Physics 2BL:
Experiments in Mechanics and Electricity
Summer Session I, 2012

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Physics 2BL: Experiments in Mechanics and Electricity

TA Coordinator:

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Mondays 10am-12pm

MHA 2722 (Lab room)

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Lectures: TuTh 8-8:50pm

TAs	Tuesday/Thursday
9-11:50 am	Section: 747203 Chang Walsh A50
12-2:50 pm	Section: 747204 Chang Sheldon A51
3-5:50 pm	Section: 747205 Walsh Sheldon A52

Today's Lecture:

- Logistics
  - Schedule
  - Text book
  - Grading
  - Lab reports, HW…
- Course general introduction, overview
- Introduction to Experiment #1
  - Error and uncertainties
  - How to report results – significant figures

Course Logistics

- Please refer to **course web site**
- All announcements will be made there
  - All course materials posted there:
    - Lecture notes
    - Experimental Guidelines
    - Grading rubrics
    - HW assignments and Solutions
- Next slides contain details about:
  - **NOTE schedule! (do not miss the final exam – NO excuses)**
  - Text book
  - Grading policy
  - Lab reports and notebooks
  - Importance of homework exercises

=> If you have any special needs/issues, please come see me!!!!

Schedule

Lecture	Exp		Date	Lecture Topics		Assignment
1			July 3	**Course Overview** **Discussion of Exp 1 – Goals, setup** ***(Deduce mean density of the earth)***	Lab: Taylor:	**-Prepare for Quiz #1** **-Read chapters 1-3, HW 1**
2	1	A	July 5	Measurements, uncertainties. Statistical Analysis Intro to error propagation	Lab: Taylor:	-Analyze data for Exp #1 -Read chapter 4, HW 2
3		B	July 10	Discussion of Exp 2 – goals, setup (*Deduction of mass distribution*) Histograms & distributions	Lab: Taylor:	-Prepare for quiz #2 -Read chapter 5, HW 3
4	2	A	July 12	The Gaussian Distribution, Maximum likelihood, Rejected data, Weighted mean	Lab: Taylor:	-Analyze data for Exp #2 -Read chapters 6-7, HW 4
5		B	July 17	Discussion of Exp 3 – goals, setup (*Tune a shock absorber*)	Lab: Taylor:	-Prepare for quiz #3 -Read chapter 8, HW 5
6	3	A	July 19	Fitting Chi-squared test of distribution	Lab: Taylor:	-Analyze data for Exp #3 -Read chapters 9 & 12
7		B	July 24	Discussion of Exp 4 – goals, setup (*Calibrate a voltmeter*)	Lab: Taylor:	-Prepare for quiz #4 -HW 6
8	4	A	July 26	Chi-squared Covariance and correlation	Lab: Taylor:	-Analyze data for Exp #4 -
9		B	July 31	Final Exam Review	Lab:	-Prepare for final exam
10			August 2	**Final Exam** 8PM, York 2722		-Pick up graded work from TAs -Pick up final from LTAC

