1st Memorial Gerald A. Leonards Lecture

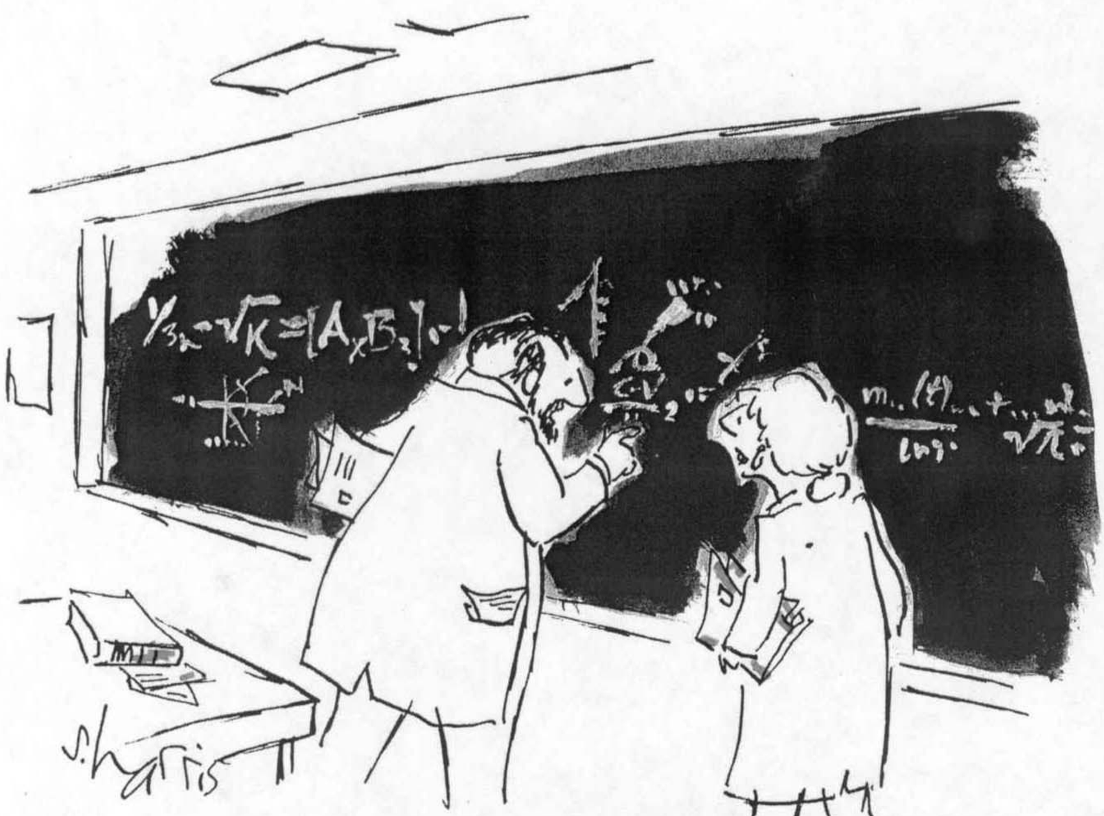
“The Fountain”

by

Professor Emeritus Milton Harr

School of Civil Engineering
Purdue University

May 22, 2003



"AT THIS POINT, THE SHORT ATTENTION SPANS DROP OUT."

. THE LAWS OF ENGINEERING

-COURTESY UMR ENGINEER & OTHERS-

1. ACTON'S LAW: Power tends to corrupt; absolute power corrupts absolutely.

2. ALBRECHT'S LAW: Social innovations tend to the level of minimum tolerable well-being.

3. ALLEN'S AXIOM: When all else fails, read the instructions.

4. BOWIE'S THEOREM: If an experiment works you must be using the wrong equipment.

N.B. → 5. CARLSON'S CONSOLATION: Nothing is ever a complete failure; it can always serve as a bad example.

6. CLARKE'S THIRD LAW: Any sufficiently advanced technology is indistinguishable from magic.

7. COHN'S LAW: The more time you spend in reporting on what you are doing the less time you have to do anything. Stability is achieved when you spend all your time reporting on the nothing you are doing.

8. CORRESPONDENCE COROLARY: An experiment may be considered a success if no more than half your data must be discarded to obtain correspondence with your theory.

9. CROPP'S LAW: The amount of work done varies inversely with the amount of time spent in the office.

10. CUTLER WEBSTER'S LAW: There are two sides to every argument, unless a person is personally involved, in which case there is only one.

11. DOW'S LAW: In a hierarchical organization, the higher the level, the greater the confusion.

12. FINAGLE'S LAWS:
(1) Once a job is fouled up, anything done to improve it makes it worse.
(2) No matter what results are expected someone is always willing to fake it.
(3) No matter what the result someone is always eager to misinterpret it.
(4) No matter what occurs, someone believes it happened according to his pet theory.

13. GUMPERSON'S LAW: The probability of a given event occurring is inversely proportional to its desirability.

14. GOVERNMENT'S LAW: There is an exception to all laws.

15. HARVARD LAW: Under the most carefully controlled conditions of presure, temperature, volume, humidity, and other variables, the organism will do as it darn well pleases.

16. HUBBARD'S LAW: Don't take life too seriously; you won't get out of it alive.

17. JENKINSON'S LAW: It won't work.

18. LARKINSON'S LAW: All laws are basically false.

19. LAW OF CONTINUITY: Experiments should be reproducible. They should all fail the same way.

20. LAW OF THE PERVERSITY OF NATURE: You cannot determine beforehand which side of the bread to butter.

21. LAW OF THE TOO SOLID GOOF: In any collection of data, the figures that are obviously correct beyond all need of checking, contain the errors.
corollary 1: No one you ask for help will see the error either.
corollary 2: Any nagging intruder, who stops by with unsought advice will spot it immediately.

22. MAY'S LAW: The quality of correlation is inversely proportional to the density of control. (The fewer the data points, the smoother the curves.)

23. MENCKEN'S LAW: There is always an easy answer to every human problem - neat, plausible, and wrong.

24. MURPHY'S LAWS:
(1) In any field of scientific endeavor, anything that can go wrong, will go wrong.
(2) Left to themselves, things always go from bad to worse.
(3) If there is a possibility of several things going wrong, the one that will go wrong, is the one that will do the most damage.
(4) Nothing is as easy as it looks.
(5) Everything takes longer than you think it will.
(6) If everthing seems to be going well, you have obviously overlooked something.
(7) Nature always sides with the hidden flaw.

25. PARKINSON'S LAW: Work expands to fill the time available for its completion.

26. PARKINSON'S LAW, MODIFIED: The junk you have will expand to fill the available space.

27. PETER'S PRINCIPLE: In every hierarchy, each employee tends to rise to the level of his incompetence.

28. PUDDER'S LAW: Anything that begins well will end badly. (note: The converse of Pudder's law is not true.)

29. RUDIN'S LAW: In a crises that forces a choice to be made among alternative courses of action, people tend to choose the worst possible course.

30. RYAN'S LAW: Make three correct guesses consecutively and you will establish yourself as an expert.

31. SATTINGLER'S LAW: It works better if you plug it in.

32. THYME'S LAW: Everything goes wrong at once.

33. UNNAMED LAW: If it happens, it must be possible.

34. WEILER'S LAW: Nothing is impossible for the man who doesn't have to do the work.

35. WHITEHEAD'S LAW: The obvious answer is always overlooked.

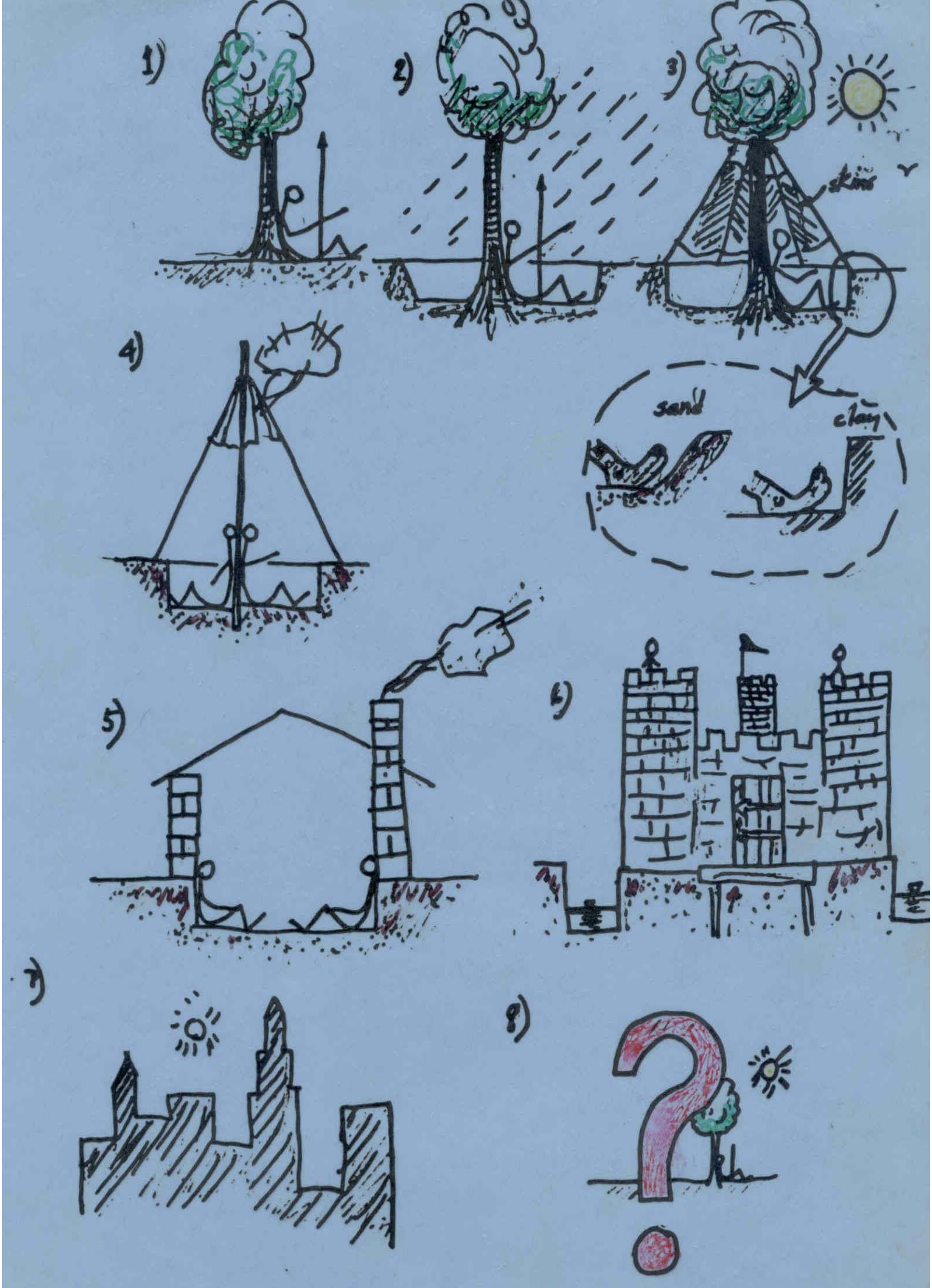
36. WILCOX'S LAW: A pat on the back is only a few centimeters from a kick in the pants.

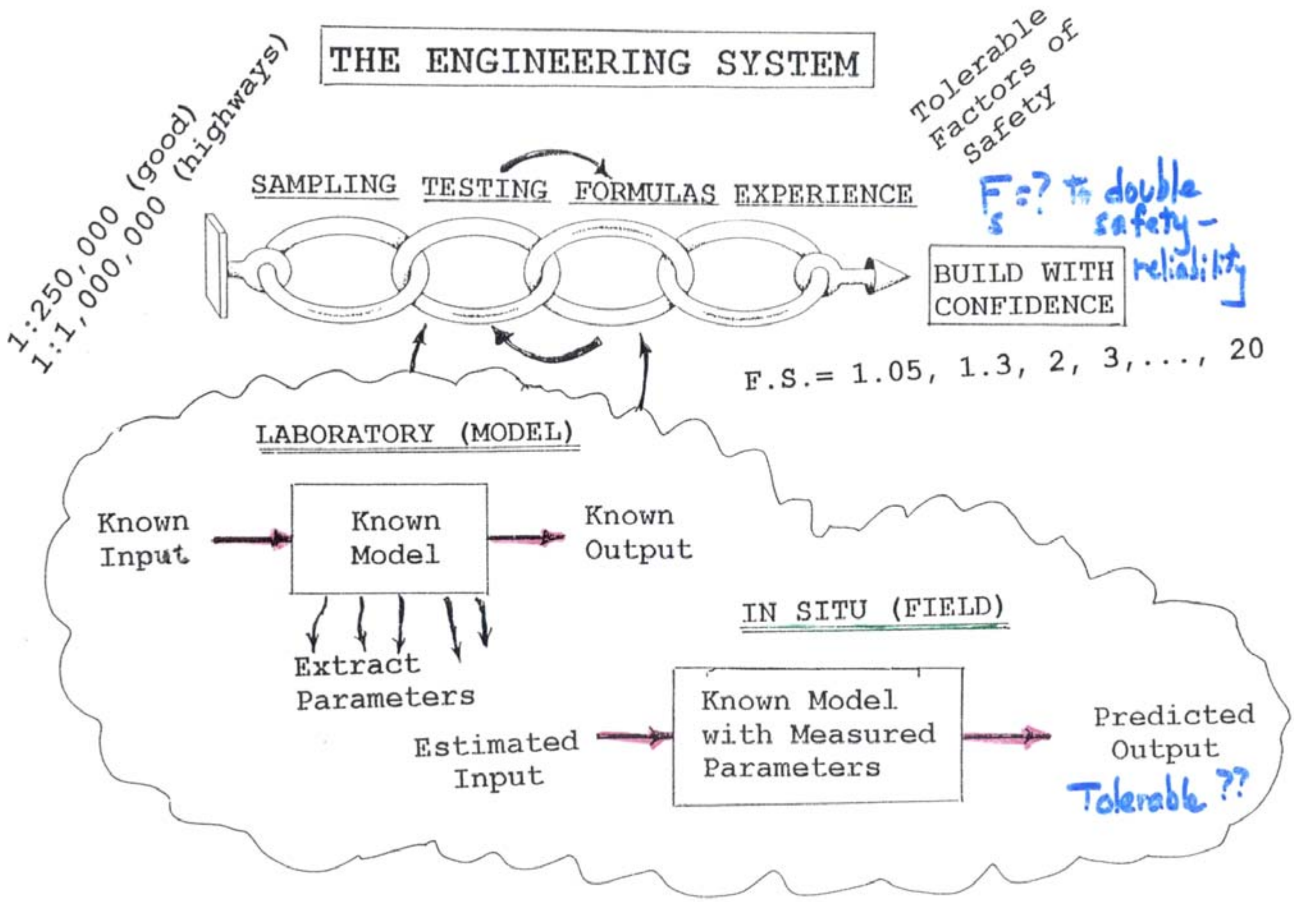
37. WOODWARD'S LAW: A theory is better than its explanation.


