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/topics/safety

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.

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Contents:

Applied Science Investigation: Automobile Energy Transformations (Part 1)

Name:____ Period:____ Date:____

1. What is the chemical difference between different octane rated gasolines? Specifically, how do the gasoline molecule structures differ from one octane to another? Cite the actual octane values available on the pump.

2. What is the energy content in 1 gallon of typical high-octane gasoline (in Joules) and how many calories of heat are released through its burning in a typical 15% efficiency vehicle?

3. How much energy (in gallons of gas) is lost when braking to a stop from 60 mph? You may assume a mass of 2000 kg for the vehicle.

4. If you run your 500 W car stereo continuously while driving, how much gasoline is used to power it on a six hour road trip?

Applied Science Investigation: Automobile Energy Transformations (Part 2)

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 / 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"

Applied Science Investigation: Time, Calendars, and the Motion of the Sun

Name:____ Period:_____ Date:_____

1. Why is a day divided into 12 hours, each hour into 60 minutes, and each minute into 60 seconds?

2. Why is the week divided into 7 days, and what is the significance of the names for each of those days?

3. There are many calendar systems other than Gregorian in use throughout the world today. Learn all about one of them and describe how it is different.

4. Date this ASI (in the usual space at the top) using the current Julian date, and express it in its officially accepted form.

5. Construct a 2 meter true north-south line where it will remain undisturbed for a few days. A string between two stakes on level ground would work fine. Be sure the area you select will not be in shade around noon. Erect a 1 meter gnomon vertically at the south end of the north-south line. Set your reference timepiece as accurately as possible. Then on two days one week apart record and report the following data:

a. dates of observations
b. time that the gnomon's shadow becomes parallel to north-south line measured to the nearest second (concentrate on watching the very tip of the gnomon's slowly sweeping shadow)
c. length of the shadow to the nearest millimeter

6. Explain any data trends you observed in 5b and 5c based on the known motions of the Sun through the sky.

7. Take a close look at a good world globe and note the strange "figure eight" symbol (usually stuck somewhere out in the open Pacific Ocean). Find out what it is. Recreate a large version of it on a full sheet of paper and include it with your ASI report. The diagram should be accurately labeled, and include a paragraph explaining what the symbol means.

8. Write an original one-page essay on the topic "What is Time". Be clever, philosophical, scientific, or anything else you feel is appropriate. But most of all, be aware that the greatest thinkers throughout history have failed to answer this question satisfactorily.

Applied Science Investigation: Water Pumping in Arizona

Name:____ Period:_____ Date:_____

The following text is an excerpt from an article about the C.A.P. (Central Arizona Project) water delivery system, now bringing Colorado River water to much of the state. Read the text, then by calculation from the given data, answer as many of the questions as you can.

In 1582, residents of London were amazed when water was pumped from the Thames River over the roof of a 65 foot tall church. Although pumping water is now common, people are still impressed by its being raised to great heights

Today, water is raised 824 feet from Lake Havasu to the mouth of the first aqueduct of the C.A.P. Each of the pumps is rated at 60,000 h.p. When all 6 are running, they pump a total of 3000 cubic feet of water each second up over the top of the Buckskin Mountains. One cubic foot of water contains 7.48 gallons, so a cubic foot weighs 62.4 pounds.

In an average year, these pumps will deliver 65.34 billion cubic feet of water into the Arizona deserts. During this time, the pumps will use 2.863 billion kilowatt-hours (kw-hr) of electricity, the same amount used by 200,000 homes in an average year. At the current cost of electricity, most of which is provided by the coal-fired Navajo Generating Station at Page, the annual bill for this operation comes to $95 million.

1. At what cost (wholesale of course) is the C.A.P. getting their electricity?

2. Power ratings of machines refer to *input* power. How many joules of energy are used by the C.A.P. pumps in one second?

3. What is the mass (in kg) of 3000 cubic feet of water?

4. How much gravitational potential energy is given to the pumped water in one second?

5. Calculate the efficiency of this pumping system.

6. If the water pumped in a single year were contained in a cube, what would its dimensions be?

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: Worlds in Collision — Two-Body Interactions

Name:____ Period:_____ Date:_____

Although the calculations in this investigation are relatively simple, you will need to research many of the numerical values required to answer the questions. Cite your references. If published values are unavailable, make reasonable assumptions and support them with an explanation.

1. "When Worlds Collide", a sci-fi classic, posits the collision of a comet with the planet Venus. Venus is "knocked out of orbit" by the event and narrowly misses Earth. Assuming Venus is hit inelastically from behind and has its speed increased to Solar escape velocity, how fast would that comet have to be moving?

2. An incoming spherical iron asteroid with a diameter of 1 mile and speed of 20 km/s is sighted 1,000,000 km from Earth. If a single nuclear warhead bursting on contact can exert 5 TN of force for 0.001 second, then:

a. By how much could the asteroid's speed be reduced with a direct head-on hit?
b. By what angle could the asteroid's direction of motion be changed by a hit on its side?

3. By how much did the Earth's speed change due to the impact of the asteroid that made Arizona's Meteor Crater? Assume the impact was head-on and inelastic.

4. The famous Voyager spacecraft "collided" gravitationally with Jupiter and had its speed boosted from 15 km/s to 25 km/s in a kind of "crack the whip" slingshot effect. As a result of this encounter, Jupiter must have slowed down slightly. Assume the interaction was perfectly elastic and linear, and calculate the amount by which Jupiter's speed changed.

Applied Science Investigation: Heliocentric vs. Geocentric Debate

Name:____ Period:_____ Date:_____

Stage a debate between Ptolemy and Copernicus with a third person acting as moderator. Record a video of the debate. The debate should last at least 15 minutes but no more than 30 minutes. Additional points can be scored through the use of period costumes and props.

