

Physics Labs You Can Do On A Limited Budget

1. **Day One Lab:** Given the information below, collect data and carry out the necessary analysis to determine the relationship posed in the TASK. Your group is to prepare a written report, including appropriate graphs of your data, and be prepared to make an oral presentation tomorrow, summarizing your problem, experimental set up, data, graph, and your conclusions.

Task: Determine the relationship between the starting height of a rolling ball and the distance it travels horizontally in the air before hitting the floor.

Materials: Ramp and C-clamp, steel ball, meter stick.

Data and Analysis:

Task: Determine the relationship between the height a ball rebounds and the height from which it was dropped.

Materials: Rubber ball, double meter stick

Task: Determine the relationship between the rate at which water flows from a container and the size of the hole from which it flows.

Materials: Graduated cylinder, stopwatch, masking tape, sink, flow rate device.

Task: Determine the relationship between the deflection of a weighted meter stick and the amount of mass being supported at the outer end of the stick.

Materials: Two meter sticks, C-clamp, mass cans, string

Task: Determine the relationship between the mass of a steel ball and the rate at which it rolls down an incline plane.

Materials: Incline plane, meter stick, balance, stopwatch, steel balls

2. **Metric Measurement Lab:** For each step below, make the required measurement in the units asked for, then make the conversions to the other metric units as indicated. Materials needed: meter stick, graduated cylinder, wood block, water, plastic glasses, sand or salt, rocks.

Part 1: Measure the length of the classroom from north to south in meters.

Part 2: Find the volume of the wood block in cm^3 .

Part 3: Use the graduated cylinder to find the volume of the liquid in the glass in mL.

Part 4: Find the mass of the solid in the cup in grams.

Part 5: Use the graduated cylinder to find the volume of the irregular shaped object in mL.

Part 6: Find the area of the lab table top in cm^2 .

3. **Measuring Long Distances By Parallax:** The parallax shift of an object relative to its background can be used to measure large distances. You will measure the distance to some object far away by using parallax and triangulation.

Introduction: Hold a pencil at arms length and look at its top with one eye closed.

Notice what object is directly behind the pencil. Now close the open eye and open the other one. Notice how the pencil has shifted relative to the background object.

This parallax shift occurs because your eyes are several millimeters apart. Now move the pencil half an arms length closer to your eyes and repeat the observations.

Q1. State a general rule about the relationship between the distance between your eyes and the amount of parallax shift.

Q2. State a general rule about the relationship between the distance from your eyes to the object and the amount of parallax shift.

Experiment:

1. You will be provided with a parallax viewer. Use a meter stick to measure the distance between the 2 nails, (sighting nails) on the viewer and record that distance OC.
2. Take the parallax viewer, meter stick, and tape measure out to the parking lot. Look to the north and find a spot in the lot where you can line up a street light pole on the distant street with the radio tower farther away.
3. Hold the parallax viewer so the 2 sighting nails, the light pole and the radio tower are all in a straight line. As you hold the viewer steady, one lab partner will lay a meter stick on the ground so it runs perpendicular to your sight line.
4. Use the tape measure to measure off 5 meters to the left or right along the perpendicular line laid out by the meter stick.
5. At that point, line up the 2 sight nails with the radio tower and you will see that the light pole has shifted. Have a lab partner slide a pencil along the viewer until it is in line with the light pole. Record how far the light pole has shifted as OS.
6. Measure off another 5 meters along the same line and repeat step 5.

7. Use the equation $BD/BC = OC/OS$ to find the distance to the light pole BD. BC is the baseline distance of 5 m and 10 m. Average your distances to find BD.

4. **Motion Lab Block:** In this lab you will be moving from station to station and making observations of motion. Follow the instructions below associated with each station. Write down any and all observations of motion that you see.

Station 1 – Beaker, card and coin: Place the card on the beaker and the coin in the middle of the card. Try to put the coin into the beaker without touching the coin.

Observations:

Station 2 – Beads and magnets: Move the magnets in the tub and observe. Place the magnets on the lab table, move and observe. Play with possibilities.

Observations:

Station 3 – Dropping objects: Drop a penny, a roll of pennies, a ping pong ball, and a crumpled piece of paper, in pairs, from the top of the lab table to the floor. (Do not roll the crumpled paper into a ball.)

Observations:

Station 4 – Ball and incline: Put the ball on the incline, release and observe.

Observations:

Station 5 – Pendulum and stop watch: Time some swings.

Observations:

Stations 6-8 – depends on what you have available. I use a movie projector, balloon pucks, van de Graff generator, strobe light in a dark storage room, motorized toy cars.

5. **Moving Your Bones** – Rectilinear Motion:

The course will be outside on the grassy area west of the building. The course will be 60 meters long, divided into 20 meter segments. You will walk slowly for the first 20 meters, then faster for the next 20 meters, then run for the 3rd 20 meters, then walk backwards to the 40 meter mark.

There will be a timer at the 20 meter mark, 2 timers at the 40 meter mark and a timer at the 60 meter mark. You will start at the starting line and signal the timers by dropping your raised hand. All clocks will start at the same time. Clock 1 will be shut off when you reach the 20 meter mark, clock 2 when you reach the 40 meter mark, clock 3 when you reach the 60 meter mark and clock 4 when you return to the 40 meter mark.

