PHYSICS 2DL – SPRING 2010

MODERN PHYSICS LABORATORY

Monday April 5, 2010

Prof. Brian Keating

2DL

- Review of policies from last week
- Theory of first few experiments continues *in lab* this week
- No lecture May 31
- Error propagation

☹ Policies ☹

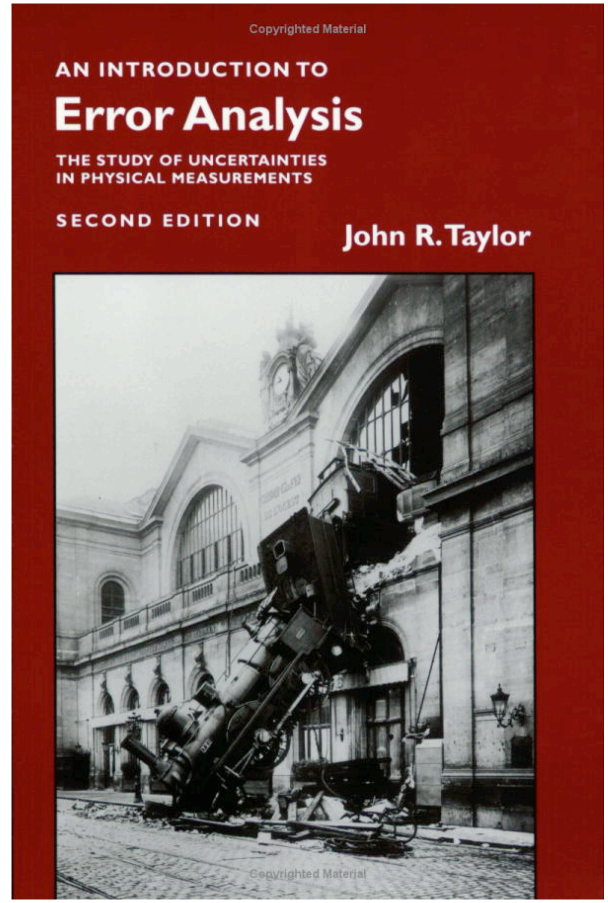
- Missed labs CAN'T be copied!
- Must attend make up lab, take data YOURSELF, and write up labs. Missing, Copying data and/or reports will result in 0 points for that lab.
- Need a note from doctor or UCSD official to be allowed to re-take lab.

Lab Manual

Printed out and bound for you.

Will be distributed in your lab section next week.

Textbook



"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. $28 used on Amazon

Homework

- Problems listed on 2DL Spring 2010 syllabus -Website:
- http://physics.ucsd.edu/students/courses/spring2010/physics2dl/
- Website has lecture notes from prev week
- All HW problems are found in Taylor
- Hand-in HW to TA in Lab as on schedule, (changed on syllabus).
- HW #10 IS due in lab, week of 31 May (Memorial Day week so no lecture).

Lab Sections (Tuesday/Thursday 12:30p & Wednesday 1p, 3 hours

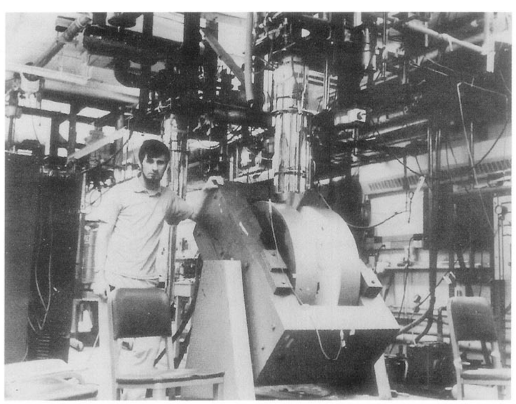
- Introduction to the experiments (this week) in lab.
- *You* start doing the labs in week 3 - next week.
- Pick your partners THIS WEEK IN LAB.
- Sign up for your weekly labs THIS WEEK IN LAB.

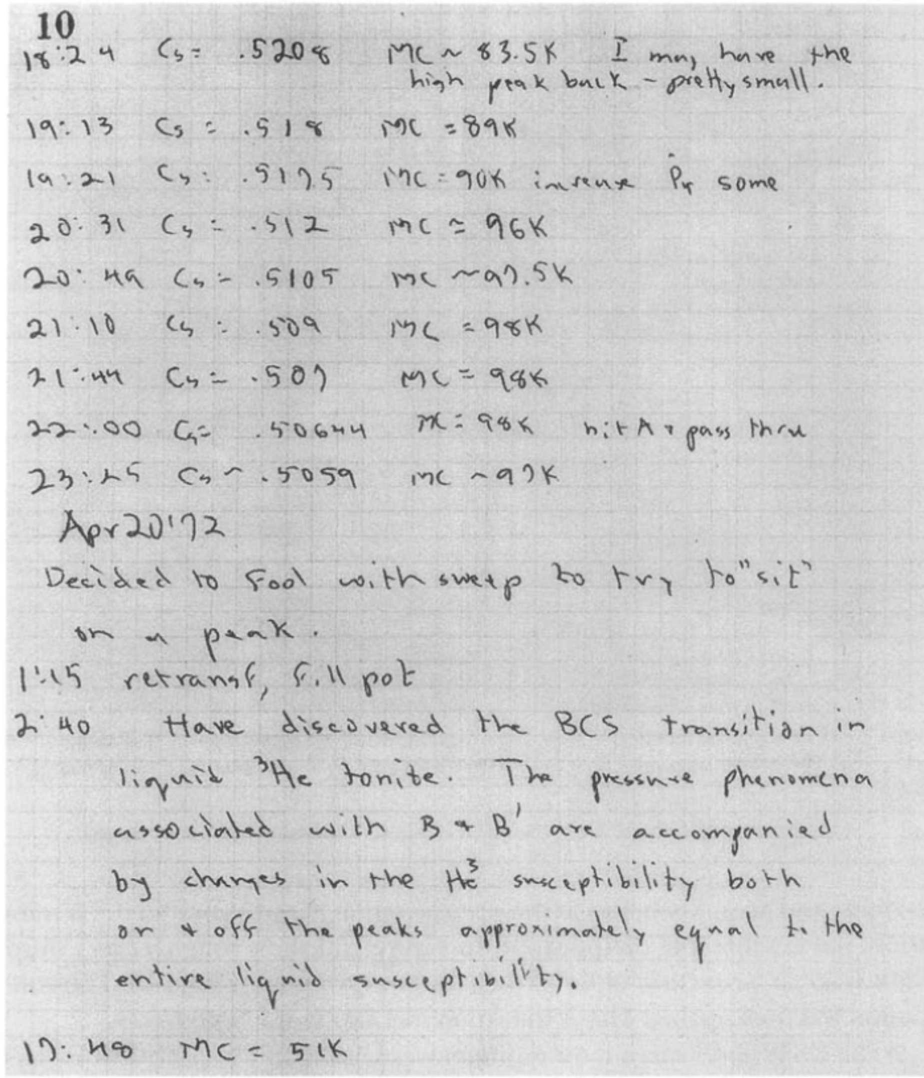
Notebooks

- Few pages of text
- Include data, plots

Lab Notebooks & Reports

- See ‘Ace your Reports’
- Include data, plots with labels, sketches, <u>in ink.</u>





10
18:24 Cs = .5208 MC ~ 83.5K I may have the high peak back – pretty small.
19:13 Cs = .518 MC = 89K
19:21 Cs = .5175 MC = 90K increase P some
20:31 Cs = .512 MC ≃ 96K
20:49 Cs = .5105 MC ~ 97.5K
21:10 Cs = .509 MC = 98K
21:44 Cs = .507 MC = 98K
22:00 Cs = .50644 MC = 98K hit A & pass thru
23:25 Cs ~ .5059 MC ~ 97K
Apr 20'72
Decided to fool with sweep to try to "sit" on a peak.
1:15 retransf, fill pot
2:40 Have discovered the BCS transition in liquid ^{3}He tonite. The pressure phenomena associated with B & B' are accompanied by changes in the He^3 susceptibility both on & off the peaks approximately equal to the entire liquid susceptibility.
17:40 MC = 51K

Figure 8: Photograph from my lab book showing entry the night of April 20, 1972, when I realized the B transition was in the liquid.

D. Osheroff, 1972. Winner of 1996 Nobel Prize in Physics

Scientific Errors

Errors → **uncertainties**

not mistakes!

inevitable and intrinsic part

of any measurement

Principal sources of errors in measurements:

1) limitations of measurements tool

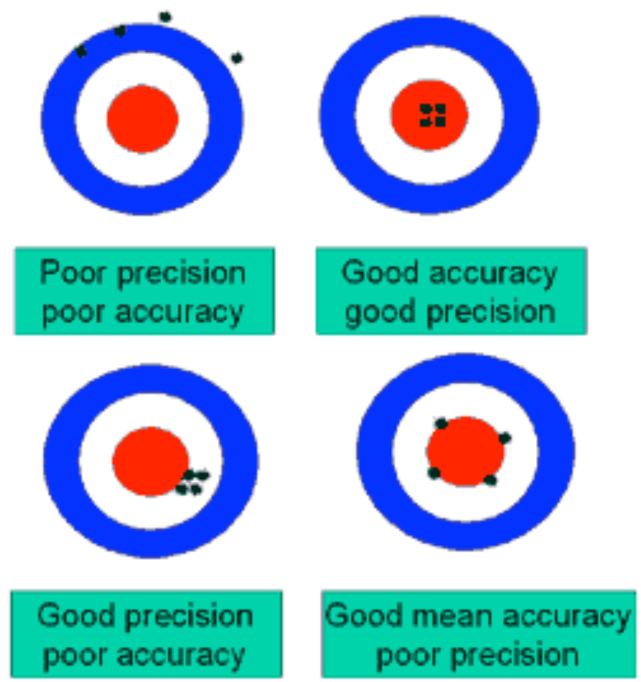
2) limitations of experiment design

3) imprecise definition of measured quantity

random errors can be reduced through statistical methods

Quantifying Errors

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



Measurements and Errors

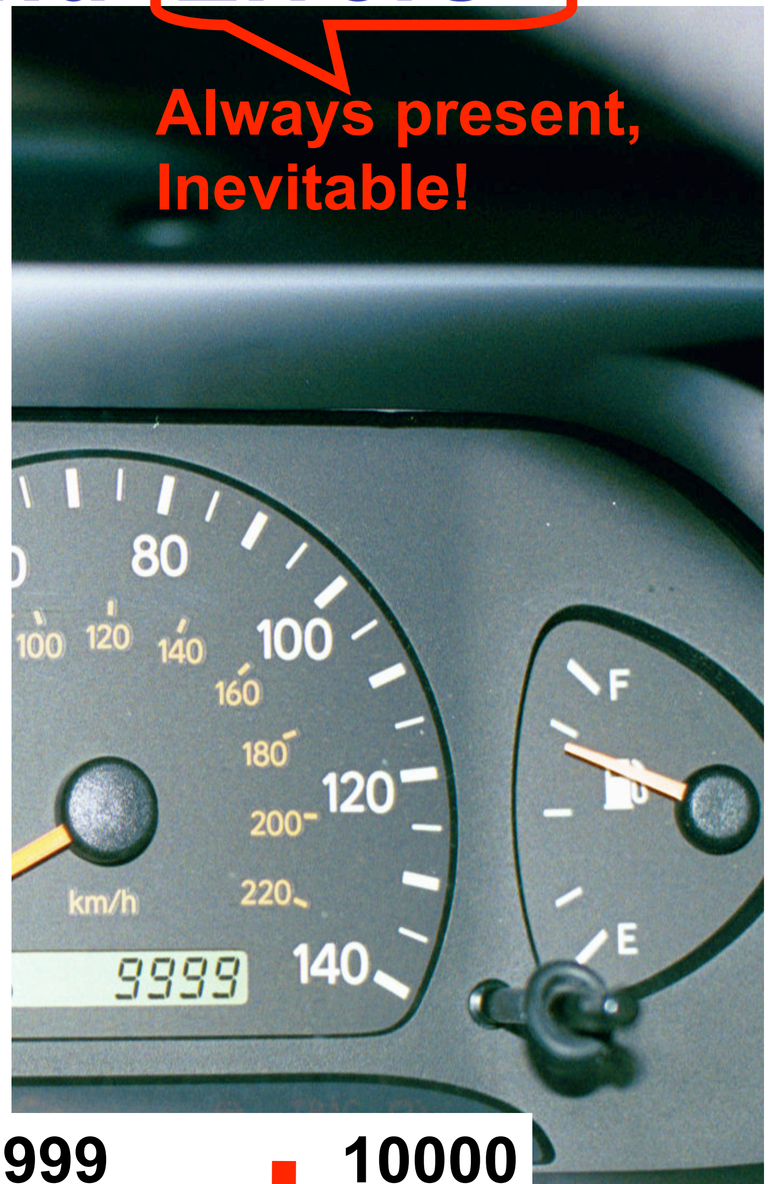
Always present, Inevitable!

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

best estimate

uncertainty

9999.7 ± 0.1



9999

10000

"true" mileage?

