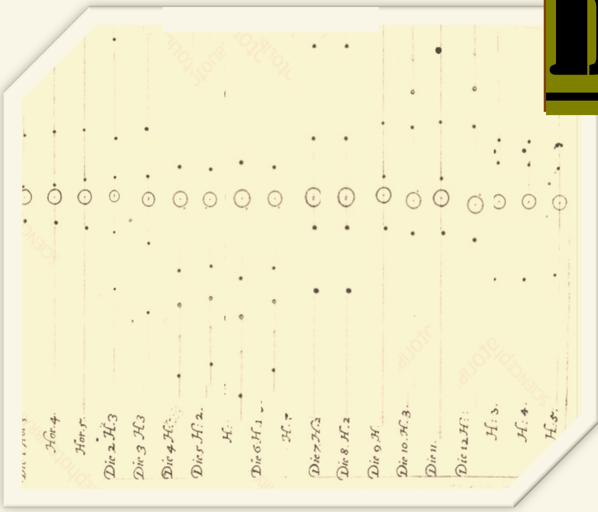
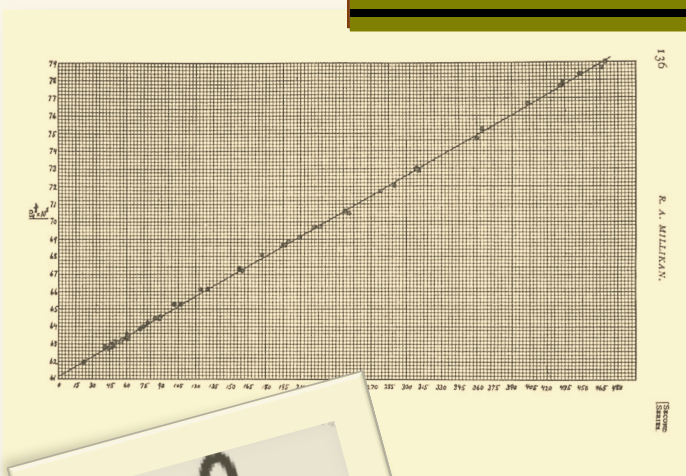
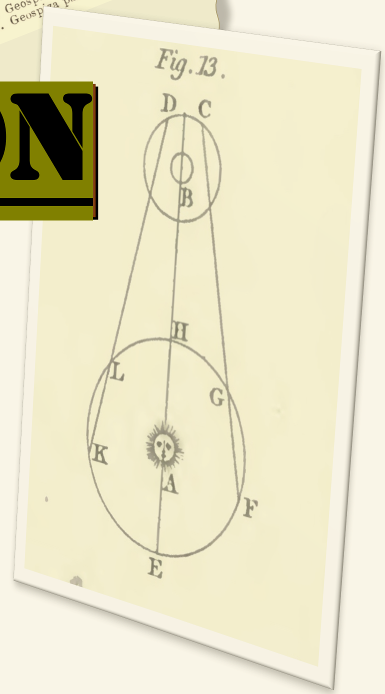
DATA

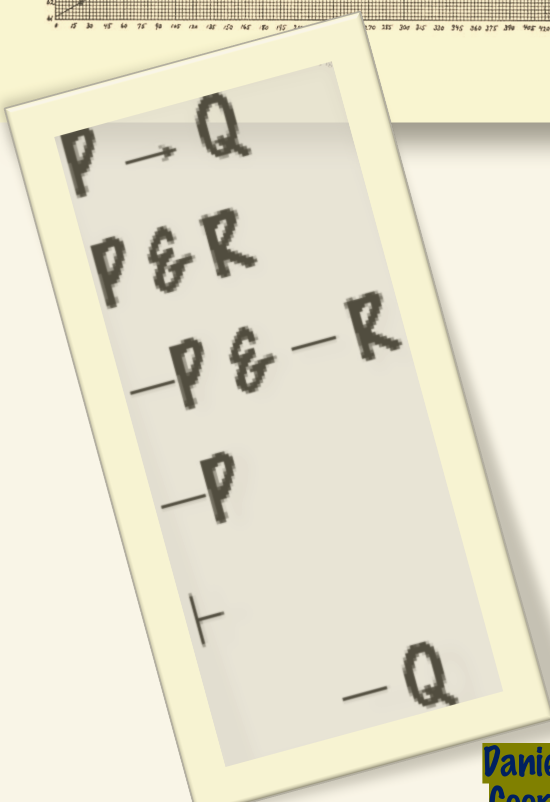


&

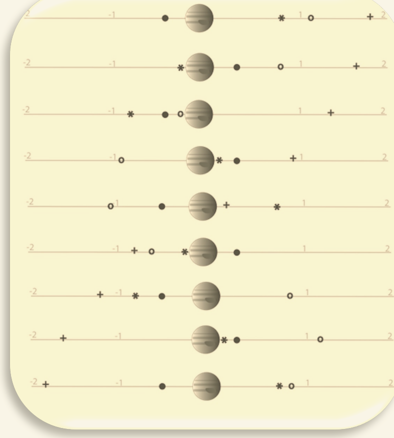
DEDUCTION







Success Express! summer 2019
Department of Sciences
John Jay College of Criminal Justice,
the City University of New York



Daniel A. Martens Yaverbaum
Coordinator, Lecturer; Physics

August 23, 2019

John Jay College of Criminal Justice, the City University of New York
Prof. Daniel A. Martens Yaverbaum, Physics Coordinator

Proceedings of the Infinity Court, Session 1.

Docket SU19.101L1

The facts:

Fact the first: In a much-awaited release to the press, the grand old leviathan of patrician barter, *Slottheby's Public Exchange,* has officially confirmed possession and intention to sell a seemingly implausible bundle of academic booty. To hear it from Sottheby's, each piece is pristine, original, and precisely what it purports to be. As a collection, purportedly, the pieces provide a new and dazzling glimpse inside landmark laboratory developments from across the 17th, 18th and 19th centuries. The general public continues to question the allegations with no less enthusiasm than that with which it rallies behind. The Slottheby's trove, it seems, has infused literal meaning and contemporary context into the phrase 'too good to be true'. Should the authenticity be independently confirmed, then the finding is of plainly unprecedented quality; the values of artifacts as yet unimagined will be judged and measured against this very one.

> "Nobody is as invested as are we on the board in slowing down this craziness. Nobody knows better than we that the more something like this looks like nothing wrong, the more wrong something somewhere must be. Yet, each of us finds him or herself left with less and less choice but to concede the one and only remaining conclusion, counter-expectations though it may seem:
>
> "For somehow every last piece of this pile," continued Al B. Damdd, M.F.S., deputy president of *AuBoard US*, an independently appointed board of artifact authenticity inspectors and investigators, "the hand-print continues to meet the most stringent and conservative of scrutinies and seems inescapably attributable, either to Charles Darwin or to Auguste Coulomb or to Galileo Galilei. Each piece comes from no scrappier than one of that gang of three. This weird little pile of surprise scraps, in other words, seems to contain raw data samplings pilfered straight from the father of biology, the father of chemistry and the father of physics."

Fact the second: Hardly a day had passed since a staggeringly improbable trove of allegedly original and primary data sets attributable to no less than Charles Darwin, Charles-Augustin de Coulomb and Galileo Galilei satisfied the last of a truly epic battery of authenticity challenges, managing to deliver performances and meet standards to an extent said to have a chilling effect on even the most disaffected of art, science or history illiterates.

Known increasingly to aficionados as the *Scratch* and to skeptics as the *Scheiss*, the set consists merely of a few sheets of paper, each with little more than a table of numbers, some hand-sketches or the like. The items themselves might be small, but the associated stakes have seemed high beyond precedent: if not original, the scraps are meaningless. If original, they are quite possibly priceless. As of yesterday, according to an uncontested vote of experts at Sotheby's, the answer was exciting, clear, definitive and *Yes*: Original? assuredly. Priceless? consequently. Game On (evidently).

