Equilibrium and Stability of Lobed Inflatable Structures

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- Equilibrium of inflatable structures
- Structural stability for inflatable structures
- Conclusions

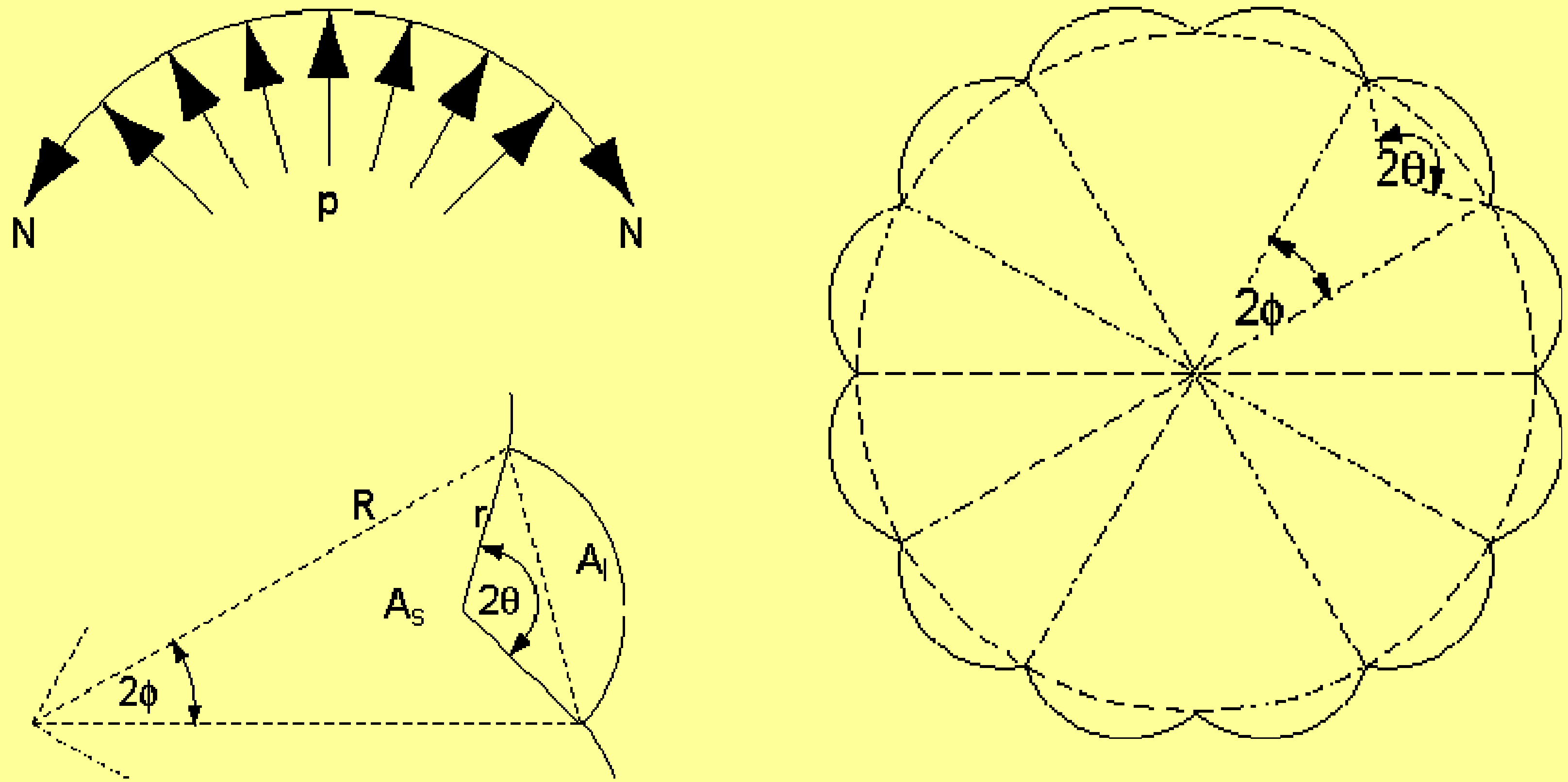
Focus of Presentation

- Structural mechanics (stability & equilibrium)
- Understanding mechanics of the problem
- Developing conceptual tools
- Simple analytical methods
- **NO FINITE ELEMENT ANALYSIS**