Error Propagation

$$v = \frac{s}{t}$$

$$s = s_{best} \pm \delta s$$

$$t = t_{best} \pm \delta t$$

$$\delta v = ???$$

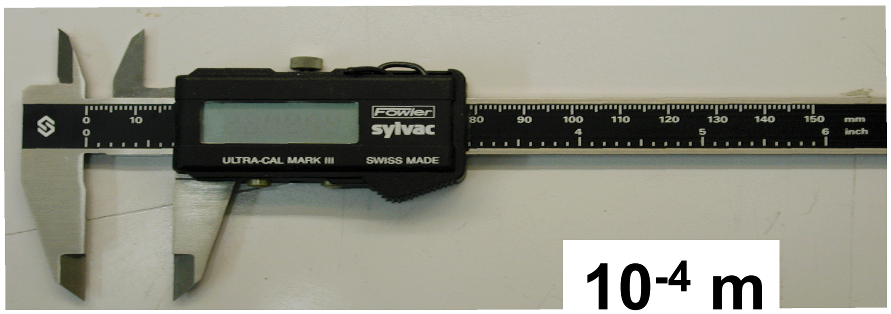
$$\tau = RC$$

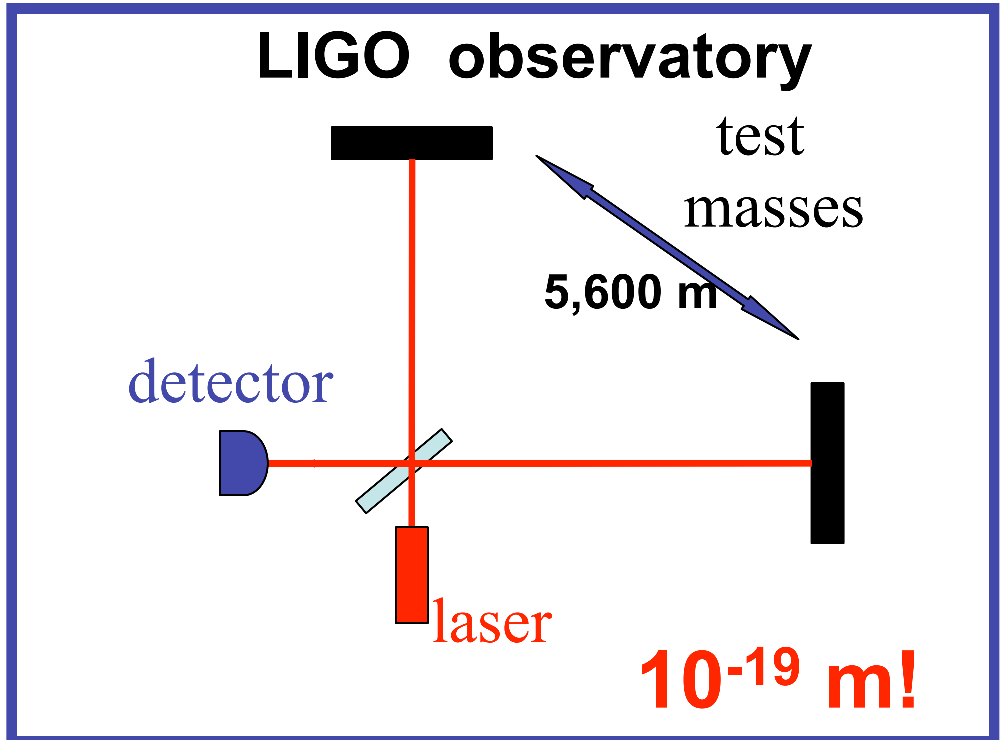
$$R = R_{best} \pm \delta R$$

$$C = C_{best} \pm \delta C$$

$$\delta \tau = ???$$

Limitations of measurement tools

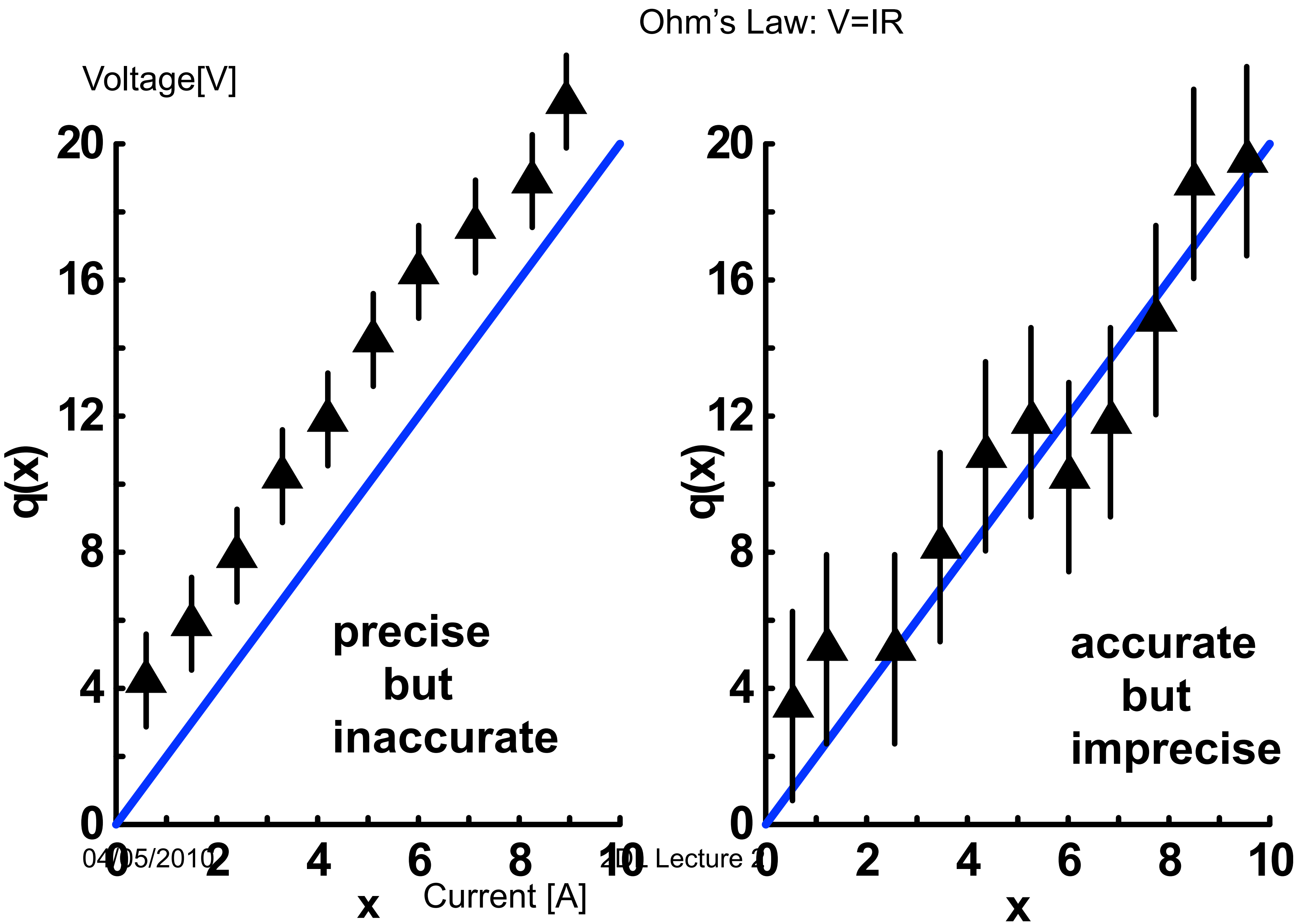




Measure L = L1 + L2

L1 = 1.01, L2 = 1.1, what is L?

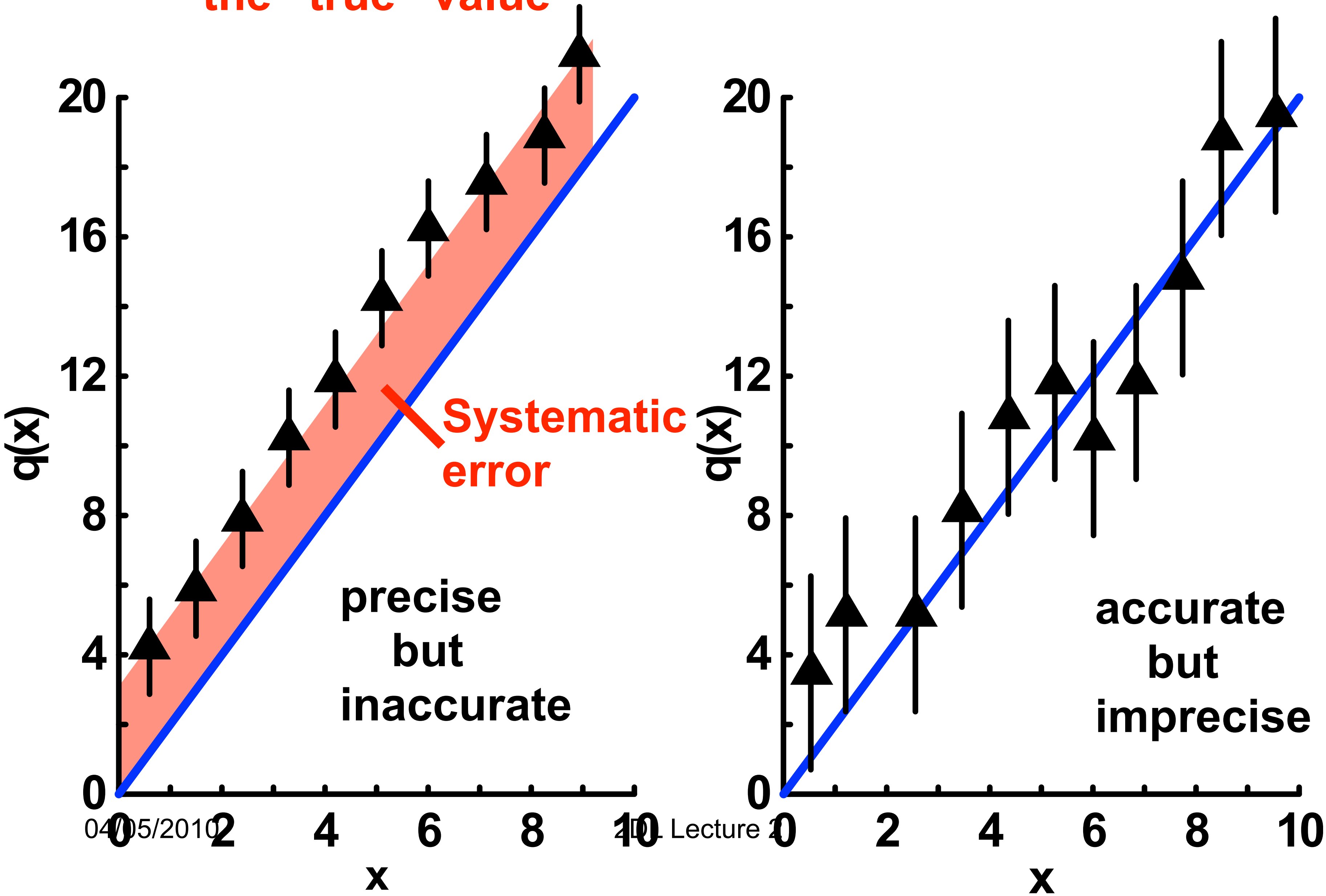
Accuracy versus Precision



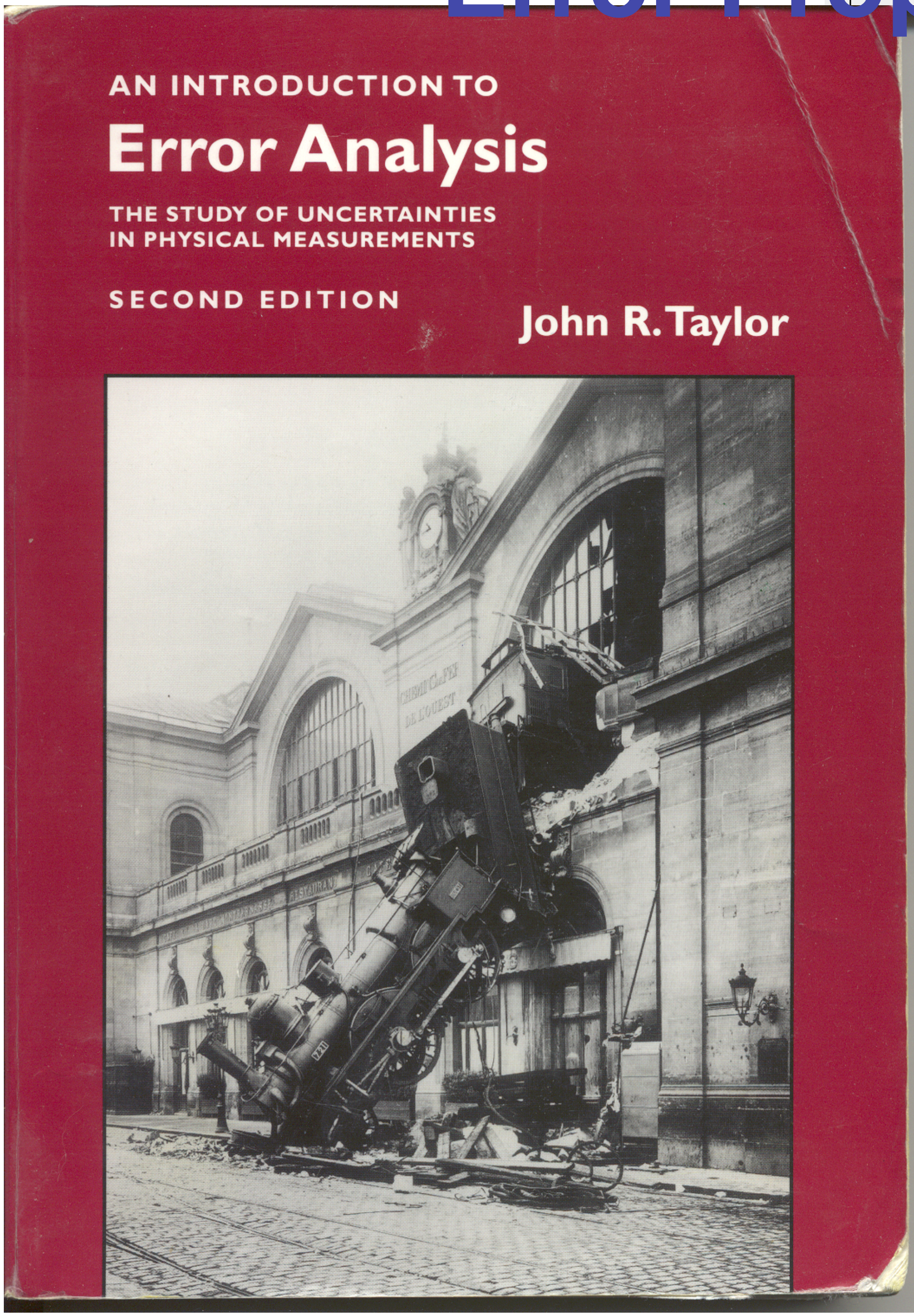
Accuracy versus Precision

… how close to the "true" value

… uncertainty



Error Propagation



Principal Formulas in Part I

Notation (Chapter 2)

$$\text{(Measured value of } x) = x_{\text{best}} \pm \delta x, \qquad \text{(p. 13)}$$

where

$$x_{\text{best}} = \text{best estimate for } x,$$

$$\delta x = \text{uncertainty or error in the measurement.}$$

$$\text{Fractional uncertainty} = \frac{\delta x}{|x_{\text{best}}|}. \qquad \text{(p. 28)}$$