Fact the third: From somewhere thick within a context of heavy and volatile price speculation, trading traffic on Wall Street came nearly to a halt – as one wheel after another got caught at a gritty intersection with a formidable if flamboyant menagerie of investment rivals identified as Sesame Street. Not our scientists! They cried. Or in some cases: Wrong Scientists! Wrong Science! Bad Science! Bad Sotheby's! Bad! Bad Bad!

It seems so. Without introducing a single trace of forgery nor plagiarism, the *Yellow Gold & Daughters Lab for Retrieval Restoration and Verification*, the small but professionally immaculate house of forensic science research education, issued their brief statement with disquieting impact:

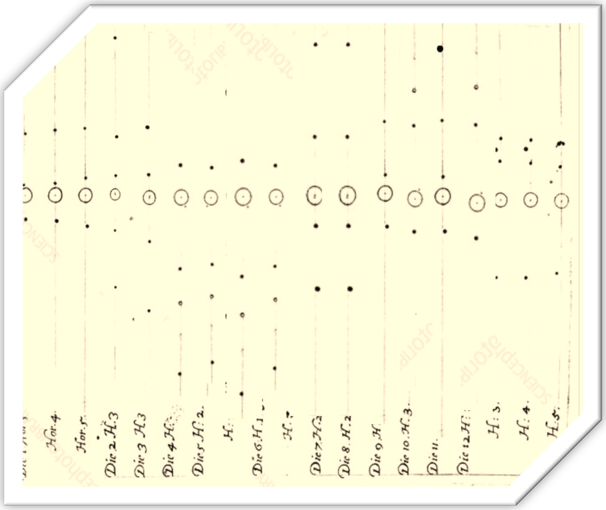
> "Look. I can speak for the physics. If these documents are really real, then Galileo himself is a fake. It's that simple. And my colleagues in the other two science areas of expertise will stand by the same regarding biology and chemistry. The longer you look at that data, the more inevitably you confidence in some ineffable but crucial aspect of its accuracy – or its integrity … or simply its scientific possibility. At anyone's hand, much less one of them."

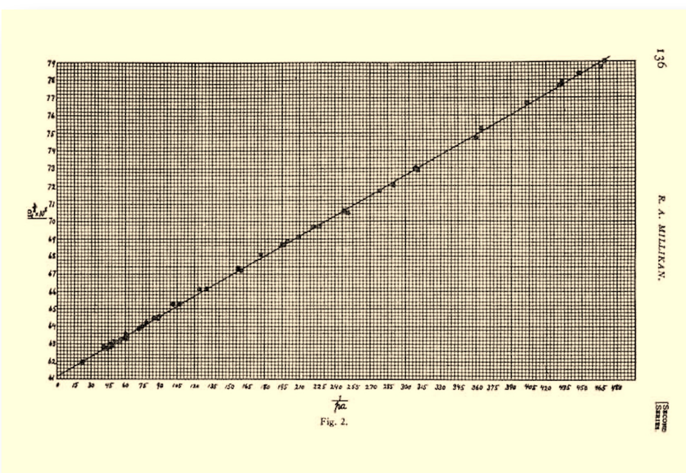
YOUR ASSIGNMENT:
FOR EACH ITEM IN THE SCRATCH SET OF ALLEGEDLY PRIMARY DOCUMENTS,
COME TO A FINDING:

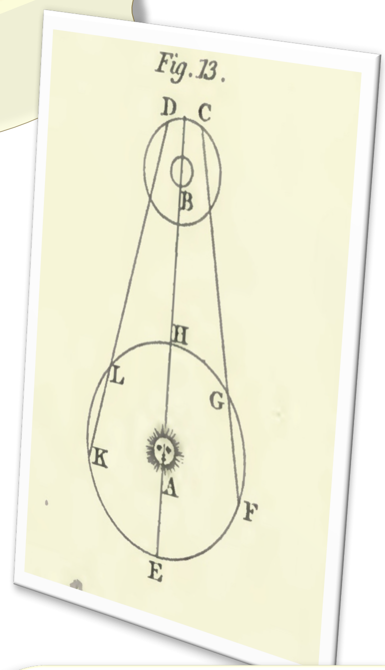
1) *Authentically attributable to the hand of Galileo, Coulomb or Darwin, as appropriate? Yes or no; why or why not?*

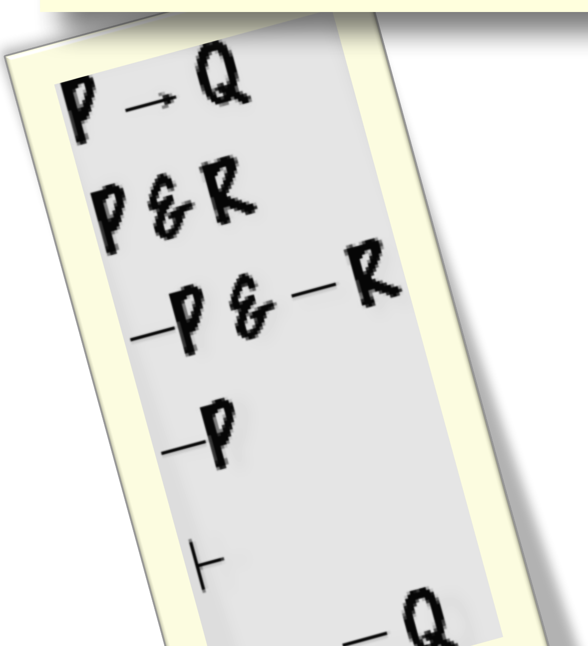
2) *Right or wrong reporting? Good or bad science? Why or why not?*

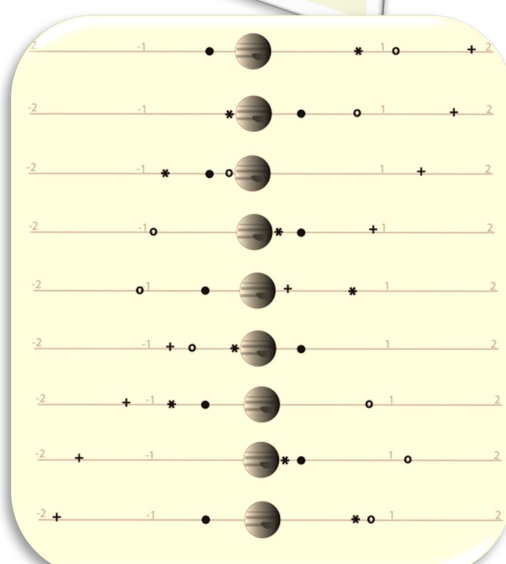
Proceedings of the Infinity Court, Session 1.











Daniel A. Martens Yaverbaum
Department of Sciences
John Jay College of Criminal Justice, the CUNY

What is the academic baseline and preparedness that students need to walk into first-year college classes having? (For example, aside from social-emotional skills and resilience, are there basic academic skills that students must have to be successful?)

I. Some Specific (STEM) Skills

(Expected, Assumed or Demanded during STEM 101)

A. (know your way around)
'***Direct proportionality***' or '***Simple Linear Equations***'.

i. In early science courses that have ***any*** quantitative component at all, this type of relationship is central. The idea is this: If an experimenter deliberately changes one measurable quantity at a certain rate (dials up the height, temperature, weight, loudness, or whatever), then some other quantity naturally and reliably responds by changing – at a similarly steady rate. (Allow light to travel for a while, then allow it to travel again but for twice as much time; if you make careful measurements, you'll find that it will travel twice as much distance). This pervasive type of relationship is found in widely varied contexts and is expressed all sorts of different ways – various English phrases, different mathematical expressions, graphs, tables, etc.

ii. Examples include:

a) Density is Mass per Volume:

$$\boldsymbol{D = \frac{M}{V}}.$$

b) Voltage is Current times Resistance:

$$\boldsymbol{V = IR}.$$

c) Pressure times Volume is directly proportional to Temperature:

$$\boldsymbol{PV = nRT}.$$

d) If the *rise* of some *dependent variable* **varies directly** with the *run* of some *independent variable*, then their graph is a straight line, i.e.: trend of constant slope:

$$y = mx + b.$$

iii. With relationships such as the above, if two numerical values are given to a student (such as the mass and volume of a cup of flour), it is expected that the student can "solve for" the missing number (in this case, the flour's density). But that's the easy part; it's necessary, but not sufficient.

