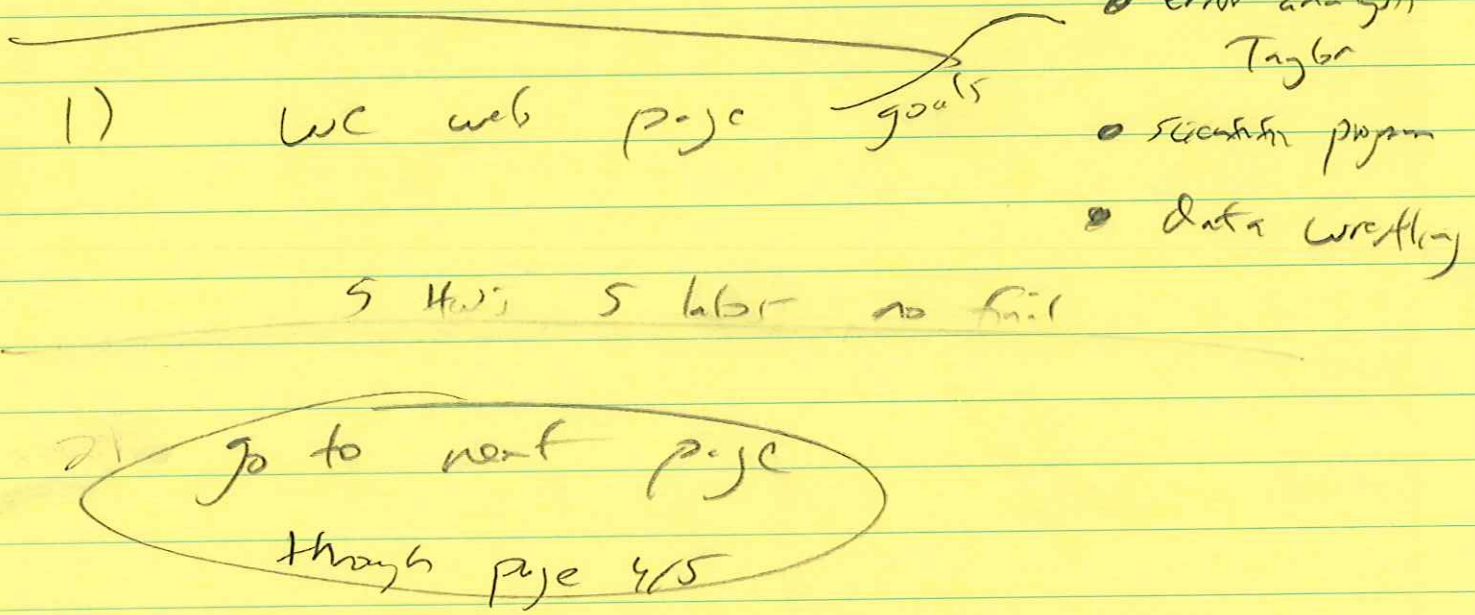
Phys 391 Lec 1
W15

1) course organization

2) a bit of error analysis

3) scientific programming



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- labs will entail using scientific programming to ascertain data, reduce it to useable or perhaps form, graph it and interpret/fit it with mathematical relationship

- some will be coding a simulation of a wave packet. All will be presenting their lab 2 results to the group.

- finally, will explore the ubiquitous Fourier Xform

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2 Error — its scientific meaning & importance

=> In science, "error" is not a mistake but, rather, an estimate of the inevitable uncertainty in a measurement

=> Indeed, no physical quantity can be measured with complete certainty, w/o error

Why care about error?

a) are 2 measurements consistent?

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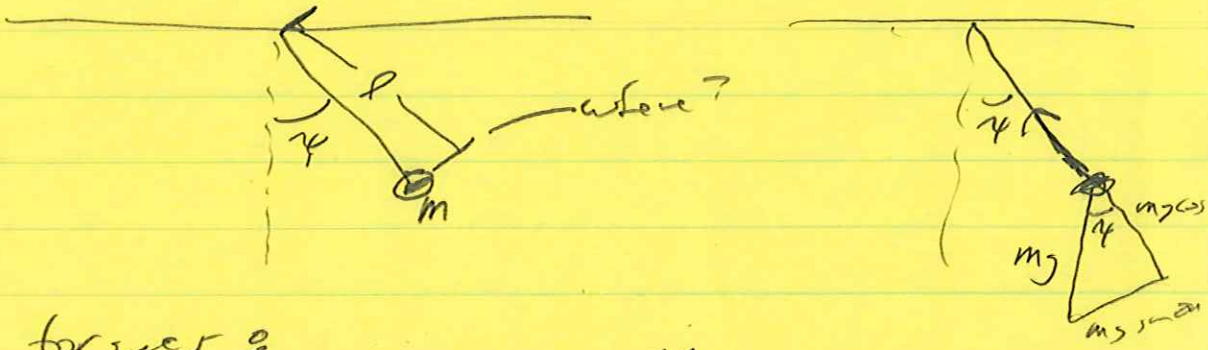
q1 (2 measures consistent?)

