Scientific Measurement

PHY-103

Dr. Eram Rizvi & Dr. Jeanne Wilson

Queen Mary
University of London

Module Overview

Scientific Measurement: Module Information
Module Organisers: Dr E. Rizvi (room 401 : office hour Tues 1400 - 1500)
Dr J. Wilson (room 507: office hour Wed 1000 - 1100)

All information is in booklet and online: http://www.ph.qmul.ac.uk/~phy103/scm.html

2 lectures per week (weeks 1 - 4 only)
Francis Bancroft Building room 2.40
Tuesday 1200 - 1300
Friday 1200 - 1300

1-2 lab sessions per week: either Mon+Tue **or** Thu+Fri
Choose this yourself with lab technicians today

Weeks 2-4	1 lab/week	Complete 3 lab experiments
Weeks 5-6	2 lab/week	Complete 2 lab experiments
Week 7	no lectures/lab	Write up experiment 4 as formal report
Weeks 8	no lectures	Obtain formative assessment of report in your lab session
Weeks 9-11	2 lab/week	Complete one longer experiment
Week 12	no lab/lectures	Write-up long experiment

Exercises 2 Sets, weeks 4 and 6
Hand in by Thursday 1600 (20th Oct and 3rd Nov)

No exam: 100% coursework

Module Overview

Labs is located on 2nd floor of Physics building:

- 2-5pm
- Choose Mon/Tue or Thu/Fri
- Sign up in lab for your chosen day **today**
- Choose lab partner or lab technician will assign for you

- Read the script (in booklet) thoroughly before starting expt
- Each expt has a worksheet
- Hand-in deadline is 1 week after the experiment
- Late submission will be penalised

Late work will not be marked! - solutions on web!

Watch the SCM website for changes, info, homework solutions!

Experiment 1-3	0%
Experiment 4	25%
Experiment 5	15%
Experiment 6-12	40%
Homework 1	10%
Homework 2	10%

It is required to submit expt 1-3

You will fail the course if you do not submit ALL coursework

Mark penalties are as follows:

Length of time after submission deadline	Mark penalty
<24 hours	-20%
1-3 days	-50%
>3 days	-100%

Module Overview

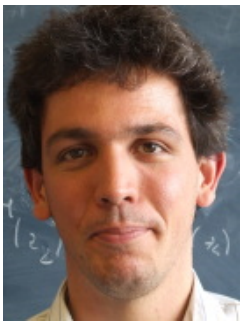
Week	Dates	Group				Marks
		A1 **Monday**	A2 **Tuesday**	B1 **Thursday**	B2 **Friday**	
1 2 3 4	Sept 26 – Sept30 Oct 3 – Oct 7 Oct 10 – Oct 14 Oct 17 – Oct 21	*Lectures on Tuesdays and Fridays 12 noon, in weeks 1–4* Complete experiments 1, 2, 3 (one per week, in weeks 2-4) according to the schedule in the laboratory				
		Monday and Tuesday		**Thursday and Friday**		
5 6	Oct 24 – Oct 28 Oct 31 – Nov 4	Experiment 4 or experiment 5 *Lectures Tuesday and Friday* Experiment 5 or experiment 4 *Lectures Tuesday and Friday*				25% or 15% 15% or 25%
7	Nov 7 – Nov 11	*Reading week: write up experiment 4 Report*				
8	Nov 14 – Nov 18	Formative Assessment of Experiment 4 Report *Lectures Tuesday and Friday*				
9 10 11	Nov 21 – Nov 25 Nov 28 – Dec 2 Dec 5 – Dec 9	Choose **one** of experiments 6–12 *Lectures Tuesday and Friday* *Continue (one of three parts per week)* *Continue (one of three parts per week)*				40%
12	Dec 12 – Dec 16	*Write up Report 6, 7, 8, 9,10,11, or 12*				
		2 Homework exercises (due in weeks 4 and 6)				20%

Module Overview

Lab Demonstrators are:

Dr Eram Rizvi

Dr Jeanne Wilson



Dr Anthony Phillips

Pete Crew

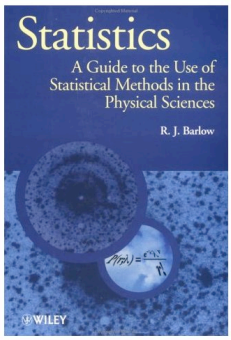
Saqib Qureshi

Dr Kevin Donovan

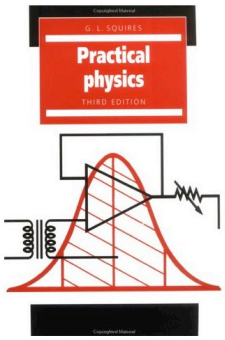
Also 2 postgraduate student demonstrators in each lab session

Module Overview

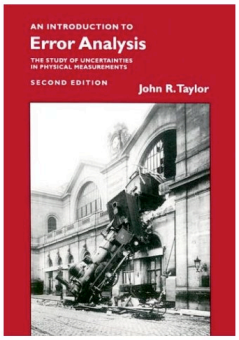
Texts available in library short loan collection - no need to buy



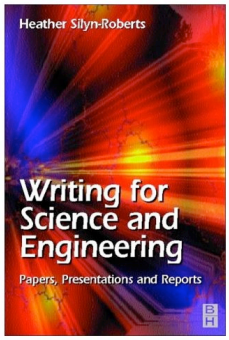
Good statistics reference
£26



Good guide to laboratory practice
£26



Another good stats ref.
£15



Guide to writing reports
£17

Module Aims

Aim of this course:

- teach experimental technique
- knowledge of underlying physics will not be tested
- experiments not of world quality
  - can get high precision none the less
- how accurate? → purpose of these lectures!
- how to obtain, manipulate, present and interpret experimental data
- teach measurement uncertainties
- Plagiarism will be treated very seriously

Scientific Methodology - The Scientific Method

Whats the difference between these lists?

Luminferous aether
Plum pudding atomic model
Aristotelian Gravity

Quantum mechanics
Special relativity
Newtonian gravity
Thermodynamics

Whats the difference between these lists?

Luminferous aether
Plum pudding atomic model
Aristotelian Gravity

Nice ideas, but flawed - proven wrong

Quantum mechanics
Special relativity
Newtonian gravity
Thermodynamics

Great pillars of modern physics!

Science is driven by experiment and data

- Only experiment can distinguish between rival theories
- Only experiment can determine fundamental constants of nature

$c, \hbar, G, k$ are all derived from experiment NOT theory

Experiment is the final arbiter of Truth

Thus experimenters have a HUGE responsibility
Honesty and Integrity are paramount
Open mindedness: do not presume to know the "answer"
Do not "fiddle" results to get 'correct' answer
Provided your method is ok - Experiment is correct (almost) BY DEFINITION!
If data & theory disagree, the theory is WRONG!
Experiment tells us what the TRUTH is - Theory tells us why

OK, measurement is important

Lets measure the same object many times:
measure a chair several times & plot results

Why is there a spread of results?
- ruler is flimsy?
- some people can't read a ruler?
- space-time is fluctuating changing the size of the chair?

Any measurement has an uncertainty or error due to:

- equipment
- definition of measurement
- sight of observer
- angle of viewing the ruler & object
- calibration of instrument

How we deal with this is the subject of these lectures!

Aside:
Physicists only measure 5 fundamental quantities

Length:	Distance travelled by light in some time interval
Time:	Number of periods of specific wavelength radiation
Current:	Force between two conductors
Temp.:	Triple point of water
Mass:	Lump of metal in Paris!