Quite often, the relationship is invoked in a far less explicit or self-referential way. Without stating the full equation or specifying a particular "unknown", we might come to understand that the density of a substance is held constant while the mass is doubled. The question is '*what happens to*' the volume? We are not being asked what the volume is, but, rather, by how much does it change? What if the volume is held constant and the density is reduced to a third? The relationship must be seen generally and flexibly. In STEM 101 classes, direct proportionalities drive many of the contexts in which students are expected to shift their thinking from concrete and particular to abstract and general.

B. (Stay steadfastly aware of the vast preponderance of)
Relations that are NOT Directly Proportional:

Knowing when to invert all the above is almost as important as knowing when to follow it. Students must be sufficiently comfortable with the specifics of a directly proportional relationship to recognize the vast sweep of relationships that do not fit such a description. Most quantitative relationships to be stumbled upon in nature, as a matter of fact, do ***not*** look like this. Steadily heat it up and you might well find that the size of a metal steadily increases. But if you add 'twice as much heat' do you find the metal growing to twice its size?! It almost seems as though this would be too perfect a match to expect; indeed, generally, it is.

The specialness and worth of a direct proportionality is that it is such a helpful way for us to organize our thoughts about natural phenomena, ***not*** that it is such a common way for natural phenomena to organize themselves. As a rock free-falls toward the ground, for example, it does *not* traverse the same amount of space (say, a foot) in each next and identical amount of time (say, a second). A freely-falling object does *not* travel at a constant speed and therefore does not cover distances that are directly proportional to time.

C. *Abstracts/ Digests*:

Each student must be able to distill and express the essential ideas from a larger piece of writing, whether the larger piece was original to the student or composed by a colleague or found in a publication. The student must be able to write about a writing – for an audience who has not yet decided whether a full read is worth the time.

D. *Collaboration:*

Each student must be able to interact, negotiate, contribute, receive and manage with other students in order to produce work that authentically results from a group (rather than from a set of disassociated individuals). A great and frequently upsetting test of this skill comes when students find out that such collaboration includes shared accountability: Are we capable of 'sharing a grade' with colleagues – particularly when we did not choose them?

E. *Graphing:*

It is not just you and it is not something about this situation: Everybody hates graphing. Until they love it. Which generally comes around the time they have been forced to face the alternatives.

F. *(general) Sketching/Diagramming:*

Similar point to (D), above: At a certain point, it is no longer acceptable to duck out by saying, "I'm not a good artist". Your friend in that class down the hall doesn't get to duck the need to mix pigments by saying, "I'm not a good scientist". A good diagram is like a written abstract. It separates the essential from the incidental and even, through its labels, defines terms. A diagram or sketch comes before the questions or problems or solutions: It captures the facts that are '*known*' and on which we rely in order to confront the unknown. Pictures, moreover, are somehow more frequently highly personal (or individuated) compared to words – or certainly as compared to memorized equations. It is often easier to develop awareness or self-awareness of ones mental model for a topic through drawing than through any other mode.

G. *Attributing Sources/Citation:*

A great deal of STEM education might take place in the lab, but not all of it. Not necessarily the M part, for example. All of it, however, is heavily concerned with the best practices underlying *research*.

H. ***Debate/Discourse:***

Withstand scrutiny. Unleash skepticism. Defend, delineate and derive. Do not, however, simply assert.

Just like you might go to the gym frequently enough to find that some sessions of working-out are simply not fun, consider: Pay enough attention and invest enough authentic interest that you sometimes hear things which do not strike you as right. Do not assume that science is truth and truth is clear and two sides is too many for a statement of science. On the contrary, be contrary: Challenge. But challenge the message, not the messenger. Date your first thought, don't marry it. Then remain faithful to the (dialectical) process, not to your position. It is no longer what it was, and it wasn't yours when it was, nonetheless.

II. Some Slice of the Greater Geshtalt

(being prepared to be unprepared)

A. Students must have some experience with mistakes, with frustration, with endeavors lacking in apparent direction and/or moments wanting for confidence.

B. They need to have flirted with the beginnings of some attempts to develop intellectual self-reliance – to have practiced even just a little bit with a gestures toward . . .

KNOWING WHAT TO DO WHEN WE DON'T KNOW WHAT TO DO.

. If you could arm all incoming college students with one thing, what would it be?

Awe.

What do you wish middle and high school teachers knew about college classes?

That there is a horrific amount of truth to the cliché they've heard: Members of a college or university faculty are, at the typical institutions, not brought in or kept or promoted to teach – not as such. They might well serve as mentors, guides, coaches, leaders and role models, and they might perhaps – in some cases -- embody the very finest instances of all these things. But they rarely manage a classroom. They are rarely, in fact, occupied with the basic ritual of 'grading homework' – not in the classic and all-consuming manner of red pens and roll books. Which is to say that the dialogue between professor and class can involve a bit more forth-and-forth than back-and-forth. They are obligated to teach, but the hours they spend teaching or preparing to teach are – more often than not – at the expense of time needed for the undertakings by which their professional progress will be evaluated.

So, it turns out:

Whatever ineffable gifts are subject to delivery via deliberate and sustained focus on pedagogy are often delivered for the very last time… by '*you*' – by the teachers.

Are there other, ~~more~~ ~~important~~ questions that you'd like to attempt to answer?

(yes) Q: Name an important ingredient of good teaching that is surprisingly rare to find within the classroom of a typical college STEM course:

A: *Creating, offering, encouraging maintaining, tolerating and/or closely-sharing a space in which students are expected to screw up.*

What do you observe about girls in science? What keeps them in the classes and the major?

In my perhaps highly specific (and/or self-selected) department, there is simply no room for doubt: women comprise the vast majority of the students who enter the major, the vast majority of the students who make it through, the students who follow through consistently and reliably with projects, who communicate clearly, who conduct themselves professionally and who perform. On the whole, with many exceptions but with very little room for doubt, the female students are the stronger students.

What keeps them in the classes and the major is that (a) they tend to give up less easily than their male counterparts and (b) at this stage, there is little reason they should even consider giving up: they run the table. According to what I am told anecdotally by faculty women, however, the success is rewarded less and proportionally as one progresses up the academic ladder.

What misconceptions do students have about college-level work in STEM from their high school experience?

That 'hard work' means spending a lot of hours on the kind of tasks for which you have already developed habits and possibly even stamina – that 'working harder' means spending even more hours on the same kind of thing.

This stands in contrast to the shock that can occur freshman year: an assignment is hard because you have not yet developed a habit or technique for whatever is being asked of you – and you might not even feel the security of knowing what is, precisely, being asked. You're ready to put in the hours, but you have no idea where.

Put another way,

a common MISCONCEPTION is:

SIMPLE = EASY
COMPLEX = HARD.

In fact, things are quite often the other way.

KNOWING WHAT TO DO WHEN YOU DON'T KNOW WHAT TO DO:

How to Do HW, Take Exams & Solve Other Real Problems in the Course of Scientific Study

February 10, 2016

Daniel A. Martens Yaverbaum
Physics Coordinator, John Jay College of Criminal Justice

WHAT IS THE QUESTION?

