Banana Questions: Conceptual Learning in Physics 170, Mechanics for Engineers

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Outline

1. What is physics 170?
2. How is it taught?
3. Why change it?
4. What did you change?
5. How do you know it worked?
6. What still needs to be worked on?

Development Timeline

The talk presents the efforts of teaching PHYS 170 for three years while **not** in charge of the course.

First Year (SCI Data)

- Developing lesson specific learning goals (tasks)
- Developing Reading Assignments
- Create at least **two clicker questions** for every lecture
- Develop Worksheets based on assessments
- Concept Evaluation using Statics Concept Inventory

Second Year (SCI Data)

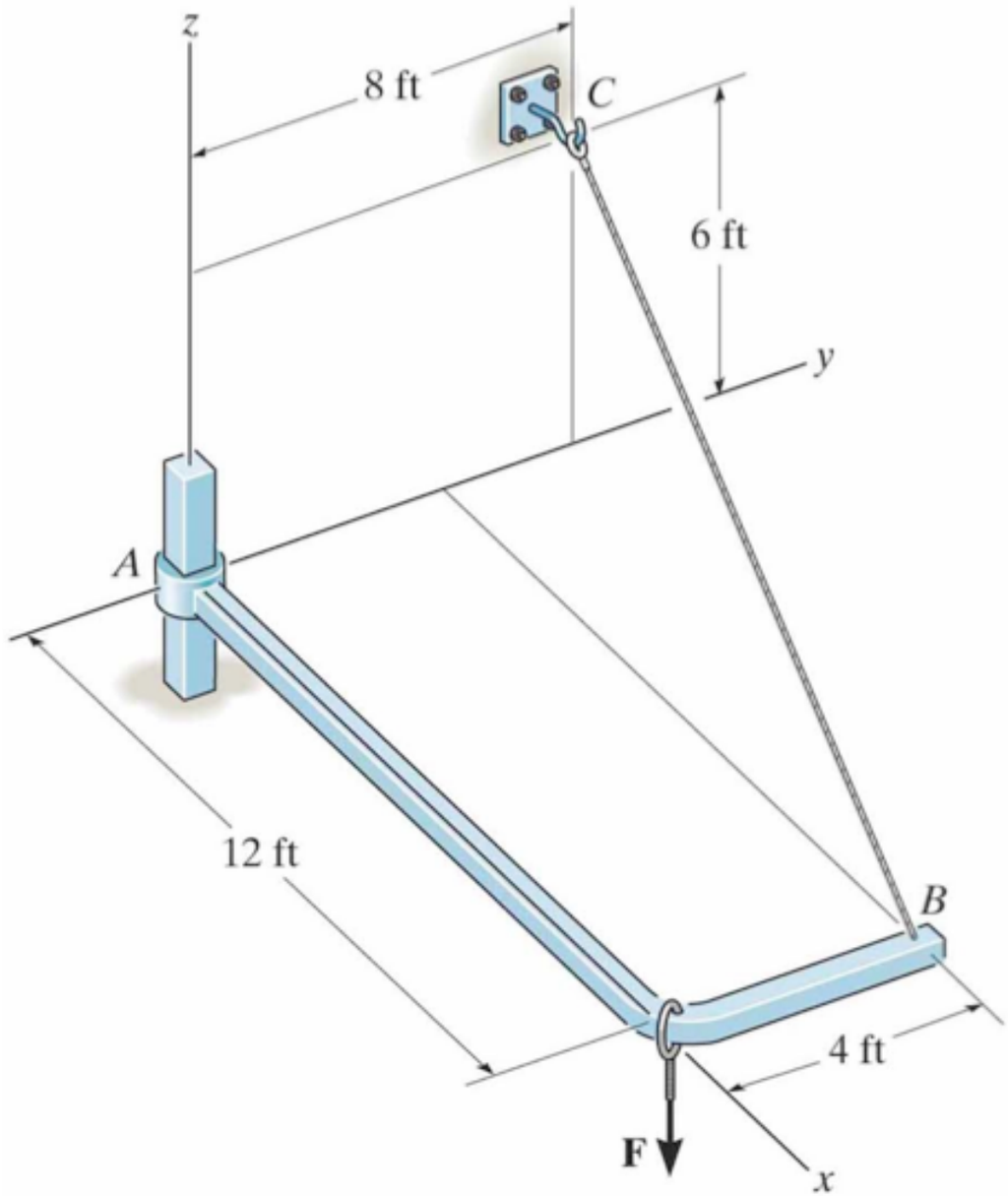
- Developing broader course learning goals (Polya's Method with Tom Mattison)
- Pair taught one section and mentored a new instructor.

Third Year (No SCI Data)

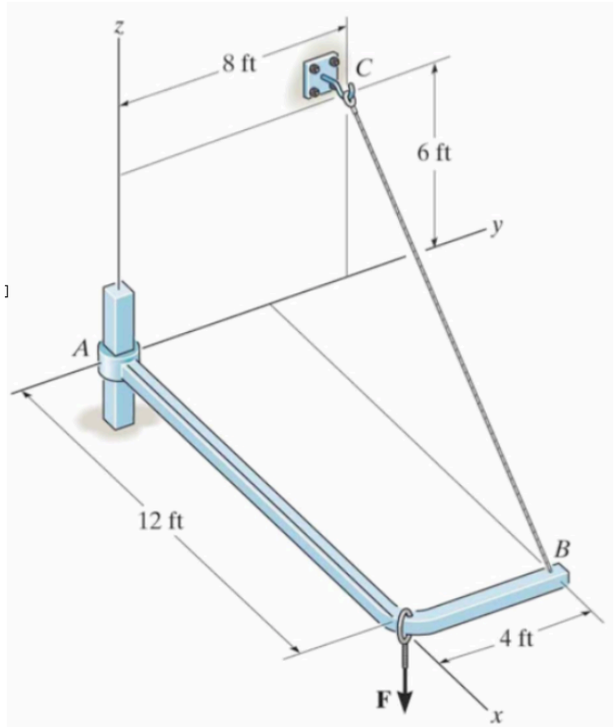
- Using **clickers to scaffold the problem** solving process in worksheets

What is PHYS 170?

- 13 week combined Statics and Dynamics course for Engineers using Hibbeler.
- 90% of grade comes from exams. 5% from assignments, 5% from tutorials.
- 800+ students in 3 sections
- Generally regarded as conceptually dry ($F_{net} = 0$ and $F_{net} = ma$) and many people don't want to teach it.
- Hard to teach because the problems are long and detail oriented (no negative sign mistakes allowed!), more so than any student has seen until this point.