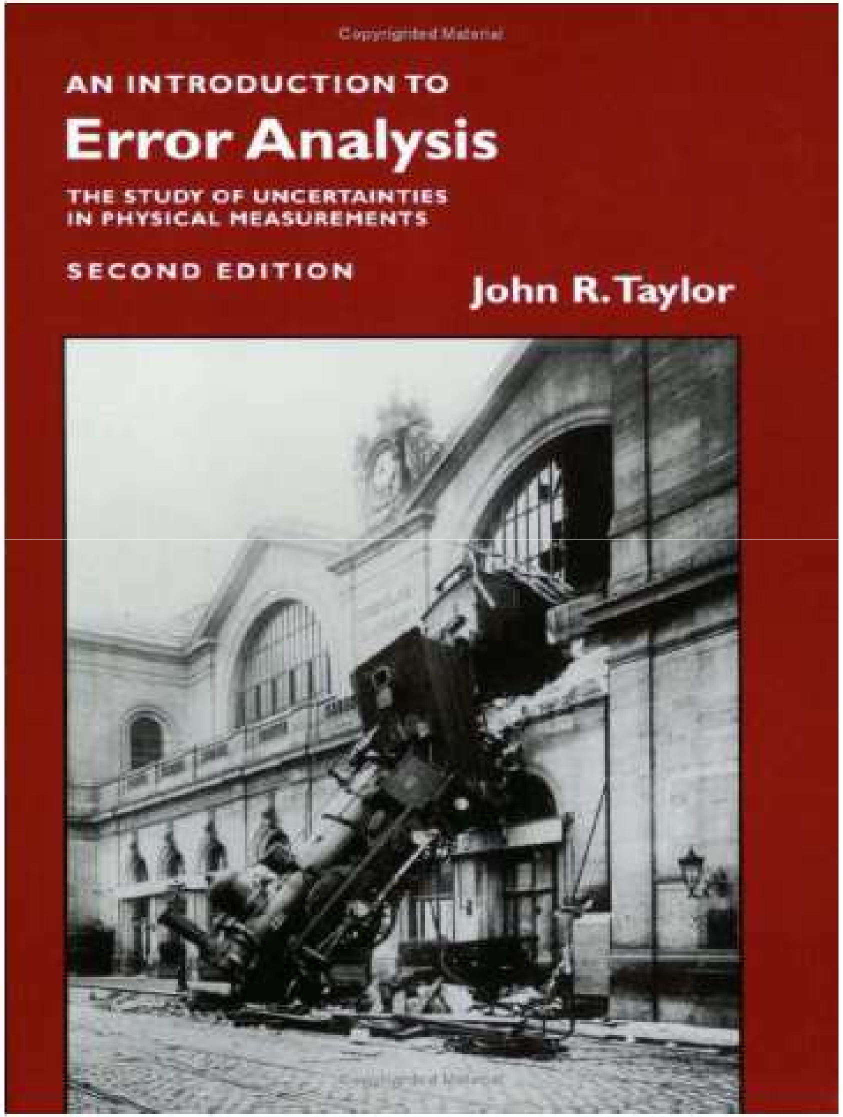
1st Quiz

2nd Quiz

3rd Quiz

4th Quiz

Readings - Text - Homework



Introduction to Error Analysis, by Taylor

No experimental information, but easy to read and contains very good info on how to handle data. Helpful with error analysis, conclusion writing…

Source of HW problems (very similar to final)

Many helpful examples!

Important physics background: *Fundamentals of Physics*, Halliday, Resnick & Walker 7th Ed.

Grading

- Quizzes 20%
- Lab Reports 40%
- Final Exam 40%
- (Extra credit) ≤5%

100%

- Preparation is key for labs!
- Time is limited, so be prepared to perform the experiment
- If you run out of time, plan to attend LTAC office hours
  - Mondays 10am-12pm

Details:

Quizzes (4) 5% each
(graded out of 10 points)

Quiz questions come directly from pre-lab & homework questions (perhaps with some numbers changed

Lab Reports (4) 10% each

Description of the experiment, diagram of apparatus, presentation of the data, error analysis, calculations, discussion and conclusions

Final Exam (1) 40%

Final will ask questions about the labs and similar to homework

Extra Credit ≤5%

Buy & register a clicker, participate

Grading Policy

- ABSOLUTE grading scale

≥95%	A+
≥90% & <95%	A
≥85% & <90%	A-
≥80% & <85%	B+
≥75% & <80%	B
≥65% & <75%	B-
≥60% & <65%	C+
≥55% & <60%	C
≥50% & <55%	C-
≥40% & <50%	D
<40%	F

Grade scale may be adjusted, but only in a way that benefits you (If everyone gets above 85%, everyone will get an A!)

Quizzes

- During first 15 minutes of session A
  - If you show up after the quiz has been collected, you will receive a "0"
- All questions are directly from HW/prelab
  - 2 prelab questions
  - 2 HW questions (w/ different numbers?)
- Open book/open notes
  - Office hours, email…
- No Makeups

Lab Reports & Notebooks

- Notebooks:
  - Write in PEN, be organized!!!!

-2.5 points for every day late!!!!

- Report (10 pts, 10% each)
  - Introduction (Objective, Essential Physics, Procedure)
  - Methodology (Apparatus, Equations)
  - Data/Observations (HOW did you estimate uncertainty?)
  - Calculations/Error Analysis/Results
  - Conclusions (dominant error source, discrepancy with published results, possible improvements)

See course web site (rubrics link) for detailed notebook guidelines

Homework Exercises

- Homework problems listed under the link "Homework & Solutions" on web site
  - Self graded: solutions will be posted on web page (after the quiz)
  - All problems are from Taylor
  - They will help you understand and practice new concepts

Solving them on your own will help you prepare for the quizzes & final!

Final Exam

- Administered during 10th lecture session
  - August 2nd
  - York 2722
- 4 problems
- Similar to HW, with some lab questions
- You will be allowed one (double sided) hand-written cheat sheet

How to do well?

- Complete recommended reading before lecture
- Show up to all lectures and labs (ON TIME!) and answer clicker questions

If you show up late you may be asked to attend a different section!

- Before each lab:
  - Review lecture slides
  - Read experiment guidelines
  - Answer all quiz questions within (bring to lab)
  - Do the homework (bring to lab)
- Analyze data before the second lab session
- Ask questions!
- Prepare for final by making your own cheat sheet

Academic Integrity

- Please read the section on UCSD Policy on Integrity and Scholarship in:

  http://www.ucsd.edu/catalog/front/AcadRegu.html

- Acknowledge your partner's contributions (write their name on your lab report)
- Do not plagiarize your partner's work
- **Collaboration** in important
  - Work on experiment in teams
  - Lab report must be written individually!
- If in doubt, *ask* your lab TAs/LTAC/me

End of logistics intro…

A different kind of lab course…

- Main goal: Introduction to data analysis, interpretation of data
  - Uncertainties associated with data from any physical source
  - Learn how to represent, deal with data
- Experiments: Intended to introduce you to physical measurement issues
- Basic, everyday knowledge crucial for scientists and engineers

Course Structure

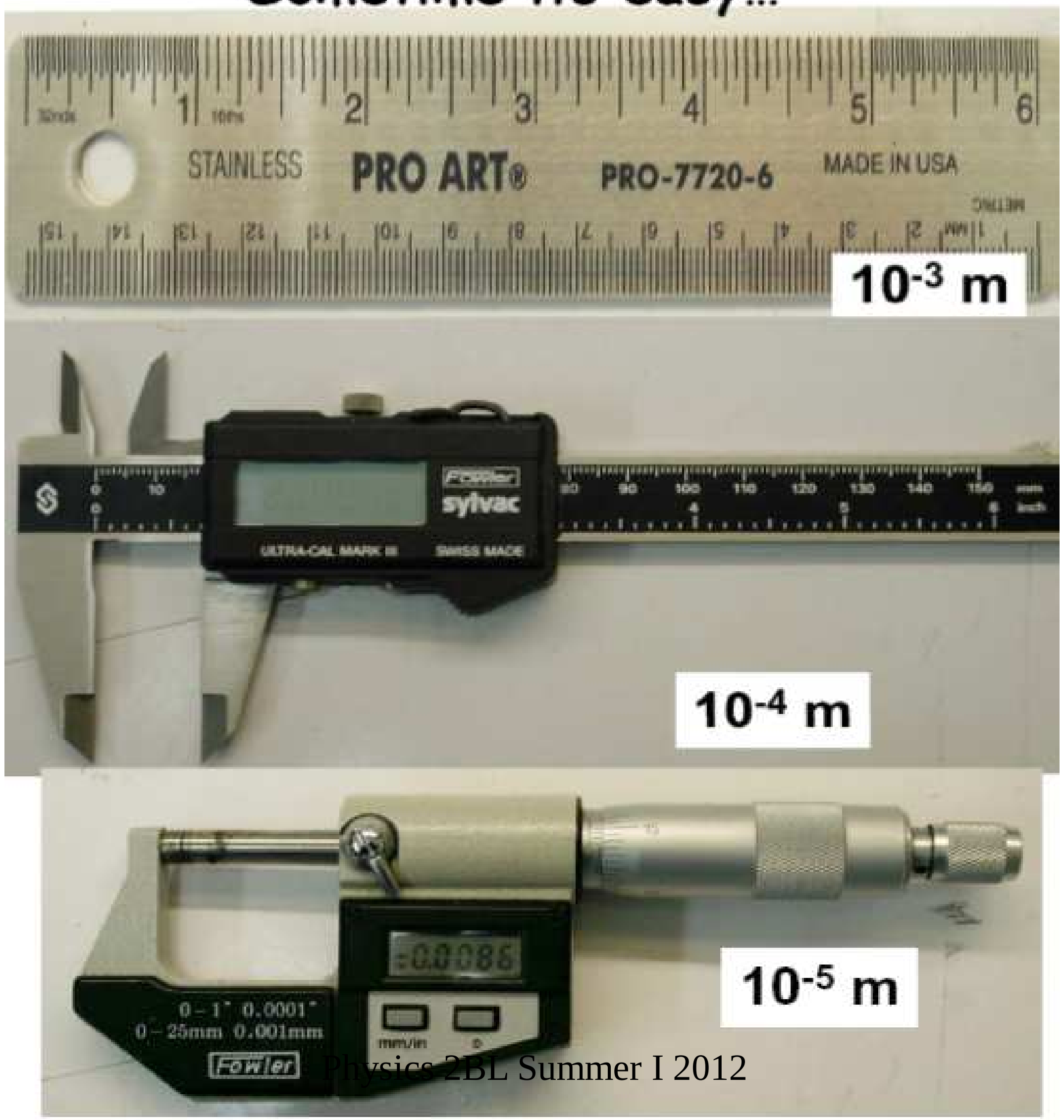
- 4 experiments, two lab sessions per experiment
  - Session A: Take all measurements
  - Session B: finish and turn in lab reports
- One lecture before each experiment begins
  - Experimental goal? What do we measure?
  - Experimental issues
- Second lecture before lab report is due
  - Focus on interpretation of the data
    - Error Propagation
    - Introduction to statistical analysis

What is uncertainty (error)?

- Uncertainty (or error) in a measurement is not the same as a mistake
- Uncertainty results from:
  - Limits of instruments
    - finite spacing of markings on ruler
  - Design of measurement
    - using stopwatch instead of photogate
  - Less-well defined quantities
    - composition of materials

Uncertainties in devices (single measurement)

