ARCHITECTURAL STRUCTURES I:
STATICS AND STRENGTH OF MATERIALS
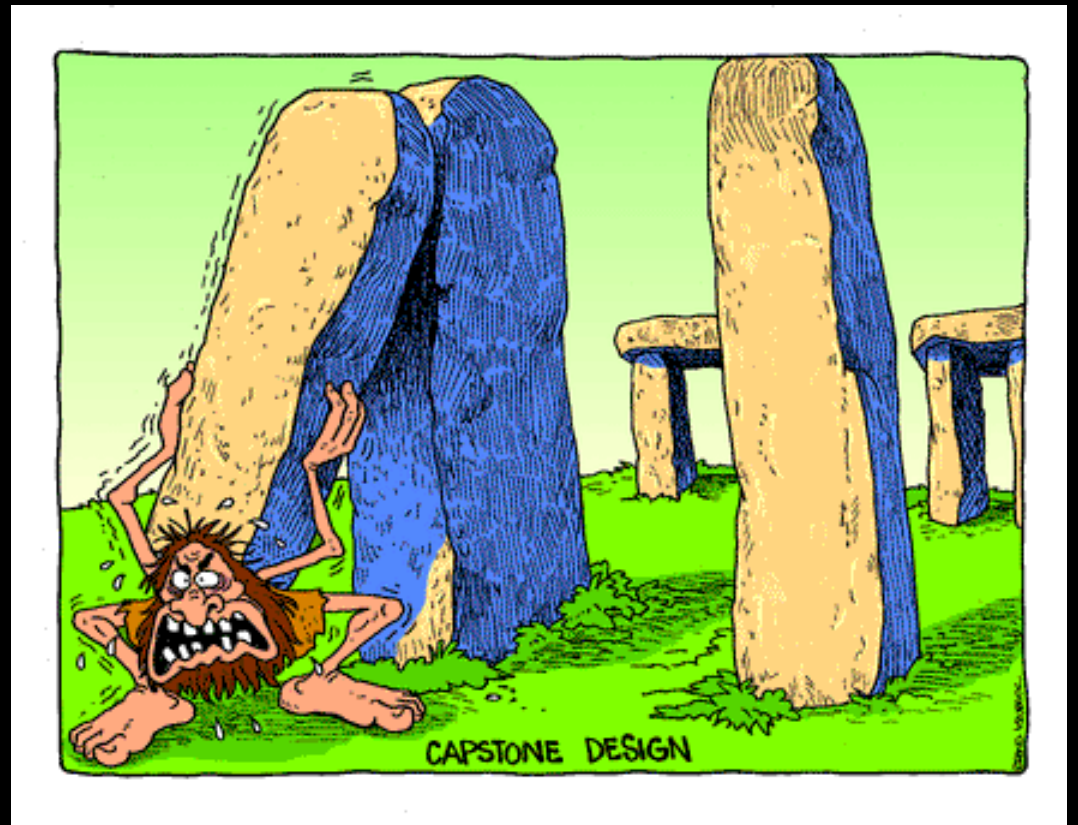
ENDS 231

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SPRING 2007

.lecture
five

rigid body equilibrium
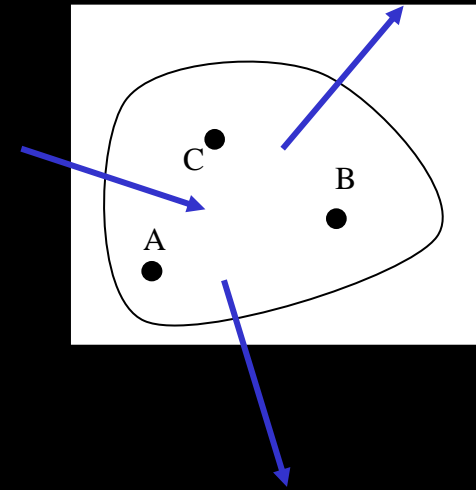

CAPSTONE DESIGN

Equilibrium

- *rigid body*
  - *doesn't deform*
  - *coplanar force systems*
- *static:*

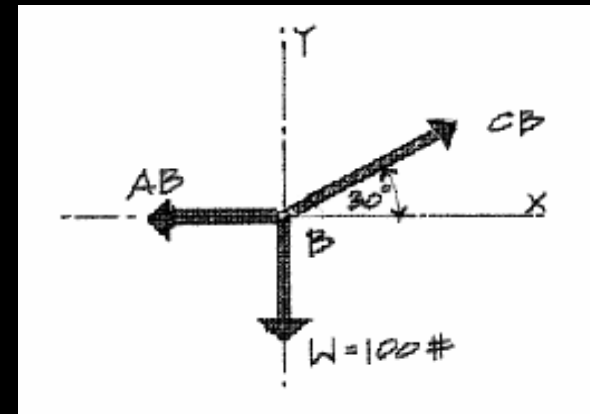$$R_x = \sum F_x = 0$$

$$R_y = \sum F_y = 0$$

$$M = \sum M = 0$$

Free Body Diagram

- ## FBD (sketch)

