For 101L Final Exam:

procedures → summarize in your own words

instruments

derivations

FORMULAS

error analysis : - linear regression
- error propagation (pdf I sent beginning of semester)
- comparisons ...

→ Revision follows

Section 1,3,5 - 2017
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Experiment : Measurement

instruments : - vibrator : define + how it works
- stroboscope : define + how it works

From manuals

derivations : $\rho = m/v$, $v = \frac{4\pi}{3} r^3 = \frac{\pi}{6} d^3$ $\Big\} \Rightarrow \rho = \frac{m}{\frac{\pi d^3}{6}}$

$\Rightarrow m = \frac{\rho \pi d^3}{6}$

Formulas: $m = \frac{\rho \pi d^3}{6}$

error analysis: ① $A = LW$

σ_A = propagation of error

$$\sigma_A = \sqrt{\left(\frac{\partial A}{\partial L}\sigma_L\right)^2 + \left(\frac{\partial A}{\partial W}\sigma_W\right)^2}$$

answer = $A \pm \sigma_A$

② plot m vs d^3
$\quad\quad\quad\;\; Y \quad\;\; X$

$\underset{Y}{m} = \frac{\rho \pi}{6} \underset{X}{d^3}$ $\Rightarrow B = \text{slope} = \frac{\rho \pi}{6}$

$\Rightarrow \rho = \frac{6B}{\pi}$

Sample questions →
find density of steel given

m (g)	d (cm)
5.5	1
29.7	1.8
66.1	2.5

* change units to SI!
* plot m vs. d^3 not d !!
* Dont forget to calculate all of
  A = y-inter =
  B = slope =
  r = corr. coef =

Experiment: Position, Speed, Acceleration

instruments : photogate : define + how it works..
picket fence : " "
motion sensor : " "
→ in this experiment its used in gate mode
check other experiments for pulse mode

derivations : /

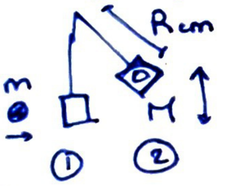
FORMULAS : $a = g$ for free falling body

error analysis : /

Experiment: Ballistic Pendulum:

instruments : photogate : repeated above.

derivations: Question: derive formula for V_b in Ballistic P. experiment.



(M → for total mass Ball + Pend)

$PE_{②} = Mgh \quad h = R_{cm}(1-\cos\theta)$

$\Rightarrow \Delta PE = Mg R_{cm}(1-\cos\theta)$

$KE_{①} = \frac{1}{2} M v_{pend}^2$

$P_{pend,①} = M v_{pend}$

$\Rightarrow P_{pend.①} = \sqrt{2M\,KE_{①}}$

$P_{ball} = m V_b$ → for m_{ball}

just before collision

momentum is conserved just before instant ① and just after

$\Rightarrow P_{just\ befo} = P_{just\ after}$

$P_{ball} + P_{pend} = P_{pend}$

$m v_b + 0 = \sqrt{2M\,KE}$

conservation of energy between ① and ② ⇒

$KE_{①} + PE_{①} = KE_{②} + PE_{②}$

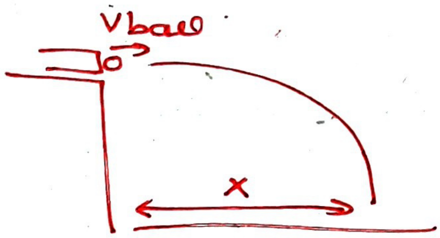
$KE_{①} \quad 0 \quad = 0 + PE_{②} \Rightarrow KE_{①} = PE_{②}$

$\Rightarrow V_b = \frac{M}{m}\sqrt{2g R_{cm}(1-\cos\theta)}$

FORMULAS:

$$v_{ball} = \frac{M}{m}\sqrt{2g\,R_{cm}\,(1-\cos\theta)}$$

$$v_{ball} = \frac{x}{t}$$



error analysis: ✓

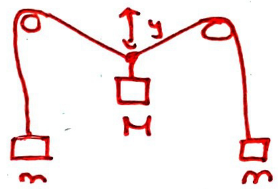
Experiment : Forces :

instruments : photogate : repeated (also in gatemode)
picket fence : repeated

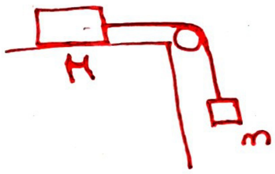
derivations : ✓

FORMULAS :

$$y = \frac{ML}{2\sqrt{4m^2 - M^2}}$$



$$mg = (m+M)a$$



error analysis: ① σ_y for $y = \frac{ML}{2\sqrt{4m^2 - M^2}}$

for $m = 200 \pm 1$ g $L = 80 \pm 0.2$ cm
$M = 100 \pm 1$ g

calculate y along with its error

final answer $y = 10.33 \pm 0.13$

② $mg = (m+M)a$ linear regression

sample question

find $m+M$ given:

m(g)	a (m/s²)
50	0.3882
40	0.3140
30	0.2296
20	0.1496
10	0.0651

final answer

$m+M = 1.2084$ Kg

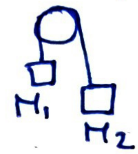
experiment : Atwood machine & motion on incline

instruments : photogate : now in pulse mode ! check definition

smart pulley

derivations :

