PHYSICS 2DL – SPRING 2010

MODERN PHYSICS LABORATORY

Prof. Brian Keating

Mayer Hall Annex 5621

Monday March 29, 2010

UCSD

UCSD

2DL

- EXPERIMENTAL TECHNIQUES
- "MODERN PHYSICS" EXPERIMENTS
- STATISTICAL ANALYSIS OF SCIENTIFIC DATA
- Considered by many to be the first really fun class in physics!

Today's Plan

- Highlights of the course syllabus
- Lab Manual
- Grading
- Labs
- Textbook and Homework
- Exams
- Introduction to Error Analysis or:

  "How to Lose a Nobel Prize..."

Rough Schedule

- Last day to add a class: Friday, April 9
- Last day to drop a class w/o a W & change grade option: Friday, April 23 [?] CHECK
- Last day to drop a class w/o an F: Friday, May 28 [?] CHECK
- Memorial Day, no lecture Monday May 31
- Final Exam: Thurs. June 10 1130am, Location TBD

Labs Done This Quarter

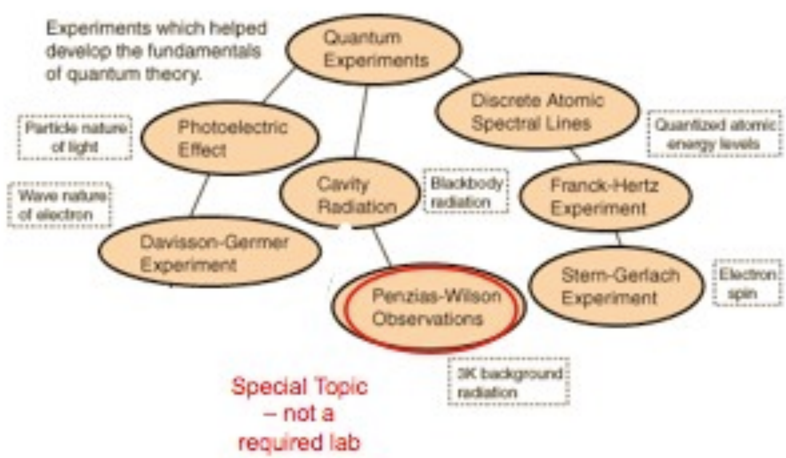
A. Using lab hardware & software

B. Analog Electronic Circuits (resistors/capacitors)

Then, in no particular order:

1. Diffraction of light
2. Interference of light
3. Photoelectric effect
4. Charge to mass ratio of the electron
5. Electron-atom scattering
6. Electron-diffraction

Fundamentals of Modern Physics



Labs Done This Quarter

1. Diffraction of light: wavelike properties of light
2. Interference: Coherence Properties of light
3. Photoelectric effect: particle properties of light
4. Charge to mass ratio of the electron: interactions between particles and fields
5. Electron-atom scattering: interaction of light and matter
6. Electron-diffraction: wavelike properties of matter

Max Planck on Experimentation

"An adult will perform an experiment and, if the results conform to their predictions, they will move on.

A child will repeat the experiment, again and again, just to have a taste of the initial thrill felt when the experiment was first performed."

Reports

- See 'Ace your Reports' in the syllabus
- See 'Lab Report Template' on 2DL website
- Include data, plots
- Template placed on course website
- Few pages of text
- Try to keep under 3 full typed pages.

Recommendations

- Get to know your TAs well!
- Don't miss labs completely – must make up before next lab
- Do the homework – graded.
- Learn how to use oscilloscope – read in lab manual -- BEFORE first lab

☹ Policies ☹

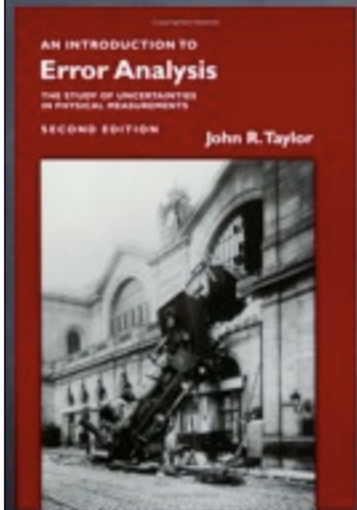
- Missed labs: Data CAN'T be copied!
- Avoid missing labs at all costs! If you must miss one, please email me and your TA to schedule a make-up.
- Must attend make up lab, take data YOURSELF, and write up labs. Missing, Copying data and/or reports will result in 0 points for that lab.

Lab Manual

Download from 2DL website

Printout before each lab.