- ## tool to see all forces on a body or a point including

  - ### external forces

  - ### weights

  - ### force reactions

  - ### external moments

  - ### moment reactions

  - ### internal forces

(Example 1)

Free Body Diagram

- ## *determine body*
- ## *FREE it from:*
  - ### *– ground*
  - ### *– supports & connections*
- ## *draw all external forces acting ON the body*
  - ### *– reactions*
  - ### *– applied forces*
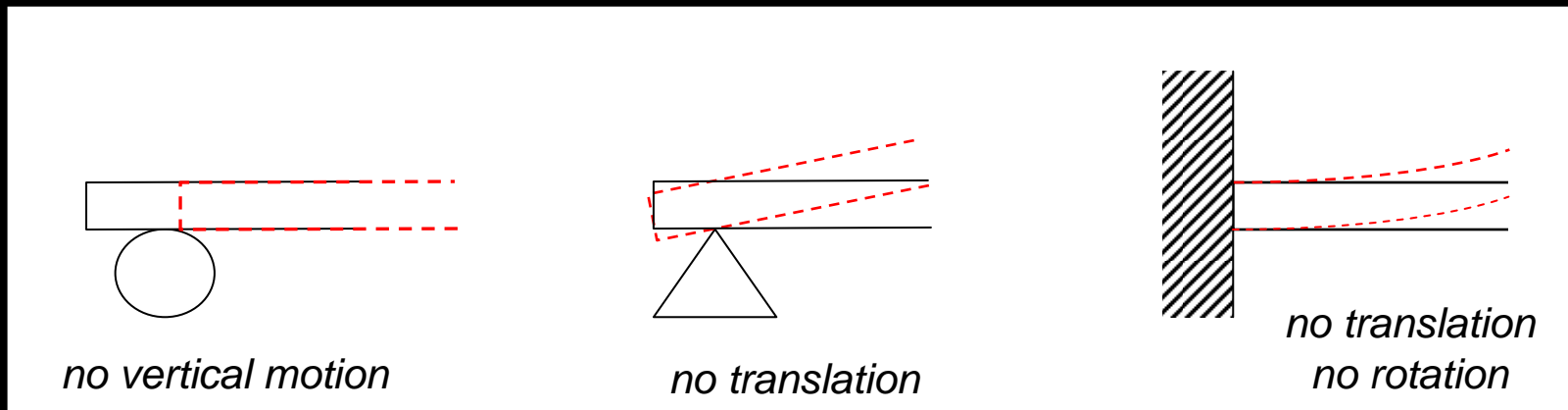 - ### *– gravity*