Record your times in the data table. When everyone has completed the course, obtain the data for 2 of your classmates.

Plot a graph of displacement (distance from the origin) on the y-axis versus total time on the x-axis. Also plot the data for the other 2 students on the same graph.

Calculate your velocity for each of the 4 segments on the course. Your velocity will be represented by what feature of your graph?

(I then give them graphs of motion that I prepared and they have to explain how they would walk each graph. Then as a quiz I divide them into groups and have them walk one of the graphs in time to a cadence I recorded, one thousand one, one thousand two, etc.

6. Flight Planning – Vector Lab: You are planning airplane trips across our great state of Nebraska. Beginning in Omaha, you will first fly to **City A** (leg 1). Then you will fly from **City A to City B** (leg 2). Then you will fly back to Omaha (leg 3). The plane you will use cruises at 250 km/hr relative to the air and consumes fuel at the rate of 28 L/hr when cruising. All flights will be made along a straight line connecting each city.

City A _____ City B _____
Part 1: Find the following for your trip on a day when there is no wind.

Data Table:

Distance
Flight Direction
Wind Speed
Wind Direction
Plane Heading
Plane Speed
Flight Time
Fuel Consumption

Part 2: Find the following for your trip if there is a 70 km/h wind from the _____. Assume the 250 km/h is the maximum plane speed into the wind. Draw all appropriate vectors on your map and turn in with your lab.

Distance
Flight Direction
Wind Speed
Wind Direction
Plane Heading
Plane Speed
Flight Time
Fuel Consumption

7. Acceleration Due To Gravity In Omaha: Isaac Newton showed that the acceleration due to gravity depends upon the objects distance from the center of the Earth. In this experiment you will measure the acceleration due to gravity at your present location. Follow the directions below.

Part A: Bouncing Ball – Use a golf ball, double meter stick, and a stop watch. One difficulty in observing the motion of a falling object is the event takes place in an extremely short period of time, making it difficult to accurately measure time. You will try to improve on this time measurement by measuring the time a ball bounces and returns to the floor. One lab partner stand on the lab table and drop the golf ball from as high as possible. When the ball hits the floor you will hear a “thunk” at this point start the stop watch. One lab partner will watch how high the ball bounces by standing the meter stick up next to the dropping ball. When the ball returns to the floor it will make another “thunk” and the stop watch is shut off. Using the bounce height as “h” and one half of the bounce time as “t”, you can find a value for “g” using the equation $h = 1/2gt^2$. Drop the ball from different heights, find “g” for each height and average your “g” values.

Part B: Pendulum: There are 2 factors that effect the period (T) of a pendulum. One is the length of the pendulum (L) and the other is the acceleration due to gravity “g”. The equation is $T = 2\pi\sqrt{L/g}$. Around the room, hanging from the ceiling, are pendulums of various lengths. Find the length L, then measure the period T, by swing the pendulum through a small arc of about 15 degrees. Time at least 5 complete cycles, then find T by dividing the total time by the number of complete swings. Collect data using 3 different length pendulums and then average your “g” values.

Data Table 1:

Trial	Drop Height	Bounce Height	Bounce Time	Fall Time	g
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Data Table 2:

Trial	Pendulum Length	Time for ____ swings	Period of 1 swing	g
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8. **Marshmallow Catapult:** Various factors determine how far a catapult can throw an object. These include mass of the object, strength of the projecting mechanism, distance the mechanism is compressed, and angle of release. In this lab, the variable will be the angle of release and the rest of the factors will be kept constant.

Materials: catapult, marshmallows, protractor, meter stick.

Procedure:

1. Place the base of the catapult on the floor and lean the length of the catapult against the leg of a lab table. Be sure the catapult is facing an empty area so the projectile (marshmallow) can fly uninhibited.
2. Adjust the catapult so the launch angle is 90° to the floor.
3. Place the marshmallow on the wooden dowel and pull the spoon back until it touches the wooden piece.
4. Release the spoon and measure the horizontal distance (range) the marshmallow flies. Repeat 2 more launches from this same position and record these distance in your data table and find the average range.
5. Change the catapult launch angle to 85° and repeat steps 3 & 4.
6. Continue to lower the launch angle by 5° increments until the launch angle is 5° repeating steps 3 & 4 for each angle.

- Plot a graph with the launch angle on the x-axis and the average range on the y-axis.

Conclusion: What is the relationship between the range and the launch angle? What is the angle that provides the maximum range?

9.Softball Throw: Using your knowledge of projectile motion, you will determine how fast you can throw a softball by measuring range and time of flight.

Materials: softball, stopwatch, throwing field

Procedure:

- Quietly proceed from the classroom to the band practice field.
- Cones are placed at 5 meter increments, starting at the 20 meter mark from the end zone line.
- One person will time how long the ball is in the air from when it leaves your hand until it lands. One person will mark the landing spot and determine the range. One person will shag the ball and roll it back to the end zone line.
- Throw the ball as hard as you can and at a launch angle above 30 degrees. You may take a running start, but you must throw farther than the minimum 20 meter line.
- Record your range and flight time in the data table. Record the range and flight time of 3 other throwers.
- Calculate the velocity of the softball as it left your hand. Do the same for the other 3 throwers.