TEXT



"Introduction to Error Analysis", by Taylor
No experimental information but good intro on how to handle data once your experiment produces some...
Full of Homework problems and helpful examples

Homework

- Problems listed on 2DL Spring 2010 syllabus.
- All problems are found in Taylor
- Hand-in HW to TA in Lab as on schedule

Grading

Grading Policy:

Lab Work 65%
Final Exam 25%
Homework 10%

Each Lecture Class

- Statistics
- Intros to experiments (2nd and 3rd weeks)
- *You* start doing the labs in week 4.
- Example problems, where appropriate

Spring 2010 Lab TAs - Physics 2DL

Lab Sections (Tuesday 12:30p & Wednesday 1p, 3 hours long)

Monday 1 - 1:50pm	Tuesday 12:30-3:20	Wednesday 1:00-3:50	Thursday 12:30-3:20
	LAB		LAB
LECTURE	LAB	LAB	LAB
	LAB	LAB	LAB
		LAB	

Labs in Mayer Hall Annex

Labs in Mayer Hall Annex

Maria Mayer

- **Maria Goeppert Mayer** was born on June 28, 1906, in Kattowitz, Upper Silesia, then Germany, the only child of Friedrich Goeppert and his wife Maria, nee Wolff. On her father's side, she is the seventh straight generation of university professors.
- In 1960 they came to La Jolla where Maria Goeppert Mayer is a professor of physics. She is a member of the National Academy of Sciences and a corresponding member of the Akademie der Wissenschaften in Heidelberg. She has received honorary degrees of Doctor of Science from Russel Sage College, Mount Holyoke College and Smith College.

What do you need?

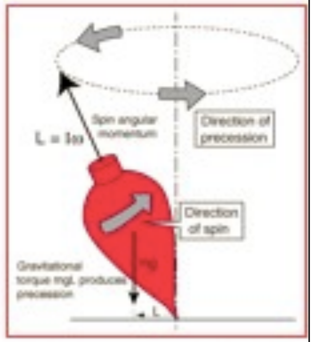
- Introduction to the experiments (2nd and 3rd weeks)
- You start doing the labs in week 4.
- Buy 2 Notebooks (lab): Same as 2CL

•Two 7 7/8 x 10 1/8 quadrille ruled notebooks

•You will work with one notebook while the other one is being reviewed by the TA.

Experiments by Richard Feynman (9/26/1961)

- Test of all knowledge. sole judge of 'truth'. Everything is always judged by experimental truth."
- Experiments give 'hints' of scientific laws
- Harder than theory in many ways.
- Experiments provide data. Then you revise theory, then retest with new experiment
- Theory: imagine, guess at laws of nature. Often "wrong".
- Experiments: Rarely wrong. How can it be wrong? Only by being inaccurate. Example: spinning top. Mass constant for low speed. 100 miles/second, mass changes less than 1 part in 1,000,000.



ERROR ANALYSIS

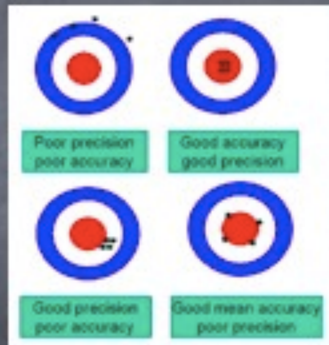
- Quantifying uncertainty in experimental measurements is the difference between science and fortune telling!

Crucial for all areas of science :

- Physical Science
- Biological Sciences -- Epidemiology
- Social Science – Psychology
- Engineering

What is "Error Analysis"?

- **a. Precision.** This is a measure of repeatability, i.e. the degree of agreement between individual measurements of a set of measurements, all of the same quantity.



- **b. Accuracy.** This is a measure of reliability, and is the difference between the True Value of a measured quantity and the Most Probable Value which has been derived from a series of measures. The True Value is, of course, never known.

- **c. Resolution.** This is the smallest interval measurable by an instrument.

Types of Errors

- **Blunders** - These may occur at any time, and are caused by carelessness on the part of the observer,, e.g. misreading an instrument, incorrect booking, incorrect computer input, etc. Blunders will always occur sooner or later, but must never be allowed to occur undetected.

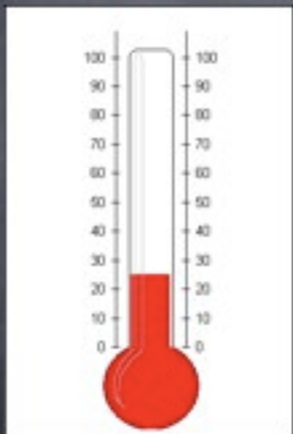
- **Constant Errors** - Errors of constant magnitude and sign, e.g., standardization error of a tape. sometimes they cannot be completely eliminated, e.g. standardization error.

- **Systematic Errors** - Errors of varying magnitude but constant sign, eg misalignment of a tape.

- **Periodic Errors** - Errors of varying magnitude and sign, but obeying some systematic law. They tend to be reduced or eliminated by repetition of observations under different conditions.

- **Random Errors** - These are all the remaining errors, are of varying sign and magnitude, and do not obey a systematic law. They are usually small, equally likely to be positive or negative, and are numerous. They will always be present in any observations and are caused by imperfections in the observer and instrument, and by varying conditions for the observations.

Physical Measurements



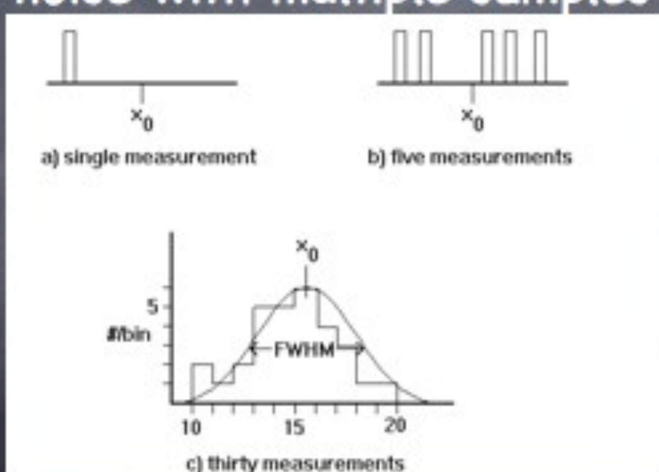
Treatment of Errors

- **Constant and Systematic Errors** are of fixed sign. They are therefore particularly troublesome in taping and leveling. Even if the errors are very small, they are cumulative and can easily become significant. Their effect cannot be reduced by repetition of observations.
- **Periodic and Random Errors** are of varying sign. Their effect is therefore reduced by taking the mean of repeated observations. No matter how large they are in each observation, the mean can be made more precise by taking more observations.

Correctable Errors

- **Random Errors**
- Measurements must be normally distributed
- Each measurement is independent of any others in the data set
- Accurate determination of standard error may not be possible for small datasets.
- **<u>Characteristics:</u>**
- Small errors occur frequently and are therefore more probable than large ones.
- Large errors happen infrequently and are therefore less probable; very large errors are likely to be blunders rather than random errors.
- Positive and negative errors of the same size are equally probable and happen with equal frequency.

Random Errors: Reduction in noise with multiple samples



And now….

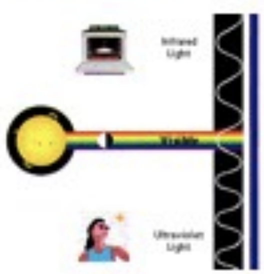
- My nightmare….

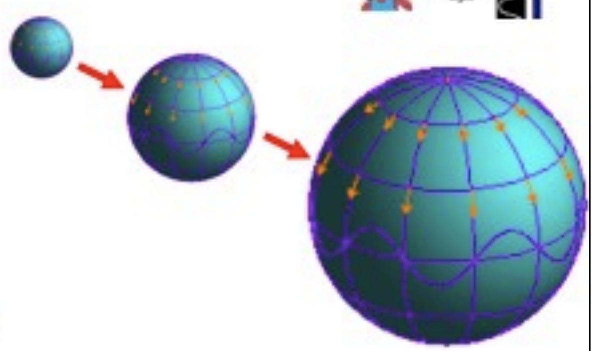
"How to lose and win a Nobel Prize…"

Science "Lost in the Noise" …in 2 different ways!

