Applied Science Investigations (ASI):

This is a collection of 36 one-page science activities. Some can be done in one class period, others require more time. All work well as take-home experiments or independent research assignments. Many require information that can be found online or in textbooks. The difficulty level is suitable for grades 9-12, or advanced grades 6-8.

Students are occasionally required to attach additional sheets to show diagrams and calculations. They should be aware that doing good science involves standardized reporting of experimental results, including such practices as:

1. appending units of measurement to quantitative data
2. labeling data with correct symbols
3. showing equations used in the analysis
4. showing all steps in the calculations
5. ensuring that all text and calculations are legible

ASIs are provided without "approved solutions" as most are open-ended. This makes it easy to spot work copied from another student, but of course requires the teacher to grade each ASI on an individual basis. Awarding of partial credit is encouraged whatever grading system is used.

Legal Disclaimer and Safety Precautions:

We provide these Applied Science Investigations for educational use. They have been tested in the field for safety, and adhere to all the guidelines specified by the National Science Teachers Association. You should get a copy of those NSTA safety guidelines from:

https://www.nsta.org/docs/MinimumSafetyPracticesAndRegulations.pdf

Some of these ASIs require the use of lab science equipment and measuring devices, but most can be done with what the student will find around an average home. Activities should be undertaken only in appropriate settings with adult supervision. Following basic safety precautions, such as the use of protective goggles, is the responsibility of individuals involved.

Heimhenge Enterprises is not responsible or liable for any loss directly or indirectly arising out of the implementation of these activities. It is the teacher's and parent's responsibility to ensure adult supervision is present, and to provide copies of the NSTA safety guidelines to all participants. By using these activities you agree to protect, indemnify and hold harmless Heimhenge Enterprises from and against any and all claims, demands, and causes of action arising out of or in connection with the implementation of any activity including, without limitation, all demands, claims and causes of personal injury or property damage arising from such use.

Contents:

Applied Science Investigation: Putting the Shot

Name:____ Period:_____ Date:_____

General Instructions:

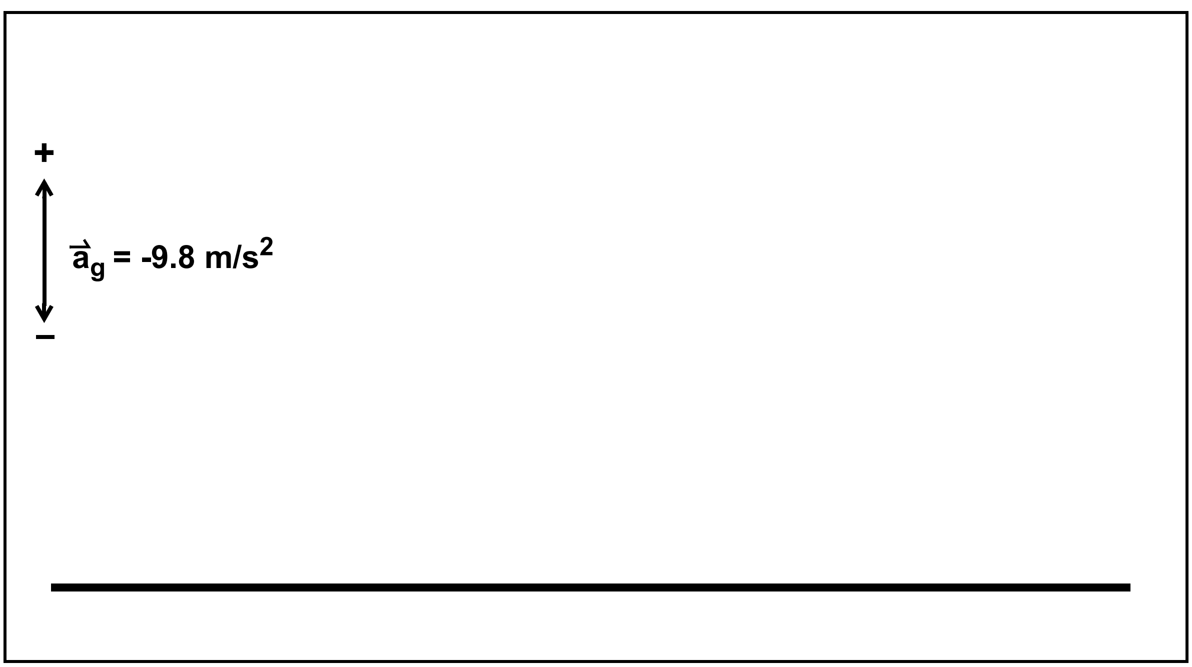
1. To do this ASI, you will need to check out the shot and a metric measuring tape from your coach and teacher. All data can be obtained in 15 minutes or less.
2. For your reference, the mass of the (HS level) shot is 4.250 kg.
3. Attach your calculations to this cover sheet.

