Science Assessment System
Through Course Task

A Need for Speed

Grade Level:
8

Phenomena:
Speed a Bigger Factor than Mass in Kinetic Energy

Science & Engineering Practices:
Analyzing and Interpreting Data
Using Mathematics and Computational Thinking
Constructing Explanations and Designing Solutions

Crosscutting Concepts:
Patterns
Cause and Effect

Designed and revised by Kentucky Department of Education staff
in collaboration with teachers from Kentucky schools and districts.

Preparing to implement Through Course Tasks in the Classroom

What is a TCT?

- TCTs are 3-dimensional tasks specifically designed to get evidence of student competency in two dimensions, Science and Engineering Processes (SEPs) and Crosscutting Concepts (CCC), untethered from Performance Expectations (PEs)/standards. Tasks are sense-making experiences.
- Tasks are to be used formatively. The goal is for both students and teachers to understand areas of strength and improvement for the SEP(s) and CCC assessed within the task.

How do I facilitate a Through Course Task (TCT)?

- TCT facilitation is a collaborative process in which teacher teams calibrate understanding of the expectations of the task and refine strategies to be used during task facilitation.

Before the task:

1. Complete the TCT as a learner – compare understanding of task through the lens of success criteria (identified in the task) in order to understand expectations. Success criteria include:
   - What is this task designed to get evidence of?
   - What is the task asking the students to do?
   - What might a student response look like?
2. Identify the phenomenon within the task. Consult resources to assure teacher teams have a deep understanding of associated science concepts.
3. Collaborate to generate, review and refine feedback questions during facilitation.
4. Identify potential "trouble spots" and plan for possible misconceptions.

During the task:

5. Collect defensible evidence of each student's competencies in 3-dimensional sense-making for the task.
6. Ask appropriate feedback questions to support student access and engagement with the task in order to elicit accurate evidence of student capacities.

After the task:

7. Reflect on the task as a collaborative team.
8. Review student work samples to identify areas of strength and areas of need.
9. Determine/plan next steps to move 3-D sense making forward through the strengthening of the use of SEPs and CCCs.

Using the materials included in this packet:

- **Task Annotation:**
  - The task annotation is a teacher guide for using the task in the classroom. Additionally, the annotation gives insight into the thinking of developers and the task overall.

    - Each task has science and engineering practices, disciplinary core ideas, and crosscutting concepts designated with both color and text style:
        - **Science and Engineering Practices**
        - *Disciplinary Core Ideas*
        - Crosscutting Concepts
- **Student Task:** The materials to be used by students to complete the TCT.

A Need for Speed Task Annotation

After **analysis and interpretation of a data set and construction of graphs showing linear and nonlinear relationships,** students will use mathematical patterns/trends in the variables to **construct an explanation** which includes **mathematics and computational thinking** to describe the cause and effect *relationships of kinetic energy to the mass of an object and to the speed of an object and changes that would result in a less massive smart car having the same kinetic energy as a more massive U-Haul.*

Phenomenon within the task

Speed is the dominant factor affecting the kinetic energy of an object. Kinetic energy increases linearly with mass, and increases quadratically with speed. Thus, if the speed of an object is reduced by a factor of two, then the kinetic energy of the object is reduced by a factor of four. If the mass of the object is reduced by a factor of two, then the kinetic energy is also reduced by a factor of two.

In the context of the task: How can a Smart Car have the same Kinetic Energy as a U-Haul? How can an object with less mass obtain the same amount of kinetic energy as an object with more mass? Students might think that less massive objects have less kinetic energy with no regard to speed or velocity. (ex. students do not take into the consideration that the velocity is squared when determining kinetic energy resulting in KE quadrupling as velocity of the object doubles). Students might also choose only one variable to change that would result in a smart car having the same kinetic energy as a U-Haul instead of addressing how each variable could be changed for a smart car to have the same kinetic energy as a U-Haul.