Your score will be based on the following:

1. correctness of astronomy and natural philosophy used in the debate

2. historical accuracy of Ptolemy's and Copernicus' arguments

3. pace and control of debate as enforced by the moderator

4. sound and video quality of your production

5. creativity and historical accuracy of costumes and props

Applied Science Investigation: Elasticity

Name:____ Period:_____ Date:_____

Elasticity is a measure of the ability of an object to deform and reform after impact. We measure it with a dimensionless factor known as the coefficient of restitution (e) — a number somewhere between 0 and 1. An elasticity of 0 means the object doesn't bounce. An elasticity of 1 means the object will bounce back to the same height from which it was dropped. All real objects have an elasticity of $0 \leq e < 1$. For a vertical drop on a hard surface:

$$e = \sqrt{h_2/h_1}$$

1. Test the following objects for rebound height when dropped from a height of 2 m onto a flat, smooth, and level concrete surface. Ensure the objects are "regulation" with proper inflation and no gross defects. Report your results in a chart and show all calculations. List the object brand names if available. If not all objects are available, test as many as you can find.

a. baseball (hardball)
b. baseball (softball)
c. golf ball
d. basketball
e. volleyball
f. billiard ball
g. steel bearing (diameter = 1 cm minimum)
h. superball
1. croquet ball
j. soccer ball

2. Prepare a chart showing your results. Explain any patterns observed, maximum and minimum elasticities observed, unexpected occurrences, and possible sources of error.

3. What happens when a perfectly elastic body (e = 1) collides with a inelastic body (e = 0)? Answer twice: first conceptually, and then by mathematical analysis.

4. If you dropped a golf ball from the top of the world's tallest building to what height would it rebound would it rebound on the first bounce?

5. Why is there an upper limit of "1" for elasticity? Use an argument based on the law of conservation of energy.

Applied Science Investigation: Creative Writing — Kepler and Galileo

Name:____ Period:_____ Date:_____

You can choose to do any or all of the following creative writing assignments. Your score will be based on creativity, historical content, scientific accuracy, and the usual style criteria for essays. Each exercise must be typed, double-spaced, and no longer than 1 page.

1. Write the "want ad" by which Tycho Brahe secured the services of Johannes Kepler.

2. Write the resume submitted by Kepler by which he gained employment at Uraniborg.

3. Write a haiku about how Kepler influenced astronomy.

4. Write a letter from Kepler to Galileo in which he describes his discovery of elliptical orbits.

5. Write a press release from Galileo describing the results and significance of his telescopic observations of the Moon.

6. Write a book review of Galileo's *Two Chief World Systems*.

Applied Science Investigation: Amusement Park Physics

Name:____ Period:_____ Date:_____

You will need to schedule a field trip to an amusement park that has a ride (usually) called "The Gravitron" or something similar. It's a spinning ride that pins the riders to an outside wall using centrifugal force after the floor drops away.

1. Tools you will need to bring with you:

a. timing device precise to at least 1 second
b. device for measuring horizontal distances to a precision of 1 cm
c. smartphone with app capable of measuring acceleration or g-force

2. Data Acquisition: (report all data in a chart)

a. Measure the radius of rotation (in meters) for riders in the machine.
b. Wait for the Gravitron hit full speed, then measure the period of rotation (in seconds).
c. Board the machine and measure the g-force experienced at full speed.

3. Calculations:

a. Calculate the speed of a rider in "m/s" and "mph".
b. Calculate the predicted g-force based on your data for R and T.
c. Using the measured g-force as the true value, calculate your experimental error.
d. Suggest some possible sources for your experimental error.

Applied Science Investigation: Kepler's Law of Periods

Name:____ Period:_____ Date:_____

1. Select any of the 4 gas giant planets in our Solar System and choose any three of the moons orbiting it. Show by calculation that the Law of Periods holds (albeit with a different common value for "k") for this orbital system. Express "k" in units of s^2/m^3.

2. Locate by research a satellite that orbits the Sun, noting its values for "T" and "R". Show by calculation that the Law of Periods holds for this orbiting body as well. Express "k" in its usual units of yr^2/AU^3.

3. Combine the Law of Periods algebraically with the equation for centripetal force. Rearrange the result to express the force/mass ratio for orbital motion. Write an interpretation of what this algebraic exercise allowed you to discover about orbital motion. Hint: An equation in science is a statement about cause and effect.

4. Is the Sun rotating? How fast? Does the Law of Periods also apply to the Sun itself? Try to apply the Law to the Sun and see if "k" works out to its usual value. State any assumptions you found necessary to do this calculation.

Applied Science Investigation: Making a Battery with a Lemon

Name:____ Period:_____ Date:_____

This experiment can be done at home or in the Lab. If you elect the former you will need to have access to an electrical multimeter capable of measuring both volts and amperes. You might be able to borrow one from the Lab if you check with your teacher.

Procedure:

1. Get a lemon. Any citrus fruit will do, but fresh lemons seem to work best. Sizes from medium to large are preferable.
2. Get four different samples of metal. Note that they must be different *types* of metal, such as copper, tin, aluminum, steel, etc. If possible, choose samples already in (or close to) the shape needed in step 3.
3. Prepare each metal sample by cutting or bending it into a strip or rod approximately 5 cm in length and not more than 1 cm in its largest cross-sectional dimension. Then use fine sandpaper to remove any tarnish or dirt from the samples. These will be your *electrodes*.
4. Poke two parallel 1 cm slits into the lemon with a sharp knife. Be careful — you do not want to create a flesh-cell battery.
5. For each of the 6 pairs (combinations) of electrodes:

a. Insert one into each slit to a depth of 2 cm.
b. Attach the voltmeter to the electrodes and measure the voltage V.
c. With the voltmeter attached, note the electrode *polarity*.
d. Attach the ammeter to the electrodes and measure the current I.

Analysis:

1. List and describe the four electrodes (metal, size, shape).
2. Create a data chart showing your results from Procedure 5.
3. Calculate the power output ($P = IV$) for each electrode combination.

Questions:

1. Are the differences between electrode combinations consistent with what you would expect based on the principles of electro-chemistry? Hint: Check an electronegativity chart.

2. How would your results change if the electrodes were pushed in to twice the depth? Try it if you like, but you still need to explain why or why not any change occurs.

Applied Science Investigation: Moon Trek

Name:____ Period:_____ Date:_____

This ASI is a "Scavenger Hunt" on the Moon. Your selenographic skills will be tested. You will need access to a map of the Moon's nearside. If your teacher doesn't have one you can find one online, or maybe one in your school library.