Procedure:

1. Put the shot at a 45^{o} angle. This may take some practice, but with a friend acting as a spotter you should be able to launch it accurately after a few tries.
2. Measure the *launch height* and *horizontal range*.
3. Without holding the shot, measure the *distance* the putter's arm extends during a throw.

Analysis:

1. Sketch a labeled diagram of the toss showing all data recorded. Use the space below.
2. Calculate the launch velocity of the shot. Hint: This is a tough calculation. You must solve two equations of kinematics simultaneously, eliminating "t" by substitution.
3. Calculate the acceleration of the shot during the launch (while the arm is acting on it).
4. Calculate the force applied during the launch.



Applied Science Investigation: Singing in the Shower

Name:____ Period:_____ Date:_____

Instructions:

1. To do this ASI you will need access to a shower stall, preferably one that is totally enclosed by solid panels (as opposed to a flexible curtain). If none is available you could also use any small enclosed area such as a walk-in closet or utility room, preferably one without a lot of clutter like shelves and hangings. Hard and smooth walls will produce the best results.
2. You will also need access to some type of musical instrument that can play an entire octave of notes (a toy might even work). There are smartphone apps that can play the notes for you, but the volume might be too low unless you have a very quiet environment.

Procedure:

1. Eliminate all ambient sound sources near the test area (fans, radios, TVs).
2. What sound source was used? ____
3. Measure the dimensions of your test area and record them below:

Dimensions: **L** = ______m **W** = ______m **H** = ______m

4. Enter the test area and position your instrument near the center point of the interior volume.
5. Using your instrument, emit a loud and steady tone starting with your *lowest* note sustainable. Step the notes upward in increments and listen for resonance — you will recognize it by a marked increase in reverberation volume.
6. Identify that note on your musical instrument and record its frequency: **f** = ________Hz

Analysis:

1. Your shower contains three 1-dimensional oscillators (L,H,W), any one of which may be the mode you caused to resonate. Use the standing wave equation for systems with nodes (walls) at both ends, and calculate the *wavelength* of the fundamental harmonic for each oscillator:

$\lambda_L =$
$\lambda_W =$
$\lambda_H =$

2. Calculate the *frequency* of each harmonic:

$f_L =$
$f_W =$
$f_H =$

3. Do any of them closely match your data for the resonant frequency? Which one (L,H,W)? Calculate the experimental error for your closest match.

Applied Science Investigation: Famous Science Quotes

Name:____ Period:_____ Date:_____

Instructions:

There is a strong relationship between physics and philosophy. The quotations below reflect the thoughts of some of our greatest thinkers on just this topic. Select a quote that intrigues you and write a one-page, single-spaced essay on your interpretation of its meaning. Include the quote in your opening paragraph. Some research on the person whose quote you choose might help put their ideas into better context. This is an open-ended free-form ASI. Have fun with it!

"The most incomprehensible thing about the universe is that it is comprehensible."
-- Albert Einstein

"Sweet and bitter, cold and warm as well as all the colors, all these things exist in opinion but not in reality; what really exists are unchangeable particles, atoms, and their motions in empty space."
-- Democritus

"All nature ... consists of two things: bodies and the vacant space in which the bodies are situated and through which they move in different directions."
-- Lucretius

"The fabric of the world has its center everywhere and its circumference nowhere."
-- Nicholas of Cusa

"If there was a creation event, it had to have a cause."
-- Alan Sandage

"Nature does nothing ... in vain, and more is in vain when less will serve."
-- Isaac Newton

"A hard sphere has always a definite position in space; the electron apparently has not. A hard sphere takes up a very definite amount of room; an electron -- well, it is probably as meaningless to discuss how much room a fear, or an uncertainty takes up."
-- Sir James Jeans

"When it comes to atoms, language can be used only as in poetry."
-- Neils Bohr

"Space and time separately have vanished into the shadows, and only a sort of combination of the two preserves any reality."
-- Herman Minkowski

