Physics Performance Assessment: Hooke's Law Rules

A Performance Assessment Task developed by Buffalo State College
in conjunction with NYSED and the Mentor Networks[1]

Task: Students observe the bending of a plastic ruler as varied forces are applied. The students determine if the ruler obeys Hooke's Law.

STANDARD 1—Analysis, Inquiry, and Design
Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.

Mathematical Analysis
Key Idea 1: Abstraction and symbolic representation are used to communicate mathematically.

M1.1 Use algebraic and geometric representations to describe and compare data.

- use scaled diagrams to represent and manipulate vector quantities
- represent physical quantities in graphical form
- construct graphs of real-world data (scatter plots, line or curve of best fit)
- manipulate equations to solve for unknowns
- use dimensional analysis to confirm algebraic solutions

Key Idea 2: Deductive and inductive reasoning are used to reach mathematical conclusions.

M2.1 Use deductive reasoning to construct and evaluate conjectures and arguments, recognizing that patterns and relationships in mathematics assist them in arriving at these conjectures and arguments.

- interpret graphs to determine the mathematical relationship between the variables

Key Idea 3 Critical thinking skills are used in the solution of mathematical problems.

M3.1 Apply algebraic and geometric concepts and skills to the solution of problems.

- explain the physical relevance of properties of a graphical representation of real world data, e.g., slope, intercepts, area under the curve

Scientific Inquiry
Key Idea 2: Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity.

S2.1 Devise ways of making observations to test proposed explanations.

- design an experiment to investigate the relationship between physical phenomena

Key Idea 3: The observations made while testing proposed explanations, when analyzed using conventional and invented methods, provide new insights into phenomena.

S3.1 Use various means of representing and organizing observations (e.g., diagrams, tables, charts, graphs, and equations) and insightfully interpret the organized data.

- use appropriate methods to present scientific information (e.g., lab reports, posters, research papers, or multimedia presentations)
- identify possible sources of error in data collection and explain their effects on experimental results

STANDARD 6 -- Interconnectedness: Common Theme
Patterns of Changes
Key Idea 5: Identifying patterns of change is necessary for making predictions about future behavior and conditions.

5.1 Use sophisticated mathematical models, such as graphs and equations of various algebraic or trigonometric functions.

- predict the behavior of physical systems, using mathematical models such as graphs and equations

5.2 Search for multiple trends when analyzing data for patterns, and identify data that do not fit the trends.

- deduce patterns from the organization and presentation of data
- identify and develop models, using patterns in data

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[1] Initially developed by Dr. J. Zawicki with students from SED401: B. Coleman, E. Dehoff, A. Hall, M. Johnson, J. Kornaker, L. McGuire, D. Rosenberg, E. Schneider, S. Skotnicki

Optimization

Key Idea 6: In order to arrive at the best solution that meets criteria within constraints, it is often necessary to make trade-offs.

- determine optimal solutions to problems that can be solved using quantitative methods

STANDARD 7: Interdisciplinary Problem Solving

Strategies

Key Idea 2: Solving interdisciplinary problems involves a variety of skills and strategies, including effective work habits; gathering and processing information; generating and analyzing ideas; realizing ideas; making connections among the common themes of mathematics, science, and technology; and presenting results.

- collect, analyze, interpret, and present data, using appropriate tools
- If students participate in an extended, culminating mathematics, science, and technology project, then students should:
  - § work effectively
  - § gather and process information
  - § generate and analyze ideas
  - § observe common themes
  - § realize ideas
  - § present results

Standard 4: The Physical Setting

Process Skills

Key Idea 4: Energy exists in many forms, and when these forms change energy is conserved.

4.1 Observe and describe transmission of various forms of energy.

iii. determine the energy stored in a spring

Key Idea 5: Energy and matter interact through forces that result in changes in motion.