1. Starting at the only point on the Moon at which we look directly "down", go northeast 70 km to find a crater. What is its name? ____________________

2. Start at the center of Mare Tranquillitatis. Go north 10° in latitude. In what mountain range are you located? ____________________

3. There is a crater named after the first Heliocentrist. Find it. What is its longitude and latitude? longitude = _________ latitude = _________

4. Go to Hell. What sea is to your immediate northwest? ____________________

5. What is the area of Mare Crisium? Express your answer in units of km^2 to a precision of 2 significant figures. A = _______________

6. Where's Billy!? On the shore of ... ____________________

7. Starting on the north end of the Straight Wall, and walking along it toward the other end, your heading would be on what azimuth? θ_a = _______________

8. The Alpine Valley joins Mare Imbrium to Mare ... ____________________

9. What is located at longitude π^2 and latitude π^π? ____________________

10. Start at the crater named after a Captain of the starship Enterprise. How far east would you have to walk before the Earth disappeared from view over your western horizon? d = _______________

Applied Science Investigation: Standing Waves in a Swimming Pool

Name:____ Period:_____ Date:_____

You will need some friends to do this ASI. And, of course, you need a swimming pool. But it must be a rectangular pool with no obstacles. You will also need a measuring tape and a timing device with a precision of one second.

1. Procedure:

a. Measure length, width, and depth for the pool.
b. Line up all participants on the deep side, seated on the edge but not in the water.
c. Start the timer as all participants enter the water with as smooth and simultaneous a movement as possible, submerging up to the neck and facing the opposite end of the pool.
d. When the resulting wave front reaches the other end all participants must emerge smoothly (the reverse of Procedure b).
e. When the first wave front returns (after reflecting from the shallow end) go back to step b and continue through the c-d-e loop at least 5 times. When you have a standing wave established, make the following measurements.

2. Measurements:

a. How long does it take the crest to travel to the shallow end and back? This is T, the period of the standing wave.
b. Does the wave amplitude increase over the 5 cycles of energy input? Estimate the "%/cycle" increase in wave amplitude.
c. Is there any change in speed as the wave moves from deep to shallow water? Estimate the amount of change.

3. Analysis:

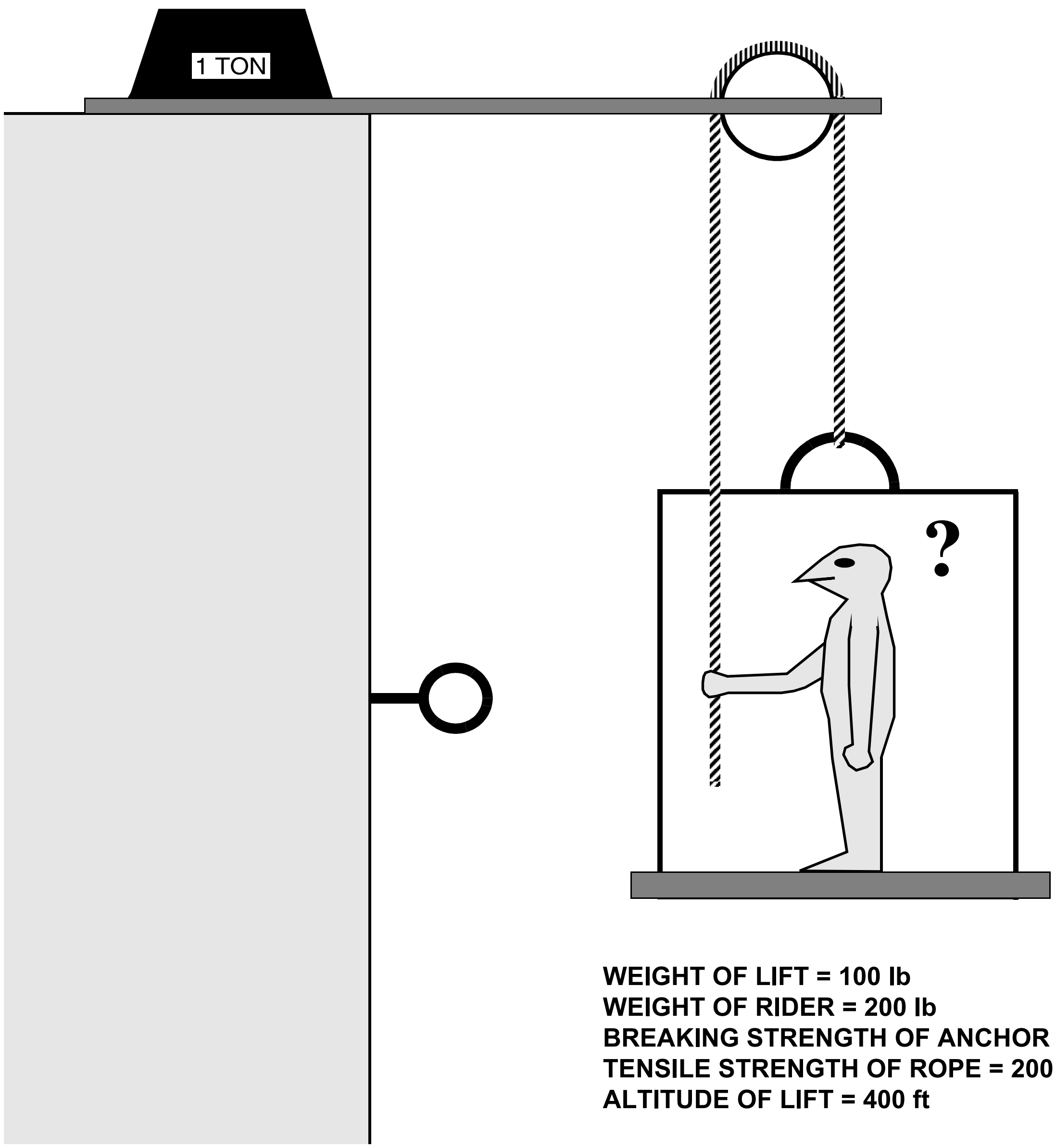
a. The water in the pool can be characterized as one of three possible 1-dimensional oscillators: open-open, open-closed, or closed-closed. Which is it?
b. Write the harmonic equation for this oscillator, identify the harmonic your team generated, and calculate the wavelength associated with that harmonic.
c. Calculate the wave speed.

Applied Science Investigation: The Ludicrous Lift

Name:____ Period:_____ Date:_____

You can work out this puzzle theoretically, or you could borrow a ring-stand, pulley, and weights from your science teacher and actually simulate the scenario. Either way, your task is to answer the question posed. Write your solution, or diagram and describe your experiment, on a single sheet of paper. All the necessary data is provided below — along with some unnecessary data. Hint: Consider the conditions needed for *equilibrium*.

The lift rider is getting tired of hanging onto that rope, so he's thinking about maybe tying it to that anchor ring on the building. If he does, what will happen?