Data Table:

Range	Time	V_x	Time/2	V_y	Launch Angle	Throw velocity
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10.Steelie In The Can: By examining the landing spot of a ball released from different heights on an incline plane, you will be able to determine the release height from which a ball will land in a can set in front of your incline plane by your teacher. You will have only one chance to put the steelie in the can.

Materials: ramp, C-clamp, steel ball, meter sticks, graph paper, target can

Procedure:

- Set up the ramp and clamp it to the table.
- Release the steel ball from different heights on the ramp with one being the very top of the ramp.
- Measure the height from the table top to the release point. Record this height in your data table along with the distance traveled horizontally from the end of the

- ramp. Do at least 3 trials from each height and determine the average horizontal distance.
- Plot a graph of horizontal distance vs release height. You may plot the graph on your graphing calculator. When your graph is completed call me to your lab table.
 - After examining your data and graph, I will assign you a horizontal distance where I will set the empty can. I will take your steel ball so there will be no practice runs.
 - When you have determined your launch height, I will set the can on the floor at the assigned distance, hand you the steel ball, and you will have one release to put the steelie in the can.
 - Award Points: In the can 10 points. Hitting the rim or side of the can 5 points. Missing the can 0 points.

11. Radius of the Earth Lab: (When I taught at Lincoln East I had a friend teaching in Austin, Texas and we had our students collect data at the same time of day on the same day. When she retired I just gave my student a copy of previously collected data.)

Background: When a meter stick is standing at a 90° angle to the Earth, it is standing on a radius of the Earth. Since the sun is so far away we can consider its rays to be parallel to each other when they strike the Earth. The angle formed by a parallel light ray and meter stick standing in Lincoln is Θ_1 and the angle formed by a parallel light ray and meter stick standing in Austin is Θ_2 . See diagram below. The angle formed at the center of the Earth from the radius extending down from Lincoln and the radius extending down from Austin is Θ . $\Theta = \Theta_1 - \Theta_2$ (analyze the geometry from the diagram)

Procedure:

- Use the data below for Trial 1 to find angles Θ_1 and Θ_2 . Calculate Θ .
- From a United States map, find the distance (arc length) along the surface of the Earth from Lincoln to Austin. Find the length in km.
- Set up a proportion: $\text{arc length}/\Theta = 2\pi R/360^\circ$ Solve for R.
- Use the data below for Trial 2 and repeat steps 1-3.
- Average your values for Trials 1 & 2.

Data: Trial 1: Time 12:00 PM

Length of meter stick shadow in Lincoln = 96.2 cm
 Length of meter stick shadow in Austin = 66.3 cm

Trial 2: Time 12:00 PM

Length of meter stick shadow in Lincoln = 114.2 cm
 Length of meter stick shadow in Austin = 80.9 cm

12. Experiencing Newton's 2nd Law Lab:

Materials: ramp, cart, can weights, stop watch, scale

Procedure:

1. Mark off a 0.60 m track distance on your lab table.
2. Find the mass of the cart.
3. Set the cart at one of the track marks and cut a piece of string long enough to be tied to the cart and the other end hang over the edge of the lab table beyond the 2nd track mark.
4. Hang 100 g on the string hanging over the lab table. Hold the cart still at the starting line.
5. Start the stop watch at the same instant the cart is released and stop it when the cart crosses the 0.60 m mark. Catch the cart before it drops off the table. Record the time in your data table. Repeat 2 more times to average the time.
6. Hang 200 g on the string and repeat step 5.
7. Hang 400 g on the string and repeat step 5.
8. Go back to the 200g on the string. Add enough mass to the cart to double it's mass. Time how long it takes the more massive cart to travel the 0.60 m.
9. Add enough mass to the cart to triple its mass and repeat step 8.
10. Calculate the acceleration of the cart for each trial using $x = \frac{1}{2} a t^2$.

Data Table:

Mass of Cart	Hanging Mass	Accelerating Force	t-1	t-2	t-3	Average t	t ²	a
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13.Slip Sliding Along: The purpose of this lab is to calculate the coefficient of friction between different surfaces. $\mu = F_f/F_N$

Materials: wood block, spring scale, sand paper

Procedure:

1. Find the mass of the wood block and calculate its weight.
2. Hook the spring balance to the wood block and place the block on the lab table.
3. Find and record the force needed to just start the block moving. Calculate the coefficient of starting friction.
4. Then find and record the force needed to just slide the block at a slow constant rate over the surface. Calculate the coefficient of sliding friction.
5. Place the wood block on the wooden board and repeat steps 3 & 4.
6. Place the sand paper on the wooden board, place the wood block on the sand paper and repeat steps 3 & 4.

Data Table:

Surface	Static Force	Kinetic Force	μ_s	μ_k
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Write a conclusive statement concerting the values for coefficient of static friction and coefficient of kinetic friction for this lab.

14. Friction on a Slope: When a block rests on an incline plane, its weight acts vertically downward, but the block will often slide down the incline. To explain this motion the downward force of the block actually has 2 components. The first F_P acts parallel to the plane and tends to make the block slide down the incline. The other F_N acts at right angles to the plane and tends to make the block stick to the incline plane surface. In this experiment you will examine these component forces using vectors and trigonometry functions.