100 lb

+ weight

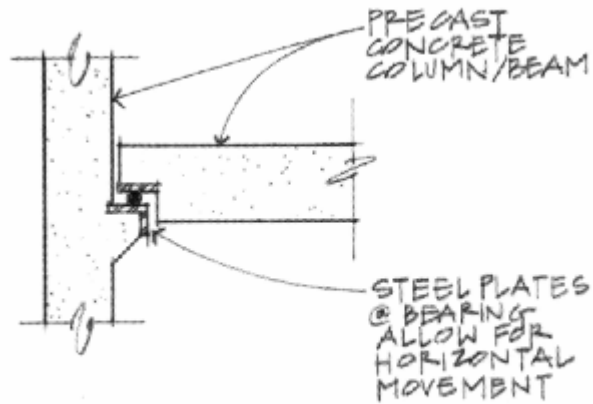100 lb

m·g
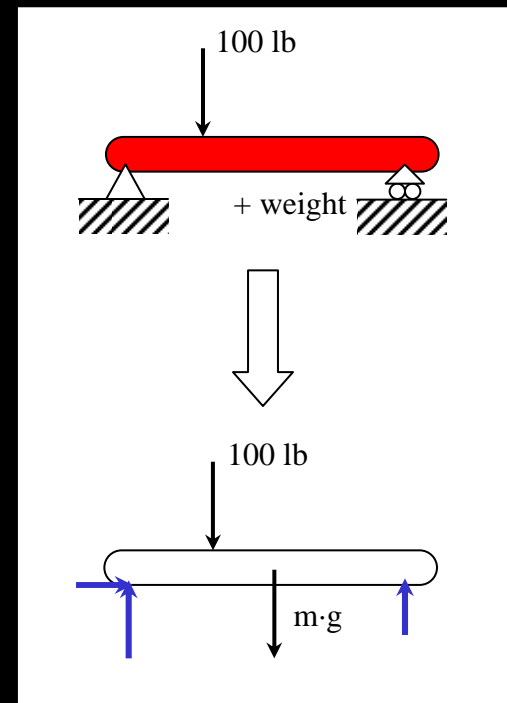
Free Body Diagram

- **include relevant geometry**
  - *guidelines helpful to see moment arms*
- **name and/or color the unknown**
  - *forces*
  - *moments*
  - *angles*
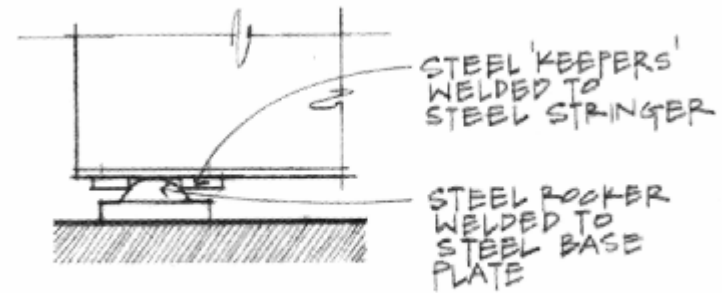- **solve up to 3 equations**

Reactions

- *result of applying force*

- *unknown size*

- *connection or support type*
  - *known direction*
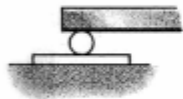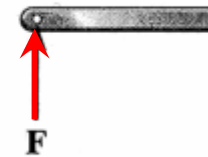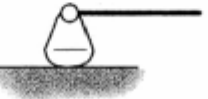 - *related to motion prevented*

no vertical motion   *no translation*   *no translation*
                                                          no rotation

Supports and Connections

PRECAST CONCRETE COLUMN/BEAM

STEEL PLATES @ BEARING ALLOW FOR HORIZONTAL MOVEMENT

Roller

STEEL 'KEEPERS' WELDED TO STEEL STRINGER

STEEL ROCKER WELDED TO STEEL BASE PLATE

Rocker

rollers

rocker

F

Supports and Connections

STEEL COLUMN/
BEAM
CONNECTION,
BOLTED.

Pin

smooth pin or hinge

F_y

F_x

CAST-IN-PLACE
CONCRETE
COLUMN/BEAM
CONNECTION.

NOTE:
OVERLAPPING
STEEL
REINFORCEMENT
MAKES ASSEMBLY
MONOLITHIC.

fixed support

F_y

M

F_x

Fixed
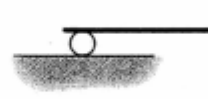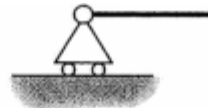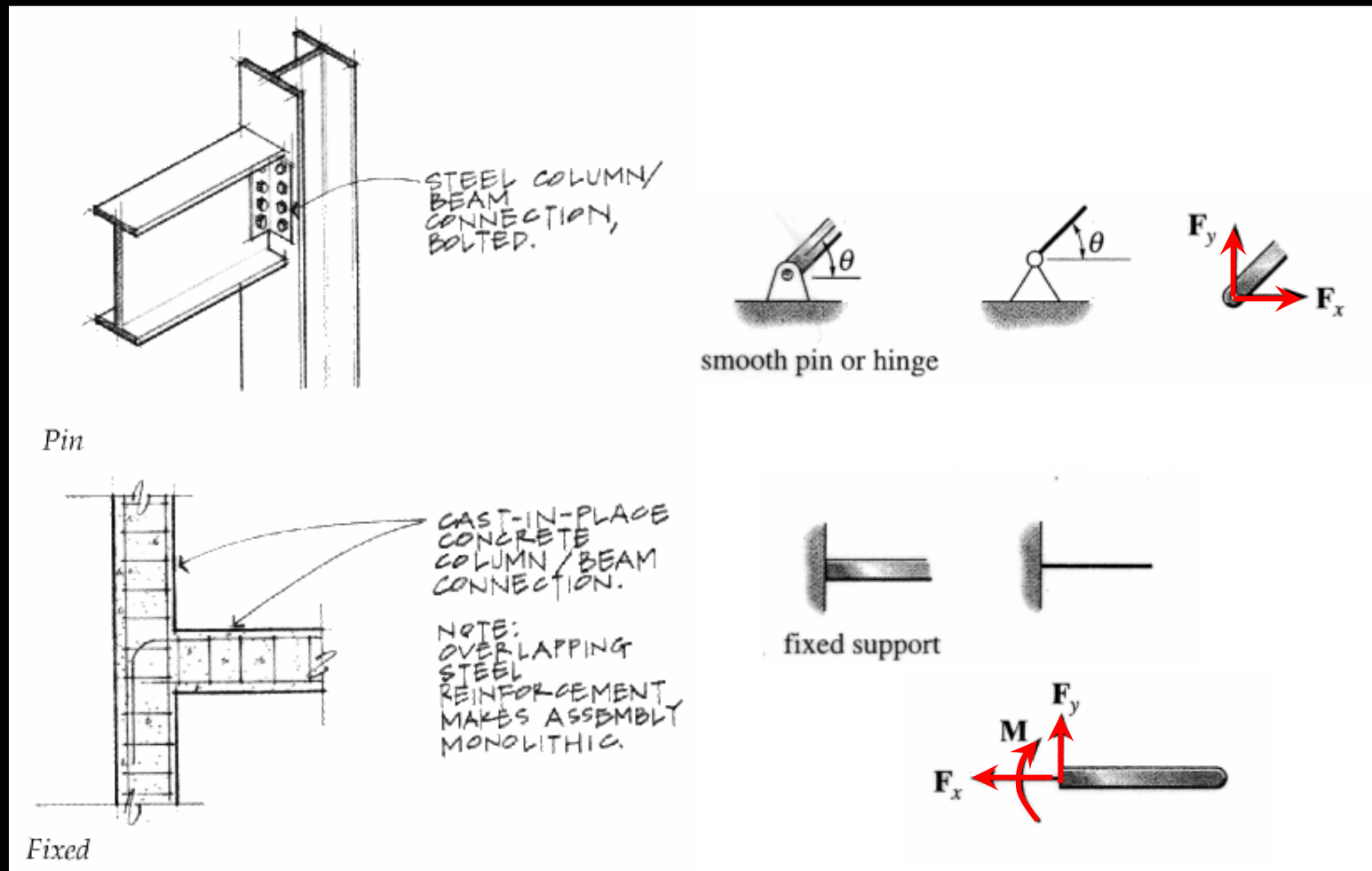
FBD Example