BENEFIT
MANKIND
WOMANKIND
ENGINEERING
SEEKS
MASTERY OF
NRG!
UTILIZE
ENGINEERS
CONTROL
HARNESS
ENERGY

HOW WAS ^ENGINEERING KNOWLEDGE ACQUIRED???

From observing successes and building one brick higher.

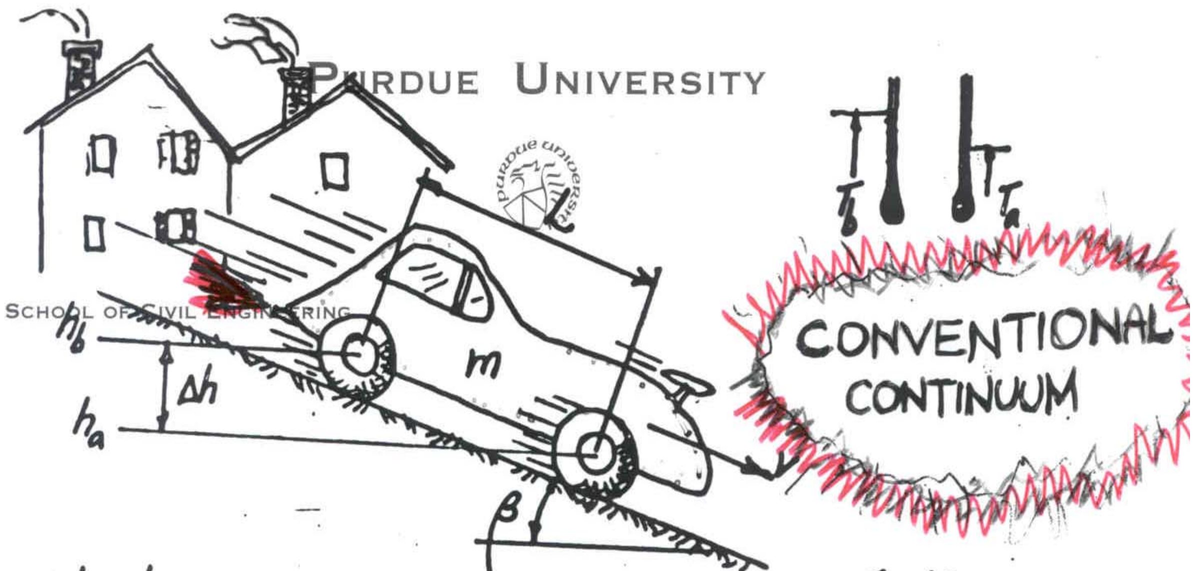

1)
2)
3)
skins
sand
clay
4)
5)
6)
7)
8)



THE ENGINEERING SYSTEM
1:250,000 (good)
1:1,000,000 (highways)
Tolerable Factors of Safety
SAMPLING
TESTING
FORMULAS
EXPERIENCE
BUILD WITH CONFIDENCE
F.S.= 1.05, 1.3, 2, 3,..., 20
LABORATORY (MODEL)
Known Input
Known Model
Known Output
Extract Parameters
IN SITU (FIELD)
Estimated Input
Known Model with Measured Parameters
Predicted Output
Tolerable ??

PURDUE UNIVERSITY

SCHOOL OF CIVIL ENGINEERING



(A)

velocity .... is PROPORTIONAL TO ... gradient; $v \propto (h_b - h_a)$

current .... voltage drop; $i \propto (v_b - v_a)$

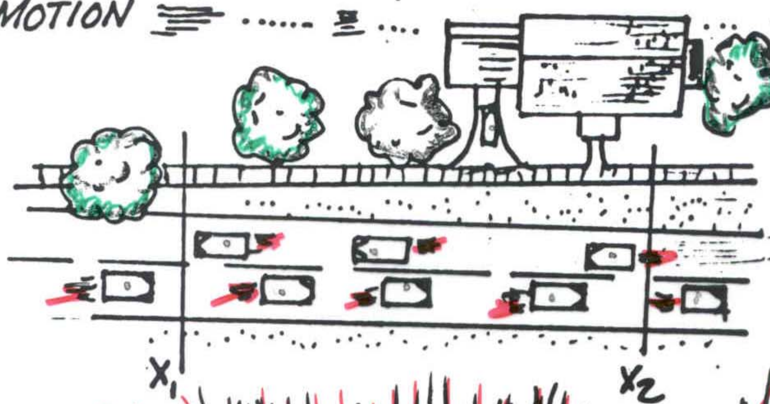
heat flow .... difference in temperature; $q \propto (T_b - T_a)$

flow rate .... pressure difference; $w \propto (p_b - p_a)$

force .... change in velocity; $F \propto (v_b - v_a)$

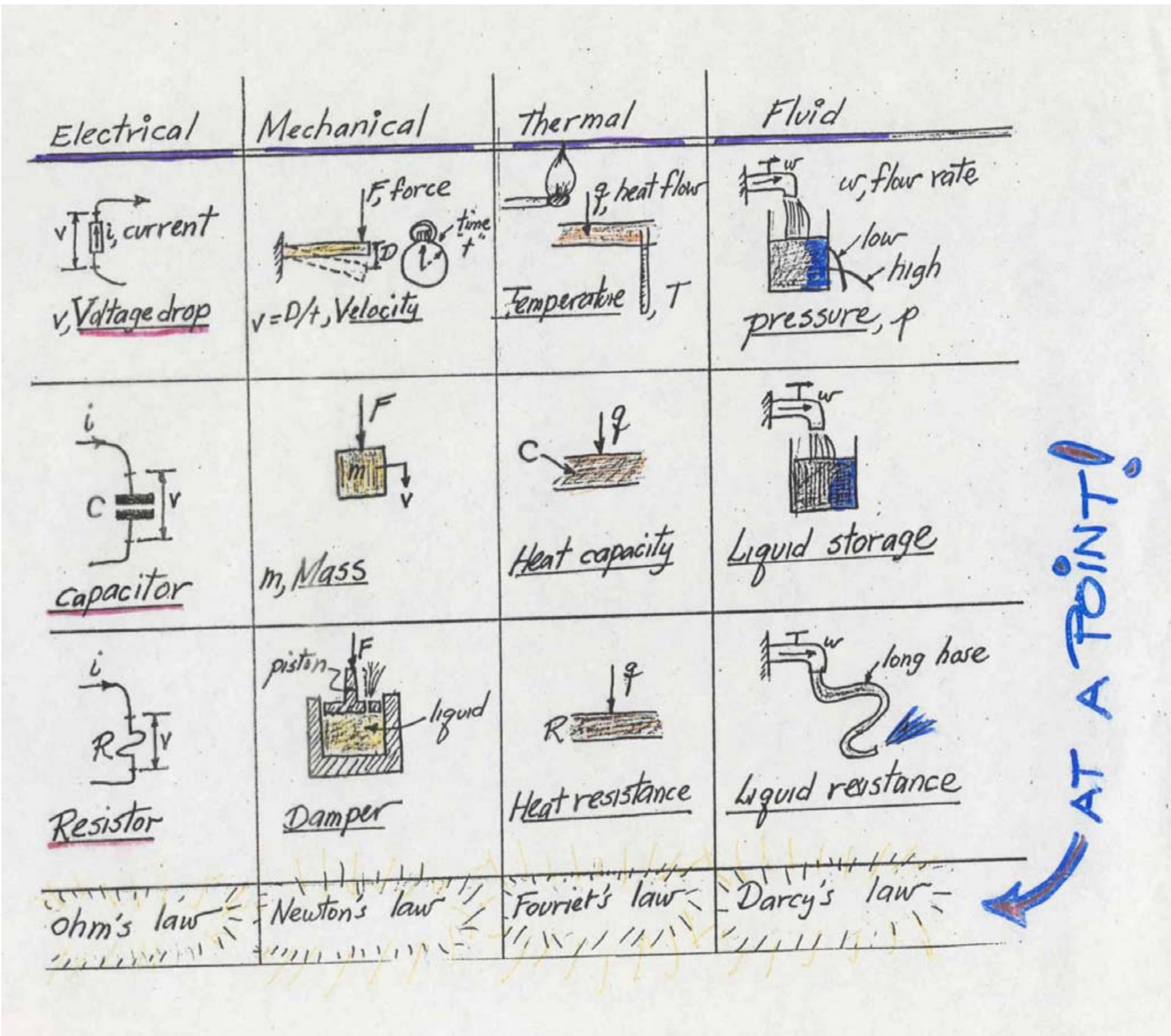
MOTION ≡ ...... ≡ .... ≡ CHANGE IN ENERGY!!!

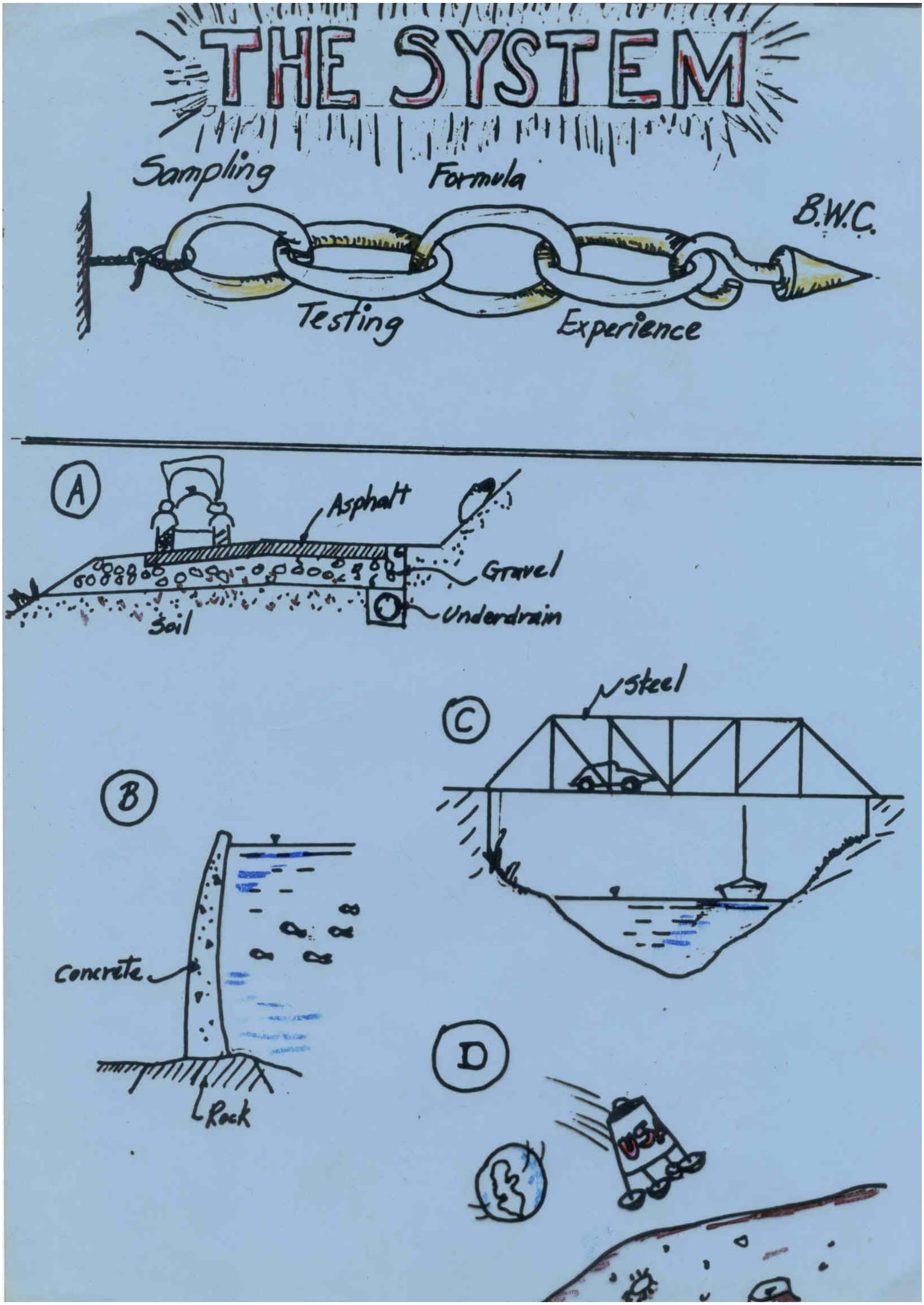
(B)