WEIGHT OF LIFT = 100 lb
WEIGHT OF RIDER = 200 lb
BREAKING STRENGTH OF ANCHOR = 500 lb
TENSILE STRENGTH OF ROPE = 200 lb
ALTITUDE OF LIFT = 400 ft

Applied Science Investigation: Putting the Shot

Name:____ Period:_____ Date:_____

General Instructions:

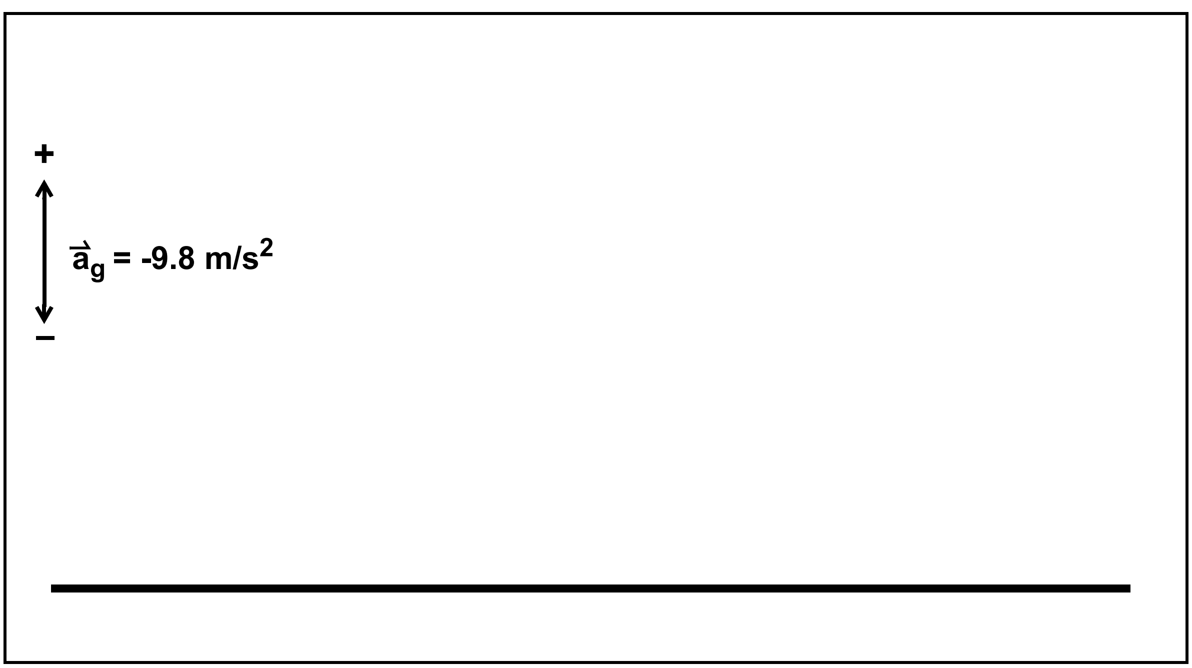
1. To do this ASI, you will need to check out the shot and a metric measuring tape from your coach and teacher. All data can be obtained in 15 minutes or less.
2. For your reference, the mass of the (HS level) shot is 4.250 kg.
3. Attach your calculations to this cover sheet.

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: Measuring the Speed of Sound

Names:____ Period:_____ Date:_____

To do this ASI you need 2 participants, a stopwatch with 0.01 s precision, a thermometer, a loud sound source, binoculars (a tripod frees your hands), and access to a large, quiet, open, outside area. The idea is to use the equation v = d/t to get a direct measurement of the speed of sound.

The sound source can be anything that is easily heard over a distance of a few hundred meters. Some possible ideas: bell struck with hammer, cap (or starter) pistol, bass drum. Details are left to you, but remember that the greater the distance, the better your accuracy.

Procedure:

1. First measure the air temperature. The predicted speed of sound depends on the temperature according to the formula: $v = 331.45 \text{ m/s} \cdot (T/273.16)$ where T is the *absolute* temperature.
2. Now set up your equipment with the sound generator on one end, and the binoculars and stopwatch on the other end of your test distance.
3. Observe the sound generator through the binoculars (stopwatch in hand). When you *see* the sound generator activated, start the stopwatch. When you *hear* the sound, stop the stopwatch.
4. Run the experiment 3 times, recording your results. Then reverse the equipment and run it 3 more times in the opposite direction also recording your results. You are done.

Analysis: (to be done on a separate attached sheet)

1. Report your data for "d", "t", and "T" in a chart.
2. Calculate "v", the speed of sound, for each data pair.
3. Calculate the average speed of sound.
4. Calculate your experimental error.

Questions:

1. Why were you told to run the experiment in both directions?
2. The speed of light is, of course, not infinite, though we ignored that fact in this analysis. At what decimal place in your result would error from this assumption appear?
3. In addition to attenuation, several problems occur when one tries to increase "d" for greater precision. Identify one of these problems and explain its repercussions.

Applied Science Investigation: Vehicle Speeds Distribution

Name:____ Period:_____ Date:_____

General Instructions:

On any given road, despite a posted speed limit, vehicles will move at a wide range of speeds that can be described mathematically with an *average speed* and a s*tandard deviation*. You will measure the speeds of 100 consecutive vehicles, and calculate those quantities.

Procedure:

1. Position yourself safely on the sidewalk near any convenient road near your home or school. Wherever you choose, there should be enough traffic at the time of day selected to complete this ASI in a reasonable amount of time.
2. Measure the speeds of 100 consecutive vehicles passing your observation post (moving in the same direction). Speeds should be recorded in units of "mi/hr". You can measure speeds by any of three methods:

a. Measure a visible distance (say, from a tree to a driveway) and time how long it takes for each car to cover it. This is probably your best choice.
b. Convince a police officer to assist you in this experiment with an official police radar gun. But if the officer is easily visible, it may bias your results.
c. Pace each vehicle using a bicycle with a speedometer (stay on the sidewalk or frontage). This would only work well if you had a friend with the right cycling equipment.
d. Regardless of method, speeds should be measured to at least 2 significant figures.