"To my mind there must at the bottom of it all be an utterly simple idea. And to me, that idea, when we finally discover it, will be so compelling, so inevitable, so beautiful, that we will all say to each other, 'Oh, how could it have been otherwise?'"
-- John Archibald Wheeler

Applied Science Investigation: Exponential Population Growth

Name:____ Period:_____ Date:_____

This chart shows the official USA Census data for the last 200+ years:

1790: 3,929,214	1870: 38,558,371	1950: 151,325,798
1800: 5,308,483	1880: 50,189,209	1960: 179,323,175
1810: 7,239,881	1890: 62,979,766	1970: 203,302,031
1820: 9,638,453	1900: 76,212,168	1980: 226,542,203
1830: 12,860,702	1910: 92,228,496	1990: 248,709,873
1840: 17,063,353	1920: 106,021,537	2000: 281,421,906
1850: 23,191,876	1930: 123,202,624	2010: 308,745,538
1860: 31,443,321	1940: 132,164,569	2020: ___________

1. Round the data to 3 significant figures, and construct a graph showing the population in Mp (mega-persons) vs. decade of time. Include a data chart with your graph.

2. Does this data show an exponential trend? Define *exponential growth*. Under what conditions does a population of any living species enjoy exponential growth? Hint: see Malthus.

3. Now plot the (rounded) data on a sheet of 3 cycle semi-log graph paper. Constant exponential growth would show up as a straight line plot, but this data will show several different periods of varying growth rates. Connect the plotted points to show these separate periods in the history of the USA (use different color lines for each period). Again, include a data chart.

4. Changes in the USA growth rate were due to specific events in the history of the country. Identify the likely event for each change in growth rate.

5. The equation describing exponential functions is: $Y = a \times e^{bX}$ where

e = 2,71828... (base for natural logarithms)
X = the independent variable (time)
Y = the dependent variable (population)
a = to the Y-intercept on a plot of the data
b = $2.303[\log(y_2 - y_1)] / (x_2 - x_1)]$ for any two data points

Note that "b" is the dimensionless *growth rate* expressed as a decimal. Find these parameters for the most recent sustained growth rate. Then write its exponential equation (including units).

6. Use the equation to extrapolate beyond your data and answer the questions: In what year will the USA's population hit the 1 billion mark? In what year was the population 1? Comment on the validity of each answer.

Applied Science Investigation: Automobile Energy Transformations

Name:____ Period:_____ Date:_____

Instructions:

1. Your objective is to measure the actual output power of an automobile engine and compare it to the rated output power published in the owner's manual.
2. If no owner's manual is available, the needed information can be obtained from a dealer.
3. This ASI must be done with the assistance of an adult driver. You will ride as a passenger to facilitate measurements. The driver must sign below verifying they were present and acting as driver, all participants wore seat belts, and speed limits were obeyed:

I WAS THE DRIVER FOR THE ABOVE-NAMED STUDENT: ____

Procedure:

1. Obtain the following data for your test automobile:

   a. make, model, year: ____

   b. engine size: ____________________ liters or cubic inches (circle units used)

   c. rated power of engine: ____________________ kW (convert from h.p. if necessary)

   d. mass of vehicle in "kg": ____________________ kg

   e. mass of driver: ____________________ kg

   f. your mass: ____________________ kg

2. Drive the vehicle to the test site. I recommend a low traffic area such as an outlying frontage road or rural highway. The road must be straight and level for a distance of about a quarter of a mile. If possible, choose a direction perpendicular to the wind. Otherwise, make a run in both directions and average the results. You will be attempting a *maximum acceleration* run to the speed limit (recommended minimum 45 mph, maximum 65 mph). Remember that spinning your tires does nothing to change the vehicle's kinetic energy — it merely wastes power.

3. Position yourself behind the driver, if possible, so that you can view the speedometer directly with no parallax error. Ready your timer and give the driver a signal to start. At the moment you reach your target speed stop the timer and record v_f and Δt below.

v_f = ______________ mi/hr

Δt = _____________ s

Analysis:

1. Calculate the following, showing all equations, substitutions, conversions and units. Express your final results (a-g below) to the correct number of significant figures.

   a. final speed in "m/s"
   b. final kinetic energy in "J"
   c. actual power output of engine in "kW"
   d. percentage of rated power actually obtained
   e. vehicle's average acceleration in "m/s^2"
   f. total force applied to vehicle through tire-to-Earth interaction in "N"
   g. force-per-tire (taking into account 2WD or 4WD) in "N"