Propagation of Uncertainties (Chapter 3)

If various quantities $x, \ldots, w$ are measured with small uncertainties $\delta x, \ldots, \delta w$, and the measured values are used to calculate some quantity q, then the uncertainties in $x, \ldots, w$ cause an uncertainty in q as follows:

If q is the sum and difference, $q = x + \cdots + z - (u + \cdots + w)$, then

$$\delta q \begin{cases} = \sqrt{(\delta x)^2 + \cdots + (\delta z)^2 + (\delta u)^2 + \cdots + (\delta w)^2} \\ \quad \text{for independent random errors;} \\ \leqslant \delta x + \cdots + \delta z + \delta u + \cdots + \delta w \\ \quad \text{always.} \end{cases} \qquad \text{(p. 60)}$$

If q is the product and quotient, $q = \dfrac{x \times \cdots \times z}{u \times \cdots \times w}$, then

$$\frac{\delta q}{|q|} \begin{cases} = \sqrt{\left(\frac{\delta x}{x}\right)^2 + \cdots + \left(\frac{\delta z}{z}\right)^2 + \left(\frac{\delta u}{u}\right)^2 + \cdots + \left(\frac{\delta w}{w}\right)^2} \\ \quad \text{for independent random errors;} \\ \leqslant \frac{\delta x}{|x|} + \cdots + \frac{\delta z}{|z|} + \frac{\delta u}{|u|} + \cdots + \frac{\delta w}{|w|} \\ \quad \text{always.} \end{cases} \qquad \text{(p. 61)}$$

If $q = Bx$, where B is known exactly, then

$$\delta q = |B|\,\delta x. \qquad \text{(p. 54)}$$

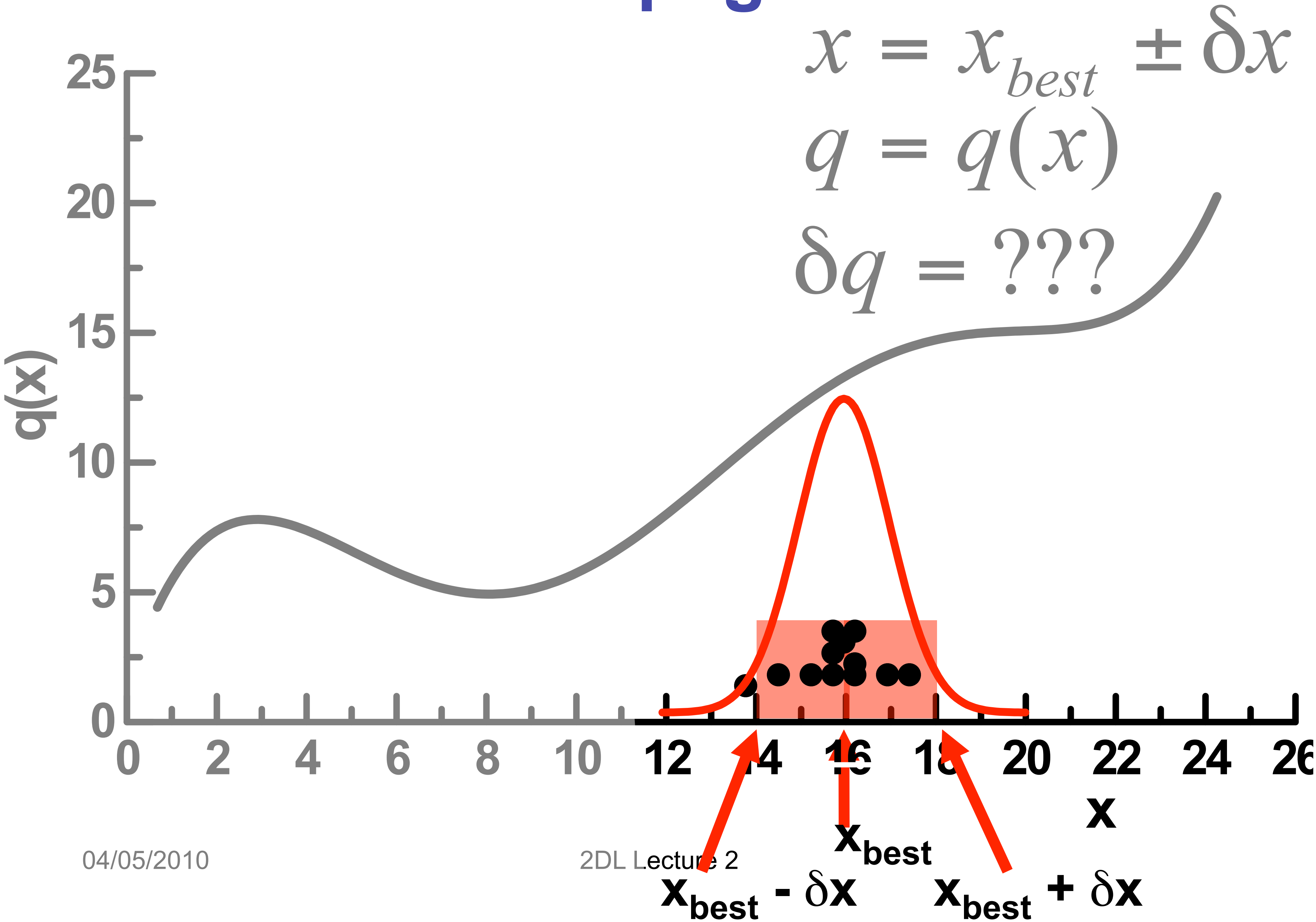
If q is a function of one variable, $q(x)$, then