5.1 Explain and predict different patterns of motion of objects (e.g., linear and uniform circular motion, velocity and acceleration, momentum and inertia).

xiii. determine a spring constant

Materials (per station)

- ☐ station diagram (elbow sheet)
- ☐ student directions
- ☐ *Reference Tables*
- ☐ ring stand
- ☐ ring stand clamp
- ☐ 2 rulers (marked in cm)
- ☐ 1 semi-flexible plastic ruler
- ☐ clay
- ☐ index card
- ☐ "Bag A" (5 washers)
- ☐ "Bag B" (weight)
- ☐ paper-clip
- ☐ graph paper

Preparation

1. Prepare copies of the station diagrams and student directions for each setup. Tape the station diagram to the table. Distribute the *New York State Reference Table for Physical Setting: Physics* to each station.
2. Place the clay on the index card. Insert the end of a hard ruler into the ball of clay in an upright position so that the one centimeter mark of the ruler is furthest away from the index card. Mold clay to the base of the ruler so that the ruler can stand without additional support. Place one ruler and clay arrangement at each lab station.
3. Set up ring stands by clamping a flexible ruler parallel to the lab table. Place the ring stand arrangement at each lab station. Be sure the flexible ruler clamped in the ring stand is level with the numbers on the upright ruler that was placed in the clay.
4. Place a bag of five washers that are of equal mass at each station. The washers for each station should be appropriate for the suppleness of the flexible ruler in the ring stand. You do not want washers that are too heavy or rulers that are to flexible; the flexible ruler should not bend excessively when a washer is placed on it.
5. Bend paperclips into hooks and attach them to the free end of the flexible ruler that was clamped into the ring stand.

Name_____ Physics Performance Assessment

Date_____ Section_____ Directions

Hooke's Law Rules

Background

Hooke's Law relates the distance a spring stretches to the force acting on the spring. Many types of objects, such as springs, obey Hooke's Law, while others, such as elastic bands, do not. Your task will be to observe bending in a plastic ruler as the force on the ruler is varied. You will determine whether the ruler obeys Hooke's Law.

Examine the diagram near your elbow. Locate each of the items identified on the paper. Raise your hand if any items are broken or missing. You will have 30 minutes to complete this task.

Procedure

You will apply weights to the end of the flat (horizontal) ruler, and record the displacement of the ruler. Use the data table to record your observations.

1. Use the vertical ruler to determine the initial position of the flat (horizontal) ruler. Record the resting position of the horizontal ruler without any washers.
2. Place one washer on the paperclip that has been placed on the end of the flat ruler. Observe and record the position of the end of the flat ruler.
3. Repeat Step #2 for each of the washers in the bag.
4. Remove the washers from the paperclip and return them to plastic bag "A."

Data Analysis

Use the information from the data table to create a graph of the bending of the flat (horizontal) ruler versus the number of washers that suspended from the paperclip.

1. Label each axis appropriately.
2. Identify the units for each axis.
3. Plot the data points.
4. Draw the line of best fit. (The best fit line may be straight or curved.)

Discussion

Based upon you data and the graph that you have drawn, explain whether the flat (horizontal) ruler obeys Hooke's Law. Your answer should include:

1. a sentence explaining to another student what a graph should look like for a spring that follows Hooke's Law
2. an statement indicating if your data supports Hooke's Law (You should explain your answer based upon the graph that you have drawn.)
3. an estimate of "k", based upon either the entire graph or an appropriate section of the graph
4. an explanation of how collecting additional data points might effect your data

Extension

Develop a new procedure to address the following situation:

> Your basketball coach notices that basketball hoops bend slightly when players hang from them. Design an experiment to determine if the deflection of basketball hoops obeys Hooke's Law.