Materials: incline plane, wood block, spring scale

Procedure:

1. Find the mass of the wood block and calculate its weight. This is the vertical force.
2. Use the spring balance to slowly pull the block along the incline plane board while it is lying flat on the lab table. Be sure your force is parallel to the board. Record this force as force applied F_A .
3. Adjust the incline plane so the angle of elevation is 15° . Pull the wood block up the incline at a constant rate and with the spring scale parallel to the incline surface. Record this force.
4. Repeat this technique as you change the incline angle to 30° , 45° , 60° , 75°
5. Knowing the angle of incline and the weight of the block, use trig functions to find F_P and F_N .
6. Find the force to overcome friction F_F and the coefficient of friction.

Data Table:

Angle	F_A	F_P	F_N	F_F	μ_K
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15. Hanging Vectors: When a system is in equilibrium all opposing forces must be equal. $F \uparrow = F \downarrow$ $F \leftarrow = F \rightarrow$ In this lab you will find the mass of pop can of water by hanging spring scales on adjacent cabinet handles and hanging a pop can of water to a string and each end of the string to one of the spring scales. Record the number on the pop can in the data table. Then find the components of the force on the spring scale by measuring the angle the spring scale makes with the horizontal and trig functions. F_L is the force on the left spring scale and Θ_L is the angle that scale makes

with the horizontal. F_R the force on the right spring scale and Θ_R is the angle it makes with the horizontal.

Repeat using 2 other pop cans.

Data Table:

Can #	F_L	Θ_L	$F_{\uparrow L}$	$F_{\leftarrow L}$	F_R	Θ_R	$F_{\uparrow R}$	$F_{\rightarrow R}$	Can Weight
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16. Energy Changes In A Projectile Launched From a Ramp: In this lab you will measure the potential energy a steel ball has when it is raised from the table top and placed on a ramp. $PE = mgh$ When the ball rolls down the ramp, some of the energy is converted into linear kinetic energy, $KE = \frac{1}{2}mv^2$, some is turned into rotational kinetic energy, $RE = \frac{1}{2}I\omega^2$, and some is lost to heat due to friction. You will calculate each of these energies. For a steel ball $I = \frac{2}{5}mr^2$ and $\omega = v/r$.
Materials: ramp, steel ball, meter sticks, scale

Procedure:

1. Find the mass of the steel ball.
2. Measure the vertical distance from the floor to the end of the ramp. Use the equation $\Delta x = \frac{1}{2}gt^2$ to find the time the ball is in the air before hitting the floor.
3. Place the steel ball on the ramp and measure the vertical height from the end of the ramp to the ball placement. Find PE.
4. Release the ball and measure how far the ball lands from the end of the ramp. This horizontal distance divided by time will give you linear velocity.
5. Find KE, and RE. Find the amount of energy lost to friction.
6. Release the ball from 4 other heights and calculated the energy involved.

Data Table: $\Delta x = \underline{\hspace{2cm}}$ $t = \underline{\hspace{2cm}}$ $m = \underline{\hspace{2cm}}$

Height	PE	KE	RE	Energy lost to friction
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17. Using Conservation of Energy to Find Stretch Constants and Spring Constants.

Materials: scale, meter stick, tape measure, sling shot, marshmallows, nerf gun and darts
Sling Shot:

1. Take one of the sling shots and the dried marshmallows that go with it. Find the mass of a marshmallow. $M = \underline{\hspace{2cm}}$ kg. Add a meter stick and tape measure to your equipment and go outside to the band practice field.
2. **SAFETY FIRST:** This lab requires you to shoot a marshmallow out of the sling shot. You must be very careful not to shoot at anyone. There are goggles available to take with you for eye protection.
3. One person hold the sling shot at chest height and insert a marshmallow into the sling and just take the slack out of the elastic bands. One lab partner measure the vertical height from the ground to the marshmallow as this will be used to find the time of flight. $\Delta y = 1/2gt^2$
4. Then measure the holding the meter stick along the line of the elastic bands, pull the sling back in preparation to shoot and measure the distance the elastic bands have been stretched. $\Delta x = \underline{\hspace{2cm}}$ m
5. Release the ball and measure how far it travels horizontally. $S = \underline{\hspace{2cm}}$
6. Using S and t find the velocity of the marshmallow as it left the sling shot.
7. Then find its $KE = \frac{1}{2}mv^2$
8. This KE came from the elastic potential energy of the stretched elastic bands. $KE = PE_E = \frac{1}{2}kx^2$ find k . $k = \underline{\hspace{2cm}}$
9. Repeat the procedure with a different lab partner shooting the marshmallow.

Nerf Gun:

1. Take one of the nerf guns and the darts that go with it. Find the mass of dart. $M = \underline{\hspace{2cm}}$ kg
2. Take the nerf gun along with a meter stick and tape measure outside to the band practice field.
3. One person hold the gun horizontal at chest height and another person measure the vertical distance from the ground to the gun. This will be used to determine time of flight. $\Delta y = 1/2gt^2$
4. When the dart is inserted into the gun, measure the distance the spring is compressed by the dart. $\Delta x = \underline{\hspace{2cm}}$ m
5. Fire the dart and measure how far the dart lands from the end of the gun. $S = \underline{\hspace{2cm}}$ m
6. Knowing the time the dart was in the air and the distance traveled, find the velocity of the dart. $V = s/t$ $v = \underline{\hspace{2cm}}$ m/s
7. Then find the $KE = \frac{1}{2}mv^2$
8. This KE came from the spring being compressed. $KE = PE_E = \frac{1}{2}kx^2$ Solve for the spring constant k .
9. Repeat the procedure with a different lab partner shooting the nerf gun.