$$\delta q = \left|\frac{dq}{dx}\right| \delta x. \qquad \text{(p. 65)}$$

If q is a power, $q = x^n$, then

$$\frac{\delta q}{|q|} = |n| \frac{\delta x}{|x|}. \qquad \text{(p. 66)}$$

Error Propagation

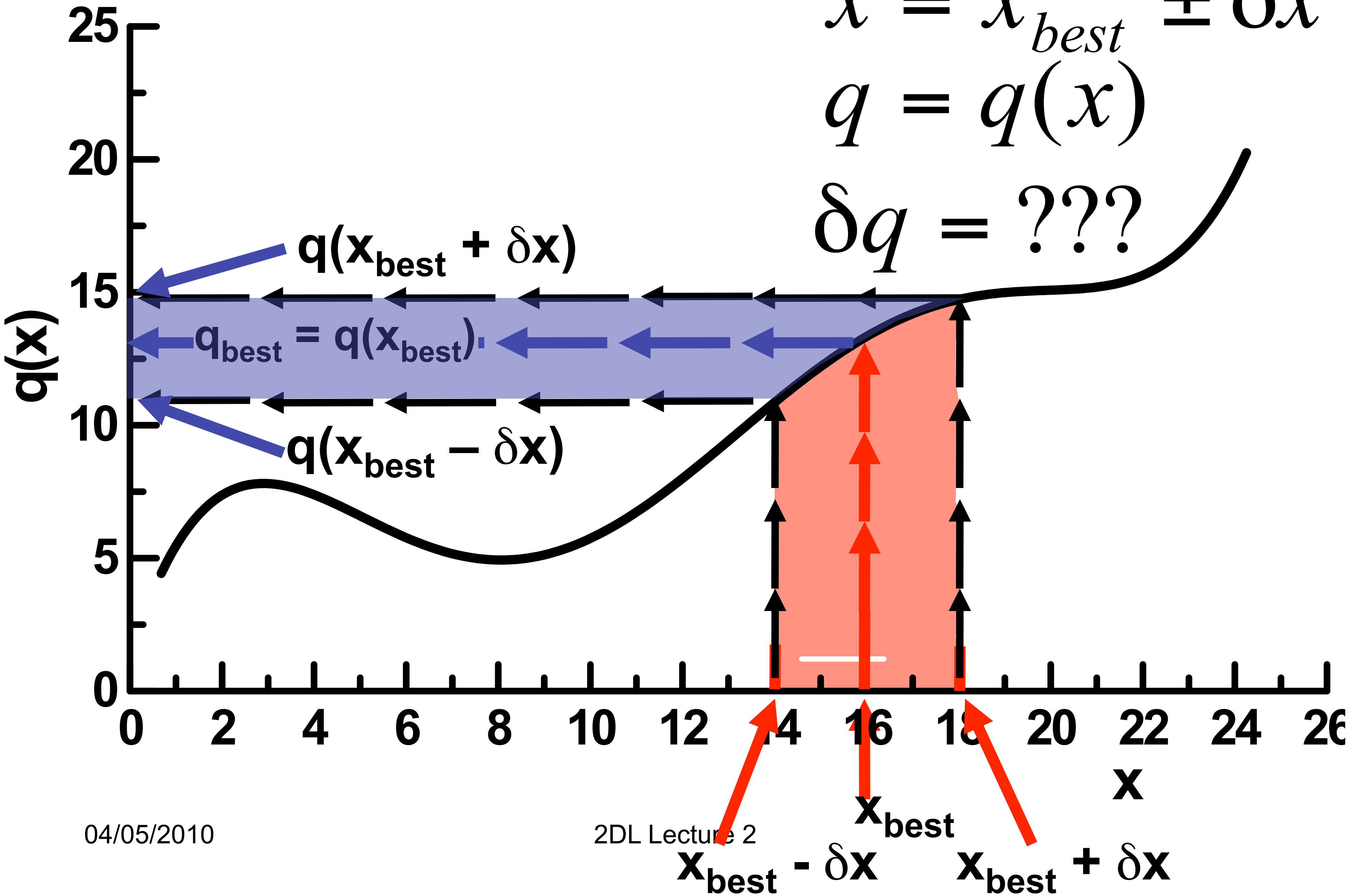


Error Propagation

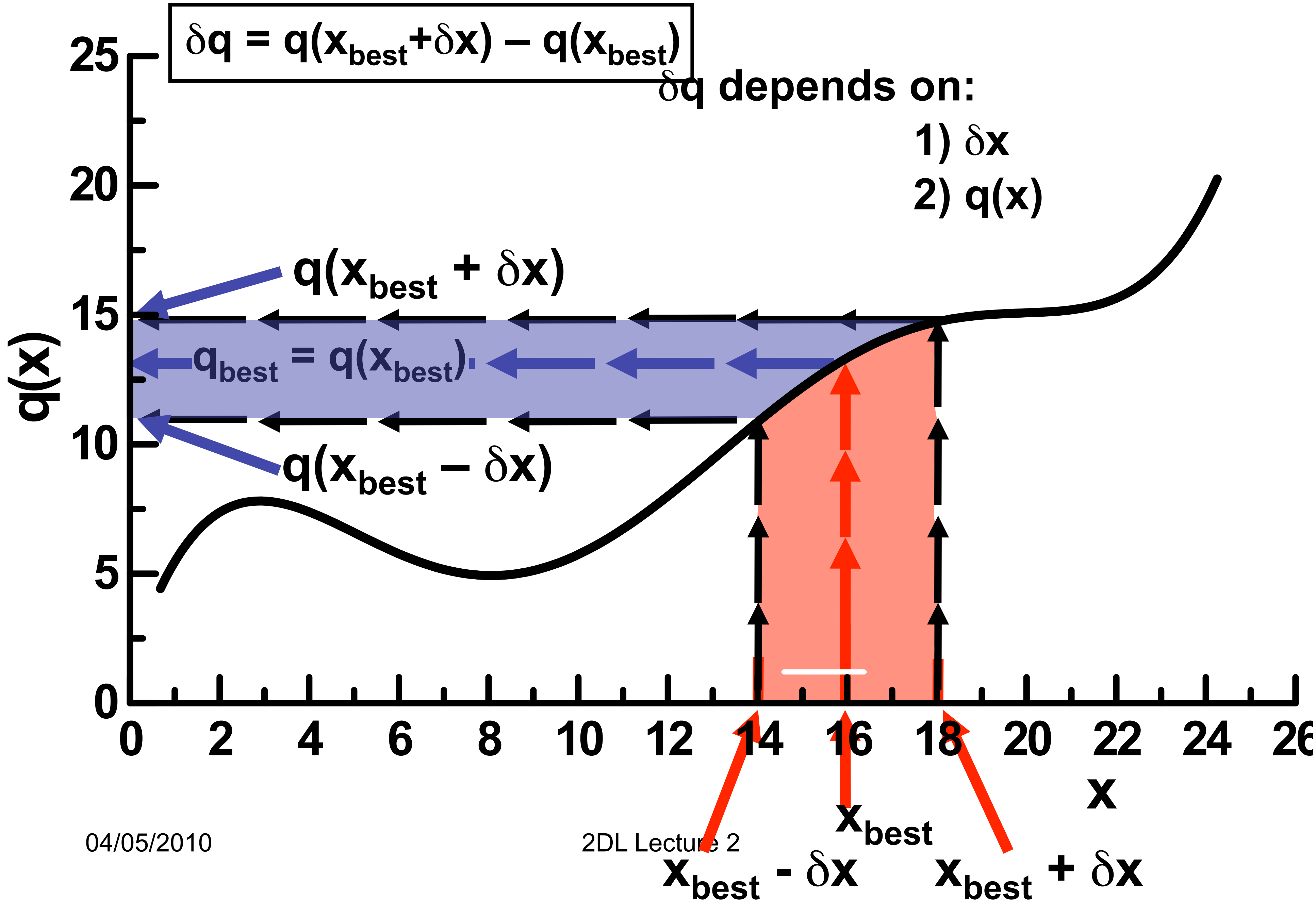
$$x = x_{best} \pm \delta x$$

$$q = q(x)$$

$$\delta q = ???$$



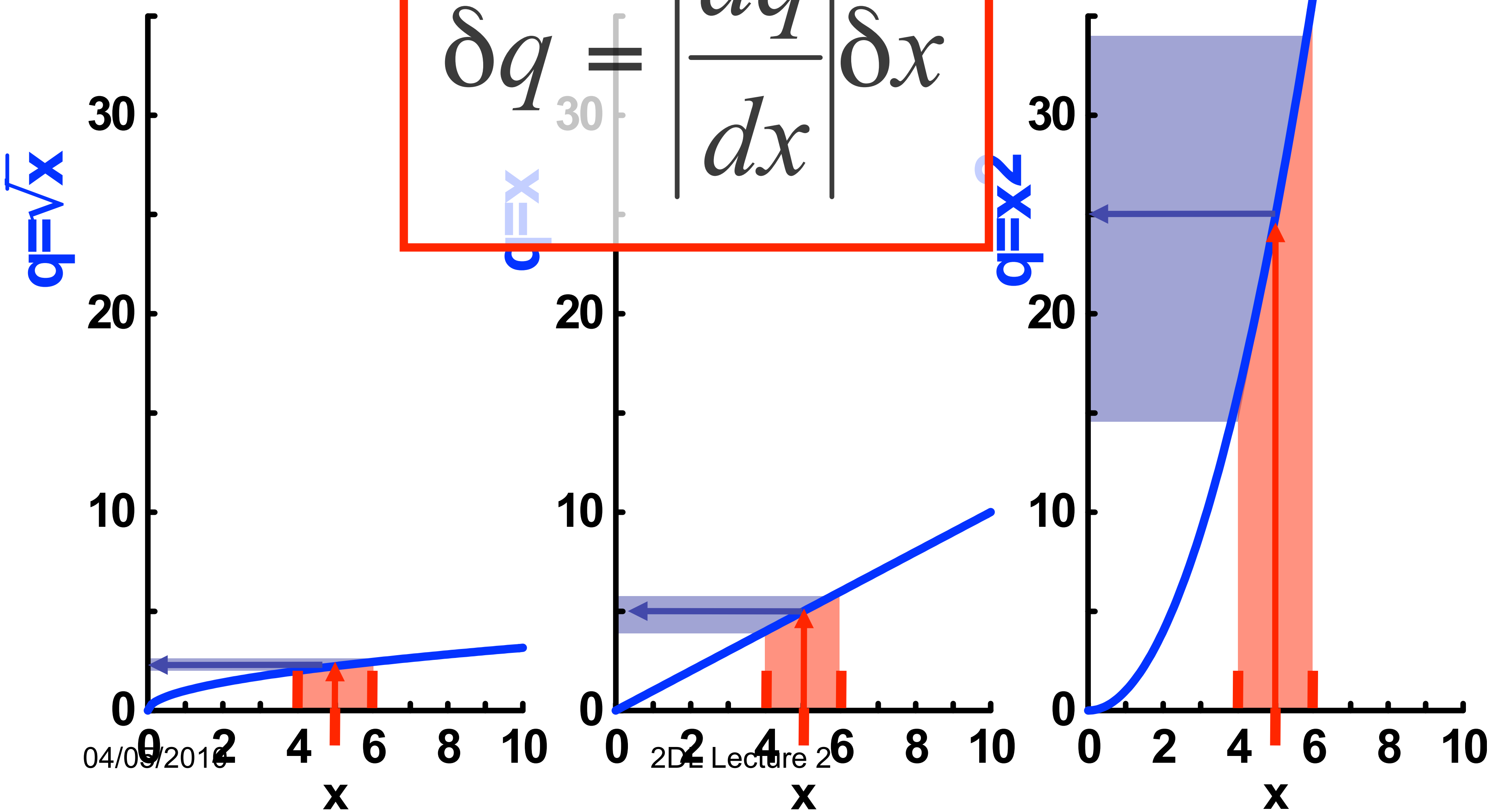
Error Propagation



Error propagation

$$\delta q = q(x_{best}+\delta x) - q(x)$$

$$\delta q = \left|\frac{dq}{dx}\right|\delta x$$



Error propagation

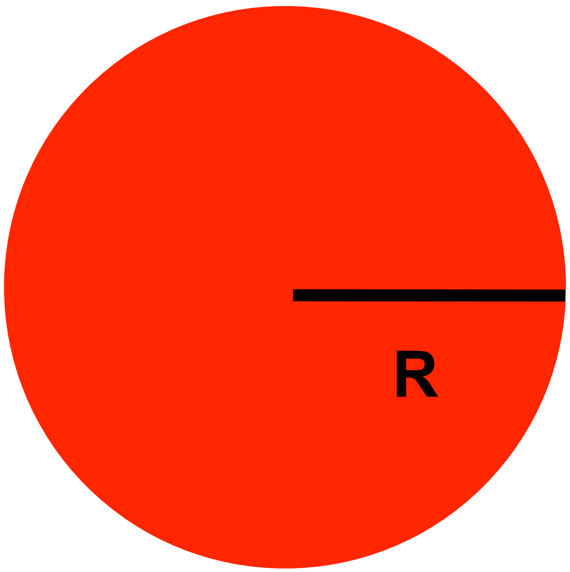
$$\delta q = \left|\frac{dq}{dx}\right|\delta x$$

$$q = q(x, y, z)$$

$$\delta q = \sqrt{\left(\frac{\partial q}{\partial x}\delta x\right)^2 + \left(\frac{\partial q}{\partial y}\delta y\right)^2 + \ldots + \left(\frac{\partial q}{\partial z}\delta z\right)^2}$$

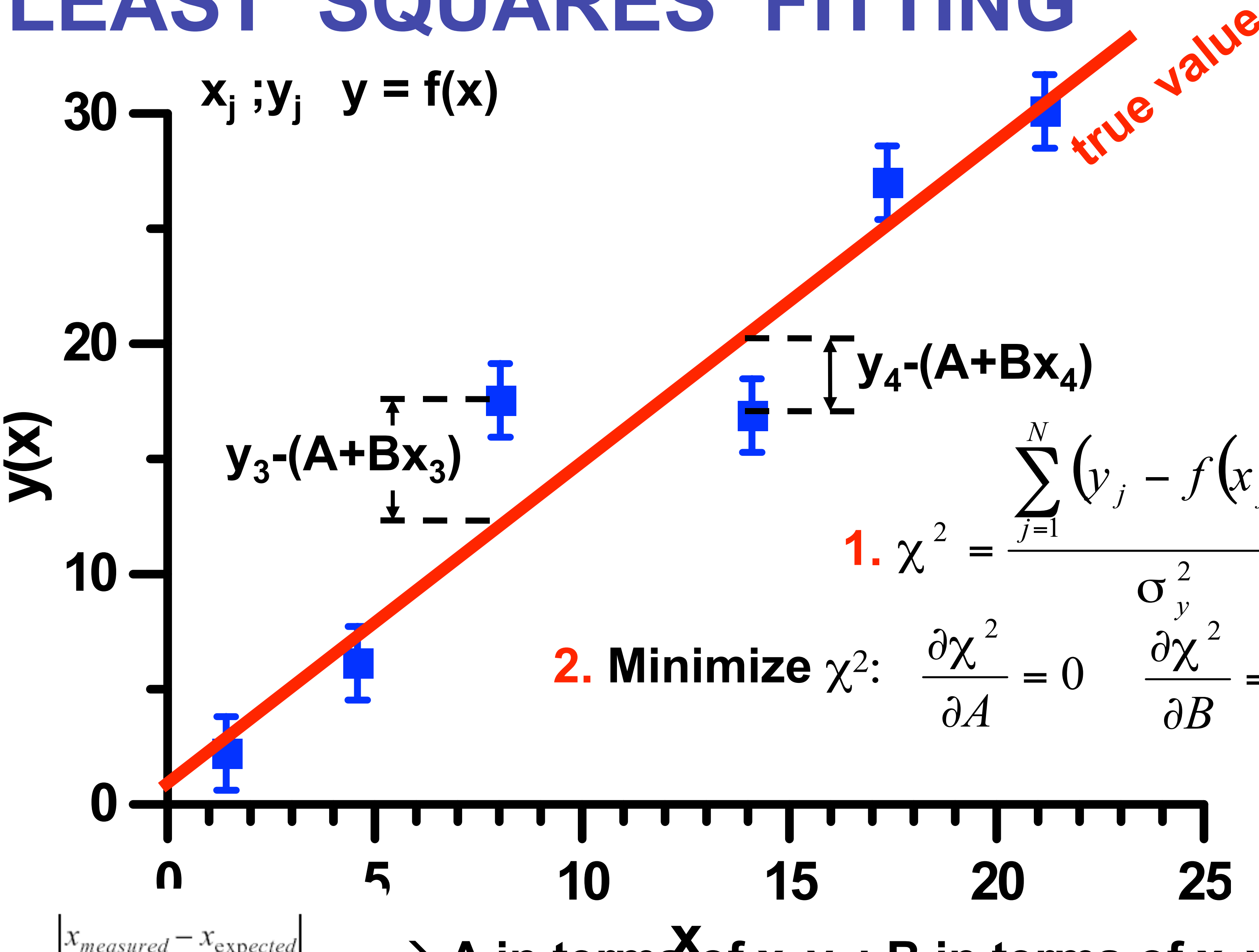
Simple Example: Adding Uncertainties

- Measure Diameter, D = 6.0 ± 0.1 m
- Radius = R?
- Circumference = C?
- C = 18.8 ± 0.3 m
- R = 3.00 ± 0.05 m



LEAST SQUARES FITTING

$x_j\,;y_j \quad y = f(x)$



1. $$\chi^2 = \frac{\sum_{j=1}^{N}\left(y_j - f(x_j)\right)^2}{\sigma_y^2}$$

2. Minimize χ^2: $$\frac{\partial\chi^2}{\partial A} = 0 \qquad \frac{\partial\chi^2}{\partial B} = 0 \quad \cdots$$

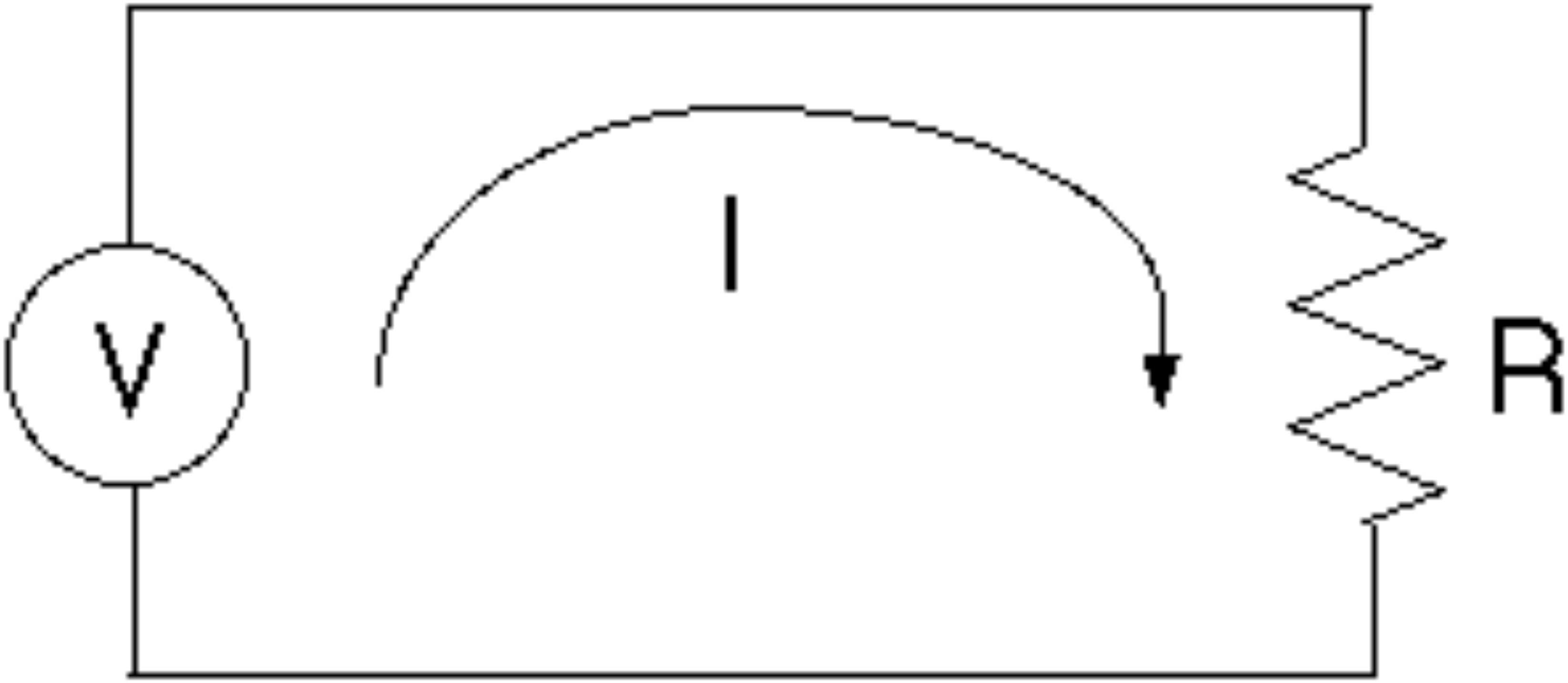
$$t = \frac{\left|x_{measured} - x_{expected}\right|}{\sigma_{total}}$$

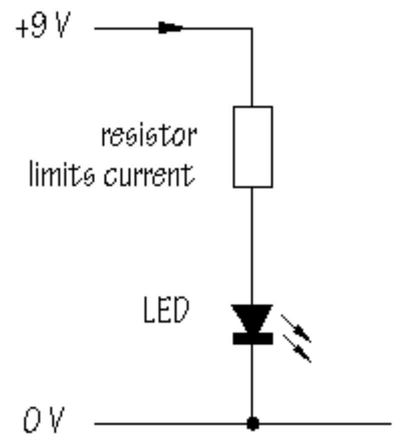
→ **A in terms of $x_j\ y_j$; B in terms of $x_j\ y_j$, …**