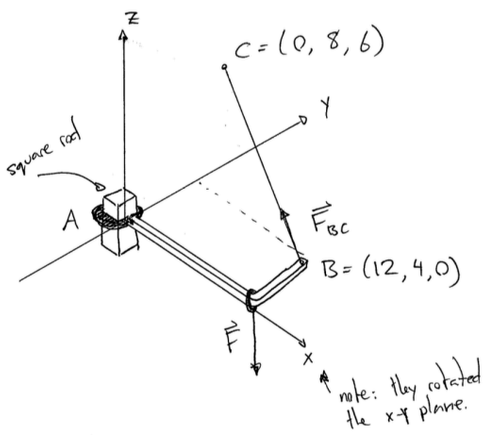


Typical Statics Problem with Solution



Member *AB* is supported at *B* by a cable and at *A* by a smooth fixed *square* rod which fits loosely through the square hole of the collar. Determine the *x, y, z* components of reactions at *A* and the tension in the cable when **F** = (20 **i** - 40 **j** - 75 **k**) lb.

Example: (5-82 12th ed)



The square rod resists all motion but that in the F_z direction.

$$\vec{F}_A = A_x\,\hat{i} + A_y\,\hat{j}$$

$$\vec{M}_A = M_x\,\hat{i} + M_y\,\hat{j} + M_z\,\hat{k}$$

We also have the forces

$$\vec{F} = 20\,\hat{i} - 40\,\hat{j} - 75\,\hat{k}$$

$$\vec{F}_{BC} = \frac{F_{BC}}{\sqrt{12^2+4^2+6^2}}\left(-12\,\hat{i} + 4\,\hat{j} + 6\,\hat{k}\right) \leftarrow X$$

The force equations for equilibrium are

① $\Sigma F_x = 0$: $\quad A_x + 20 - 12X = 0$

② $\Sigma F_y = 0$: $\quad A_y - 40 + 4X = 0$

③ $\Sigma F_z = 0$: $\quad -75 + 6X = 0$

We now have to find the moments. Let's choose point B to calculate them around. This lets us avoid calculating the moment of $\vec{F}_{BC}$ about anything.

$$\vec{M}_{RB} = 0$$

$$= M_x\,\hat{i} + M_y\,\hat{j} + M_z\,\hat{k} + (\vec{r}_{BA} \times \vec{F}_A) + (\vec{r}_{BF} \times \vec{F})$$

$$= M_x\,\hat{i} + M_y\,\hat{j} + M_z\,\hat{k} + \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -12 & -4 & 0 \\ A_x & A_y & 0 \end{vmatrix} + \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & -4 & 0 \\ 20 & -40 & -75 \end{vmatrix}$$

The moment equations are

④ $\Sigma M_x = 0$: $\quad M_x + 4(75) = 0$

⑤ $\Sigma M_y = 0$: $\quad M_y = 0$

⑥ $\Sigma M_z = 0$: $\quad M_z - 12A_y + 4A_x + 4(20) = 0$

Solve by substitution:

⑤ $M_y = 0$

④ $M_x = -4\text{ ft}\,(75\text{ lb}) = -300\text{ ft·lbs}$

③ $X = \dfrac{75\text{ lbs}}{6\text{ ft}} = 12.5\ \dfrac{\text{lbs}}{\text{ft}}$

$$\Rightarrow F_{BC} = X\sqrt{12^2+4^2+6^2}$$

$$= 175\text{ lbs}$$

① $A_x = 12X - 20 = 130\text{ lbs}$

② $A_y = -4X + 40 = -10.0\text{ lbs}$

⑥ $M_z = -4(20) - 4A_x + 12A_y$

$$= -720\text{ ft·lbs}.$$

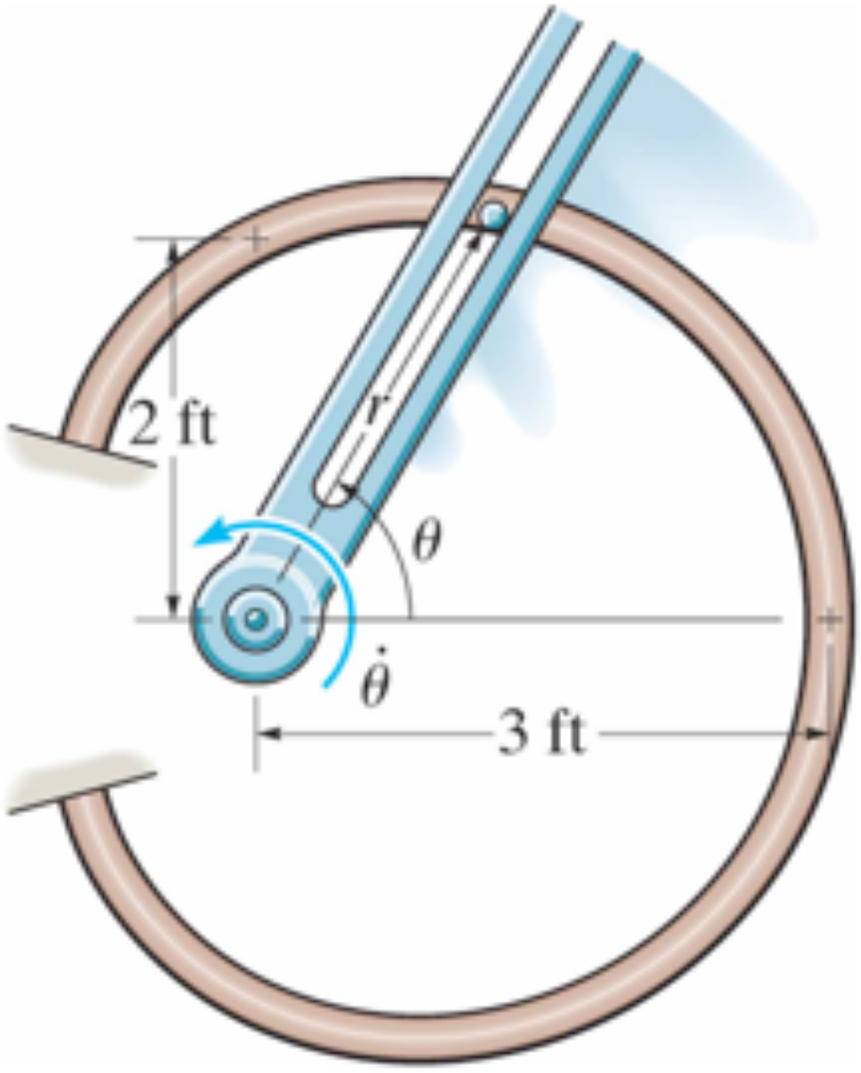
We're the best!

