Laboratory Manual for Phys. 2001

Written by:

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Outline of a Lab Report

Your name

Your group members names

Title of the experiment

Section: Introduction (2 point)

Briefly (in a short paragraph) explain why we are doing this experiment and what is the physics concept we are probing.

Section: Data (2 points)

Here goes all the raw (before any manipulation, conversion,...) quantities you measured in the lab. There must be only math symbols and numbers in this section. **No English sentences!** Data is what is measured in the lab, not the result of algebraic manipulations.

Section: Calculations (3 points)

Here write only the calculations and algebraic manipulation of the data you need to do to get to the final result. Do not write English sentences explaining the steps, algebraic equations are sufficient. **Show every detail of your calculations**.

Subsection: Sources of error At the end of the calculations section you must explain in your own words, **the $2-3$ most important** sources of error in your measurement. **Think of possible errors that you made while making your measurements that affected your results**. Note: simply saying "human error" or "equipment error" is not sufficient; you need to comment in detail about all the experimental and theoretical factors that could have affected your results. **If** you are comparing your results to "known" values. you will also need to calculate the **percentage of error** in your experimental results defined as

$$\%\ error \equiv \frac{value_{exp} - value_{known}}{value_{ave}} \times 100 \quad (1)$$

where $value_{ave} \equiv \frac{value_{exp}+value_{known}}{2}$.

Section: Conclusions (3 points)

Clearly, precisely and concisely explain the physics concept you probed and the physics you learned in detail, i.e. whereas learning to use a piece of equipment or how to measure something is important, that is not the main goal of the experiment. The main goal is to experimentally test the underlying physics theory presented in lectures and to gain some intuition about the physical phenomena discussed in lectures. **Conclusions section is not a summary or procedure section, so do not summarize what you did and how you did it, instead explain the physics you learned in detail and in specific terms**. If there are any questions posed in the manual answer it and discuss your answers.

Some miscellaneous requirements

1) You must write every part of your own lab report individually, do not copy from others or from the Internet, that will be considered cheating and you will not get any credit for that report.

2) Follow the lab report guidelines, do not write one continuous report, break it up into sections clearly separated by proper headings as outlined above.

3) Lab reports (including calculations) must be **printed** and handed it to the instructor. **Lab reports sent by email will not be accepted**.

"Errors": limitations on the accuracy of measurements

Measurement "errors", or accuracy limitations, may arise from various sources. For example,

- accuracy of the *measurement device*: if you measure the diameter of a CD with a ruler with minor tics of 1 mm apart then you can not determine the radius with a precision much better than ± 1 mm (think about it); you would quote your result in the form $d = 12$ cm ± 1 mm, or as $d = 12.0$ cm (see below).

- systematic errors, i.e. limitations due to the *setup* or *measurement procedure*: say you would like to actually determine the surface area of the CD but you only have a ruler; you need to actually measure the radius or diameter and then *assume* that the CD is a circle so that you can use the relation $A = \pi R^2$. Since your CD will not truly be a perfect circle, by using this relation you are going to introduce an error.

- measurement errors due to external influences: if the temperature in your lab is higher in summer than in winter, the CD will have a slightly different radius in summer as compared to winter; this is because objects expand as they are heated. If you mean to provide a "universal" value of the radius which is valid both in summer and in winter you should quote a sufficiently large $\pm \Delta R$ which covers the variation with the seasons.

- *human error*: read-off errors, forgotten or neglected calibration etc.; such kind of sources of error should obviously be avoided whenever possible.

In your lab report you should at least mention what you consider to be the most important source of error (or limitation on the precision of the measurement). **Be specific and precise** when discussing the sources of error; saying "human error" or "equipment error" is not enough. Think of possible errors that could be involved when you make your measurements.