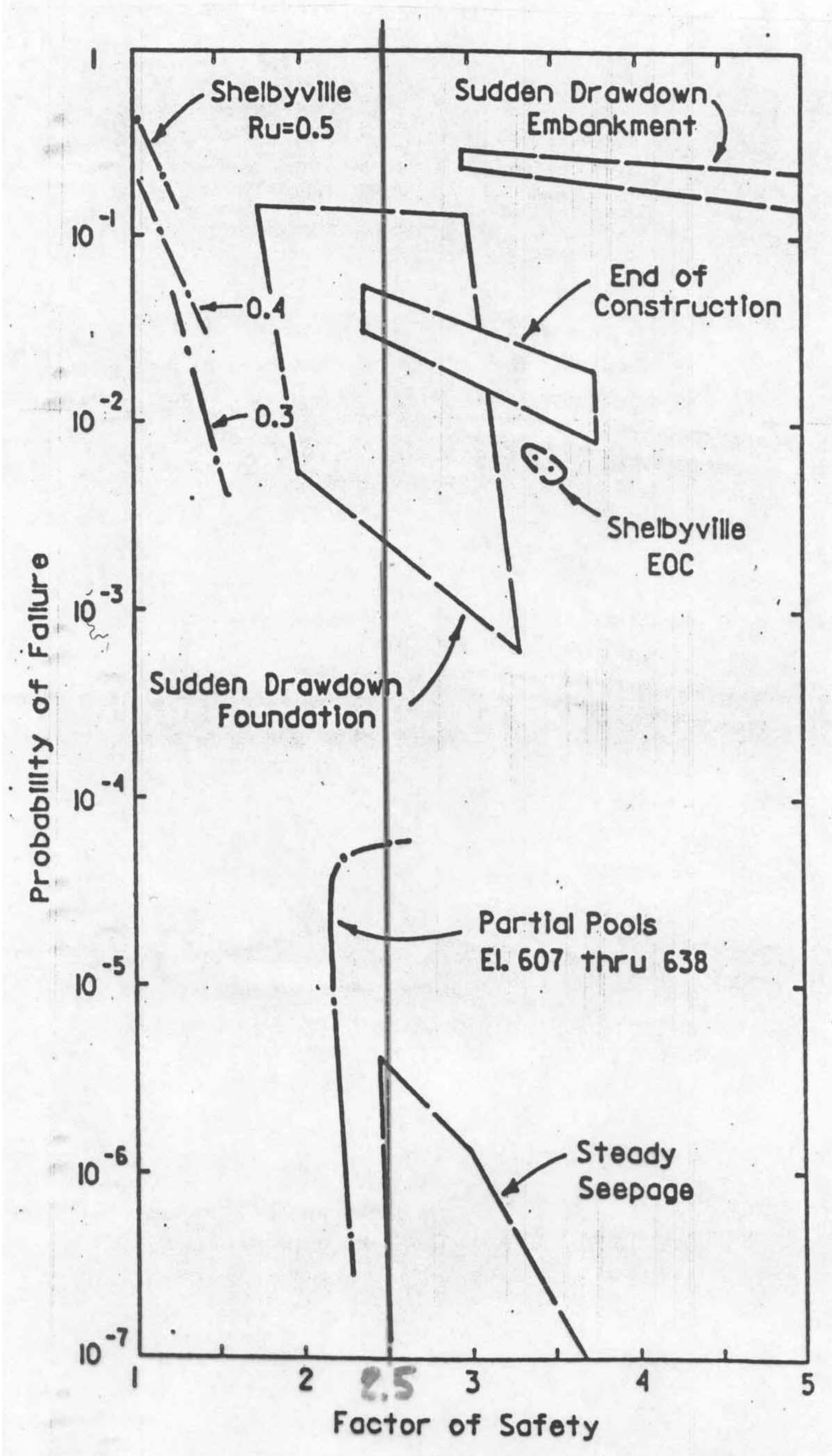


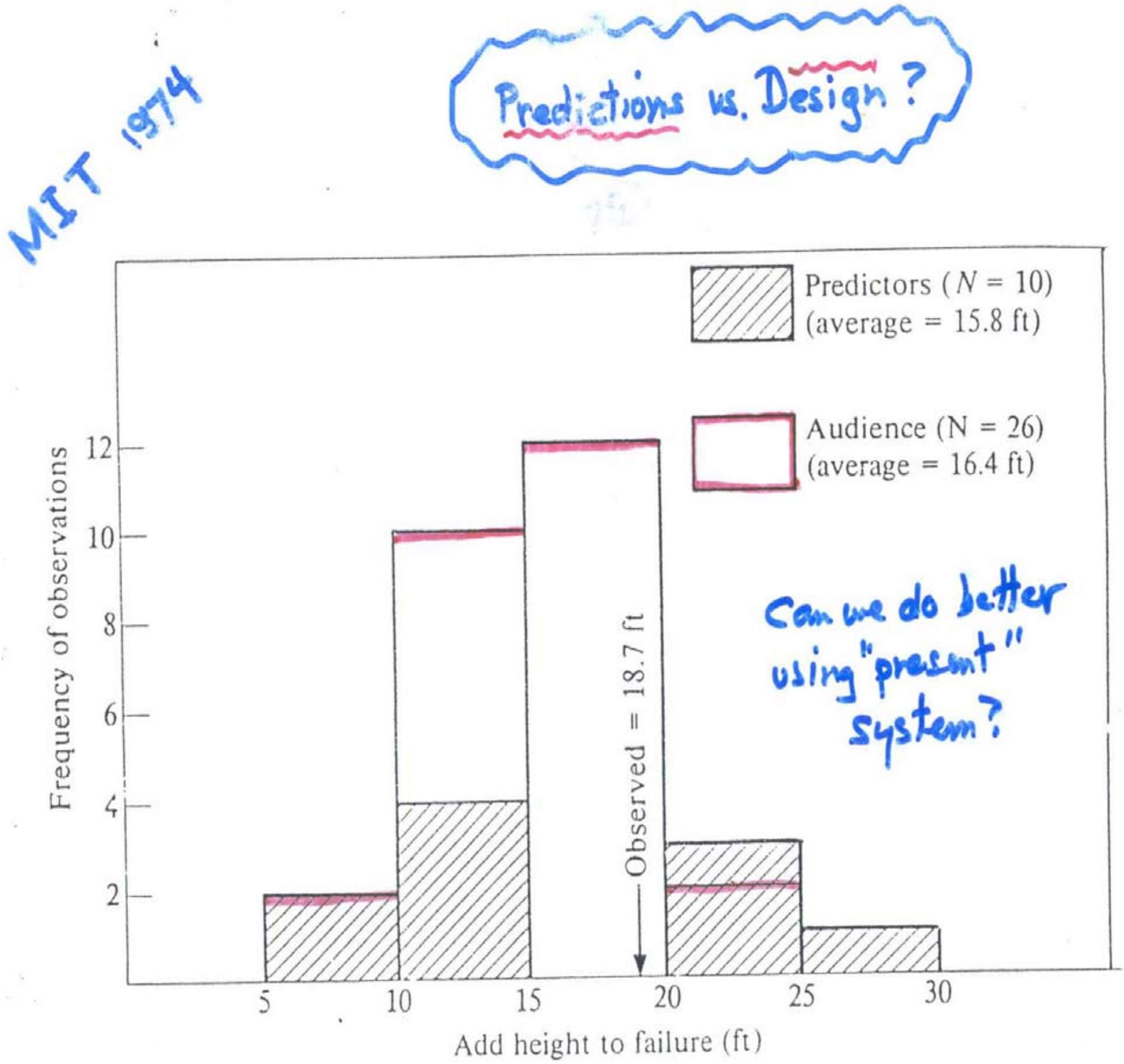
LAW OF CONSERVATION OF CARS

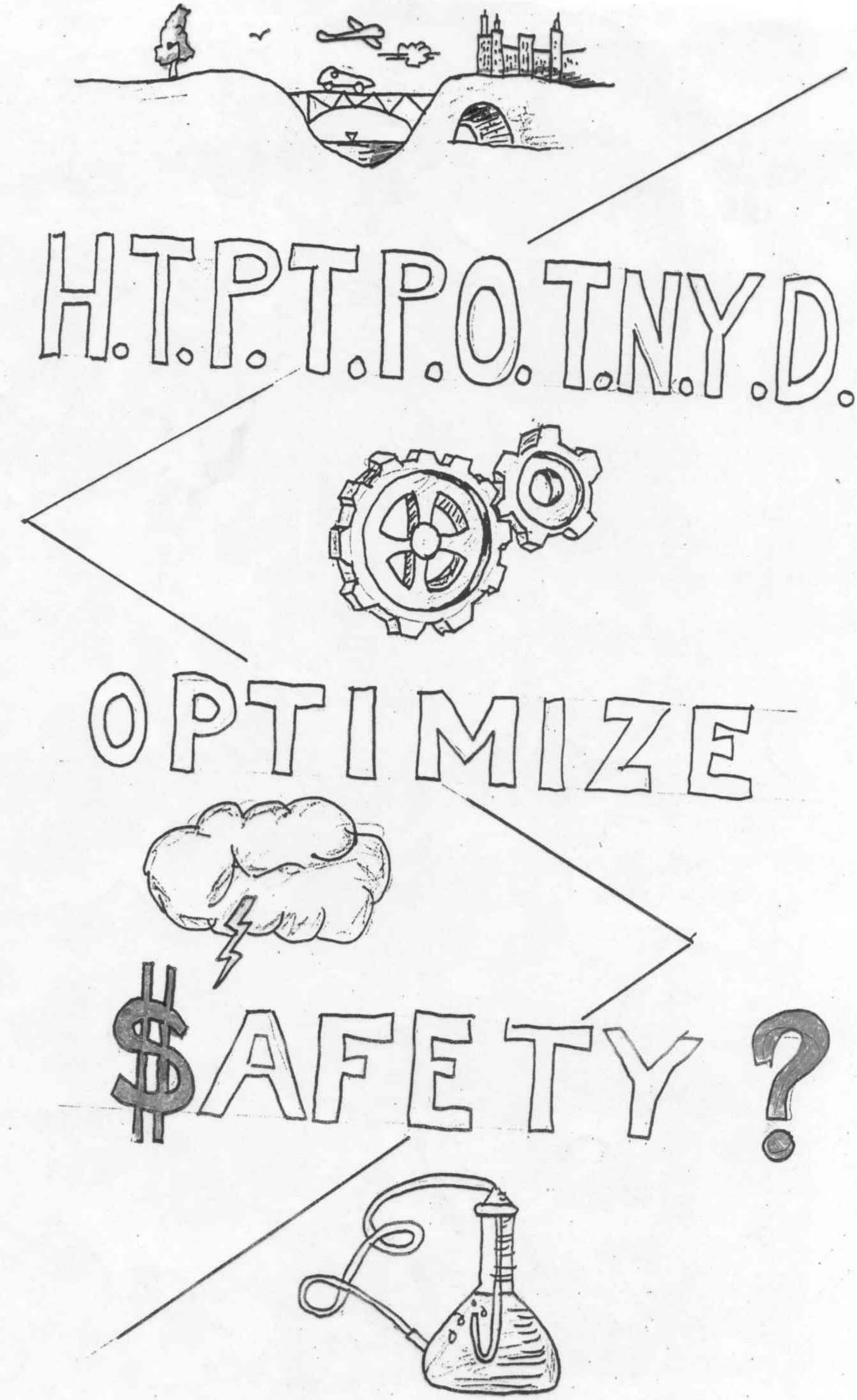
The net change in the number of vehicles on the section of highway between x_1 and x_2, during any time interval, is the difference between the number entering and leaving that section!!!


Electrical
Mechanical
Thermal
Fluid
i, current
v, Voltage drop
F, force
D
time t
v = D/t, Velocity
q, heat flow
Temperature, T
w, flow rate
low
high
pressure, p
i
C
v
capacitor
F
m
v
m, Mass
q
C
Heat capacity
w
Liquid storage
i
R
v
Resistor
piston
F
liquid
Damper
q
R
Heat resistance
w
long hose
Liquid resistance
ohm's law
Newton's law
Fourier's law
Darcy's law
AT A POINT!

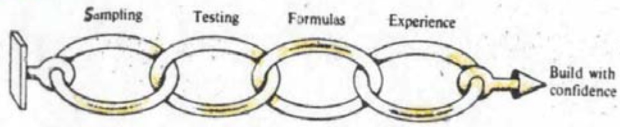

THE SYSTEM
Sampling
Formula
B.W.C.
Testing
Experience
A
Asphalt
Gravel
Underdrain
Soil
C
Steel
B
Concrete
Rock
D
USA


Shelbyville
Ru=0.5
0.4
0.3
Sudden Drawdown
Embankment
End of
Construction
Shelbyville
EOC
Sudden Drawdown
Foundation
Partial Pools
El. 607 thru 638
Steady
Seepage
Probability of Failure
1
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
1
2
2.5
3
4
5
Factor of Safety


MIT 1974
Predictions vs. Design?
Predictors (N = 10)
(average = 15.8 ft)
Audience (N = 26)
(average = 16.4 ft)
Can we do better
using "present"
system?
Observed = 18.7 ft
Frequency of observations
12
10
8
6
4
2
5
10
15
20
25
30
Add height to failure (ft)


H.T.P.T.P.O.T.N.Y.D.
OPTIMIZE
$AFETY?

FOOTPRINTS IN THE SAND



BUILD

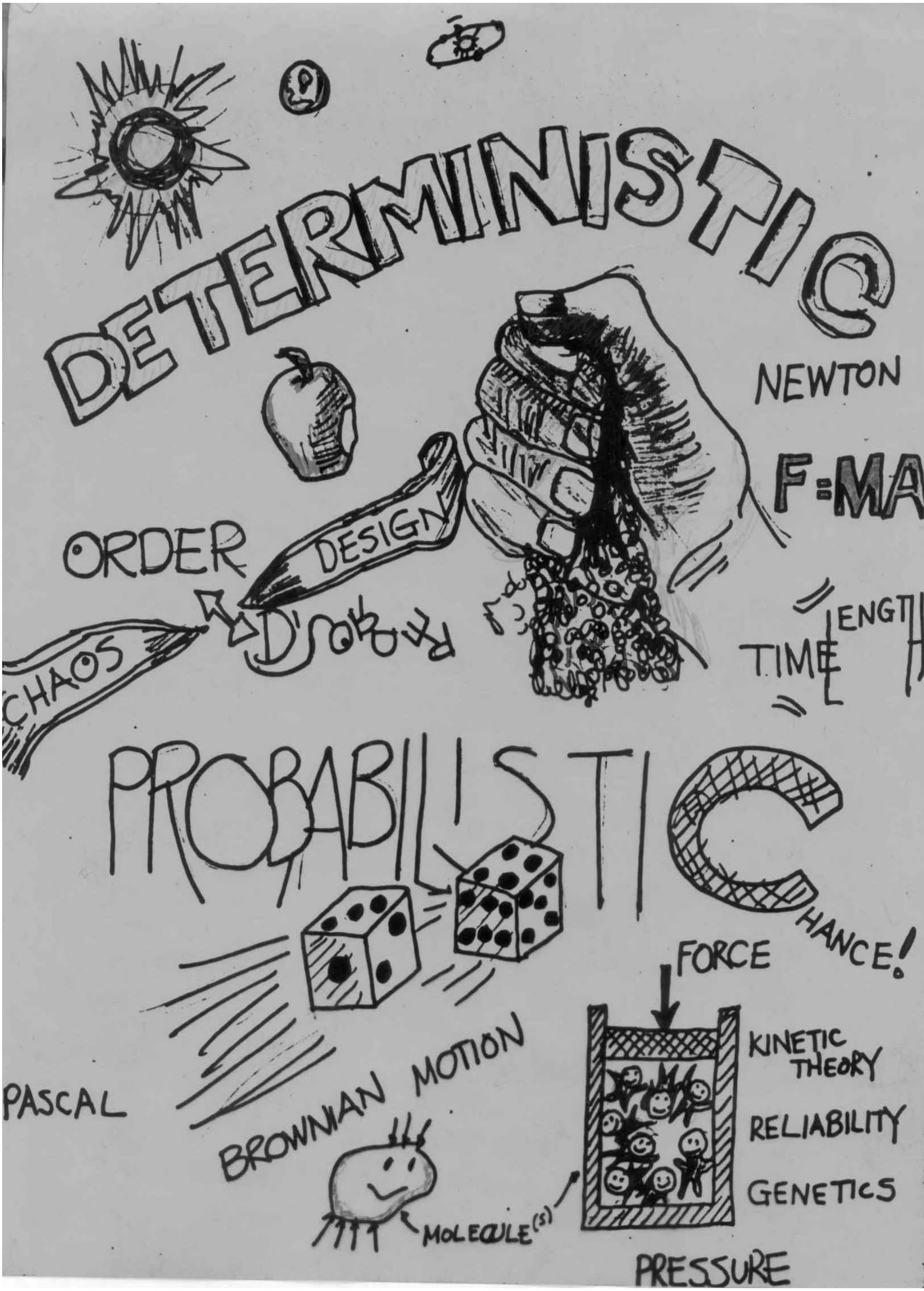
WITH

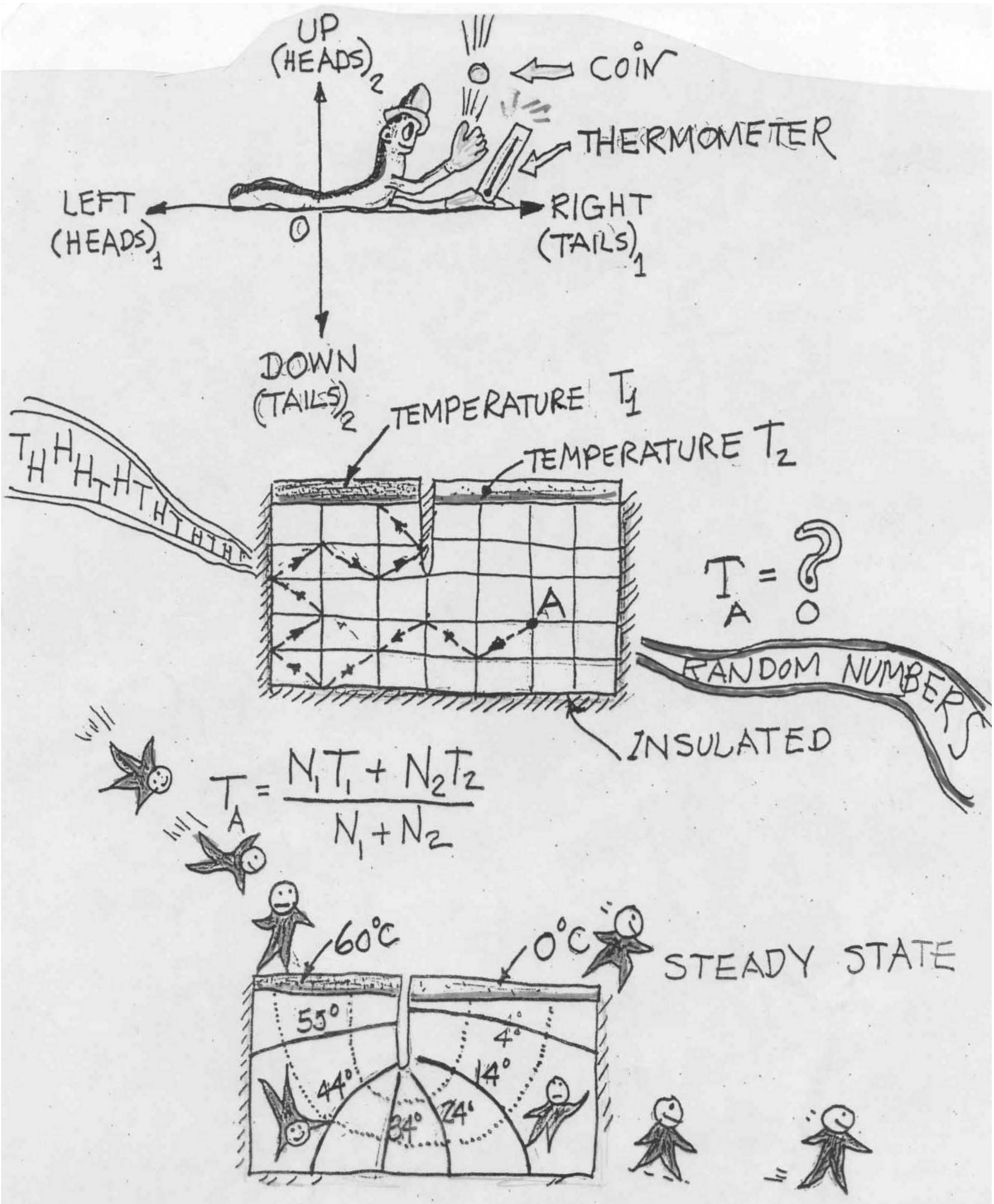
CONFIDENCE

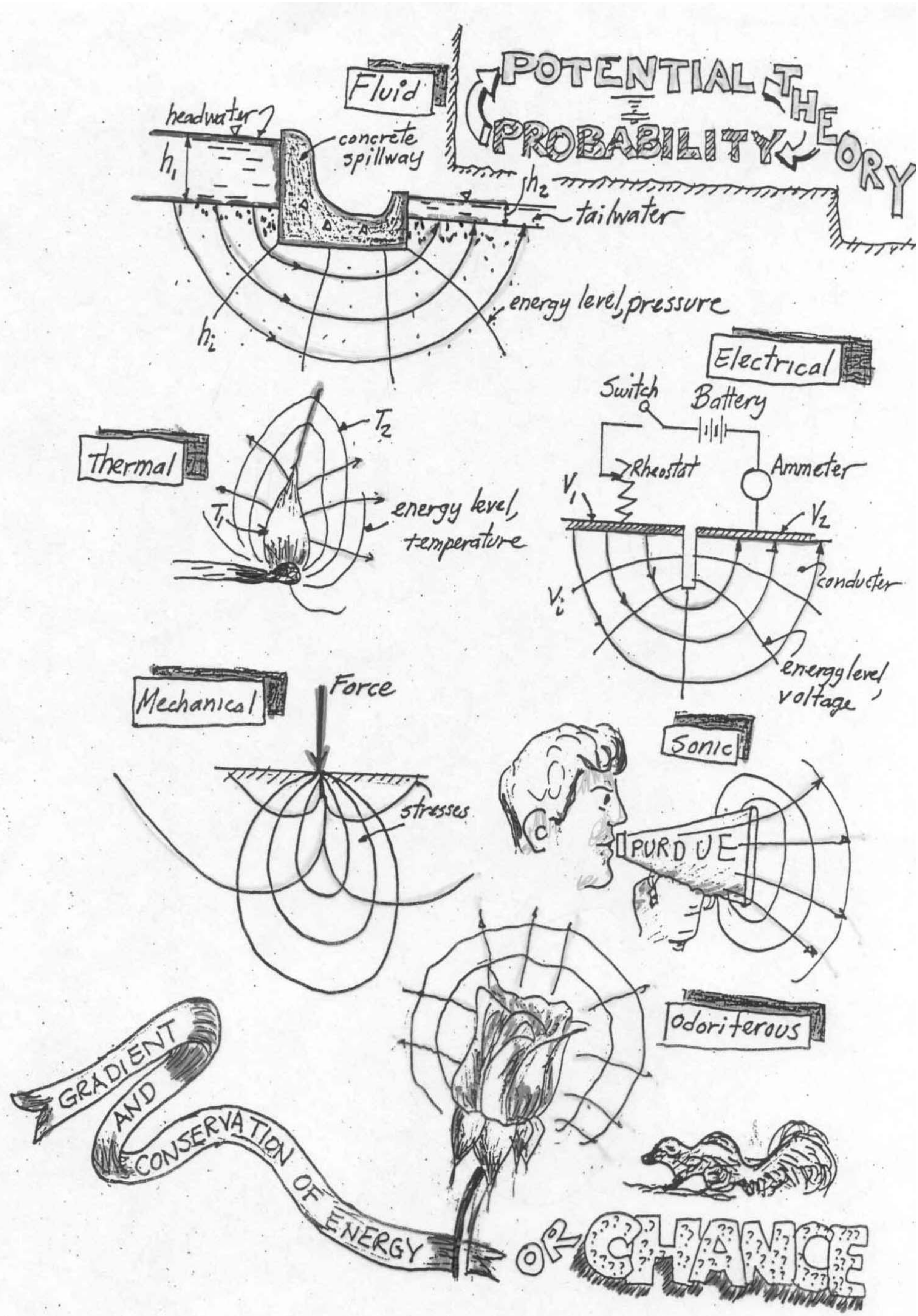
VS

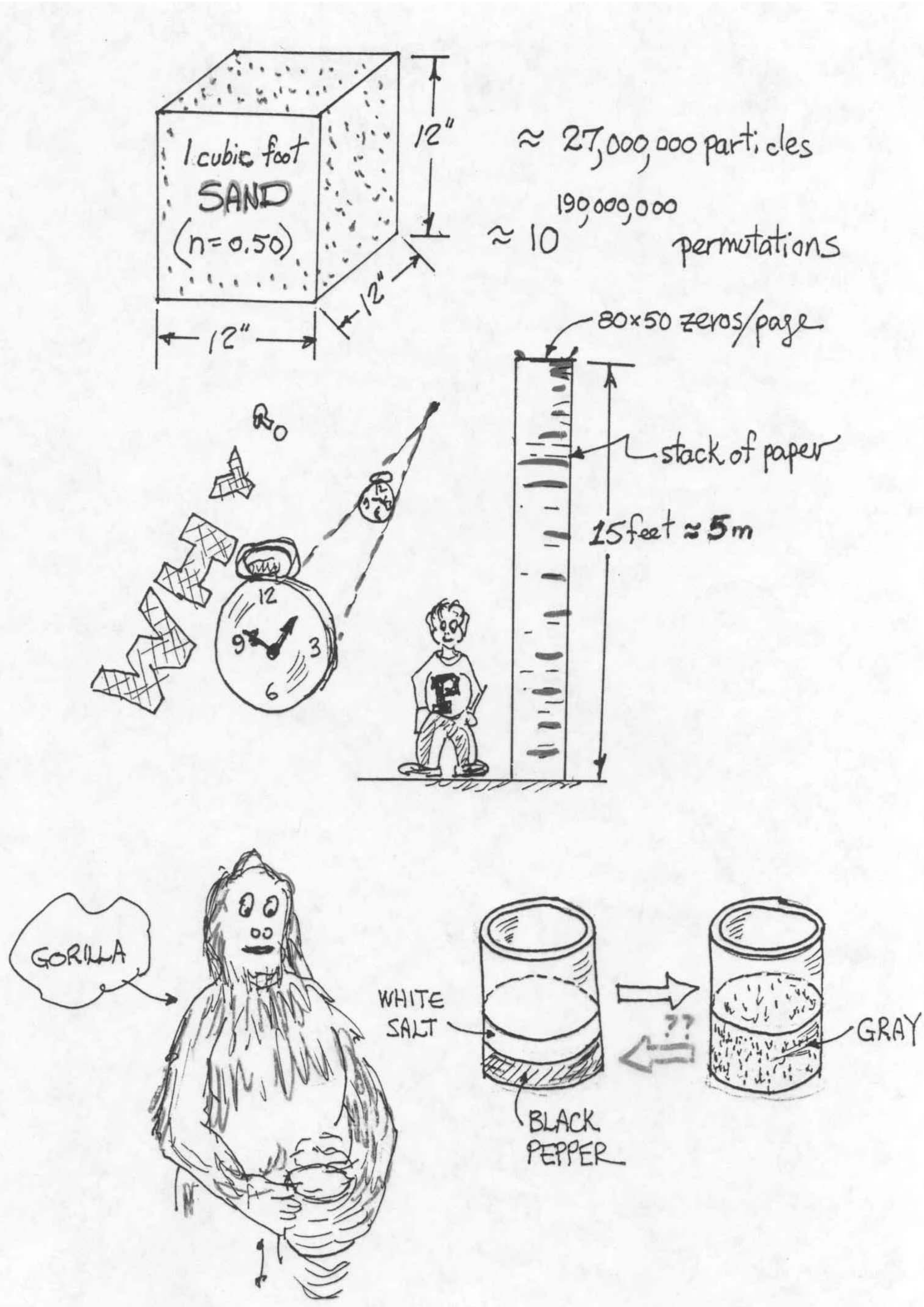
PREDICTING PERFORMANCE OF THINGS NOT YET DONE!

