The laboratory notebook provides a personal record documenting the progress of the experiment. The laboratory report serves a quite different purpose. It communicates your experimental work to other persons. This demands a different style and approach.

All "real" scientific work of any value (and some that isn't) eventually finds expression in a written report. In industrial research and development, reports communicate to supervisors and directors, may circulate internally within the company, and may even reach other scientists in the same field around the world. Some reports get published in technical and scientific journals. Even technicians sometimes write reports.

Many a scientist or engineer discovers the hard way that people judge the quality of experimental work by the quality of the reports. Ineffective reports may cause people to ignore the research itself, and, on a very practical level, may jeopardize the funding of that research.

Style and appearance of reports:

1. Use good quality standard size 8 1/2 by 11 inch paper: plain, unlined, and with no holes or ragged edges. (Some instructors may accept handwritten reports on lined paper, a practice considered unprofessional in a real work situation.)

2. Leave at least a 3/4 inch margin on the top, bottom and sides of the sheets.

3. Organize the report for easy reading. The structure and organization of the report should impress itself on the reader even with a casual skim. Use headings and subheadings to make the structure clear.

Essential parts of the report:

Here's a list of the usual parts of a complete report. The nature of the experiment will determine which ones are necessary, and what heading is appropriate for each.

- **ABSTRACT**. A **brief** (one paragraph) summary of the purpose, method, and significant results of the experiment.

- **INTRODUCTION (PURPOSE OR BACKGROUND**). A review/summary to acquaint the reader with facts, theory, or research specifically relating to what was done in this experiment.) Material readily available in any textbook needn't be included.

- **EQUIPMENT LIST**, including any identifying model and serial numbers.

- **BACKGROUND**. A review/summary to acquaint the reader with facts, theory, or research specifically relating to what was done in this experiment.) Material readily available in any textbook needn't be included.

- **MATERIALS, EQUIPMENT LIST, METHODS, AND** PROCEDURES . This tells the reader what specific experimental methods were used. Apparatus (including any identifying model and serial numbers.) and setup procedures unique to this experiment must be described, drawn, and explained. Standard procedures needn't be elaborated, but should be referenced.

- **DATA AND ANALYSIS**, including graphs, and tables of results, as appropriate. Should be broken down in two sections: **EXPERIMENTAL RESULTS** and **THEORETICAL ANALYSIS** make sure you include **error calculations** or refer to appendix that does.
- **DISCUSSION OF RESULTS**, and of their uncertainties.
- **CONCLUSIONS** (You may prefer to include this in the discussion of results.)
- **REFERENCES**
- **ACKNOWLEDGEMENTS**

Avoid unnecessary duplication. Don't include data and procedure in the results section. Don't include minor details of procedure, theory and results in the abstract. Include only material directly related to what you did in the experiment. Omit idle speculation.

FORMAL AND INFORMAL REPORTS

The informal report differs from the formal report in three major respects. The informal report omits: (1) the abstract, (2) description of procedure (except where there were significant deviations from the procedures of the instruction manual), and (3) exposition of the physics underlying the experiment.

Your instructor may want a copy of your laboratory record included as an appendix to the report, for completeness. This will include the equipment list, original data, calculations, preliminary graphs and sketches, record of observations made in the laboratory, etc. The instructor may, in the informal report, allow you to insert this after the "purpose" section of the report, to preserve chronological continuity. Don't expect that anyone will necessarily read this! Whatever you want the reader, or instructor, to consider in evaluating your work must appear in its appropriate place elsewhere in the report.

GENERAL CONSIDERATIONS OF REPORT WRITING

A real experiment may occupy months or years. The laboratory record may consist of several filled notebooks, computer printouts, photographs, charts, etc. You must distill, reorganize and repackage this scattered source material into a clear and concise document of a just a few pages. The report must communicate efficiently. It must have a clear and logical structure which allows the reader to extract the essential points easily.