Why Change It?

- Course has very poor performance on Statics Concept Inventory (SCI) developed by Carnegie Melon.

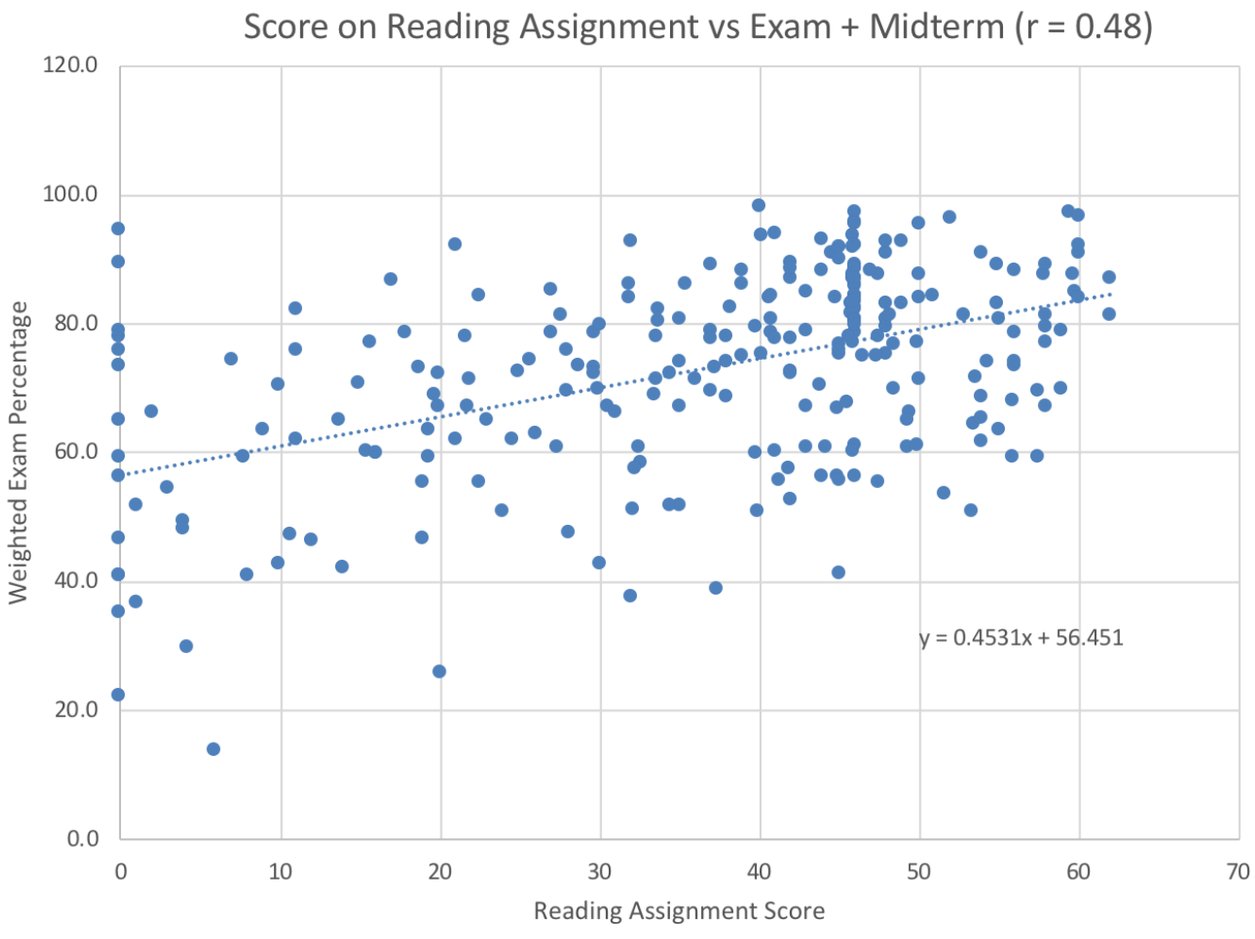
- Perception was that it didn't contain enough concepts to create clicker questions and active learning in the course was a "lost cause".

- I wanted to teach the course around my teaching philosophy under the constraint of a multi-section course that wasn't aligned with my philosophy.



Reading Assignments

- A set of **4-5 simple problems** that use the skills needed for class.
- Students recognize that they're useful, but can't motivate themselves to do them without grade incentive (2%)



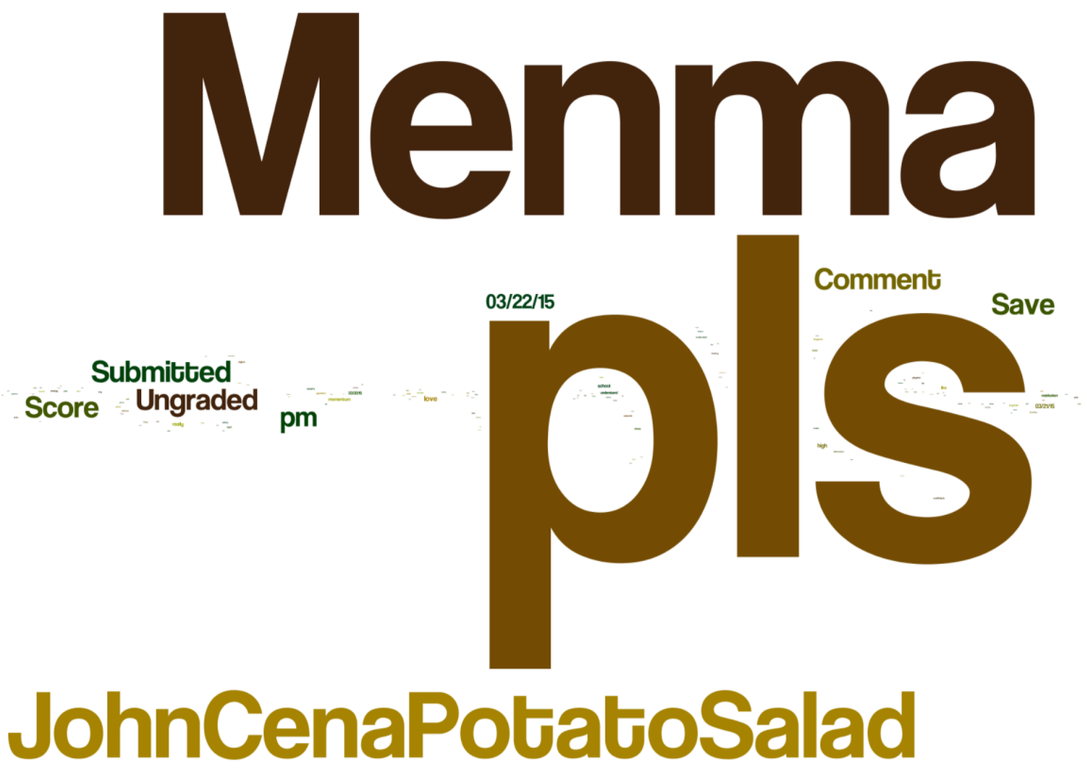
"though at first i thought the extra reading assignment were annoying they forced me to keep up with the course material and ended up being very beneficial"

"The instructor also added pre-reading component to the course, which is, even though at times annoying, very effective."