Analysis:

1. Create a graph of your data by plotting "number of vehicles in a speed range" vs. "speed range" using 2 mph ranges (e.g., 20-22 mph, 22-24, mph, 24-26 mph, etc.). Use a full sheet of graph paper, and include a chart of your data. Draw the "best" bell-shaped curve approximating your data points. Do <u>not</u> connect the data points dot-to-dot.
2. Calculate the *average* (v_{ave}) and *standard deviation* (σ) of your data set.
3. Are any of your data outside the 3σ limits? What are some of the possible explanations for these anomalies (did you notice anything peculiar about the very fast or very slow cars)?
4. Even if there were no posted speed limits, motorists would still average some particular speed on any given road. What physical factors would determine that average speed? Explain.
5. When a new road is built, how do "they" decide what speed limit to enforce? Who are "they"?
6. One of the complaints about the (now-defunct) 55 mph speed limit was that the interstate highways were built for 65 mph. What does "built for 65 mph" mean?
7. How does an automobile speedometer work? Draw a labeled diagram to assist you in your explanation. Cite any references used.

Applied Science Investigation: Strobe Photography and Sports Kinematics

Names:____ Period:_____ Date:_____

You need a strobe photography app on your smart phone to do this ASI. Several are available in the online stores. Some are free, others cost a few bucks. All will allow you to capture multiple images of a moving object in a single photo. You also need an image editing app for the analysis. This ASI is easiest with two people: one as the photographer and one as the athlete.

Procedure:

1. Choose a sports-related movement that involves acceleration and not just constant motion, and can be easily captured in a single frame. Examples: a golf swing, tennis serve, baseball pitch.
2. You need a reference length visible in the photo to facilitate measurements. A meter stick mounted perpendicular near the athlete works nicely. Athlete and meter stick must be the same distance from the camera for accurate measurements.
3. Shoot a strobe photo showing the full range of motion of the athlete and equipment. You'll need to experiment with the strobe speed settings to get 5-6 images of the motion captured in a single photo.

Analysis: (use MKS units of measurement)

1. Using an image editor, measure the distance covered in each segment of the motion. Hint: If you measure the length of the meter stick in the photo, other lengths can be measured and then converted into real distances using simple ratios.
2. Create a data summary chart showing all relevant measured values.
3. Calculate the speed of the athlete/equipment in each segment of the motion.
4. Calculate the acceleration of the athlete/equipment in each segment of the motion.

Questions:

1. What was the fastest speed measured? At what point in the motion did this speed occur?
2. What was the greatest acceleration measured? At what point in the motion did this happen?
3. At what point (if any) was the motion most nearly uniform?
4. Create a graph of speed vs. time for the motion analyzed.
5. Strobe photos of athletes are often used to diagnose execution problems. Do you see anything in your photo that, if corrected, could improve the performance of your athlete? Explain.

Applied Science Investigation: Using Newton's Synthesis Equation

Name:____ Period:_____ Date:_____

This ASI is a series of advanced calculations based on the Synthesis Equation of Newton's gravitation theory. Solutions to all the problems can begin with this equation:

$$G\frac{m_1 m_2}{R^2} = F_g = F_c = m_2\frac{4\pi^2 R}{T^2}$$

where m_1 is the orbited body's mass and m_2 is the orbiting body's mass, R and T are parameters of the orbit, and G is the universal gravitational constant. Each problem will require you to solve for a different variable in that equation. Do that before substituting any values. Some of those values will need to be researched, some are given, all must be converted to MKS units. You need not complete every problem, but the more you do the higher your score.

1. What is the speed of a circular orbit that skims a mere 10 km above the surface of the Moon? Due to the lack of atmosphere an orbit this low is possible, though dangerous, as it barely misses the peaks of the tallest lunar mountains.

2. Use the radius and period of the Sun's motion around the center of the Milky Way to calculate the total mass of our galaxy. This calculation only gives you the mass *inside* the Sun's orbit, so increase your answer by an appropriate ratio to correct for that omission.

3. At what orbital radius would an Earth satellite have a period of 24 hours? This would be the orbit used by g*eostationary* communications satellites.

4. The Milky Way galaxy and the Andromeda galaxy attract each other with gravity and are, in fact, accelerating toward their common center of mass. The Andromeda galaxy is estimated to have about 18 times the mass of the Milky Way. Calculate the period of their orbital motion.

5. How much gravitational force do the Earth and Moon exert on each other?

6. At what distance would Earth and Moon attract each other with exactly 1 N of force?

7. How much time does it take for the International Space Station to circle the Earth once?

8. How much less do you weigh at the top of Mt. Everest compared to at the bottom of Death Valley? Use your own actual mass to do this calculation.

Applied Science Investigation: Three Types of Waves

Name:____ Period:_____ Date:_____

You can do any or all of the following exercises related to waves.

1. There are three defined types of waves in physics: *transverse*, *longitudinal*, and *torsional*. Each has a different geometry for the direction of propagation vs. medium distortion. Be on the watch for examples in your environment, and identify one of each wave type. For each:

a. specify the wave type
b. describe your discovery (diagrams encouraged)
c. identify the medium
d. identify the energy source
e. define a measure (and units thereof) for amplitude
f. estimate the wave speed and explain your estimation method

Cite your results in the form of a standard experiment report.

2. The following is a quote from Gerald Holton, one of the authors of Harvard Project Physics, on the topic of "unity in physics."

"*We are very good at making, and talking about, the bricks in the temple of science, but most of us are shy about the mortar, or about the speculative blueprint of the whole design*."

What do you think Holton means by the terms "brick", "mortar" and "blueprint"? Would you categorize *waves* as a brick, mortar, or the blueprint for the temple of science? Write a 1-page essay responding to this question.

3. We've all seen "The Wave" performed by spectators at athletic events. Physics has a very specific definition for what qualifies as a wave. Cite this definition. In what ways is "the Wave" not a true wave? In what ways is it a true wave?

Applied Science Investigation: Measuring Centripetal Force

Name:____ Period:_____ Date:_____

Instructions:

1. This ASI requires 2 participants, one to ride the merry-go-round (and act as a test mass) and another to do the spinning and take measurements.
2. To do this ASI you will need access to a playground with a non-powered (other than by you or your friend) merry-go-round.
3. Equipment required is a stopwatch and measuring tape (but distance must be expressed in units of meters). Most smart phones come with stopwatch apps, but any timer precise to 0.1 s will do.

Procedure:

1. Situate the rider at a point on the circumference where he/she can hang on tight.
2. Measure the radius of the merry-go-round from its center to the center of mass of the rider.
3. Spin the ride up to a speed where it will rotate on its own for a few minutes.
4. Immediately after spin-up, measure the time for 10 cycles of rotation.
5. Help your rider off and comfort him/her while their equilibrium returns.