Area of Study

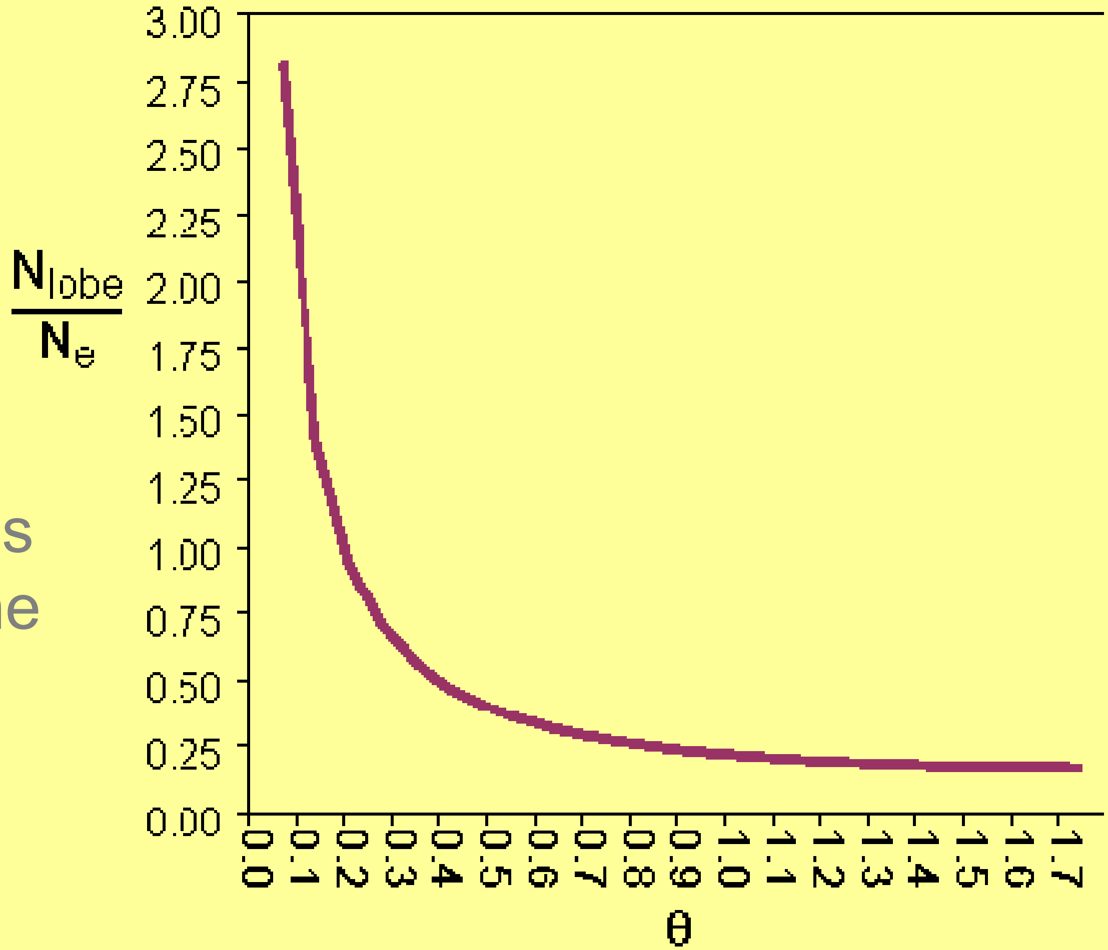
- Equilibrium and stability of inflatable membrane structure
- Membrane structure — no bending stiffness
- Negligible membrane strain
- Simplified examples

