Physics 202 Lab
Lecture/Lab 2

1. WebWork Exercises
2. Lab 1 Notebook
3. Working on Lab 1

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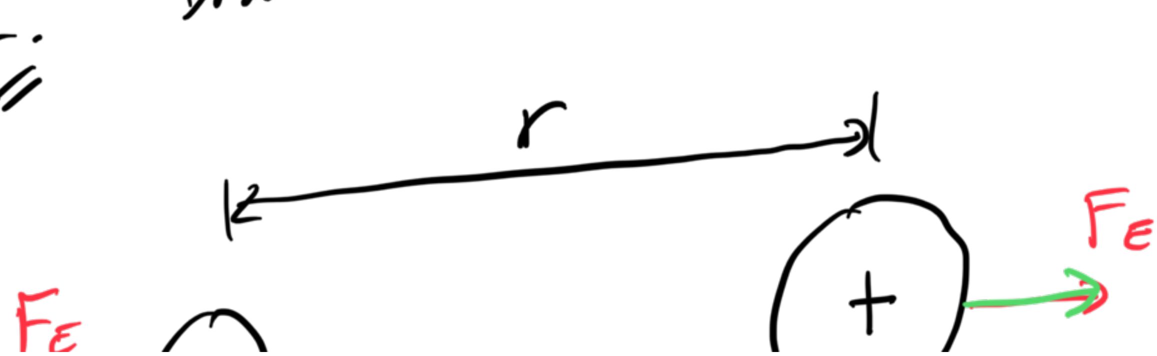
1. Draw Picture



$$\underbrace{|\vec{F}_E|}_{+ve} = \underbrace{k_e \frac{|Q_1||Q_2|}{r^2}}_{+ve}$$

$$= \frac{\left(8.99 \times 10^9 \frac{N \cdot m^2}{C^2}\right) \times (1.5 \times 10^{-5} C)(1.2 \times 10^{-5} C)}{(.89)^2}$$

$$= \cancel{2.042365} \ldots \ldots = 2.0 \text{ N}$$

$\boxed{\text{significant digits}}$

quantity

→ can't know a calculated quan[illegible]

to more precision than the

least well known raw quantity!

$$|Q_1| = \underbrace{1.5}_{} \times 10^{-5}\,C \quad \text{(2)}$$

$$|Q_2| = \underbrace{1.2}_{2} \times 10^{-5}\,C$$

$$r = \underline{0.89}\,m = \underbrace{8.9}_{2} \times 10^{-1}\,m$$

2.