Name_____ Physics Performance Assessment

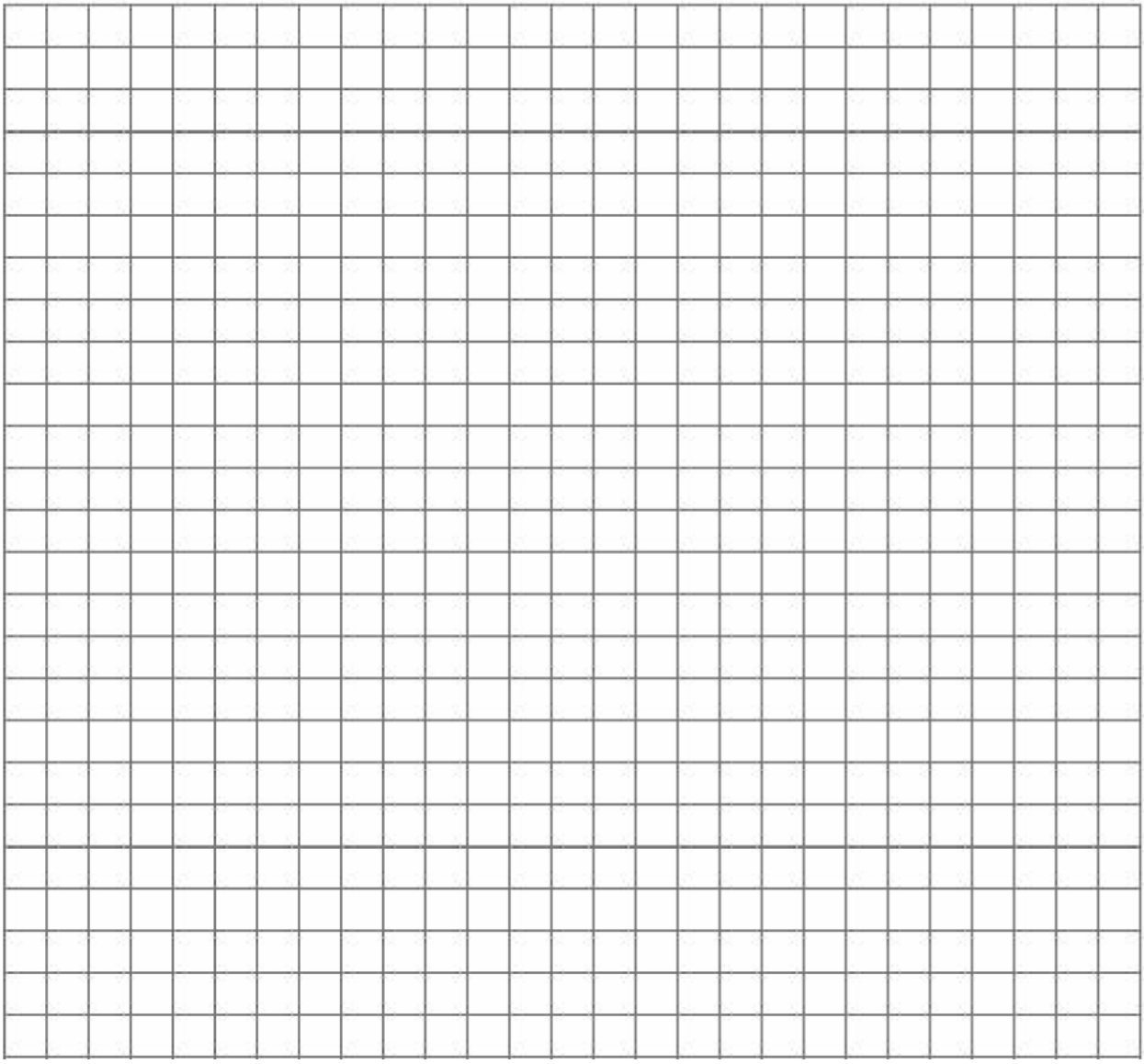
Date_____ Section_____ Answer Sheet

Hooke's Law Rules

Data Table

Observation #	*Number of Washers*	*Displacement*	*Change in Displacement (Current – Previous)*
1	0		
2	1		
3	2		
4	3		
5	4		
6	5		

Graph Paper



Name_____ Answer Sheet (Page #2)

Discussion

Extension

Station Elbow Sheet: