# SI Physics - Full Discipline Demo

## Energy

## Final Report - Answer Guide

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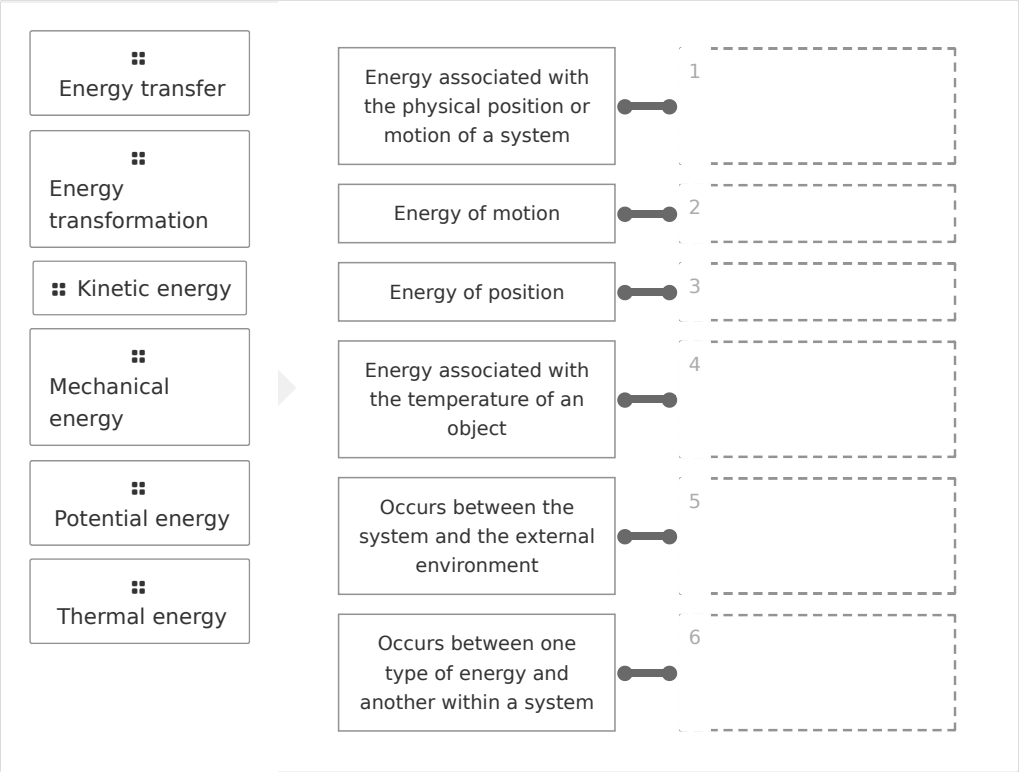
|---|---|
| **Institution** | Science Interactive University |
| **Session** | SI Physics - Full Discipline Demo |
| **Course** | SI Physics - Full Discipline Demo |
| **Instructor** | Sales SI Demo |