Measurement of our chair should reflect the uncertainty!

write it as: 45 ± 2 cm

means TRUE value lies in range 43 - 47 cm

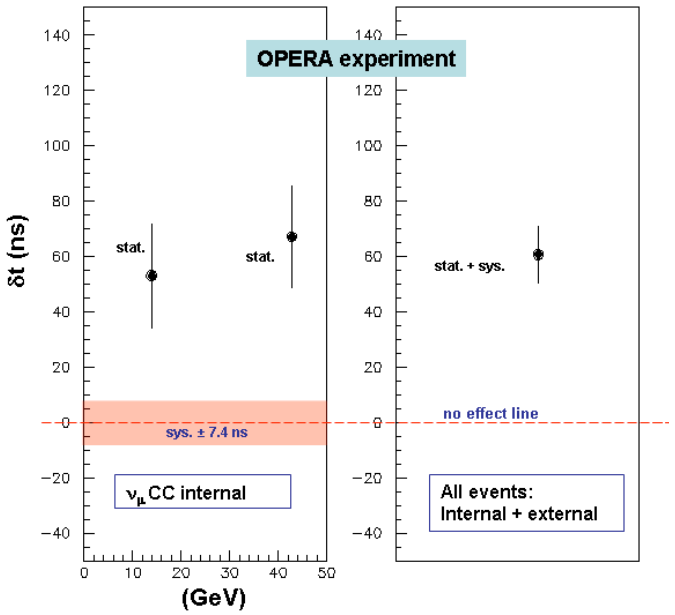
UNLIKELY to be >51

UNLIKELY to be <39

On a graph we show this as an error bar:

Any measurement is WORTHLESS unless you estimate it's uncertainty

This is the only way of comparing measurements and deciding on compatibility



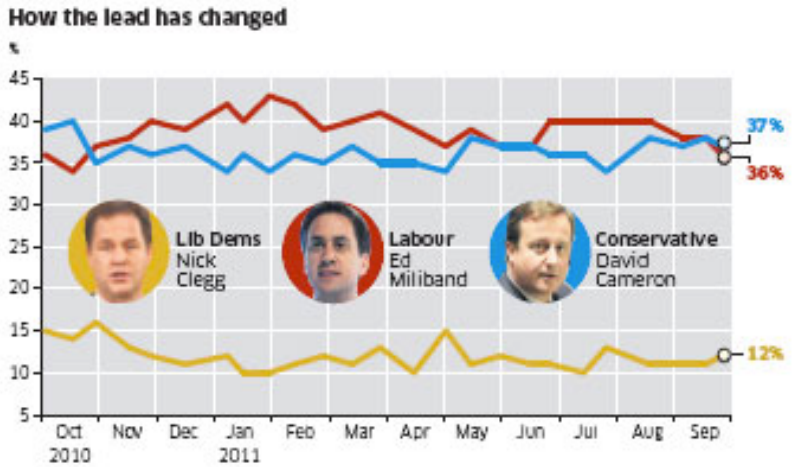
Real measurement published 4 days ago...
http://arxiv.org/abs/1109.4897v1

YouGov poll - June 2010

On the whole, Islam is a violent religion

	Total	Gender		Age				
	Base	Male	Female	18 to 24	25 to 34	35 to 44	45 to 54	55+
Weighted Sample	2152	1035	1117	258	365	367	396	766
Unweighted Base	2152	986	1166	167	326	333	367	959
	%	%	%	%	%	%	%	%
Strongly agree	9%	12%	6%	10%	8%	8%	8%	10%
Tend to agree	21%	22%	19%	11%	17%	18%	20%	28%
TOTAL AGREE	30%	34%	25%	21%	25%	26%	27%	38%
Neither agree nor disagree	22%	20%	24%	20%	18%	23%	26%	23%
Tend to disagree	25%	25%	25%	27%	26%	24%	27%	23%
Strongly disagree	12%	13%	12%	21%	16%	14%	9%	9%
TOTAL DISAGREE	37%	38%	37%	48%	42%	38%	37%	32%
Don't know	11%	8%	13%	11%	14%	14%	10%	8%

Polls use a sample of usually about 2000 people
Results quoted for 40 million adults!
Do 30% of the UK agree with this?
Or could it be 27%? ... or 43% ....