Equilibrium of 2-D Lobed Membrane Structure



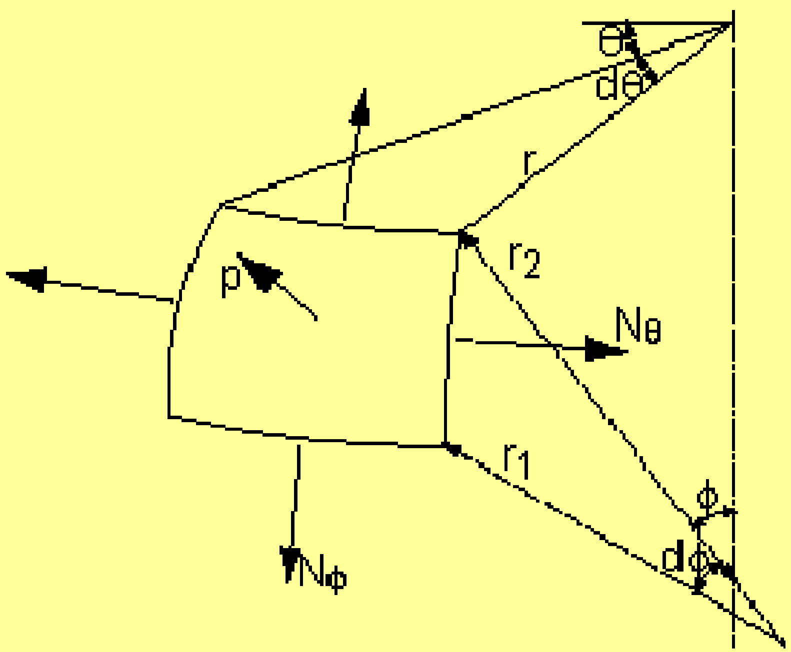
Tension in 2-D Lobed Membrane Structure

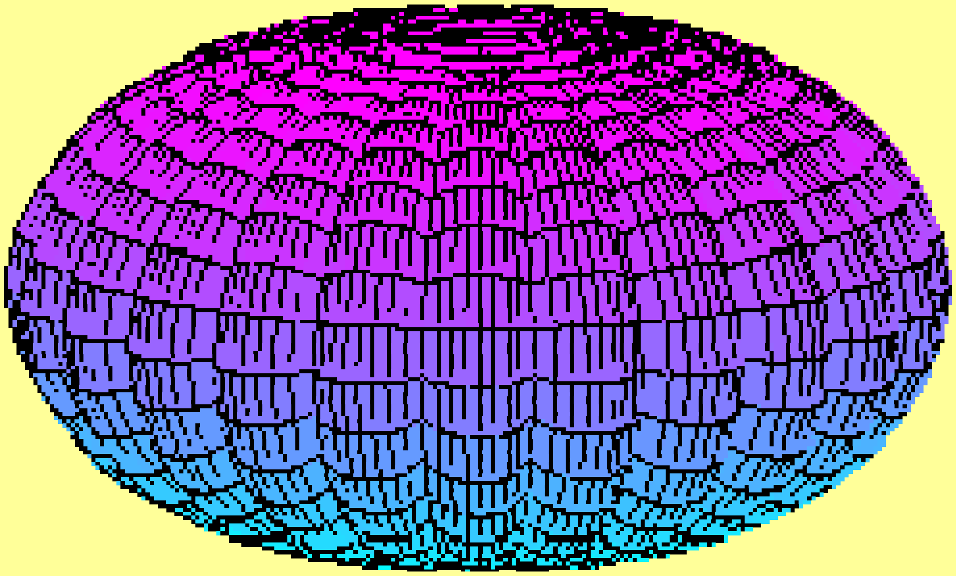
$$\frac{N_{lobe}}{N_e} = \frac{r}{R_e}$$



Where e denotes the circle with the same enclosed area

Equilibrium 3-D Lobed Membrane Structure





Structural Stability

- Definition: for a given equilibrium configuration of a structure, this configuration is structurally stable if the structure returns to the configuration after application of a small perturbation

- In practice: we can apply a small movement and the structure does not adopt a different configuration

Assumptions for Structural Stability

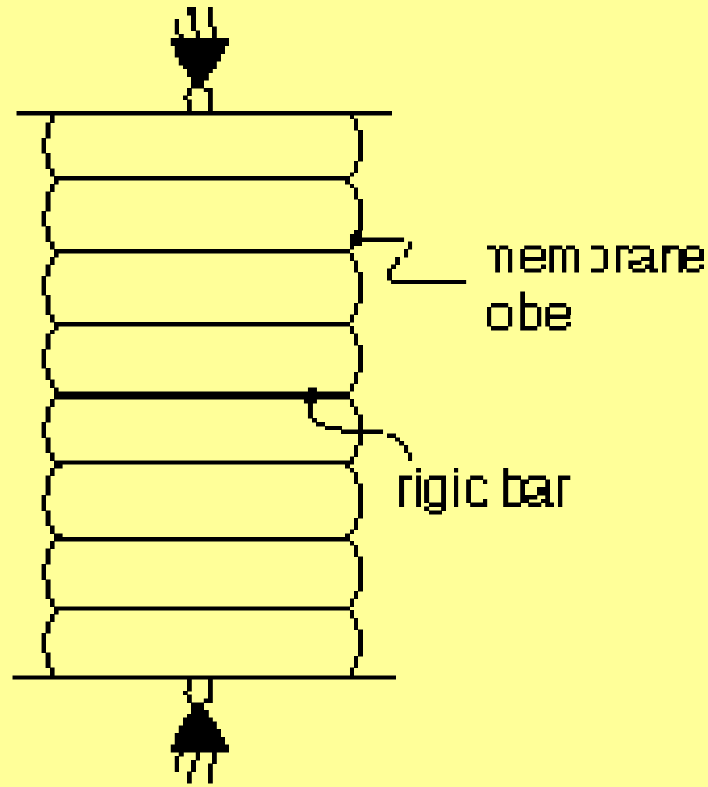
- Assume inflation gas is at constant pressure, density, temperature
- Negligible strain energy
- Neglect any higher-order effects (no postbuckling analysis)

