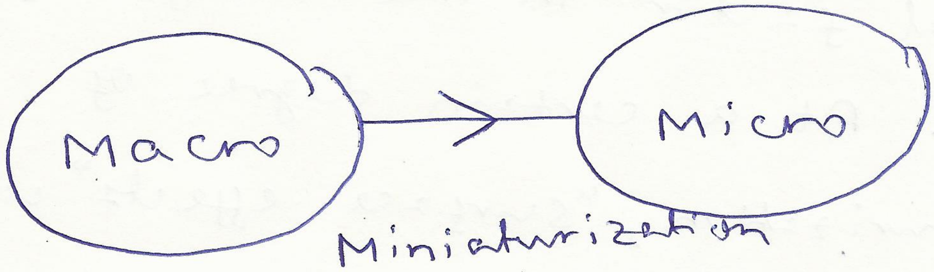
Q: What is more importent – Surface tension or Gravity?

Scaling



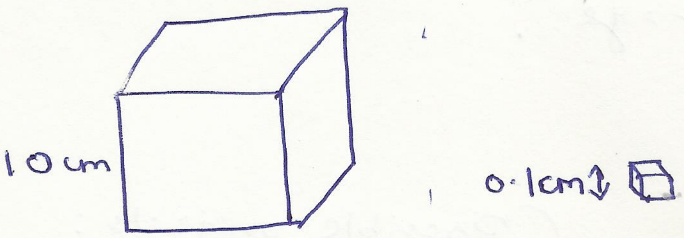
Implications of size reduction

Bread crumb & rubbed plastic rod

Why crumb is attracted but not the entire bread loaf?

Ans. Mass smaller + "MORE".

"MORE": Electrostatic force $\propto$ charge on surface.



$V = 1000\,[cm^3]$	$V = 10^{-3}\,[cm^3]$
$S = 600\,[cm^2]$	$S = 6\times10^{-2}\,[cm^2]$
$\frac{V}{S} = 1.6\,[cm]$	$\frac{V}{S} = 0.016\,[cm]$

As size decreases, volume goes down faster than surface; inertia goes down faster than electrostatic force.

<u>Statement</u>*: Decrease in $\frac{V}{S}$ ratio is a crucial factor in the design of MEMS. At a certain degree of miniaturization, "surface effects" will start dominating over the "volume effects".

<u>Examples</u>

As $\frac{V}{S}$ decreases,

- "Friction" becomes larger than "Inertia".
- "Heat dissipation" ↑ ; "Heat storage" ↓ .
- "Energy coupling" is preferred over "Energy storage".

<u>Demo: Microrobot</u>

Possible projects:
- Tuning fork based "microbee"
- "Microtrimet" [solar powered].
- Android app for magnetic microbot.

[Note: Mr. S. Chourey recieved INAE 2014 award for best student project].

* Further details: W. Trimmer, Sensors & Actuators. <u>19</u> 267 (1989).
[Title: Microrobot & micromechanical systems].

Variation of physical quantities as a power of arbitrary scale variable "l".

$$V \sim l^3, \quad S \sim l^2$$

$$\frac{V}{S} \sim l^1.$$

Force	Scaling law	
Electrostatic	l^2	HW1
Magnetic	l^3	
Pressure	l^2	In class
Gravitational	l^4	
Surface tension	l^1	HW1
Muscle	l^2	

- Surface tension is annoying for non-fluidic applications.
- Electrostatic force is more interesting than magnetic force as relevant scale goes down.
- more. (HW2: Draw few more possibilities?)

Manufacturing accuracy:

A result from solid mechanics for stiffness of a cantilever beam:

$$k = \frac{Y}{4} \frac{w^3 t}{l^3} .$$

$l \rightarrow$ length
$w \rightarrow$ width
$t \rightarrow$ thickness
$Y \rightarrow$ Young's modulus.

HW3: How would you decide the tolerance on k (design!).

Brief introduction* to

Hall effect sensing ⟷ Electronic compass

&

Piezo sensing ⟷ Accelerometer

* A (not so) short introduction to MEMS
Frank Chollet, Haobing Liu