## Test Your Knowledge

**Match each term with the best description.**

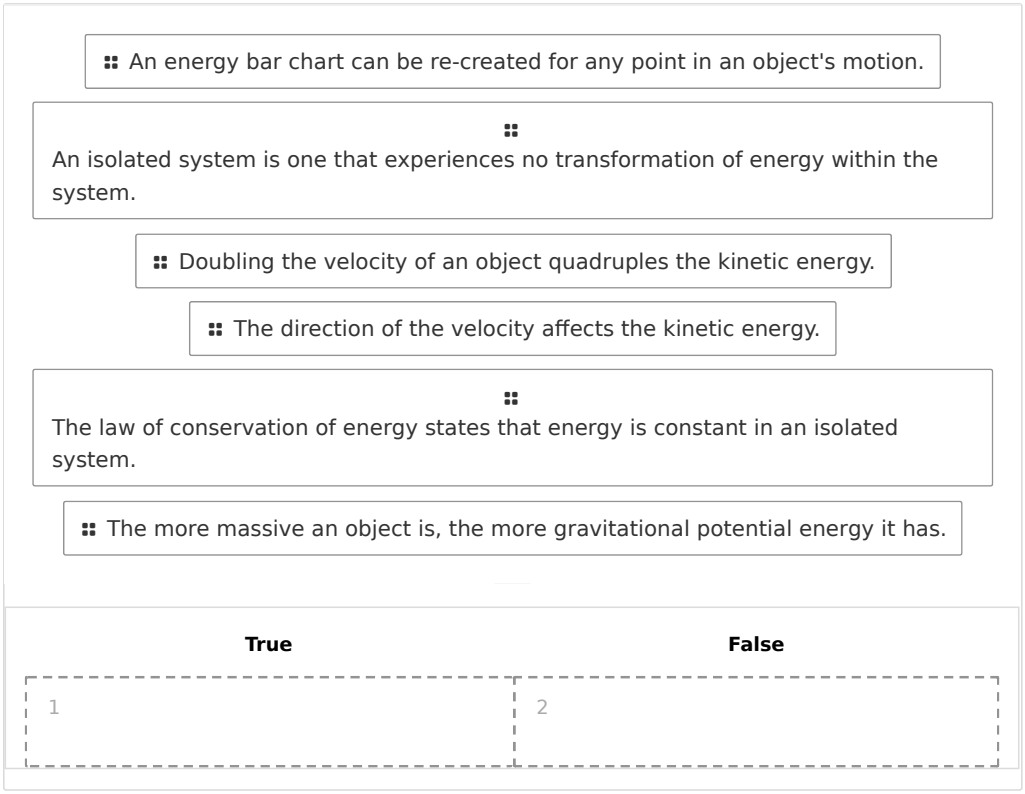



Correct answers:

1 Mechanical energy 2 Kinetic energy 3 Potential energy

4 Thermal energy 5 Energy transfer 6 Energy transformation

**Categorize each statement as true or false.**




Correct answers:

1 An energy bar chart can be re-created for any point in an object's motion.

Doubling the velocity of an object quadruples the kinetic energy.

The law of conservation of energy states that energy is constant in an isolated system.

The more massive an object is, the more gravitational potential energy it has.

2

An isolated system is one that experiences no transformation of energy within the system.

The direction of the velocity affects the kinetic energy.

## Exploration

**Energy is measured in units of _____.**

- joules ✔
- kilograms
- meters per second
- All of the above

**Kinetic energy _____ with increasing mass and velocity.**

- can increase or decrease
- increases ✔
- decreases
- None of the above

**Energy is a vector quantity (has magnitude and direction).**

- True
- False ✔

**_____ is the energy stored due to an object's mass and height above the ground.**

- Potential energy
- Gravitational potential energy ✔
- Elastic potential energy
- None of the above

**Thermal energy is the macroscopic manifestation of the sum of the _____ energy of each microscopic molecule of an object.**

- total
- potential
- kinetic ✔
- None of the above

**Compressing and expanding a spring increases its thermal energy.**

- True ✔
- False

**During energy transfer, the amount of energy within a system is the same.**

- True
- False ✔

**Energy loss is energy _____ a system.**

- transformation within
- transfer out of ✔
- conversion from kinetic to potential within
- All of the above

**In physics, _____ means that there is no change before or after an interaction.**

- isolated
- transferred
- conserved ✔
- All of the above

**An energy bar chart can be re-created for _____ an object's motion.**

- any point in ✔
- only the beginning of
- only the end of
- None of the above

# Exercise 1

**How does the shape of a ramp affect a skater's motion in the absence of friction? How does the addition of friction affect the skater's motion? Explain your answer referencing Data Tables 3, 4, and 5**.

In the absence of friction, the skater's motion on both ramps is similar. On each ramp the skater reaches the same height on the other side of the ramp, which is equal to the starting height. The addition of friction results in the skater losing more energy to friction on the W-shaped ramp compared to the standard ramp, thus returning to a lower height on the opposite side of the ramp compared to the skater on the standard ramp.

Data Table 1: Maximum Velocity Calculations for the Conservation of Energy
(SAMPLE ANSWER BELOW)

| Starting Position $h_i$ (m) | $h_f$ | Maximum Velocity (m/s) |
|---|---|---|
| 4.00 | 4.00 | 8.86 |
| 3.00 | 3.00 | 7.76 |
| 2.00 | 2.00 | 6.26 |
| 1.00 | 1.00 | 4.43 |

Data Table 2: Describing Motion on a W-Shaped Ramp
(SAMPLE ANSWER BELOW)

| Starting position $h_i$ (m) | Description of Motion |
|---|---|
| 4.00 | The skater travels the entire ramp path, reaching a maximum height of 4.00 m. |
| 3.00 | The skater travels the entire ramp path, reaching a maximum height of 3.00 m. |
| 2.00 | The skater reaches to top of the central bump, a maximum height of 2.00 m, but does not travel beyond this point. (Note: If the skater is not placed exactly at 2.00 m, they may go over the bump.) |
| 1.00 | The skater does not travel over the central bump, reaching a maximum height of only 1.00 m. |

