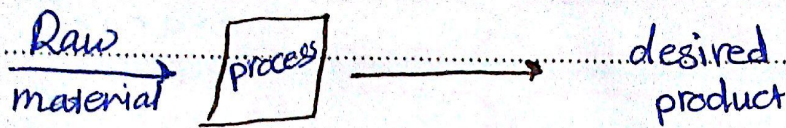


CH 2: Introduction to Engineering Calculations



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amounts properties $\longleftrightarrow$? amounts properties.

Sec 2.1 Units and Dimensions

Each quantity has a numerical value and a unit.

e.g. distance in 2.5, what does it mean?

2.5cm ? 2.5Km ? 2.5ft ?

Both value and unit are essential

* Dimensions $\rightarrow$ a property that can be measured or calculated by multiplying / dividing other dimensions.

* measured $\rightarrow$ length (L), mass (m), time (t),
temperature (T)

* calculated $\rightarrow$ velocity (L/t), density (m/L³)
volume (L³), force (m.L/t²)

measurable units $\rightarrow$ specific value defined by convention, custom or law.

eg $\rightarrow$ g for mass, cm for length
s for time

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* The numerical value of two quantities can be added / subtracted only if the units are the same.

e.g. $3\text{cm} - 1\text{cm} = 2\text{cm}$ ($3x - x = 2x$)

$$3\text{cm} - 1\text{m} = ?$$

$$\neq 2$$

$$(3x - y = ?)$$

* Numerical value and their unit can always be combined multiplication / division.

e.g. $3\text{N} \times 3\text{m} = 9\text{N}\cdot\text{m}$ ($3y \cdot 2z = 6yz$)

$$\frac{50\text{km}}{2\text{h}} = 25\text{ km/h}$$

$$\frac{6\text{g}}{2\text{g}} = 3 \text{ (Dimension)}$$

$$\left(\frac{5\text{kg}}{\text{s}}\right) / \left(\frac{0.2\text{kg}}{\text{m}^2}\right) = 25 \frac{\text{kg}}{\text{s}} / \frac{\text{m}^3}{\text{kg}} \Rightarrow 25\text{ m}^3/\text{s}$$

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Sec 2.2 ~ Conversion of units

The equivalence between two expressions of the same quantity may be defined in terms of a ratio.

e.g. $\frac{1\text{m}}{100\text{cm}}$ (1m per 100 cm) $\rightarrow$ Conversion factor.

$\left[\frac{1\text{cm}}{100\text{mm}}\right]^2$ $\left(\frac{1\text{cm}^2}{100\text{mm}^2}\right)$ $\rightarrow$ Conversion factor.

* This ratio equals to 1 *

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ect:.....

eg ~ a) convert 36 mg to its equivalent in g

$$\frac{36 \cancel{\text{mg}}}{1000 \cancel{\text{mg}}} \times \frac{1 \text{ g}}{1} = 0.036 \text{ g}$$

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b) P2.2(b) ~ convert 921 kg/m³ to lbm/ft³

$$\frac{921 \text{ kg}}{\text{m}^3} \times \frac{2.20462 \text{ lbm}}{1 \text{ kg}} \times \frac{1 \text{ m}^3}{35.3145 \text{ ft}^3} = 57.5 \text{ lbm/ft}^3$$

Sec 2.3 ~ System of units

SI system / CGS system / American Engineering system

What does it consist of?

1. Base units for mass, length, time, temperature, electrical current, light intensity.
2. Multiple units & multiples or fractions of base units,
e.g., minute, hours, millisecond
For the base unit (second)

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3. Derived units & obtained by &

- a) multiplying / dividing base or multiply unit
Compound
- b) defined equivalent of compound units

Subject:

/ /

Unit system	length	mass	time	temp	elect	light intensi
SI	m	kg	s	K	Amp	Candela
CGS	cm	g	s	K	Amp	cd
American Eng	ft	lbm	s	°R	Amp	cd

