16.00 Structures Lecture

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Lecture outline

- Motivation
- What are structures?
- The great principles

First your thoughts…

- What is a structure?
  - Natural examples
  - Human-built examples
- What are some primary characteristics of structures?
  - Support or carry loads (forces)
  - Must not fail or collapse during regular use or extreme circumstances (strength, stability)
  - Components must maintain the correct relative positions during use (stable)

Your thoughts…(cont.)

- What are some structural design issues?
  - Weight to be supported
  - Size and weight of the structure
  - Materials selection
  - Strength, stability, durability
  - Safety
  - Aesthetics
  - Manufacturability
  - Cost

What is structural engineering?

- "Application of statics and solid mechanics to devise structures with sufficient strength, stiffness, and longevity to fulfill a mission without failure with a minimum amount of weight." – *course text*

Why study structures?

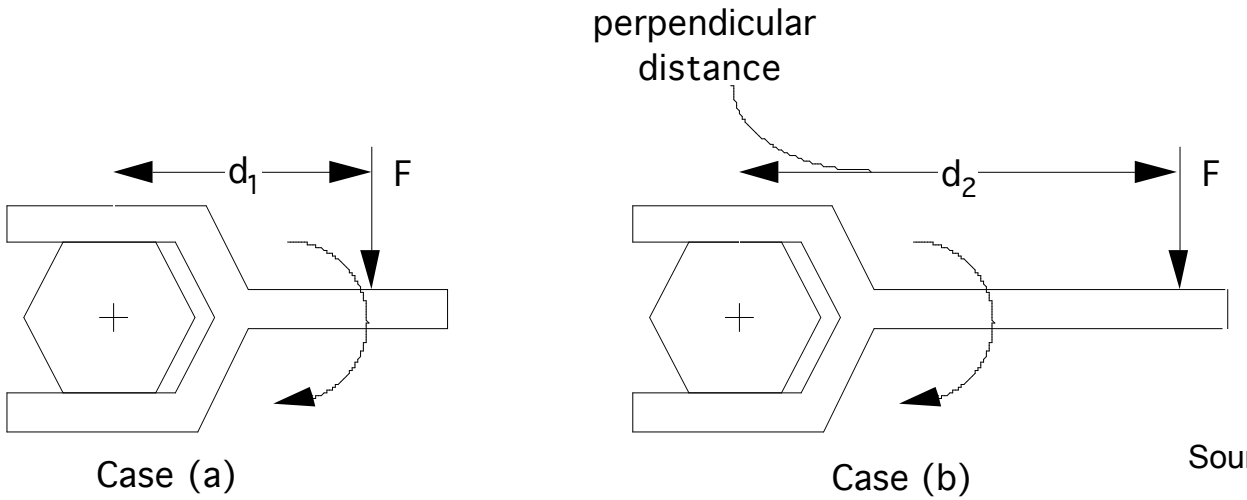
- (run video clip of Galloping Gerdie)
- http://content.lib.washington.edu/farquharsonweb/

Three principles

- Equilibrium – *relationship among forces*
- Compatibility – *relationship among displacements*
- Constitutive relations – *relationships between forces and displacements*

Forces and moments

- What two characteristics describe a force?
  - Magnitude
  - Direction
- Moment = torque = rotation = turning effect
  - force x perpendicular distance to the pivot