Analysis:

1. Include a sketch of your experiment with the following information:

a. name and location of park
b. correctly oriented centripetal and centrifugal force vectors
c. summary of data

2. Perform the following calculations:

a. Calculate the mass of the rider in "kg", given their weight in "lb".
b. Calculate the period of rotation.
c. Calculate the circular speed of the rider.
d. Calculate the rider’s centripetal acceleration.
e. Calculate the centrifugal force acting on the rider.
f. Convert the preceding answer into units of "lb".

Applied Science Investigation: Hitting a Small Leather Sphere with a Wooden Cylinder

Name:____ Period:_____ Date:_____

1. Given the relative speeds with which a baseball approaches and recedes from the bat, the coefficient of restitution of an offical MLB baseball, and the equation describing collisions between objects of different elasticity, calculate the elasticity of a wooden baseball bat.

2. Given the time of contact between ball and bat, and the change in velocity of the ball, calculate the ball's acceleration in units of g's.

3. Given your answer to question 2, and the mass of the ball, validate or refute the claim that 8000 pounds of force are required to get a home-run caliber (110 mph) hit.

4. Validate or refure the claim that "swinging 1/100 second too late produces a foul ball. Hint: the tip of the bat moves about 70 mph along a roughly circular path.

5. Which MLB stadium (in the contiguous 48 states) would have the lowest gravitational acceleration? There are two or three likely choices. Support your choice with calculations.

6. If a regulation baseball were dropped from a second story window (measure h) onto a flat concrete surface, to what height it rebound? Try it and compare the predicted and actual results.

7. Baseballs could easily be manufactured without stitches, but almost certainly never will. Why not? There are three good reasons.

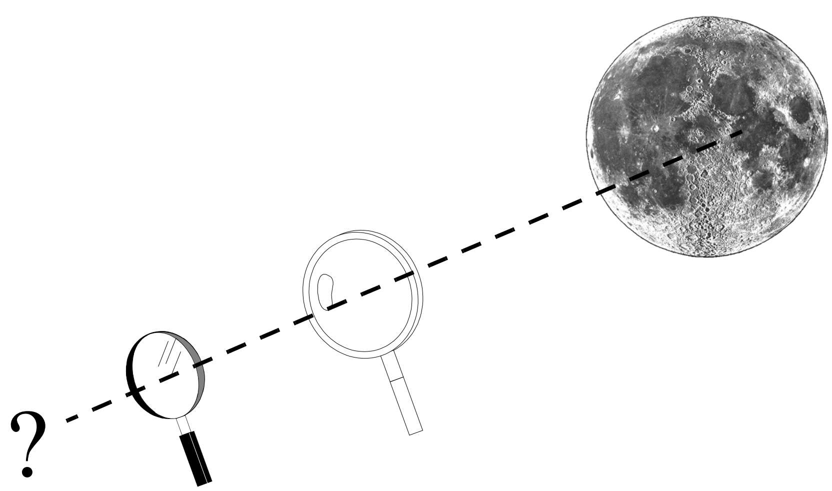
8. A few years ago there was a rumor being circulated that if you keep any non-inflated type of ball really cold it will travel faster and farther after being struck. It has also been claimed that a ball hit on a warm day will go farther than on a cold day. Is there a contradiction here or is this only an apparent disparity?

Applied Science Investigation: Editorial on Galileo’s Discoveries

Name:____ Period:_____ Date:_____

Instructions:

1. Imagine you are on the staff of a newspaper somewhere in Italy, circa 1610. You’ve just read *The Starry Messenger*, reporting Galileo’s fantastic claims regarding his telescopic discoveries. Write an editorial that takes either a "pro" or "con" stance regarding those claims. You can take either a heliocentric or geocentric bias in your editorial.
2. If your word-processor has graphic capabilities, you can increase your score in the "creativity" category by designing a clever masthead for your editorial page. You can also do this by hand if you want to showcase your artistic talents.
3. This work must be typed in black ink, double-spaced, and use only one side of an 8.5x11 sheet of white, unlined paper.
4. Part of your grade will be based on spelling, grammar and appropriate editorial style. You may refer to any standard style guide for newspapers.



Applied Science Investigation: Electrical Power Use

Name:____ Period:_____ Date:_____

Instructions:

1. This is a one-person ASI that must be done at home.
2. You must have access to your electric meter. Readings are required for the calculations. If you are an apartment dweller, or otherwise don't have access to your individual meter, you may use the readings at the house of a friend or relative.
3. You must also have access to your last month's electric bill to do the rate calculations.
4. If your meter is different than that shown in Figure 1, cross it out and sketch what you have.

Procedure:

1. Enter the street address of your test site:____
2. Locate your electric meter. It's typically a glass-enclosed device with several numbered dials similar to what is shown in Figure 1.
3. The dials are sometimes numbered in opposite clockwise senses. Each dial reads much like a car's odometer, with the right-most dial in units of "kilowatt-hours".

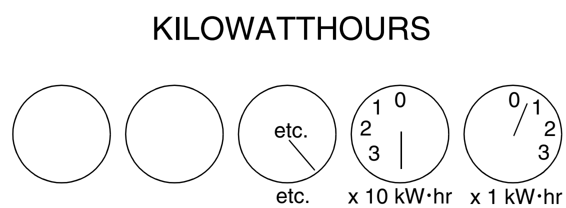


Figure 1

4. The total value of each reading is meaningless, as it is a cumulative total since the meter was first connected. What you must do is take 2 readings one day apart; their difference will give you the electrical energy used in one day. Readings must be made at the *same time* each day.

Day 1: _____________________ kW-hr
Day 2: _____________________ kW-hr
ΔE = _____________________ kW-hr

5. Get the stub from last month's electric bill and locate the current cost of electrical energy. The rate will be given in units of "\$/kW×hr". Enter that value here: ________________ \$/kW-hr

Analysis:

1. The unit "kW-hr" (actually kW×hr) represents 1000 W of power supplied for a time of 1 hour. It represents the *energy* as *power* x *time* ($\Delta E = P \times \Delta t$). Calculate the number of "joules" of energy your home used over this 1-day interval.
2. Calculate the cost of this 1-day's dose of energy.
3. The calculations above ignore the fact that some of the energy entering your home is *chemical potential energy* (natural gas), which must also be paid for. Locate and list the machines in your home that use this form of energy.