Readers of your report want to know what you accomplished, and you must say that clearly and effectively. Every experiment has certain objectives, and you must state the extent to which these were accomplished. If you set out to determine the constancy of the acceleration due to gravity, you must, in your discussion of results, state whether your experiment demonstrated its constancy, and within what uncertainty. If you set out to measure the size of the acceleration due to gravity, you must give your one best determination of that acceleration, along with its estimated uncertainty. These statements must appear in the "results" section, even if they appear elsewhere in the report.

1. Condense and prune the presentation to make your points effectively. Emphasize the important points. Don't waste the reader's time with trivia.

2. A good rule for improving your prose is:

   WHEN IN DOUBT, LEAVE IT OUT!

3. Don't clutter the text with calculations unless you must explain something about them.

4. Don't pad the text. Readers don't appreciate having to read through trivial and irrelevant passages to find the important parts.

   ESCHEW SPECIOUS PROFUNDITY!

GRAPHS

1. Use genuine graph paper, not cheap substitutes. Every graph must have a title, written out in words. Not: "T vs. L." Not: "Period vs. Length." Rather, something more specifically descriptive, like: "Pendulum period as a function of suspension length." Choose the size of the axis scales so that the graph nearly fills the page.

2. Label each graph axis with the quantity, symbol, and units plotted on that axis. Example: PERIOD (T) in seconds.

3. Label the axis scales neatly and clearly. You must re-label logarithmic scales on commercial log paper.

TABLES

1. Use tables for large amounts of data, especially when you wish to display the relations inherent in the data.

2. Column headings of tables must indicate quantity, symbol, and units, just as graph axes do. Each table must have a title and an identifying number, for reference.

3. Indicate the errors (uncertainties) for all quantities. Minimize the clutter within tables by grouping information when possible. If all data entries in a column of a table have the same absolute or relative error, put that information at the top of the column only. The same applies to unit labels, which you may place at the top of the column.

DISCUSSION AND ANALYSIS OF ERRORS (UNCERTAINTIES)

1. Show how you arrived at your uncertainty estimates.

2. Show the error propagation equation(s) you used. Error propagation equations motivate decisions about experiment design and procedure. They also justify the uncertainties you assign to results. If some error sources dominate others, this fact may deserve comment. Tell how you designed the procedure and strategy to minimize uncertainties. [You need not mention the usual precautions; only those specific to the particular experiment, or in some way unusual.]

3. Make meaningful comparisons where appropriate. When the experiment has numeric results which you can compare with other independent sources, comment on that comparison. Do not call this comparison the "error", call it the "experimental discrepancy." When you can quote both error and discrepancy, do so, and comment on their relative size. (A discrepancy larger than the error certainly requires some comment!)

4. The methods of science never prove anything. The word "proof" refers to a strictly mathematical process. Nor does science claim absolute truths. Avoid the word "truth" in scientific discussion. In a single experiment you might "verify" or "confirm" the validity of a physical law, in a particular situation.

DISCUSSION OF RESULTS, AND CONCLUSIONS

1. Your conclusions must relate to your stated purposes or "objectives". Tell the reader to what extent your objectives were realized.

2. Don't claim more than the facts warrant. Support your assertions with evidence, logic, or specific references to the literature. State specifically what you achieved, and the estimated uncertainty of the results, but don't make broad and unfounded generalizations.

3.

YOU CAN'T EXPLAIN SOMETHING TO SOMEONE ELSE
IF YOU DON'T UNDERSTAND IT YOURSELF

ORIGINALITY

Students benefit from study groups, learning from each other. Strongly resist the temptation to rely too heavily on others. When exam time comes, you must work alone.

Laboratory partners discuss each experiment and share ideas. But in a classroom situation the written report represents your own work, not that of a committee. Don't let others do your thinking and analysis.