18. Power Lab: In this lab you will measure your leg power and arm power.
Materials: meter stick, stop watch, weights

Part 1: Leg Power

1. Take a meter stick and stop watch, go out into the hallway and to the stairwell to your left. Measure the height of a step in the stairway, count the number of steps from the floor below to our floor and find the vertical height from that floor to our floor. $y = \underline{\hspace{2cm}} \text{ m}$
2. Have your lab partner time how long it takes you to run up the stairs making sure you touch each step on the way up. $T = \underline{\hspace{2cm}} \text{ s}$
3. Convert your weight from pounds to Newtons using $1\text{ lb} = 4.448 \text{ N}$ $w = \underline{\hspace{2cm}} \text{ N}$
4. Find the power expended by your legs in bring you up the stairs. $P = wh/t$
 $P = \underline{\hspace{2cm}} \text{ watts}$
5. If one horsepower is 745.7 watts, what equivalent horsepower did you expend?
 $\text{Hp} = \underline{\hspace{2cm}} \text{ hp}$

Part 2: Arm Power

1. On the front table is an assortment of masses. Select one you would be comfortable lifting. Calculate it's weight in Newtons: $\underline{\hspace{2cm}} \text{ N}$
2. Have your lab partner stand a meter stick vertically beside your hand as you hold the weight resting on the table top. Signal your partner to start the stop watch as you lift the mass vertically 1 meter, quickly return it to the table top and lift it again. Continue this pattern until you have lifted the mass up and down 10 times. Stop the clock. $T = \underline{\hspace{2cm}} \text{ s}$
3. Calculate the power used in lifting the mass 10 times. $P = 10wh/t = \underline{\hspace{2cm}} \text{ watts}$.
4. Convert your arm power to horsepower. $P = \underline{\hspace{2cm}} \text{ hp}$

19. Momentum in 2 Dimensions:

Materials: ramp, meter stick, steel ball, golf ball, clay

Part 1: Total momentum before collision.

1. Secure the ramp to the lab table using the C-clamp.
2. Find the mass of steel ball. $m = \underline{\hspace{2cm}} \text{ kg}$
3. Place a sheet of wrapping paper, white side up, on the floor in front of the ramp.
4. Mark a spot on the paper directly below the end of the ramp.
5. Measure the height from the end of the ramp to the floor and use this distance to measure time of flight for each ball. $\Delta y = 1/2gt^2$ $\Delta y = \underline{\hspace{2cm}} \text{ m}$ $t = \underline{\hspace{2cm}} \text{ s}$
6. Select a height on the ramp from which to launch the steel ball and mark that spot so you will always release the ball from the same spot.
7. Release the steel ball from your selected spot and mark on the paper where the ball lands. Run 3 trials and take an average of the landing distance.
8. Draw a line on the paper from the end of the ramp to where the ball landed.

9. Use the average distance traveled and the time of fall to calculate velocity of the ball. $v = \underline{\hspace{2cm}}$ m/s
10. Calculate the momentum of the steel ball before collision, $P = mv$. $P = \underline{\hspace{2cm}}$ kgm/s

Part 2:

1. Slide the ramp back about 1 inch and place a wad of clay on the table in front of the ramp.
2. Find the mass of the golf ball. $m = \underline{\hspace{2cm}}$ kg
3. Insert a golf tee into the clay so the top of the tee is in front of ramp but slightly to the left of center. Place the golf ball on the tee.
4. Release the steel ball from the marked point on the ramp and mark on the paper the landing spots of both the steel ball and golf ball. Run 3 trials and average the distance traveled from the end of the tee. Steel ball = $\underline{\hspace{2cm}}$ m golf ball = $\underline{\hspace{2cm}}$ m
5. Use the distance traveled and time of fall to calculate the velocity of each ball. Steel ball $v = \underline{\hspace{2cm}}$ m/s golf ball $v = \underline{\hspace{2cm}}$ m/s
6. Calculate the momentum of each ball along it's line of flight. $P = mv$ Steel ball $p = \underline{\hspace{2cm}}$ kgm/s golf ball $p = \underline{\hspace{2cm}}$ kgm/s
7. Draw a line from directly in front of the ramp to the landing spot for each ball. Measure the angle between the line drawn in #8 above and the line to where the steel ball landed, from the same line and the line where the golf ball landed.

Part 3 Analysis

1. On a blank sheet of paper, place a dot in the middle of the short side of the paper. From this point draw a vector that represents the momentum of the steel ball before collision.
2. Measure the angle from this line to the path of the steel ball after collision and draw a vector representing the momentum of the steel ball after collision.
3. Measure the angle from the line representing the steel ball before collision and the golf ball after collision and draw a vector representing the momentum of the golf ball after collision.
4. Add these last two vectors graphically and write a statement comparing the sum of these two vectors and the vector of the steel ball before collision.

20. Egg Bungee Jump You will need to calculate the length an elastic cord needs to be for an egg to bungee jump from the ceiling and come within 5 cm of the lab table without breaking.