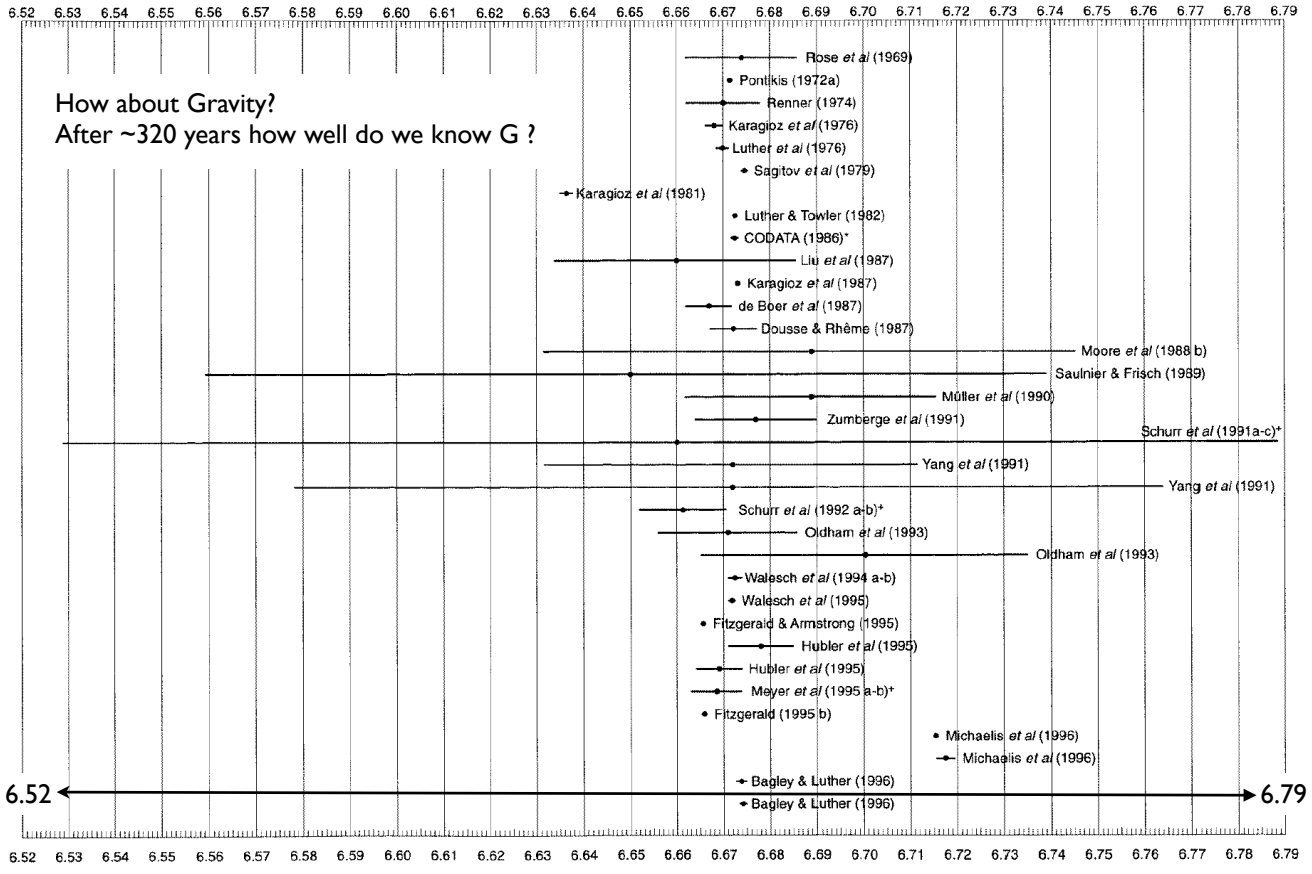
Typical uncertainty is usually ~ 2.5%
poll is not as conclusive as news readers think!

Comres poll - today

"How can a sample of only 1,000 or 2,000 possibly reflect the opinions of 42 million Britons within a 3% margin of error?"