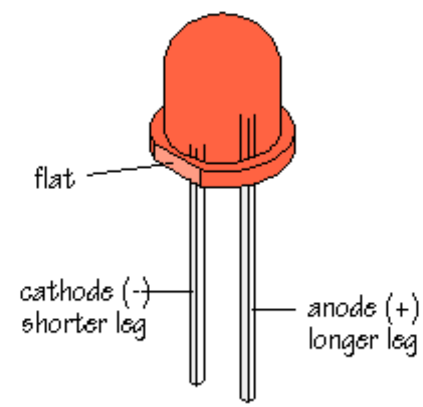
Basic Electronics- this week in Lab

- Play with RLC circuit elements and Oscilloscopes

Simplest Circuit







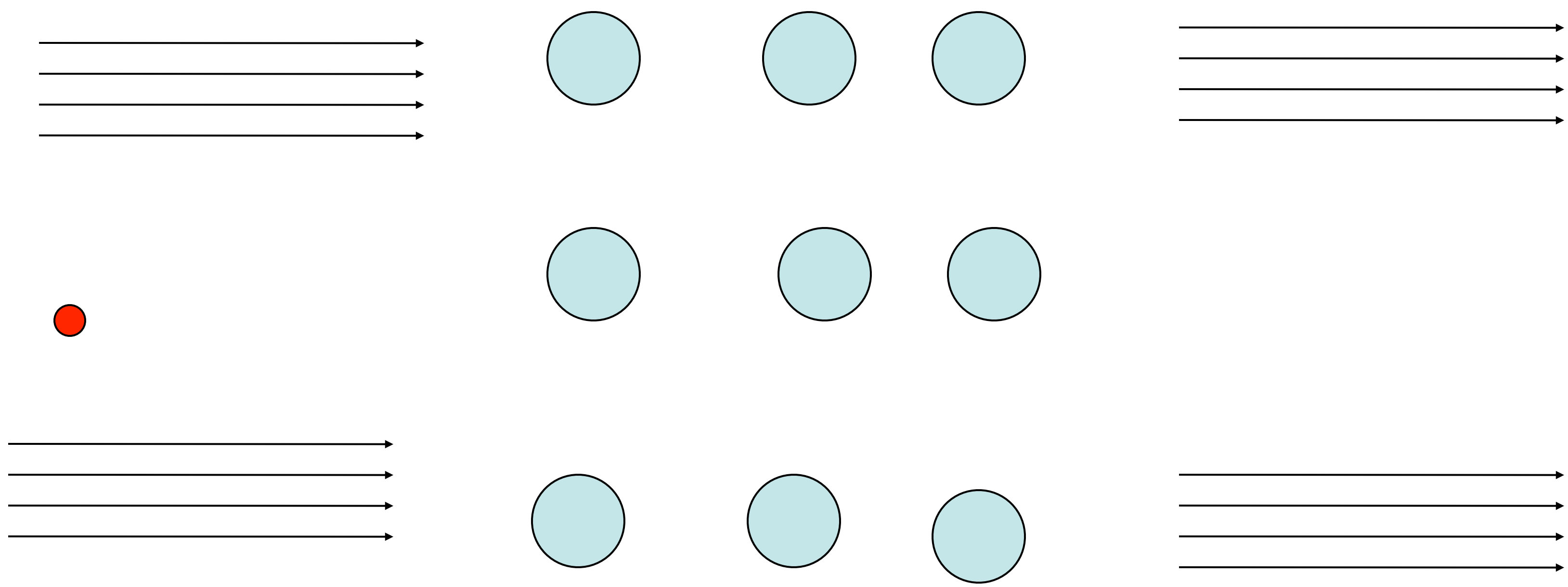
04/05/2010

Electrons in a Resistor

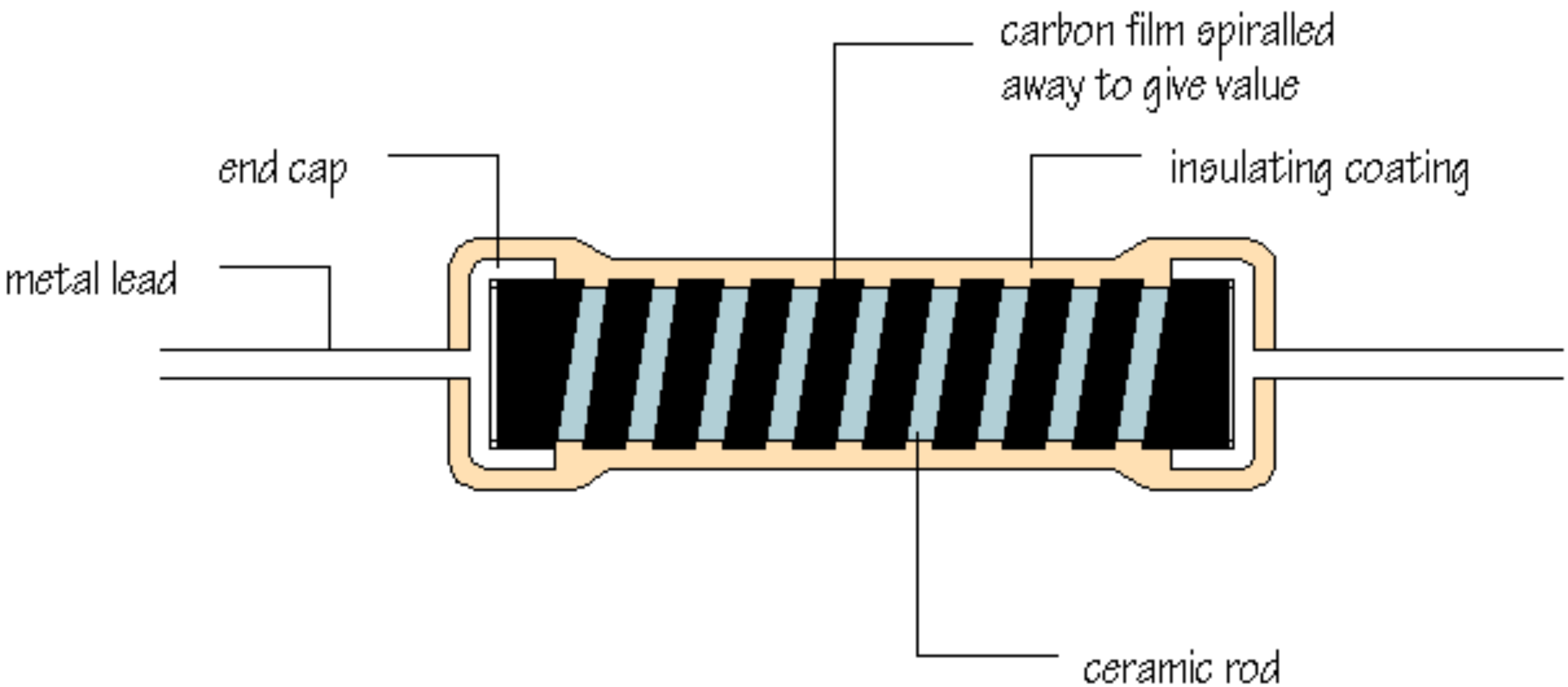
$F = ma = qE$

Lines of Electric Force
(-Electric Field)

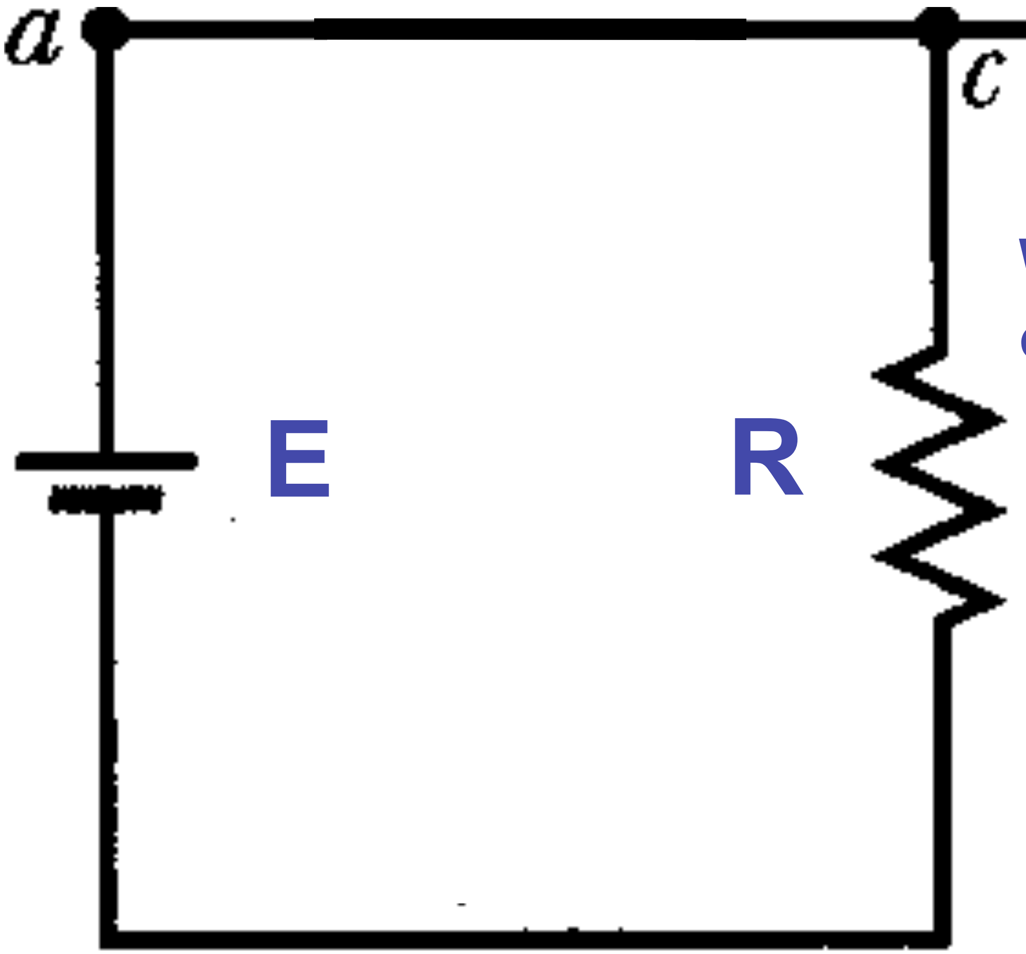
Atoms of Resistor
Material (e.g. Carbon)



Resistor Fabrication



RLC Circuits: the Loop Rule



Work done by battery on the charge:

$$dW = E\,dq = E\,i\,dt$$

$$E\,i\,dt = i^2 R\,dt \quad (\sim Fd)$$

Thermal energy at the resistor

$$E = iR$$

More Advanced Circuits

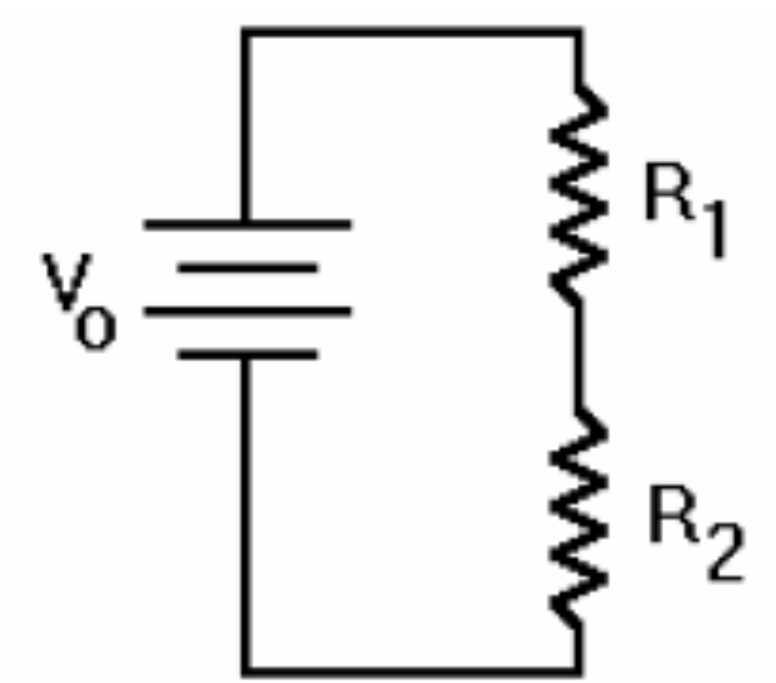


Figure 1 *Resistors in series*

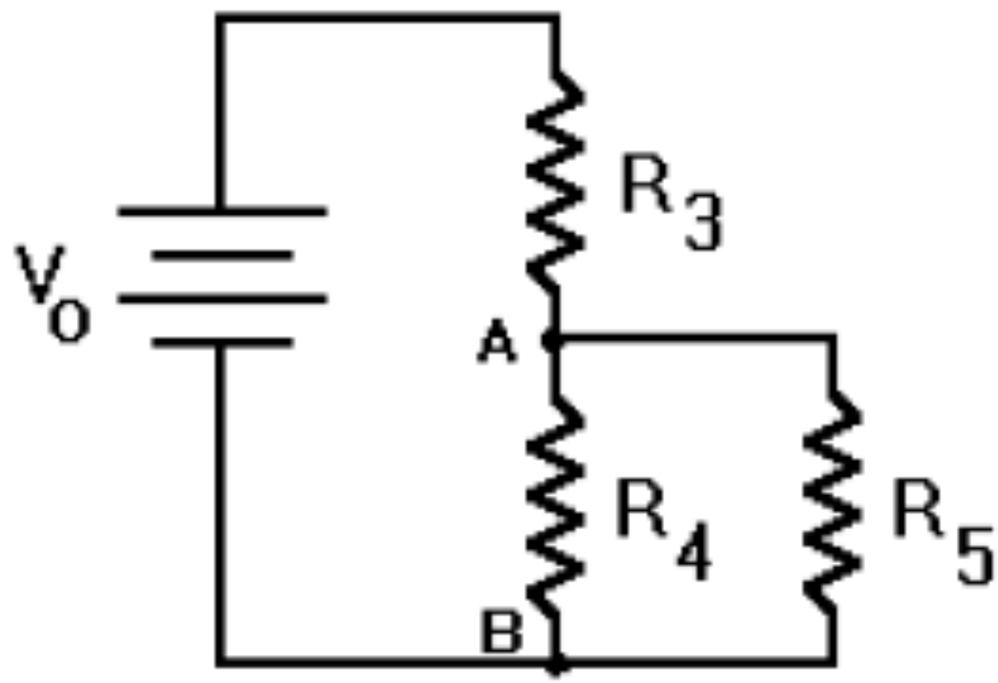


Figure 2 *Resistors in parallel*

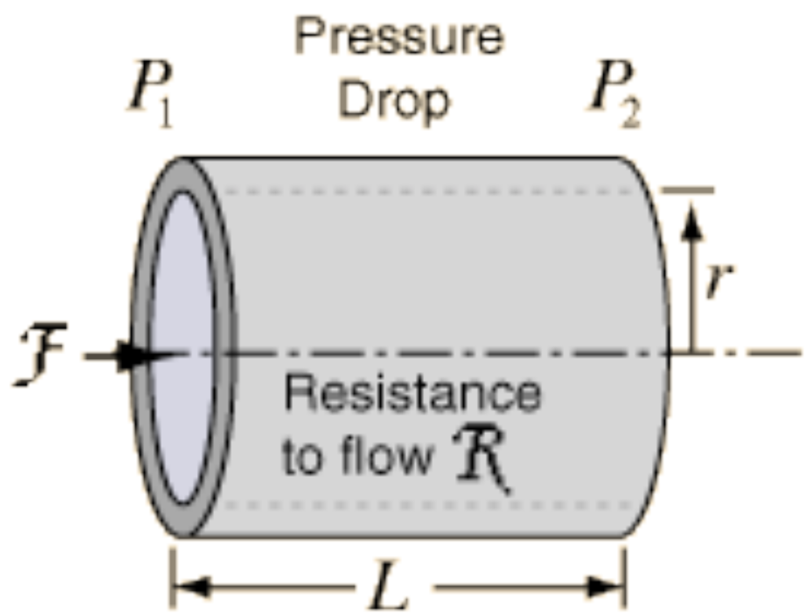
E&M & H_2O

- Example analogies

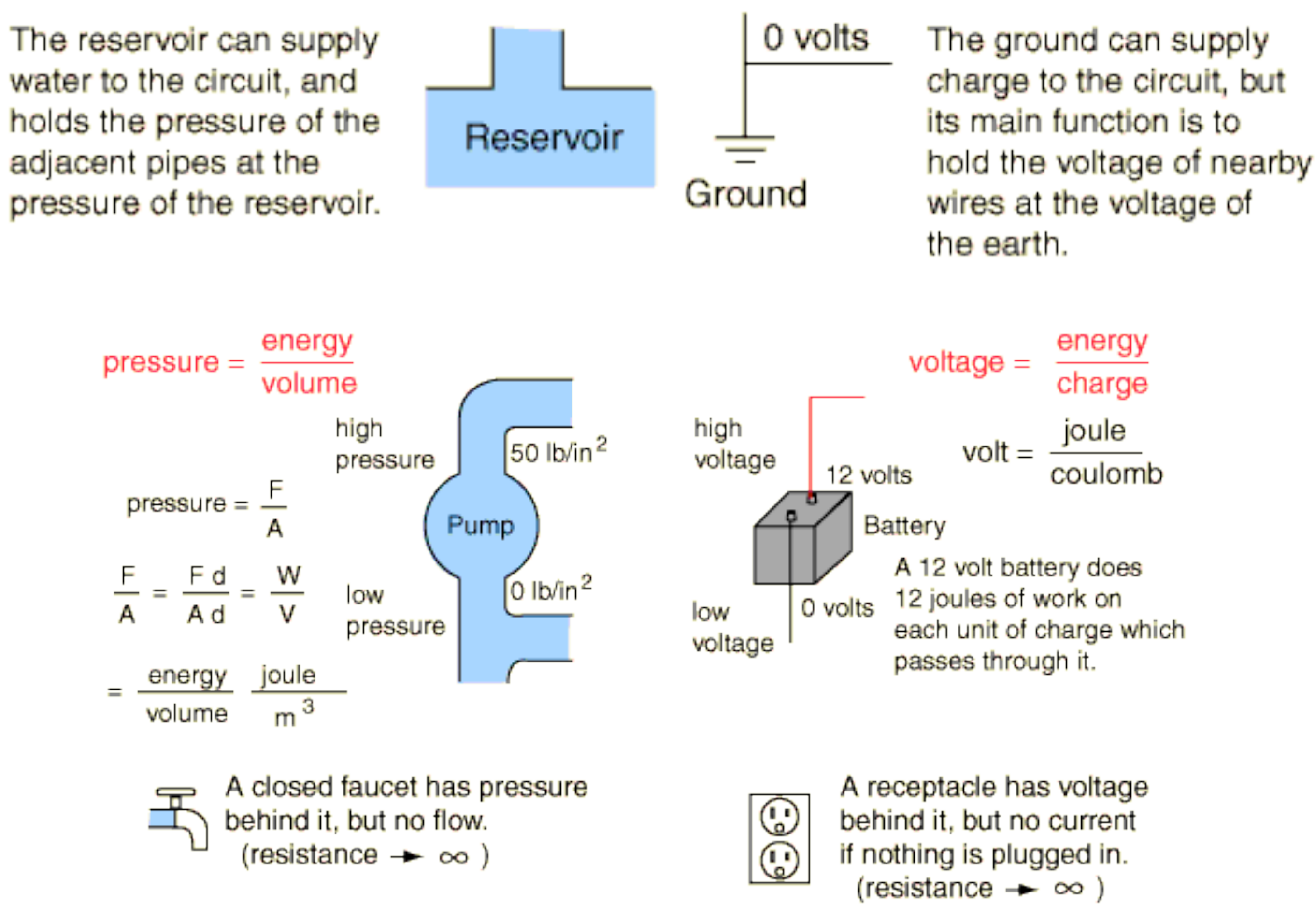
H_2O resistor

$$\text{Volume Flowrate} = \mathcal{F} = \frac{P_1 - P_2}{\mathcal{R}} = \frac{\pi(\text{Pressure difference})(\text{radius})^4}{8(\text{viscosity})(\text{length})}$$

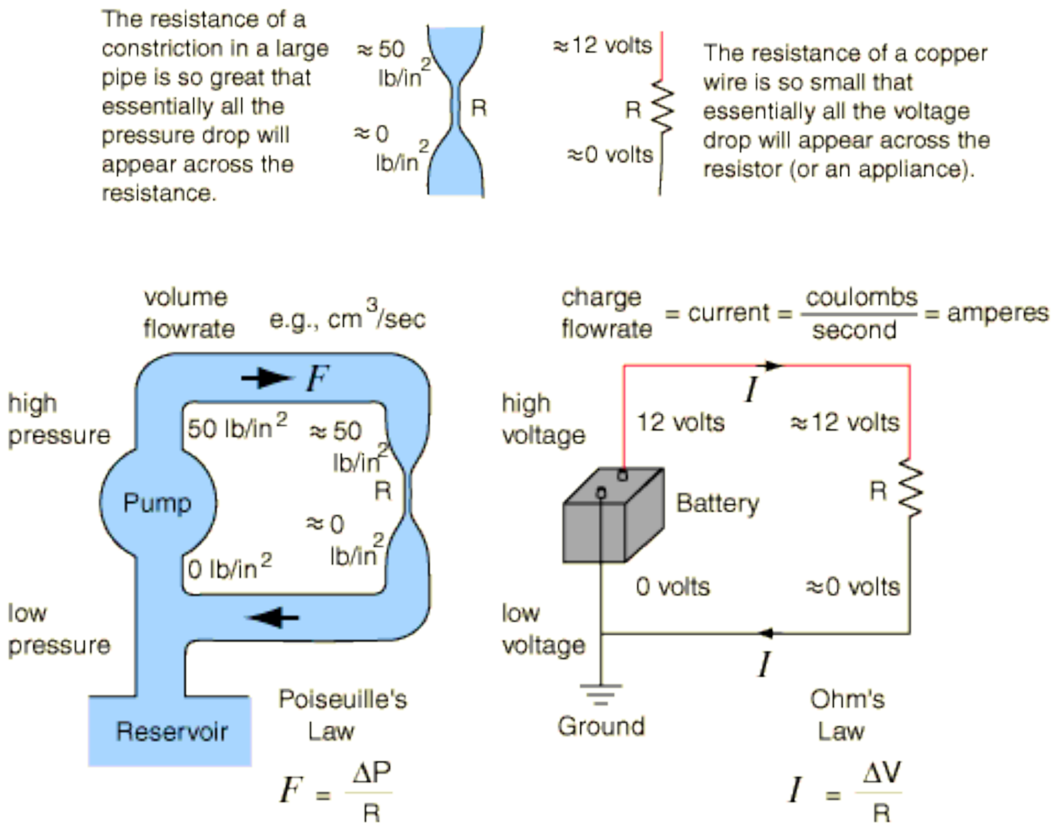
$$\text{Resistance to Flow} \quad \mathcal{R} = \frac{8\eta L}{\pi r^4}$$



E&M & H_2O

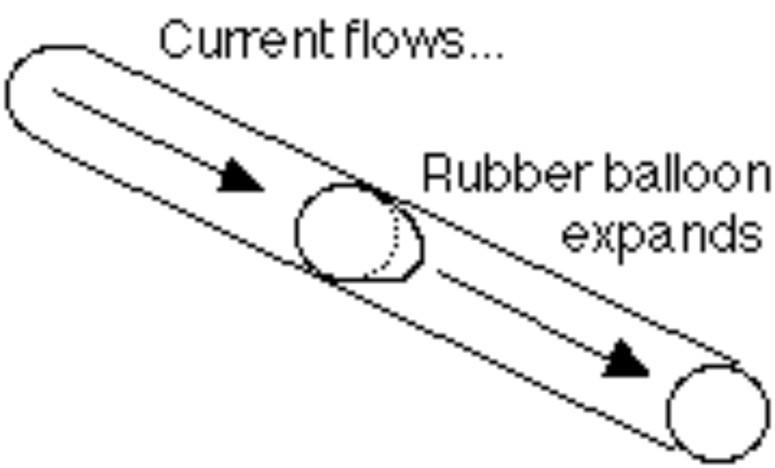

The reservoir can supply water to the circuit, and holds the pressure of the adjacent pipes at the pressure of the reservoir.
Reservoir
0 volts
Ground
The ground can supply charge to the circuit, but its main function is to hold the voltage of nearby wires at the voltage of the earth.
pressure = energy / volume
high pressure
50 lb/in²
Pump
pressure = F / A
F/A = F d / A d = W / V
low pressure
0 lb/in²
= energy / volume   joule / m³
voltage = energy / charge
high voltage
12 volts
volt = joule / coulomb
Battery
A 12 volt battery does 12 joules of work on each unit of charge which passes through it.
low voltage
0 volts
A closed faucet has pressure behind it, but no flow.
(resistance → ∞)
A receptacle has voltage behind it, but no current if nothing is plugged in.
(resistance → ∞)