Materials: eggs, weights, fabric elastic cord, meter stick, masking tape, ring stand, scale

Procedure:

1. Open the package of elastic cord and cut off a piece about a foot long. Tie your cord to the bar on the ring stand. Find the length with no mass hanging on the elastic cord.
2. Tape a 50 g mass onto the cord using masking tape. Be sure the end of the cord reaches the end of the mass. (See picture below) Measure the new stretched length.
3. Lift the mass so it just touches the bar on the ring stand and release it. Measure the length bounced.
4. Add 10 g of mass to the 50 g and repeat steps 2 & 3. Add another 10 g and repeat steps 2 & 3. Add another 10 g and repeat steps 2 & 3.
5. Make two graphs: Mass vs Stretch due to hanging and Mass vs Per cent bounce.

Data Table:

	A	B	C	D	E	F
Mass	original	hanging	stretch due to	bouncing	stretch due to	% due to
	Length	length	hanging	distance	bounce	bounce
			(B - A)		(D - B)	E/A x 100%

6. Now select a raw egg from the carton in the front of the room. Find its mass. $M = \underline{\hspace{2cm}} \text{g}$
7. Given the equation: $H = B + \underline{\hspace{2cm}}\% \times B + C$
8. H is the vertical distance from the table top to the ceiling, measure it. $H = \underline{\hspace{2cm}} \text{cm}$.
9. C is read from your hanging mass vs stretch due to hanging graph using the mass of your egg.
10. Read the per cent bounce graph for the % bounce and put it into the equation as a decimal rather than a percent.
11. Solve your equation for B. This should be the length of cord for a fall from the ceiling to just touching the table top.
12. When you cut your elastic cord, be sure to leave enough extra to allow you to hold the cord to the ceiling.
13. When attaching the egg to the cord, remember the cord must run along the side of egg from one end to the other just like the weights. Tape the cord to the egg.
14. There are no practice runs. When you are ready, bring your egg and cord to the drop table.

21. Specific Heat of a Liquid: In chemistry class you did a specific heat experiment where you measured the specific heat of different metals, like aluminum, copper, and iron. Now you will use one of those metals to measure the specific heat of liquid ethylene glycol often just called glycol. (antifreeze).

Materials: calorimeter, thermometer, metals samples, ethylene glycol, scale, string, beaker, hot plate

Procedure:

1. Fill a beaker 2.3 full with water and heat to boiling on the hot plate.
2. Find the mass of your metal cylinder and record. Tie a string around the metal cylinder and lower it into the beaker of boiling water.
3. Measure the mass of the empty Styrofoam cup. Record. Add 120 mL of ethylene glycol to the cup and find the new mass. Find the mass of the glycol.
4. Measure the temperature of the glycol. Record.
5. Measure the temperature of the boiling water as this will be the starting temperature of the metal. Record.
6. Quickly move the cylinder from the boiling water to the glycol in the cup, cover with the Styrofoam lid and insert the thermometer. Lightly stir the solution with the thermometer.
7. When the temperature levels off, record the final temperature.
8. Return the metal cylinder to the boiling water and repeat the experiment 2 more times.
9. Find the average value for the specific heat of the glycol.

Data Table:

Metal Used _____ Specific heat of metal used _____
 Mass of metal cylinder _____ kg Mass of Styrofoam cup _____ kg

	Trial 1	Trial 2	Trial 3
Mass of glycol			
Initial Temperature of Metal			
Initial Temperature of Glycol			
Final Temperature of mixture			
Temperature change of metal			
Heat lost by the metal			
Heat gained by glycol			
Temperature change of glycol			
Specific heat of glycol			

22. Measuring the Rate of Heat Flow: Some materials are good conductors of heat and others are not. Materials that are not good conductors of heat are called insulators. Heat is transferred through a material by the collision of adjacent molecules passing along the energy from one end of the material to the other. Heat will be conducted only if there is a temperature difference between the two ends of the material. The rate of heat flow is found using these equations.

$$Q/t = kA(T_H - T_C)/L \quad Q = mc\Delta T$$

Materials: scale, thermometer, calorimeter, ruler, calipers, stop watch
 Thickness of containers: plastic film can 0.0006 m, juice can 0.0009 m, glass beaker 0.00175 m, Styrofoam coffee cup 0.0018 m

Procedure:

1. For each container find the following and record:
 - a. The area of the bottom in m^2 .
 - b. The area of the side of the container to the depth of water within in m^2 .
 - c. The mass of the container.
2. Fill the calorimeter 1/3 full of ice water. Find the temperature of this water right before you insert the container of hot water.
3. Take the temperature of the water in the coffee maker. That will be the initial temperature of the hot water.
4. Fill the container to be tested to a depth not to exceed 5 cm with hot water and quickly place it in the calorimeter of cold water. Start the stop watch.
5. When the time reaches 240 seconds, remove the container of water from the calorimeter and quickly measure the final temperature of the water within.
6. Dry off the outside of the container and find the new mass of the container and water and thus find the mass of the water in the container.
7. Measure the depth of the water and use that value to find the area of the side of the container for part 1 b above.