How many significant digits to quote

Mathematically, the numbers 12 and 12.0 are the same. When quoting measurements, they are not. Say you measured the diameter of a CD with an accuracy of ± 1 cm: you would write this is $d = 12$ cm. This implies an uncertainty of ± 1 *on the last quoted digit*. You could also write this explicitly as $d = (12 \pm 1)$ cm which is equivalent.

On the other hand, $d = 12.0$ cm implies an uncertainty of only about 0.1 cm = 1 mm ! This is a much more accurate measurement than the one above, implying that the true radius should be in the range 11.9 cm to 12.1 cm.

This accuracy limitation carries through to derived quantities. For example, say you measured width, depth and height of a book to determine its volume $V = d \cdot w \cdot h$. As a rule of thumb, the number of significant figures of V is given by the least accurate of d, w, or h (the one with the smallest number of significant digits). If, say, $d = 0.9$ cm has only two significant digits then V needs to be rounded off accordingly, regardless of how accurate you measured h and w !

Multiplying $h = 20.5$ cm, $w = 10.7$ cm and $h = 0.9$ cm we obtain $V = 197.415$ cm^3. Since we can only keep two figures, we should write it either as $V = (200 \pm 10)$ cm^3 or as $V = 2.0 \cdot 10^2$ cm^3. Converting to m^3 does not improve nor deteriorate the accuracy as we are multiplying by an exact number: 1 m^3 = 10^6 cm^3; hence $V = 2.0 \cdot 10^{-4}$ m^3. Seeing is believing so redo the calculation of V with $h = 0.84$ cm and $h = 0.96$ cm, respectively, and compare to $V = 197.415$ cm^3. This should convince you that indeed we can not determine V more accurately than 1.9 – 2.1 times 100 cm^3.

Measurements and Conversion of Units

Goals: the goal of this experiment is to gain experience in converting from one set of units to another.

Experimental procedure:
1) Measure the mass of a penny in grams and convert it to kg. Use the conversion factor 1 kg = 1000 g.

2) Measure the length, width and height of your textbook (or notebook) in cm. Calculate the volume of the textbook in cm^3 and then convert it to m^3 using 1 m = 100 cm.

3) Measure the diameter (d) of a CD in inches. Calculate the radius (r) of the CD ($r = \frac{d}{2}$). Calculate the area (A) of the CD in $inch^2$ using $A = \pi r^2$ (this is the area of a circle) where $\pi \simeq 3.1416$. Convert the area to m^2.

Gravitational Acceleration g

Goals: the goal of this experiment is to measure g, the gravitational acceleration near the surface of the Earth and to compare it with the known value $g = 9.81\,\frac{\mathrm{m}}{\mathrm{s}^2}$.

Experimental procedure: Cut a paper tape, about 1.5 m long. Attach the weight to one end of the tape using an alligator clip. Pass the other end of the tape underneath the black carbon paper of the spark machine and hold it steady. Turn on the sparker and release the weight. Turn off the sparker after the weight hits the floor. Make sure the tape leaves the sparker before it hits the floor. If you set the sparker frequency to 40 Hz then the time difference between two adjacent points is 1/40 s. For example, let the time at y_0 be $t = 0$ s. Then the time at y_1 is $\frac{1}{40}$ s, the time at y_2 is $\frac{2}{40}$ s, $\cdots$, the time at y_{14} is $\frac{14}{40}$ s and so on.

1) You should have about $10 - 15$ points (black dots) on your tape. Choose one of the first points to be the origin y_0; it should be a point close to the beginning of the tape but should be clearly visible with no other points too close to it.

2) Label and measure the position of all the points on the tape, starting with the origin labeled y_0 and the rest as y_1, y_2, $\cdots$. These are your data points. Measure the distances y_1, y_2, $\cdots$ from the origin y_0.

3) Calculate the average velocity v at each data point using $v_1 \equiv \frac{y_2 - y_0}{\Delta t}$, $v_2 \equiv \frac{y_3 - y_1}{\Delta t}$, $\cdots$, $v_{14} \equiv \frac{y_{15} - y_{13}}{\Delta t}$ so that v_1 is the average velocity of the weight at the point labeled 1, v_2 is the average velocity of the weight at the point labeled 2, and so on. Determine the velocities for at least $7 - 8$ data points using $\Delta t = \frac{2}{40}\,s$. Show all details of your calculations.