- *500 lb known*

- *pin – A_x, A_y*

- *smooth surface – B at 4:3*

- *3 equations*

- *sum moments at*
  - *A?*
  - *B?   (B_x)*
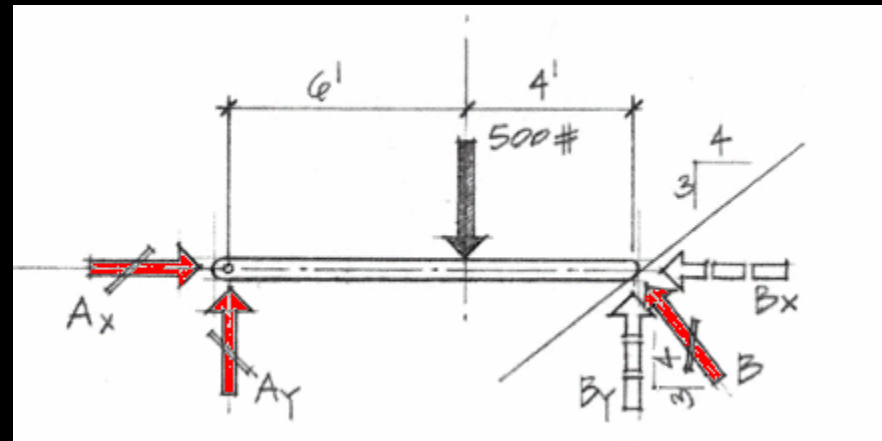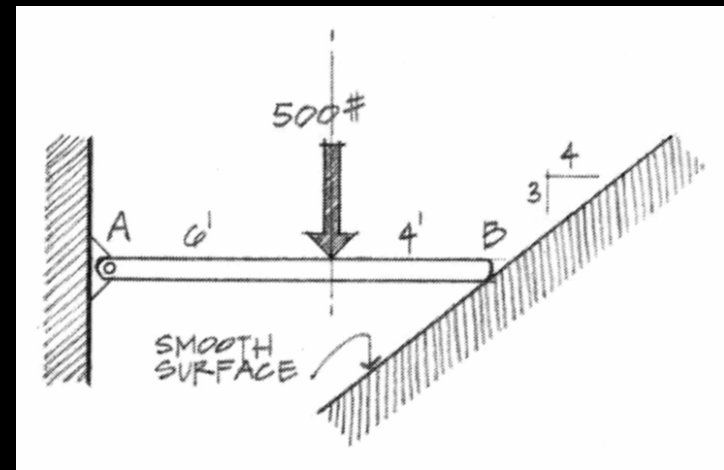
Moment Equations