Partners' data will, of course, consist of the same sets of numbers, but each partner will organize the report to suit his or her own personal tastes and style. Each will do the data analysis independently. Partner's reports will, therefore, not look alike, even superficially. If mistakes or blunders occur, the partners won't usually make identical ones. Plagiarizing something wrong or absurd makes you appear not merely unprofessional, but also thoughtlessly lazy! To sign your name to a totally wrong statement copied word-for-word from someone else demonstrates very clearly that your own brain wasn't engaged in the process. Better to make your own mistakes, honestly. Better yet to use critical thinking so that you discover your mistakes, and those of others.

When you write the discussion of results yourself you'll gain the valuable experience of drawing your own conclusions, unprejudiced by the opinions of anyone else. All details of the report will reflect your individual style and individuality.

THINGS YOU SHOULDN'T DO

Don't include idle speculation about sources of error. To say that certain conditions of the experiment "may have caused error" communicates no useful information unless you cite some specific evidence or a plausible mechanism pointing to that fact.

Don't include such trivial comments as: "There may have been "human error." We all know that human blunders, misperceptions, and misinterpretations can occur. We expect the experimenter to take every precaution to avoid them. This "goes without saying." The other classes of "human error" due to limitations of instruments, and limits of human observation of instruments belong in the quantitative error discussion.

Likewise, don't say "There may have been calculation error." If you mean blunders, this statement tells us nothing we didn't already know (we still wouldn't know whether there were blunders). If you mean the error introduced by calculating devices, then you haven't done your job properly. Your responsibility includes choosing calculation techniques which do not introduce significant error. You should do everything necessary to keep calculation errors negligible compared to the experimental errors. If for any reason you did not, or could not, accomplish this, you must give good reason why you didn't.

STYLE

Most elements of good style common to other types of writing also apply to scientific writing. One of the best general references for the student is:

Strunk, William, Jr., and White, E. B. *The Elements of Style.* Macmillan Paperbacks, 1962. This book demonstrates by example the clarity and brevity which it advocates. The 1918 edition is online and has internal links, which are very handy.

Other useful references are:

- Menzel, Jones, and Boyd. *Writing a Technical Paper.*
- Vallins. *Good Writing, Better Writing.*
- Gunning. *The Technique of Clear Writing.*
- Flesch. *The Art of Plain Talk.*

On matters of technical style for research journals, consult The American Institute of Physics Style Manual.

Examples of style faults.

We list below some faults frequently found on student laboratory reports, with suggestions for improvement.

(1) A report organized as follows:

"First we...
Then we...

Next we...
Finally we...

Aside from the overuse of "we" this "chronological" style doesn't convey any sense of the relative importance and logical connections inherent in the material.

(2) "The acceleration of gravity is one of the most fundamental constants in physics." This lacks content. It says nothing important. Stick to the facts and avoid empty generalities and attempts at "profundity."

(3) "Our object in this experiment was to prove the truth of the law F = ma and to measure the value of the acceleration." This uses the words "prove" and "truth" in a questionable manner. Reserve "prove" for mathematical theorems. Avoid the word "truth" entirely in scientific writing. An experiment may disprove a law, but no finite number of experiments ever establishes a law as absolutely true.

(4) "The apparatus was in the northeast corner of room 216 of the science building, in a sunny spot on a maple table 31 inches from the floor." Extraneous details annoy the reader. Include only those details you've shown to have some effect on the experiment. Some other details may deserve a place in the laboratory notebook, for future study may show that they weren't insignificant after all.

(5) "I enjoyed this experiment very much and learned a lot from it."
Save personal comments for other occasions. Don't include them in the laboratory report. The reader may easily misinterpret the motives behind such statements.

(6) "Due to poor equipment we were unable to get good results."

No scientist ever has perfect equipment. The experimenter must learn the limitations of the equipment and how these affect the quality of the results. Sometimes experiments using very crude equipment have confirmed or rejected a law or theory.