4) Plot the average velocities you obtained vs. time on a graph. Velocities should be on the vertical axis and time is on the horizontal axis. Make sure to utilize the full page in order to make your figure as big as possible. Draw the best straight line through your velocity points. The best fit is the one where your drawn line comes as close to as many data points as possible.

5) Calculate the slope of the line using **two points which are on the line**. Note: these two points don't have to be actual data points, they just need to be on the line. For the best accuracy choose them as far apart as possible. The slope of a line is defined as the rise over the run, in this case it is $\frac{\Delta v}{\Delta t}$. Compare the value of the slope with the known value for g and find your percentage of error using

$$\frac{|g_{\text{measured}} - g_{\text{known}}|}{g_{\text{ave}}} \otimes 100.$$

Questions: What is the meaning of the intercept (the point where the line crosses the vertical axis)? Remember the relation between velocity and acceleration $\vec{v}_f = \vec{v}_i + \vec{a}\,t$.

Adding vectors in 2-D, Force Table

Goals: the goal of this experiment is to understand Newton's 1st and 2nd laws, to gain experience in adding vectors (in this case, forces) in 2 dimensions and to reconstruct a vector from its components. Use $g \simeq 9.81 \, \frac{m}{s^2}$.

Experimental procedure: Using the provided force table, define a $x - y$ coordinate system; the x coordinate should point along the $\theta_1 = 0°$ angle and the y coordinate along the $\theta_2 = 90°$ angle. You should attach three hangers to three strings which are connected to a white loop which is centered around the pin in the middle of the force table.

1) Put a mass of $m_1 = 100$ g on the hanger along the x ($\theta_1 = 0$) direction and another mass $m_2 = 100$ g on the hanger pointing along the y ($\theta_2 = 90°$) axis. Find out how much mass m_3 is needed on the third hanger, and at what angle θ_3 it needs to be placed so that the white loop is centered perfectly around the pin.

2) Find the force of gravity acting on the three masses, i.e. their weights $|\vec{F}_1| = m_1 \, g$, $|\vec{F}_2| = m_2 \, g$, $|\vec{F}_3| = m_3 \, g$. These are the *experimental* values of the gravitional forces acting on the masses.

Theory: From the laws of vector algebra one can show that (you should be able to derive this on your own)

$$|F_{3x}| = |\vec{F}_1| \quad , \quad |F_{3y}| = |\vec{F}_2| \tag{2}$$

and

$$|\vec{F}_3|^{theory} = \sqrt{F_1^2 + F_2^2} \quad , \quad \theta_3^{theory} = 180° + \tan^{-1} \frac{|\vec{F}_2|}{|\vec{F}_1|} \; . \tag{3}$$

Here, $\tan^{-1}$ denotes the inverse function of the tangent (on some calculators, this is written as "atan"); make sure that your calculator is in the mode where angles are given in degrees, not radians.

This is the prediction of theory for $\vec{F}_3$. Compare the measured values for θ_3 and $|\vec{F}_3| = m_3 \, g$ with the values expected from theory, compute the percentage of error for both $|\vec{F}_3|$ and θ_3.

4) Repeat the experiments with $m_1 = 100$ g and $m_2 = 200$ g. Keep track of which mass is attached to which string: eq. (3) for θ_3 assumes that $\vec{F}_1$ and $\vec{F}_2$ point at 0° and 90°, respectively.

Question: How is Newton's 2nd law manifest in this experiment (think of the white loop and the net force acting on it).

<u>Newton's second law</u> (Atwood's machine)

Goals: the goal of this experiment is to test Newton's $2nd$ law and to gain experience using it.