$$|\vec{F}| = k_e\,Q^2$$

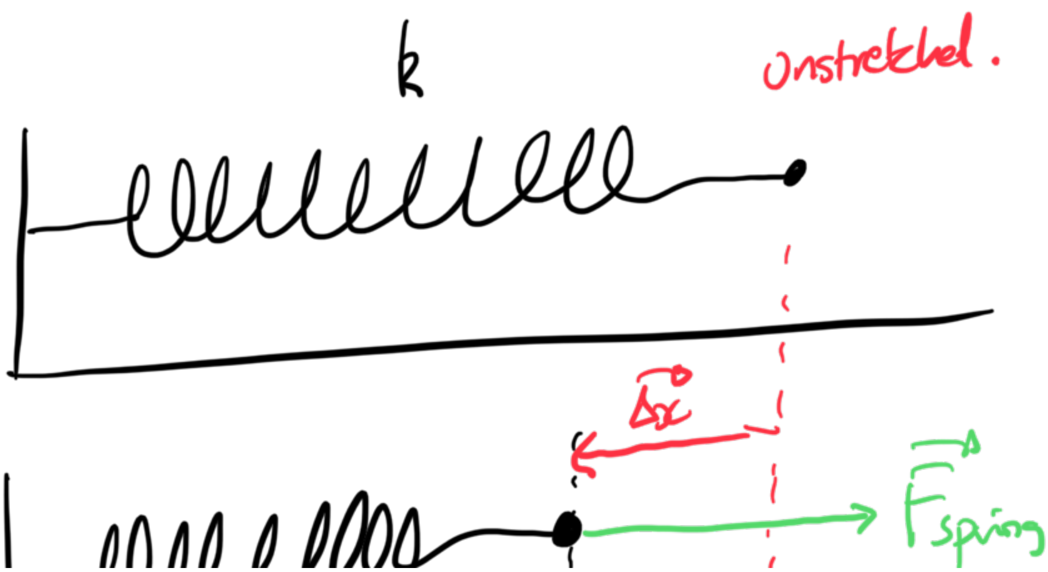
$$|\vec{F}_E| \quad \frac{\quad}{r^2}$$

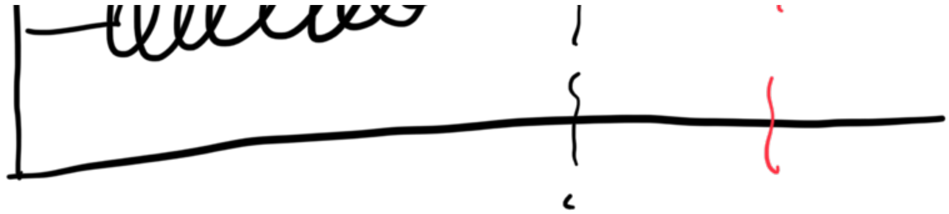
$$Q^2 = \frac{|\vec{F}_E| r^2}{k_e}$$

$$Q = \pm\sqrt{\frac{|\vec{F}_E| r^2}{k_e}}$$

$$= \pm 2.785 \times 10^{-6}\ C$$

3.





$$\vec{F}_{spring} = -k\,\vec{\Delta x}$$

!!!

$$|\vec{F}_{spring}| = k\,|\vec{\Delta x}|$$

$$k = \frac{|\vec{F}_{spring}|}{|\vec{\Delta x}|} = \frac{30.9\ N}{0.16\ m}$$

$$= 193.1\ N/m$$

$$\delta k = ?$$

<u>Uncertainties:</u>

Two Types.

Instrumental Uncertainty

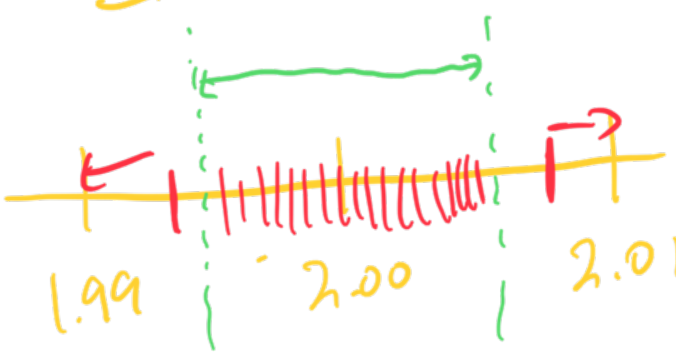
meter stick $\pm \frac{1}{2}$ smallest division

digital → maximum possible error.

Voltmeter $\boxed{2.00}$ V

not 1.99 V

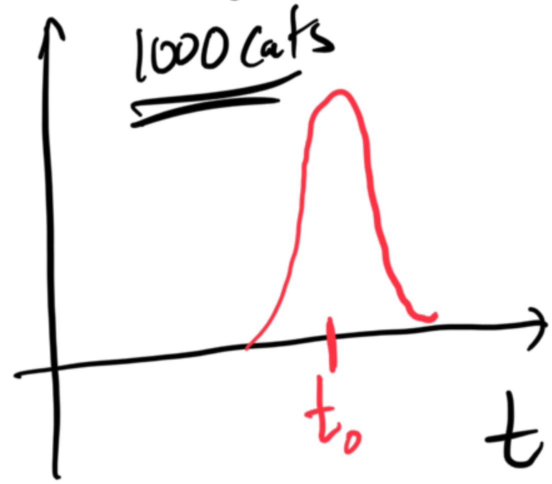
not 2.01 V



Statistical Uncertainty.

measure the same thing, many times.

1000 cats



→ Bell Curve.