Applied Science Investigation: Exponential Growth

Name:____ Period:_____ Date:_____

Instructions:

1. This ASI requires data research and the creation of two graphs.
2. You will need *Cartesian* and *semi-log* graph paper, both of which are available online.

Graph 1:

1. Find population data for any country spanning at least a 100 year period. Cite your source here:

SOURCE:____

2. Prepare a graph of your data using Cartesian coordinates.

3. Indicate your chosen country on the map below with a small, blue, accurately-located "**X**".

Graph 2:

1. Population growth, as well as anything that directly relates to population, such as energy use, food production, GNP, etc., usually follows an *exponential function* characterized by a rate of change that is a constant percentage. For example, world population has been increasing at an average rate of around 2%/year for the last few decades. Given the 1990 global population of around 5 billion, in that year 100 million people were added. In the year 2000, if the rate holds constant, 120 million people (2% of a now larger total) will be added.

Choose the semi-log graph paper with enough cycles to cover your data, and prepare a second graph of your data showing this exponential growth as a straight-line plot. Note that it will not be a perfectly straight plot due to random data variations, but it should be close to straight.

2. Calculate the *doubling time* for the population of your chosen country.

Applied Science Investigation: Science & Society Issue Analysis

Name:____ Period:_____ Date:_____

Instructions:

This ASI will test your ability to recognize and analyze an issue where Science & Technology interacts with Society. It is a chance to improve your understanding of any one of those many issues you know you should know more about but don't.

This is also a test of technical communication skills, as cogent discussion of technological issues requires the mastery of certain new terms and concepts. Informed citizens are needed to make intelligent choices on many such issues facing Society today.

Part 1:

Find a magazine articles that presents both sides of a technological issue exemplifying the feedback that occurs between Science and Society. Acceptable sources include Discover, Scientific American, Popular Science, National Geographic, Smithsonian. Copy or scan your chosen article for reference and later submission.

Part 2:

Write a 1-2 page summary of the issue consisting of:

a. title which states the issue in abbreviated form
b. paragraph citing the two opposing positions and identifying the opposing parties involved
c. paragraph summarizing main arguments on PRO side
d. paragraph summarizing main arguments on CON side

Part 3:

Write a 1-2 page statement of *your* position on the issue (feel free to cite additional references).

Part 4:

Prepare and submit this assignment as follows:

1 = this cover sheet
2 = 1-2 page summary
3 = 1-2 page personal position statement
4 = copy of article

Applied Science Investigation: Newton’s Three Laws in Action

Name:____ Period:____ Date:____

Instructions:

1. Find a photo or cartoon that shows all 3 of Newton’s Laws in action. Technically, an image of a rock at rest on a table (with an excellent Analysis) could cover all three laws and get a perfect score. However, your grader will be biased to award higher scores to more creative selections.
2. Copy your selected image into the space below.
3. Attach a second page on which you will present your Analysis.

Analysis:

1. a. Write a one-paragraph explanation of how Newton’s First Law is being demonstrated.
   b. Label the object(s) involved as "A", "B" etc.
   c. Draw-in and label the relevant force vectors.
2. Do the same for Law 2.
3. Do the same for Law 3.

Applied Science Investigation: The Efficiency of Your Microwave Oven

Name:____ Period:_____ Date:_____

Instructions:

This is a home experiment that requires the following equipment:

a. any size microwave oven
b. styrofoam, paper or plastic water cup
c. preferably distilled water but tap water will do
d. device for measuring liquid volume or mass
e. 100 °C or 212 °F thermometer.
f. cocoa mix or tea bags (Why waste all that nice hot water you'll be making?)

Procedure:

1. Look on the back panel of the oven for a manufacturer's label. Record the *make*, *model*, and *power input* (in units of "W"). You may also find this information in the owner's manual.

make/model: ____

P = ________________

2. Measure 200 cm^3 of cold water into the cup, insert the thermometer, and record the initial temperature in degrees Celsius.

T_o = ________________

3. **Warning**: Remove the thermometer before Procedure 4.

4. Center the cup in the microwave. Set the power to its highest level and the timer to 60 s. After heating is complete you must act quickly: open the door, leave the cup in the oven, and reinsert the thermometer. Measure and record the final temperature.

T_f = ________________

Analysis:

Do the following calculations on a separate sheet. Show equations, substitutions with units, conversions, and answers to the correct number of significant figures.

1. Calculate the energy input to the microwave in 60 s. Express your answer in "J".
2. Calculate the energy absorbed by the water during those 60 s. Express your answer in "J".
3. Calculate the efficiency of your microwave oven.

Applied Science Investigation: Evolution of the Mile Run

Name:____ Period:_____ Date:_____

Instructions:

1. Use the data provided for the record times in the mile-run, as well as your natural fluency in the language of mathematics, to answer as many of the questions as you can.
2. Answer essay questions with at least one full paragraph. On calculations, show all steps, with units, and a clearly indicated answer.

Data:

3:59.4	Roger Bannister	1954
3:58.0	John Landy	1954
3:57.2	Derek Ibbotson	1957
3:54.5	Herb Elliot	1958
3:54.4	Peter Snell	1962
3:54.1	Peter Snell	1964
3:53.6	Michel Jazy	1965
3:51.3	Jim Ryun	1966
3:51.1	Jim Ryun	1967
3:51.0	Filbert Bayi	1975
3:49.4	John Walker	1975
3:49.0	Sebastian Coe	1979
3:48.8	Steve Ovett	1980
3:48.53	Sebastian Coe	1981
3:48.40	Steve Ovett	1981
3:47.33	Sebastian Coe	1981
3:46.32	Steve Cram	1985
3:44.39	Noureddine Morceli	1993
3:43.13	Hicham El Guerrouj	1999

Questions:

1. Plot this data on a full sheet of graph paper in landscape orientation. Choose the scale for the horizontal axis such that the plotted data fills up about half the available space. You do not need to include runners' names on the data chart. Use "year" as the independent variable.
2. Are the record times evolving in a *linear* or *nonlinear* manner? Based on your knowledge of anatomy-physiology, which of the two would you expect, and why?
3. Describe this data with a mathematical equation. If you judge the trend to be linear, derive the equation for the *line of best fit*. If nonlinear, use whatever mathematical means you can find to derive the equation of the *curve of best fit*.
4. The chart shows record times for the mile run since 1954, when Roger Bannister broke the 4 minute barrier. In what year will the 3 minute barrier be broken? To answer, either *extrapolate* an answer graphically, visually approximating the data trend and extending the curve as needed (show this line), or calculate and answer using your equation from Question 3.
5. Note that in 1981 the precision of official timing was improved. Why do you think this was done? Why not measure times to even better precisions yet, say 0.001 s or 0.0001 s?
6. Calculate Hicham El Guerrouj's average speed over the mile run, and express it in units of "mi/hr". How fast is that in units of "m/s"?
7. What was the *instantaneous rate of change* of the world record time the mile run at t = 1967? Express your answer in units of "s/yr". Yes, you'll need to draw a tangent to answer this one.
8. Why is the mile run actually a test of *average speed*, whereas the 100 yd dash is considered to be a test of *acceleration*?