Experimental procedure: Put masses m_1 and M_2 (with $M_2 > m_1$) on the two hangers attached by a string, and pass the string over the two pulleys. Hold on to one of the pulleys so that masses do not move. Make sure masses are not swinging.

Let go of the pulley so that the masses start moving, the heavier mass M_2 will move downward while the lighter mass will move upward. Measure the time it takes for the masses to travel a certain vertical distance $\Delta\, y$ (better to decide this in advance and to keep it the same for different trials). Repeat the experiment 5 times and measure the time each time keeping the distance the same. Make sure the masses start from rest so that one can set the initial velocity equal to zero. The experimental value for the acceleration is given by

$$a^{exp} = \frac{2\,\Delta\, y}{t_{ave}^2} \tag{4}$$

where the average time is $t_{ave} \equiv \frac{t_1+t_2+\cdots+t_5}{5}$.

Theory: According to Newton's $2nd$ law the acceleration (magnitude) of either mass is (you should know how to derive this on your own)

$$a^{th} = \frac{M_2 - m_1}{M_2 + m_1}\, g \tag{5}$$

Compare the theoretical and experimental values of the acceleration and calculate the percentage of error.

Momentum Conservation

Goals: the goal of this experiment is to **indirectly** test the law of conservation of momentum when there is no net external force.

Experimental procedure: Take two carts, one with a plunger and one without, and place them on the track (back to back). Make sure they are at rest. Gently hit the cart with the plunger on the pin, this will release the plunger and the carts will move apart. The idea is to make sure that the carts hit the opposite ends of the track *at the same time*. Measure the distance traveled by each cart before it hits the end of the track. Ignoring friction, the speed of either cart is constant and is given by $|\vec{v}| = \frac{d}{t}$.

Theory: According to the law of conservation of momentum, the final momentum of the *entire* system must be equal to its initial momentum. In our experiment, initially both carts are at rest ($\vec{v}_1^i = \vec{v}_2^i = 0$) and the total momentum is zero

$$\vec{P}^i = \vec{p}_1^i + \vec{p}_2^i = m_1\,\vec{v}_1^i + m_2\,\vec{v}_2^i = 0\ .$$

Hence, if total momentum of the system is conserved, the final momentum must also be zero,

$$\vec{P}^f = \vec{p}_1^f + \vec{p}_2^f = m_1\,\vec{v}_1^f + m_2\,\vec{v}_2^f = 0\ . \tag{6}$$

Replacing $\vec{v}_1^f$ and $\vec{v}_2^f$ in eq. (6) by $\frac{d_1}{t}$ and $-\frac{d_2}{t}$, respectively (note that the velocities point in opposite directions), and then multiplying both sides of the equation by t, we get

$$m_1\,d_1 - m_2\,d_2 = 0\ . \tag{7}$$

The relation (7) follows from the law of momentum conservation and we will check to see if it is true. First, try this with the two carts and no other masses on them. In this case, $m_1 \simeq m_2$. Using the measured values of d_1, d_2 check to see how accurately eq. (7) holds by calculating the percentage of error; divide the left hand side of eq. (7) by the average,

$$\frac{m_1\,d_1 + m_2\,d_2}{2}\ . \tag{8}$$

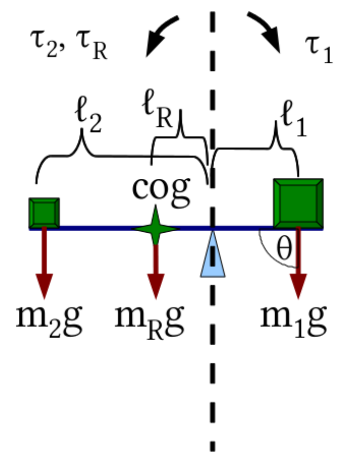
and multiply by 100 to get % of error.

In a second run, choose two different masses by adding an iron block to one of the carts so that $m_1 > m_2$. Repeat the experiment and calculate the percentage of error. Explain the various factors that could lead to discrepancies between your measurements and the theoretical expectations.