NEED BOTH


DETERMINISTIC
NEWTON
F=MA
ORDER
DESIGN
CHAOS
DISORDER
TIME
LENGTH
PROBABILISTIC
CHANCE!
FORCE
KINETIC THEORY
RELIABILITY
GENETICS
PASCAL
BROWNIAN MOTION
MOLECULE(S)
PRESSURE


UP
(HEADS)$_2$
COIN
THERMOMETER
LEFT
(HEADS)$_1$
0
RIGHT
(TAILS)$_1$
DOWN
(TAILS)$_2$
TEMPERATURE T_1
TEMPERATURE T_2
A
$T_A = ?$
RANDOM NUMBERS
INSULATED
$T_A = \frac{N_1 T_1 + N_2 T_2}{N_1 + N_2}$
60°C
0°C
STEADY STATE
55°
4°
44°
14°
34°
24°


POTENTIAL THEORY
=
PROBABILITY
Fluid
headwater
concrete spillway
h_1
h_2
tailwater
h_i
energy level, pressure
Electrical
Switch
Battery
Rheostat
Ammeter
V_1
V_2
V_i
conducter
energy level, voltage
Thermal
T_2
T_1
energy level, temperature
Mechanical
Force
stresses
Sonic
PURDUE
Odoriferous
GRADIENT AND CONSERVATION OF ENERGY
OR CHANCE


1 cubic foot
SAND
(n=0.50)
12"
12"
12"
≈ 27,000,000 particles
≈ 10^190,000,000 permutations
80×50 zeros/page
stack of paper
15 feet ≈ 5m
12
9
3
6
GORILLA
WHITE SALT
BLACK PEPPER
GRAY
??