- *sum moments at intersection where the most forces intersect*

- *multiple moment equations may not be useful*

- *combos:*

$$\sum F_x = 0$$

$$\sum F_y = 0$$

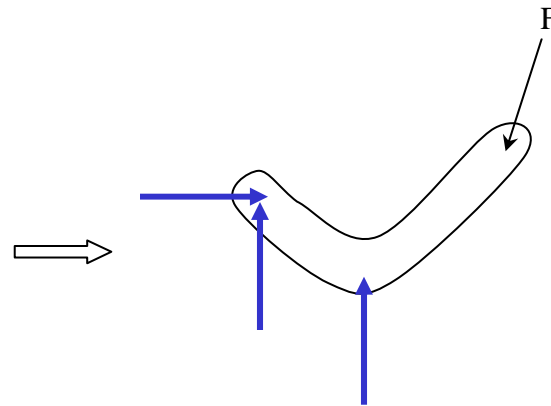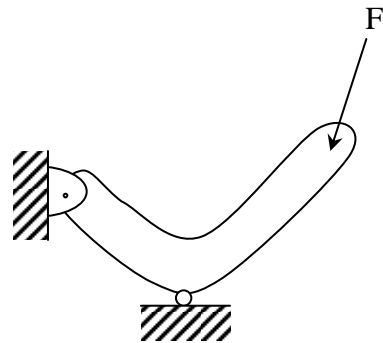$$\sum M_1 = 0$$

$$\sum F = 0$$

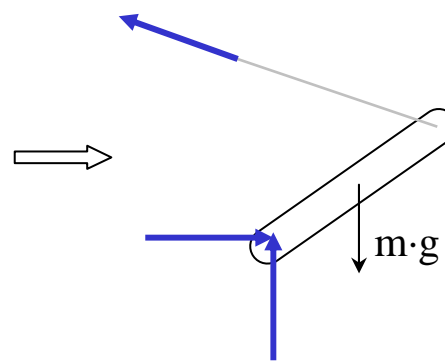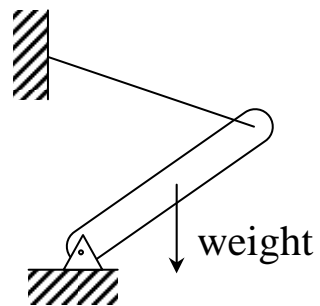$$\sum M_1 = 0$$

$$\sum M_2 = 0$$

$$\sum M_1 = 0$$

$$\sum M_2 = 0$$

$$\sum M_3 = 0$$

Recognizing Reactions

Recognizing Reactions

$\underline{3}$
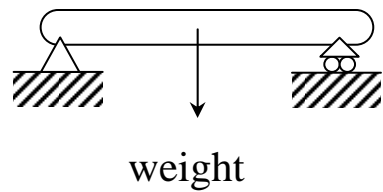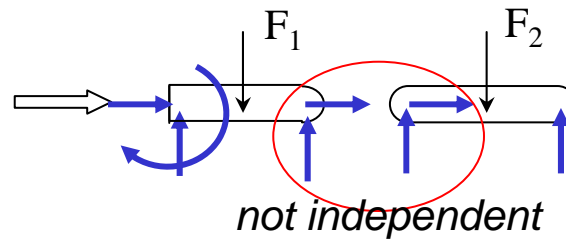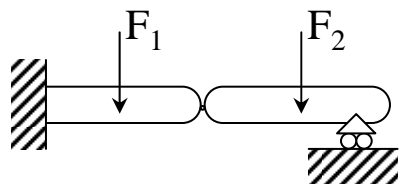unknowns