Sometime its easy…

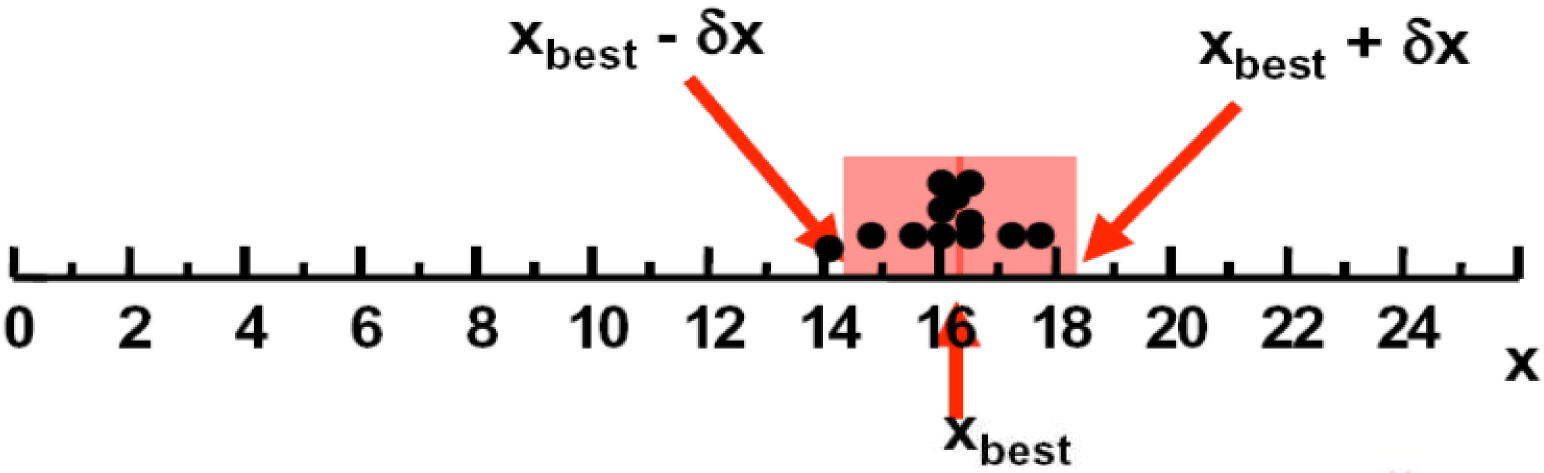


Determine range of values from multiple measurements

Statistically - Take a few measurements of some variable x

1. Find the most likely value - "best"
2. Estimate the spread - uncertainty

$$x = x_{best} \pm \delta x$$



The Four Experiments

- **Determine the average density of the earth**

Weigh the Earth, Measure its volume

– Measure simple things like lengths and times

– Learn to estimate and propagate errors

- **Non-Destructive measurements of densities, inner structure of objects**

– Absolute measurements *vs.* Measurements of variability

– Measure moments of inertia

– Use repeated measurements to reduce random errors

- **Construct and tune a shock absorber**

– Adjust performance of a mechanical system

– Demonstrate critical damping of your shock absorber

- **Measure coulomb force and calibrate a voltmeter.**

– Reduce systematic errors in a precise measurement.

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Experiment 1, Density of the Earth: Basics

Gravitational force

$$F = \frac{GM_e m}{r^2}$$

At surface…

$$mg = \frac{GM_e m}{R_e^{\ 2}}$$

Mass of Earth

$$M_e = \frac{gR_e^{\ 2}}{G}$$

$G = 6.673 \times 10^{-11}$ m^3/kg s^2

Determine using pendulum

Assuming a sphere with uniform density…

$$\rho = \frac{M_e}{\left(\frac{4}{3}\pi R_e^{\ 3}\right)} = \frac{3g}{4\pi G R_e}$$

What is the value of g?

What is the radius of the earth?

Determine by walking to cliffs

Measure Earth's Radius using Δt Sunset

From right triangle $L^2 + R_e^2 = (R_e + h)^2$

h - height above the sea level

L - distance to the horizon line

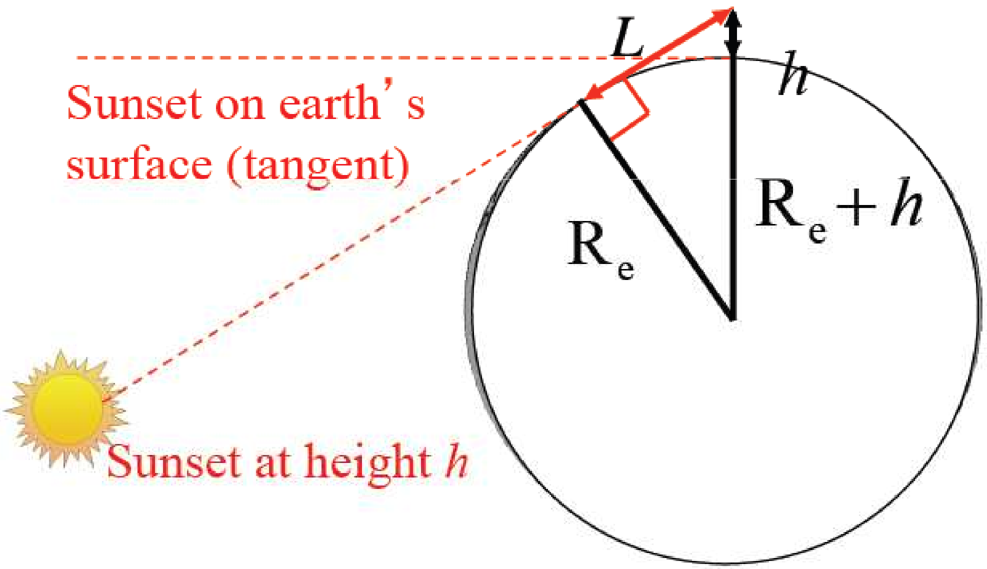
$$L^2 = 2R_e h + h^2 \approx 2R_e h \qquad L \approx \sqrt{2R_e h}$$

How do we convert the distance to the horizon line, ***L***, into the sunset time delay, ***t*** ?

The length of the earth's circumference, $2\pi R_e$ corresponds to a time delay of $T = 24\,\text{hr}$

Therefore,

$$t = \frac{L}{2\pi R_e} T = \frac{T}{2\pi}\sqrt{\frac{2h}{R_e}}$$



Is this time delay measurable?