Applied Science Investigation: The Thickness of a Sheet of Paper

Name:____ Period:_____ Date:_____

Instructions:

1. Your objective is to measure the thickness of a sheet of paper.
2. You will need a ruler or measuring tape, and your science textbook.
3. Show all your calculations, and the answer to the question, in the space below.

Procedure:

1. Measure the thickness of your textbook, not including covers. D_P = ______________
2. Note the total number of pages. N_P = ______________
3. Record the precision of the measuring device used. precision = _________

Analysis:

Calculate the thickness of a single page of your textbook. d_P = _______________

Question:

If your textbook had 1000 pages how thick would it be?

Applied Science Investigation: Your Personal Parameters

Name:____ Period:_____ Date:_____

Instructions:

1. You will measure and calculate several parameters of your body. You need not be an athlete to participate, but you will be required to engage in some minimal physical activity.
2. You must complete these measurements and calculations in the given sequence.
3. All results must be fully supported. Explain how measurements were made and/or show all calculations with units of measurement. Significant figure limitations must be followed.

Procedure:

1. What is your *height* (in "m")?
2. What is your *surface area* (in "m^2")? Hint: This is tricky, but see Procedure 3 below.
3. What is your *volume* (in "m^3 ")? Hint: You could use the *displacement of water* method to do this, or approximate your body as a collection of geometric solids.
4. What is your *weight* (in "N")?
5. What is your *mass* (in "kg")?
6. How many quarks does your body contain? Assume that each quark has a mass of 1/3 amu, and that your electron mass is negligible.
7. What is your *density* (in "kg/m^3")?
8. In terms of *net force*, your leg muscles are the strongest in your body. When you begin a sprint from rest your acceleration spans about the first 10 m. From that point your speed is essentially constant. Time your 10 m sprint, then calculate your rate of *acceleration* (in "m/s^2").
9. Calculate the *force* exerted by your leg muscles (in "N").

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: Finding Your Rainbow

Name:____ Period:_____ Date:_____

Instructions:

1. You may not remember seeing your first rainbow, and you may not even remember your last one, but you can always create your own once you understand some basic physics.
2. Equipment required: one garden hose with an adjustable spray nozzle, one compass (or at least a reasonably accurate sense of compass directions at your test site).

Procedure:

1. This experiment must be performed within one hour before sunset or one hour after sunrise, on a day when the Sun is shining clearly.
2. Your objective is to find the combination of nozzle setting and spray direction that produces the clearest rainbow. Experiment. Try all settings and all directions until you get it. You'll know (and see) immediately when you have it right, since rainbows created in this manner can often be even more intense than those provided by nature.
3. When you've discovered the ideal combination, take a moment to study the arrangement of colors and the shape and orientation of the bow. Then sketch what you see on the back of this sheet, using accurate colors. Include labels to identify the details, and draw its curved shape accurately. Imagine you are trying to describe a rainbow to a person who has never seen one.
4. Complete this data chart:

DATE OF OBSERVATION: ____
TIME OF OBSERVATION: ____
ADDRESS OF TEST SITE: ____
DIRECTION FROM YOU TO SUN (i.e., N, NW, NNW, WNW, W, etc.): ____________________
DIRECTION FROM YOU TO CENTER OF RAINBOW (i.e., N, NW, NNW, WNW, W, etc.): __________

5. Answer in 2 printed lines: Next time you notice it's raining while the Sun is shining (not that rare) where will you look, with respect to the Sun, to find your rainbow?

____
____

6. Answer in 2 printed lines: Under what conditions could you see a rainbow at high noon, and in what direction would you have to look to see it?

____
____

Applied Science Investigation: Rolling Friction

Name:____ Period:_____ Date:_____

Instructions:

1. This ASI requires two participants: a driver and a spotter. You will be the spotter. The driver must be an adult, and 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: ____

2. By measuring your vehicle's coasting distance from a given starting speed, you will determine its coefficient of rolling friction.
3. You will need a safe, low-traffic area for Procedure B. An empty parking lot after hours works well. Another good venue is a remote frontage road or side street. In any case, select a paved area that is level and of uniform surfacing, and long enough to coast in a straight line.

Procedure A: Preliminary Data

1. State the make and model of the test vehicle: ____________________________________
2. State the brand of tires on the test vehicle: ____________________________________
3. Describe the road surface in the test area: ____________________________________
4. Measure the radius of your tires: R = __________m
5. Determine the mass and weight of your vehicle + driver + spotter. You may find some of this data in your owner's manual. If you have no manual, consult a dealer.

m = __________kg

Fg = __________N

Procedure B: Test Run

1. Designate a fixed starting point from which your vehicle will begin its "coast".
2. Drive in a straight line at 10 mph (4.5 m/s) toward the starting point.
3. When you reach the starting point, begin your "coast": standard transmissions disengage the clutch, automatics shift into neutral. Drive a straight line until your vehicle comes to rest.
4. If your vehicle has an accurate digital odometer or GPS system this will be easy. Otherwise, you'll need a long tape or trundle wheel. For reasonable accuracy you'll need to measure d_1 (the coasting distance) to a precision of 1 meter: d_1 = __________m
5. Repeat steps 1–4 in the opposite direction: d_2 = __________m
6. Calculate the average of these two runs: d_{ave} = __________m

Analysis: (Show all equations, substitutions and significant figures.)

1. Calculate "a", the (negative) acceleration of your car during the coasting run.
2. Calculate "F_R", the rolling friction acting during this run.
3. Calculate "C_R", the coefficient of rolling friction for your vehicle.

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 standard 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.