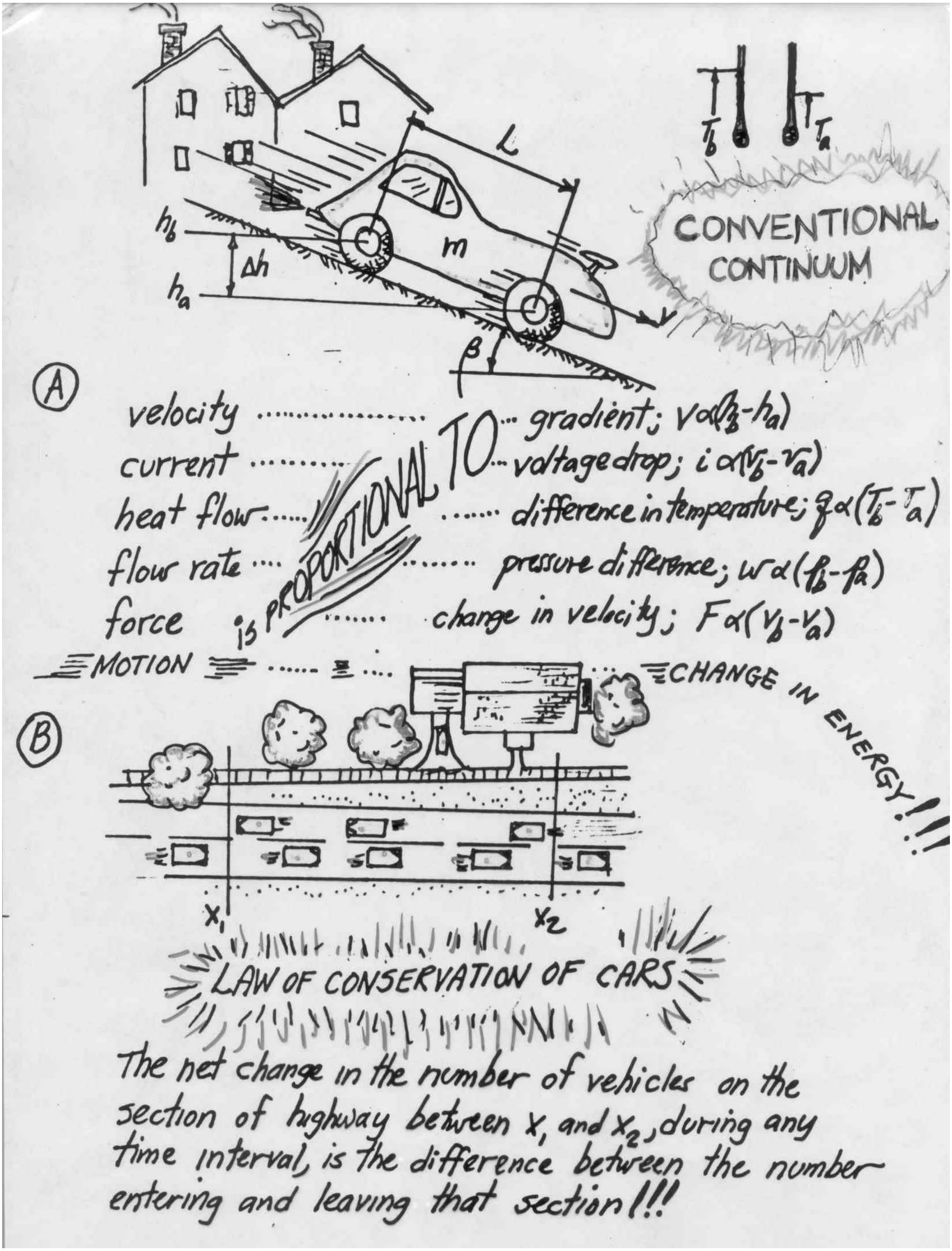
THE

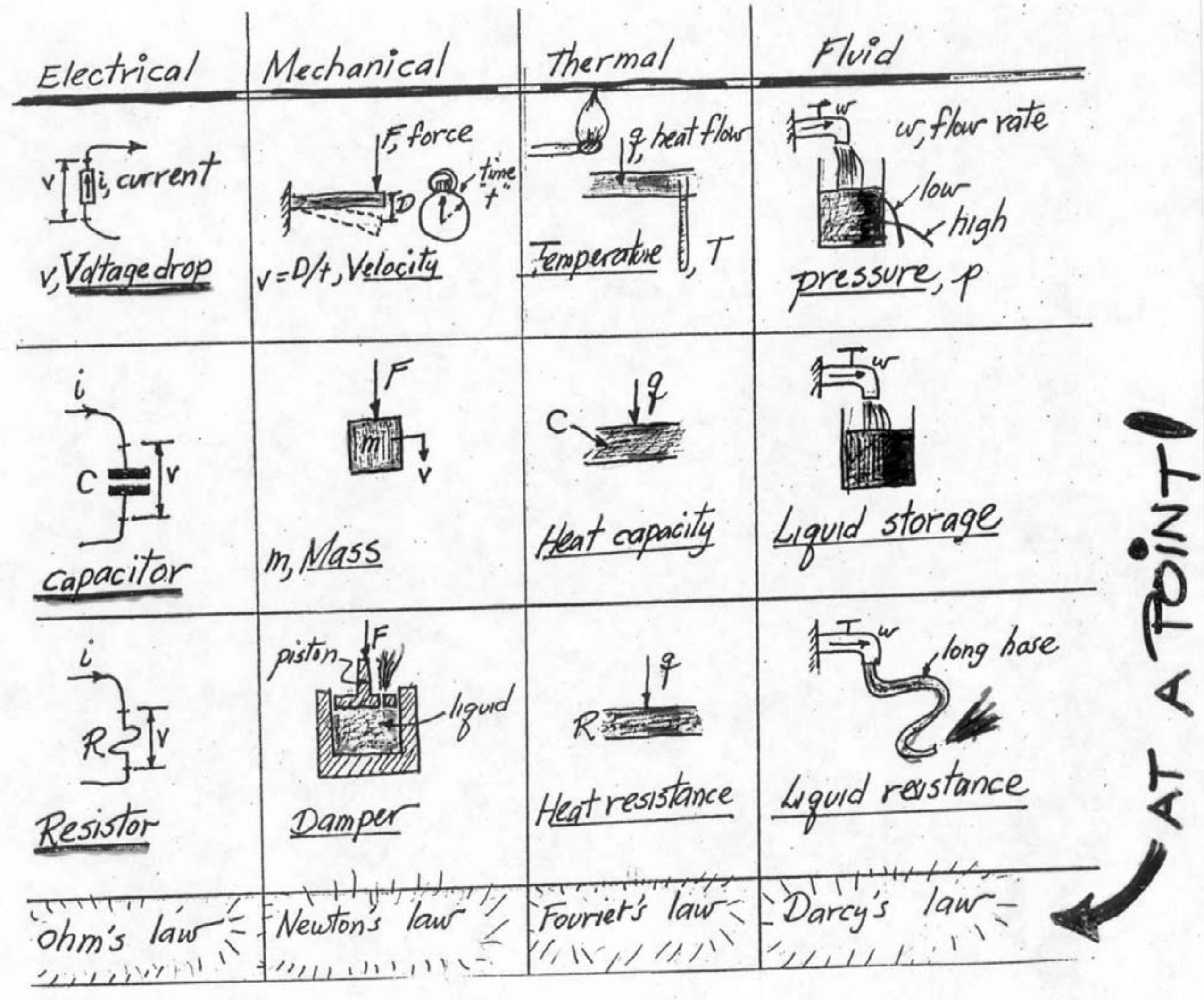
PRINCIPLE

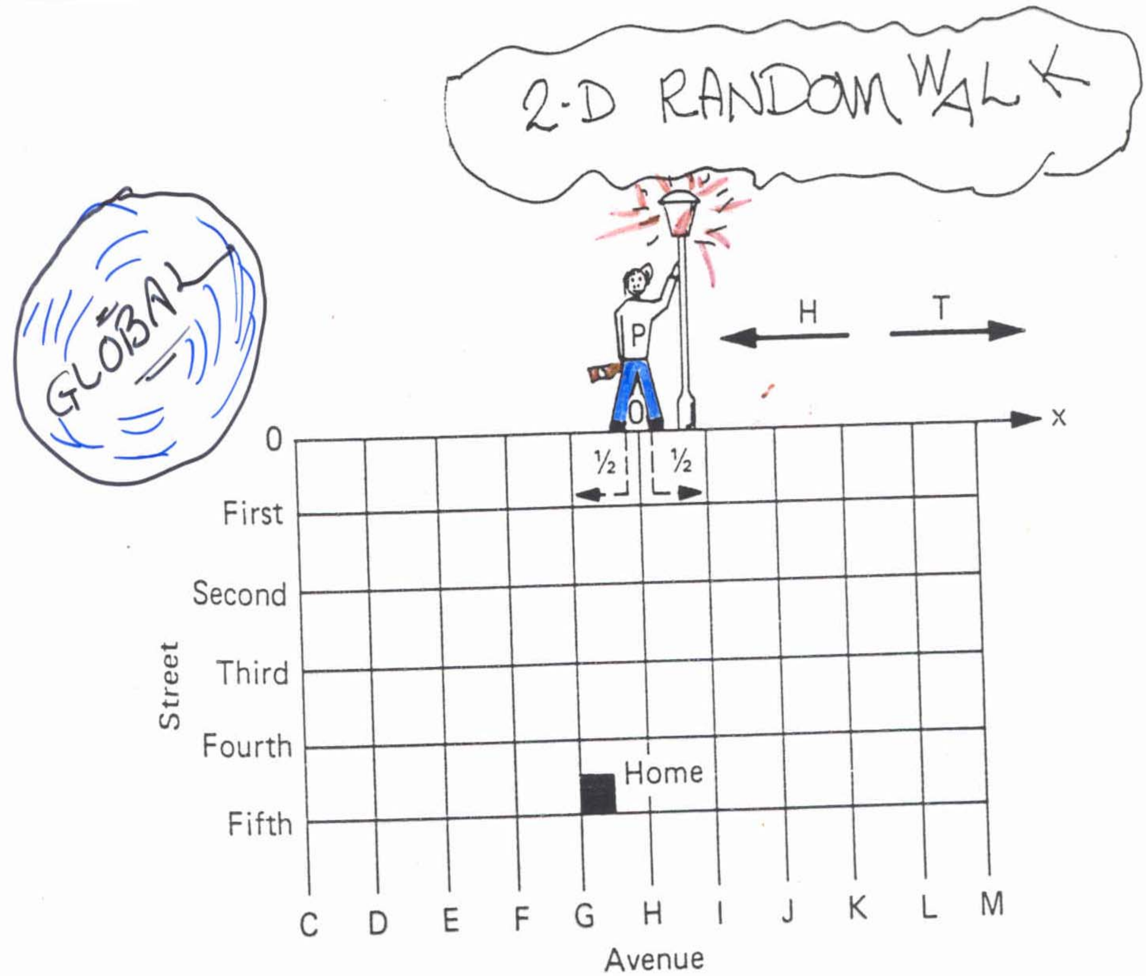
OF

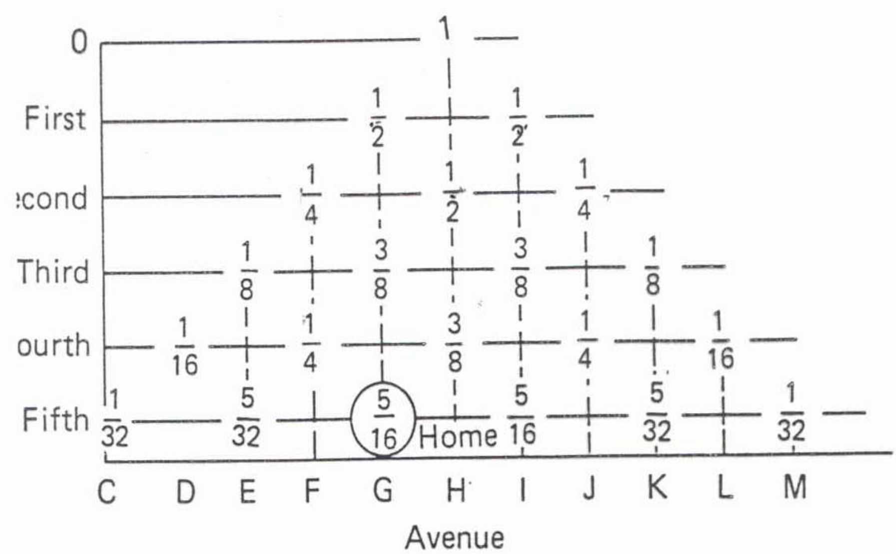
MAXIMUM

ENTROPY

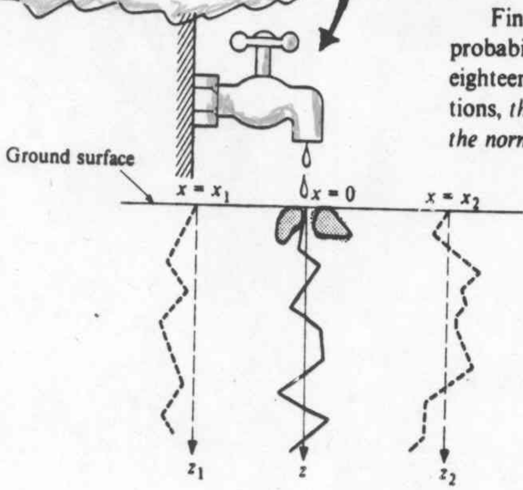

L
m
h_b
Δh
h_a
V
β
T_b
T_a
CONVENTIONAL CONTINUUM
(A)
velocity ... gradient; $V \alpha (h_b - h_a)$
current ... voltage drop; $i \alpha (v_b - v_a)$
heat flow ... difference in temperature; $q \alpha (T_b - T_a)$
flow rate ... pressure difference; $w \alpha (p_b - p_a)$
force ... change in velocity; $F \alpha (V_b - V_a)$
is PROPORTIONAL TO
MOTION ... CHANGE IN ENERGY!!!
(B)
x_1
x_2
LAW OF CONSERVATION OF CARS
The net change in the number of vehicles on the section of highway between x_1 and x_2, during any time interval, is the difference between the number entering and leaving that section!!!


Electrical
Mechanical
Thermal
Fluid
i, current
v, Voltage drop
F, force
time t
D
v = D/t, Velocity
q, heat flow
Temperature, T
w, flow rate
low
high
pressure, p
i
C
v
capacitor
F
m
v
m, Mass
q
C
Heat capacity
w
Liquid storage
i
R
v
Resistor
piston
F
liquid
Damper
q
R
Heat resistance
w
long hose
Liquid resistance
ohm's law
Newton's law
Fourier's law
Darcy's law
AT A POINT!


2-D RANDOM WALK
GLOBAL
H
T
P
0
x
½
½
First
Second
Third
Fourth
Fifth
Street
Home
C D E F G H I J K L M
Avenue

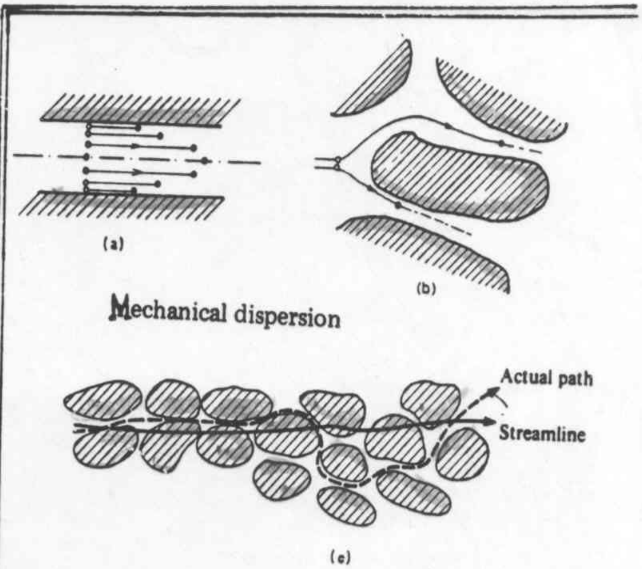

0
1
First
1/2 1/2
:cond
1/4 1/2 1/4
Third
1/8 3/8 3/8 1/8
ourth
1/16 1/4 3/8 1/4 1/16
Fifth
1/32 5/32 5/16 5/16 5/32 1/32
Home
C D E F G H I J K L M
Avenue

Leaky Faucet Problem



Central Limit Theorem

Finally, we give the most remarkable and most important theorem of all probability theory, the *central-limit theorem* (first introduced by De Moivre in the eighteenth century but so named by G. Polya in 1920). Under very general conditions, *the distribution of the sum of random variables converges (or approaches) to the normal distribution as the number of variables in the sum becomes large.*



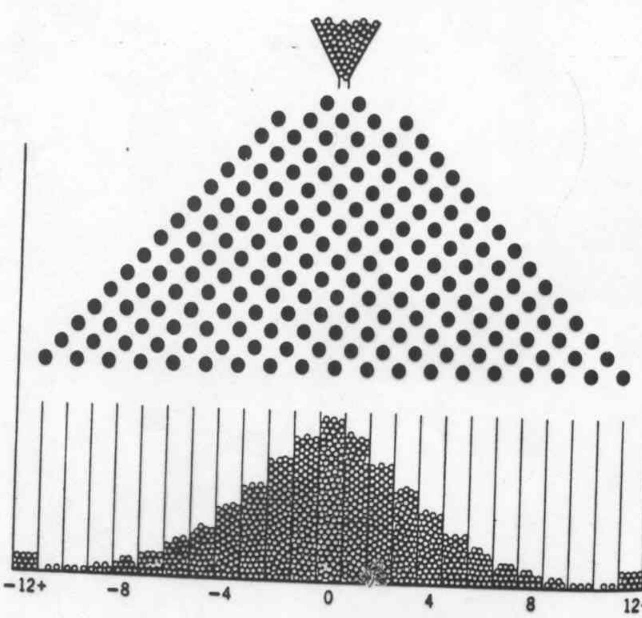
Dispersion Coef...

$$P(x, t) = \frac{1}{\sqrt{4\pi D t}} \exp\left|-\frac{x^2}{4Dt}\right| \qquad D = \frac{v_0 d}{2}$$

Normal/Gaussian Distribution

see σ_i below

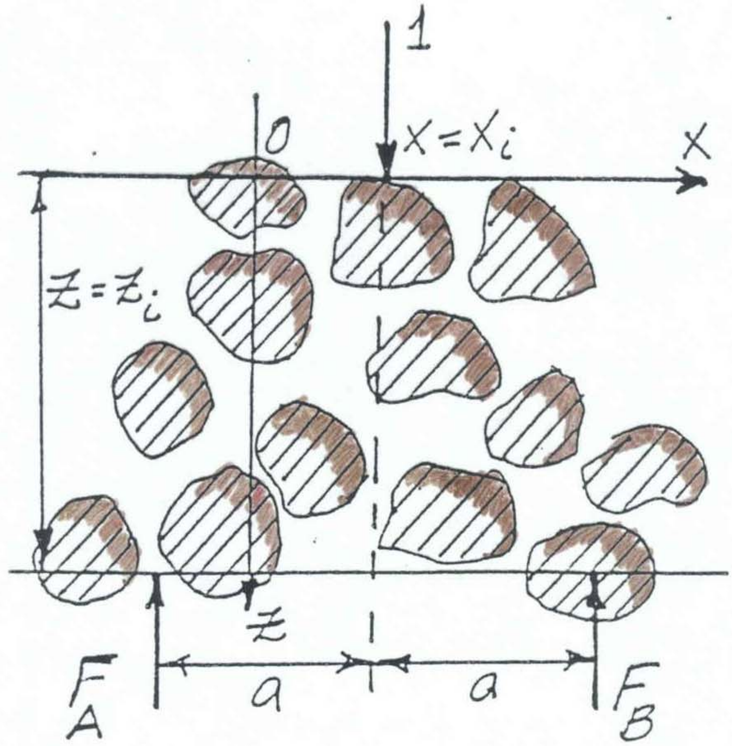
Gaussian Plume Equation



Galton's Board

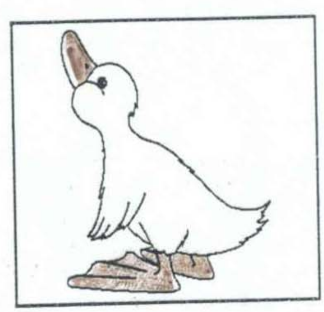
EXPECTED VALUE OF STRESS AT A POINT ?

P[particles touching in plane] → 0



P[stress = 0] = ?

P[stress = pore water pressure] = ?



STRESS DISTRIBUTION

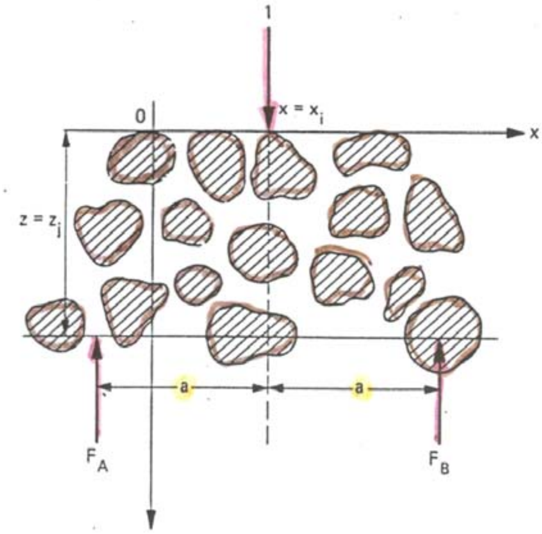
CENTRAL LIMIT THEOREM

ATTRACTOR??