- pers 1. measures length of pendulum to be
  $\ell = 30.9$ cm
- pers 2 measures period of pendulum to be
  $T = 1.14$ seconds

So this

P — are 2 measures consistent?
how to check?

• turn pers 2's T info on ℓ (or vice versa)



suggest use torques:

$$\tau = I\ddot{\psi}$$

$$\Rightarrow -mg\sin\psi \cdot \ell = I\ddot{\psi} = m\ell^2\ddot{\psi}$$

P — still problematic, why?

assum small angle approx $\sin(\psi) \approx \psi$

$$\Rightarrow -mg\psi\ell = m\ell^2\ddot{\psi}$$

discuss m

propose soln $\psi = \psi_0 \cos(\omega_0 t + \phi)$

where $\omega_0 = \sqrt{\frac{g}{\ell}} = \frac{2\pi}{T_0}$

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④ ⑤

Use matlab $\ell = 30.9\ \text{cm} = .309\ \text{m}$

$T = 1.145$

$\frac{(2\pi)^2}{T_0^2} = \sqrt{\frac{g}{\ell}} \Rightarrow \ell = \frac{g T_0^2}{(2\pi)^2} = ??$ .3225 .323 m

(unit analysis check)

is .309 m consistent w/ .323 m?

$\Rightarrow$ need errors for each ℓ to tell?

Skip forward to ⑤

(pers 1) error for ruler measurement

30.9 cm means measuring to 0.1 mm, very hard to do?

- assume pers 1 make 10 measurements, calculates std as 1.3 mm so state measure as (31 ± 1) cm

(pers 2) does measure 10 times, "statistics" 5 oscillations each time, does error prop. (we'll get to this?) (32 ± 2) cm

① $\Rightarrow$ are they consistent?

---

3) why study error?

(1904-05) Einstein's postulated gen. theory of relativity.

3pt with

(2pt)

(5)

Now say first measured gives

$l = (30.7 \pm 0.5)$ cm

and second gives $T = (1.14 \pm 0.05)$ s

If second measurement same pendulum / same conditions

$$l_2 = \frac{g T_0^2}{(2\pi)^2} \qquad \text{say} \quad g = (-7.80 \pm \tfrac{0.05}{0.1})\ \tfrac{m}{s^2}$$

need $l_2 \pm \delta l_2$ for comparison

need to add error in quadrature

$$\frac{\delta l_2}{|l_2|} = \sqrt{\left|\frac{\delta g}{g}\right|^2 + \left|2\frac{\delta T_0}{T_0}\right|^2}$$

$$\left|\frac{\delta g}{g}\right| = .065, \quad \left|\frac{\delta g}{g}\right|^2 = 2.6 \times 10^{-5}$$

$$\frac{\delta T_0}{T_0} = 0.0438 \qquad \left(2\frac{\delta T_0}{T_0}\right)^2 = .0077$$

$$\frac{\delta l_2}{|l_2|} \approx \sqrt{.0077} = .087 \Rightarrow$$

$$\delta l_2 = 32.3 \times .0876 = 2.8$$

$$l_2 = (32.3 \pm 2.8)\ \text{cm}$$

3rd WIS (Lec 1)

(6)

yes, they are consistent

$l_1 = (30.9 \pm 0.5)$ cm

$l_2 = (32.3 \pm 2.0)$ cm

$[\ 32.3 - 2.0 = 29.5 < 30.9\ ]$

plot to show comparison

→ go to Dyson description

3

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(7) (5) (6)

(3) why study error)

- Gen. rel. predicts light bends around a star @ $\alpha = 1.8''$ (seconds of arc)
- "Classical theory" says $\alpha = 0.9''$

(1919) Dyson, Eddington, Davidson do "small experiment"*, get

$$\alpha = (2.0 \pm 0.3)''$$

→ So, result is consistent with G.R. but not C.T.