THE COSMIC MICROWAVE BACKGROUND RADIATION

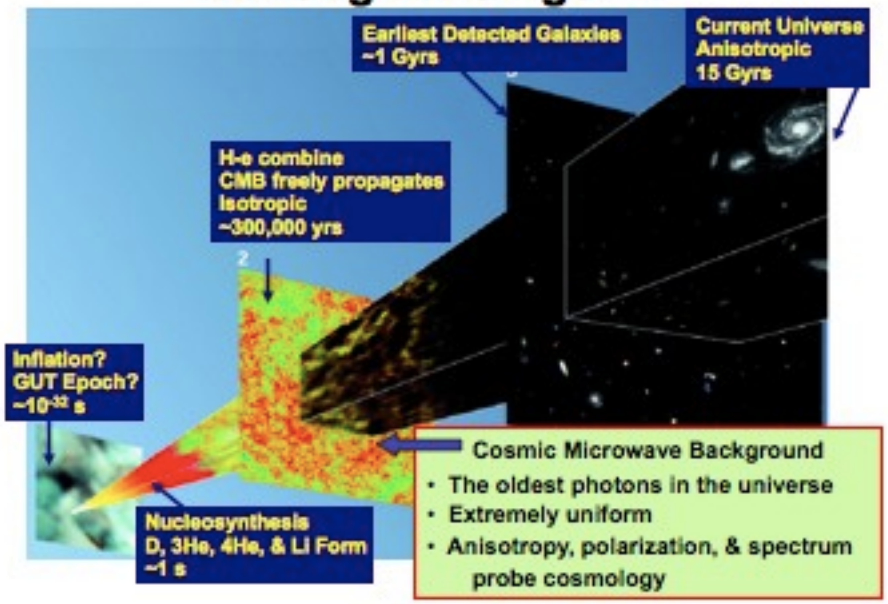
- A.K.A. the "3K BACKGROUND" – LOWEST TEMPERATURE IN INTERSTELLAR or INTERGALACTIC SPACE.
- HEAT LEFT OVER FROM THE BIG BANG



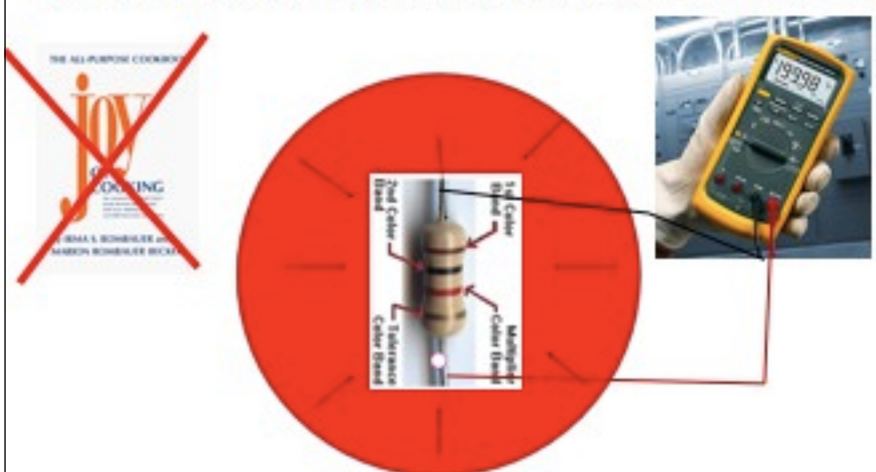


1% of static noise on TV…not cable!

A Long Time Ago….

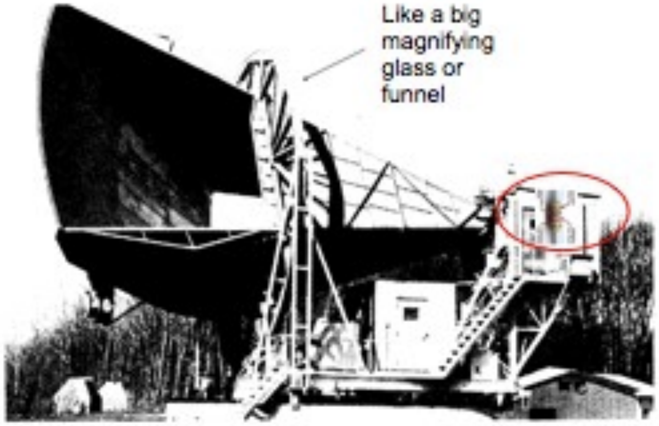


Observational Preliminaries: Resistor in an oven



- Random motion of electrons produces alternating current/voltage
- Higher temperature, higher AC voltage .

The Telescope



Exactly the Way 'Good Science' is Done

24.4K

Meas.

20.0K

21.9K

15.9K

Theory

From Ohm 1960

TABLE II — SOURCES OF SYSTEM TEMPERATURE

Source	Temperature
Sky (at zenith)	2.30 ± 0.20°K
Horn antenna	2.00 ± 1.00°K
Waveguide (counter-clockwise channel)	7.00 ± 0.65°K
Maser assembly	7.00 ± 1.00°K
Converter	0.60 ± 0.15°K
Predicted total system temperature	18.90 ± 3.00°K

the temperature was found to vary a few degrees from day to day, but the lowest temperature was consistently 22.2 ± 2.2°K. By realistically assuming that all sources were then contributing their fair share (as is also tacitly assumed in Table II) it is possible to improve the over-all accuracy. The actual system temperature must be in the overlap region of the measured results and the total results of Table II, namely between 20 and 21.9°K. The most likely minimum system temperature was therefore