Methods for Assessing Structural Stability

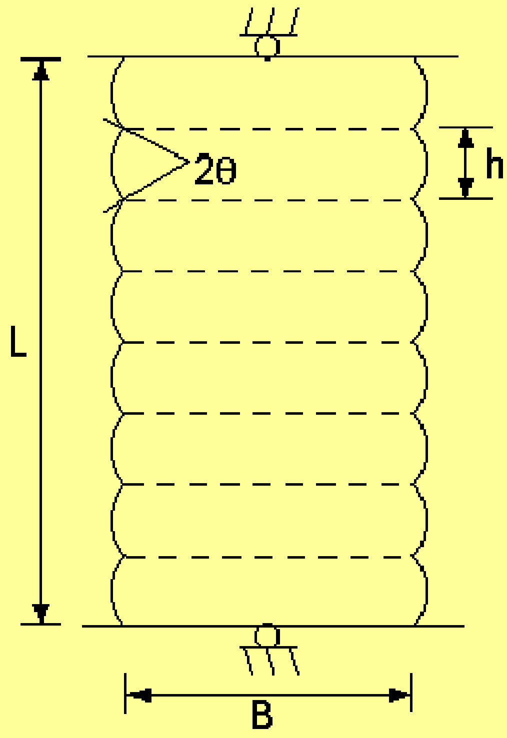
- Enclosed volume (potential energy is inversely proportional to enclosed volume)
- Analogy with conventional structure (e.g. Euler strut)
- Finite element analysis (includes strain energy). Not covered in this presentation.