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* prefixes used is SI systems (multiples of 10)

$$\text{mega} = M = 10^6 \quad \text{eg/} \quad \mu W = 10^6 W$$

$$\text{kilo} = K = 10^3 \quad 1 \text{ km} = 1 \times 10^3$$

$$\text{centi} = C = 10^{-2} \quad 1 \text{ cg} = 1 \times 10^{-2} \text{ g}$$

$$\text{milli} = m = 10^{-3}$$

$$\text{micro} = \mu = 10^{-6}$$

$$\text{nano} = n = 10^{-9}$$

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* In American Engineering System, this is much more difficult &

$$1 \text{ ft} = 12 \text{ in} \quad , \quad 1 \text{ yd} = 3 \text{ ft}$$

eg Convert 1) $3.2 \times 10^{-6} \text{ m}$ to mm.

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$$\frac{3.2 \times 10^{-6} \text{ m}}{10^{-3} \text{ m}} = 32 \times 10^{-3} \text{ mm}$$

2) P2.2(c) $5.37 \times 10^3 \text{ kJ/min} \rightarrow \text{hp}$

$$\frac{5.37 \times 10^3 \text{ kJ}}{\text{min}} \times \frac{1.341 \times 10^{-3} \text{ hp}}{1 \text{ J/s}} \times \frac{10^3 \text{ J}}{\text{kJ}} \times \frac{1 \text{ min}}{60 \text{ s}} = 120 \text{ hp}$$

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Subject:

Sec 2.4 $\rightarrow$ Force and Weight

Force = mass $\times$ acceleration

(Newton's 2nd law)

SI & Force [=] $\text{kg} \cdot \text{m/s}^2$ $\xrightarrow{\text{natural unit, derived unit}}$ = N

CGS & Force [=] $\text{g} \cdot \text{cm/s}^2$ $\longrightarrow$ = erg

American & Force [=] $\text{lbm} \cdot \text{ft/s}^2$ $\longrightarrow$

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but derived unit is lbf defined as the product of a unit mass (1 lbm) and the acceleration of gravity at sea level 45° latitude $\Rightarrow 32.174 \text{ ft/s}^2$

$$= 1 \text{ lbf} = 32.174 \text{ lbm} \cdot \text{ft/s}^2$$

g_c = Conversion Factor From natural to derived Force units

$$g_c = \frac{N}{1 \text{ kg} \cdot \text{m/s}^2} = \frac{1 \text{ lbf}}{32.174 \text{ lbm} \cdot \text{ft/s}^2}$$

$$[W = mg]$$

$$g = 9.8066 \text{ m/s}^2$$

$$= 980.66 \text{ cm/s}^2$$

$$= 32.174 \text{ ft/s}^2$$

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very
important

$$1 \text{ N} = 1 \text{ kg} \cdot \text{m/s}^2$$

$$1 \text{ dyne} = 1 \text{ g} \cdot \text{cm/s}^2$$

$$1 \text{ lbf} = 32.174 \text{ lbm} \cdot \text{ft/s}^2$$

Subject:.....

5 / Oct / 2015

$$\begin{aligned} * W = mg &\Rightarrow m = 25 \text{ lbm} \quad W = mg \\ &= 25 \text{ lbm} \times 32.174 \frac{\text{ft}}{\text{s}^2} \times \frac{1 \text{ lbf}}{32.174 \text{ lbm} \cdot \text{ft}} \\ &= 25 \text{ lbf} \end{aligned}$$

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2.5 Numerical Calculations and Estimations.

A) Scientific Notation and Significant Figures.

a number is expressed as the product of another number (between 0.1 and 10) and a power of 10. e.g. $\Rightarrow 123,000,000 = 0.123 \times 10^9$

$$= 1.23 \times 10^8$$

$$0.00028 = 0.28 \times 10^{-3}$$

$$= 2.8 \times 10^{-4}$$

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Significant Figures $\Rightarrow$ the digits from the non zero digit on the left to either

1- the last digit to the right (zero or non zero)

IF there is a decimal point

$$\text{e.g. } \Rightarrow 0.035 \Rightarrow 2 \text{ sig. Fig}$$

$$2300. \rightarrow 4 \text{ sig. Fig}$$

2- the last non zero digit if there is no decimal point

$$\text{e.g. } \Rightarrow 2300 \rightarrow 2 \text{ sig. Fig}$$

of sig. fig. $\longleftrightarrow$ precision

more sig. fig. $\Rightarrow$ more precision the value is e.g.
if you report a mass as 8.3 ± 0.1 g (2 sig. fig.)

the mass lies between 8.25g and 8.35g.

