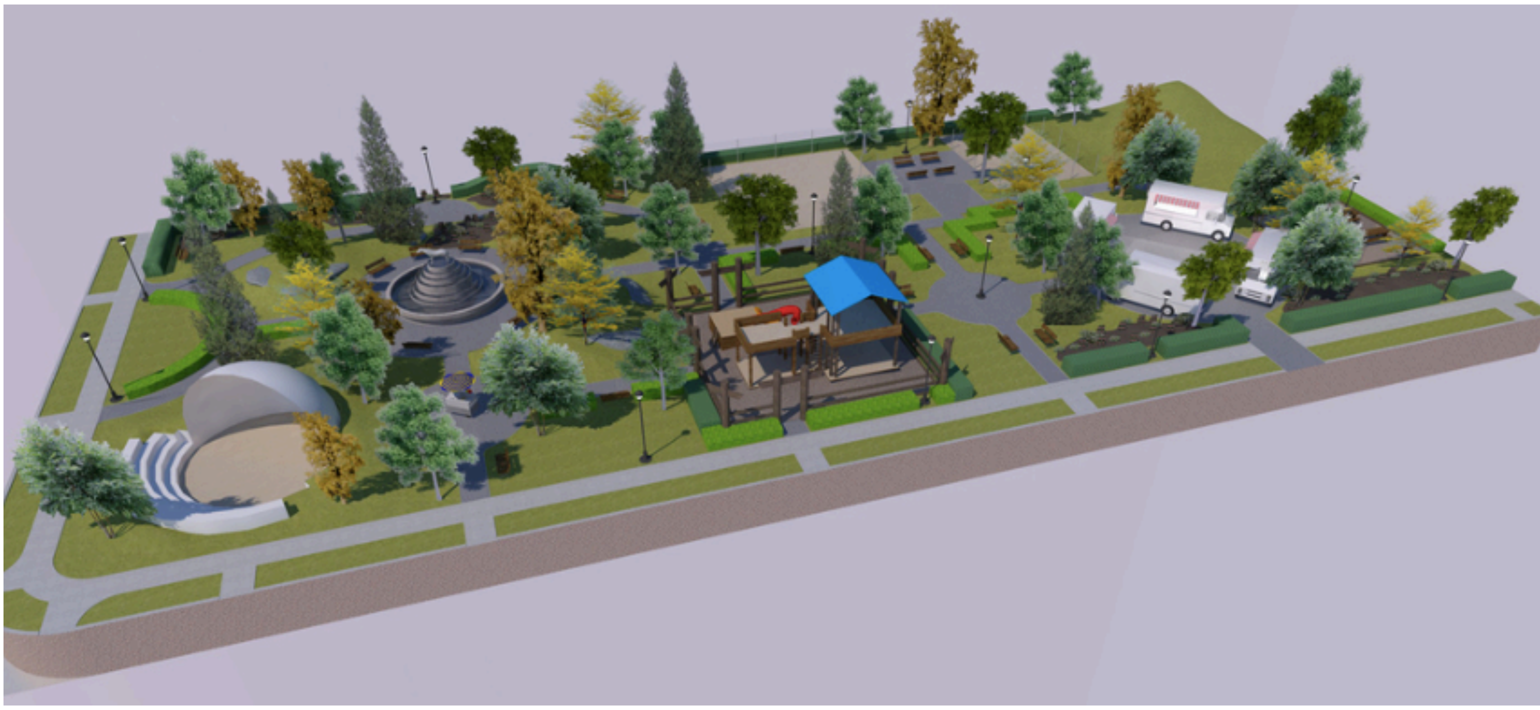


PAWNEE COMMONS

LAB:
12:50-2:40

Lot 48

Names: 1) Aziz Alwatban 2) Coby Fan
3) Andrew Logue
4) Hayden Gebhardt

OMEP Learning Objectives:

1) Model real life systems as free body diagrams
2) Select support conditions to mimic real life constraints
3) Determine reasonable minimum and maximum external forces based off of the design environment (design requirement development)
4) Calculate moments using force vectors, unit vectors, and position vectors.
5) Set up equilibrium equations for open ended free body diagrams
6) Apply distributed loads and point loads to open ended free body diagrams
7) Distinguish between statically indeterminate and determinate problems
8) Perform constructive design/analysis reviews with student colleagues

Note: You do not have to write your group's responses in this PDF.