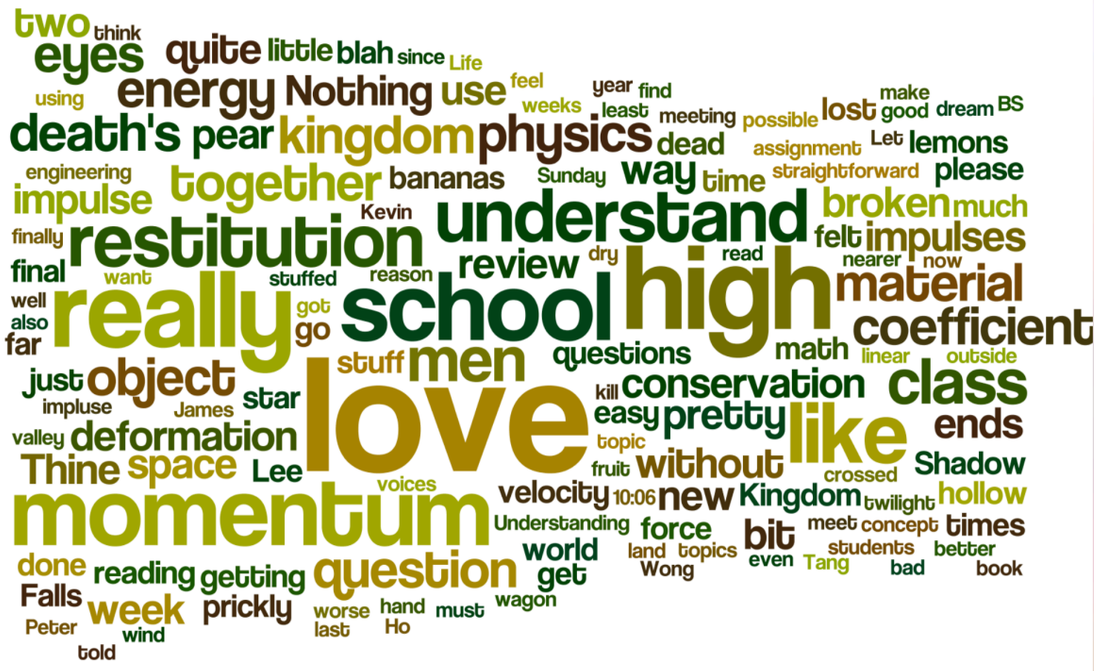
"He prepared very useful reading assignments the other section did not have. This gave us a very strong concept of what we were learning and the type of questions we would see."

Reading Assignments Build Community

“without a doubt one of the only classes I genuinely enjoy going to (especially on mondays when he reads out the student feedback from the reading assignments)!”



10/10 quality pre-reading assignment, an emotional rollercoaster that kept me on the edge of my seat the entire time. I laughed, I cried, I learned 42 new ways to season and cook a pork shoulder. Truly a new standard has been set that all future pre-readings will be held in comparison to.



- The coefficient of restitution and other wordy terms seem pretentious, a simpler explanation in class of what they actually represent would be much appreciated!

- The restitution constant was menacing. Trying to wrap my mind around it made me feel like Oberyn Martell when he lost to Slandor Clegane in Game of Thrones. :P

Teaching Tasks and Setlists

Setlist L13

More Equilibrium
prep: print worksheet

1. Last class – reduction to a wrench. My laptop is broken.
2. Equilibrium again
3. Clicker Question – peeling a banana – C
4. Clicker Question – placing *O* – E
5. Choosing *O*
6. Reaction forces and moments
7. Clicker Question - reaction forces – B
8. Clicker Question – reaction moments – B
9. Show sheet of all of them.
10. Worksheet 5 Q1 *
11. Worksheet 5 Q2

9 min
20 min
25 min
30 min

demo physical bearing to debrief clicker questions.

10. Finished part of it.
    1) gave them 5 minutes. people didn't seem to know what they were doing.
    2) Wrote down Forces and moments drew picture, gave them a bit more time. to write down $\Sigma F_i = 0$ $\Sigma M_i = 0$
    3) Started getting equations.

* You didn't clearly explain your choice of O.

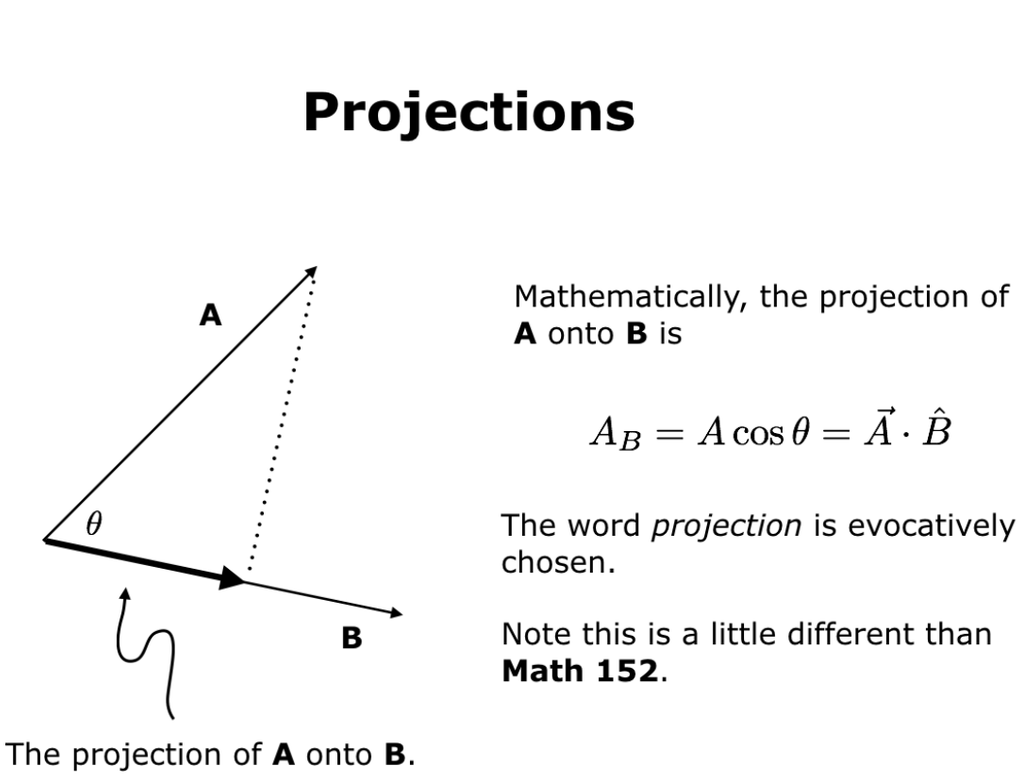
* explain what a reaction force is more clearly. Talk about it resisting forces.