Measure Earth's Radius using Δt Sunset

Now, is this time delay measurable?

h - height above the sea level

L - distance to the horizon line

$$t = \frac{L}{2\pi R_e} T = \frac{T}{2\pi}\sqrt{\frac{2h}{R_e}} \quad \left(\frac{T}{2\pi} = \frac{1}{\omega}\right)$$

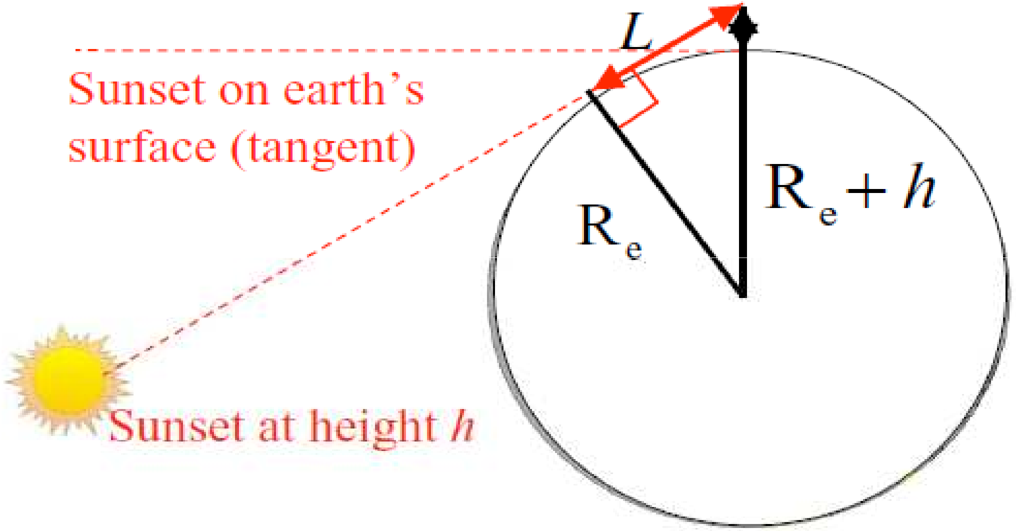
$$T = 24\,\text{hr} = 24 \cdot 60 \cdot 60\ \text{s}$$
$$= 86400\ \text{s}$$

$$R_e = 6{,}000{,}000\ \text{m}$$

$h \sim 100$ m - our cliff

$$t = \frac{86400\ \text{s}}{2\pi}\sqrt{\frac{200}{6\times 10^6}} \approx 80\ \text{s}$$

Looks doable!



Have we forgotten something?

Correct for our latitude and for the angle of the earth's axis from the plane of its orbit

The Equation for Experiment 1

To correct for lattitude, introduce C

$$t = \frac{1}{\omega}\sqrt{\frac{2Ch}{R_e}} \qquad \left(\omega = \frac{2\pi}{24hr}\right)$$

(t relative to sunset at horizon)

Time difference between the 2 sunset observers:

$$\Delta t = t_1 - t_2 = \frac{1}{\omega}\sqrt{\frac{2C}{R_e}}\left(\sqrt{h_1} - \sqrt{h_2}\right)$$

Season dependant factor (slightly greater than 1)

$$C = \frac{1}{\cos^2(\lambda)\cos^2(\lambda_s) - \sin^2(\lambda)\sin^2(\lambda_s)}$$

You will measure Δt outside of lab with your partner!