A shocking realization: 'I have no idea what the question is asking!' An insult to your injury: What you're looking at isn't even the question. A reason for hope: It's no accident. You are now in research. Finding and holding onto the question is a big part of the job. A technique: Begin by trying to picture what a *wrong* answer would look like.

WHAT IS THE CHOICE?

An recurring nightmare – experienced in broad daylight: I have no idea what to do next. A crucial technique: Trade 'I have no idea' for 'I have no idea *whether*...' and thereby trade confusion for conflict. A deflection: The choice I face is a mess of multiplicity! hardly simple! Should I go *this way* or ***that way ... or yet another way?*** An Aristotlean antidote: False. You must either go this way or *not* this way. Take the way which might well take you you *farther*. Make the move which seems more likely to facilitate... *another* one.

WHAT WOULD YOU ASK DURING A SINGLE SLOT OF(fictional) FACULTY OFFICE 'MINUTES'?

A taunting tautology: You don't know what you don't know. A further fact: You can't get very far without finding out; you need to locate the first point at which you dropped the thread. An easily overlooked means: Find the last point when you were still holding on. Imagine the one question you would ask your favorite professor – if she only had 60 seconds to give.

DO YOU FEEL DESPERATELY AND INEXPLICABLY STUCK JUST TRYING TO SHOW THAT SOMETHING RELEVANT IS TRUE?

Well, then stop doing that! How about maybe consider: sending your train of thought in a different direction... one that is, for example, ***not*** backwards. Scientific analysis proceeds from that which is generally (perhaps even obviously) true toward that which is particularly relevant, rather than the other way 'round. That's one reason it occasionally seems credible – even to non-scientists!

Some Samples of STEM-Speak

An Undergraduate Underglossary of UnderStandard Overstanding

(Abridged, Approximate and Uncomplete):

A. **Less**	= More.
B. **Simple**	= NOT Easy. (The opposite of easy is hard, but the opposite of simple is complex.)
C. **Obvious**	= Worth your extremely critical & continued attention.
D. **Show all work** (said to the writer)	= Sort, split, stack, scrub and *subtract* all need for work (from the reader).
E. **Repetition** of something that seems the same	= A difference that makes a difference.
F. **The notes you take during lecture**	= Your uniquely customized copy of a leaked final exam.
G. **The notes you take while studying**	= Your granddaughter's inheritance & heirloom.

so . . .

Buy an art journal or similarly lush volume of *unlined*
yet quite possibly flamboyant sheets of acid-free
and fill it like a rock star.
Expound, exclaim, draw, critique, reconstruct, translate, own and err.

Do not erase;

Cross out – if you must –

But gently.

How many blades of grass in the average American football field?

Assume:

(1) an average football field is approx. 100 yards in length by 50 yards in width.

(2) you are going to '*estimate*' -- but no less mindfully nor accurately than you estimate which mark on a measuring tool is closest to some designated point in space/time.

(3) a correct answer exists -- to the same extent as correct or incorrect ever exists with respect to measurable data (see (2), above). That is, a *range* exists -- within which all values are possibly correct and without no values are possibly correct.

(4) you will solve for a *range*, such as that between two successive orders of magnitude, and you will be correct when your range overlaps nicely with the generally accepted range.

For example, you might find $n \approx 5 \times 10^3$.
We will take that to mean: $(1 \times 10^3) < n < (9 \times 10^3)$.

If the accepted answer is 2 x 103,
then you are *precisely* as right (*accurate*)

as the accepted answer is in the first place --
by the *definition* of *data*.

"WIN AS MUCH AS YOU CAN" TALLY SHEET

1. You will be placed in a group of four players. For each of ten successive rounds, play either the "X" or "Y" at the same time the other members play their cards. Depending on the pattern of Xs and Ys, you will receive a score for each round. See the Payoff Schedule below.
   - If, for instance, there are four Xs, each person loses 1 point.
   - If there are four Ys, each player wins 1 point.
   - If there are 2 Xs and 2 Ys, the X players each win 2 and the Ys each lose 2, and so on.
2. *Keep score each round* on this scoresheet:
   - Write down your individual “throw” - "X" or "Y."
   - Write down the pattern of throws in your group - e.g., 2 X 2 Y.
   - Write down your individual payoff for the round.
   - Write down your cumulative payoff (the total of individual payoffs as you go along).
3. You must play *each* of the ten rounds.
4. *Just before you play rounds 5, 8 & 10, you may confer* with the other players in your group.
5. *You may not talk before playing the first four rounds, or before playing rounds 6, 7 & 9.*
6. Rounds 5, 8 & 10 are *bonus rounds*: Payoffs are increased as follows:
   Round 5: multiply your score times 3; Round 8: times 5; Round 10: times 10.

PAYOFF SCHEDULE

4 X's:	**Lose**	**1**	**Each**
3 X's:	**Win**	**1**	**Each**
1 Y:	**Lose**	**3**	
2 X's:	**Win**	**2**	**Each**
2 Y's:	**Lose**	**2**	
1 X:	**Win**	**3**	**Each**
3 Y's:	**Lose**	**1**	
4 Y's:	**Win**	**1**	**Each**

SCORE CARD

ROUND	YOUR INDIVIDUAL “THROW” (circle an X or Y)	THE PATTERN OF THROWS IN YOUR GROUP	YOUR POINTS IN *THIS* SINGLE ROUND	YOUR *TOTAL* SCORE
1	X Y	____ X ____ Y		
2	X Y	____ X ____ Y		
3	X Y	____ X ____ Y		
4	X Y	____ X ____ Y		
5 BONUS	X Y	____ X ____ Y	(multiply x 3)	
6	X Y	____ X ____ Y		
7	X Y	____ X ____ Y		
8 BONUS	X Y	____ X ____ Y	(multiply x 5)	
9	X Y	____ X ____ Y		
10 BONUS	X Y	____ X ____ Y	(multiply x 10)	

X

Y

PROCEEDINGS OF THE INFINITY COURT, SESSION 2

Claim Types

SYNTHETIC	ANALYTIC
A POSTERIORI	A PRIORI

ANALYTIC: An analytic claim is a claim the truth or falsity of which is verifiable by means only of language (definitions).

SYNTHETIC: A synthetic claim is a claim that is ***NOT*** ANALYTIC.

A POSTERIORI: An a posteriori claim is a claim the truth or falsity of which is verifiable by means only of empirical (sensory) evidence.

A PRIORI: An a priori claim is a claim that is ***NOT*** A POSTERIORI.

Refutation Types

NON: A NON refutation is a refutation that asserts the strictly ANALYTIC opposite of the claim to be refuted. For example, if the given claim is “This chair is red,” then the NON refutation is “This chair is ***not*** red.” More rigorously, the NON refutation would be “It is ***not*** the case that this chair is red.” For any given claim, there is one and only one possible NON refutation.

POP: A pop refutation is a refutation that asserts some sort of SYNTHETIC opposite of the claim to be refuted. For example, if the given claim is “This chair is red,” then on example of a POP refutation might be “This chair is green.” For any given claim, there may be a wide array of possible POP refutations.