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S Notebook

Subject:

* if you report the mass as 8.300 g $\rightarrow$ 4 sig. fig.
 $\Rightarrow$ the mass lies between 8.299 g and 8.3005 g.

هذا الخرقم $\leftarrow$

$$\begin{array}{l} 2300 \div 50 = 2250 \\ \downarrow \\ \frac{100}{2} = 50 \rightarrow 2350 \end{array}$$

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$$2300 \pm 0.5$$

$$\frac{1}{2} = 0.5$$

هذا الخرقم فتأخذ المنزلة

* This rule applies only to measured quantities or numbers calculated from measured quantities.

* What about counted number like 5 oranges?

the value contains infinite number of sig. fig.,

5 oranges = 5.0000 —

[pure integer]

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* Multiplication / Division Rule :

Ex: 1) $(3.57)(4.286) = 15.30102$ $\Rightarrow$ the product can't be more precise than the original numbers.
 $\downarrow$ 3 sig. fig. more precise than the original numbers.
 $\downarrow$ 3 sig. fig. more precise than the original numbers.

$$2) \underbrace{(5.2 \times 10^{-4})}_{2 \text{ sig. fig.}} \underbrace{(0.1635 \times 10^7)}_{4 \text{ sig. fig.}} = 318.426966 \xrightarrow{2 \text{ sig. fig.}} 320$$

$2 = 67 (3)$

* Addition / Subtraction Rule :

Ex: 1) $15.30 - 2.56 = 15.2744 \rightarrow 15.30$

$$2) \begin{array}{r} 1.0000 \\ + 0.036 \\ + 0.22 \\ \hline 1.2560 \end{array} \Rightarrow 1.26$$

Rule $\Rightarrow$ the furthest to the left

القاعدة $\Rightarrow$ الأبعد إلى اليسار

Subject:.....

/ /

$$\begin{aligned} 3) \quad 2.75 \times 10^6 + 3.400 \times 10^4 \\ = (2.75 + 0.03400) \times 10^6 = 2.78400 \times 10^6 \\ \Rightarrow 2.78 \times 10^6 \end{aligned}$$

Rule of thumb $\rightarrow$ Rounding off numbers in which the digit to be dropped is 5 $\rightarrow$ always make the last digit even

$$1.35 \Rightarrow 1.4 \quad / \quad 1.65 \Rightarrow 1.6$$

Exercise $\rightarrow$ Tys - pg 15

Q3.8

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$$\begin{aligned} a) \quad (5.74)(38.27) / (0.001250) = \\ 175735.84 = 176000 \end{aligned}$$

$$c) \underset{\uparrow}{1.000} + \underset{\uparrow}{10.2} = 11.2$$

$$d) \underset{\uparrow}{18.76} - \underset{\uparrow}{7} = 11.76 \approx 12$$

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Q4: Round the following to 3 sig. fig.

$$1) 1465 \Rightarrow 1460$$

$$2) 13.35 \Rightarrow 13.4$$

Q5: Give ranges within which each of the following values lies:

$$a) 4.3 \rightarrow 4.25 \text{ to } 4.35$$

$$b) 4.30 \rightarrow 4.295 \text{ to } 4.305$$

$$d) 2500 \rightarrow 2450 \text{ to } 2550$$

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S Notebook

Subject:

e) $2.500 \times 10^3 \rightarrow 2499.5 \text{ to } 2500.5$

$2.499.5 \times 10^3$

$2.500.5 \times 10^3$

2.6 ~ Validating Results &

When you get a solution, how do you know it's right

(Validation)

→ Back substitution

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→ order of magnitude estimation

(crude and easy to obtain estimation)

→ Test of Reasonableness (does it make sense)

e.g. order of magnitude estimation.