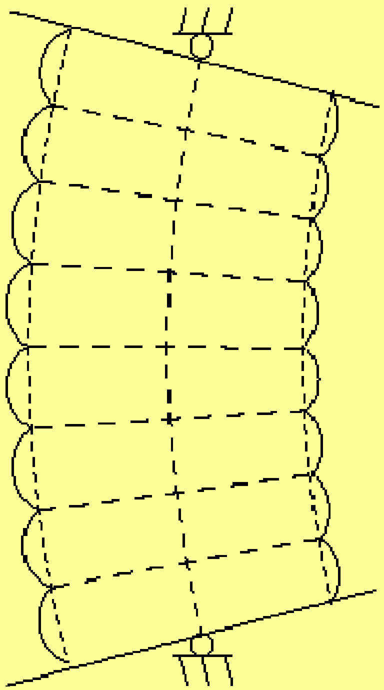
Example: Lobed Column

- Equilibrium
- Stability: volume method
- Stability: structural analogy

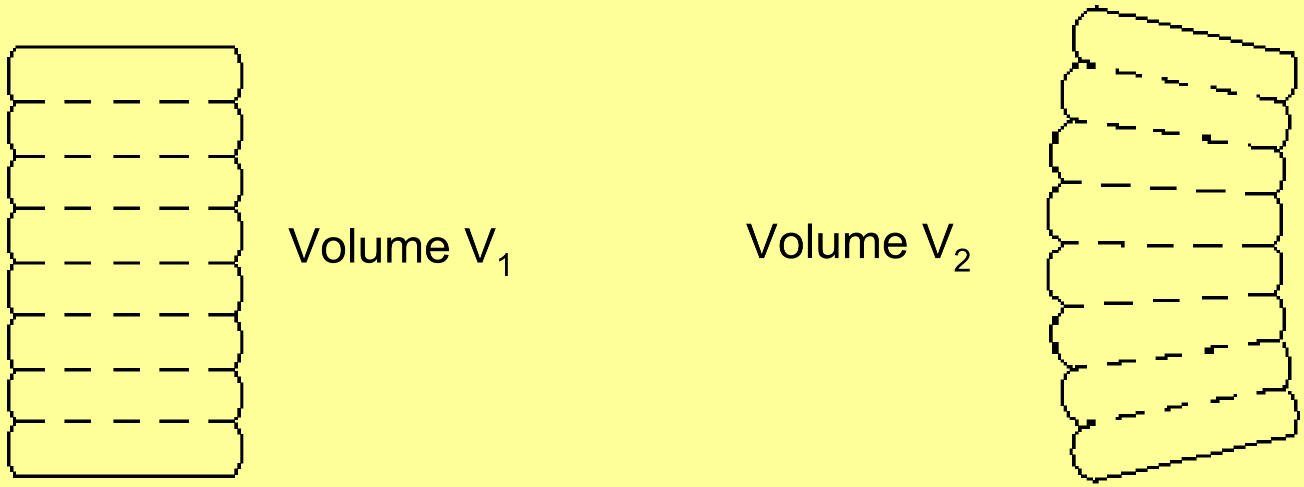


Structural Stability of Lobed Column



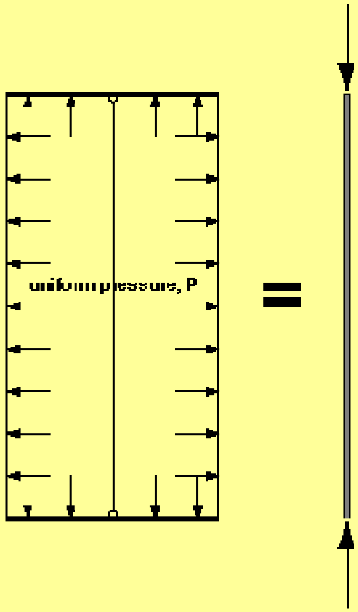


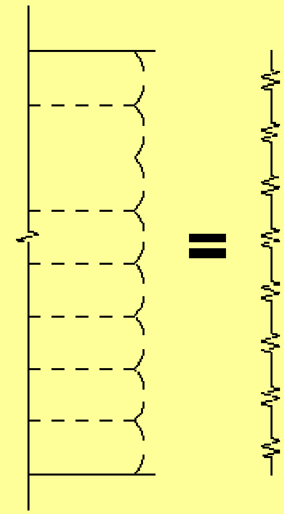
Stability: Enclosed Volume



- If $V_1 > V_2$ then stable
- Calculate area of segment (area between opposing lobes) and sum
- $V_1 = \Sigma(A_i)$ and $V_2 = \Sigma(A'_i)$

Stability: Structural Analogy





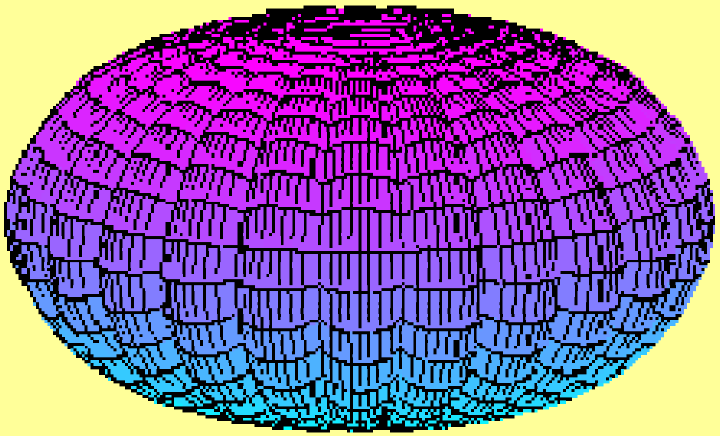
- Lobe deformation is analagous to elastic stiffness
- Calculate equivalent bending stiffness
- Calculate Euler buckling load