How the phenomenon relates to DCI

MS-PS3-1 *Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of the object. Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object resulting in a linear relationship when graphed and grows with the square of its speed resulting in a non-linear relationship when graphed.* (PS3.A in MS-PS3- 1). This is the only physical science (PS) PE at the 8^{th} grade level in KAS for Science. The reason that this PE is in the 8^{th} grade is due to the mathematics used in the standard. The equation for kinetic energy involves a quadratic ($KE = \frac{1}{2} mv^2$), and quadratic functions are not used in mathematics until the 8^{th} grade according to KAS for Mathematics.

DCI - PS3 A: Definitions of energy (Grade 8)
Motion energy is properly called kinetic energy. It is proportional to the mass of the moving object and grows with the square of its speed.

DCI - PS3.C: Forces and motion (Grade 7)
When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.

DCI - PS2.A: Forces and motion (Grade 6)
The motion of an object is determined by the sum of the forces acting on it. If the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.

DCI - PS3.A Definitions of energy (Grade 4)
The faster a given object is moving, the more energy it possesses.

What information/data will students use within this task?
Students will be provided with a data table displaying different quantities of mass and velocities for some selected vehicles and the resulting kinetic energy and section to graph data.

Students need to know what a proportion is and be able to use basic math skills. Students should know the meaning of kinetic energy, mass and velocity. The difference between velocity and speed should be clarified since students sometimes use them interchangeably. **Velocity** is a vector quantity (velocity specifies direction in addition to speed) and **speed** is a scalar quantity (only distance per unit time is specified, and not direction). The term velocity is frequently used in place of speed even though a direction is not provided. As an example, the **velocity** of a hypothetical vehicle could be **30 mph west**, and the **speed** would be **30 mph**.

Ideas for setting up the task with students
Students could design an investigation to produce their own data to analyze and interpret and determine the mathematical relationships of changing mass on kinetic energy and velocity on kinetic energy and creating graphs from their data.

Data can also be obtained using online interactive simulations and resources that allow them to change magnitudes of the variables of mass and velocity to determine the effect of changing each one on the resulting kinetic energy. Here is an example of a web resource that also allows students to see the effects of other variables like crumple zones, seat belts, friction.

Students can be given a different set of data that can be used to analyze and determine patterns and mathematical relationships without using a formula to practice the skill of looking for patterns and trends mathematically and predicting values for points not included in the data set.

Intent of the Task for Assessment

The intent of the task is to assess whether students can correctly determine the relationships that exist between variables in quantitative data sets and determine mathematical proportions and relationships **without** using an existing mathematical formula, and construct an explanation of how the variables interact. In other words, students will be "discovering" the relationships of variables in an existing equation for themselves based on a data set without seeing or knowing the equation. The intent is **not** to assess the ability to insert values into an existing equation and get a correct answer, it is using patterns/trends in data to determine the nature of the mathematical relationships of variables in data sets. Questions are scaffolded to lead students to understand how the variables of mass and velocity are related and how changes in each variable affects the kinetic energy of objects. From their analysis and graphical displays, students will construct an explanation that describes how the mathematical relationships between the variables of mass and velocity creates changes in magnitudes of the resulting kinetic energy at different rates. Students will demonstrate understanding by showing how to change the magnitudes of the variables to get a specific amount of kinetic energy. Students will then graph kinetic energy and mass and kinetic energy and velocity in two separate graphs and describe the linear and nonlinear relationships that result. At this point, they will be asked to make connections between the shapes on the graphs and rates of change to the formula, $KE = \frac{1}{2} mv^2$.

The mathematical evidence will then be used to provide evidence for supporting an explanation of how mathematically a less massive object (smart car) can have the same amount or greater kinetic energy as a more massive object (U-Haul).

Success Criteria

Evidence of Learning Desired based on Progression from Appendices

Analyzing and interpreting data

Derive meaning from data patterns and trends by tabulation, graphical interpretation, etc.

- Construct, analyze and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships. (MS-PS3-1)
- Analyze and interpret data to provide evidence for phenomena.

Using mathematics and computational thinking

Mathematical and computation are fundamental tools for representing physical variables and their relationships.

- Use mathematical representations to describe and/or support scientific conclusions.
- Apply mathematical concepts and/or processes (ratio, rate, percent, basic operations, and simple algebra) to scientific questions.

Constructing explanations and designing solutions

Construction of theories provide explanatory accounts of the world.