George Gallup: Developed opinion polling in the 1930s:
If you have a large bowl of soup, you don't have to drink the whole bowl to decide if it has too much salt in it - just stir it well, and one spoonful will suffice.

Background on the gravitational constant



* See Cohen and Taylor (1987).
+ The error bars represent the quadrated sum of the individually listed Type A and Type B uncertainties.

x	y
0.41	0.17
-0.01	0.00
2.41	5.81
2.79	7.77
-0.48	0.23
0.82	0.68
1.85	3.42
3.10	9.59
0.93	0.86
2.97	8.83
1.40	1.97
-0.07	0.01
2.11	4.44
2.40	5.75
0.25	0.06
2.33	5.44
1.13	1.29
-0.09	0.01
0.92	0.84
2.37	5.63
2.86	8.17
1.03	1.06
1.28	1.63
2.02	4.06
0.79	0.63
3.06	9.38
0.72	0.51

In an expt. x was varied and y was measured.
Is there a relationship between them?
What is the relationship between the two data?

x	y
0.41	0.17
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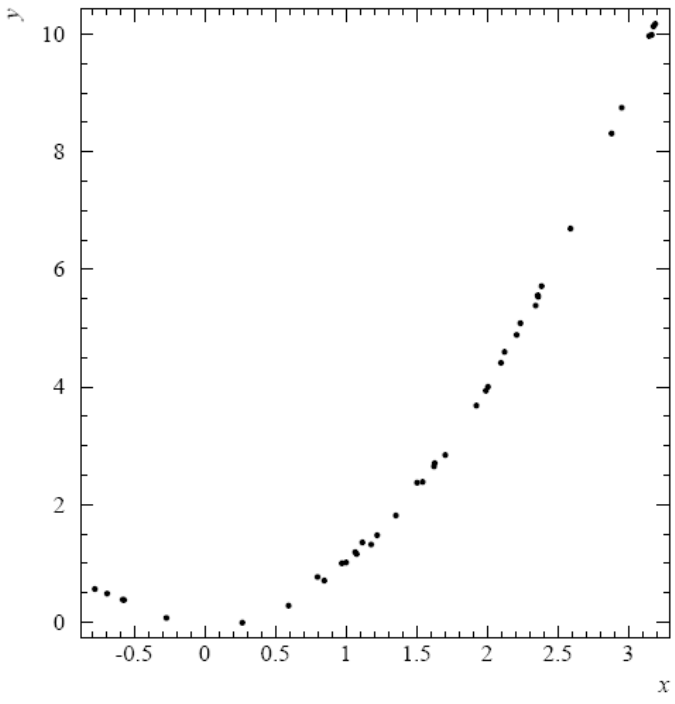

Humans are visual animals - brains recognise visual patterns very well
Plotting graphs of data is a powerful technique in discovering patterns

What is the difference between these numbers?

3×10^2
314
314.159 265
314.159 26535 89793 23846 26433 83279 50288 41971 69399 37510
$\pi \times 100$

All are representations of the same number.

Number of sig.figs implies precision of that number.

Only in rare cases will you know a number to more than 3-4 sig figs!

Presenting Data

What is the difference between these numbers?

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314
314.159 265
314.159 26535 89793 23846 26433 83279 50288 41971 69399 37510
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Quantum electrodynamics: gyromagnetic ratio of the electron: g

Theory : $\frac{1}{2}(g_{th} - 2) = 1159652140(28) \times 10^{-12}$
Experiment : $\frac{1}{2}(g_{exp} - 2) = 1159652186.9(4.1) \times 10^{-12}$

I never want to see more than 3 sig figs unless you can justify it!!!

note: $1159652140(28) \times 10^{-12}$ is same as $(1159652140 \pm 28) \times 10^{-12}$

Summary

Only experiment can determine the truth
Measurement ALWAYS has uncertainty
Never quote a measurement without its uncertainty
Plotting data graphically is very useful
Never plot graphs without error bars
... ever!
Never quote more sig figs than necessary