TRUTH TABLES

P	**Q**	**~P**	**~Q**	**P&Q**
T	T	F	F	T
T	F	F	T	F
F	T	T	F	F
F	F	T	T	F
~(P&Q)	**PvQ**	**~(PvQ)**	**P->Q**	**Q->P**
F	T	F	T	T
T	T	F	F	T
T	T	F	T	F
T	F	T	T	T
~P->~Q	**~Q->~P**	**P<->Q**	**P&~P**	**Pv~P**
T	T	T	F	T
T	F	F	F	T
F	T	F	F	T
T	T	T	F	T

PROOFS

1. P->Q, P |- Q **[->o: Modus Ponens]**

1.	P->Q	A	1
2.	P	A	2
3.	Q	->o 1,2	1,2
			QED

**** NOTE: This is*** ***NEITHER*** **P->Q, Q** **|- P**
NOR **P->Q, ~P** **|- ~Q**
NOR **P->Q** **|- Q.** **See Truth Table for ->.**

2. P&Q |- P **[&o]**

1.	P&Q	A	1
2.	P	&o 1	1
			QED

3. P, Q |- P&Q **[&i]**

1.	P	A	1
2.	Q	A	2
3.	P&Q	&i 1,2	1,2
			QED

4. P->Q, P&R |- Q **[->o, &o]**

1.	P->Q	A	1
2.	P&R	A	2
3.	P	&o 2	2
4.	Q	->o 1,3	1,2
			QED

5. P |- PvQ **[vi]**

1.	P	A	1
2.	PvQ	vi 1	1
			QED

6. P->Q, P&R |- Q **[~o]**

1.	P->Q	A	1
2.	P&R	A	2
3.	~Q	PA	3
4.	P	PPA	4
5.	Q	->o 1,4	1,4
6.	Q&~Q	&i 3,5	1,3,4
7.	~P	~i 4-6	1,3
8.	P	&o 2	2
9.	P&~P	&i 7,8	1,2,3
10.	Q	~o 3-9	1,2
			QED

7. Av~A **[~o: ULEM form #2]**

1.	~(Av~A)	PA	1
2.	A	PPA	2
3.	Av~A	vi 2	2
4.	(Av~A)&~(Av~A)	&i 1,3	1,2
5.	~A	~i 2-4	1
6.	~A	PPA	6
7.	Av~A	vi 6	6
8.	(Av~A)&~(Av~A)	&i 1,7	1,6
9.	A	~o 6-8	1
10.	A&~A	&i 5,9	1
11.	Av~A	~o 1-10	---
			QED

8. P->R, Q->R, PvQ |- R **[vo]**

1.	P->R	A	1
2.	Q->R	A	2
3.	PvQ	A	3
4.	R	vo 1,2,3	1,2,3
			QED

9. A->P, ~A->P |- P **[vo: ULEM form #2]**

1.	A->P	A	1
2.	~A->P	A	2
3.	~(Av~A)	PA	3
4.	A	PPA	4
5.	Av~A	vi 4	4
6.	(Av~A)&~(Av~A)	&i 3,5	3,4
7.	~A	~i 4-6	3
8.	~A	PPA	8
9.	Av~A	vi 8	8
10.	(Av~A)&~(Av~A)	&i 3,9	3,8
11.	A	~o 8-10	3
12.	A&~A	&i 7,11	3
13.	Av~A	~o 3-12	---
14.	P	vo 1,2,13	1,2
			QED

10. P->(PvQ) **[->i]**

1.	P	PA	1
2.	PvQ	vi 1	1
3.	P->(PvQ)	->i 1-2	---
			QED

11. P->Q, Q->P |- P<->Q **[<->i]**

1.	P->Q	A	1
2.	Q->P	A	2
3.	(P->Q)&(Q->P)	&i 1,2	1,2
4.	P<->Q	<->i 3	1,2
			QED

12. P<->Q |- P->Q **[<->o]**

1.	P<->Q	A	1
2.	P->Q	<->o 1	1
			QED

13. P->Q |- ~PvQ [-> |- v]

1.	P->Q	A	1
2.	~(~PvQ)	PA	2
3.	P	PPA	3
4.	Q	->o 1,3	1,3
5.	~PvQ	vi 4	1,3
6.	(~PvQ)&~(~PvQ)	&i 2,5	1,2,3
7.	~P	~i 3-6	1,2
8.	~P	PPA	8
9.	~PvQ	vi 8	8
10.	(~PvQ)&~(~PvQ)	&i 2,9	2,8
11.	P	~o 8-10	2
12.	P&~P	&i 7,11	1,2
13.	(~PvQ)	~o 2-12	1
			QED

14. (~PvQ)->(P->Q) [v |- ->]

1.	~PvQ	PA	1
2.	P	PPA	2
3.	~P	PPPA	3
4.	~Q	PPPPA	4
5.	P&~P	&i 2,3	2,3
6.	Q	~o 4-5	2,3
7.	~P->Q	->i 3-6	2
8.	Q	PPPA	8
9.	Q&P	&i 2,8	2,8
10.	Q	&o 9	2,8
11.	Q->Q	->i 8-10	2
12.	Q	vo 1,7,11	1,2
13.	P->Q	->i 2-12	1
14.	(~PvQ)->(P->Q)	->i 1-13	---
			QED

15. ~(P&Q) |- ~Pv~Q [& |- v: DeMorgan's Law form #1]

1.	~(P&Q)	A	1
2.	~(~Pv~Q)	PA	2
3.	~P	PPA	3
4.	~Pv~Q	vi 3	3
5.	(~Pv~Q)&~(~Pv~Q)	&i 2,4	2,3
6.	P	~o 3-5	2
7.	~Q	PPA	7
8.	~Pv~Q	vi 7	7
9.	(~Pv~Q)&~(~Pv~Q)	&i 2,8	2,7
10.	Q	~o 7-9	2
11.	P&Q	&i 6,10	2
12.	(P&Q)&~(P&Q)	&i 1,11	1,2
13.	~Pv~Q	~o 2-12	1
			QED

16. (~Pv~Q)->~(P&Q) [v |- &: Converse, DeMorgan's Law form #1]

1.	~Pv~Q	PA	1
2.	P&Q	PPA	2
3.	P	&o 2	2
4.	~P	PPPA	4
5.	Q	PPPPA	5
6.	P&~P	&i 3,4	2,4
7.	~Q	~i 5-6	2,4
8.	~P->~Q	->i 4-7	2
9.	~Q	PPPA	9
10.	~Q&(~Pv~Q)	&i 1,9	1,9
11.	~Q	&o 10	1,9
12.	~Q->~Q	->i 9-11	1
13.	~Q	vo 1,8,12	1,2
14.	Q	&o 2	2
15.	Q&~Q	&i 13,14	1,2
16.	~(P&Q)	~i 2-15	1
17.	(~Pv~Q)->~(P&Q)	->i 1-16	---
			QED

17. (P->Q)->~(P&~Q) **[-> |- &]**

1.	P->Q	PA	1
2.	P&~Q	PPA	2
3.	P	&o 2	2
4.	~Q	&o 2	2
5.	Q	->o 1,3	1,2
6.	Q&~Q	&i 4,5	1,2
7.	~(P&~Q)	~i 2-6	1
8.	(P->Q)->~(P&~Q)	->i 1-7	---
			QED

18. ~(P&~Q)->(P->Q) **[& |- ->]**

1.	~(P&~Q)	PA	1
2.	P	PPA	2
3.	~Q	PPPA	3
4.	P&~Q	&i 2,3	2,3
5.	(P&~Q)&~(P&~Q)	&i 1,4	1,2,3
6.	Q	~o 3-5	1,2
7.	P->Q	->i 2-6	1
8.	[~(P&~Q)]->(P->Q)	->i 1-7	---
			QED

19. (P->Q)->(~Q->~P) **[-> |- <-: Contrapositive]**

1.	P->Q	PA	1
2.	~Q	PPA	2
3.	P	PPPA	3
4.	Q	->o 1,3	1,3
5.	Q&~Q	&i 2,4	1,2,3
6.	~P	~i 3-5	1,2
7.	~Q->~P	->i 2-6	1
8.	(P->Q)->(~Q->~P)	->i 1-7	---
			QED

Lab 1: Magnitude, Measurement & Motion

Physics 203

John Jay College of Criminal Justice, the CUNY

Profs. Martens Yaverbaum & Bean

*** PLEASE NOTE: For all experiments in both Physics 203 and Physics 204, each lab *group* will submit *two separate reports*; the detailed requirements and instructions for each are explained at the end of this Lab 1 Manual.