- Construct an explanation that includes qualitative or quantitative relationships between variables that predict and/or describe phenomena.
- Apply scientific reasoning to show that the data or evidence is adequate for the explanation or conclusion.

Patterns

Observed patterns of forms and events guide organization and classification and they prompt questions about relationships and the factors that inform them.

- Patterns and rates of change and other numerical relationships can provide information about natural and human designed systems.
- Patterns can be used to identify cause and effect relationships.
- Graphs, charts, and images can be used to identify patterns in data.
- Cause and Effect

Events have causes. Mechanisms can then be tested across given contexts and used to predict and explain events in new contexts. Cause and effect relationships can be used to predict phenomena in natural or designed systems.

Success Criteria

- Student constructs the graphs and then describes the mathematical relationship between mass & kinetic energy (linear) and velocity & kinetic energy (non-linear) based on patterns/trends in the data.

- Student describes how the trends/patterns in the graphs are represented in the equation for kinetic energy (KE=1/2mv^2) and explains which variable (mass or velocity) has a bigger effect on kinetic energy.
- Student constructs an explanation for how both the mass and velocity of the smart car would have to change to have the same kinetic energy as a 15' U-Haul using quantitative reasoning developed from patterns/trends in the data (calculated independently for mass and velocity), and makes a claim as to which variable would be best to change to increase the kinetic energy of the smart car, supported with evidence and reasoning from their analysis.

Possible Student Responses

Students would be expected to correctly predict kinetic energy values for the smart car in the blank spaces in Table 1 of the task.

- Smart car at 13.4 m/s - KE = 82.6 KJ
- Smart car at 26.8 m/s - KE = 330.4 KJ
- Smart car at 53.6 m/'s - KE = 1321.6 KJ

They should show how they used the patterns reflected in the data in the table to predict the missing kinetic energies for the smart car. They can half the values of the kinetic energies of the corvette or find the first value for 13.4 m/s for the smart car and multiply by 4 to predict the values for 26.8 m/s and multiply the result by 4 to get the value for kinetic energy of the smart car at 53.6 m/s. Students should identify velocity as having a greater rate of change in kinetic energy than mass from the analysis of the data in the table and the graphs. Graphs should show a linear relationship for kinetic energy and mass and a nonlinear relationship for kinetic energy and velocity. Students should attribute the shape of the lines to the position and exponents of the variables in the formula, $KE = \frac{1}{2}mv^2$. KE and m are directly related. KE and v are nonlinear because of the exponent. Both relationships are positive in relation to KE as one increases so does the other, but at different rates.

Student explanation should be based on a claim that the smart car could have the same kinetic energy as the U-Haul by either increasing the mass or velocity. Because of the patterns and trends in the data table and the linear graph, increases or decreases in the mass will be directly reflected in the kinetic energy of the smart car. For the kinetic energy of the smart car to be equal to the U-Haul at 26.8 m/s, the smart car mass would have to be increased by a factor of 4 and be traveling at 26.8 m/s. Increases in the velocity will have a greater impact on increasing the kinetic energy because doubling the velocity will quadruple the kinetic energy according to the relationships of the variables in the data table, graph and formula. In order for the smart car at 920 kg to have the same kinetic energy as a U-Haul traveling at 26.8 m/s, the smart car velocity must be doubled from 26.8 m/s to 53.6 m/s. This change in the velocity is supported because of the trends in the data table, graph, and the squared term in the formula. They should include in their explanation that the mathematical relationship of kinetic energy and mass to be proportional or direct, while the mathematical relationship of kinetic energy and velocity is quadratic. When the mass doubles so does the kinetic energy. Whatever math operation is performed with mass, it is directly reflected in the kinetic energy that results as long as the velocity stays the same. Some students may even indicate that being able to increase the mass of a smart car by a factor of four would be unlikely. Most students will not know the more familiar mi/hr velocities and might not know that the velocities in the table are 30 mi/hr, 60 mi/hr and 120 mi/hr. The optional extension will bring this to their attention and they will be able to identify 53.6 m/s as an unsafe speed for a smart car even though the kinetic energy is equal to a U-Haul traveling at 26.8 m/s.