Source: DTEACh, UT Austin

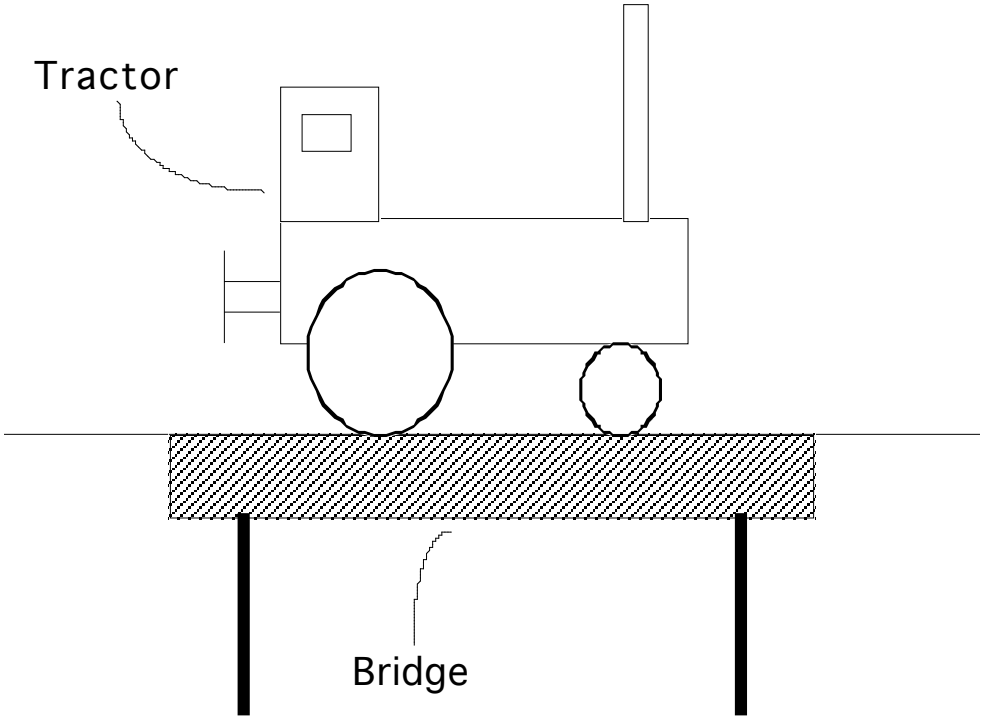
Static equilibrium

- Condition that must be satisfied:

$$\sum \mathbf{F} = 0 \text{ and } \sum \mathbf{M} = 0$$

- Free body diagrams (FBDs)
  - Translation of a real-world static equilibrium into a drawing illustrating forces on bodies using vectors
  - Let's practice…

Tractor on a bridge



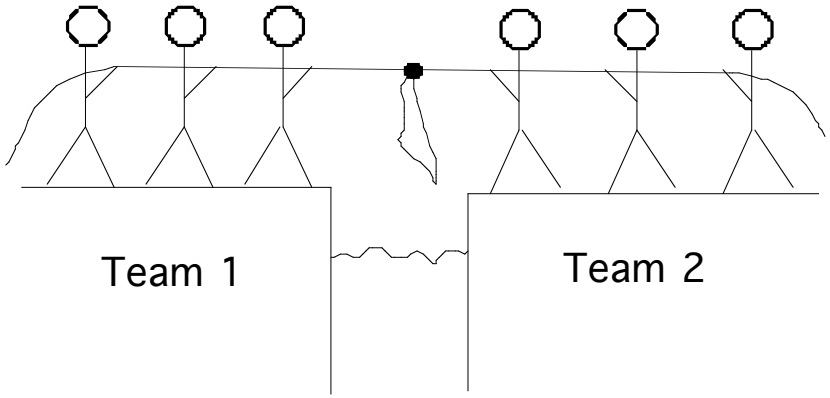
Source: DTEACh, UT Austin

Steps in constructing an FBD:

1. Identify object to be isolated
2. Make an approximate sketch of object removed from surroundings
3. Draw vector approximations of external forces and body forces
4. Choose a coordinate system
5. Visually check sketch for equilibrium