Height of cliff

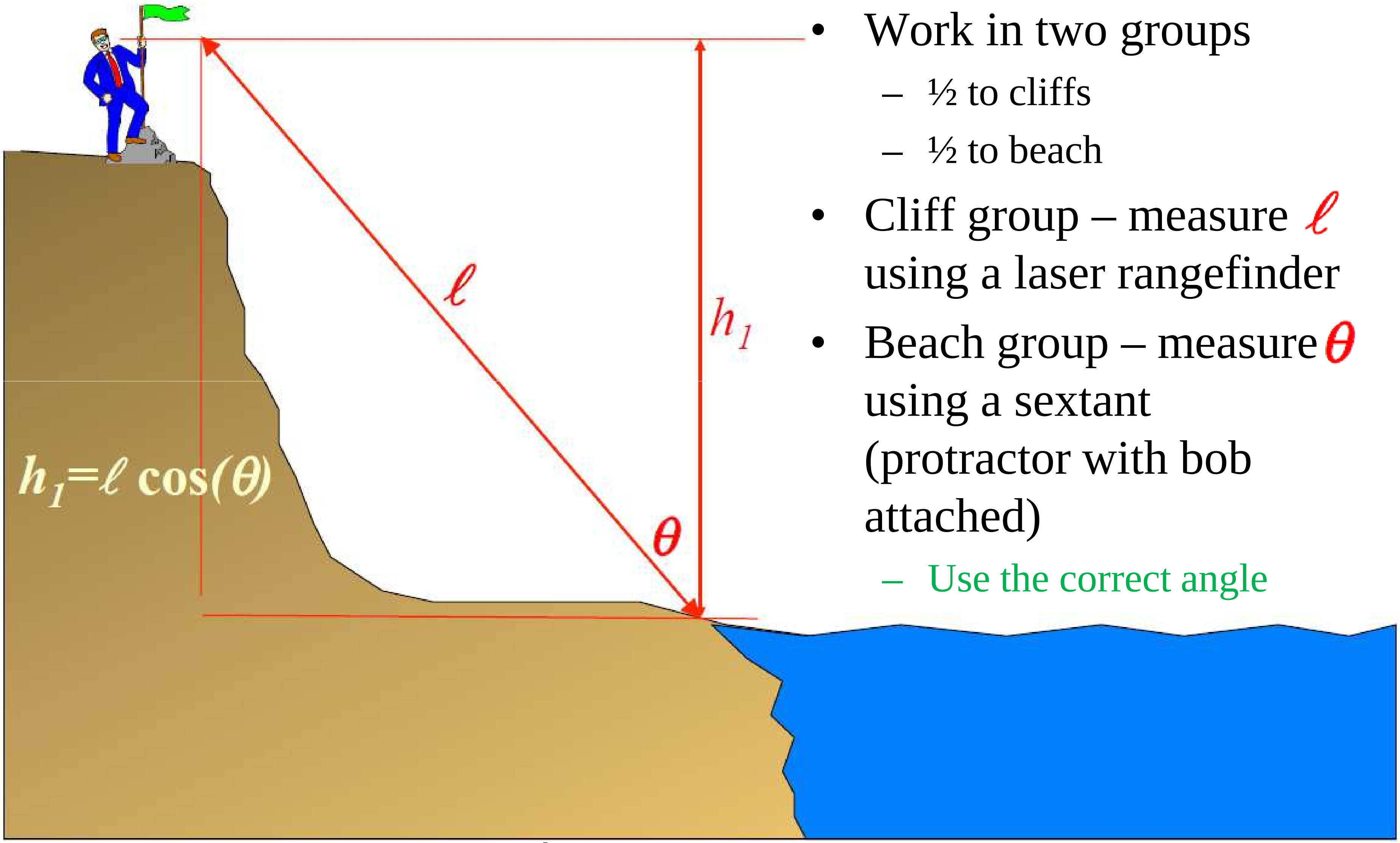
Height of person

The formula for error analysis:

$$R_e = 2C\left(\frac{\sqrt{h_1} - \sqrt{h_2}}{\omega \Delta t}\right)^2$$

Time between sunsets

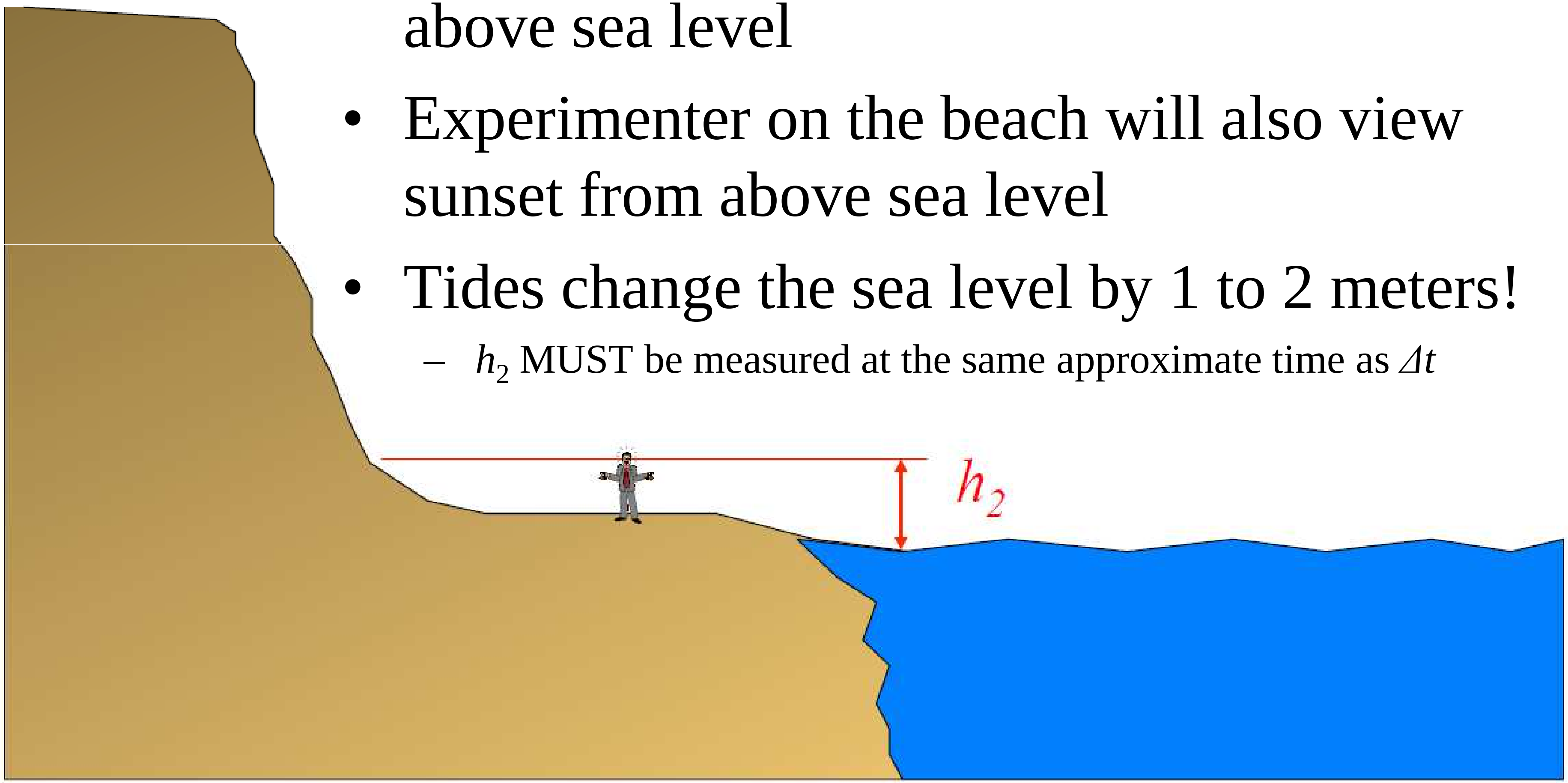
Measuring the Height of the Cliff



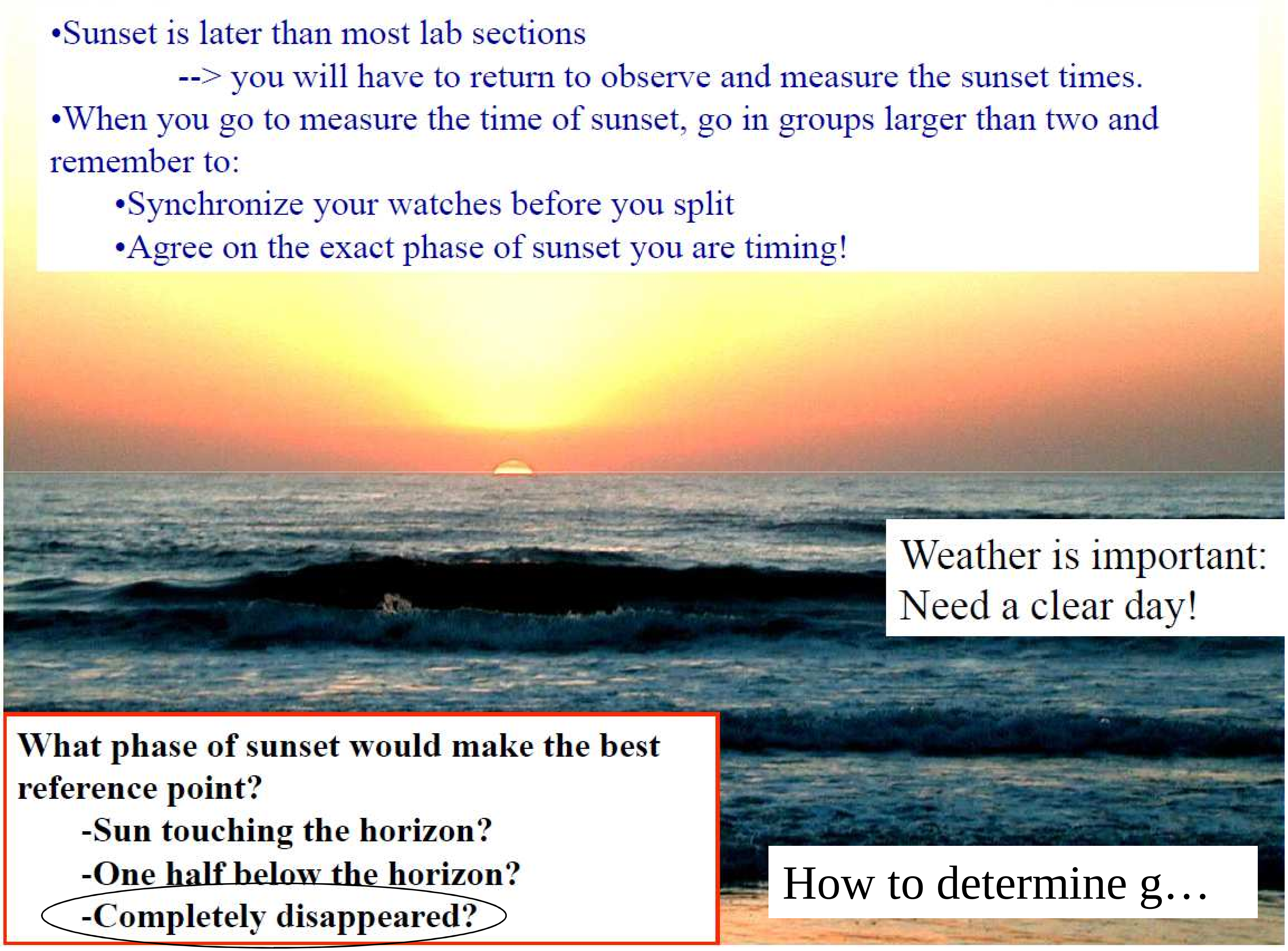
- Work in two groups
  - ½ to cliffs
  - ½ to beach
- Cliff group – measure ℓ using a laser rangefinder
- Beach group – measure θ using a sextant (protractor with bob attached)
  - Use the correct angle

Measuring your height above sea level on beach

- The formula for Earth’s radius is for height above sea level
- Experimenter on the beach will also view sunset from above sea level
- Tides change the sea level by 1 to 2 meters!
  - h_2 MUST be measured at the same approximate time as Δt



Cliffs west of Muir Campus (not to scale)



•Sunset is later than most lab sections

--> you will have to return to observe and measure the sunset times.

•When you go to measure the time of sunset, go in groups larger than two and remember to:

- •Synchronize your watches before you split
- •Agree on the exact phase of sunset you are timing!

Weather is important:
Need a clear day!

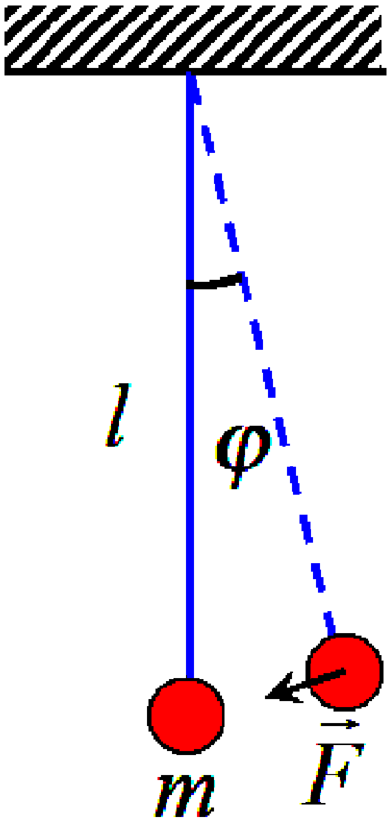
What phase of sunset would make the best reference point?