The first of the two reports is a ***Physics Post-Lab***. Methodical completion of each ***Post-Lab*** exercise helps us maintain a clear idea of what we should expect to know (therefore deploy) and what we should not expect to know (therefore figure out) from one laboratory investigation to the next. It is a document designed to sharpen thought and communication among physics students—within, for example, a university classroom. Among other intended educational purposes, each ***Post-Lab*** should help us build a ***Formal*** Laboratory ***Report***, briefly introduced below; the ***Post-Lab*** is therefore always the first of two reports to be written.

The second of the two reports is the ***Formal Report***. This document is a complete scholarly accounting of everything you did for a particular laboratory investigation and why. All sections of this ***Formal Report*** are ultimately directed toward the answering of a ***Research Question*** (or, in some cases, up to three related ***Research Questions***): The ***Formal Report*** explains to any and all uninitiated readers precisely how and why a set of data was collected, by what means these data were analyzed, and in what way this analysis—within a specified range of measurement uncertainty—led to a finding that, finally, answered the ***Research Question***.

This ***Formal Report*** is composed and presented in the manner of a research physicist submitting her experimental findings to a ("peer-reviewed") journal. The ***Formal Report***, that is, is formal in the following fundamental sense: Imagine that an intelligent and interested reader is randomly selected from far outside the context of all John Jay syllabi, discussions and experiences; this reader, although familiar with general scientific research, might not even know any physics. Such a reader, with no specific background nor supplementary explanations, should be able to use a properly written ***Report*** in order to reproduce our methods and pursue his own answer to the self-evidently meaningful ***Research Question*** found within. A strong ***Formal Report*** is, in principle, ready for publication.

As you read any of the Lab Manuals for Physics 203 or Physics 204, notice directions that are preceded by three asterisks (***). These refer to steps of measurement or thought that you will be expected to emphasize, and therefore carefully consider, in your ***Formal Report***. Three asterisks essentially mean "Make certain to recall this step even after you have left all your measuring equipment behind".

I. The ***<u>Research Questions</u>*** for today's lab.

All your lab thoughts, designs, actions, measurements, mathematics and writings must begin and end with focused attention toward the ***Research Question***(s). Always. Whenever you are not sure what to do or write next, ask yourself, "How can I somehow connect/relate what I just did to the ***Research Question***?" Today's ***Research Questions*** are presented below.

A. What is the *average speed* of an aluminum glider as it travels along an approximately horizontal *air track*?

B. Does this *average speed* vary significantly as the glider moves from section to section of the air track? How so?

II. MEASUREMENT: THE UNITS.

A measurement is in many ways a strange thing. But one thing it ultimately appears to be is a comparison. To say that something is "1 meter" long is to say that it is the same length as something else--something else that we all recognize and call a "meter".

A. LENGTH.

i. *** Come up with your OWN standard of comparison by which you could **MEASURE** a length. This standard could be the length of your index finger, the length of a shoelace, whatever. But before you spontaneously arrive at any old standard, contemplate what might make one standard more useful than another: To what extent is shorter better? To what extent is longer better? One thing may be so obvious that you might neglect to consider it:

   *** For something to function as a standard of measurement, it should NOT change its size during the act of measurement.

ii. Come up with an official name for your standard. You will use it throughout the central stage of the lab.

B. TIME.

i. *** Repeat the above directions for a standard of TIME. All the issues are the same, but this undertaking is unquestionably more difficult than the above. You will essentially have to "BUILD" something that can function as a clock. This is where the above triple-starred (strange-font) requirement becomes EXTREMELY IMPORTANT!

ii. MAKE CERTAIN that your clock runs faster than the slowest heart-rate found in your lab group.

III. MEASUREMENT: THE ACT.

NECESSARY EQUIPMENT

i. Air Track.
ii. Glider.
iii. Your Personal Ruler.
iv. Your Personal Clock.

A. Static Measurement: DISTANCE.

1) You and your partner have now each devised a measuring unit for space and a measuring unit for time.

2) Clear your lab table and set a track along it.

3) *** PLAY WITH and get accustomed to THE TRACK UNTIL IT IS AS HORIZONTAL AS POSSIBLE! TAKE YOUR TIME WITH THIS!

3) Have one partner hold a glider in place at the top of the track . During this time, the other partner must use his/her personal unit of length in order to measure the interval between the center of the glider and the bottom of the track. This will be the length of one full one-way car trip.

4) *** Write down the DISTANCE that should be covered in a full one-way trip length. Include (your personal) UNITS!

5) *** In your personal units, write down the greatest number of units by which you think your measurement might be off in either direction. That is, your answer to question (4) might be "11 fingernails". Your answer to this question, (5), might then be something like "+/- 3 fingernails." This +/- quantity is your most conservative estimate of measurement uncertainty. You may not know how to do this, or you may know a way that we will not ultimately use in this course. Either situation is OK for now. The idea for now is to come up with your own creative but intelligent thought as to how far off your measurement might reasonably be in either direction. This is an estimate, but it's not random. You should have some solid logic for how you derived your estimate.

B. Dynamic Measurement: TIME.

1) You are now ready to begin some time-trials. Before measuring anything, let the glider undergo a number of one-way trips from one end. Place the glider at whichever end it cannot seem to sit still and get a feel until you observe the glider move as far as possible without hitting the other side. This is your basic trip. It will be measured in various ways, so make sure that this basic trip is essentially reproducible.

2) Once you're comfortable, allocate labor between you and your partner so as to maximize the accuracy of time measurements for a one-way trip.

3) Set up your personal clock and "start" it the instant a glider is released. "Stop" your clock the instant the glider reaches the bottom. You have taken a time measurement for a one-way trip.

4) *** Write down your time measurement for a one-way trip. Include (your personal) UNITS!

5) *** In your personal units, write down a conservative estimate for your time measurement uncertainty.

6) Repeat instructions (3) - (5) for approx. 3 different sections of this basic trip, for example: Half of the trip, a quarter of the trip, etc. YOU consider and design the most seemingly accurate way to obtain these different sub-trip measurements.

7) When finished, you will have written the distance and time measurements for approximately 3-4 different trip lengths.

8) *** For these different trips, set up a table of values in which you will record "distance", "time," "time uncertainty," "average speed" and "average speed uncertainty".

9) *** Now consider and apply the following definition:

$$AVERAGE\ SPEED \equiv \frac{TOTAL\ DISTANCE}{TOTAL\ TIME}$$

10) *** For each of your trips, compute the average speed of the car. This average speed should written down with units. In order to do and record this average speed computation, you will entirely ignore all the information about 'uncertainties.'

11) Given your uncertainty estimates for length and time, devise a means that you find reasonable for relating/combining the two uncertainties into a final one for average speed. At first, this will seem quite challenging. You will have to think about what you are trying to accomplish. You are recognizing that imperfections in your use of a ruler and imperfections in your use of a clock BOTH contribute to the ultimate imperfection in your determination of average speed. We might like to add both uncertainties together and thereby have some kind of total uncertainty. Addition is on the right track, but it cannot be quite that simple. Inches, for example, cannot be added to minutes. HINT: pure 'dimensionless' fractions (or decimals or percents) that don't have units CAN be added to other pure fractions…

12) *** Write down your best inference for the uncertainty in each of your average speed results. Make sure that somewhere you have clearly written down how you arrived at a value for uncertainty in the average speed.

IV. Computation: On Average, the Average Speed.

In your own personal units, write down and circle a clear, complete answer to the following question:

*** On average, what is the average speed of the glider as it travels down the track?

Note that the word "average" is used twice. This is not an accident. It is being used in two slightly different (but related) ways. Make sure you understand these uses before attempting to compute an answer. Your final answer will include (a number) followed by units +/- (another number) followed by the same units. It will look like the following example answer. This example has the correct form but arbitrary (and probably unrealistic) numbers:

Example: On average, $v_{av} \approx 35$ fingers/tick+/-2 fingers/tick.