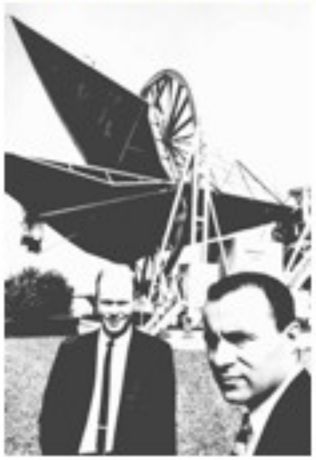
$$T_{system} = 21 \pm 1°K.$$

The inference from this result is that the "+" temperature possibilities of Table II must predominate.

Fig. 8 is taken from the paper in which E. A. Ohm described the receiver on the 20-foot horn reflector which was used to receive signals bounced from the Echo satellite. He found that its system temperature was 3.3 K higher than expected from summing the contributions of the components. As in the previous 5.3 cm work, this excess temperature was smaller than the experimental errors, so not much attention was paid to it. In order to determine the unambiguous presence of an excess source of radiation of about 3 K, a more accurate measurement technique was required. This was achieved in the subsequent measurements by means of a switch and reference noise source combination which communications systems do not have.

From Wilson 1980

Bell Labs (now *Lucent*) Crawford-Hill, NJ in the1960's



Penzias & Wilson on Systematic Errors

ment would not be possible. We considered a number of possible reasons for this excess and, where warranted, tested for them. These were:

a. At that time some radio astronomers thought that the microwave absorption of the earth's atmosphere was about twice the value we were using - in other words the "sky temperature" of Figs. 6 and 8 was about 5 K instead of 2.5 K. We knew from our measurement of sky temperature such as shown in Fig. 7 that this could not be the case.

b. We considered the possibility of man-made noise being picked up by our antenna. However, when we pointed our antenna to New York City, or to any other direction on the horizon, the antenna temperature never went significantly above the thermal temperature of the earth.

c. We considered radiation from our galaxy. Our measurements of the emission from the plane of the Milky Way were a reasonable fit to the intensities expected from extrapolations of low-frequency measurements. Similar extrapolations for the coldest part of the sky (away from the Milky Way) predicted about .02 K at our wavelength. Furthermore, any galactic contribution should also vary with position and we saw changes only near the Milky Way, consistent with the measurements at lower frequencies.

d. We ruled out discrete extraterrestrial radio sources as the source of our radiation as they have spectra similar to that of the Galaxy. The same extrapolation from low frequency measurements applies to them. The strongest discrete source in the sky had a maximum antenna temperature of 7 K.

Thus we seemed to be left with the antenna as the source of our extra noise. We calculated a contribution of 0.9 K from its resistive loss using

The right-hand column of Fig. 10 shows the final results of our measurement. The numbers on the left were obtained later in 1965 with a new throat on the 20-foot horn-reflector. From the total antenna temperature we subtracted the known sources with a result of 3.4 ± 1 K. Since the errors in this measurement are not statistical, we have summed the maximum error from each source. The maximum measurement error of 1 K was considerably smaller than the measured value, giving us confidence in the reality of the result. We stated in the original paper that "This excess temperature is, within the limits of our observations, isotropic, unpolarized, and free of seasonal variations". Although not stated explicitly, our limits on an isotropy and polarization were not affected by most of the errors listed in Fig. 10 and were about 10 percent or 0.3 K.

	New Throat		Old Throat
He Temp.	4.20	4.22	
Calculated Contribution from Cold Load Waveguide	.38	.70 ± 0.2	
Attenuator Setting for Balance	2.73	2.40 ± 0.1	
Total C.L.	7.33	7.32 ± 0.3	6.7 ± 0.3
Atmosphere	2.3 ± 0.3		2.3 ± 0.3
Waveguide and Antenna Loss	1.8 ± 0.3		.9 ± 0.3
Back Lobes	.1 ± 0.1		.1 ± 0.1
Total Ant.	4.2 ± 0.7		3.3 ± 0.7
Background	3.1 ± 1		3.4 ± 1

Fig. 10 Results of our 1965 measurements of the microwave background. "Old Throat" and "New Throat" refer to the original and a replacement throat section for the 20 foot horn-reflector.

Penzias & Wilson (1965)

What was the result?

The 1978 Nobel Prize!!!!

725,000 Swedish Crowns in 1978 = $100K, $1.3 M today!