Data Table 3: Determing Percent Loss
(SAMPLE ANSWER BELOW)

| Starting Position $h_i$ (m) | 5 | 4 | 3 |
|---|---|---|---|
| $h_1$ (m) | 3.8 | 3.0 | 2.2 |
| $h_2$ (m) | 2.8 | 2.2 | 1.7 |
| | 2.1 | 1.7 | 1.3 |

| | | | |
|---|---|---|---|
| $h_3$ (m) | | | |
| Percent Loss: $h_i$ to $h_1$ (%) | 24.0 | 25.0 | 26.7 |
| Percent Loss hi to $h_2$ (%) | 26.3 | 26.7 | 22.7 |
| Percent Loss hi to $h_3$ (%) | 25.0 | 25.0 | 26.5 |

Data Table 4: Determining Percent Loss with Two Ramp Shapes
(SAMPLE ANSWER BELOW)

| Ramp Shape | Standard | W-Shaped |
|---|---|---|
| Starting Position $h_i$ (m) | 5 | 5 |
| $h_1$ (m) | 3.8 | 3.0 |
| $h_2$ (m) | 2.8 | 2.0 |
| $h_3$ (m) | 2.1 | 1.4 |
| Percent Loss: $h_i$ to $h_1$ (%) | 24.0 | 40.0 |
| Percent Loss hi to $h_2$ (%) | 26.3 | 35.0 |
| Percent Loss hi to $h_3$ (%) | 25.0 | 28.0 |

Data Table 5: Describing Energy Transformations in the Presence of Friction
(SAMPLE ANSWER BELOW)

| Ramp Shape | Description of Motion |
|---|---|
| Standard | Initially, the potential energy is equal to the total energy, which remains constant throughout the skater's motion. As the skater travels down the ramp, potential energy is converted to kinetic and thermal energy. As the skater continues through the ramp, energy transforms between potential and kinetic, but these values decrease as the thermal energy continues to steadily rise with continued motion on the ramp. The skater eventually comes to a stop at the bottom of the ramp, when the thermal energy is equal to the total energy. |
| W-Shaped | Initially, the potential energy is equal to the total energy, which remains constant throughout the skater's motion. As the skater travels down the ramp, potential energy is converted to kinetic and thermal energy. As the skater continues through the ramp, energy transforms between potential and kinetic, but these values decrease as the thermal energy continues to steadily rise with continued motion on the ramp. After a certain point, the skater does not have enough potential/kinetic energy to travel over the central bump. The skater eventually comes to a stop at the bottom of the ramp before the central bump, when the thermal energy is equal to the total energy. |

## Exercise 2

**How does initial drop height affect the percent potential energy loss of a bouncing ball? Reference Data Table 6 in your answer.**

The height does not affect the potential energy loss. As is seen in Data Table 6, the percent energy loss for each initial height is approximately 45%, indicating the percent of energy loss by the ball is independent of the starting position.

**The kinematic equation provided to find the velocity in Part 2 can only be used to describe free fall motion. In general, the equation to solve for velocity is $v=v_0+at$ and it can only be used for motion in a straight-line path. Based on your results from Exercise 1 and Exercise 2, explain why using conservation of energy would be more beneficial to use than kinematics when describing velocities on a ramp like those seen in Exercise 1.**

In Exercise 1, the shape of the ramp did not affect conservation of energy in the absence of friction. If energy is conserved, the velocity of the skater at any height can be determined, regardless of ramp shape. Kinematics requires straight line paths or complicated formulas to take ramp shape into account. Using conservation of energy allows the shape of the ramp to be ignored when calculating velocity.