V. WRITING THE REPORT -- A FORMAT REQUIRED FOR EVERY LAB.

A. The *Post-Lab*.

All responses to the 4 parts of every *Post-Lab* must be submitted on clean, separate sheets of paper. The *Post-Lab* must be headed with the names of all Lab Group members and each response must somehow make clear precisely what question it is intended to address. No other document or reading should be necessary in order for a reader to follow the meaning and sense of a properly completed *Post-Lab*.

Post-Labs in Physics 203 have a very specific four-part format. Each part is graded out of 2.5, for a total possible score of 10.0.

The ***Post-Lab*** is designed to help you write your ***Formal Report.*** Therefore, you should always complete post-lab *first*, AS A GROUP, *then* work on the ***Formal Report***. If you don't have time to work as a group on the post lab, then we STRONGLY RECOMMEND that each group member complete it on his/her own; that way, the group can compare answers remotely. If the group is not in agreement on the ***Post-Lab***, it will be unable to write a good ***Formal Report***, and any group member who has not worked on the ***Post-Lab*** is not prepared to work on the ***Formal Report***.

For this first Physics ***Post-Lab***, we will now walk through each of the four different parts and explain how it works. At the end of each explanation, the specific Post-Lab question for THIS LAB (Lab #1) is presented in a different typeface and introduced by the phrase <u>WHAT TO DO FOR THIS PARTICULAR (Lab #1) POST-LAB</u>.

ON CLEAN SHEETS OF PAPER, PLEASE ANSWER THE FOUR QUESTIONS FOUND IN THE FOLLOWING PAGES. THIS IS YOUR POST-LAB.

In future labs, you will simply be given the four particular questions and expected to know how to approach them. They will be of the same four types every lab.

1. *Epistemological Table.*

BACKGROUND EXPLANATION.

From now on in this lab course, there are five basic types of knowledge with which we are primarily concerned. We might engage in hearty and reasonable debates as to which type applies to a given ***claim*** (statement, proposition, assertion, sentence), and it might even be the case that some claim might fall into some sort of intriguing combination of more than one type, but the following types nonetheless provide a clarifying guide for thinking about how we know what we think we know. The five basic ways in which we tend to build laboratory physics knowledge are, put another way, five common processes or undertakings: Claims that we tend to treat with a reasonable amount of confidence or trust seem, in general, to be generated by one of the five sources listed below.

Note! A claim is a <u>full statement</u>; a claim is expressible as a complete sentence of English, and must therefore contain both a subject *and* a predicate.

If we feel that we ***know*** the truth of some ***claim*** made in the physics lab, then chances are good that some physical objects or some words and/or numbers have been previously

- Measured (Observed),
- Defined,
- Derived,
- Calculated or
- Postulated

The following table captures three examples for claims that played an important role in physics Lab #1.

WHAT TO DO FOR THIS PARTICULAR (Lab #1) POST-LAB:

Choose among the five categories listed above and elaborated in the general explanation for ***Post-Labs***—in order to reproduce and complete this table.

Claim	Type of Knowledge
The glider for Lab Group ***F*** traveled 23 index cards.	
Gliders on cushions of air tend not to sit stably.	
Average speed = $\frac{\text{total distance}}{\text{total time}}$	

2. ***Research Design Chart.***

BACKGROUND EXPLANATION.

The chart begins with your ***Research Question*** and shows how you proceeded from data collection methods all the way toward an answer for that ***Research Question*** (***RQ***).

Note: For this and all future ***Post-Labs***, you need only select ONE particular ***RQ*** and one particular data thread for depiction in a ***Chart***.

RQ: ??

A measurement you took in the lab	→	Some analysis you did on that measured quantity	→	A conclusion you drew from that analysis	→	How that conclusion helps answer that research question?

Example:

<u>Example</u>

RQ: how does changing the volume of a chamber affect the temperature of a the gas inside the chamber?

We measured the length of the base of the box and got 5 cm	→	We multiplied this value by the width of the base of the box: 5cm×6cm	→	We concluded from this that the area of the base of the box was 30cm^2	→	Knowing the area of the base helped us find the volume which we needed to answer the RQ.

<u>WHAT TO DO FOR THIS PARTICULAR (Lab #1) POST-LAB</u>:

Using the model provided by two figures above, make a *Research Design Chart* that applies specifically to what you did in Lab #1.

3. ***The Counter-Factual*.**

BACKGROUND EXPLANATION.

At this point in the semester, we let this portion of the ***Post-Lab*** speak for itself. It is simply a question or small set of questions that asks you to consider the implications of something that most probably did NOT happen in your laboratory experience. Though it might seem as though we are asking you to waste thought or time on a non-sequitur (to something entirely unrelated to the issues at hand), we are not.

In fact, we are asking you to identify, scrutinize, test or possibly challenge some kind of reasoning that is central to the lab—and therefore to the ***Formal*** Lab ***Report***.

WHAT TO DO FOR THIS PARTICULAR (Lab #1) POST-LAB:

In complete sentences of English, answer the following questions:

Imagine that you arrive late for Lab #1. It is such a blazingly hot August day in NYC that the laboratory air conditioner is broken and you find everybody doing the lab outside. Your group has decided to use an ice cube as their unit of distance measurement. For the purpose of this *counter-factual* assignment, let the imaginary group be known as the "Hot Group". The actual lab group with whom, in real life, you actually worked shall be known as the "Cold Group".

a. **How might the *Hot Group*'s answer to RQ #1 compare to the *Cold Group*'s answer to RQ #1? How might the *Hot Group*'s answer to RQ #2 compare to the *Cold Group*'s answer to RQ #2?**

b. **Imagine that the *Hot Group* deliberately tilted their track at a dramatically steep angle and then measured distance and time. How might their answer to RQ #1 compare to what it was when the track was still essentially horizontal? Would you consider their response to RQ #1 more reliable than their response to a horizontal track? Less reliable? Equally reliable? Why?**

4. ***The Wild Card.***

BACKGROUND EXPLANATION.

There is no Background Explanation for something called a ***Wild Card***. We claim that you know that. Please see option (row) #2 for the ***Epistemological Table***, Part 1 of the Post-Lab.

WHAT TO DO FOR THIS PARTICULAR (Lab #1) POST-LAB:

In complete sentences of English, choose and answer ONE of the following questions.

(1) If the average speed of a glider were to *change* while it traveled along an air track, might there be any kind of steady quantity or specific knowledge on which we could rely – in order to ***predict*** how far away the glider would be after a certain amount of time?

(2) In complete sentences of your own English words, what is the difference between knowing that one of your measurements is ***erroneous*** versus knowing that one of your measurements is ***uncertain***. Is it possible for a measurement not to be ***erroneous***? Is it possible for a measurement not to be ***uncertain***?

HOW DO YOU KNOW?

1. The ***Formal Report.***

Overview.

The ***Formal Report*** is a complete scholarly accounting of everything you did for a particular laboratory investigation and why. All sections of this ***Formal Report*** are ultimately directed toward the answering of a ***Research Question*** (or, in some cases, up to three related ***Research Questions***): The ***Formal Report*** explains to any and all uninitiated readers precisely how and why a set of data was collected, by what means these data were analyzed, and in what way this analysis—within a specified range of measurement uncertainty—led to a finding that, finally, answered the ***Research Question***.