$$\begin{aligned}
 P2.17 \Rightarrow R &= \frac{(0.6700)^{[4]} (264.980)^{[5]} (5.386 \times 10^4)^{[4]} (6)^{\text{pure integer}}}{(3.14159)^{[5]} (0.479 \times 10^7)^{[3]}} \\
 &\approx \frac{(0.7) (300.00)^{100.00} (5 \times 10^4)^{10} (6)}{(3) (0.5 \times 10^7)} \\
 &= \frac{(0.7)(10)(6)}{10^3} = 42 \times 10^2 \\
 &\rightarrow 3812.59329 \approx 3810
 \end{aligned}$$

(C) Estimation of Measured Values &

Exm $A \rightarrow \text{products}$

$\boxed{\infty}$ $T = 450^\circ\text{C}$

Sample is taken after 2 minutes to calculate conversion x of reactant A. For 10 successive runs, the values of x are:

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Subject:.....

7/05/2015

Run	1	2	3	4	5	6	7	8	9	10
X (%)	67.1	73.1	69.6	67.4	71.0	68.2	69.4	68.7	68.7	70.2

Reasons For different values of x ?

May be estimation by taking the average (sample mean) of N runs (as $N \uparrow$, estimation is more accurate).

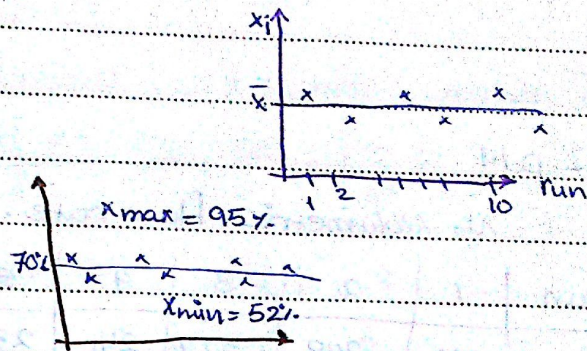
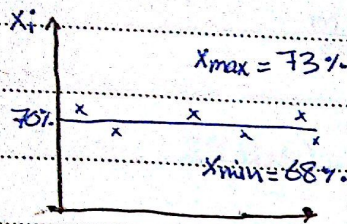
$$\text{Sample Mean} : \bar{X} = \frac{\sum_{i=1}^N x_i}{N}$$

$$\bar{X} = 69.3\%$$

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* Estimation of Measured Values &

$$\bar{X} = \frac{\sum_{i=1}^N X_i}{N}$$



* Sample Varince and Scattered Data &

To express how scattered the data points are we use &

1- rang, $R = X_{max} - X_{min}$

2- Sample Varince & $S_x^2 = \frac{1}{N-1} \sum_{i=1}^N (X_i - \bar{X})^2$

3- Sample Standard deviation

$$S_x = \sqrt{S_x^2}$$

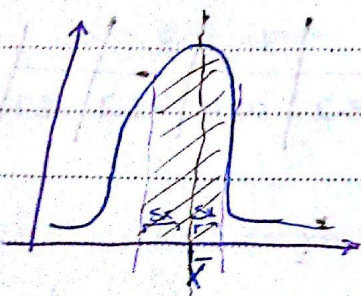
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* for (A), $S_x^2 = 0.98$, $S_x = 0.99$

(B), $S_x^2 = 169$, $S_x = 13$

→ smaller S_x^2
+ S_x → less
Scattered data

Subject:



Typical Random Distribution.

$\frac{2}{3}$ of all measured values fall within one standard deviation ($\bar{X} \pm S_x$).

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95% of data fall within $\bar{X} \pm 2S_x$

99% $\rightarrow$ within $\bar{X} \pm 3S_x$

*

Representing measured values &

$X = 48.2 \pm 0.6$ $\rightarrow$ could be range limits, S_x , $2S_x$, $3S_x$

almost always = the mean.

you have to be clear

about what your

error limit are.