Data Table 6: Energy Loss of a Bouncing Tennis Ball
(SAMPLE ANSWER BELOW)

| Trial | 1 | 2 | 3 |
|---|---|---|---|
| Mass (g) | 59 | 59 | 59 |
| Initial height $h_i$ (m) | 2.50 | 3.02 | 3.51 |
| Final height $h_f$ (m) | 1.39 | 1.67 | 1.92 |
| v (m/s) | 7.004 | 7.698 | 8.299 |
| $PE_i$ (J) | 1.447 | 1.748 | 2.032 |
| $PE_f$ (J) | 0.805 | 0.967 | 1.111 |
| ΔPE (J) | -0.642 | -0.781 | -0.920 |
| Percent PE Loss (%) | 44.4 | 44.7 | 45.3 |

Data Table 7: Energy Loss of Different Bouncing Balls
(SAMPLE ANSWER BELOW)

| Object | Marble | Tennis Ball | Hockey Ball |
|---|---|---|---|
| Mass (g) | 3 | 59 | 162 |
| Initial height $h_i$ (m) | 3.00 | 3.00 | 3.00 |
| Final height $h_f$ (m) | 2.18 | 1.65 | 1.10 |
| Drop Time (s) | 0.798 | 0.791 | 0.778 |
| $v_E$ (m/s) | 7.672 | 7.672 | 7.672 |
| $v_k$ (m/s) | 7.828 | 7.760 | 7.632 |

| | | | |
|---|---|---|---|
| v Percent Error (%) | 2.0 | 1.1 | 0.5 |
| $PE_i$ (J) | 0.088 | 1.736 | 4.768 |
| $PE_f$ (J) | 0.064 | 0.955 | 1.748 |
| ΔPE (J) | -0.024 | -0.781 | -3.020 |
| Percent PE Loss (%) | 27.3 | 45.0 | 63.3 |

## Competency Review

**_____ energy is energy associated with the physical position or motion of a system.**

- Potential
- Kinetic
- Mechanical ✔
- None of the above

**_____ are types of mechanical energy.**

- Kinetic and potential ✔
- Kinetic and thermal
- Potential and thermal
- None of the above

**A ball falling from shoulder height experiences energy _____ as potential energy becomes kinetic energy.**

- transfer
- transformation ✔
- exchange
- All of the above

**A block sliding down a ramp experiences energy _____ as friction increases the thermal energy of the ramp.**

- transfer ✔
- transformation
- exchange
- All of the above

**When energy is conserved, there is no _____ of energy into or out of an isolated system.**

- transfer ✔
- transformation
- transfer or transformation
- None of the above

**A bouncing ball gains or loses _____ energy at some point during its motion.**

- kinetic
- potential
- thermal
- All of the above ✔

**In an energy bar chart the _____ energy remains constant throughout the interaction.**

- kinetic
- potential
- total ✔
- All of the above

**A skater on a frictionless ramp will reach their maximum velocity at the _____ of the ramp.**

- top
- bottom ✔
- middle
- None of the above

**A skater on a frictionless ramp where the acceleration due to gravity is 9.8 m/s$^2$ has a maximum velocity of 8.0 m/s and started at a height of _____ m.**

- 0.4
- 3.3 ✔
- 6.5
- None of the above

**A skater on a ramp with friction starting at a height of 4 m will reach a maximum height of _____ m after passing through the bottom of the ramp.**

- exactly 4
- greater than 4
- less than 4 ✔
- The answer depends on the amount of friction present

**A 0.5 kg ball dropped from a height of 5 m has a velocity of _____ m/s at a height of 1 m, if the acceleration due to gravity is 9.8 m/s$^2$.**

- 9 ✔
- 78
- 10
- None of the above

**A 0.5 kg ball dropped from a height of 5.0 m has an initial potential energy of _____ J, if the acceleration due to gravity is 9.8 m/s$^2$.**

- 4.9
- 24.5 ✔
- 6.3
- None of the above

## Extension Questions

**In a device called the ballistic pendulum, a compressed spring is used to launch a steel ball horizontally into a soft target hanging from a string. The ball embeds in the target and the two swing together from the string. Describe the energy transfers and/or transformations that take place during the use of the ballistic pendulum and at what points they occur.** (SAMPLE ANSWER BELOW)

The compressed spring has elastic potential energy and when it is released, the spring potential energy is transformed into the kinetic energy of the ball. The kinetic energy of the ball is transformed into gravitational potential energy of the ball and target when the ball is embedded in the target and swings upward. As the target swings back down, the gravitational potential energy is transformed back into kinetic energy. When the ball is embedded in the target, some of the kinetic energy of the ball transforms into thermal energy of both ball and target through friction. Air resistance gradually causes a transfer of kinetic energy into thermal energy of the air surrounding the swinging pendulum, causing it to ultimately stop swinging at its lowest point.