

UC Berkeley

EE C247B - ME C218 Introduction to MEMS Design Spring 2017

Prof. Clark T.-C. Nguyen

Dept. of Electrical Engineering & Computer Sciences
University of California at Berkeley
Berkeley, CA 94720

Lecture Module 9: Energy Methods

EE_C245: Introduction to MEMS Design LecM 9 C. Nguyen 9/28/07 1

UC Berkeley

Lecture Outline

- Reading: Senturia, Chpt. 10
- Lecture Topics:
 - ↳ Energy Methods
 - ↳ Virtual Work
 - ↳ Energy Formulations
 - ↳ Tapered Beam Example

EE_C245: Introduction to MEMS Design LecM 9 C. Nguyen 9/28/07 2

UC Berkeley

Energy Methods

EE_C245: Introduction to MEMS Design LecM 9 C. Nguyen 9/28/07 3

UC Berkeley

More General Geometries

- Euler-Bernoulli beam theory works well for simple geometries
- But how can we handle more complicated ones?
- **Example:** tapered cantilever beam
- **Objective:** Find an expression for displacement as a function of location x under a point load F applied at the tip of the free end of a cantilever with tapered width $W(x)$

Top view of cantilever's $W(x)$


$W(x) = W\left(1 - \frac{x}{2L_c}\right)$

50% taper

$x = L_c$

F

EE_C245: Introduction to MEMS Design LecM 9 C. Nguyen 9/28/07 4

 **Solution: Use Principle of Virtual Work**

- In an energy-conserving system (i.e., elastic materials), the energy stored in a body due to the quasi-static (i.e., slow) action of surface and body forces is equal to the work done by these forces ...
- **Implication:** if we can formulate **stored energy** as a function of the deformation of a mechanical object, then we can determine how an object responds to a force by determining the shape the object must take in order to **minimize the difference U** between the stored energy and the work done by the forces:

$$U = \text{Stored Energy} - \text{Work Done}$$

- **Key idea:** we don't have to reach $U = 0$ to produce a very useful, approximate *analytical* result for load-deflection

EE_C245: Introduction to MEMS Design LecM 9 C. Nguyen 9/28/07 5