$M_2 > M_1$



Newton Law on M_1 : $T - M_1 g = M_1 a$ ①

" on M_2 : $M_2 g - T = M_2 a$ ②

① + ② $\longrightarrow$

$(M_2 - M_1) g = (M_1 + M_2) a$

$a = \dfrac{(M_2 - M_1) g}{M_2 + M_1}$ called Fnet

$F_{net} = (M_2 - M_1) g$

Formulas : $a = \dfrac{(M_2 - M_1) g}{M_2 + M_1}$

$ma = mg\sin\theta \rightarrow a = g\sin\theta$

error analysis : $\underbrace{a}_{Y} = g \underbrace{\sin\theta}_{X}$ not $X = \theta$!

choose a linear relation for linear regression

Sample Questions :

find the value of gravity given :

$a (m/s^2)$	θ (degree)
0.575	4
1.30	8
1.095	6

plot a_{exp} vs net force and find slope prove $M_1 + M_2 = 100g$

$M_1 (g)$	$M_2 (g)$	a_{exp}
45	55	0.922
40	60	1.85
30	70	3.81
35	65	2.7
20	80	5.56

Experimnt Centripital Force *

instructs : \

derivations : $F = ma_n = m\frac{v^2}{r} = mr\omega^2$ ω angular velocity

$v = \frac{2\pi r}{T}$ for uniform circular motion.

$\begin{pmatrix} x = r\theta \\ v = r\omega \\ a = r\alpha \end{pmatrix}$

$\Rightarrow F_{centrip} = \frac{m}{r}\left(\frac{2\pi r}{T}\right)^2 = \frac{4\pi^2 mr}{T^2}$

FORMULAS $F = \frac{4\pi^2 mr}{T^2}$

error analysis:

plot $\underset{Y}{r}$ vs $\underset{X}{T^2}$ $F = \frac{4\pi^2 mr}{T^2} \rightarrow T^2F = 4\pi^2 mr$

$r = \underbrace{\frac{F}{4\pi^2 m}}_{} T^2$

B = slope

find centripital $F \pm \sigma_F \rightarrow \frac{F}{4\pi^2 m} = B$

$F = B\,4\pi^2 m$

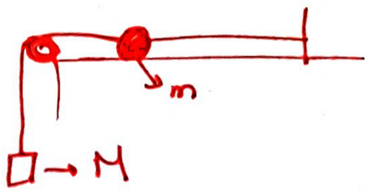
$\sigma_F = \frac{\partial F}{\partial m}\sigma_m = 4\pi^2 B\,\sigma_m$

plot F vs. $\frac{1}{T^2}$ $\rightarrow \underset{Y}{F} = \underbrace{4\pi^2 mr}_{B}\ \underset{X}{\frac{1}{T^2}}$

find $m \pm \sigma_m \rightarrow m = \frac{B}{4\pi^2 r} \rightarrow \sigma_m = \frac{\partial m}{\partial r}\sigma_m = \frac{B}{4\pi^2}\frac{\sigma_m}{r^2}$

* dont confuse M and m

$Mg = F_c = \frac{4\pi^2 mr}{T^2}$



sample question:

plot F vs. $\frac{1}{T^2}$ and deduce $m \pm \sigma_m$ object

mass over pulley (g)	T (sec)
20	2.404
30	1.904
50	1.440

$r = 11.8 \pm 0.05$ cm

Experiment: Linear Air Track

instruments: photocell gate timer ...

derivations: /

FORMULAS: $KE = \frac{1}{2}mv^2$ $\quad \Delta KE = W_{fex} = f \cdot d$

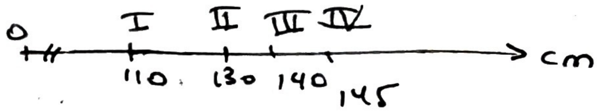
$|f_r| = \frac{\Delta KE}{d}$

error analysis: /

sample questions:

estimate force of friction

location of glider



	I	II	III	IV
V_{glider}	0.24	0.266	0.27	0.296

Experiment: collision:

instruments: /

derivation: /

FORMULAS:

assuming $v_{2i} = 0$

elastic

$$\left[\begin{array}{l} V_{1final} = \frac{m_1 - m_2}{m_1 + m_2} V_{1initial} \\ V_{2final} = \frac{2m_1}{m_1 + m_2} V_{1initial} \\ \frac{1}{2}m_1 v_{1i}^2 = \frac{1}{2}m_1 v_{1f}^2 + \frac{1}{2}m_2 v_{2f}^2 \end{array}\right.$$

inelastic $\quad m_1 v_{1i} = (m_1 + m_2) V_{sys\,f}$

explosion $\quad P_{before} = 0 = P_{after} = m_1\vec{v}_1 + m_2\vec{v}_2$

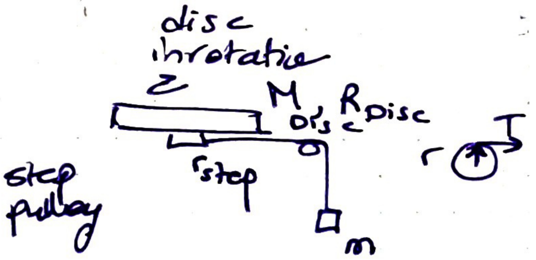
error analysis: /

Experiment: Rotational Inertia:

instruments: /

derivations: Rotational motion

$\rightarrow \underset{\text{torque}}{\tau} = \underset{\text{moment of inertia}}{I} \alpha$

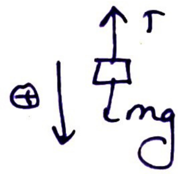


$I = \frac{\tau}{\alpha}$ ① $r\alpha = a$

$\tau = r \times F = rT \sin 90 = rT$

$\Sigma F = ma = mg - T$

$T = m(g-a)$



② $\tau = r\,m(g-a)$

Don't confuse $r_{step\,pulley}$ + R_{disc}, M_{Disc} + $m_{hanging}$

using ①, ② $\rightarrow I = \frac{\tau}{\alpha} = \frac{rm(g-a)}{\frac{a}{r}}$

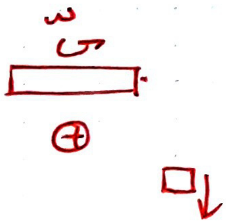
$= mr^2\left(\frac{g-a}{a}\right)$

$I = mr^2\left(\frac{g}{a} - 1\right)$

FORMULAS: $I_{Disc} = mr^2\left(\frac{g}{a} - 1\right)$ → theoretical

(m: hanging object; r: step pulley)

$I_{Dis} = \frac{1}{2} M_D R_D^2$



$KE_{tot} = KE_{rot} + KE_{translation} =$

$= \frac{1}{2} I_{Disc} \omega_{max}^2 + \frac{1}{2} m_{hanging\,object} v_{max}^2$

$r\omega = v \Rightarrow \omega = \frac{v}{r}$

$KE_{tot} = \frac{1}{2} I_{Disc} \left(\frac{v_{max}}{r}\right)^2 + \frac{1}{2} m v_{max}^2$

$I_{ring} : \frac{1}{2} M_{Ring} (R_{outer}^2 + R_{inner}^2)$

NOTES:

* change units to SI before using them in tables!...
* Dont forget units for your answers
* write answer in complete form $X \pm \sigma_X + \underline{\underline{(\overset{SI}{\text{unit}})}}$ (matching decimal place, significant figures, Rounding)

* sometimes σ is given

$10.3 \pm 1\% \longrightarrow \sigma = \frac{1}{100} \times 10.3 = 0.103$

$\Rightarrow 10.30 \pm 0.10$

* you can use your calculator for double checking derivatives

*

Sample questions

Gnd % Diff betwe $mg\Delta h$ and KE_{tot}

$\Delta h = 1m$

m(g)	a (m/s²)	Vmax (m/s)
100	0.007	0.11
150	0.0109	0.138
200	0.0145	0.162
250	0.0186	0.178
300	0.022	0.197

Experiment : simple Harmonic Motion.

instruments : torsional pendulum
Force sensor

derivation /

FORMULAS :

translational SHM

Rotational SHM

$F = kx$

$\tau = rF = C\theta$

$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{K}}$

$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{I}{C}}$

if spring is not massless

$\hookrightarrow T = 2\pi\sqrt{\frac{m + \frac{m_{spring}}{3}}{k}}$

$I_{Disc} = \frac{MR^2}{2}$

error propagation :

plot F vs. Δl $\quad F = k\Delta l \quad B = k$

plan F vs. θ $\quad rF = C\theta$

$F = \frac{C}{r}\theta \quad B = \frac{C}{r}$

* plz note that C should have units of $\frac{mN}{rad}$ → not deg

also $k \rightarrow \frac{N}{m}$ → SI