- **-Sun touching the horizon?**
- **-One half below the horizon?**
- **-Completely disappeared?**

How to determine g…

Measure g with simple pendulum

Ideal simple pendulum is a point mass on the end of a massless, perfectly flexible string, suspended from a rigid support



$$F = -mg\sin\varphi = ma$$

$$a = \frac{dv}{dt} = l\frac{d^2\varphi}{dt^2}$$

$$-g\sin\varphi = l\frac{d^2\varphi}{dt^2}$$

Measure g with simple pendulum

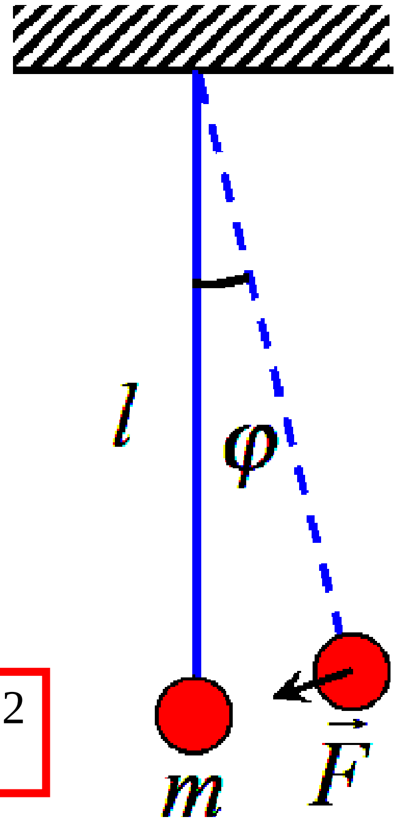
Don't know how to solve EOM: $-g\sin\varphi = l\dfrac{d^2\varphi}{dt^2}$

Simplify with small angle approx: $\sin\varphi \approx \varphi$

EOM simplifies

$$l\frac{d^2\varphi}{dt^2} + g\varphi = 0$$

$$\frac{d^2\varphi}{dt^2} + \omega^2\varphi = 0 \qquad \omega = \sqrt{g/l}$$



Harmonic oscillator with frequency ω,

and period $T = 2\pi\sqrt{l/g} \longrightarrow \boxed{g = 4\pi^2 l/T^2}$

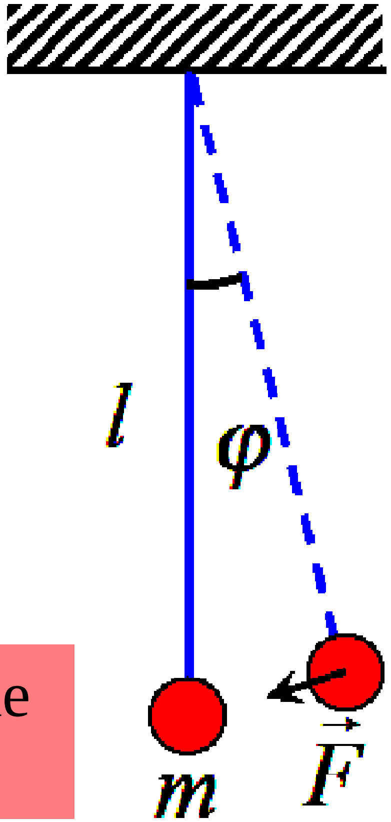
Experimental Considerations

What assumptions have been made

$$T = 2\pi\sqrt{l/g}$$

$$g = 4\pi^2 l/T^2$$

- ***m*** is a point mass: measure ***l*** from pivot point to center of mass
- String is massless: choose a string material and pendulum bob so that the mass of the string is "negligible"
- The angle is small (period will be constant unless the angle is too large)
- Rigid, stable support (clamp to table!)



Important: Start calculations at home, before the second lab session

Stating the Result of a Measurement with Correct Significant Figures

Best estimate ± Uncertainty

- The correct way to state the resultant of any measurement is to give your best estimate of the quantity *and* the range within which you are confident the quantity lies:

  Best estimate ± Uncertainty

  or: $x \pm \delta x$

Example: $\boldsymbol{l}$ = 1.7 ± 0.2 cm means

-your best estimate for the length is 1.7 cm

-you estimate its length could be b/n 1.5 and 1.9 cm

Proper Sig Figs

Be sure you understand the rules! You **WILL** miss points on lab reports, quizzes, & the final for not using proper sig figs!

Experimental uncertainties should almost always be rounded to ONE significant figure!

NOTE: The exception is when that sig fig is equal to 1, then keep two sig figs

Measure L = 13.4 cm, estimate uncertainty to be ¼ cm…

L = 13.4 ± 0.25 cm – WRONG

L = 13.4 ± 0.3 cm – **RIGHT!**

Calculate g = 9.85 m/s^2, uncertainty to be 0.095 m/s^2 …

g = 9.85 ± 0.1 cm – WRONG

g = 9.85 ± 0.10 cm – **RIGHT!**

The last significant figure in the best estimate should be in the same decimal position as the last (or only) decimal position of the uncertainty

Measure θ = 25.75°, estimate uncertainty to be 2°…

θ = 25.75 ± 2° – WRONG

θ = 26 ± 2° – **RIGHT!**

Homework

Read Taylor chapters 1 - 3

Prelab problems for Exp 1

HW1: Taylor problems 2.1, 3.10, 3.28, 3.36