Teaching Tasks - these are what I identify as the granular tasks that make up a lesson (running a clicker question, mini lecture, facilitating worksheet, etc)

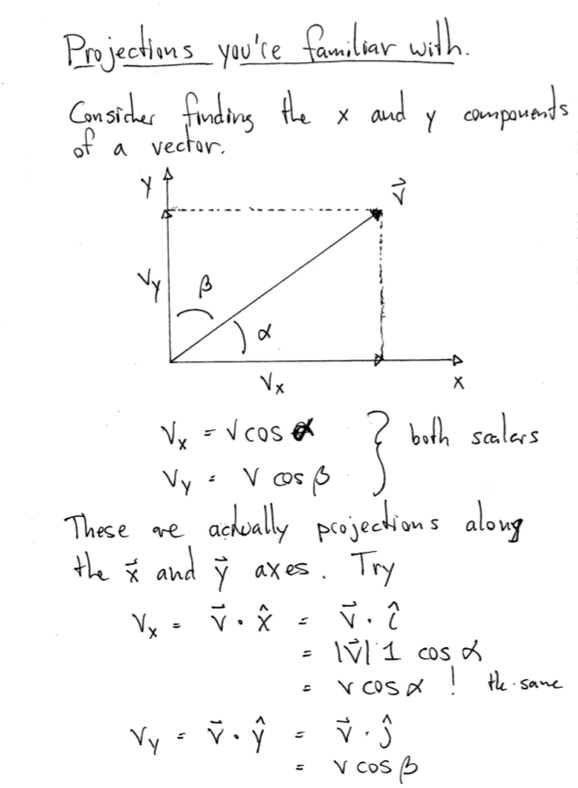
Setlist - the outline of teaching tasks that occur in a lecture, with prep necessary

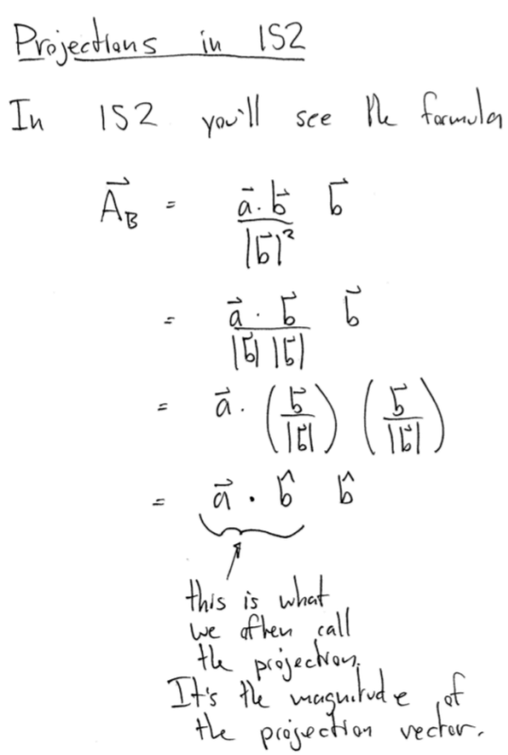
Slide Design and Notes

Slide design is intentionally stark and minimal, but accompanied detailed notes. Research shows that students with **low working memory struggle to divide attention** between cluttered slides and the professor talking.



The projection of **A** onto **B**.





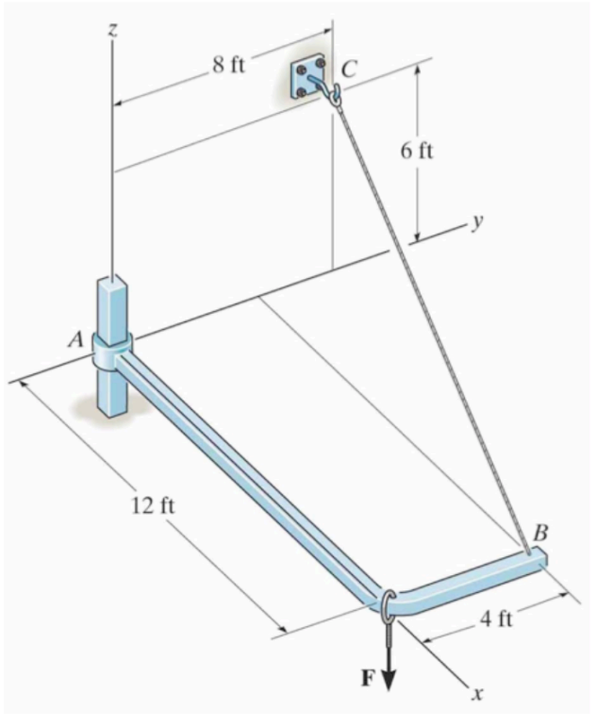
"His lecture slides were truly a work of art - concise, detailed, rife with yellow fruits, and even animated."

"The quality of resources he provided, including notes, lecture slides, and custom weekly homework was unprecedented and far better than my other courses."

Worksheets

- Used problem from **old exam problems**.
- Length of the problems made them **hard to solve** in class.
- Many students had **difficulty starting** them.
- Goal of the worksheets became to **understand the problem**, and make a plan, rather than to do the question.

Worksheet Week 5 Q6



Member *AB* is supported at *B* by a cable and at *A* by a smooth fixed *square* rod which fits loosely through the square hole of the collar. Determine the *x, y, z* components of reactions at *A* and the tension in the cable when **F** = (20 **i** - 40 **j** - 75 **k**) lb.