weight

F_1 F_2

F_1 F_2

$\underline{6}$
unknowns for
2 bodies

not independent

m·g

weight

m·g
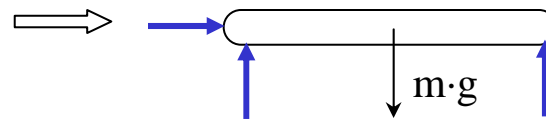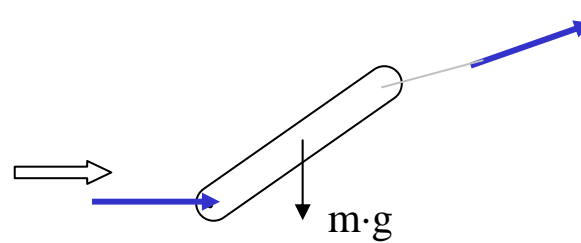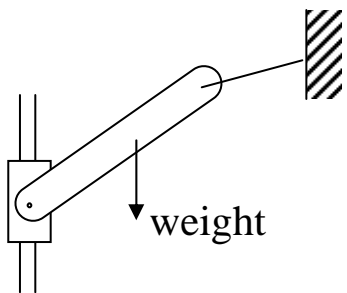
$\underline{2}$
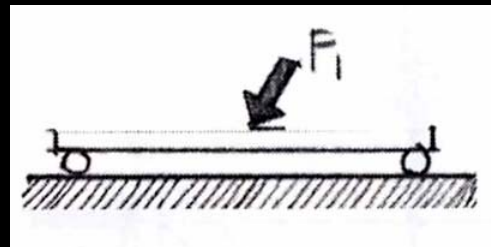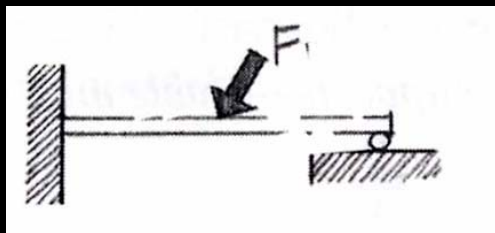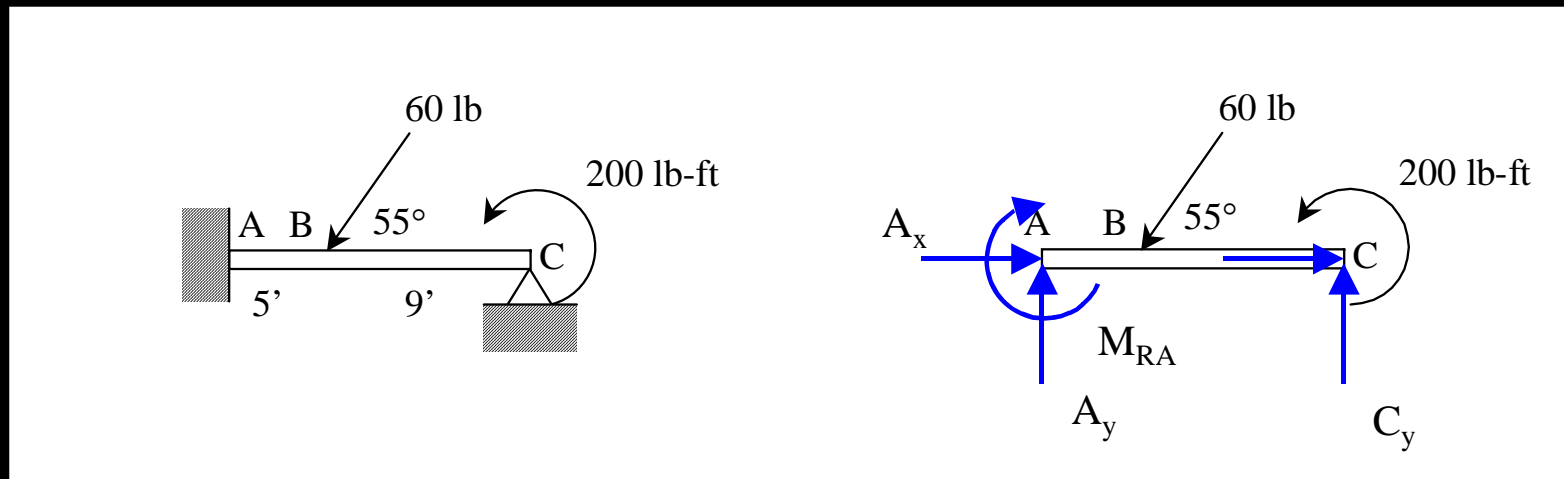unknowns

Constraints

- *completely constrained*
  - *doesn't move*
  - *may not be statically determinate*
- *improperly or partially constrained*
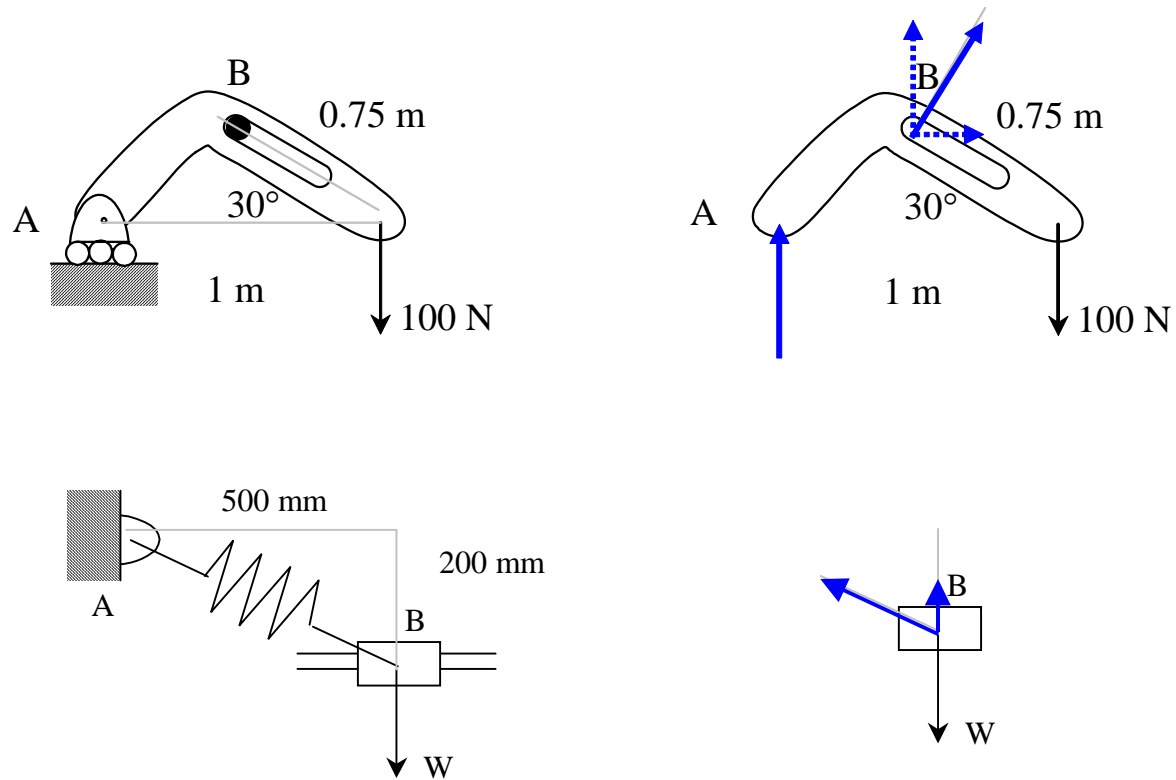 - *has $\leq$ unknowns*
  - *can't solve*
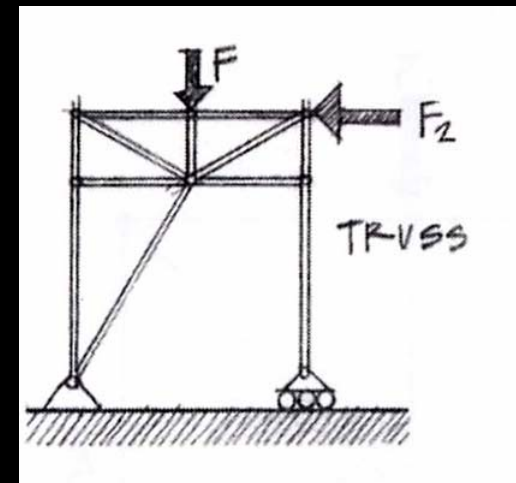
Constraints

- *overconstrained*
  - *won't move*
  - *can't be solved with statics*
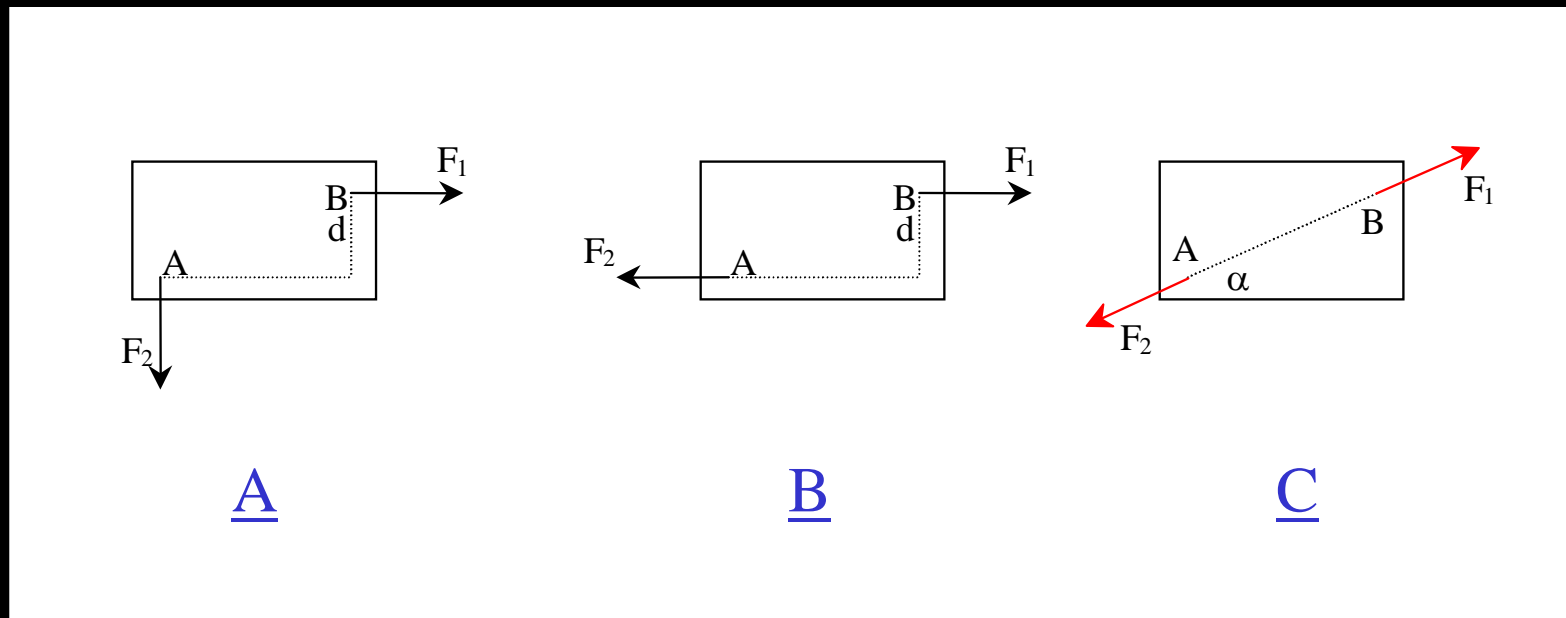 - *statically indeterminate to n^{th} degree*