Second example: Your turn

Source: Bluewater Tug-of-War Club

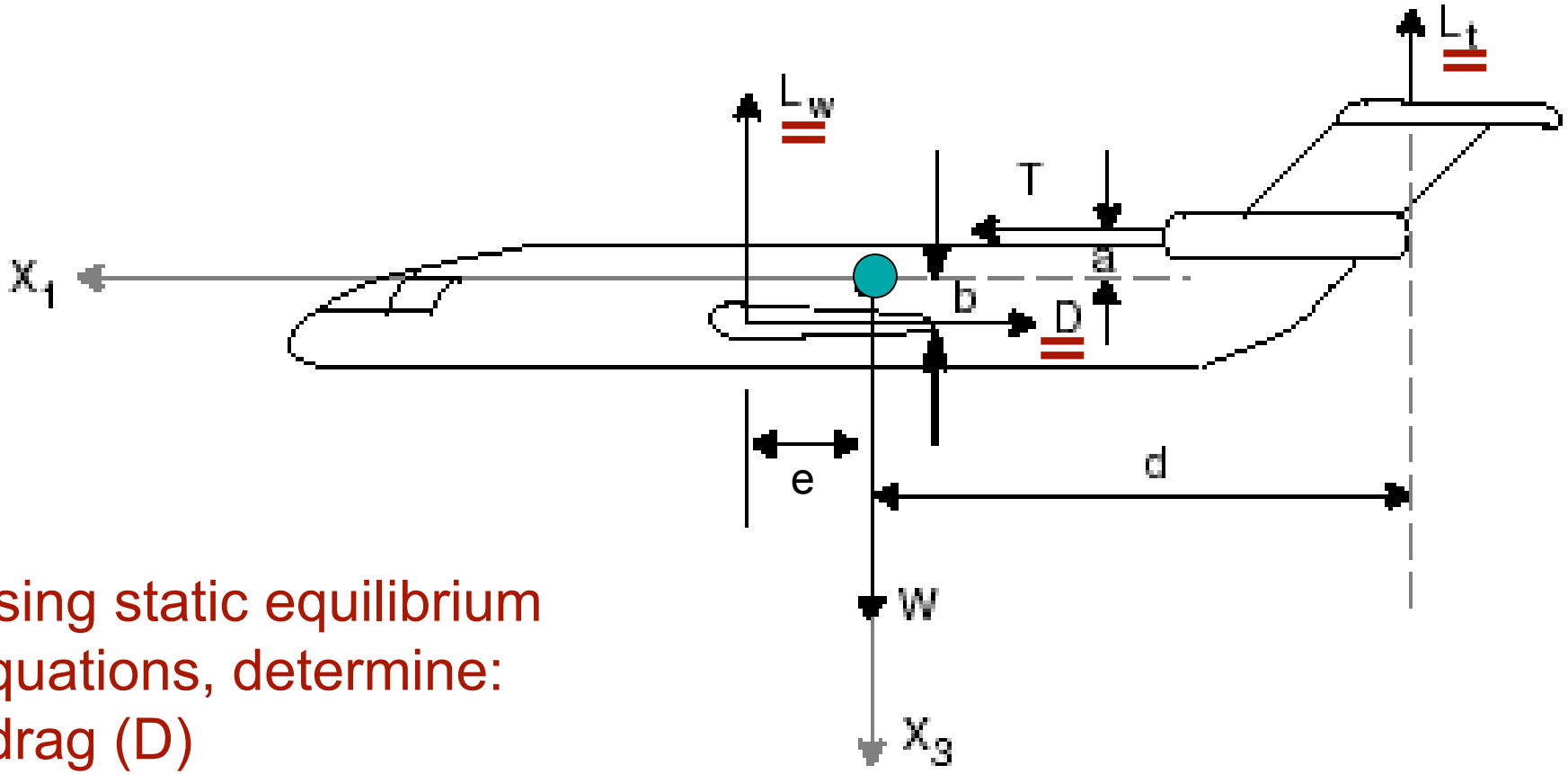


Source: DTEACh, UT Austin

The FBD?

The equations of equilibrium?

