment, do you think that the energy of the matchbox car is being conserved when you include any heat loss (friction)?

Part 3B Investigation: Burning Calories (3.2.3b)

Pre-Investigation Questions - *Prepare verbal responses as a group for these questions. Raise your hand when you're ready to present your explanations. Your instructor will provide feedback and decide if you can proceed to the investigation. SEP: Developing & Using Models*

1. *What does it mean to 'burn calories' while exercising? Where does this energy ultimately go?*
2. *How is the concept of calories similar and different from potential energy?*
3. *How are exercise and kinetic energy related? How are they different?*
4. *What are some experimental errors you could encounter when trying to determine how much exercise is needed to burn off the calories of a candy bar?*

This activity was completed ______________________________ (*instructor signature*)

Overview: You will determine how far you need to walk in order to burn off the calories in one snack size candy bar. Each candy bar contains a predetermined amount of calories, which can be converted into Joules. A student's weight and the distance they move determines the work (in Joules) that they perform.

Calories in one candy bar = ____________ Cal. = ___________ J (1 Cal. = 4,184J)

Weight of student = ___________ lbs. = __________ N (1 lb. = 4.4N)

The center of gravity of the student is raised and lowered with each step. (measured from a belt loop to the floor when standing straight up, to when a person makes a step with their foot out on the floor)

One step changes the person's center of gravity = _________ meters

Therefore the total change in distance is (x 2) = _________ meters

Calculate the work performed by the student to do one step:

Calculate the number of steps to burn off the equivalent amount of Joules in one candy bar:

The number you calculated above would mean that your body works at 100% efficiency. This simply isn't true. Your body really only works at about 15% efficiency. Calculate the actual number of steps it would take to burn off the calories in one candy bar.

$$.15 = \frac{\text{number of steps}}{x}$$

Part 3C Investigation: Conservation of Energy (3.2.3a)

Pre-Investigation Questions - *Prepare verbal responses as a group for these questions. Raise your hand when you're ready to present your explanations. Your instructor will provide feedback and decide if you can proceed to the investigation. SEP: Developing & Using Models*

1. How would I measure the initial potential energy of an object?
2. How would I measure the final kinetic energy of an object?
3. What equation would we use to find the potential and kinetic energy of an object?
4. How would you verify that the initial potential energy is converted to kinetic energy?
5. What are some experimental errors you could encounter doing this experiment?

This activity was completed ______________________________________ (*instructor signature*)

Overview: You will calculate the spring constant of an elastic object using conservation of energy through projectile motion. The amount of elastic potential energy (EPE) of a stretched rubber band is equal to the total amount of kinetic energy (KE) as calculated from its range. By measuring the range of the rubber band and calculating the time in the air from the initial height, you can calculate the velocity and KE of the rubber band, which is coming from the stored EPE. You can then calculate the spring constant, k, of the rubber band:

Δ EPE = Δ KE (Δ = *"change in"*)

$\frac{1}{2} k x^2 = 1/2\ m v^2$

Objective - You will fire a stretched rubber band horizontally off a lab table using a ruler or meterstick.

By measuring how far it travels before hitting the floor, you will:

1. Determine the launch speed of the rubber band
2. Calculate its **kinetic energy (KE)** at launch
3. Assume KE ≈ **elastic potential energy (EPE)** stored in the stretched band
4. Use EPE to determine the **spring constant k** of the rubber band

Materials

- Rubber band
- Meterstick
- Electronic balance
- Ruler
- Masking tape
- Calculator
- Lab table (measure height)
- Safety goggles

Independent Variable: Stretch distance x: ***Distance the rubber band is stretched beyond its normal length.***
Dependent Variable: Range R, launch speed v, KE, EPE, spring constant k
Controlled Variables: Table height h, type of rubber band, release angle (horizontal)

Procedure

1. **Measure table height** h and record it.
2. **Measure the mass** m of the rubber band (convert grams → kg).
3. Select a **stretch distance** x. Measure how much longer the band is compared to its relaxed length.
4. Pull the rubber band back on the ruler or meterstick, release it **horizontally**, and let it fly off the edge.
5. Mark where it first hits the floor. Measure the **horizontal range** R.
6. Repeat **3 trials** for each stretch distance.
7. Compute the **average range**.
8. Use projectile motion to calculate the **launch speed**:
9. Calculate kinetic energy:
   $KE = \frac{1}{2} m v^2$
10. Assume KE ≈ EPE
11. Use the elastic energy equation to compute the **spring constant**:

$EPE = \frac{1}{2} k x^2 \Rightarrow k = 2\,KE / x^2$

Measurements

Table Height: h = ____________ m

Rubber Band mass: m = ______________ kg (remember 1 g = 0.001 kg)

Data Table

Trial	Stretch Distance = x	Range 1	Range 2	Range 3	Average Range
1					
2					
3					

Calculations

1. Time to fall from table:

$H = ½ g t^2 = 5 t^2$

2. Launch speed: Range = $R = v t : v = R / t$

3. Kinetic energy:

$KE = 1/2\ m v^2$

4. Elastic Potential Energy:

EPE ≈ KE = ____________ J

5. Spring constant k:

$½ k x^2 = EPE = KE$ $k = 2 KE / x^2$

Trial 1:

Trial 2:

Trial 3:

Follow-Up Questions

1. Describe how you ensured the rubber band was released horizontally.

2. Explain why we can assume EPE ≈ KE in this experiment.

3. List **two** sources of energy loss that would make KE = EPE less than the stored EPE.

4. Compare your calculated k values for different stretch distances. Were they similar? What does this tell you?

5. If the rubber band were heavier, how would that change the range and the calculated KE? Explain why.

6. Suggest one improvement to make the experiment more accurate.

Part 4A: Review & Assessment (3.2.4a)

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Step 1: Rank each Driving Question in Part 2 based on your comprehension (you can rank them as *1,2,3* or *green/yellow/red*, or any other method). Then work in teams to review anything that is still unclear.
Step 2: Identify any remaining areas of confusion or concern. Then review these topics with your instructor.
Step 3: Complete the Formative Assessment (*last page of the packet*). Your instructor will determine if you will work individually, in pairs, or in small groups. Then compare and evaluate your responses as a class.
Step 4: Individually complete a Mastery Check (link on pg. 1). If your performance indicates that additional support is needed, your instructor will determine how to help you move forward.

Part 4B: Practice Problems (3.2.4b)

Formulas: $KE = \frac{1}{2} m v^2$ $PE = m g h$ $F = k x$ $EPE = \frac{1}{2} k x^2$

1. Describe both gravitational potential energy (GPE) and kinetic energy (KE), also give an example of both you have experienced.

2. How much GPE does a 150 kg coaster have at the top of a hill if it is 70 m above the ground?

3. How high off the ground is the same coaster if it has 23000 J of energy at the top of a hill?

4. What happens to the GPE as a coaster moves down a track? (What types of energies is it converted into)

5. What is the mass of a car at the top of a hill that is 20 m high and the car has 15550 J of energy?

6. How much mechanical energy does a coaster have that is moving at 35 m/s, is 25 m off the ground, and has a mass of 100 kg?

7. How much KE is produced at the end of a ramp from a vehicle moving at 12.5 m/s and has a mass of 550 kg?

8. How fast is the vehicle in question #7 going if it has 50000 J of energy?

9. Name as many types of energy that you can think of.

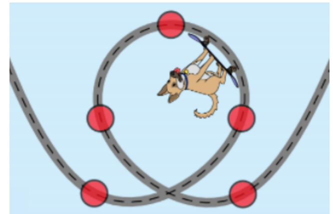
10. Using the conservation of energy how fast will a rock be going if released from the edge of a 125 m cliff and its mass is 100 kg? For this question conservation of energy where the GPE and KE are set equal to each other. Find the GPE first and use that number equal to the KE and solve for velocity.

11. A rubber band is stretched to 15 cm by a force of 30 N. What is the rubber band's spring constant?

12. How much energy is stored in a rubber band that is stretched 0.5 m and has a spring constant, k, of 8.0 N/m?

13. Assuming all of the energy goes into the release of the rubber band in the previous problem, how fast will the 0.005 kg rubber band be going?

Part 5: Life Connections – Skate Park Physics



Directions: For this activity you will visit this website and create your own skate park to demonstrate what you have learned from this week's material. Utilize each section of the website (Introduction, Measure, Graphs, and Playground) to collect your data. Be creative and you must explain your data.

Work & Power Packet 3.2 Formative Assessment (3.2.4)

Name: ______________________________ Hour____ Date:__________ Score:________

Directions: A 3x5 notecard with *handwritten* notes can be used to guide your answers. Your instructor may allow you to work in assigned groups. If so, have a different person write each response while others assist.

Formulas Needed: $\Delta PE = m g h$, $\Delta KE = 1/2 m v^2$, $EPE=1/2 kx^2$

1. **Explain the difference between kinetic energy and gravitational potential energy.** Use these equations in your explanation: $\Delta PE = m g h$, $\Delta KE = 1/2 m v^2$

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2. Two people on a 10-story skyscraper each drop 5-gallon buckets of window cleaner due to a sudden gust of wind (one from the 10th story, and one from the 7th story). **Explain which bucket had more potential energy at the start and which had more kinetic energy right before hitting the ground.** Use these equations in your explanation: $\Delta PE = m g h$, $\Delta KE = 1/2 m v^2$

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3. **Mr. Hendricks enjoys jumping his RC car, often reaching a height of 10 feet. The car's shocks (springs) have a specific elastic potential energy. Should he prefer a high or low spring constant for the shocks? Explain.** Use this equation in your explanation: $EPE = 1/2 kx^2$

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4. **Three students are trying to explain why a pendulum eventually stops swinging. Do you agree or disagree with each student's claim**?
    a. Kevin: "The kinetic energy is eventually completely transformed into potential energy, which has no motion." Agree/ Disagree
    b. Jo: "The kinetic energy is eventually completely absorbed by the matter in the pendulum." Agree / Disagree
    c. Nicki: "The kinetic energy is transferred to air particles around the pendulum." Agree / Disagree

5. **Based on the data shown here, which claim is most accurate**? ______________ **Explain how you know**:

6. **Summarize the terms "conservative force" and "nonconservative forces" and use these concepts to explain why a pendulum eventually stops moving.**

7. A 1 kg pendulum has 10 Joules of potential energy when released.
A) At what height was the pendulum released?
B) What is the velocity of the pendulum when potential energy is reduced to 2 J?
Show your work below. Disregard losses to energy from striking air particles.
Formulas Needed: $\Delta PE = m\,g\,h$, $\Delta KE = 1/2\, m\, v^2$