---

4) Prelim data(s

best est. 32.5 cm : range 32.2 → 32.8 cm

Stop

$$(32.5 \pm 0.3)\ \text{cm}$$

not $(32.5 \pm .003)$ cm
nor (32.5 ± 2) cm

(Pg 15 of Taylor)

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* expedition to west Africa & Brazil to observe stars in daytime during lunar eclipse of sun, compare position of stars near sun w/ nighttime positions

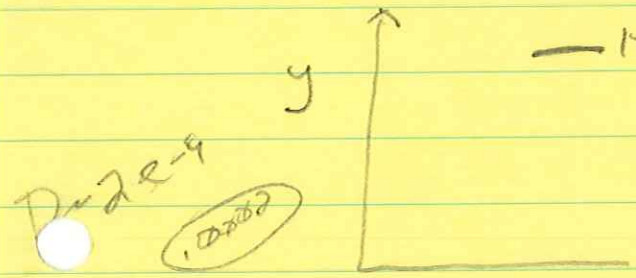
L26

2) Coding in for loops for air resistance

Note, we didn't account for air resistance in previous problem.?

⇒ could we fix this computationally? signs?

need new ΔF on steel ball, $= F_g + F_{drag}$



eqn $\frac{F_{tot}}{m} = a = \frac{v_f - v_i}{dt}$

$v_f - v_i = \left(\frac{F_{tot}}{m}\right) dt$

$v_f = v_i + \left(\frac{F_{tot}}{m}\right) dt$

what sets the F_{tot}

$F_a = \frac{F_{tot}}{m} = ge - \frac{F_Q}{m}$

$= ge - Dv^2$?

$= ge - D(v_{avg})^2$?

$\frac{h_f - h_i}{dt} = v_{avg} * dt$

ge = -7.8 (final)

y(1) = 17.1

t(1) = 0

Vi = 0

dt = 0.1 (5)

Fnm = ge ;

V(1) = Vi + Fnm * dt

Vavg = 0.5 * V(1)

y(2) = y(1) + Vavg * dt

for i = 2:10000

FQ = + D * Vavg(i-1)^2 ;

Fnm = ge * m + FQ ;

V(i) = Vi + (Fnm/m) * dt ;

Vavg(i) = (Vi + V(i))/2 ;

Vi = V(i) ;

y(i) = y(i-1) + Vavg(i) * dt ;

end

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L2.1

1) more about error



accuracy involves knowing what is a good answer.

2 things

1) can reduce statistical error (increase precision) by increasing N

2) must address accuracy by removing/reducing systematic error

391 W8

(2.2)

looking at 1)

a.) distribution of 10 integer numbers

26, 24, 26, 28, 23, 24, 25, 24, 26, 25

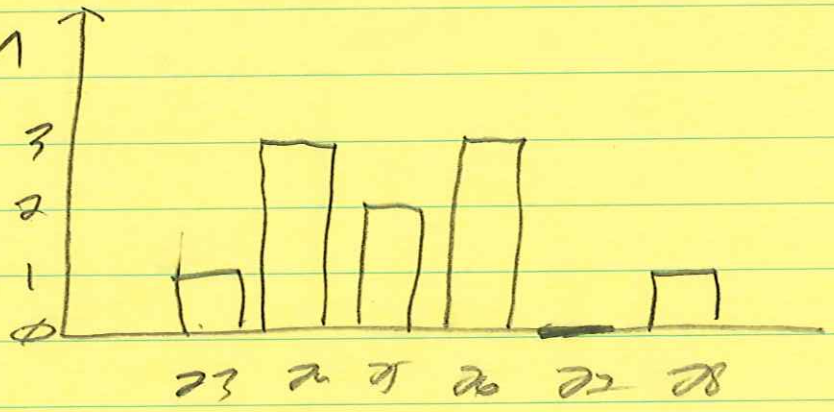
want to look @ distribution, what to do?

a) sort

23	24	25	26	27	28
1	3	2	3	0	1

b) count

c) plot "frequency" vs. value



d) represent as mean $\bar{x} = \frac{\sum x_i}{N}$

L 2.3

but could do this way:

$$\bar{x} = \frac{\sum_{j=1}^{m} n_j x_j}{\sum n_j \quad (=N)}$$

- j ranges over m "bins" (23, 24, etc)
- x_j is value of j^{th} bin
- n_j is # in j^{th} bin
- could write $f_j = \frac{n_j}{N}$

$$\Rightarrow \quad \bar{x} = \sum_j f_j x_j$$

---

b) bin width,
what if read this measured
26.4, 23.7, 27.1, etc

what to choose for "bin widths?"