Example: Ideal Lobed Isotensoid

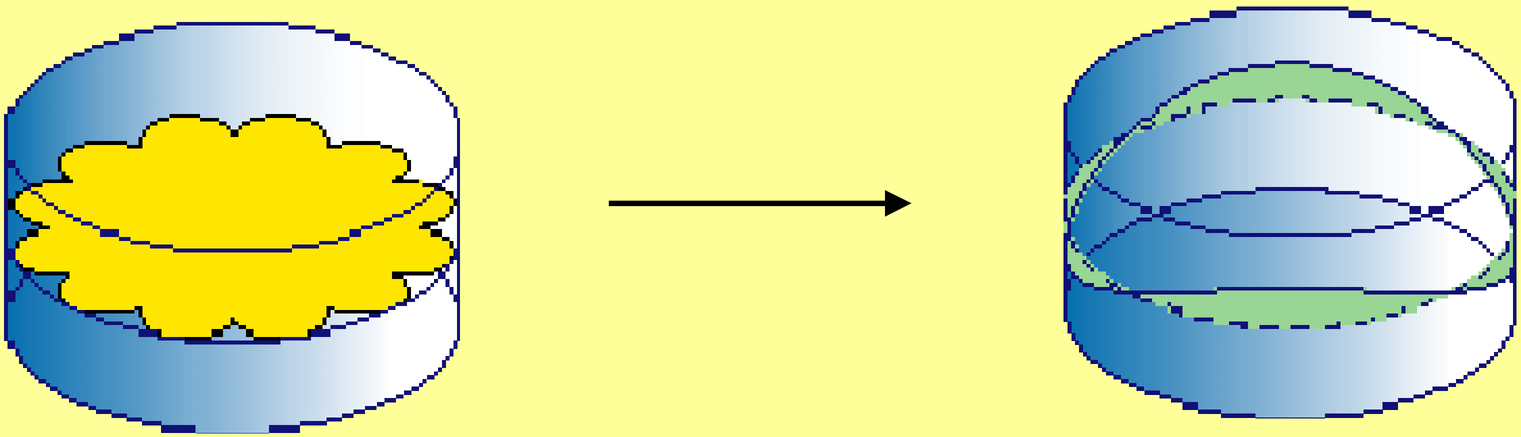
- Equilibrium: hoop stress in lobes, meridional load in lines at lobe intersection

- Stability by volume method: numerical calculation

- Stability by structural analogy: buckling of a ring

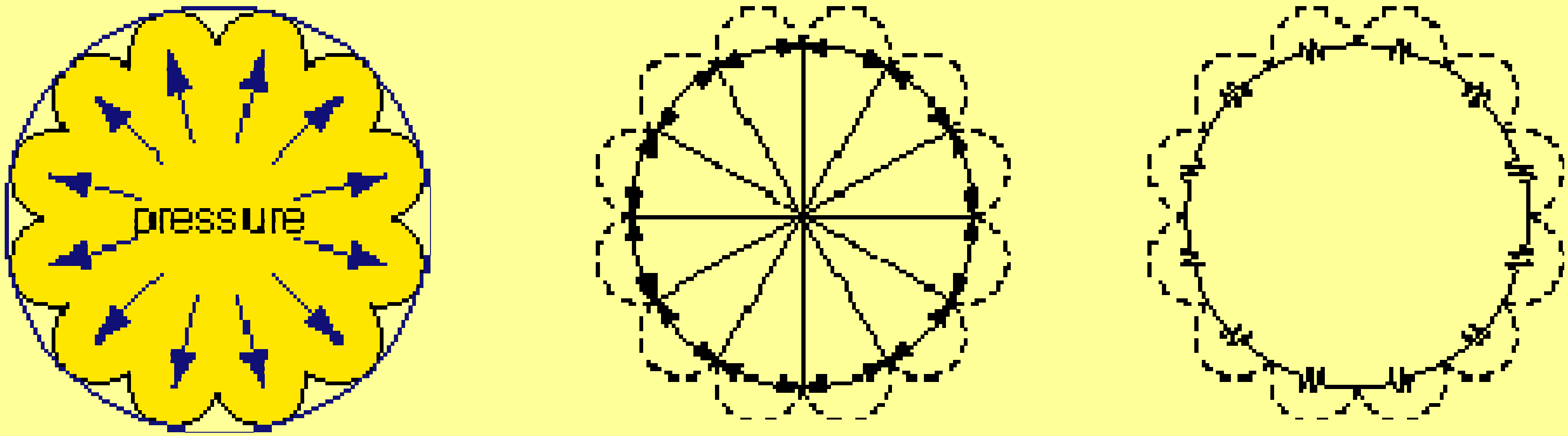


Stability: Structural Analogy



- Lobe deformation is analagous to elastic stiffness
- Calculate equivalent bending stiffness
- Calculate buckling load

Stability: Structural Analogy



- Deformation is analagous to elastic buckling of a ring
- Calculate equivalent bending stiffness
- Calculate buckling load

Conclusions

- Formulate the problem.
- Study the mechanics.
- Use simple tools to understand behaviour …
- … and only then move to detailed analysis with FEA and other powerful tools