This ***Formal Report*** is composed and presented in the manner of a research physicist submitting her experimental findings to a ("peer-reviewed") journal. The ***Formal Report***, that is, is formal in the following fundamental sense: Imagine that an intelligent and interested reader is randomly selected from far outside the context of all John Jay syllabi, discussions and experiences; this reader, although familiar with general scientific research, might not even know any physics. Such a reader, with no specific background nor supplementary explanations, should be able to use a properly written ***Report*** in order to reproduce our methods and pursue his own answer to the self-evidently meaningful ***Research Question*** found within. A strong ***Formal Report*** is, in principle, ready for publication.

a. Specific Format and Sequence of Sections: In BRIEF

i. Title Page,
ii. Abstract,
iii. Introduction,
iv. Research Question,
v. Data Collection: what you measured and how you measured it: similar to that which is sometimes known as *Materials & Methods*,
vi. Diagram: not a photograph: an original rendering of your experimental design, fully labeled with all variables & constants,
vii. Analysis: a thorough step-by-step narrative that both quantitatively and qualitatively explains how a trend, relationship and/or generalized finding was ultimately inferred from the data,
viii. Uncertainty: a precise explanation of the uncertainty associated with each individual (type of) measurement as well as a meaningful application of the combined uncertainty for all measurements taken together,
ix. Conclusion: a clear, concise and final answer to your Research Question(s), explicitly including uncertainty.
x. Appendices.

b. Sections explained in greater detail.

1) Title Page.

Title of Lab
Date
Lab Section Number
All members of Lab Group: Listed in alphabetical order by last name.

2) Abstract.

One paragraph. A clear, concise yet quantitative summary of what you did and found in your experiment. It is a distillation of (headline for) the whole document to come. Put another way, the abstract is an expansion of the conclusion. It is the reason anybody would want to turn the page and read the entire report. It can stand on its own as the "Sneek Preview" or "Readers Digest" version of your whole report: If you were to present your report at a conference, then the abstract would be advance printed in the conference literature. The abstract must explicitly contain the R.Q., the answer to the R.Q. and a couple to a few sentences summarizes the methods deployed in order to get from the former to the latter.

3) Introduction.

Also one paragraph. This one provides a brief bit of physics background: Which particular physics thoughts are treated as known but somehow provoking by the research team before they walk through the laboratory door? How do these assumptions lead to a curiosity that finds shape as a ***Research Question***. The introduction section offers a bit of freedom to place the entire report into some kind of helpful context. The specific context might vary from lab group to lab group, but, no matter what, the introduction must and will always culminate in an explicit statement of the Research Question.

4) The Research Question.

Pose a clear and direct question that best captures the curiosity your investigation seeks to address: the question toward which all your planning, tinkering and thinking were ultimately pointing. Your question should be as concise as it can possibly be, but it does have to make sense on its own. The report starts and ends with the question. Colleagues read your report in order to understand what you found to be the answer and how: Nobody should have to read the report in order to understand the question in the first place. The question itself, therefore, must mention any conditions/context in which it operates. The question, moreover, must somehow be of generalized interest or at least generalizable application. We can all grow curious about some one-shot-deal particular instance of something that suddenly demands our attention, like a well-timed 3-point shot in the local high school basketball championship, but we would find it quite challenging to raise a question of global interest and reproducibility about that one specific event.

A constructive ***Research Question*** generally asks about a relationship between two quantities—one that we alter deliberately and continually (the ***independent variable***) and one that we observe in order to find out how nature tends to respond to such changes (the ***dependent variable***). In order to confine the scope and significance of these two variables, an implicit "if… then" usually underlies the question—whether or not the words "if… then" are actually used. "How fast does it go?" might be a question, for example, but it is NOT a ***Research Question***. Even, "How fast does a marble roll?" is not quite a ***Research Question***.

This is one example of a strong and realistic Research Question for Physics 203:

"Given a long and approximately smooth slide, how does the average speed of a rolling marble depend on the slide's angle of elevation?"

5) Data Collection.

Provide a thorough and specific narrative that explains in plain, fluid English what you actually did with your set-up: what measurements you took and how you related them to one another. Here, you will refer to specific numbers only insofar as they provide clear examples for your flowing explanation. You are focusing more on *types* of numbers (variables, constants, etc.) This explanation should be one that any reasonable person could read and follow. All the details of specific trials will be covered in your tables, graphs and other prior steps. Place all tables and graphs in 'Appendices' and refer to these appendices in your findings section.

6) Diagram.

Begin with a clearly labeled diagram of your experimental set-up. Any variable or constant to which you refer in your findings section must first be established as a label in the diagram. This is NOT a photograph of your apparatus. While you may certainly also provide captured images, you must first provide a hand-drawn or computer-created schematic that reveals just the essential elements of the set-up. It is your job to decide and convey what is important and therefore worthy of a label: such as an algebraic variable or constant.

7) ANALYSIS

Analysis is the central **core** of your entire narrative. If the ***Research Question*** is thought of as two bookends (framing the entire report in between the ***Abstract*** and the ***Conclusion***), then ***analysis*** comprises the books themselves. It is generally the most difficult and the most important to write. Asking one member of a lab group to write the entire analysis is an extremely unwise strategy—one that demonstrates a fundamental misunderstanding of labs and lab reports in general.

The ***analysis*** section is a written communication of the **thinking** that brought your research team from a bunch of seemingly disconnected raw measurements (dots on a page) all the way to some general discovery about the world. Of everything you do in the laboratory, this type of dot-connecting most closely resembles that which you will have to do in order to prepare for and take physics exams. Your narrative began with a description of measuring procedures and measurement results. Here, it will proceed to a discussion of how/why all these numbers mean anything with regard to one another. Such apparent meaning and connection is that which allowed the R.Q. to be experimentally tested in the first place. So, the analysis (body of the report) is where you show everything that you did with, for and from the measurements you made. This is the part where raw numbers evolve into thoughts, relationships and results.

Here, you will establish and use mathematical equations. Center every equation on its own line of text. Never use an equation unless every term has been explained (by means of the diagram) and unless the relationship is also developed in CLEAR ENGLISH.

8) Uncertainty.

Fully discuss the minimum systematic uncertainty associated with each measurement. Then show how these uncertainties combined to create one final uncertainty in your finding. Use this final uncertainty to relate your ultimate finding to your ***Research Question***. This section often provides the most challenge to students, but it is crucial. All measurements are associated with some amount of quantifiable uncertainty—even measurements made by computers. Uncertainty in measurement distinguishes experimental science from pure mathematics, pure philosophy and, indeed, pure drivel.

Compute and combine all uncertainties by the method explained in the first lab of both Physics 203 and Physics 204.

9) Conclusion (Finding).

Conclude with what you ultimately, finally found out (or learned, discovered, confirmed or emphasized) at the end of the laboratory investigation. This ultimate finding will generally (although not always) be a relationship between one variable and another. It will often be expressed as an equation. No matter what it is, the ultimate finding must be clearly explained -- both quantitatively (as a mathematical equation) and qualitatively (in words). THE CONCLUSION MUST EXPLICITLY ANSWER THE RESEARCH QUESTION(S). It must, moreover, include and make meaningful use of your uncertainty range. Your conclusion must ultimately communicate a finding, that is, that relied in some important way on physical experimentation, observation and measurement—on, that is, science. If there is no acknowledgment of uncertainty, then you have not answered a scientific research question. Quite possibly, rather, you have dissected some definitions. You might even have thrust into some theology. Most vexingly, though, you might have just flirted with some falsehoods. In physics, we can be comfortable not knowing what we think. But we would prefer not to think that we know what we do not. So don't be wrong. Just be uncertain.

Within a range of uncertainty,
conclude by answering your *Research Question*.

10) "Appendices" Section:

Here, you will include all graphs, data tables, supplementary diagrams, etc. You refer to them throughout your Methods & Findings section (for example, "see Appendix I: Graph of Spring Period vs. Spring Mass). By isolating all data and figures, your narrative becomes a far smoother reading experience than otherwise. Even graphs (etc.) that are vital to your analysis should be placed in appendices and then referred to at the appropriate time.