- reorder, smallest → largest
look at gaps between successive values

23.7, 23.8, 23.9, 23.9, 24.0
✓ 0.1 ✓ 0.1 ✓ 0 ✓ 0.7, etc.

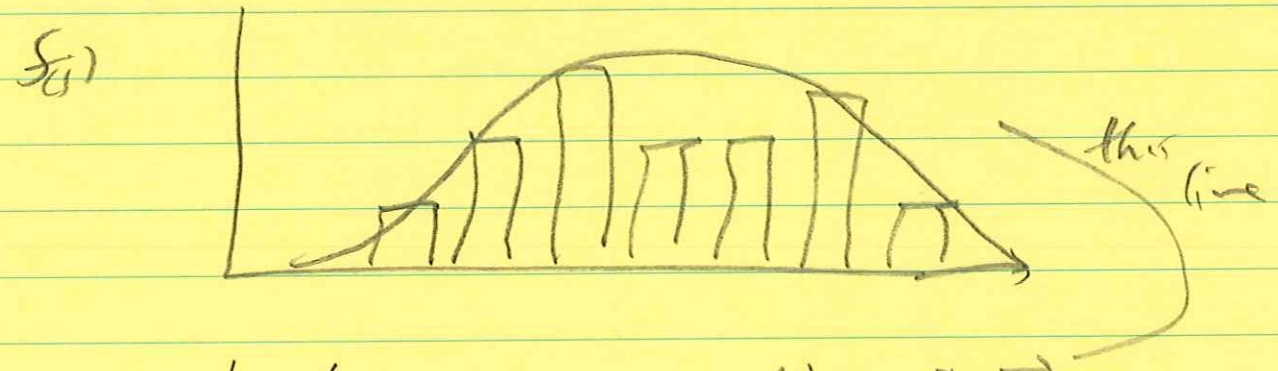
b.) cont'd (L2.4)

Pick some reasonable average of y_{ave} or bin width.

---

c) $f(x)$ ← working towards this (prob. dist. func.)

Note that $f_j \Delta_j$ is the fraction of measurements in j^{th} bin



limit as $\Delta_j \to 0$, $N \to \infty$ ⇒

then $f(x)\,dx$ is fraction of samples between x & $x + dx$

or, more properly:

$$\int_a^b f(x)\,dx = \text{fraction between } a \text{ & } b$$

---

d) need to normalize

$$\int_{-\infty}^{\infty} f(x)\,dx = 1$$

L 2.5

e.) now we can formally state that:

$$\bar{x} = \int_{-\infty}^{\infty} x\, f(x)\, dx \quad \text{"expectation value"}$$

and $\sigma_x^2 = \int_{-\infty}^{\infty} (x-\bar{x})^2 f(x)\, dx$ "variance"

(note limits (∞, ∞) can be typically reduced to finite spans.

f.) Central Limit Thm (CLT)

States conditions when the mean of a sufficiently large # of independent, random variables, each w/ mean & variance, will be approx <u>normally</u> distributed

key idea is that variables are identically distributed.

g) typically, assuming CLT met,

$f(x) =$ "Gaussian" $= e^{-\frac{x^2}{2\sigma^2}}$

or $= e^{\frac{-(x-\bar{x})^2}{2\sigma^2}}$

(L26)

σ = "width fctn" (for now)
+ $\bar{x}$ = Maximally prob value

Now have to normalize s.t. $\int_{-\infty}^{\infty} f_G \, dx = 1$
(you can do this ...)

h) ERF

can think of the probability of finding some measure within σ of $\mu = \bar{x}$

$$P(\mu-\sigma, \mu+\sigma) = \int_{\mu-\sigma}^{\mu+\sigma} \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} dx$$

to solve, let $z \equiv \frac{x-\mu}{\sigma} \Rightarrow$

$$\int_{-1}^{1} \frac{1}{2\pi} e^{-\frac{z^2}{2}} dz$$

called error fctn or ERF

use tables (appendix A) in Taylor for this

2.) Sci programming