→ Gaussian

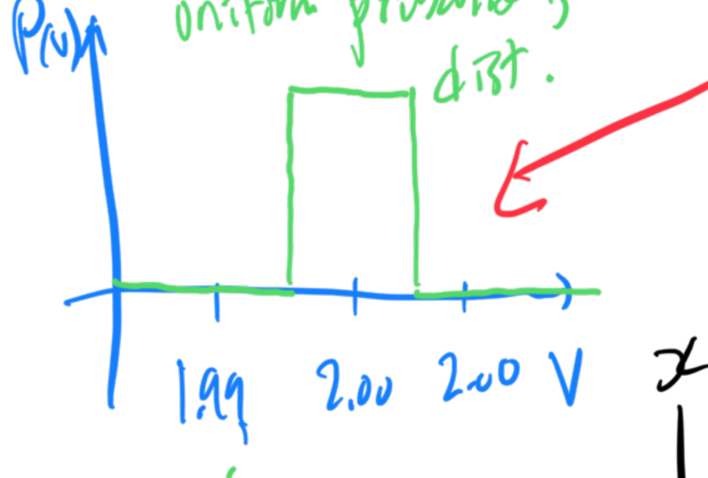
→ Normal Dist.

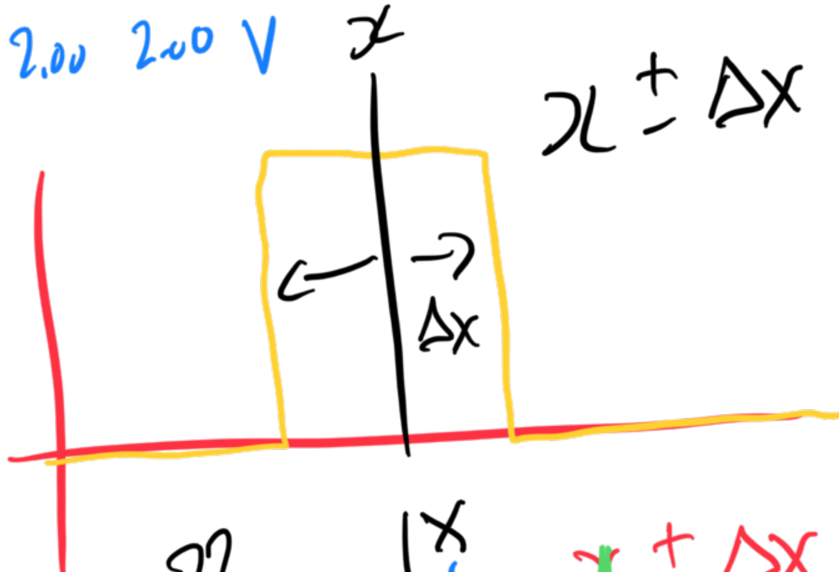
1.995 2.005

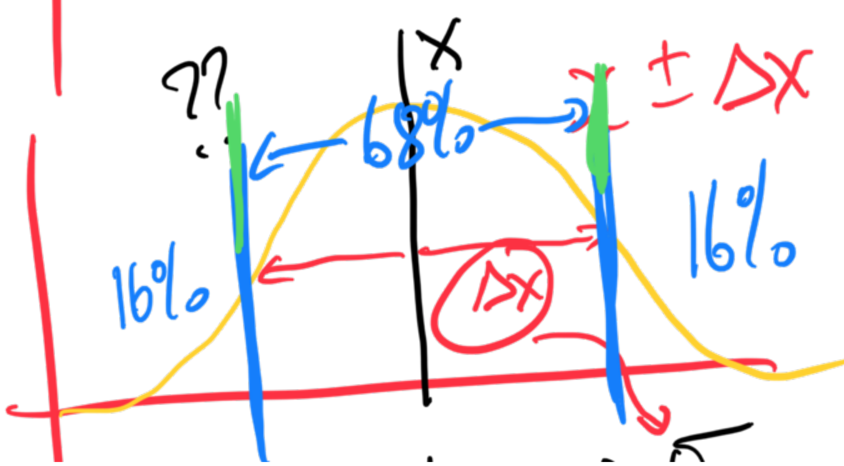
equally probable

$(2.00 \pm .005)\,V$

uniform probability dist.







std. deviation. → U

Uniform Uncertainty → conservative.
Gaussian Uncertainty → risky

$k = (16 \pm .16)\ cm$??