Data Table:

Container	Plastic	Tin	Glass	Styrofoam
Thickness (L)				
Area of bottom (πr^2)				
Depth of water (h)				
Area of side (πdh)				
Temperature of ice water				
Temperature of hot water				
Final temperature				
Temperature change of water in the container				
Mass of empty container				
Mass of container and water				
Mass of water				
Heat lost by water in container				
Thermal conductivity (k) for container				

23. Can A Penny Sink You In The Brink? You will be given an empty film canister. Your objective to determine the how much sand you should place in the canister so that the canister will float with just the top of the lid at water level. Will it sink when I place a penny on top of the lid of your canister. Verify all your work by showing your calculations including formulas below.

24. Hydrodynamics Lab: In this lab you will proceed from station to station and perform the activity designed for that station. Record all your observations (Stations can vary, I have listed some that I have used over the years.)

Station 1: Here you will find a large plastic syringe with a plastic cap. With the cap off, push the plunger all the way down. Put the cap on the syringe, stand it up on the

lab table and pull up on the plunger. Take the cap off, pull the plunger all the way to the top, replace the cap, stand the syringe on the lab table and push the plunger down.

Station 2: Here you will find pieces of notebook paper. Use both hands to hold the paper by the corners of one of short sides and let the paper hang loose. Then bring the paper edge to your bottom lip and blow air over the top of the paper edge.

Station 3: Here you will find 2 ping pong balls suspended by threads from a ring stand. Take a new straw and gently blow air between the 2 ping pong balls.

Station 4: Light the candle. Use your straw from station 3 and gently blow a stream of air on one side of the candle flame.

Station 5: Here you have a container that has a hole on the side near the bottom. Fill the container about 1/3 full of water and observe how far the water shoots out of the hole. Fill the container 2/3 full of water and observe how far the water shoots out and again after you filled the container to the top.

Station 6: Place a pop can on the hot plate. Add several drops of water to the can using the eye dropper. Let the can heat up until you can see steam rising out of the can opening. Using the tongs, quickly but carefully, raise the hot pop can off the hot plate and invert it into the tub of ice water.

25. Lift of an Airplane Wing: Your task is to use Bernoulli's equation to calculate the lift force on the wing of toy airplane.

Procedure:

1. Take one of the toy airplanes and measure the area of one of the wings in m^2 .
2. Find the middle of the wing and measure the distance from mid-thickness of the front of the wing to mid-thickness of the back of the wing. Then measure the same distance across the bottom of the wing.
3. Take the plane, stop watch and tape measure out to the band practice field.
4. One person will time the flight length by starting the stop watch when the plane leaves the throwers hand and stopping it when the plane hits the ground.
5. The distance from throwers hand to where the plane landed will be flight distance. The velocity found by dividing distance by time will be the velocity (m/s) of the air under the wing of the plane.
6. At this velocity find the time it takes the air to flow under the bottom of the wing. Use time and the distance over the top of the wing to find the velocity over the top of the wing.
7. Use Bernoulli's equation to find the pressure difference between the top and bottom of the wing, ΔP .
8. Using the area of the bottom of the wing find the lift force on one wing of the plane, then double it for the total lift force of the 2 wings.

26. Introducing Static Electricity: This is a simple introduction to attractive and repulsive forces in static electricity.

Procedure:

1. Take a 3 inch piece of scotch tape and stick 2.5 inches of it to your desk top. Take a second 3 inch piece of tape and stick 2.5 inches of it to a second spot on your desk. Quickly rip both pieces of tape from your desk. Try bringing the dangling ends of tape together.
2. Take a 3 inch piece of tape and stick 2.5 inches of it to your desk top. Take a second 3 inch piece of tape and stick 2.5 inches of it right on top of the first piece. Quickly pull off the combined strips of tape, then pull the two pieces of tape apart. Now try to bring the two dangling ends of tape together.
3. Take a small amount of paper and tear it into small pieces. Take a 3 inch piece of tape and stick 2.5 inches of it to your desk top. Quickly pull off the tape and bring its dangling end close to the paper pieces.
4. Divide the small pieces of paper into 2 piles. Repeat the tape set up in step 2, except when you separate the 2 pieces of tape, bring the dangling end of each tape to a different pile of paper pieces.
5. What conclusions can you draw from your observations.

27. Mystery Resistor Lab: Set up your electrical circuit as diagramed in your textbook. Be sure the ammeter is connected in series to the resistor and the voltmeter is connected across the resistor in parallel. For each resistor, take 3 readings, by opening the switch and closing it again. (If you have power supplies other than batteries, you can adjust the voltage up and down for additional readings.) Find the resistance of 3 different resistors.

Data Table:

Resistor #	Ammeter reading	Voltmeter reading	Resistance
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28. Finding Resistance Using Color Codes: You will be given a card with 5 resistors. Use the color code to find the resistance of each resistor.

Data Table:

Card _____

Resistor #	1 st Color	2 nd Color	3 rd Color	4 th Color	Resistance	Tolerance
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29. Thermal Effects of an Electric Current: The purpose of this experiment is to help you understand the relationship between electrical energy and thermal energy. The apparatus used will be a common hardware variety cup heater.

Warning: NEVER plug in the heater UNLESS the metallic portion of the heater is SUBMERGED in liquid. DO NOT submerge the heater BEYOND the top of the metallic portion of the heater.