NO PROPERTY OF MATERIAL

Flamant solution

$$\bar{s}_z(x,z) = \frac{P}{z\sqrt{2\nu\pi}} \exp\left[-\frac{x^2}{2\nu z^2}\right] \qquad \sigma_z(x,z) = \frac{2Pz^3}{\pi(x^2+z^2)^2}$$



$\frac{x}{z}$	$z\bar{s}_z = \left(\frac{2}{\pi}\right) \exp\left[-\frac{4x^2}{\pi z^2}\right]$	$z\sigma_z = \left(\frac{2}{\pi}\right)\left[1+\frac{x^2}{z^2}\right]^{-2}$
0.0	0.64	0.64
0.1	0.63	0.62
0.2	0.61	0.59
0.3	0.57	0.54
0.4	0.52	0.47
0.5	0.46	0.41
0.6	0.40	0.34
0.8	0.28	0.24
1.0	0.18	0.16
1.2	0.10	0.11
1.5	0.04	0.06
1.8	0.01	0.04
2.0	0.004	0.03

$\nu = \pi/8$

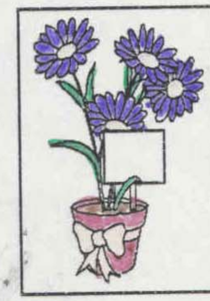
3d

CENTRAL LIMIT THEOREM

TRANSMISSION OF VERTICAL STRESS

$$\overline{S}_z = \frac{P}{2\pi v z^2} \exp\left[-\frac{x^2 + y^2}{2 v z^2}\right] = \frac{P}{2\pi v z^2} \exp\left[-\frac{r^2}{2 v z^2}\right]$$

EXPECTED VALUE



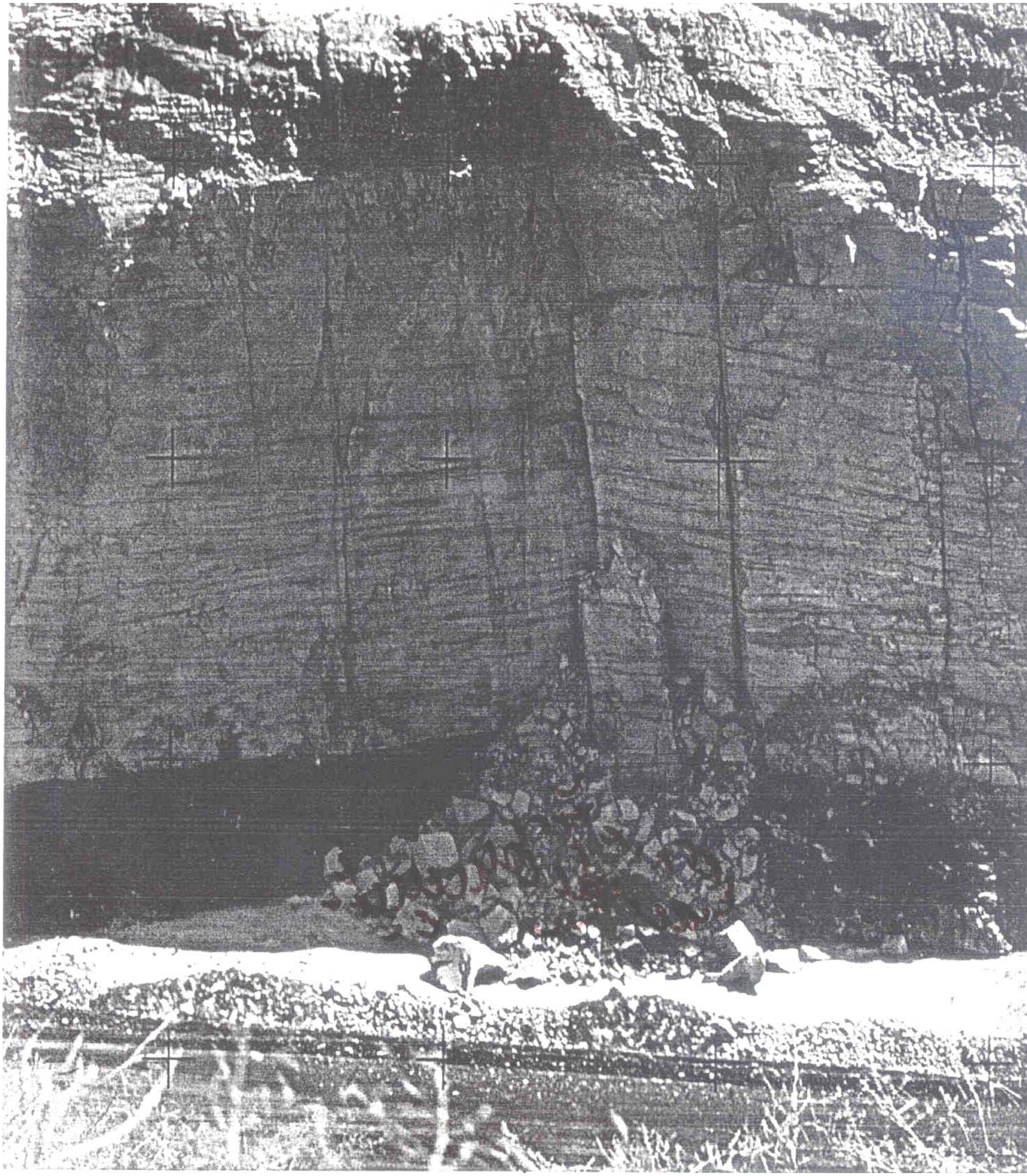
$$\sigma_{z_{max}} = \frac{3P}{2\pi z^2}$$

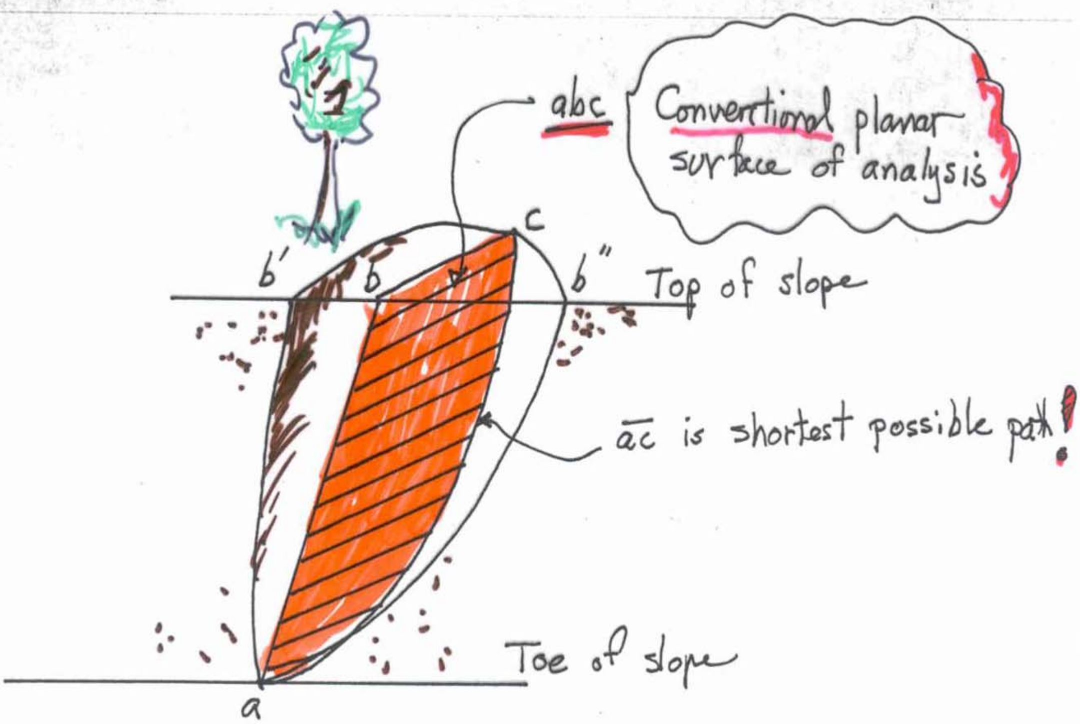
$$\overline{S}_{z_{max}} = \frac{P}{2\pi v z^2}$$

$v = 1/3.$

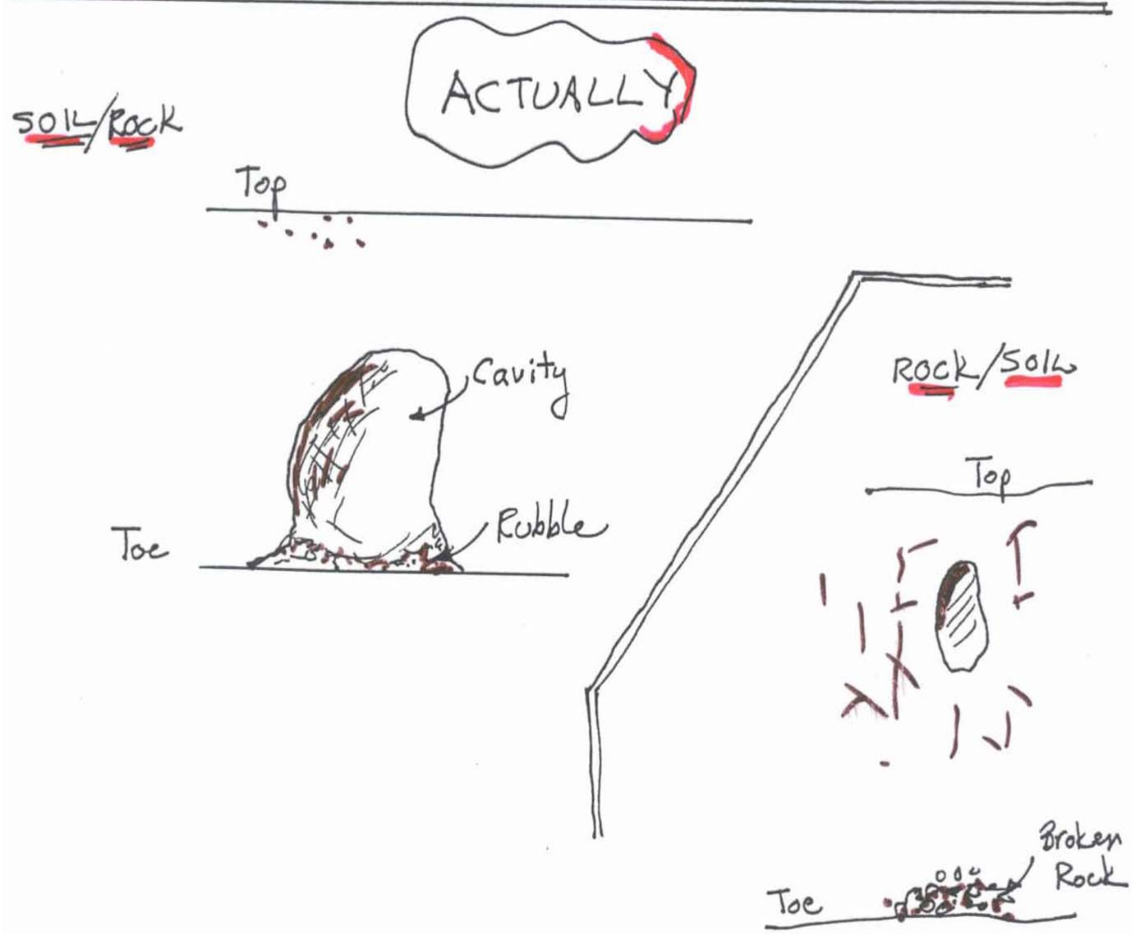
KA/o/P

$\frac{r}{z}$	$\frac{z^2 \overline{S}_z}{P}$	$\frac{z^2 \sigma_z}{P}$
0.0	0.48	0.48
0.1	0.47	0.47
0.2	0.45	0.43
0.4	0.38	0.33
0.6	0.28	0.22
0.8	0.18	0.14
1.0	0.11	0.08
1.2	0.06	0.05
1.5	0.02	0.03
2.0	0.001	0.01



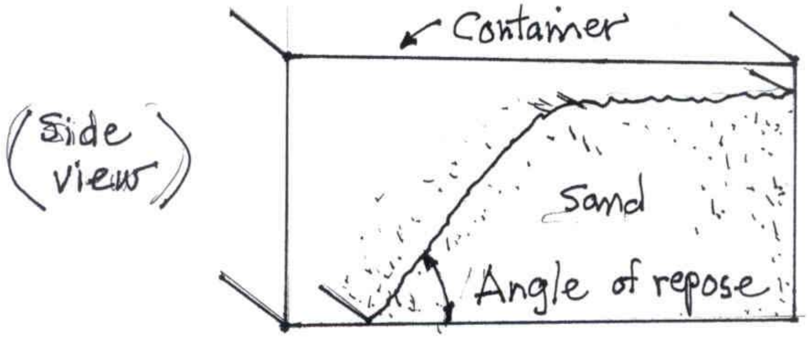


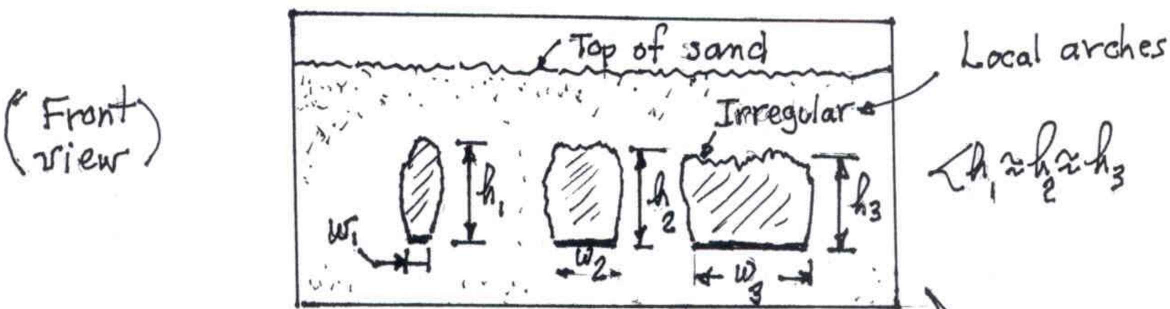
abc
Conventional planar surface of analysis
c
b'
b
b"
Top of slope
$\bar{ac}$ is shortest possible path!
Toe of slope
a

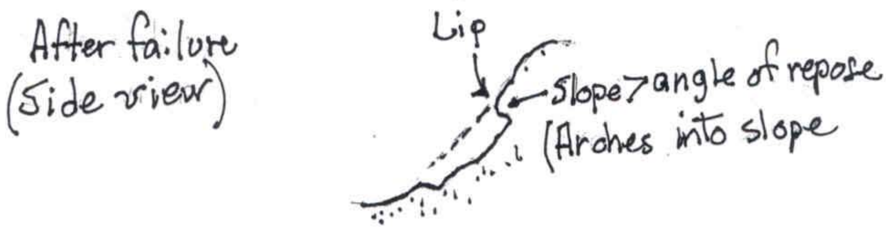


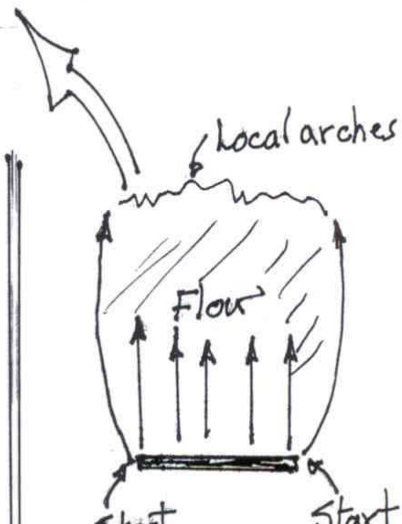
ACTUALLY
SOIL/ROCK
Top
Cavity
Rubble
Toe
ROCK/SOIL
Top
Broken Rock
Toe