(7) "Our results agreed exactly with the textbook value, so the experiment was a success." Even with the worst equipment and technique one may accidentally obtain a zero discrepancy. This tells nothing about the quality of the experiment. The limits of uncertainty tell us the quality of the experiment.

(8) "A force of 9 kg was required to stretch the spring 5 cm, therefore the work done was (9)(0.05)(9.8)/2 = 22.05 Nt. From this we calculated the efficiency of the spring by...

"Don't clutter the report with routine calculations. We don't fault the "force of 9 kg" in the first line. The context makes clear that the writer means "A force equal to the weight of 9 kg at the earth's surface."

AN EXAMPLE LABORATORY REPORT

Proper Inflation of a Basketball

Ima Student

Lab Partners : Tom Smith, Jane Doe

Date: Sept 1, 2008

Instructor: The Professor.

Abstract

This paper describes an experiment to determine how to correctly inflate a basketball using a hand pump. A basketball is correctly inflated when it rebounds to approximately 60% of the height from which it is dropped. In this experiment, the basketball's rebound height is measured as a function of the number of strokes of the pump used to inflate it. We find that for the pump used in this experiment, 12 strokes gives the correct pressure in the basketball. We derive a formula to determine the correct number of strokes for different hand pumps. We discuss the effects that the air temperature and the material from which the ball is made have on the accuracy of our results.

Introduction

Basketball is a game that relies on the skill of dribbling—that is, walking or running while bouncing the basketball on the floor. To play the game most effectively, players need to be able to rely on the rebounding of the ball off the floor as they move with it around the court. The "springiness" of the ball also affects shots that rebound off the backboard. The amount that the ball rebounds depends on how much air is used to inflate it. A ball with too little air is flat and difficult to dribble. A ball with too much air is too lively and more difficult to control when dribbling and shooting. Inflating a basketball with the correct amount of air is important to being able to play the game well.

According to international basketball rules, a basketball is properly inflated "such that when it is dropped onto the playing surface from a height of about 1.80 m measured from the bottom of the ball, it will rebound to a height, measured to the top of the ball, of not less than about 1.2 m nor more than about 1.4 m" (Fédération Internationale de Basketball 1998). Accounting for the 24-cm diameter of the ball, this means that a properly inflated ball rebounds to 62 ± 6% of the height from which it is dropped. Unfortunately, using this standard alone to determine when a ball is properly inflated implies a significant amount of trial and error—pump some air into the ball, remove the pump, drop the ball and test its rebounding, pump more air into the ball, and so forth. In this experiment, we develop a method to determine the correct number of strokes of a hand pump needed to correctly inflate a basketball, based on the size of the pump.

Materials and Methods

The basic setup for this experiment is shown in Figure 1. We used a wooden 2-meter stick to set a uniform height, h_0 = 1.8 m, from which we dropped a basketball and to measure the height h of its rebound. As shown in Figure 1, h_0 was measured from the floor to the bottom of the ball, while h was measured from the floor to the top of the ball, in accordance with international rules (Fédération Internationale de Basketball 1998). We used a video camera to record the motion of the basketball. By examining the video recording frame-by-frame, we could capture the ball at the top of its rebound.

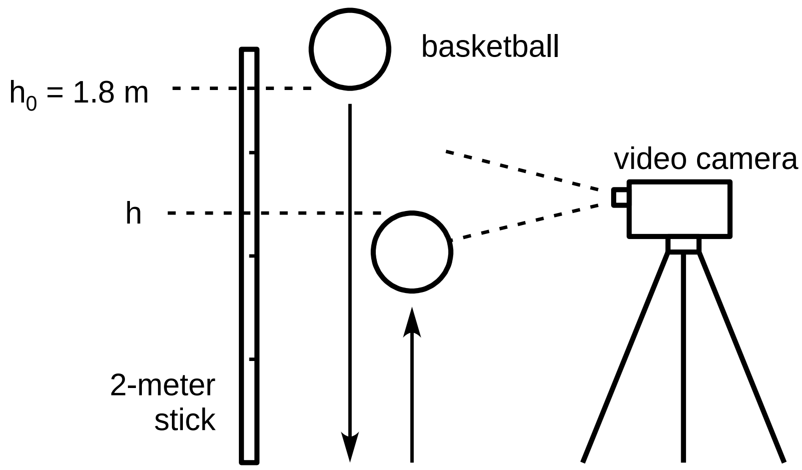

Figure 1. To determine the rebound height of a basketball, a video camera was used to record its motion with a meter stick in the background.