NOTE

Technically speaking, neither changing just the mass nor the velocity is realistic since the maximum speed for a smart car is about 96 miles per hour and it would not be able to reach the approximately 120 miles per hour needed to reach a velocity of 53.6 m/s. In addition, most rental trucks have governors that only allow maximum speeds of about 55 to 65 miles per hour, but these issues can researched and discussed after the task or before the CER completion if desired. Students can extend and make a claim of how neither change alone is practical and provide evidence and reasoning for it. No student work showed any signs of considering these issues since the velocities were in m/s, which is not a familiar unit to them.

Other information teacher teams might find useful when preparing to use this task in the TCT process

Resources available to connect kinetic energy to vehicle safety, the use of seat belts, crumple zones and the role of the coefficient of friction on driving surfaces and the effects of friction and speed on stopping distance of a car can be found on the website of Dr. T. Griffith Jones of the University of Florida.

*KDE offers no endorsement of these resources.

Extensions and/or other uses after the task is implemented

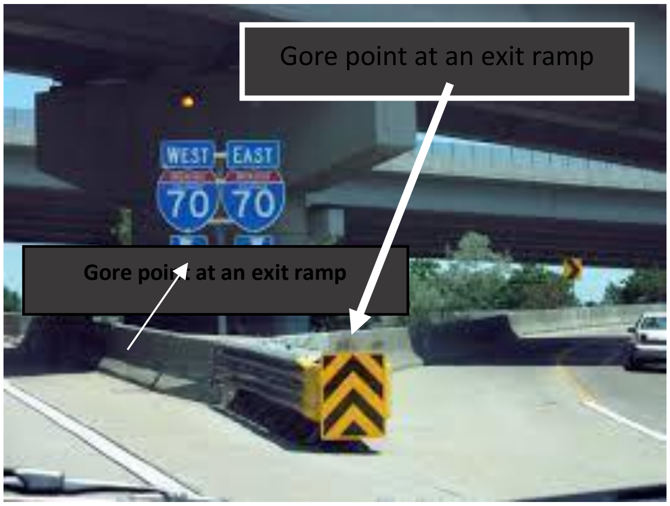
- Students would be ready to work with unit and rate conversions after the task.
- Integration with math standards and collaboration with math instructors as a team would make this task a stronger

experience for students.

- Students would be ready to evaluate formulas and determine reasonability of answers or predict the effect of changing the magnitude of variables on answers when working with variables in different positions and varying exponents in formulas and equations.
- Students can also begin identifying other variables that influence dissipation of kinetic energy in collisions like restraints, coefficient of friction, crumple zones, air bags, etc.

Through Course Task – A Need for Speed

Name: ______________________ Class Period:__________



State highway engineers design systems to decrease the severity of vehicle accidents on our nation's highways. One design challenge in large cities is a limited amount of area to separate highway and exit lanes. The separation between the travel and exit lanes creates triangular areas that highway engineers call "gore points." In large cities, concrete barriers are placed in these gore points. When vehicles collide with the concrete barriers in the gore points, injuries and damage to vehicles are significant.

Currently, states are using collapsing guardrails placed in front of the concrete that crumple to help absorb kinetic energy in a crash. The mass and the velocity of a vehicle determines the kinetic energy with which it hits the barrier and affects the resulting damage to vehicles and severity of injuries. In order to design the guardrails to withstand collisions and prevent impact with concrete barriers, engineers need to determine amounts of kinetic energy that different vehicles traveling at different velocities would exert on the guardrails. This information can be used to determine the safest speed limits or velocities for a variety of vehicles exiting or remaining on the highway.

Highway engineers have calculated the kinetic energy of different vehicles with different masses at different velocities to make sure the guardrails can absorb the kinetic energy of vehicles in the event of an accident. Vehicles with a smaller mass can exert equal amounts of kinetic energy as those with a larger mass. A smart car, under certain conditions, can exert equal or greater kinetic energy as a more massive 15' U-HAUL truck. A portion of the data is in Table 1.