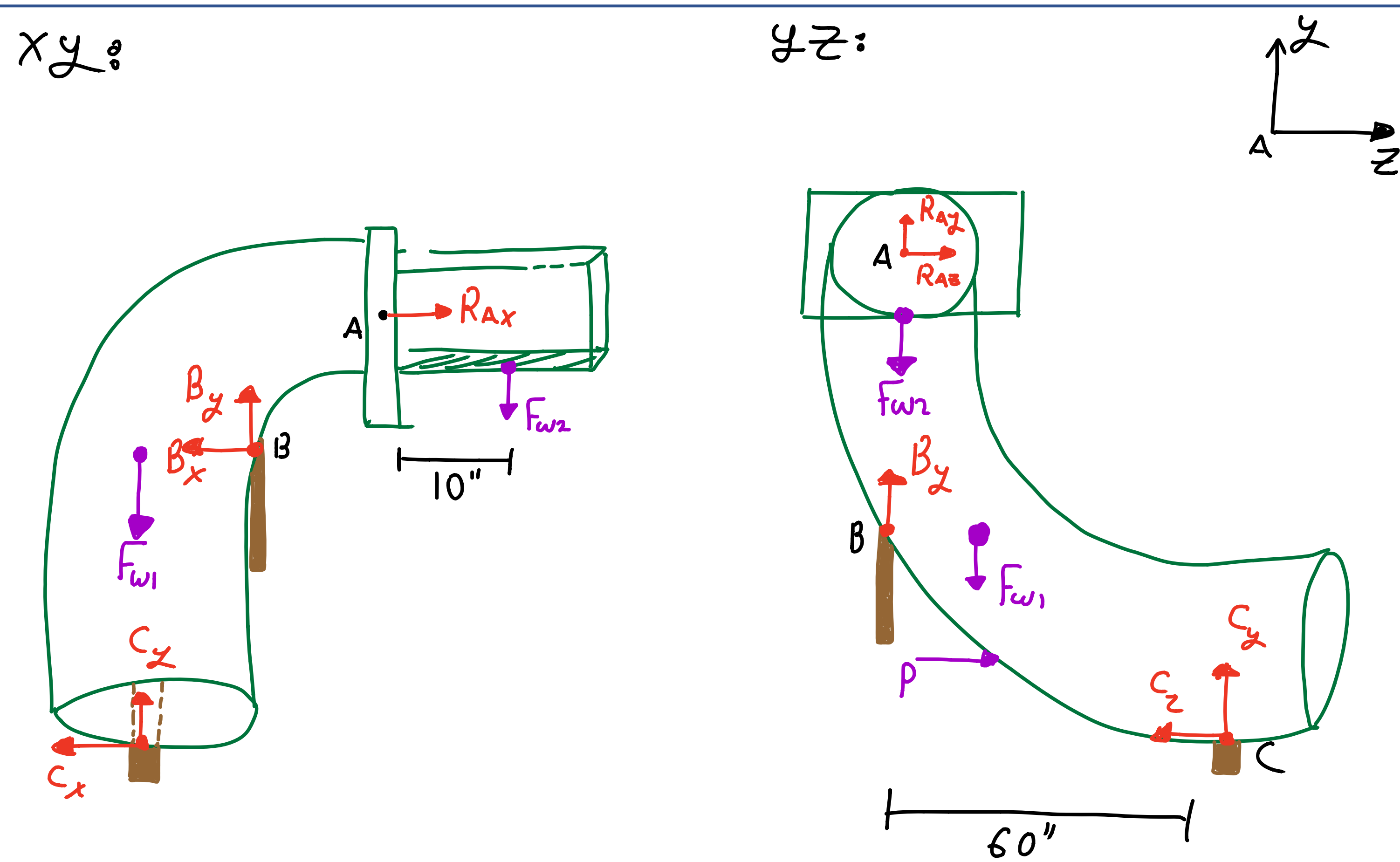
OMEP 2: Lot 48

Discuss each team members' approach to modeling the slide and defining a worst case static loading scenario. Pick one group member's loading scenario and free-body diagram to use for the rest of the group assignment.

1) Worst case loading scenario (from individual assignment, Problem 7):

Two kids in the slide each weight 88 lb in the center of the slide pointing downward.
Also, there is a kid pushing the slide along the positive z direction with a magnitude of P = 40 lbf
And lastly, a parent is standing in the slide cage weighing Fw2 = 200 lbf

2) Free-body diagram, with external loads included (from individual assignment, Problem 8):



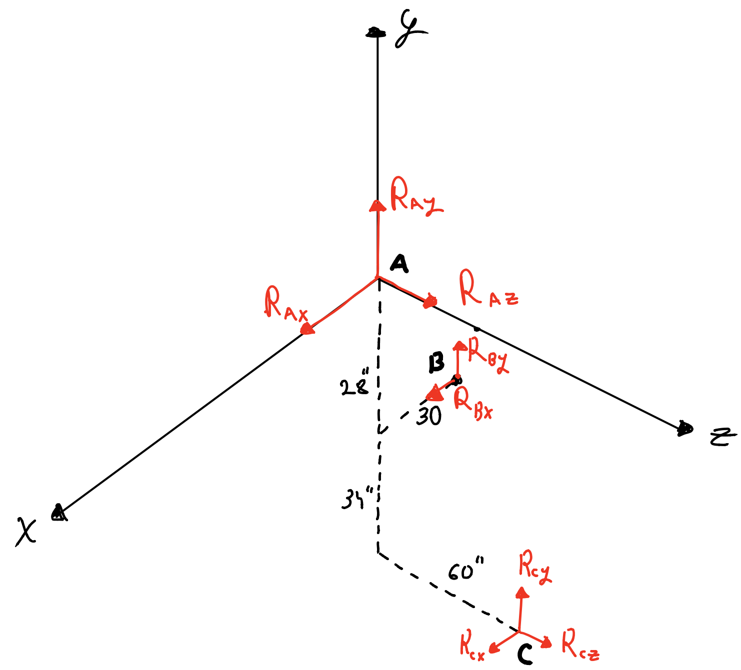
OMEP 2: Lot 48

3) Write out each support's position vector relative to the origin.
4) Write out each support's reaction force vector in terms of arbitrary values (e.g., R_{AX}, R_{AY}, etc.)
5) Write out each support's reaction moment vector in terms of arbitrary values (e.g., M_{AX}, M_{AY}, etc.)

$$\bar{r}_A = 0$$

$$\bar{r}_B = -28\,\hat{j} - 30\,\hat{i}$$

$$\bar{r}_C = -62\,\hat{j} + 60\,\hat{k}$$



$$\bar{R}_A = R_{Ax}\,\hat{i} + R_{Ay}\,\hat{j} + R_{Az}\,\hat{k}$$

$$\bar{R}_B = R_{Bx}\,\hat{i} + R_{By}\,\hat{j}$$

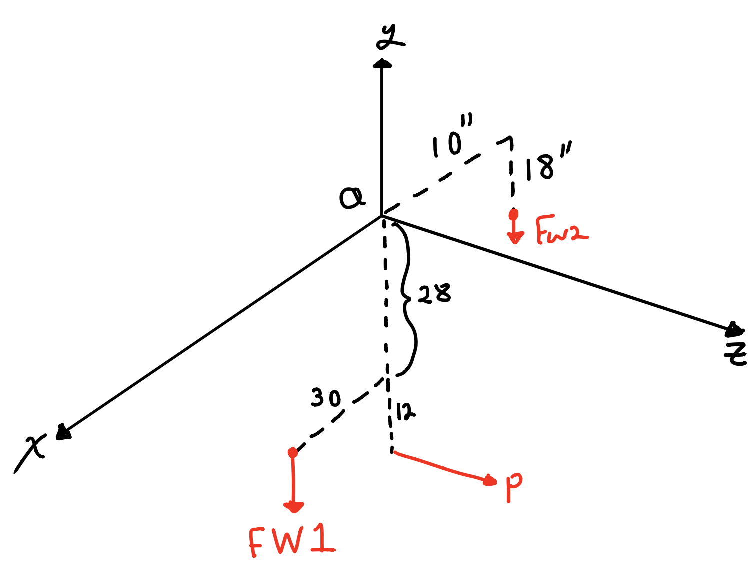
$$\bar{R}_C = R_{cx}\,\hat{i} + R_{cy}\,\hat{j} + R_{cz}\,\hat{k}$$

6) Write out the position vectors of where each external point load is applied relative to the origin.

$$\bar{r}_{w1} = -28\,\hat{j} + 30\,\hat{i}$$

$$\bar{r}_{w2} = -10\,\hat{i} - 18\,\hat{j}$$

$$\bar{r}_p = -40\,\hat{j}$$



7) Write out the equilibrium equations for the free body diagram. Use cross products, position vectors, and force vectors. Ensure your final equations are boxed and fully simplified- you must COMPLETE the cross product. Show work. More space is available on the next page.

① $\sum M_x = 0: \hat{i}\cdot(\bar{r}_p \times \bar{P}) + \hat{i}\cdot(\bar{r}_c \times \bar{R}_c) = 0$

$\hat{i}\cdot\left[(-40\hat{j}) \times (p\hat{k})\right] + \hat{i}\cdot(-62\hat{j} + 60\hat{k}) \times (R_{cx}\hat{i} + R_{cy}\hat{j} + R_{cz}\hat{k})$

$= \hat{i}\cdot(-40\hat{i}) + \hat{i}\cdot(-62R_{cz}\hat{i} - 60R_{cy}\hat{i} + 60\cancel{R_{cx}}\hat{j} + 62\cancel{R_{cx}}\hat{k})$

$= \boxed{-40 - 62R_{cz} - 60R_{cy} = 0}$

② $\sum M_y = 0: \hat{j}\cdot(\bar{r}_B \times \bar{R}_B) + \hat{j}\cdot(\bar{r}_c \times \bar{R}_c) = 0$

$\hat{j}\cdot(\bar{r}_B \times \bar{R}_B) = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -30 & -28 & 0 \\ R_{Bx} & R_{By} & 0 \end{vmatrix} = \hat{j}\cdot(0) = 0$

$\hat{j}\cdot(\bar{r}_c \times \bar{R}_c) = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & -62 & 60 \\ R_{cx} & R_{cy} & R_{cz} \end{vmatrix} = \hat{j}\cdot(+\hat{j}\,60R_{cx}) = 60R_{cx}$

$\therefore \quad 60R_{cx} = 0 \longrightarrow \boxed{R_{cx} = 0}$

③ $\sum M_z = 0: \hat{k}\cdot(\bar{r}_B \times \bar{R}_B) + \hat{k}\cdot(\bar{r}_c \times \bar{R}_c)$

$+ \hat{k}\cdot(\bar{r}_{w1} \times \bar{F}_{w1}) + \hat{k}\cdot(\bar{r}_{w2} \times \bar{F}_{w2}) = 0$

7 cont.) Write out the equilibrium equations for the free body diagram. Use cross products, position vectors, and force vectors. Ensure your final equations are boxed and fully simplified- you must COMPLETE the cross product. Show work.

- $$\hat{k}\cdot(\bar{r}_B \times \bar{R}_B) = \hat{k}\cdot\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -30 & -28 & 0 \\ R_{Bx} & R_{By} & 0 \end{vmatrix} = \hat{k}\cdot(-30R_{By} + 28R_{Bx})\,\hat{k}$$
$$= -30\,R_{By} + 28\,R_{Bx}$$

- $$\hat{k}\cdot(\bar{r}_c \times \bar{R}_c) = \hat{k}\cdot\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & -62 & 60 \\ R_{cx} & R_{cy} & R_{cz} \end{vmatrix} = \hat{k}\cdot(62R_{cx}\,\hat{k}) = 62\,R_{cx}$$

- $$\hat{k}\cdot(\bar{r}_{w1} \times \bar{F}_{w1}) = \hat{k}\cdot\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 30 & -28 & 0 \\ 0 & F_{w1} & 0 \end{vmatrix} = \hat{k}\cdot(30\,F_{w1}\,\hat{k}) = 30\,F_{w1}$$

- $$\hat{k}\cdot(\bar{r}_{w2} \times \bar{F}_{w2}) = \hat{k}\cdot\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -10 & -18 & 0 \\ 0 & F_{w2} & 0 \end{vmatrix} = \hat{k}\cdot(-10\,F_{w2}\,\hat{k}) = -10\,F_{w2}$$

$$\therefore \sum M_z = 0: \boxed{-30\,R_{By} + 28\,R_{Bx} + 62\,R_{cx} + 30\,F_{w1} - 10\,F_{w2}}$$

$$\sum F_x = 0: \quad R_{cx} + R_{Ax} = 0 \longrightarrow \boxed{R_{cx} = -R_{Ax}}$$

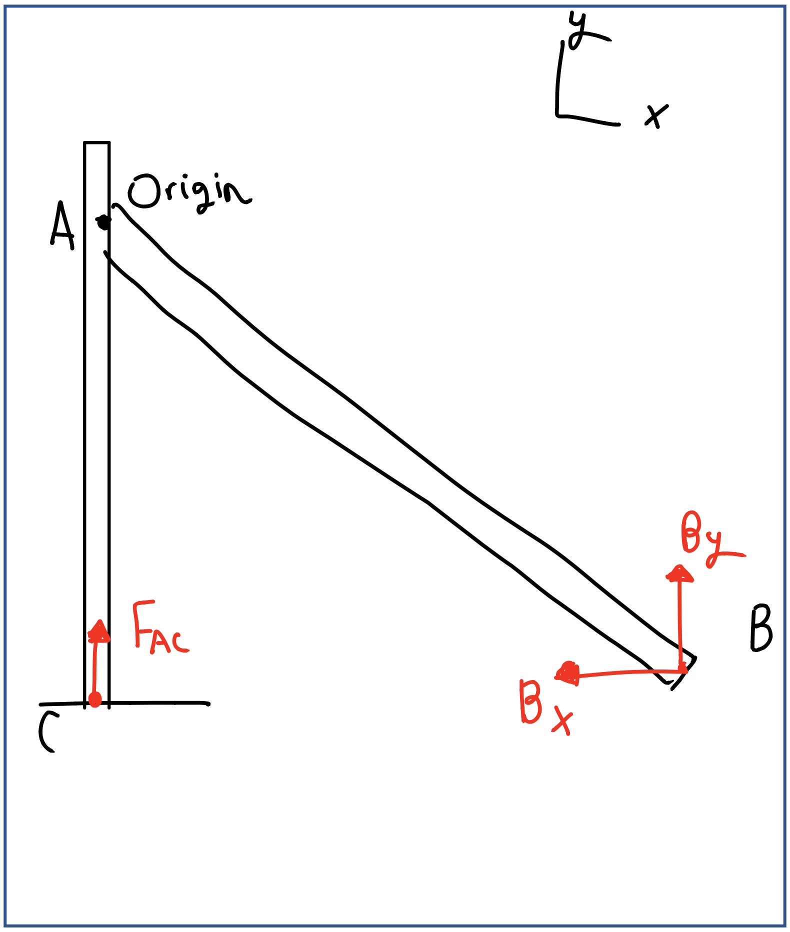
$$\sum F_y = 0: \quad -F_{w1} - F_{w2} + R_{Ay} + R_{cy} + R_{By} = 0$$

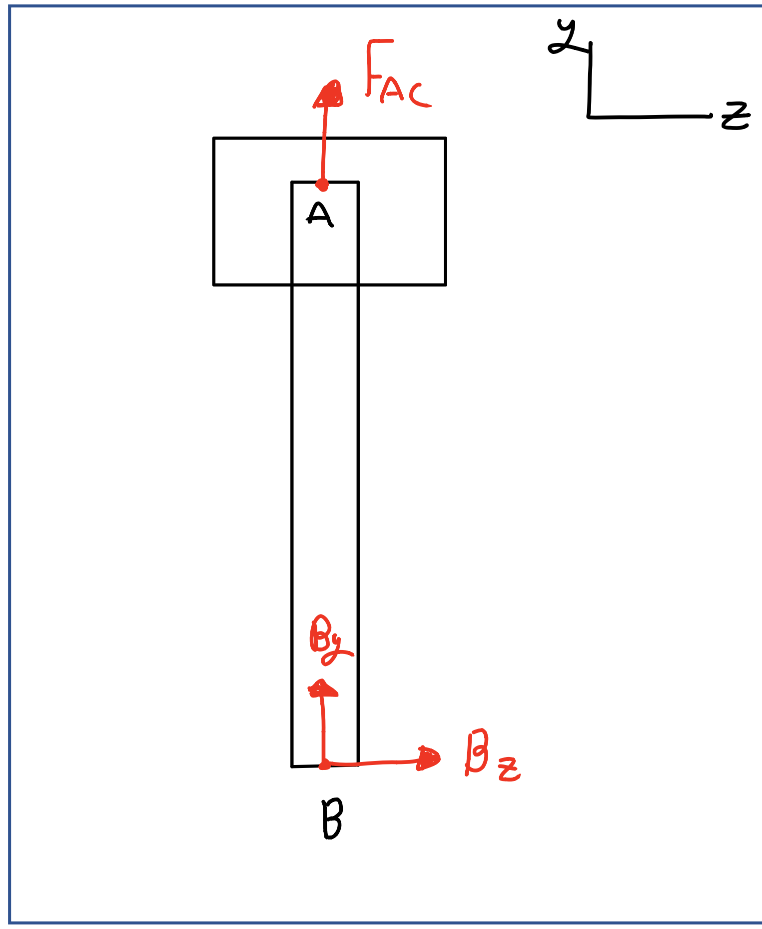
$$\sum F_z = 0: \quad P + R_{Az} + R_{cz} = 0$$

OMEP 2: Lot 48

As your system is statically indeterminate, you cannot solve the equilibrium equations. You will learn to solve statically indeterminate systems in ASEN 3112. For now, design a **new straight slide** so it is static, has at least one two-force member as a support, and is STATICALLY DETERMINATE.

8) Draw the XY and YZ free body diagrams of your newly designed slide. Label supports with the type. Set the origin to be at the top and center of the slide.





9) Write out all the support types, the reactions at these supports, and the position vectors where the support reactions are applied relative to the origin.

C and B: Fixed Support

$$\bar{r}_{CA} = -72\,\hat{j} + 0\,\hat{j} + 0\,\hat{k}$$

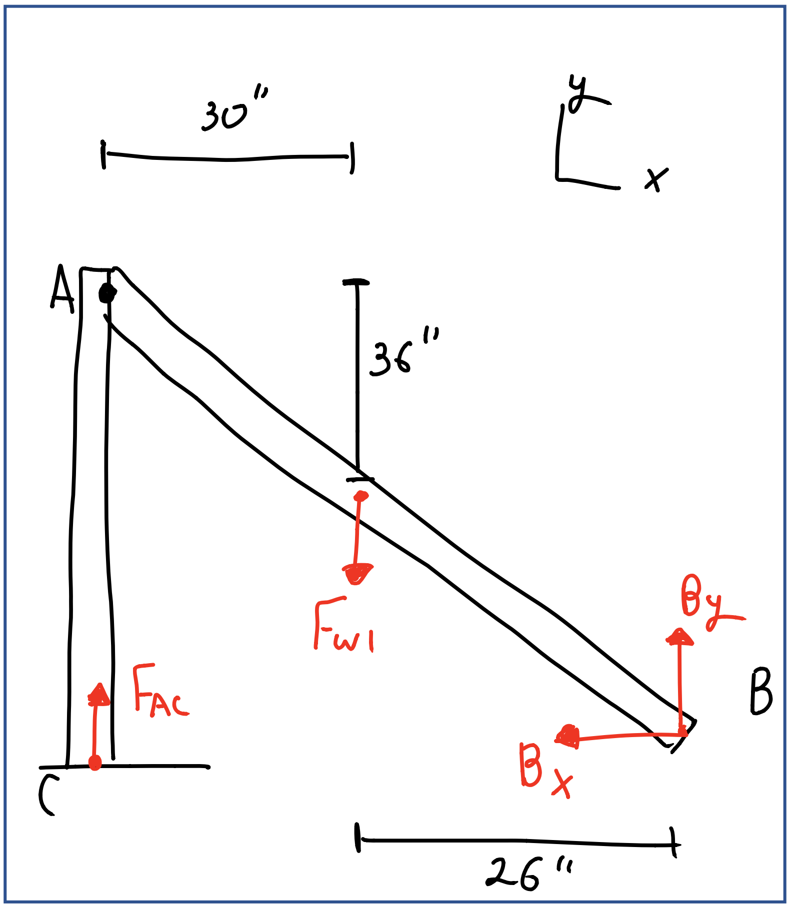
$$\bar{r}_{BA} = -72\,\hat{j} + 56\,\hat{i} + 0\,\hat{k}$$

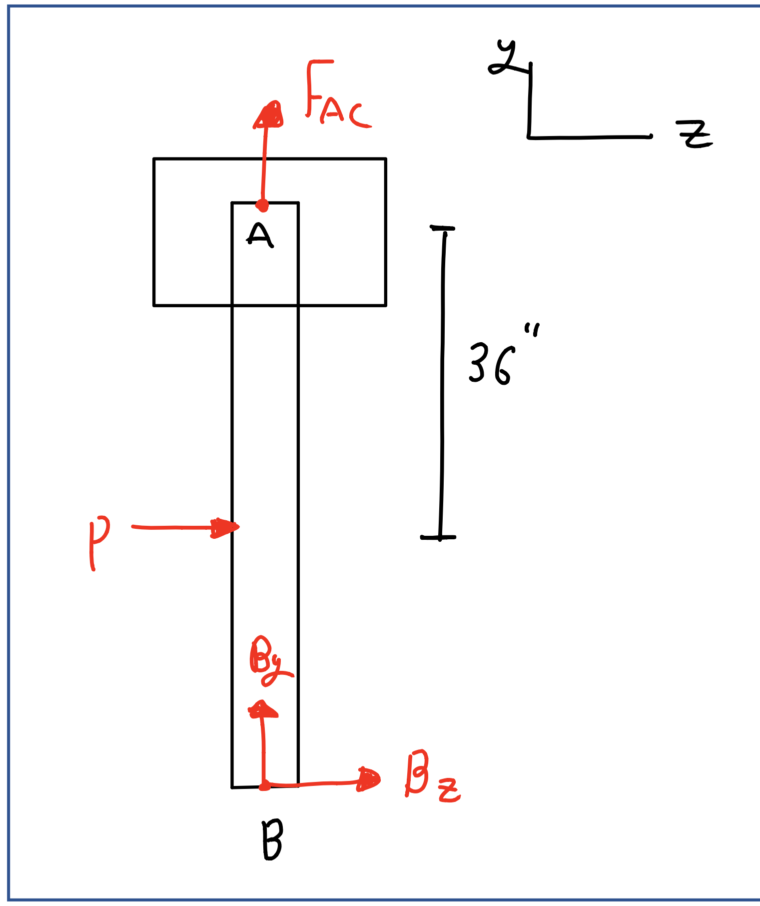
$$\bar{R}_B = R_{Bx}\,\hat{i} + R_{By}\,\hat{j} + R_{Bz}\,\hat{k}$$

OMEP 2: Lot 48

As your system is statically indeterminate, you cannot solve the equilibrium equations. You will learn to solve statically indeterminate systems in ASEN 3112. For now, design a **new straight slide** so it is static, has at least one two-force member as a support, and is STATICALLY DETERMINATE.

10) Draw the XY and YZ free body diagrams of your newly designed slide. Label supports with type and position vector from origin. Add in external forces to prove your slide is statically determinate.





11) Write out all external force vectors and their position vectors relative to the origin.

We removed the external force Fw2 not that it makes the system indeterminate but only it complicates calculations and the rest of the forces are sufficient to be considered worst-case scenario.

$$\bar{r}_{w1} = 30\hat{i} - 36\hat{j} + 0\hat{k}$$

$$\bar{F}_{w1} = -F_{w1}\hat{j} = (-176\hat{j})\ lb$$

$$\bar{r}_p = 30\hat{i} - 36\hat{j} + 0\hat{k}$$

$$\bar{p} = p\hat{k} = (40\hat{k})\ lb$$

OMEP 2: Lot 48

As your system is statically indeterminate, you cannot solve the equilibrium equations. You will learn to solve statically indeterminate systems in ASEN 3112. For now, **design a new straight slide** so it is static, has at least one two-force member as a support, and is STATICALLY DETERMINATE.

12) Write out the equilibrium equations for your statically determinate system in final form. Show your work and any cross products.

$\sum F_x = 0$: $\boxed{B_x = 0}$

xy:

$$\boxed{\sum M_A = 0 : -F_{w1}(30) + B_y(56) - B_x(72) = 0}$$

yz:

$$\boxed{\sum M_A = P(36) + B_z(72) = 0}$$

$$(40)(36) + B_z(72) = 0$$

$$B_z = -20 \text{ lb}$$

$$\boxed{\sum F_y = 0 : \bar{F}_{AC} - F_{w1} + B_y = 0}$$

OMEP 2: Lot 48

As your system is statically indeterminate, you cannot solve the equilibrium equations. You will learn to solve statically indeterminate systems in ASEN 3112. For now, design a **new straight slide** so it is static, has at least one two-force member as a support, and is STATICALLY DETERMINATE.

13) Solve the equations for the reaction forces. State the reaction forces below.

$$\sum M_A = -(176)(30) + 56 B_y = 0$$

$$\boxed{B_y = 94.3 \text{ lb}}$$

$$\bar{F}_{AC} = 176 - 94.3 = 81.7 \text{ lb}$$

14) Calculate the normal stress in **one** of the two force members. (If you have more than one, pick one and indicate which it is.) Assuming a factor of safety FS = 3, and that any plastic deformation of the bar would result in design failure, first choose a realistic material using the MMPDS and then calculate the diameter of the two force member. Show all calculations below.

Material: steel AerMet 100 $\rightarrow$ Y.S. = 236 – 281 Ksi

For worst case scenario: Y.S. = 236 Ksi

The two Force member is AC since no external forces are applied there

$$n = \frac{Y.S.}{\sigma_N}$$

$$3 = \frac{236 \text{ Ksi}}{\sigma_N} \rightarrow \boxed{\sigma_N = 78.6 \text{ Ksi}}$$

$$\sigma_N = \frac{F_{AC}}{A} \rightarrow \frac{\pi}{4} D^2 = \frac{F_{AC}}{\sigma_N} \rightarrow D^2 = \frac{4 \cdot 81.7}{78.6 \times \pi}$$

$$\boxed{D = 1.15 \text{ in}}$$

OMEP 2: Lot 48

As your system is statically indeterminate, you cannot solve the equilibrium equations. You will learn to solve statically indeterminate systems in ASEN 3112. For now, design a **new straight slide** so it is static, has at least one two-force member as a support, and is STATICALLY DETERMINATE.

15) Normal stress in two force member:

$\sigma_N = 78.6$ Ksi

16) Chosen material and strength:

Steal AerMet 100 Alloy

17) Calculated diameter:

$D = 1.15$ in

18) Is this diameter physically realistic? Justify your answer.

It is realistic since the beam is not experiencing extensive weights and our factor of safety is 3 which does not require strong support. Also, real-life playgrounds use similar value to that which we calculated.

19) Name at least three other factors beyond strength that an engineer might consider when selecting the material and diameter for a bar that supports a slide.

1) Environmental factors: The playground will experience different weather conditions including rain which cause rusting.

2) Toxicity: Since children will use the playground, engineers need to ensure that the materials are not toxic to the children nor the environment.

3) Cost: Playgrounds do not need high material properties so cost should be low

Slide Supports