The video camera we used was an 8-mm format (Sony model CCD-F301). The resolution of the image in the "stop-action" frame was the critical factor in determining the precision of our height measurements. In order for the marks on the meter stick to be seen in the frame, we darkened every centimeter marking with a permanent marker. The precision of our individual height measurements was ± 1 cm.

The basketball we used (Wilson "Zone Buster" model P1350) was made of molded rubber. We measured the diameter of the ball by holding it flush to the wall with a book (a convenient right angle) and then measuring the distance from the edge of the book to the wall. The ball had a diameter D = 24 cm, as shown in Figure 2. We estimated that the wall thickness of the ball was 0.25 cm. We therefore considered the wall thickness to be negligible compared to the diameter of the ball. Before beginning the experiment, we inserted an inflating needle into the basketball to equalize its internal pressure with that of the surrounding air.

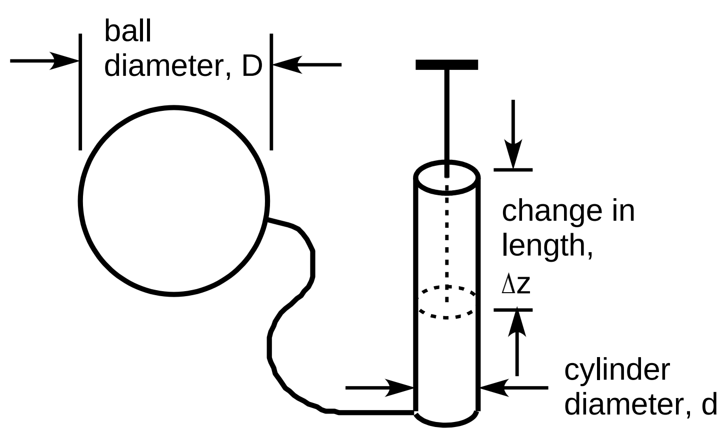

Figure 2. The outside diameter of the basketball we used was D *= 24 cm. The inside diameter of the pump cylinder was* d *= 3.4 cm and the length of its stroke was* Δz *= 38 cm.*

The pump we used to inflate the basketball was a common hand pump. We disassembled the pump to measure the inside diameter of the cylinder, d = 3.4 cm, and reassembled it to measure the length of its stroke, Δz = 38 cm. These measurements allowed us to determine the volume of air that was pumped into the ball with each stroke of the pump. We conducted our experiment inside, using the thermometer of the room's thermostat to measure the temperature of the surrounding air, T = 70 °F (equivalent to 21 °C). We dropped the ball onto a hardwood floor.

To complete the experiment, we inflated the basketball, counting the number of strokes N that we used. We then dropped the ball from a 1.8-m height and recorded its rebound height h. We repeated this measurement five times. We then inflated the ball some more, counting the additional number of strokes ΔN that we used, and repeated our measurements of the ball's rebounding with this new total number of strokes N. We repeated this process until the ball rebounded to over 62% of its initial height.

Data and Analysis

The specific results from this experiment allow us to determine the proper number of strokes of our hand pump needed to properly inflate the basketball, and to calculate the proper number of strokes to use with any pump.

Experimental Results

Some typical data describing the rebounding of the basketball are shown in Table 1. From these data we can see that there is a small amount of variation in the rebound height from one trial to another, even for identical conditions. This is most probably due to variations in the initial height from which we dropped the ball. For each set of trials, we took the average of the individual rebound heights to represent the rebounding of the ball at that amount of inflation. We took the standard deviation of the five trials to be the uncertainty in each of these averages.