An aircraft example



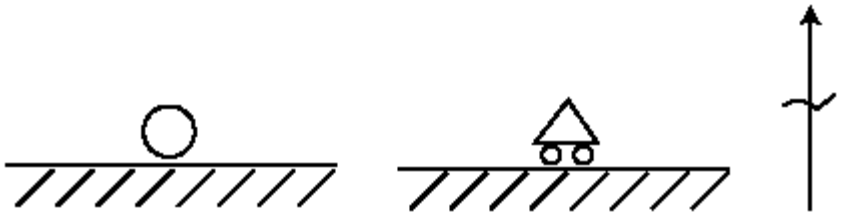
Using static equilibrium equations, determine:

- drag (D)
- lift produced by the wing (L_w)
- lift produced by the tail (L_t)

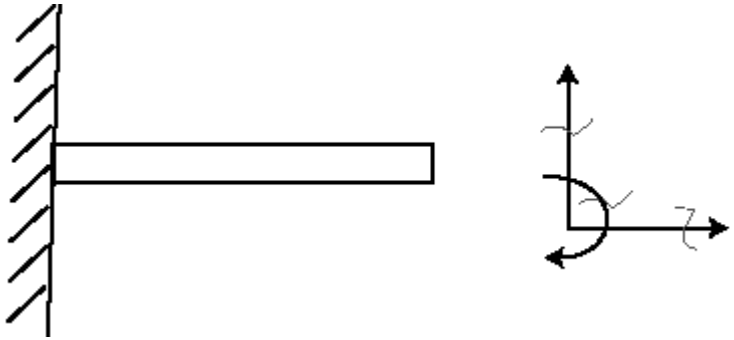
Source: D. Newman, *Interactive Aerospace Engineering and Design*

Supports and reaction forces

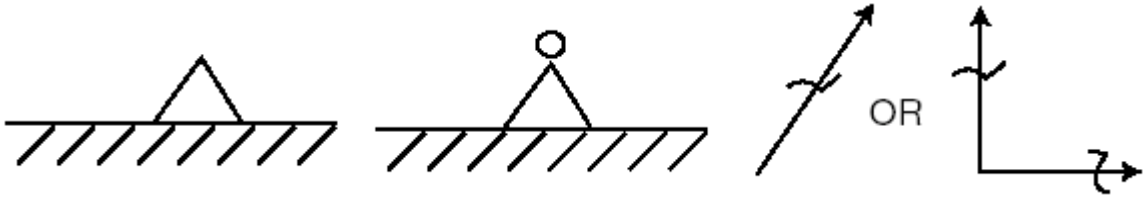
Roller support: produces one reaction force, or allows rotation and translation in one direction



Clamp support: produces two reaction forces and a reaction moment, or allows no rotation or translation



Pin support: produces two reaction forces, or allows rotation but no translation



Source: D. Newman, *Interactive Aerospace Engineering and Design*

Truss analysis

- Determines forces in each member of a truss structure

Source: J. Carr, Tallahassee Community College

Static determinacy

- 3 classes of structures
  - *Statically determinate*: structure is exactly restrained. # reactions = # equations
  - *Not statically determine*: structure not sufficiently restrained and will move! # reactions > # equations
  - *Statically indeterminate*: structure is over-restrained. # reactions < # equations

Can use Method of Joints for analysis of statically determinate trusses

Assumptions in method of joints

- Truss members (bars) are straight and massless
- Bars are assumed rigid
- Bars are connected at their ends through joints
- External loads are applied only at joints
- Supports (pins, rollers) are frictionless
- Loads in a bar have lines of action collinear with the bar axis; force is uniaxial and can be compressive or tensile

Steps in method of joints

- Draw FBDs – one with supports, one replaced with reaction forces
- Write the equations of equilibrium, find determinacy
- Solve equilibrium equations, redraw FBD labeling quantities
- Determine the internal loads, label on diagram
- Check your solution to see that forces and moments sum to zero