"Also the worksheets with online solutions are a great study tool that I use to stay caught up in the course. "

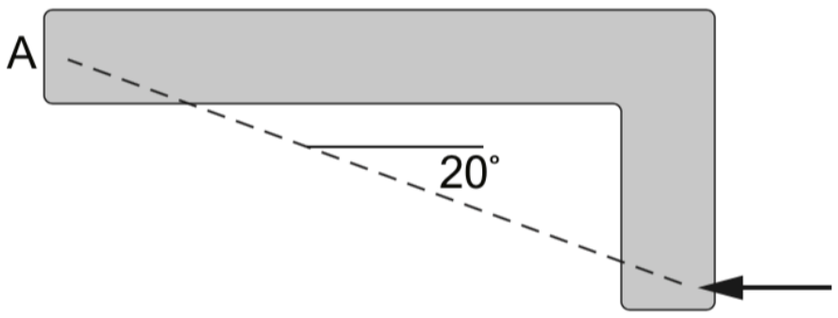
"Weekly worksheets saved me."

"I find that his teaching method is quite effective; we are given worksheets for each topic and the Mr. Charbonneau posts extremely detailed online solutions for them."

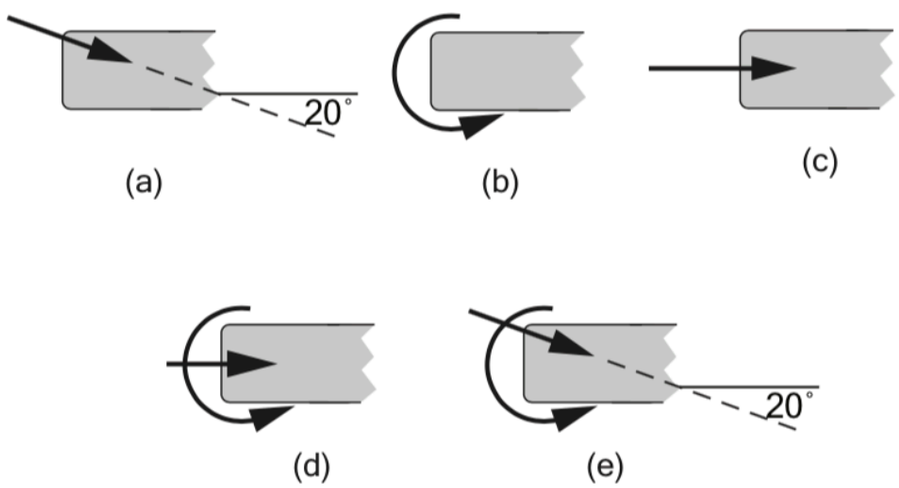
Banana Problems

Design problems similar to those that appear on the **Statics Concept Inventory (SCI)** to tackle to core concepts in an engaging way.

25. The member is subjected to the force at the lower right corner, and is maintained in equilibrium by a hand (not shown) gripping the end A.

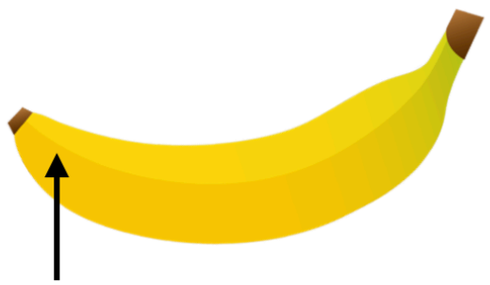


Which of the following could represent the load(s) exerted by the gripping hand?



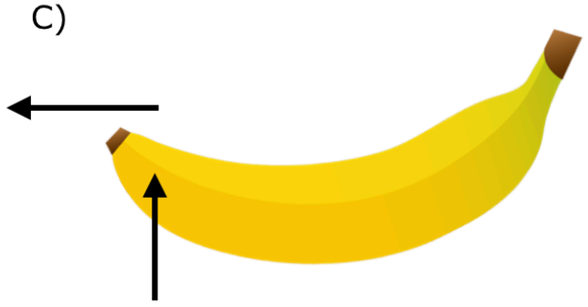
You want to peel your banana. To do so you act a force on the right end, shown above, and grip the left end with your hand to maintain **equilibrium**. Which reaction load could represent your hand?

A)

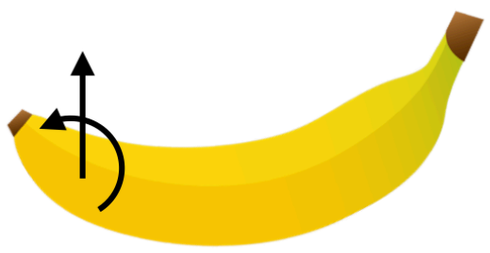


B)

C)



D)



SCI Results (First Transformation Year)

Pretest scores are indistinguishable from each other and have been the same for years.

	SCI PreTest % (SDM)	SCI PostTest % (SDM)
Traditional 1	21.5 (0.9)	28.0 (1.0)
Traditional 2	23.2 (0.9)	31.7 (1.7)
Transformed	**21.5 (2.1)**	**37.4 (1.2)**

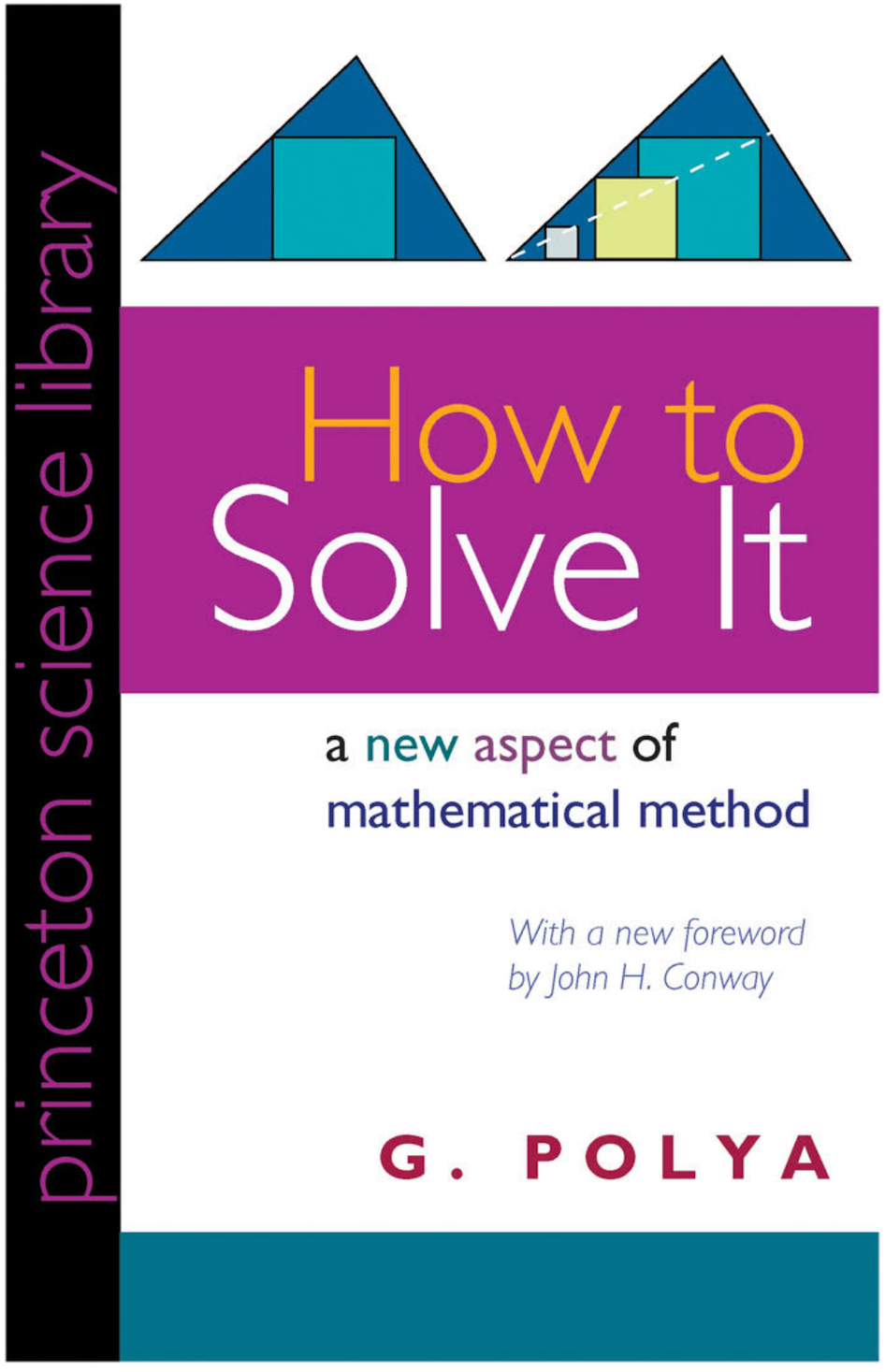
Transformed class shows a much **larger jump in conceptual learning**.

*The final exam grades show that time spend on conceptual learning didn't sacrifice pure computational training. Course assessment was unchanged.

Framing Around Polya's Method

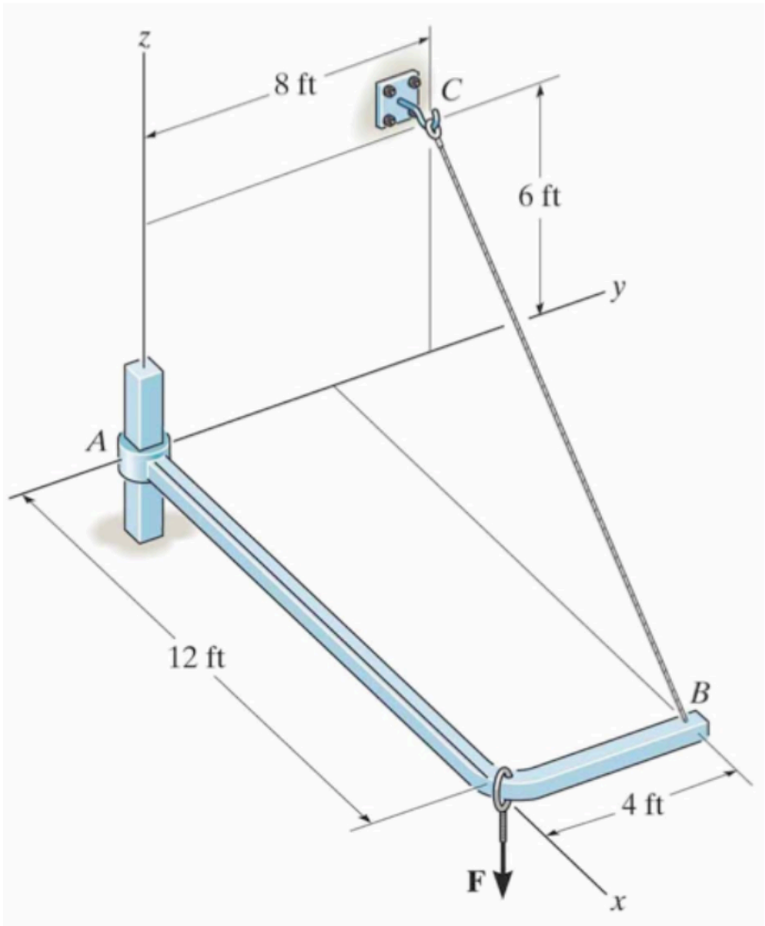
A lecture can be designed around Polya's method for problem solving.

1. **Understand the Problem**
   - scaffolded clicker questions
2. **Make a Plan**
   - Students work on worksheet
3. **Execute the Plan**
   - expert solution by the instructor
4. **Reflect**
   - instructor reflects on answer