Name______________________

TABLE 1: Kinetic Energy of Vehicles with Different Masses at Different Velocities

Type of Vehicle	Mass (kg)	Velocity (m/s to barrier)	KE (kJ)
15' U-Haul	3680	13.4	330.4
15' U-Haul	3680	26.8	1321.6
15' U-Haul	3680	53.6	5286.4
Corvette	1840	13.4	165.2
Corvette	1840	26.8	660.8
Corvette	1840	53.6	2643.2
Smart Car	920	13.4	
Smart Car	920	26.8	
Smart Car	920	53.6	

1) **Analyze and interpret the data in the table for the U-Haul and Corvette and identify patterns/trends in the mathematical relationships of the variables within the data set. Use the data in the table to complete A-I. You may want to use separate paper to complete your analyses.**

A. What pattern or mathematical relationship exists between the masses of the different vehicles?

B. How are the kinetic energy values affected mathematically by changes in mass? (How does the amount of energy change as the mass of the vehicle decreases or increases?)

C. How would you describe the relationship between kinetic energy and mass to someone else?

D. What pattern or mathematical relationship exists between the velocities of each different vehicle?

E. How are the kinetic energy values affected mathematically by changes in velocity? (How does the amount of energy change as the velocity of the vehicle decreases or increases?)

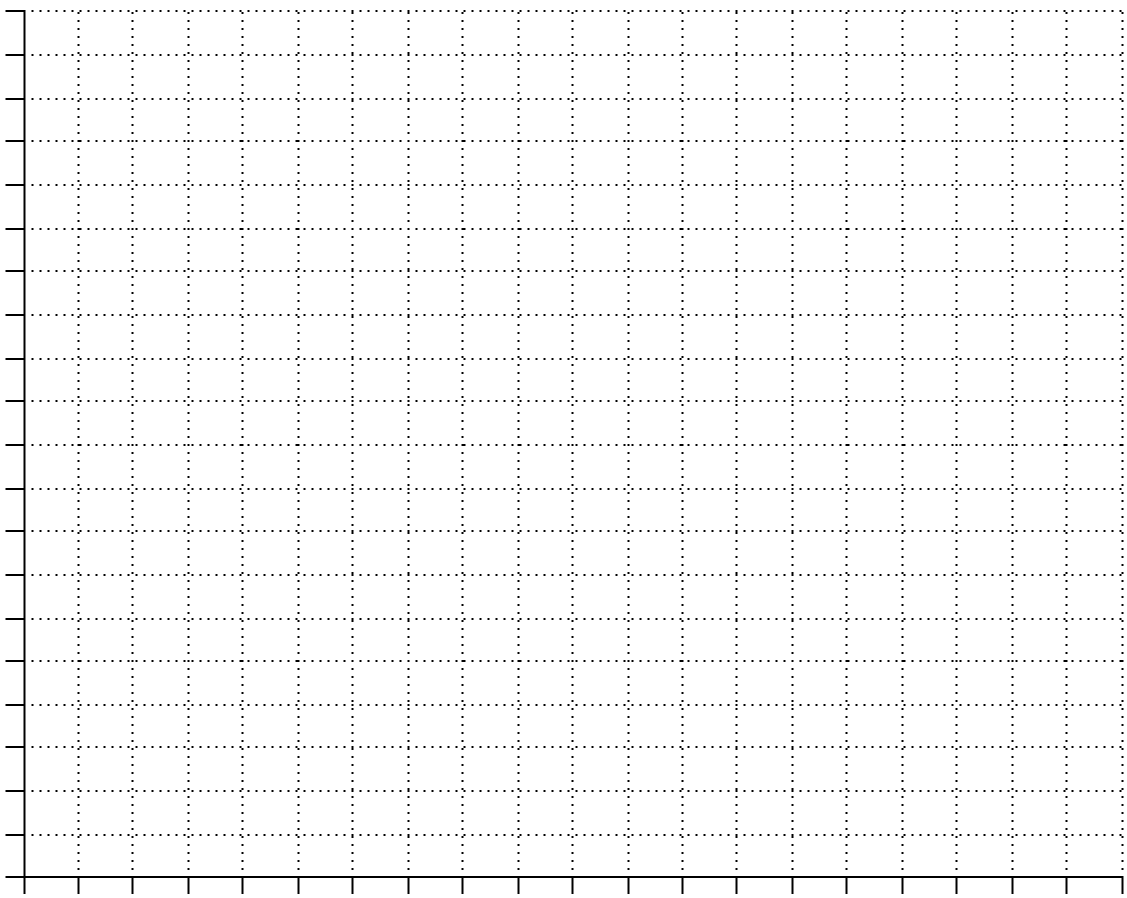
F. How would you describe the relationship between kinetic energy and velocity to someone else?

