Paper ID #18889

One Paragraph and a Few Simple Questions - Giving Statics Problems Human Context

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One paragraph and a few simple questions—giving Statics problems human context.

Introduction

The engineering problem solving method (EPS), as it is commonly and classically taught, tends to remove the human and social context from consideration. While the EPS method produces well-posed problems with easily checked solutions, it unintentionally reinforces the worldview that engineering is value-free profession where the rigor of one's technical analysis is more important than the context in which engineering is practiced[1]. Recognizing this consequence, a growing body of literature calls for changing engineering education to be more human-centered through awareness of the limitations of purely technical solutions[2-5].

Changing one's approach to teaching in this way poses big challenges: how to add ideas to an overstuffed curriculum—particularly ideas that involve a disciplinary background different from what makes us comfortable, what kinds of human and social context to consider, how to not trivialize such concerns by doing a bad job, etc. Perhaps the question is not "What happens if this goes badly?" but "What are the consequences of not even trying?"

As a first encounter with EPS, statics courses are a place where efforts to introduce human and social context might be particularly effective—before years of core technical courses have established the priority of the technical over everything else. However, any change to the standard way of teaching statics must acknowledge that the course is already filled with content, as statics is often a prerequisite for all subsequent solid mechanics courses. Simple, easy changes are a good place to start.

A first attempt to acknowledge context in statics problems might be as easy as adding one paragraph at the beginning and asking a few simple questions at the end. This paper will give a few different examples of what this approach to context might look like. The paragraph will authentically introduce the human and social context in which statics problems arise, acknowledging that simplifications are being made to make the situation well-posed. Next, the statics problem will be presented, much as it is usually done. Finally, the few simple questions will prompt students to consider the impact of the result—who, what, why, and how questions.

The goal is not to establish a definitive set of examples, but to demonstrate that acknowledging context in a core engineering course is feasible without wholesale rethinking of the content. Hopefully, this paper will encourage statics instructors, and engineering instructors in general, to consider taking steps to balance the EPS approach with acknowledgement of the human and social context in which engineering work takes place.

Method

I identified example problems based on real-world situations that illustrate core technical ideas within the Statics curriculum. I then elaborated the problem description to place the situation in a human and social context. While keeping the technical questions basically unchanged, I added "Reflect" questions at the end of the problem.

These questions require the student to move beyond the numbers, think about the relationship between the assumptions or "given" in the problem and the outcome, and consider an expanded role of engineering. This role places engineers not just as people who provide numerical answers, but who also can serve the public by considering the impact of engineering solutions on others. I chose reflection questions that engineering educators could be expected to be comfortable with answering and leading a class discussion on. No extensive training in humanitarian engineering or social justice is required. Simply reading the National Academy of Engineering's "Educating the Engineer of 2020" report[5] would be a good way for an instructor to prepare for these discussions.

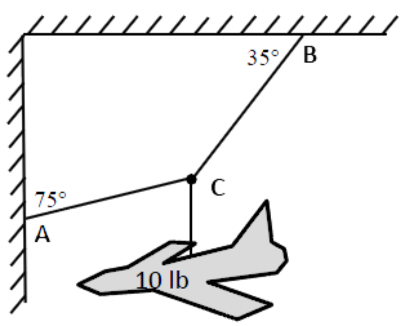
Results

Three problems are used to illustrate concepts common to statics curricula. Presenting human and social context all throughout the course—not just at the beginning or in open-ended design problems—is important to establish such context as an important part of the things that engineers think about and discuss.

Day 4 FBDs & 2D particle equilibrium EM121

A model airplane enthusiast has built a 10 lb scale model of an airplane. She has suspended it in her dorm room above her bed using three pieces of fishing line, tied together at C and nailed to the wall and ceiling at A and B. The fishing line has a rated strength of 12 lb, so she reasons it should be strong enough.

Assume the system is in equilibrium and find the tension in cable AC and cable BC.



Reflect: Is the fishing line actually strong enough for this job? What if the angles are changed? What language might you put on the package to help people understand the danger of supporting a weight with fishing line offset from vertical?

Figure 1. A contextualized particle equilibrium problem asks students to go beyond the numerical answer and consider the role of engineers in communicating danger to the public.