Scaffolded Clickers and Worksheets

Worksheet Week 5 Q6



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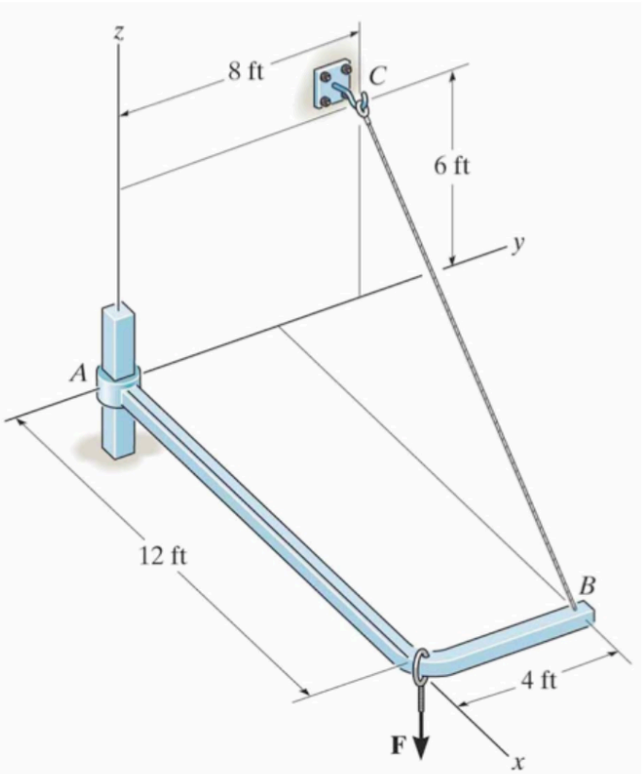
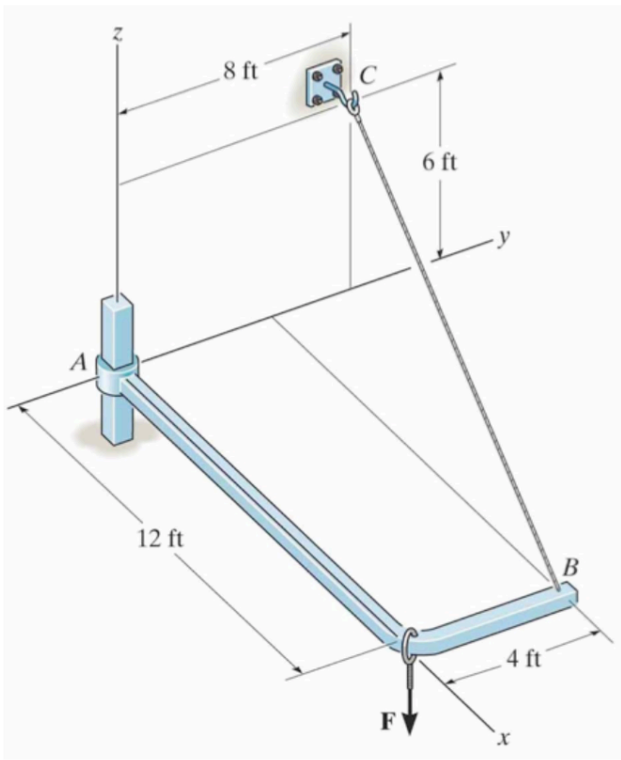
- **Expand the role** of conceptual Banana questions to actual problems.
- The clicker questions take the role of **understand the problem.**
- **Give the students time** to make a plan/start the problem.
- The **instructor guides** the students through the execution/reflection.

Scaffolded Clickers and Worksheets



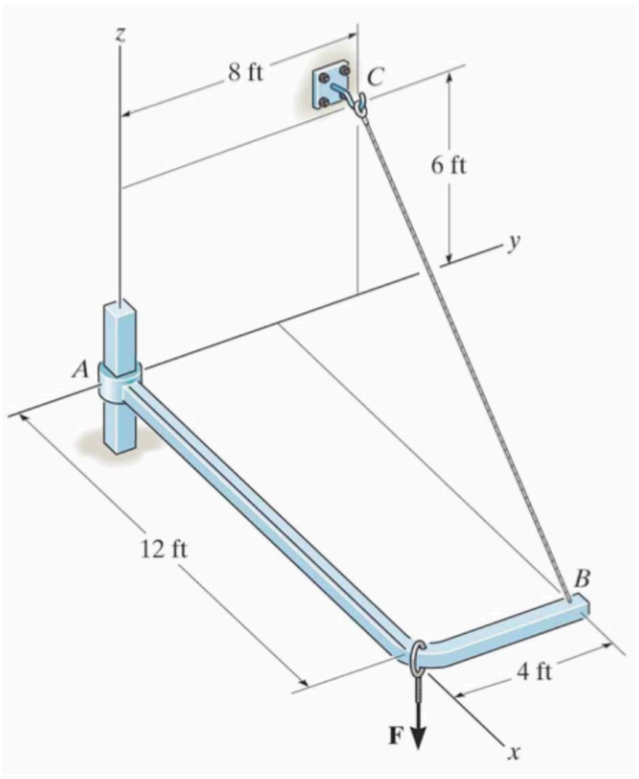
A is a square collar. What are the possible reaction forces that act at *A*?

A) F_x, F_y, F_z
B) F_x, F_y
C) F_z
D) None of the above



A is a square collar. What are the possible reaction moments that act at *A*?

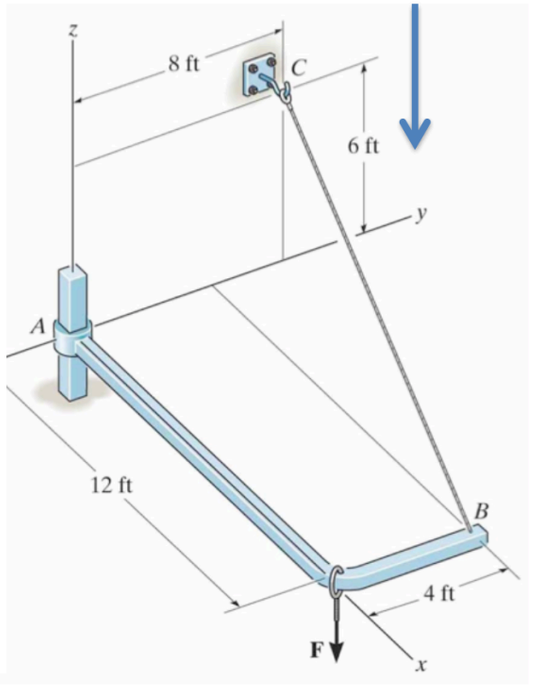
A) M_x, M_y, M_z
B) M_x, M_z
C) M_y
D) None of the above



Which point should we choose as *O* to calculate our moments about?

A) *A*
B) *B*
C) *C*
D) Where the **F** is acting.
E) Any of the above is fine

Worksheet Week 5 Q6



Member *AB* is supported at *B* by a cable and at *A* by a smooth fixed *square* rod which fits loosely through the square hole of the collar.

a) Write down all the reaction components at A.

b) Write down the equations of equilibrium for forces.

c) Write down the equations of equilibrium for moments.

d) Determine the *x, y, z* components of reaction at *A* and the tension in the cable when **F** = (20 **i** - 40 **j** - 75 **k**) lb.

Remarks

- Banana questions provided movement on SCI is decent for a 6 week course, but would be much better if the assessments were designed around testing these concepts. The inability to have complete control over the assessments made is difficult.

- Do the scaffolded questions cause an improvement in the SCI?

- I didn’t want to “penalize" this section with “extra work” so reading assignments and clicker questions had no grade incentive. This worked of clickers, but not for reading.

- Clicker questions did not have to be graded. The philosophy is that is they’re good enough they’ll do them, if they’re garbage they won’t.