$F = (30.9 \pm .309)\ N$ instrumental

Error Propagation:

Tiny amount of calculus:

$z = f(x, y)$

$z = x + y$

$z = x - y$

$z = x^2 y$

Chain Rule of Differentiation.

$z = \log x \cdot \sin y$

If the uncertainties in x, y are uniform.

$$\boxed{\delta z = \left|\frac{\partial f}{\partial x}\right| \delta x + \left|\frac{\partial f}{\partial y}\right| \delta y}$$

If the uncertainties in x, y are Gaussian. $\left(e^{-x^2}\right)$

$$\boxed{(\delta z)^2 = \left|\frac{\partial f}{\partial x}\right|^2 (\delta x)^2 + \left(\frac{\partial f}{\partial y}\right)^2 (\delta y)^2}$$

$F \qquad F x^{-1}$

$$k = \frac{F}{x} \leftarrow$$

$$\delta k = \left|\frac{\partial k}{\partial F}\right| \delta F + \left|\frac{\partial k}{\partial x}\right| \delta x$$

$$\left|\frac{\partial k}{\partial F}\right| = \frac{1}{x} \qquad \left|\frac{\partial k}{\partial x}\right| = + \frac{F}{x^2}$$

$$\frac{\delta k}{k} = \frac{\frac{1}{x}\,\delta F}{F/x} + \frac{\frac{F}{x^2}\,\delta x}{F/x}$$

$$\boxed{\frac{\delta k}{k} = \frac{\delta F}{F} + \frac{\delta x}{x}}$$

$$\delta k = k\left(\frac{\delta F}{F} + \frac{\delta x}{x}\right)$$

$$= 193.1\left(\frac{.309}{30.9} + \frac{0.16}{16}\right)$$

$$= 3.9 \text{ N/m}$$

$$\boxed{k = (193.1 \pm 3.9} \text{) N/m}$$

conservative.

Assumed Gaussian Uncertainties.

$$\left(\frac{\delta k}{k}\right)^2 = \left(\frac{\delta F}{F}\right)^2 + \left(\frac{\delta x}{x}\right)^2$$

$$\delta k = 2.731 \text{ N/m}$$

$$k = (193.1 \pm 2.731) \text{ N/m}$$

smaller!! Right!!

Workflow

brash99 / Phys 202L

johnsmith / Phys 202L

Google Colaboratory

Initial Angle.

$$\theta_0 = \underline{\underline{25.5}} \pm 0.5^\circ$$

$$\rightarrow \theta_1 = 160.0 \pm 0.5^\circ$$

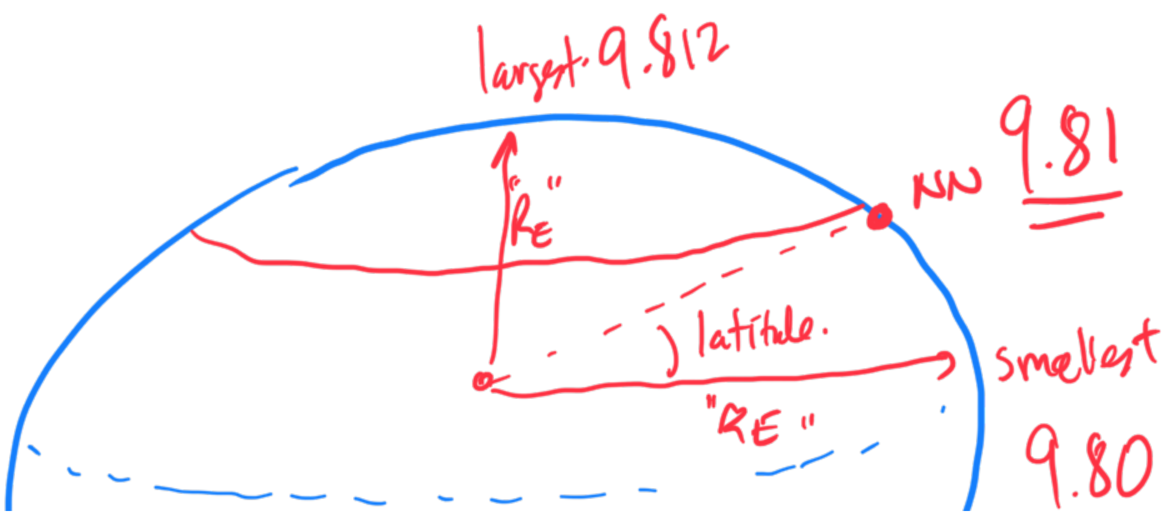
$$\boxed{\theta = \theta_1 - \theta_0}$$