Questions: Did we actually test conservation of momentum or a consequence of it? Using the setup in this experiment what quantity you would need to measure in order to be able to test conservation of momentum? How would the theoretical relations given by (6) and (7) change if the carts were initially moving toward each other rather than being at rest?

Torque and Angular Acceleration

Goals: With this experiment we test the idea that if there is no net torque on an extended object, it will not undergo angular acceleration. That is, if it is initially at rest, it will remain at rest and will not rotate.



Experimental procedure: Take a ruler, measure its mass m_{ruler} and balance it on the balance beam. Measure the location of the pivot point. If the density of the ruler is uniform then the pivot point should coincide with the geometric center of the ruler (also called center of gravity of the ruler since one can assume that the force of gravity of the Earth on the ruler acts in that point).

In the first part of the lab, place a mass of $m_1 = 100$ g at the right end of the ruler. Shift the pivot point to restore balance and measure its distance from the location of mass m_1; this distance is the lever arm ℓ_1.

In part two, place another mass m_2 at the left end of the ruler, keeping m_1 where it was before. Move the pivot point again to restore balance. Measure the two lever arms ℓ_1 (note: this will differ from ℓ_1 from above !) and ℓ_2.

Theory: In analogy with Newton's 2$^{\text{nd}}$ law there is a law for rotation which states that the angular acceleration of an object is proportional to the net torque acting on it. For our experiment this implies that when the ruler is balanced, the net torque should be zero.

The torque acting on an object is defined as

$$\vec{\tau} = \vec{F} \times \vec{\ell} \quad , \quad |\vec{\tau}| = F\,\ell\,\sin\theta \ . \tag{9}$$

F is the force applied to the object and ℓ is the lever arm while θ denotes the angle between them (in this experiment $\theta = 90°$ so that $\sin\theta = 1$).

In part one, there are two torques acting on the ruler: one is caused by the weight of the ruler itself, the other is due to the weight of m_1. When they balance,

$$\tau_{net} \;=\; \tau_{\text{ruler}} - \tau_1 = m_{\text{ruler}}\,g\,\ell_{\text{ruler}} - m_1\,g\,\ell_1 = 0 \ . \tag{10}$$

Note that the torques have opposite directions: the torque due to the weight of the ruler acts counter clockwise while the torque due to mass m_1 acts clockwise. This is the reason for the relative minus sign between the two terms in eq. (10). Now calculate the net torque using the measured lever arms and masses and compute the percentage of error; a useful measure for discrepancies is constructed by dividing both sides of eq. (10) by the *average of the absolute values* of the two torques,

$$\frac{m_{\text{ruler}}\,g\,\ell_{\text{ruler}} + m_1\,g\,\ell_1}{2} \ . \tag{11}$$

In part two, three torques act on the ruler. When balanced, the net torque on the ruler must be zero. Repeat the calculation of τ_{net} for this case and compute a percentage of error for your measurement.

Questions: Is there a net torque acting on the ruler before we added m_1 and m_2 ? Why or why not ?

Simple Pendulum

Goals: the goal of this experiment is to study a pendulum, to measure its period of oscillation and the frequency, and to discuss the concept of conservation of mechanical energy.

Experimental procedure: Take a pendulum and a ruler from the instructor's desk. Measure the length ℓ of the pendulum from where it is attached to the horizontal bar to the center of the bob. Raise the pendulum bob slightly such that the pendulum string makes a $10-15°$ angle with the vertical. Release the bob from rest and watch it as it swings to the other end and comes back to where it was released from. The time it takes to complete one full oscillation is the period of oscillation T. The frequency f tells you how many oscillations have been performed per unit time, so that $f \equiv \frac{1}{T}$.

a) To measure the period of oscillation T, raise the pendulum $(10-15°)$ and release it from rest. Let is oscillate about 5 times and measure the time it took with the stop watch. To obtain the period, divide by the number of oscillations.

b) Increase the length of the pendulum and repeat part a.

c) Increase the length of the pendulum again and repeat part a.