E&M & H_2O

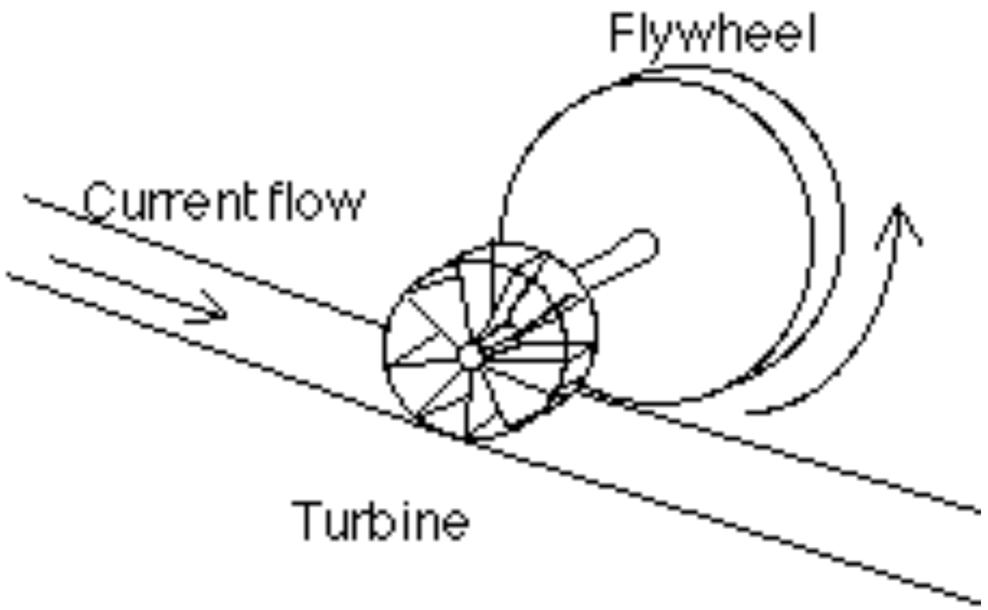


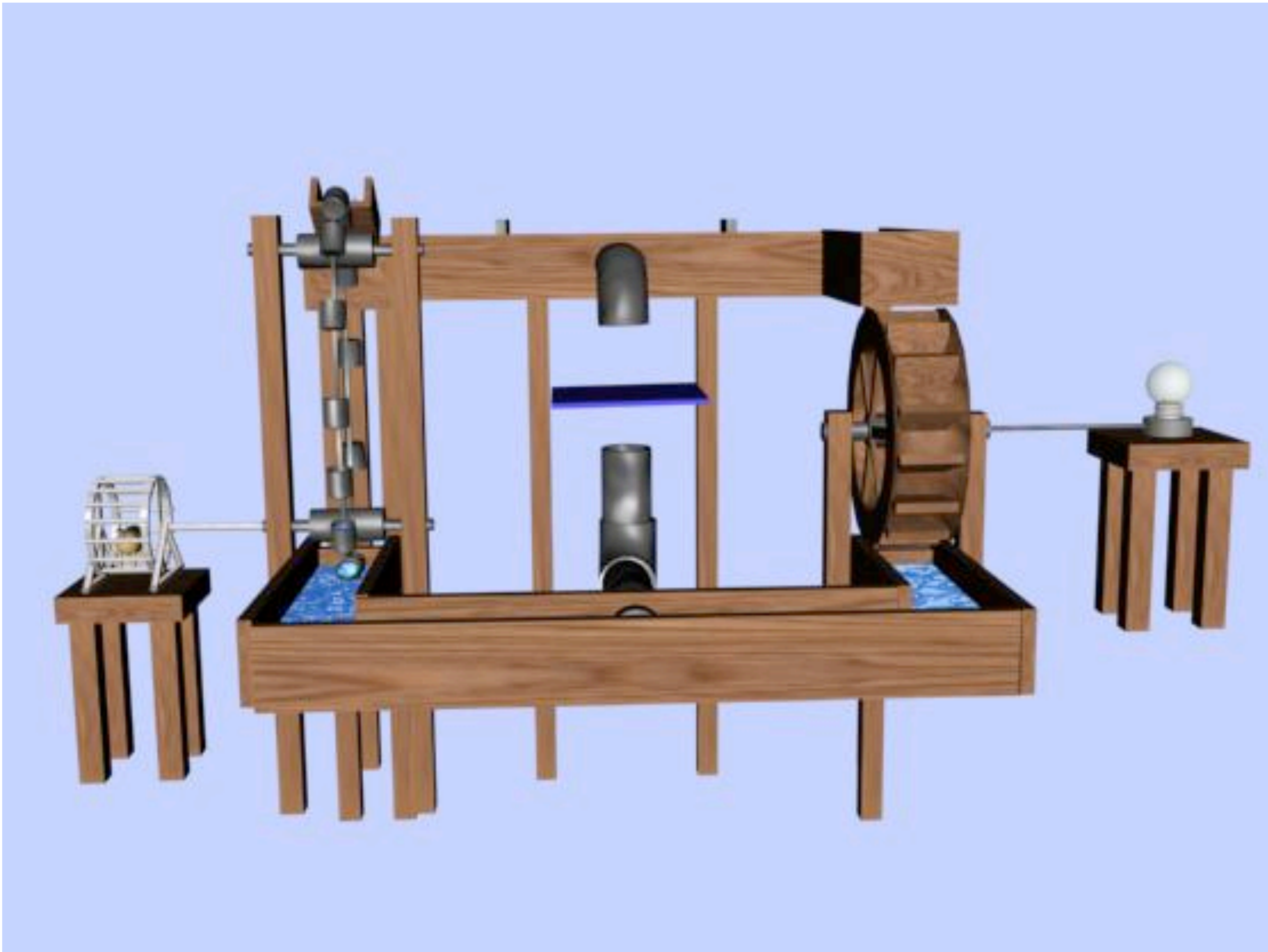
The resistance of a constriction in a large pipe is so great that essentially all the pressure drop will appear across the resistance.
≈ 50 lb/in2
≈ 0 lb/in2
R
≈12 volts
≈0 volts
R
The resistance of a copper wire is so small that essentially all the voltage drop will appear across the resistor (or an appliance).
volume flowrate
e.g., cm3/sec
F
high pressure
low pressure
Pump
50 lb/in2
≈ 50 lb/in2
R
≈ 0 lb/in2
0 lb/in2
Reservoir
Poiseuille's Law
F = ΔP/R
charge flowrate = current = coulombs/second = amperes
high voltage
low voltage
I
12 volts
≈12 volts
Battery
R
0 volts
≈0 volts
I
Ground
Ohm's Law
I = ΔV/R