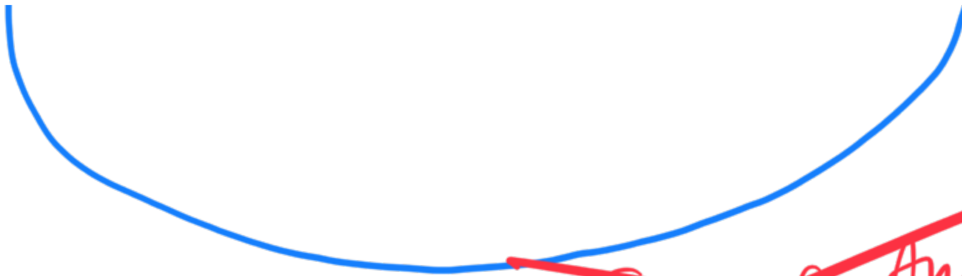
$$= 134.5^\circ \pm ?$$

$$\delta\theta = \underbrace{\left|\frac{\partial\theta}{\partial\theta_1}\right|}_{1}\delta\theta_1 + \underbrace{\left|\frac{\partial\theta}{\partial\theta_0}\right|}_{|-1| = 1}\delta\theta_0$$

$$\boxed{\delta\theta = \delta\theta_1 + \delta\theta_0}$$

$g = ?$ $\quad g_{\text{Newport News @ CNU}}$





~~Force vs. Angle.~~

Uncertainties.

Calibration factor:

1×10^{-6} N

(1.475 ± 0.008) degree

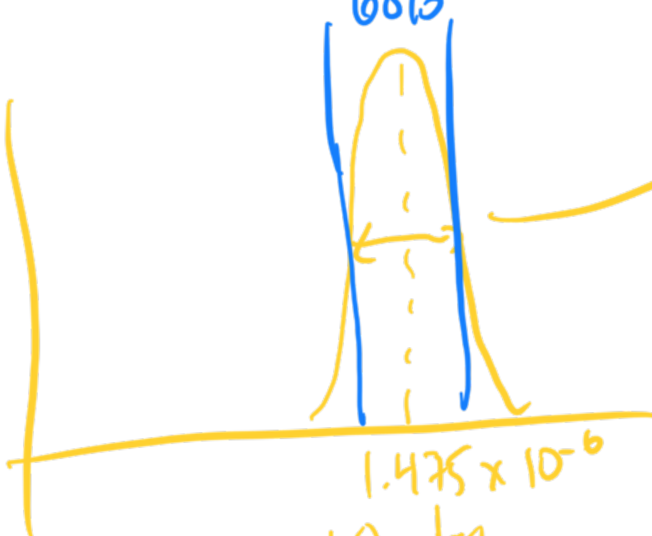
instrumental.