G. Which variable, mass or velocity, causes a larger change in kinetic energy?

H. Based on your answers to A-F, predict the kinetic energy of a smart car for each velocity in the table. Support the predictions you make for the kinetic energies of the smart car with quantitative evidence from the data in the table.

Graphing data is an important part of analysis as it identifies trends and relationships that are less visible then when data is only presented with in a table or chart.

2) Graph the kinetic energy and mass of each vehicle traveling at 53.6 m/s. Consider what variable will be on the X axis and Y axis.

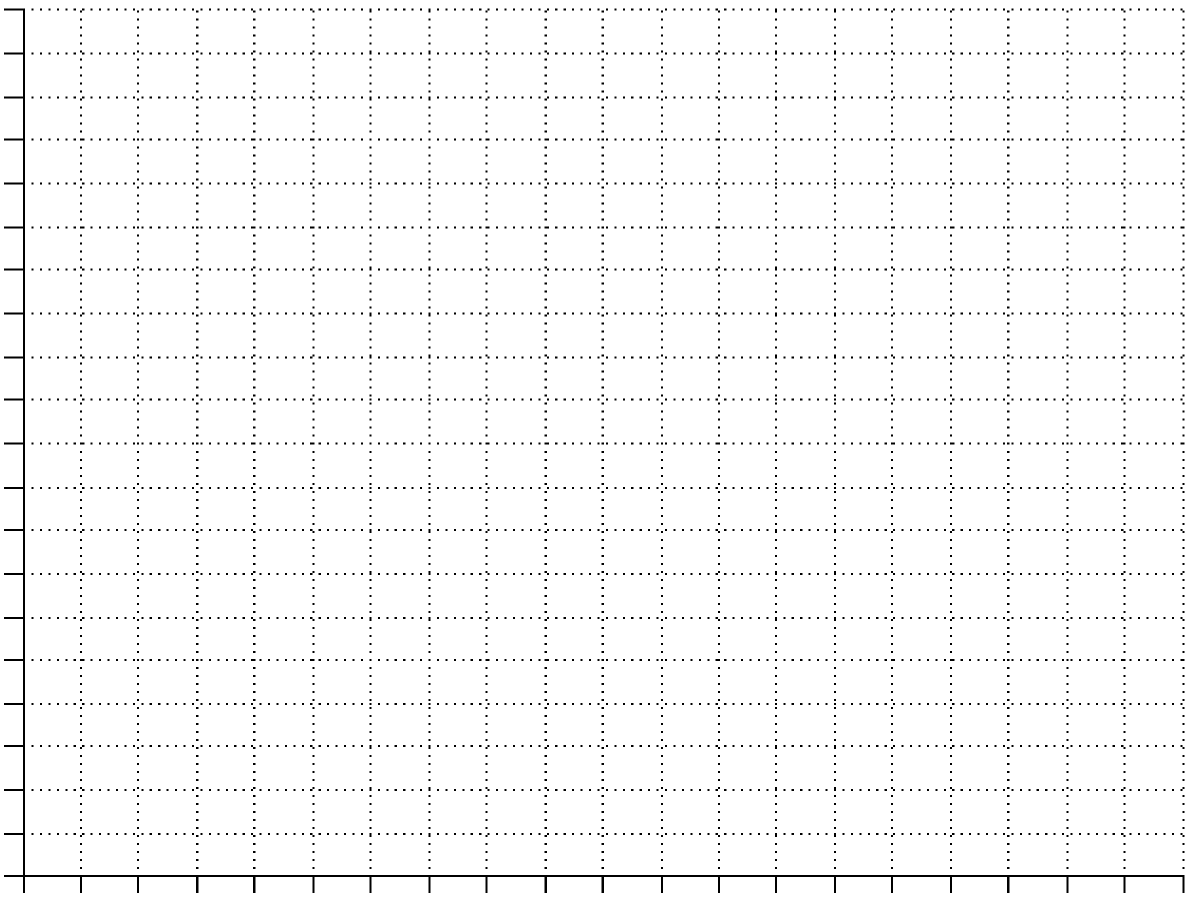


3) A) Describe how kinetic energy changes as the mass of the car changes. What kind of relationship do you notice between these two variables? Is it linear or nonlinear?