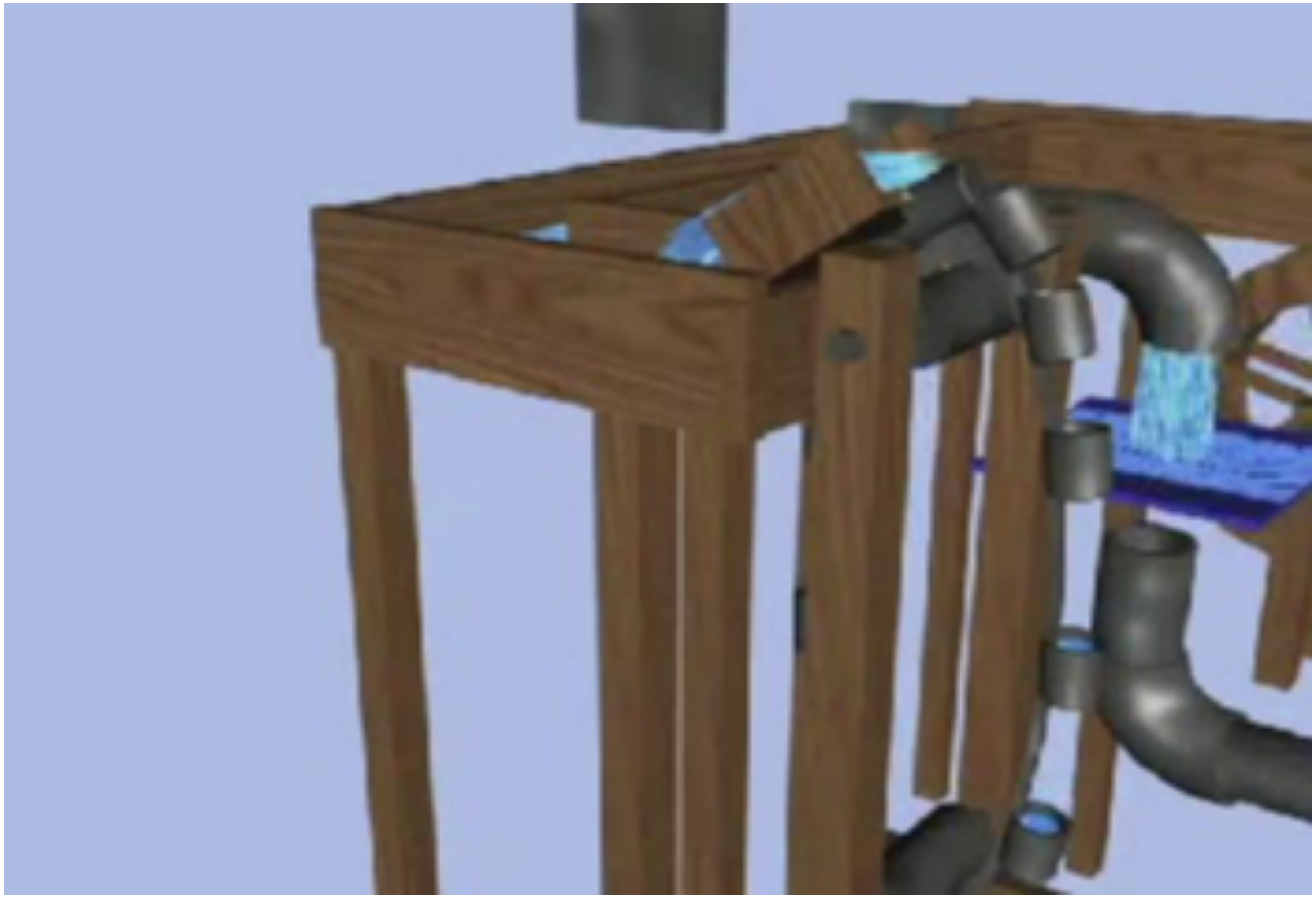
Capacitor

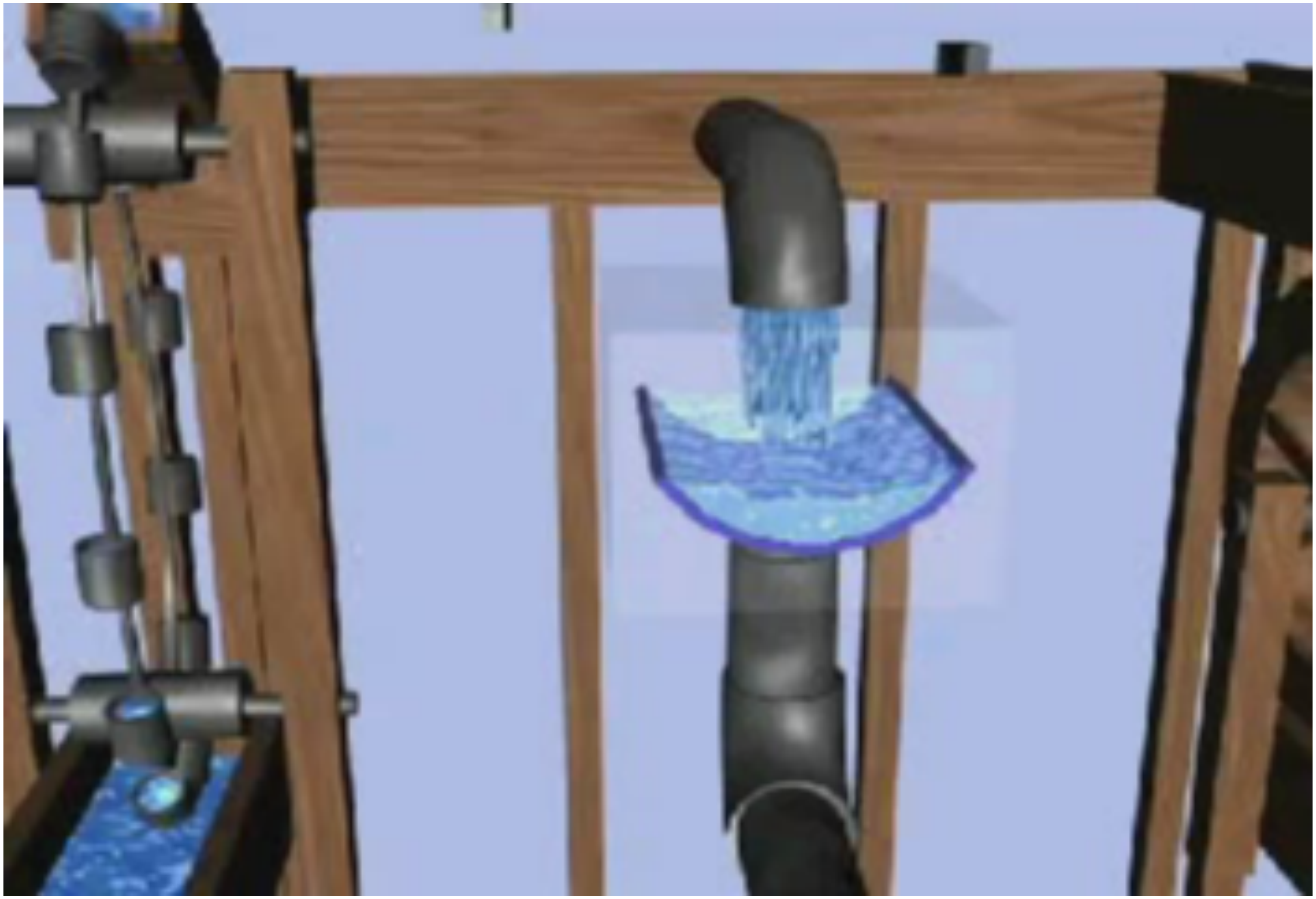


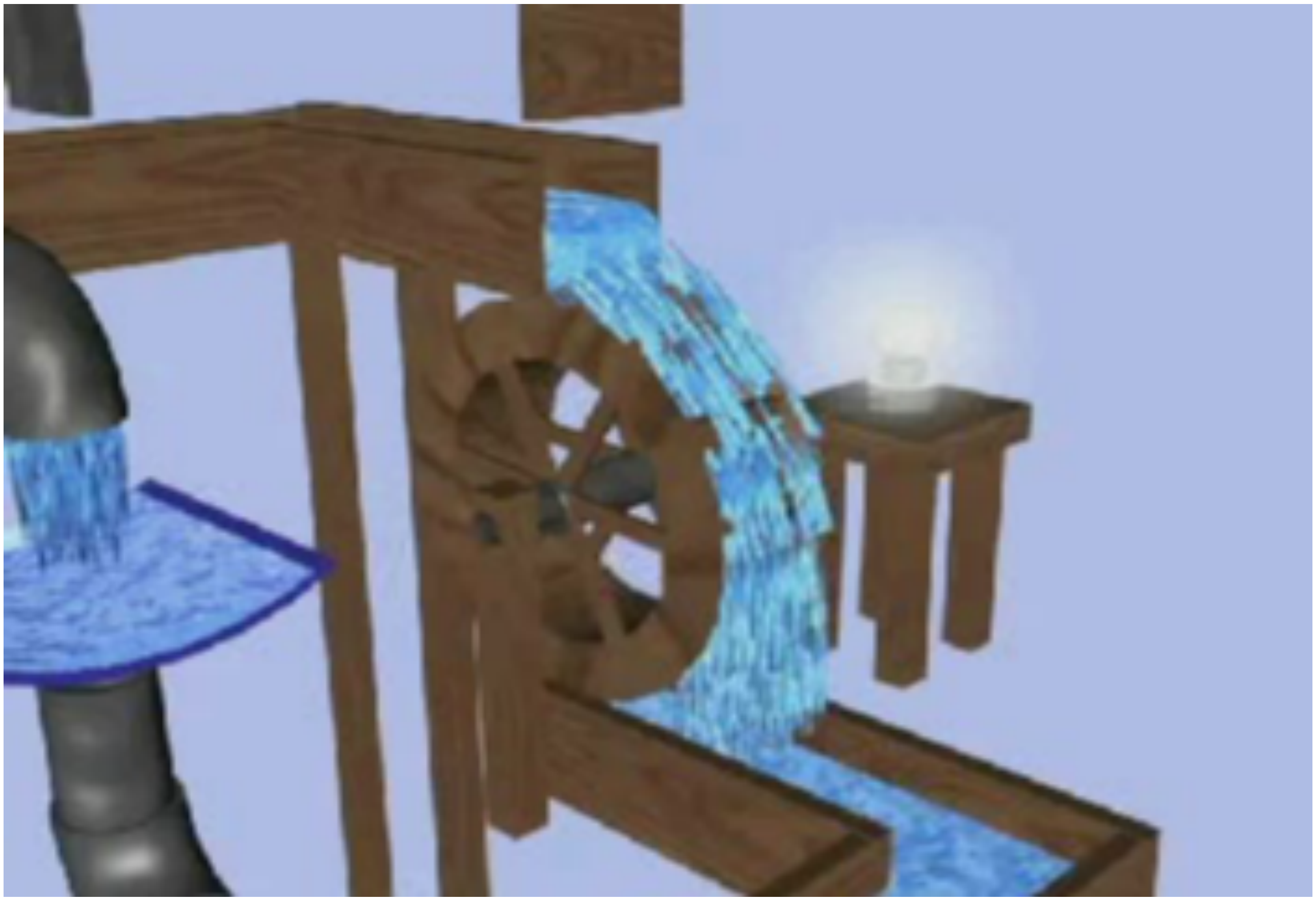
Inductors





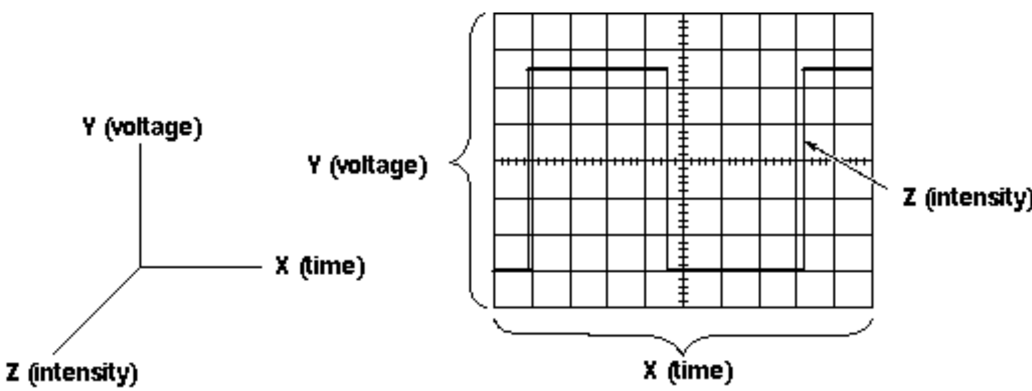


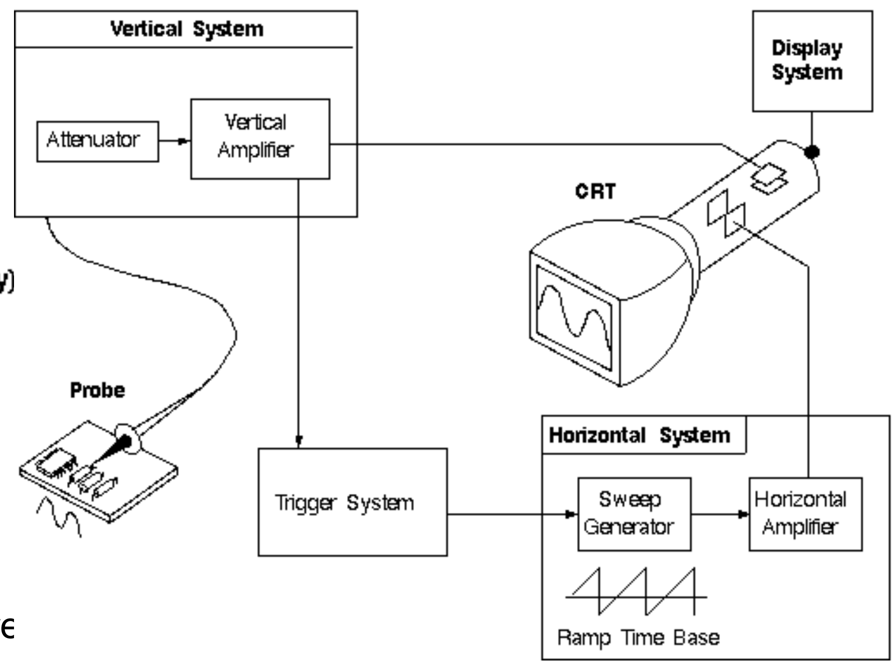




Oscilloscopes

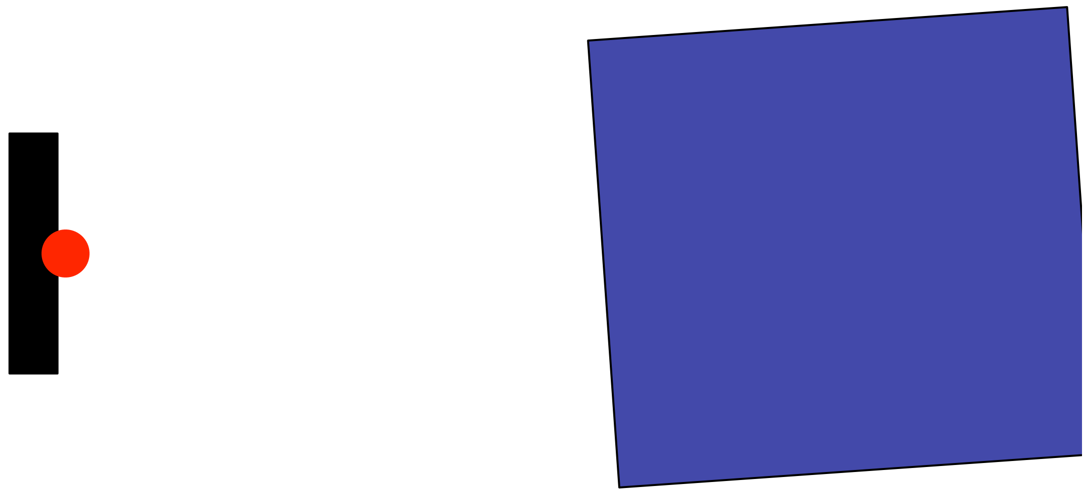
- You can determine the time and voltage values of a signal.
- You can calculate the frequency of an oscillating signal.
- You can tell if a malfunctioning component is distorting the signal.
- You can find out how much of a signal is direct current (DC) or alternating current (AC).
- You can tell how much of the signal is noise and whether the noise is changing with time.





Oscilloscope

J.J.Thomson
N.P. physics 1906



Oscilloscope

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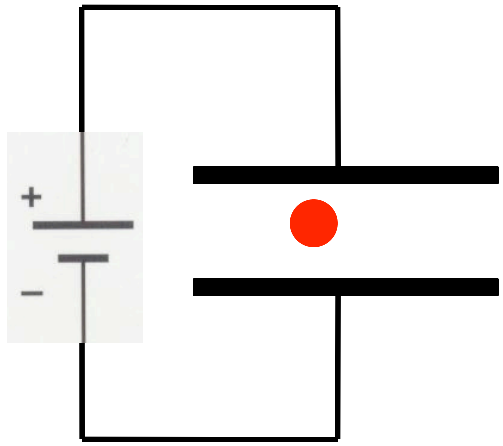

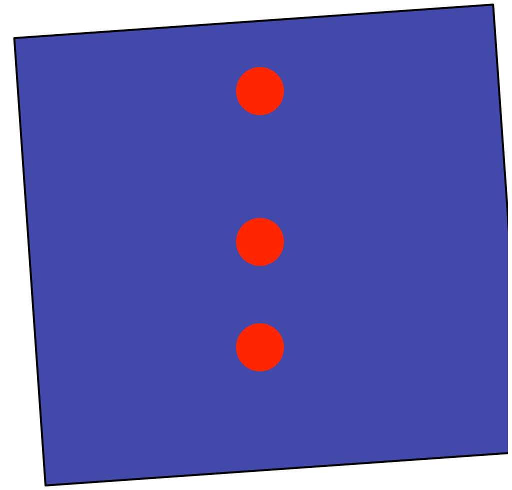

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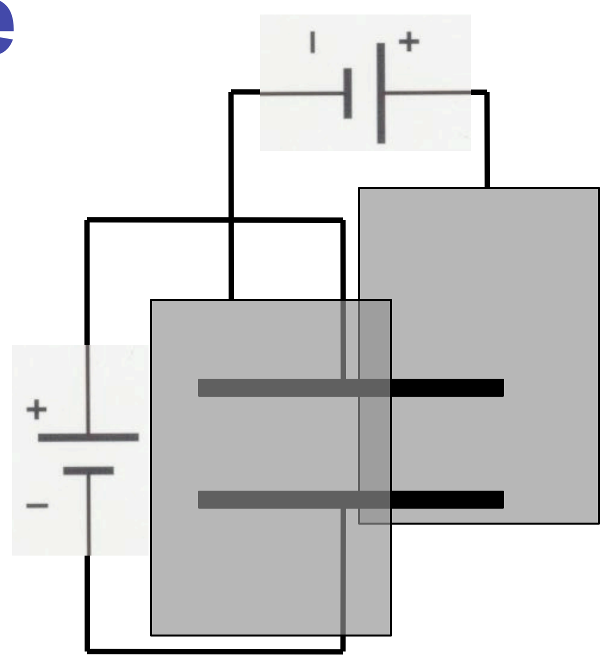
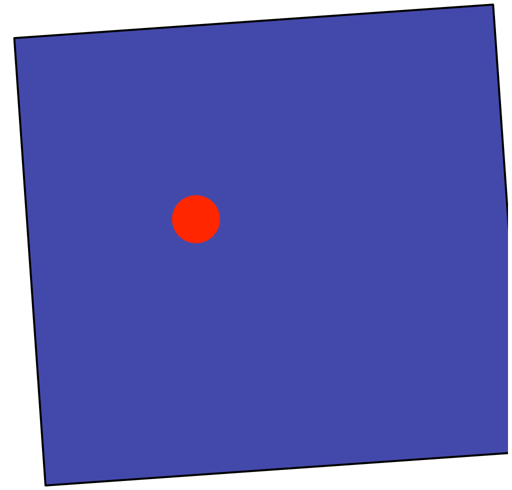
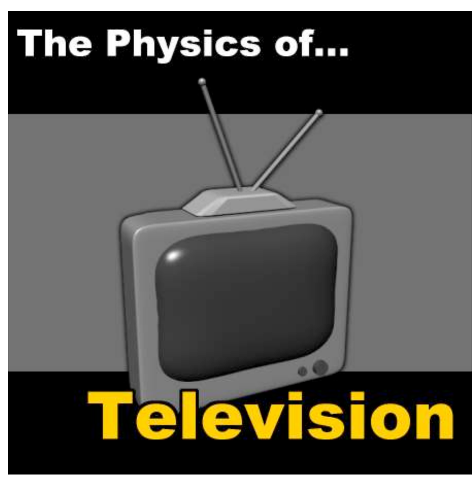




Similar to the TV…



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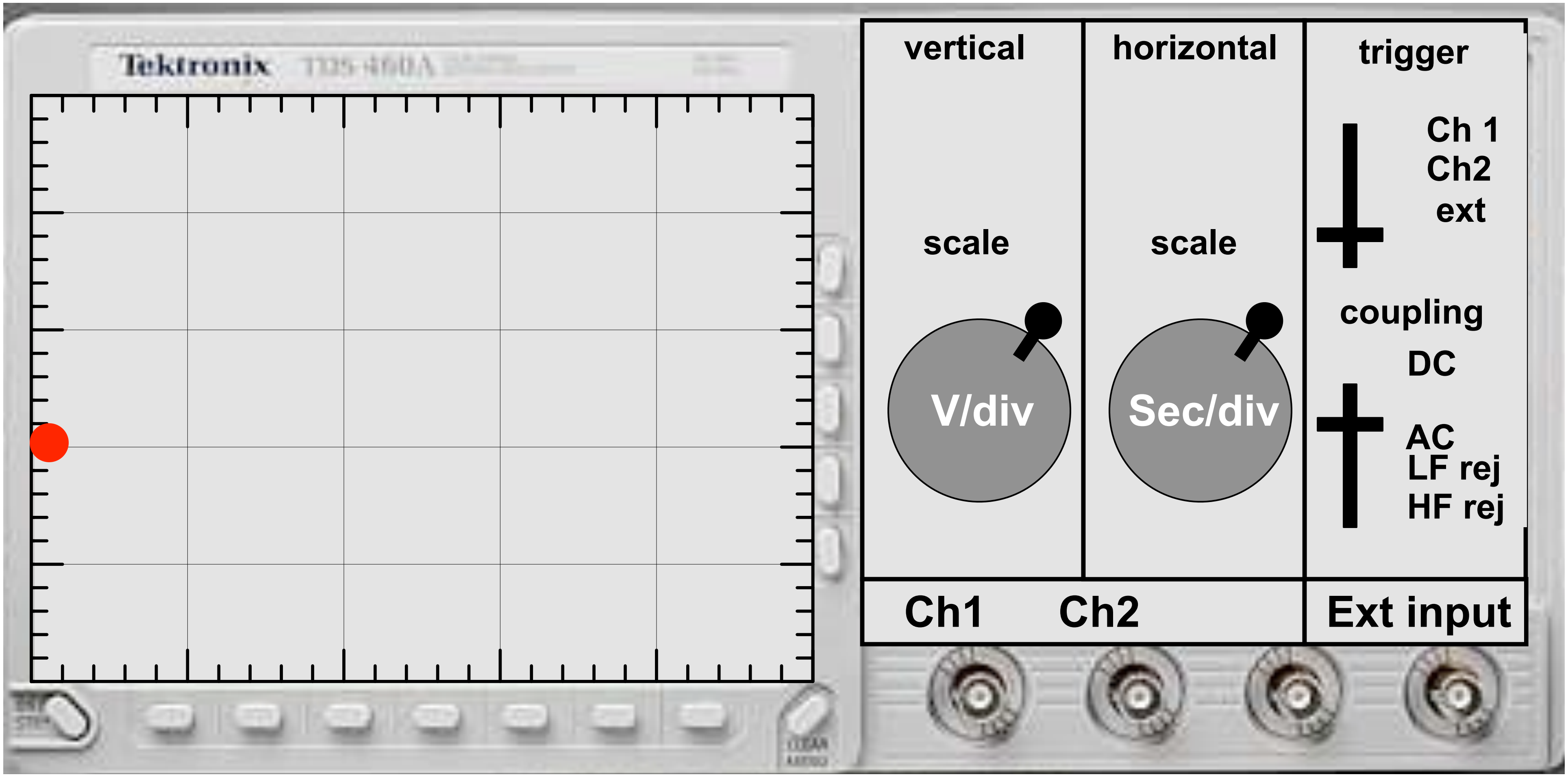
Oscilloscope



Oscilloscope