Procedure:

1. Very accurately measure 100 mL of cold water and pour it into the Styrofoam cup.

2. Measure the initial temperature of the cold water.
3. Immerse the cup heater into the cup of water.
4. Plug the heater into an outlet and start timing. At 120 seconds, unplug the heater, stir the water with the heater end for a few seconds, then remove the heater from the water.
5. Find the new temperature of the water.
6. Discard the water and repeat steps 1-5 for a 2nd trial.

Data Table:

	Trial 1	Trial 2
Mass of cold water		
Initial temperature of cold water		
Final temperature of water		
Heat gained by the water		
Heat provided by the cup heater		
Electric potential of the outlet (110 V or 120 V)		
Resistance of the coil		

30. Determining the Speed of Sound Using a Resonating Air Column: An air column in a closed tube (closed by water at the bottom) produces its best resonance at one-fourth the wavelength of the sound it reinforces. A small correction is made for the inside diameter of the tube. The equation is:

$\lambda = 4(L + 0.4d)$ where λ is the wavelength, L is the length of the air column, and d is the diameter of the tube. You will also use the relationship $f\lambda = \text{speed of wave}$.

Procedure:

1. Measure the diameter of the plastic tube and record it in the data table. Also record the frequency of the tuning fork.
2. Hold the tube vertically in a cylinder nearly full of water. Hold the tube so very little of the tube is out of the water.
3. Hit the tuning fork and hold it over the water as your lab partner raises the tube until you hear the loudest reinforcement of the sound of the fork.
4. Measure the distance from the surface of the water to the top of the tube. (L)
5. Use the above equation to find the wavelength of the sound wave. Then using the frequency and wavelength find the speed of sound in air.
6. Repeat using a tuning fork of different frequency.

Data Table: $d =$ _____ $f_1 =$ _____ $f_2 =$ _____

Trial 1: $L =$ _____ $\lambda =$ _____ $v =$ _____

Trial 2: $L =$ _____ $\lambda =$ _____ $v =$ _____

(You can replace the water in the cylinder with ice water or hot water to look for variation with air temperature.)

31. Strength of a Magnetic Field:

Part 1:

1. On a sheet of wrapping paper, lay out a pair of perpendicular intersecting lines such that one line is at least 50 cm long. From the point of intersection, mark off the 50 cm line in 5 cm increments.
2. Set a magnetic compass at the intersection of the 2 lines so the compass points north along the shorter line. (you will have to adjust the paper) Keep the magnet away from the compass while you are trying to align it.
3. Place the bar magnet at the far end of the 50 cm line with the north pole of the magnet pointing toward the compass. Read and record the angle of deflection of the compass. Move the compass in 5 cm and read angle again. Continue moving the magnet in and recording the angle of deflection.
4. Reverse the poles of the magnet and repeat the process.
5. Find the tangent of each angle and record that value.
6. Plot a graph of the tangent of the angle of deflection and the distance to the magnet.

Data Table:

Distance

Deflection angle

Tangent

Part 2:

1. Secure 2 circular magnets, a wooden block magnet holder and a dozen washers. Find the mass one of the magnets and set the block on table and place the circular magnets onto the dowel so the magnets are repelling each other with the one you found the mass of on top. As accurately as possible, measure and record the distance between the magnets.
2. Place one of the washers onto the dowel so it rests on the top magnet. Measure the distance between the magnets and record. Continue adding washers one at a time taking a distance measurement after each addition.
3. Find the mass of the 12 washers and find the average mass of a washer. Convert this mass to weight in Newtons. _____N. Convert the mass of the top magnet to weight in Newtons. _____N These weights will help you determine the force being exerted on the field.
4. Plot a graph of the force on the field versus the distance between the magnets.

Data Table:

Washers 0 1 2 3 4 5 6 7 8 9 10 11 12

Force on the Field (N)

Distance between Magnets

32. Images Formed By Lenses: To examine the change in images as a lens is placed at different distances from an object.

Part 1: Determining the focal length of the lens.

1. Place a small piece of clay at the 10 cm mark of a meter stick. Place a lens in the clay so that it stands upright.
2. Take this assembly into the hallway, where it is fairly dark, and point the short end toward windows at the far end of the hallway.
3. Place a 4 x 4 screen card on the other side of the lens so that an image appears on the card. Adjust the distance until you have the clearest possible image.
4. Measure the distance from the card to the lens. This is the approximate focal length of the lens.

Part 2: Measuring images formed by an object.

1. Plug in the light box and place a meter stick so that it extends out from the front of the light box.
2. The object will be the number on the front of the light box. Measure the height of one side of this object (h_o) and record it. When you measure the image height you will want to measure the corresponding side of the image.
3. Place the lens at the midpoint of the meter stick, using clay to stand it upright.
4. Place the screen card on the opposite side of the lens and adjust the distance until there is a clear image of the object. Measure the height of the image. (h_i) Measure the distance from the light box to the lens, this is the object distance. (d_o) Measure the distance from the lens to the card, this is the image distance. (d_i) Record all of these measurements in the data table.
5. Move the lens in 10 cm increments farther from the light box and record the measurements in step 4.
6. Move the lens in 10 cm increments closer to the light box and record the measurements in step 4.
7. Repeat with other lenses if you have a variety.

Data Table:

d_o	d_i	h_o	h_i	f (exp)
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(You may also want to have them use the lenses to form a telescope)