B) Now add the data for mass and kinetic energy for the other 2 velocities in the data table (26.8 m/s and 13.4 m/s). How would you describe this graph to someone else? What does it say about the relationship between mass and kinetic energy? What happens to the kinetic energy of an object if the mass is doubled but the velocity is held constant?

Graphing data is an important part of analysis as it identifies trends and relationships that are less visible then when data is only presented with in a table or chart.

4) Graph the relationship between velocity and kinetic energy of all 3 types of vehicles below.
U-Haul= Blue Line   Corvette= Red Line   Smart Car = Green Line



5) A) Describe how kinetic energy changes as the velocity of the car changes. What kind of relationship do you notice between these two variables? Is it linear or nonlinear?

B) How would you describe this graph to someone else? What does it say about the relationship between velocity and kinetic energy? What happens to the kinetic energy of an abject if the velocity is doubled but the mass is held constant?

Name______________________

6) Analyze the 2 graphs (mass vs. KE and velocity vs. KE) to determine the relationships between kinetic energy and mass and kinetic energy and velocity.

A) How is the relationship between kinetic energy and mass alike and different from the relationship between kinetic energy and velocity in the graphs? Which variable has a stronger effect on kinetic energy, mass or velocity?

B) The formula to calculate kinetic energy is $KE = \frac{1}{2} mv^2$. How are the mathematical relationships between the variables in the formula reflected in the rates of change and the shape of the lines on each of the graphs? How does this equation help you identify which variable has a stronger effect on kinetic energy, mass or velocity?

Name______________________

Using evidence from the:

- data table
- kinetic energy graphs, and
- kinetic energy formula

1) Describe how the:
    - mass of a smart car could be changed so the smart car would have the same kinetic energy as a U-Haul that is traveling at 26.8 m/s.

    AND

    - velocity of a smart car could be changed so the smart car would have the same kinetic energy as a U-Haul that is traveling at 26.8 m/s.

2) Make a claim about whether it would be best to change the mass or the velocity of the smart car to equal the kinetic energy of the U-Haul traveling at 26.8 m/s, and support your claim with evidence and reasoning from your analysis.

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(Reference your analysis of the data table, graphs, and equation in your explanation)

Name______________________

Need For Speed

Graphic Organizer

CLAIM How can mass and velocity change for a smart car to have equal the kinetic energy of a U-Haul traveling at 26.8 m/s? Is mass or velocity a better option to change?			
EVIDENCE Mathematical patterns Evidence from graphs Relationships between variables	Evidence from data table	Evidence from graphs	Evidence from formula
REASONING Apply mathematical and scientific principles			
COUNTER-CLAIM Alternative claim or option			
REBUTTAL Evidence/Reasons why counter-claim is not a better option than the claim.			

OPTIONAL EXTENSION 1

Name______________________

If 1 m/s is equal to 2.2 mi/hr, based on the data in the table and your analysis, make a claim for a speed limit that would be safe for all the vehicles in Table 1 continuing on the highway and not exiting. Provide evidence including kinetic energies of the vehicles at different velocities and scientific reasoning to support your claim.

(Show your rate conversions and data analysis below and reference your calculations in your explanation)

Name______________________

OPTIONAL EXTENSION 2

The following formula can be used to calculate power:

$P = I^2 \times R$

P is power, I is current, and R is resistance.

Based on the variables shown in the equation:

- Predict by what factor the power, “P” will change when the value of “I” doubles and the value of “R” remains the same.
- Predict by what factor the power, “P” will change when the value of “R” doubles and the value of “I” remains the same.

Describe what the graph of “I” and “P” would look like and what the graph of “R” and “P” would look like.

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