1. Stress and Strain continued

Si, Poly Si and Si nitride are brittle materials

→ little or no plastic deformation

→ catastrophic failure after elastic regime exceeded

a. Single crystal Si

$130\ GPa \le E \le 187\ GPa$

→ crystal plane dependant

$0.055 \le \nu \le 0.36$

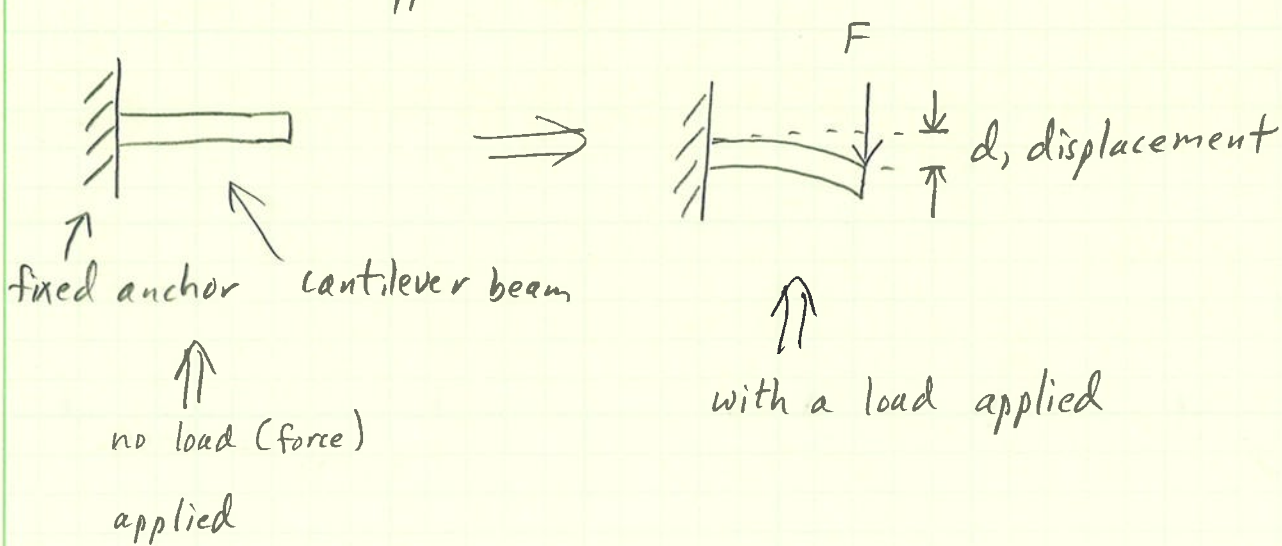
→ Compare Si + steel ($E = 200\ GPa$)

Si is 65% to 90% as strong as steel in the elastic regime

But steel deforms plastically while Si does not

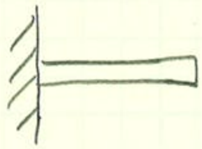
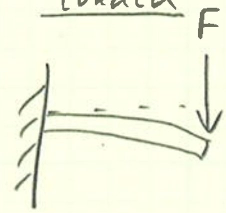
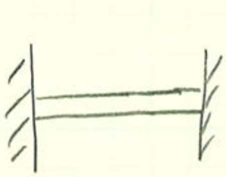
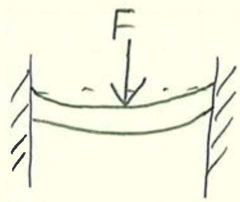
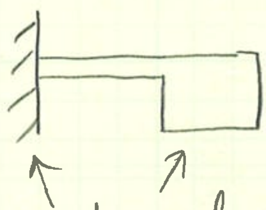
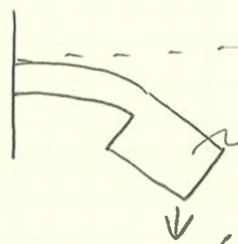
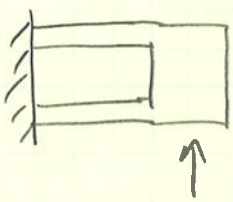
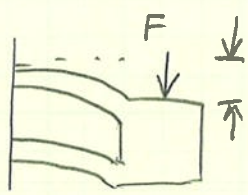
2. Beams

→ def: a structural member experiencing lateral loads and that responds by elastically deforming in proportion to the applied load



A "beam" is also called a "spring" or a "flexure"