Partial Constraints

Two Force Rigid Bodies
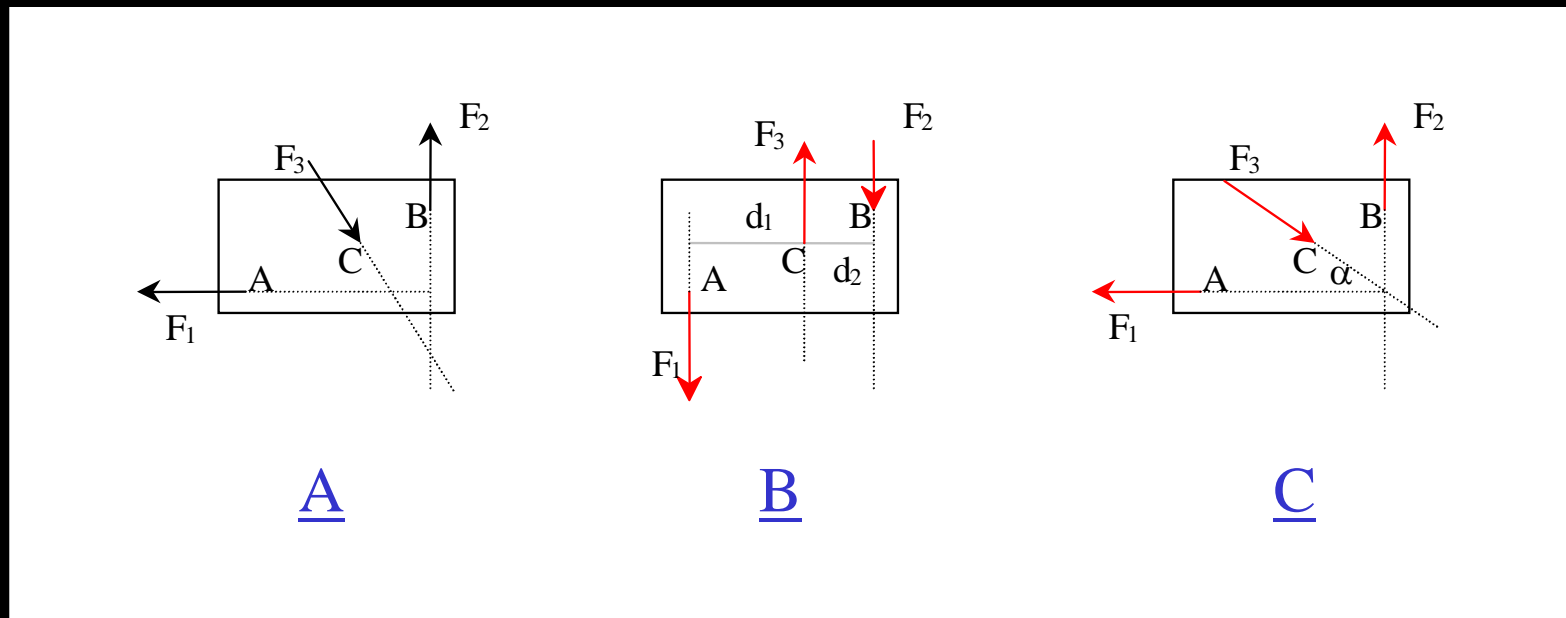
- *equilibrium:*

  – *forces in line, equal and opposite*

A   B   C

Three Force Rigid Bodies

- *equilibrium:*

  – *concurrent or parallel forces*

A   B   C

Cable Reactions

- *equilibrium:*
  - *– more reactions (4) than equations*
  - *– but, we have slope relationships*
  - *– x component the same everywhere*