EXPERIMENT WITH SAND: BRISBANE 7/01

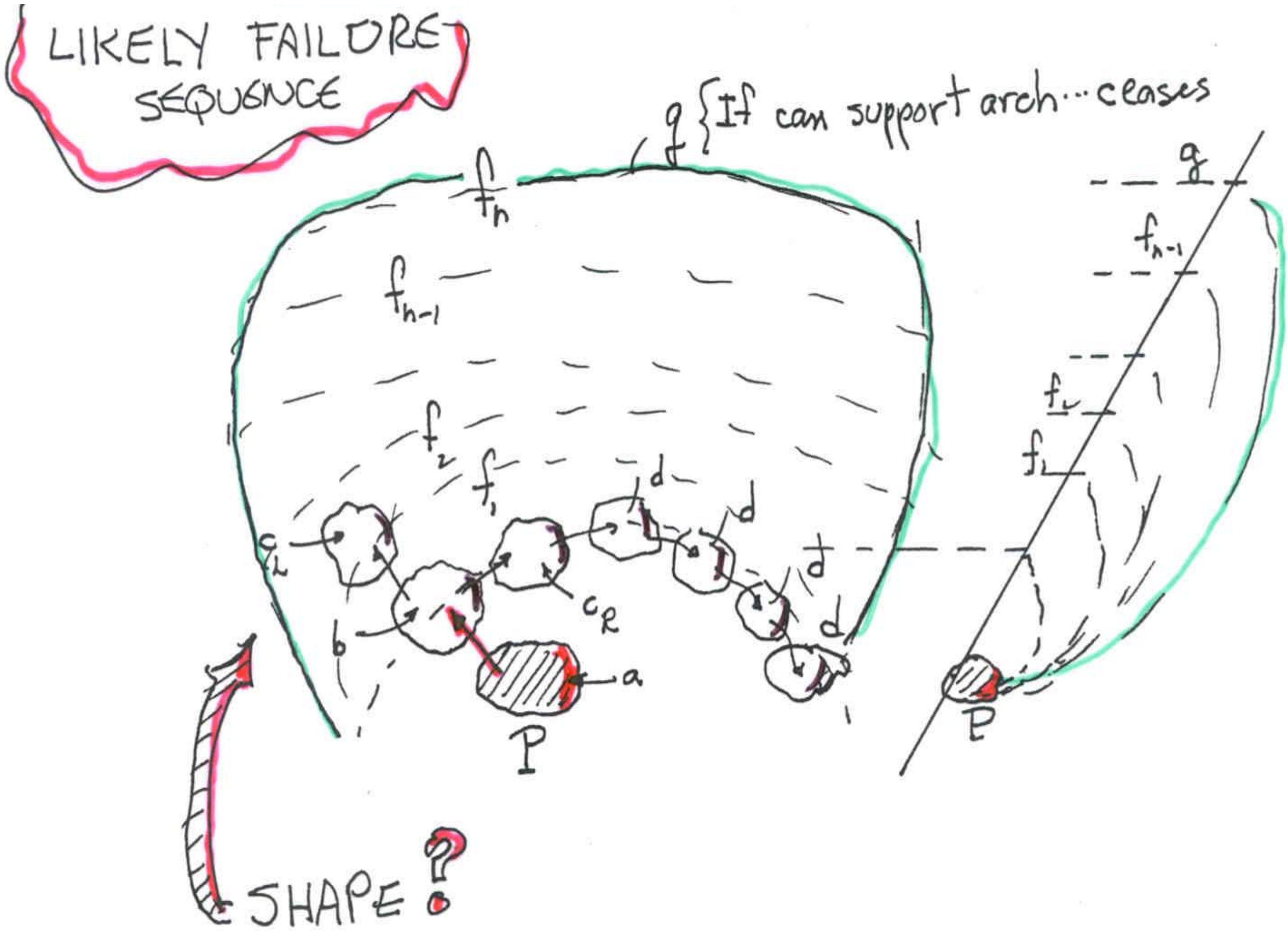






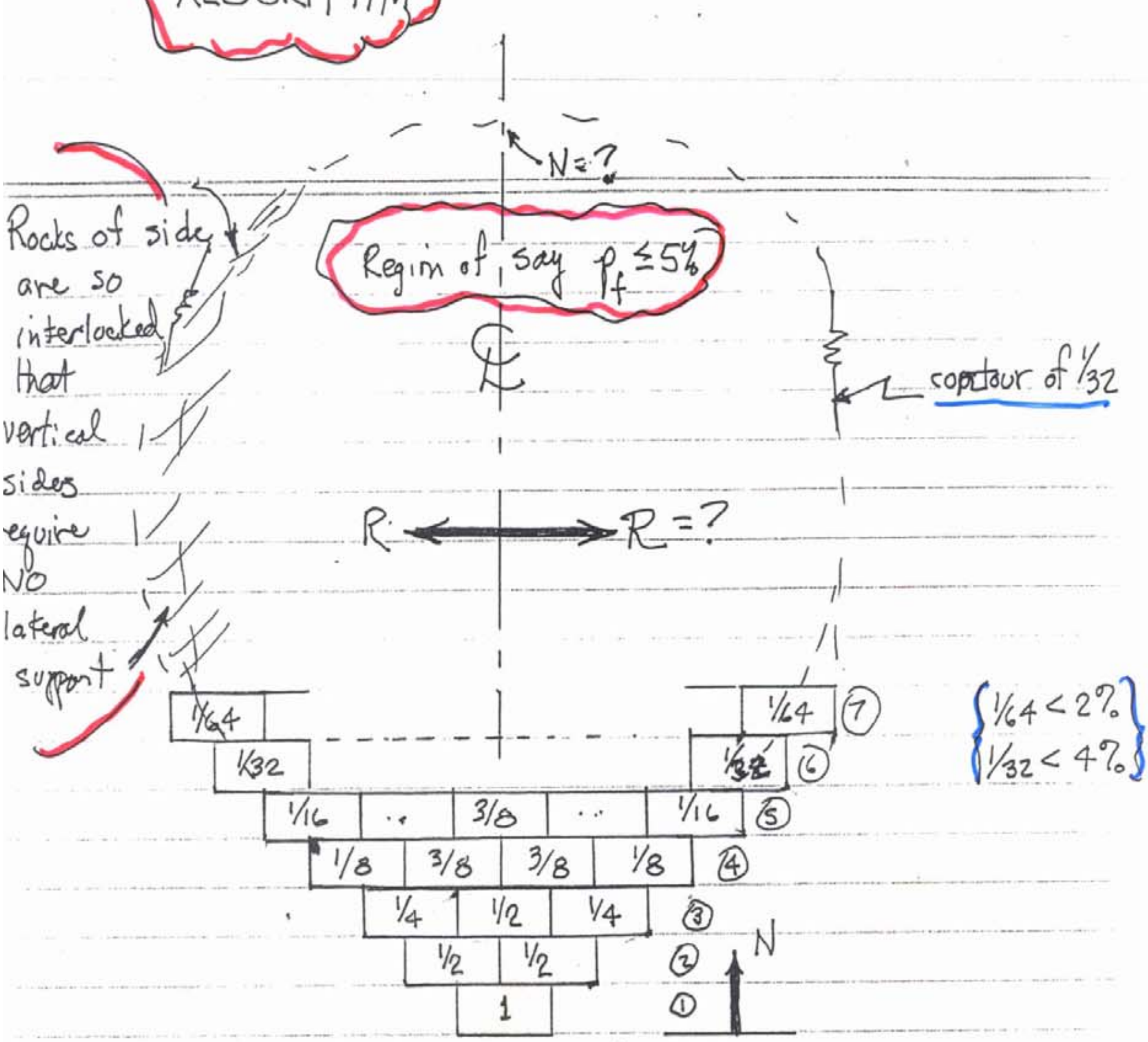


Repeated tests with gravel – Results similar
BUT height of plume decreased with increasing particle size (up to 2"–3") ~ where height is number of particles ~ Again height was independent of width of cut.



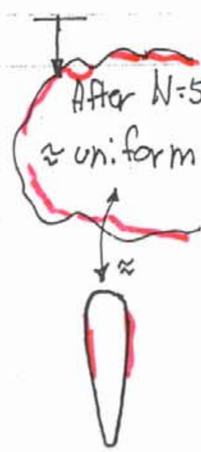
WHY DOES RUPTURE CEASE ?

ARCH CAN SUSTAIN LOAD !



Along ℄	
N	Probability
1	1
3	0.5
5	0.375
7	0.313
17	0.2
29	0.15
65	0.10
113	0.075
175	0.06
209	0.055
250	0.050

Lateral to ≥ 0.05	
N	R (blocks from ℄)
1	—
3	2
5	4
7	6
17	7
29	8
65	7
113	7
175	8
209	7
250	4



cohesionless sand. A detailed description of these tests will be presented in a companion volume on *"Earth Tunneling with Steel Support."* The test results led to the following conclusions regarding the prerequisites for arch action and the factors which determine the load on the roof support in tunnels through crushed rock and cohesionless sand located above the water table.

(a) The arch action is the inevitable consequence of the local stress relaxation produced by mining operations. The mechanics of the arch action are illustrated by *Fig. 25.* In this figures the ground arch is represented by the shaded area **a c d b.** The ground arch has a width B_1. While the tunnel is being excavated and the support installed, the mass of crushed rock or cohesionless sand constituting the ground arch

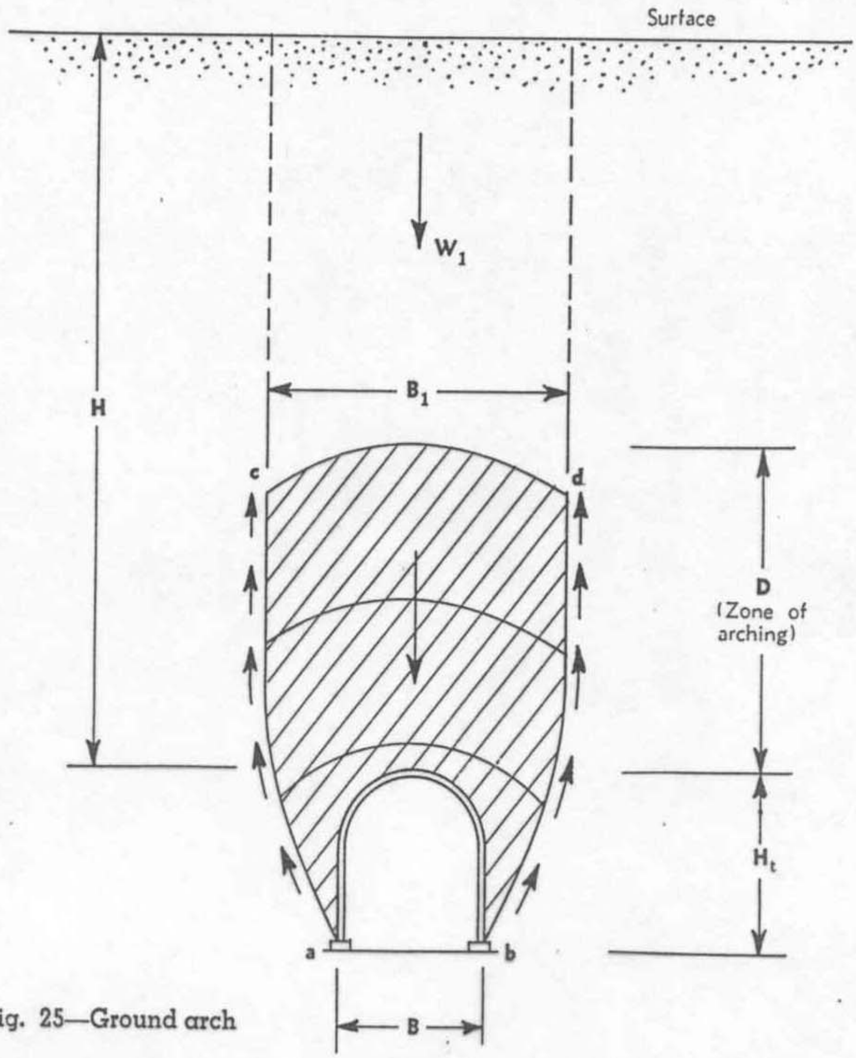


Fig. 25—Ground arch

tends to move into the tunnel. This movement is resisted by the friction along the lateral boundaries **a c** and **b d** of this mass. The friction forces transfer the major part of the weight of the overburden, with height **H** onto the material located on both sides of the tunnel and the roof support carries only the balance, equivalent to a height H_p.

(b) The thickness **D** of the ground arch is roughly equal to 1.5 B_1. Above the ground arch the pressure conditions in the rock remain practically unaffected by the tunnel operations.

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I was Jerry's first Ph.D. He was my academic father. We shared 40 magnificent years together at Purdue, often with two coffee breaks and lunch. Our discussions ran the gamut, from Monday morning quarterbacking to philosophy and, of course, liberal doses of soil mechanics. **It is said that nature abhors a vacuum. The vacuum that Jerry's (and Bill Dolch's) death created will never be filled.**