Figure 3 shows the variation of rebound height h as a function of the number of strokes of the pump used to inflate the basketball. We used the "trendline" feature in Microsoft Excel® to fit the data to a polynomial function. The functional fit we found was

$$h = 0.64 + 0.093N - 0.0040N^2 + 0.000067N^3 \qquad (1)$$

where N is the number of strokes of the pump and h is measured in meters. From these data, we see that the proper number of strokes to inflate the basketball is N = 12.

Table 1. Typical data describing the rebounding of the basketball. These data were taken for the case of 15 strokes having been used to inflate the ball.

rebound height h [m]					average	uncertainty
trial 1	trial 2	trial 3	trial 4	trial 5	h [m]	σ_h [m]
1.31	1.34	1.34	1.34	1.36	1.34	0.02

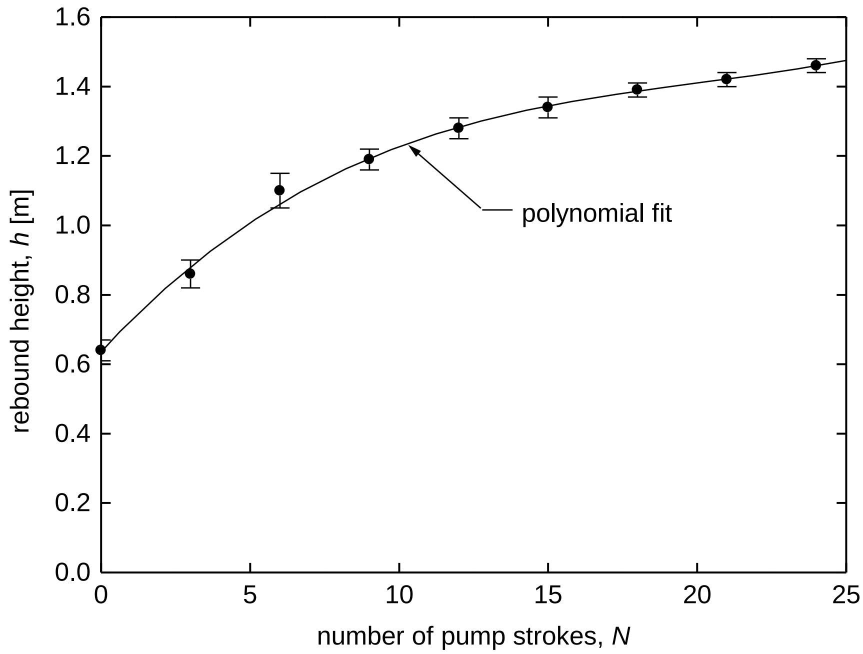

Figure 3. Rebound height h *as a function of the number of strokes of the pump used to inflate the basketball.*

Theoretical Analysis

It is important to realize that the number of strokes needed to properly inflate the basketball is valid only for the particular pump that we have used. The important quantity is the pressure of the air that is in the ball. Fortunately, we can use the ideal gas law to determine the pressure in the ball from our measurements. The ideal gas law states that (Serway 1997, p. 542)

$$PV = nkT \tag{2}$$

where P is the pressure of an amount of gas, V is the volume the gas occupies, n is the number of molecules in this amount of gas, T is the temperature of the gas, and k is Boltzmann's constant. In SI units, $k = 1.38 \times 10^{-23}$ J/K (Serway 1997, p. 542). In this equation, the temperature is measured on the absolute scale of degrees Kelvin or K.