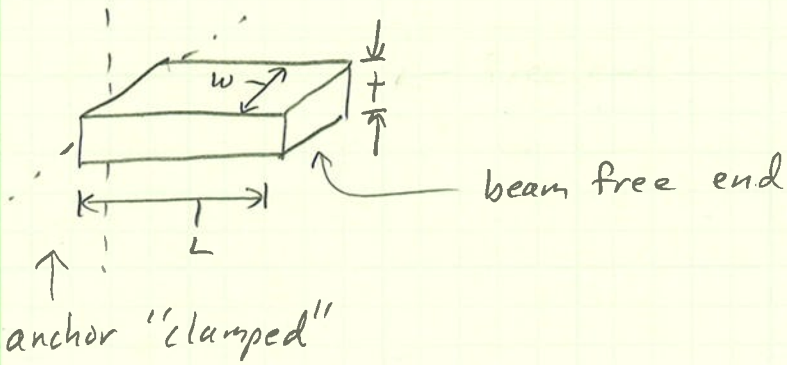
a. Some example beams encountered in MEMS:

unloaded		loaded
	simple cantilever (fixed-free)	
	bridge (fixed-fixed)	
	Cantilever with attached proof mass	 mass of proof mass = m; g (gravity); F = mg
anchor and proof mass are rigid		
	2 beams in parallel	 displacement
rigid section		

⋮

and more complicated designs

b. Simple Cantilevered beam (rectangular)



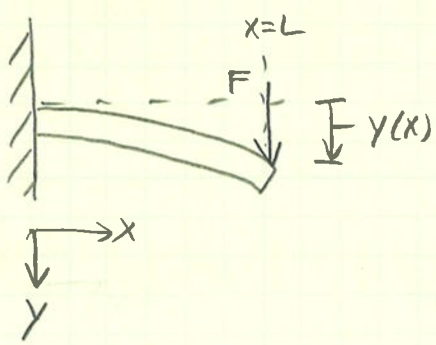
<u>Definition</u>: t → <u>thickness</u> → direction in which beam bends or deflects

L → <u>length</u> → this dimension curls as the beam deflects

w → <u>width</u> → direction perpendicular to t and L

Moment of inertia $\equiv I = I_z = \frac{wt^3}{12}$ → for a rectangular beam

<u>Deflection due to an applied force</u>



$$y(x) = \frac{Fx^3}{3EI} \quad , \quad I = \frac{wt^3}{12}$$

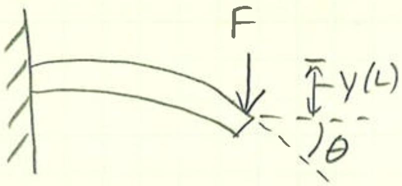
$$\therefore y(x) = \frac{4Fx^3}{Ewt^3}$$

$$\text{at } x = L \rightarrow y(L) = \frac{4FL^3}{Ewt^3}$$

<u>Define spring constant</u>, $k = \frac{\text{Applied Force}}{\text{Displacement}}$, $[k] = N/m$

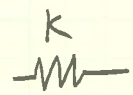
$$k = \frac{F}{y(L)} = \frac{Ewt^3}{4L^3}$$

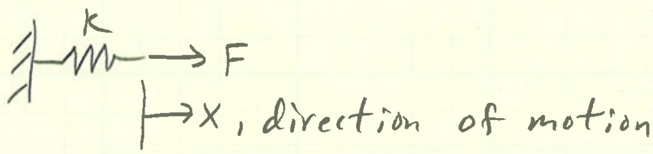
<u>Deflection Angle</u> : θ

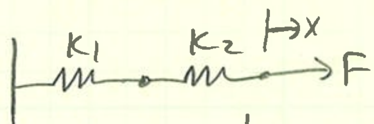


$$\theta = \frac{FL^2}{2EI} = \frac{6FL^2}{Ewt^3}$$

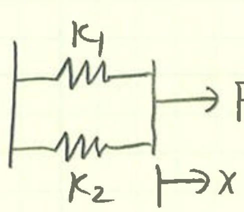
<u>note</u> : θ is the angle at the <u>end</u> of the beam <u>only</u>

schematic symbol for a spring : 

An anchored spring : 

Two springs in series : 

$$K_T = \frac{1}{\frac{1}{K_1} + \frac{1}{K_2}}$$ $\Rightarrow$ adds like capacitors

Two springs in parallel : 

, $K_T = K_1 + K_2$