Theory: According to theory, the period of oscillation of a simple pendulum is given by

$$T_{theory} = 2\pi\sqrt{\frac{\ell}{g}}$$

(This expression is valid for small angle oscillations). Compare your measured values of the period to the theoretical expectation.

Questions/comments: Can you confirm, within measurement errors, that the period is proportional to the *square root* of the length ℓ of pendulum ? Explain what frequency and period mean in your own words. Also, think about conservation of mechanical energy during the oscillation: when is the kinetic energy maximal, when is it minimum? How about the potential energy? Explain how "conservation of mechanical energy" is manifest in oscillation of simple pendulum.

Oscillations of a weight attached to a spring

Goals: in this experiment we determine the spring constant k of a given spring and measure the oscillation frequency of a weight attached to it.

Experimental procedure: Obtain a tripod, spring, a timer and some weights from the instructor. Check the mass of the weights with a scale.

First, you need to determine the spring constant k. To do so, attach an object (mass about 100 g) to the spring and measure by how much it stretches. If the object is at rest in the stretched configuration then the net force is zero and so its weight W must equal the force F exerted by the spring (in magnitude). With $W = mg$ and $F = -kx$ you find that $k = mg/|x|$.

Next, we let the object perform an oscillation: pull the object *a little* further down and start the timer while you let go. Let it perform 5 full oscillations and measure the time it takes. This is t_{total}. To determine the period T for a single oscillation divide t_{total} by 5.

Theory: according to Newton's theory, the oscillation frequency turns out to be related to the spring constant and the mass of the object via

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m + \frac{1}{3}M_s}} \qquad (12)$$

where M_s is the spring mass and frequency f is related to the period T as follows:

$$f = \frac{1}{T} \quad , \quad T = \frac{1}{f}. \qquad (13)$$

Compare this theoretical result to the measured oscillation frequency (or period) and determine the percentage of error.

Speed of Sound in Air

Goals: the goal of this experiment is to measure the speed of sound in air and to compare it to the "world average" of $v_{sound} \simeq 340\,\frac{m}{s}$.

Experimental procedure: Fill up the water container that is attached by a small rubber tube to the big glass cylinder containing some water. Make sure it does not overflow. You can lower and raise the water level in the big glass cylinder by lowering and raising the water container. Practice this a few times so that you feel comfortable with it. When you are ready, raise the water level in the glass cylinder to the highest level without spilling. Hit the tuning fork on the table so that it vibrates. Hold it above the glass cylinder, very close to its opening but without touching it. Make sure to hold the tuning fork such that the two arms are vertical rather than horizontal; also, the tip of the tuning fork should be at the center of the opening of the glass cylinder.

With the tuning fork vibrating, lower the water level in the glass cylinder slowly and listen for a loud sound (a so-called resonance). Try to fine-tune the water level to determine the loudest sound as accurately as possible. Note the location of the water level, ℓ_1.

Now lower the water level in the glass cylinder further and again hit the tuning fork against the table to keep it vibrating. The resonance should disappear but eventually reappear at a lower water level. Write down the location ℓ_2 of the second loud sound as well.

Theory: Sound waves need a medium to propagate in, such as air. In this experiment a sound wave is generated by the vibrating tuning fork which then travels down the glass cylinder and bounces off of the water. As the sound waves travel up and down the glass cylinder they interfere and can produce a standing wave (think of what a sin or *cos* function looks like). The distance between two successive maxima or two successive minima is called the wavelength of the standing wave. In our experiment, the location of the two successive loud sounds in fact correspond to an adjacent maximum and minimum of the standing wave so that the distance between two resonant sounds is half of the wavelength of the sound wave.
There is a relation between the wavelength (λ) of the sound wave, its frequency (f) and speed v. It is given by

$$v = f\,\lambda \tag{14}$$

The frequency of the sound wave is set by the frequency of the tuning fork that generates the sound wave. It is written on the tuning fork (remember 1 Hz $\equiv 1\,\frac{1}{\mathrm{s}}$). Using the measured value of the wavelength and the given frequency, calculate the speed of sound v in air. Compare this value with the world average of $v_{sound} \simeq 340\,\frac{m}{s}$. Compute the percentage of error in your measurement.