When we use a pump to inflate a basketball, we take a fixed number of air molecules, n, initially at room temperature and pressure, and squeeze them into a smaller volume. Although the process of compressing the gas heats it, it quickly looses this heat and returns to room temperature. Since n and T in Equation (2) are constants, we can rewrite this equation as

$$P_1V_1 = P_2V_2 \tag{3}$$

where the subscripts "1" and "2" refer to the initial and final conditions of the gas. Here, the initial pressure of the gas is atmospheric pressure at room temperature, P_{atm}. The initial volume of the gas is the volume of the basketball, V_{ball}, and N times the volume of the pump, V_{pump}.

Recall that N is the number of strokes of the pump we used to inflate the ball. The situation is described graphically in Figure 4.

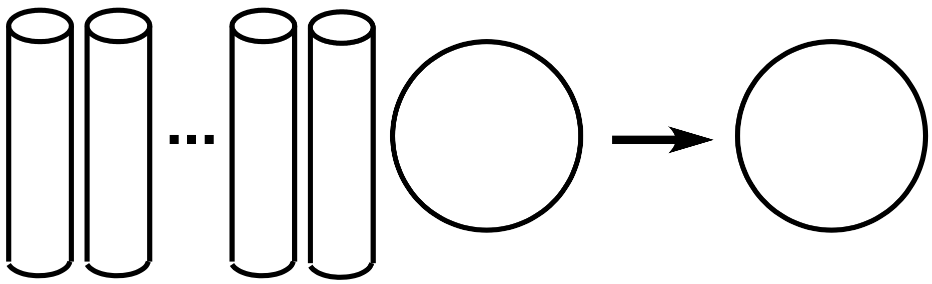

Figure 4. When we use a pump to inflate a basketball, we take a fixed amount of air and squeeze it into a smaller volume.

The relative increase in the pressure of the ball, using Equation (3), is just

$$\frac{P_2}{P_{atm}} = \frac{V_{ball} + NV_{pump}}{V_{ball}} \tag{4}$$

Because we know the dimensions of the ball and the pump, we can calculate these volumes. The volume of the pump is its cross-sectional area times the length of its stroke, or

$$V_{pump} = \frac{\pi d^2 \Delta z}{4} = 3.45 \times 10^{-4} \text{ m}^3 \tag{5}$$

and we can find the volume of the ball from the formula for the volume of a sphere, so

$$V_{ball} = \frac{\pi D^3}{6} = 7.24 \times 10^{-3} \text{ m}^3 \tag{6}$$

This tells us that the increase in pressure that makes the ball bounce properly is $P_2/P_{atm} = 1.57$. With this knowledge, we can use Equation (4) to derive a formula that is useful in general for the number of strokes to properly inflate the ball, namely

$$N = 0.57 \frac{V_{ball}}{V_{pump}} \tag{7}$$

where we use Equations (5) and (6) to calculate the volume of the pump and the ball, respectively.

See Appendix for error Calculations

Discussion

These results were obtained at a fixed temperature. The ideal gas law (Equation (2)) tells us that as the temperature increases, the pressure in the basketball will go up. Conversely, as the temperature goes down, the pressure will decrease. We observed this firsthand: when we brought the ball in from the cold garage, it was noticeably flat. This is the largest source of uncertainty in this experiment. Our results are not valid for different temperatures. One way to address this problem would be to account for it in our analysis, using the ideal gas law. This would make our result more complicated mathematically, but more generally useful. Another method would be to take data under at different temperature conditions (such as outside during hot and cold weather).

We neglected the effect of the material of the ball on its rebounding when doing this experiment. The material of the ball has some elasticity to it, and a leather basketball would bounce slightly differently than a rubber one. Our results show that this is a more important effect when there is very little air in the ball (see Figure 3). Even a little air dramatically changes the ball's rebounding, as shown by the initially large slope in the best-fit line. The experiment could be improved by repeating it with other basketballs of different materials to verify this assertion.