or

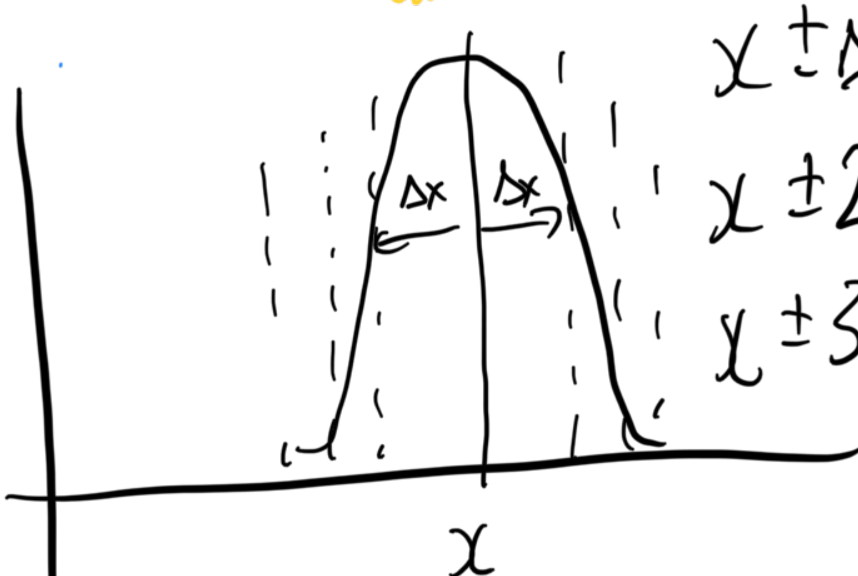
statistical.

fit

Many pts. → fit



calibration.



$x \pm \Delta x \rightarrow 68$%

$x \pm 2\Delta x \rightarrow 95$

$x \pm 3\Delta x \rightarrow 99$

$$\boxed{x \pm 3\sigma} \rightarrow 99\%$$

close 100%
=
max. poss. error.

$$F = \frac{k_e |Q_1||Q_2|}{r^2}$$

F vs. $\frac{1}{r^2}$

calibration factor

$$F = C \cdot \theta$$

$C \pm \delta C$ $\quad$ $\theta \pm \delta\theta$

max. possible error 30

$$\left(\frac{\delta F}{F}\right) = \left(\frac{\delta c}{c}\right) + \left(\frac{\delta \theta}{\theta}\right)$$

$$\delta F = F\left(\frac{\delta c}{c} + \frac{\delta \theta}{\theta}\right)$$

Raw Data → Prepared Data → Fit

X-axis → $\frac{1}{R^2}$

n^{-2}

$$\boxed{x = \frac{1}{R^2}}$$

$x = R$

$\frac{\partial x}{\partial R} = -2R^{-3}$

$\left|\frac{\partial x}{\partial R}\right| = \frac{2}{R^3}$

$$\delta x = \left|\frac{\partial x}{\partial R}\right| \delta R$$

$$\frac{\delta x}{x} = \frac{\frac{2}{R^3}\,\delta R}{1/R^2}$$

$$\frac{\delta x}{x} = 2\,\frac{\delta R}{R}$$

$$\boxed{\delta x = x\left(\frac{2\,\delta R}{R}\right)}$$

$$\boxed{Q = \frac{K_{sphere}}{k} V}$$

$$\text{Slope} = k\,Q_1\,Q_2$$

$$= \cancel{k}\left(\frac{R_s}{\cancel{k}}V\right)\left(\frac{R_s}{k}V\right)$$

$$\text{Slope} = \frac{R_s^2 V^2}{k}$$

$8.99 \times 10^9 \frac{Nm^2}{C^2}$

$$\boxed{k = \frac{R_s^2 V^2}{\text{slope}}} \checkmark$$

$R_s \approx 1.9\,cm = .019\,m$

$V \approx 6000\,V$

$$\boxed{\delta V = 10 + 0.01V} = 70\,V$$

$\delta R_s = ? \approx 1\,mm = 0.001\,m$

$$\boxed{\frac{\delta k}{k} = 2\left(\frac{\delta R_s}{R_s}\right) + 2\left(\frac{dV}{V}\right) + \frac{\delta slope}{slope}}$$

% % % %

$k = (13.0 \pm 3.3) \times 10^9 \frac{Nm^2}{C^2}$

don't agree

$(9 \pm) \times 10^9\, Nm^2/C^2$

→ close

→ enough?

Theory : Point charges.

Final Reports:

Who is the audience?

$\boxed{\text{Another classmate who is struggling}}$

→ Lab instructions
→ theory
→ method
→ data
→ apparatus

1. Analysis

   WITH COMMENTS

2. Explanation of Results

   agree / disagree ?

   ✓

   WHY ?