Questions: Would you get a different result for the speed of sound if you used a tuning fork with a different frequency? What would need to change in order to get the same speed? If in doubt, repeat the experiment using a tuning fork with a different frequency or compare your measurements for ℓ_1 and ℓ_2 to those of another team who used a different tuning fork.

Specific Heat of Metals

Goals: the goal of this experiment is to use conservation of heat energy in order to determine the specific heat capacity of some metals.

Experimental procedure: Fill a Styrofoam cup about half-way with tap water (not more than about 300-500 g of water). Weigh the Styrofoam cup with and without its water content to determine the mass of the water. Place a thermometer in the water to monitor its temperature and wait until it is steady. This is the initial temperature T_i^w of the water.

Now also weigh the metal object provided by the instructor and then immerse it in the boiling water on the counter. Once you place the metal in the boiling water, it will stop boiling. Wait a little until the water is boiling again and the metal has reached the same temperature as the water. The initial temperature of the metal is now $T_i^m = 100\,^\circ\mathrm{C}$.

Remove the metal from the boiling water and quickly (and completely) immerse it in the water in the Styrofoam cup. Monitor the temperature of the water in the Styrofoam cup until it is steady. Write down the temperature, this is the final temperature T_f of the water and the metal.

Theory: Assuming that no heat is emitted into the environment as you perform the experiment, conservation of heat energy implies that the heat Q_m lost by the metal is equal in magnitude to the heat Q_w gained by the water in the Styrofoam cup. We define "emitted heat" to be negative while absorbed heat is positive. Hence,

$$\begin{aligned} -Q^m &= Q^w \\ -m_m\, c_m\, (T_f - T_i^m) &= m_w\, c_w\, (T_f - T_i^w) \ . \end{aligned} \tag{15}$$

This equation can be used to calculate the specific heat capacity c_m of the metal. Since every metal has a particular specific heat capacity, this tells us what the metal is.

$$c_m = c_w\, \frac{m_w}{m_m} \frac{T_f - T_i^w}{T_i^m - T_f} \ . \tag{16}$$

Using the measured masses of water and metal, the final and initial temperatures of the water and metal and the known value of the specific heat capacity of water, $c_w = 1\,\frac{\mathrm{cal}}{\mathrm{g}\,^\circ\mathrm{C}}$, calculate the specific heat capacity of the metal c_m. Compare this value to $c_{\mathrm{steel}} = 0.110\,\frac{\mathrm{cal}}{\mathrm{g}\,^\circ\mathrm{C}}$, $c_{\mathrm{alum}} = 0.215\,\frac{\mathrm{cal}}{\mathrm{g}\,^\circ\mathrm{C}}$, $c_{\mathrm{lead}} = 0.030\,\frac{\mathrm{cal}}{\mathrm{g}\,^\circ\mathrm{C}}$, $c_{\mathrm{copp}} = 0.093\,\frac{\mathrm{cal}}{\mathrm{g}\,^\circ\mathrm{C}}$, $c_{\mathrm{brass}} = 0.092\,\frac{\mathrm{cal}}{\mathrm{g}\,^\circ\mathrm{C}}$ to decide what sort of metal you've been experimenting with. Calculate the percentage of error and the amount of heat lost by the metal and gained by the water. What are the biggest sources of error in this experiment ?

Questions: Based on your results, is heat conserved ? Assuming conservation of heat energy would your result for c_m depend on the altitude (height) where you perform the experiment at high altitudes (several kilometers high) ? If so, what would be different ?