Conclusions

We have determined the optimum number of strokes of a hand pump needed to properly inflate a basketball. We have found that 12 strokes of our pump inflates our basketball so that it rebounds to within $62 \pm 6\%$ of its original height when dropped. Inflating the ball raises the pressure of the air inside it and gives it additional elasticity. On this basis, we have devised an method for determining the correct number of strokes necessary to inflate a basketball that can be used with any hand pump, if the volume of the air it compresses in a single stroke can be determined. Our results are valid for a temperature of 70 °F. Extending our results to other temperatures would require additional analysis, measurement, or both. Repeating these tests with basketballs made of other materials would confirm our assertion that the material of the ball has little effect on its rebounding once it is fully inflated.

References

Fédération Internationale de Basketball. *Official Basketball Rules.* URL: http://www.worldsport.com/worldsport/sports/basketball/rules/rules2.html, December 29, 1998.

Serway, R. A. *Physics for Scientists and Engineers,* Fourth Edition. Philadelphia: Saunders College Publishing, 1997.

Acknowledgements

The authors gratefully acknowledge Dr. Mary Handley's helpful comments during the writing of this report.

Western Kentucky University — PHYSICS LABORATORY — Form for DATA (only)

Experiment: Newton's Second Law

Student Name: Joe Student — Page 1

Partner in Taking Data: Sue Student — Date 1-28-99

Position Measurements from Spark Tape

i	Time (s)	Position (cm) $\pm .02$ cm
11	11/60	15.78
12	12/60	16.39
13	13/60	17.02
23	23/60	24.33
24	24/60	25.16
25	25/60	26.00
35	35/60	35.26
36	36/60	36.28
37	37/60	37.30
47	47/60	48.52
48	48/60	49.76
49	49/60	51.03
59	59/60	64.25
60	60/60	65.61
61	61/60	67.04
71	71/60	82.22
72	72/60	83.82
73	73/60	85.45

CALCULATIONS

Displacement

$\Delta x_i = x_{i+1} - x_{i-1}$

$\Delta x_{12} = x_{13} - x_{11} = 17.02 - 15.78$

$\Delta x_{12} = 1.24$ cm

Uncertainty in displacement

$\delta_{\Delta x} = \delta_{x_{i+1}} + \delta_{x_{i-1}} = .02 + .02 = .04$ cm

VELOCITY

$V_i = \frac{\Delta x_i}{\Delta t}$

$V_{12} = \frac{\Delta x_{12}}{\Delta t} = \frac{1.24 \text{ cm}}{1/30 \text{ s}} = 37.2$ cm/s

$\delta v = \frac{\delta_{\Delta x}}{\Delta t} = \frac{.04}{1/30} = 1.2$ cm/s

From the Graph the acceleration is the slope or

$a_{measured} = 59.1 \pm 1.5$ cm/s^2

Experiment: Newton's Second Law

Student Name: Joe Student Page 2

Partner in Taking Data: Sue Student Date 1-28-99

Mass measurements (mechanical balance)

$m = 10.23 \pm .02$ g

$M = 154.35 \pm .02$ g

Predicted value of acceleration (eqn. 5)

$$a = \frac{m}{m+M} g = \frac{10.23\,g}{10.23\,g + 154.35\,g} (9.80\,m/s^2) = 0.609\,m/s^2$$

or

$$a = 60.9\ cm/s^2$$

The uncertainty in this value of a (due to uncertainties in m & M) is

$$\frac{\delta a}{a} = \frac{\delta m}{m} + \frac{\delta(m+M)}{m+M} = \frac{.02}{10.23} + \frac{.04}{10.23 + 154.35} = 0.0022$$

$$\delta a = (.0022)\, a = (.0022)(60.9\ cm/s^2) = ~~0.01~~\ 0.1\ cm/s^2$$

So $a_{predicted} = (60.9 \pm 0.1)\ cm/s^2$

Comparing measured & predicted values

$$\%\ discrepancy = \frac{a_{meas} - a_{pred}}{a_{pred}} \times 100\% = \frac{59.1 - 60.9}{60.9} \times 100\% = -3\%$$