Tue 10

* $T_{ys} = p_{19}$

N = Volumetric Flow rate.

run	1	2	3	4	5
$N(\text{cm}^3/\text{s})$	232	248	227	241	239

* Calculate $\bar{x}$ 1) $\bar{N} = 237 \text{ cm}^3/\text{s}$

$$R = 248 - 227 = 21$$

$$S_x^2 = \frac{1}{5-1} \sum_{i=1}^5 (x_i - \bar{x})^2$$

$$\frac{1}{4} [(232 - 237)^2 + (248 - 237)^2 + (227 - 237)^2 + (241 - 237)^2 + (239 - 237)^2] = 66.3 \text{ cm}^6/\text{s}^2$$

$$S_x = \sqrt{66.3} = 8.2 \text{ cm}^3/\text{s}$$

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Subject:

b) $\bar{V} \pm 2\delta_v$

$$= 23.7 \pm 2(8.2) = 23.7 \pm 16 \text{ cm}^3/\text{s}$$

* 2.6 ~ Dimensional Homogeneity and Dimensionless Quantities

Rule ~ Every valid equation must be dimensionally homogeneous. All additive terms on both sides of the equ. must have the same dimensions.

E.g. ~ $U = U_0 + g$

$$\frac{L}{t} = \frac{m}{s} \quad \frac{m}{s} / \frac{m}{s^2} \cdot \frac{L}{t^2}$$

→ Not dimensionally homogeneous

$$U = U_0 + gt$$

$$\frac{m}{s} = \frac{m}{s} + \frac{m}{s^2} \cdot s$$

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→ dimensionally homogeneous.

TYP - P22 Q2 & $y (m/s^2) = az (m^3)$, a unit ?

$$\frac{m}{s^2} = \frac{[a] | m^3}{\Rightarrow [a] = \frac{m}{s^2 | m^3} \Rightarrow [a] = \frac{1}{m^2 \cdot s^2}}$$

Q4 & $Z(lbf) = a \sin(\theta)$, $[Q] = ?$

$$[a] = ?$$

Q. $[=]$ dimensionless

$$lbf = [a]$$

* Dimensionless quantity & Pure number / multiplicative



combination of variables with NO net dimension.
exponents x^2

transcendental functions & $\log, \exp, \sin, \dots$

functions' arguments & $\sin(x), \log(y)$

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Subject:.....

2.7 → Process Data Representation and Analysis &

- How do we measure concentration of a solute in solution?

by measuring thermal / electrical conductivity or light absorbance, or volume of titr.

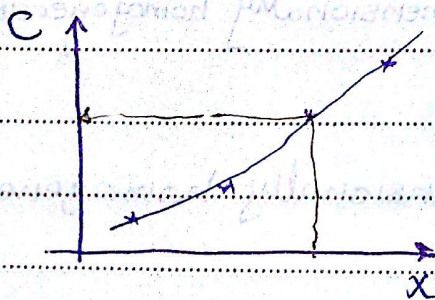
→ we need a calibration curve first &

1. prepare solutions of known concentration and measure its x

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2. Draw calibration curve

3. Use calibration curve to find the concentration from measured x



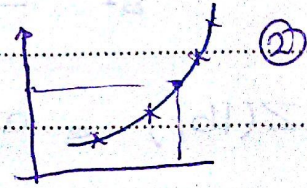
interpolation

extrapolation

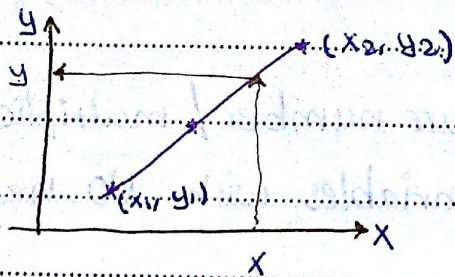
(أي شيء خارج النطاق)

* Inter / Extra polation methods &

- 1- two points linear inter polation
- 2- graphical interpolation →
- 3- Curve fitting



1- Two -points Linear Inter polation.



$$\text{slope} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{y - y_1}{x - x_1}$$

$$y = y_1 + \frac{y_2 - y_1}{x_2 - x_1} (x - x_1)$$

Provides and accurate estimate for y when point 1 and point 2 are relatively close together

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Subject:

Exercise 2

F	1	4	8
t	1	2	3

$$F(t=1.3) = 2$$

$$\frac{F-1}{t-1} = \frac{4-1}{2-1} \Rightarrow \frac{F-1}{t-1} = 3 \Rightarrow F-1 = 3t-3$$
$$F = 3t - 2$$

$$F = 1.9$$

$$(F=5) = 2$$

$$\frac{t-2}{5-4} = \frac{3-2}{8-4}$$

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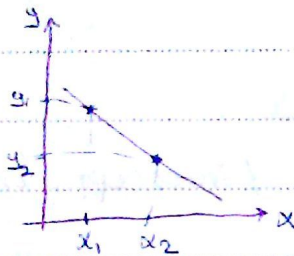
$$t-2 = \frac{1}{4} \Rightarrow t = \frac{1}{4} + 2 \Rightarrow t = \frac{1}{4} + \frac{8}{4}$$

$$t = 2.25$$

II. Fitting A straight line

$$y = ax + b \rightarrow \text{intercept}$$

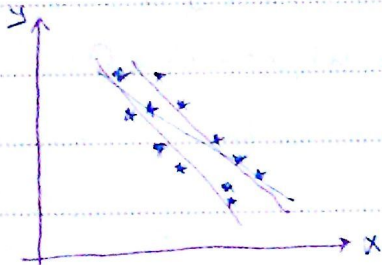
a slope



$$\text{Slope} = a = \frac{y_2 - y_1}{x_2 - x_1}$$

$$b = y_1 - ax_1$$

$$y = ax + b$$



Method of Least Square

Appendix A.1 $\rightarrow$ Study
H.W
e-learning

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Subject: _____

III Fitting Non Linear Data

anything other than ($y = ax + b$)

- * usually much harder than straight line fitting.
- * by some manipulation, you can make it a straight line.

Eg $\rightsquigarrow$ 1) $y^2 = ax + b \rightsquigarrow y^2$ vs. x is straight line

2) $\frac{1}{y} = a(x+3) + b \rightsquigarrow \frac{1}{y}$ vs. $x+3$ OR x

3) $\sin y = \frac{a}{x^2-4} \rightsquigarrow \sin y$ vs. $\frac{1}{x^2-4}$ ($b=0$, pass by the origin)

* Exponential Function and Power law

$$y = ae^{bx}$$

$\downarrow$
 $\ln$

$$\rightsquigarrow \ln y = \ln a + bx \rightsquigarrow \ln y \text{ vs } x$$

slope = b / intercept = $\ln a$

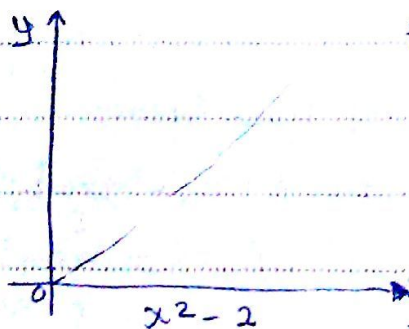
$$y = ax^b$$

$$\ln y = \ln a + b \ln x \rightsquigarrow \ln y \text{ vs. } \ln x$$

slope = b / intercept = $\ln a$

* TYS - Pg 278

Q1 $\rightsquigarrow$



what equation would you use to relate x and y ?

$$y = a(x^2 - 2) + 0$$

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Subject:

/ /

Q2 ~ How would you plot (log) to get straight line?

$$a) \frac{1}{y} = a(x-3)^2 + b$$

$$\frac{1}{y} \text{ vs } (x-3)^2$$

$$b) \sin y = \frac{x}{(ax+b)^2}$$

$$\Rightarrow \frac{1}{\sin y} = \frac{(ax+b)^2}{x} \Rightarrow \frac{x}{\sin y} = (ax+b)^2$$

$$\Rightarrow \left(\frac{x}{\sin y} \right)^{\frac{1}{2}} = \sqrt{ax+b} \Rightarrow \left(\frac{x}{\sin y} \right)^{\frac{1}{2}} \text{ vs } x$$

$$c) y = ax^b$$

$$\ln y = \ln a + b \ln x$$

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