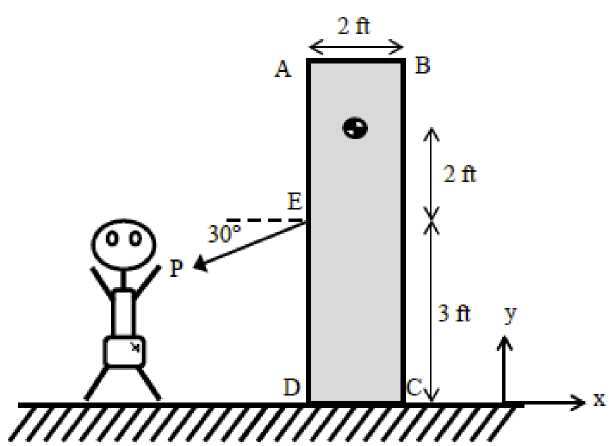
The first example, shown in Figure 1, addresses particle equilibrium from early in a typical statics course. This topic is often familiar to students from their physics classes. The struggle is to get students to use the engineering approach and correct vector math in a problem where the scalar versions of the equations are easy to see. The context and reflection for this problem address the challenge of anticipating how a customer might misunderstand the way they use a product and accidentally endanger themselves or others. Directly contested is the view that absolves engineers from responsibility because the technical capability of the product was correctly stated.

Day 33 Friction: slip vs. tip EM121

Parents of young children are warned to anchor bookshelves and tall dressers to the wall to prevent children from tipping them over and getting hurt. Let's try to understand the danger of *not* following this advice.

Assume a toddler can reach a shelf that's 3 ft high and pull at an angle of 30°. Further assume as a worst-case scenario that the bookshelf is loaded with books only on the top shelf so the center of mass of the bookcase and books is 5 ft high. As a reasonable start, assume the coefficient of friction between the floor and bookcase is 0.40 and the bookcase plus books weigh 50 lbs. The bookcase is not anchored to the wall.

Based on the schematic below, **what force P** would a child apply in order to **cause impending motion (either slip or tip)**? Based on these values, which will occur first?



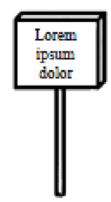
Reflect: Is the force you found something that a child could exert? Will moving the books around so the center of mass is closer to the floor make the bookshelf more likely to slip before tipping (which is arguably slightly better than tipping)? If not, why do bookshelf instructions always warn the user to place heavy items on the lowest shelf first?

Figure 2. A contextualized slip/tip problem asks students to go beyond the numerical answer and consider the reasoning for common practices.

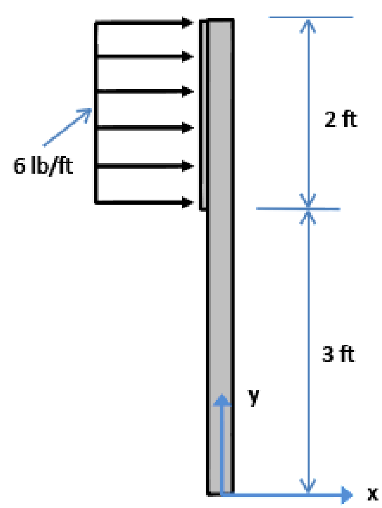
The second example, shown in Figure 2, addresses slip and tip of rigid bodies. This topic challenges students because of the physical reasoning required and because they must essentially solve the problem twice. The statics analysis used here can explain some common practices (the need to anchor bookshelves) but leaves unanswered other aspects (why a high center of mass affects stability). In doing so, the fact that one engineering idea does not necessarily explain everything is highlighted. Students might begin to perceive the limitations of their own engineering knowledge.

Day 39 Distributed loads EM121

A concerned citizen has made a protest sign by attaching a stiff piece of cardboard to a length of PVC pipe. The grassroots protest has been organized to happen on a windy day, so making the sign easy to carry even in a gust of wind is important. Since this citizen has taken Statics, a quick analysis of the loading situation will allow prediction of the reactions needed to hold the sign.



Find the support reactions at the bottom of the pipe (where the citizen's hand will act like a built-in support) that will keep this pipe and sign in equilibrium. The sign is 2 ft by 2 ft and the pipe is 5 ft long. Estimate the distributed wind load as 3 lb/ft^2, symmetrically loaded so in the side view the load is 6 lb/ft.



Reflect: Do these reactions seem like something that would be easy to provide for an extended amount of time? How might the design of the sign be modified to reduce these reactions? How would these modifications influence the effectiveness of the sign in a large crowd?

Figure 3. A contextualized distributed load problem presents statics students as agents of civil discourse and social engagement.

Distributed loading, shown in Figure 3, is the final example presented. This topic uses the mathematical idea of a centroid as a tool in modeling a system to find support reactions. The noun “citizen” is consciously used here instead of “protester” to emphasize that social engagement is a fundamental part of citizenship. Furthermore, engineering approaches are presented as tools for more effective social engagement.

Conclusion

Statics instructors will recognize the technical concepts seen in these problems as parallel to their usual example problems. However instead of featureless boxes, ropes, and forces, the problems here are contextualized in a meaningful way for students. The presentations of the context and reflection questions subtly challenge the view of what engineering is and is not.

Clearly, just three examples of this type would not be effective in changing the overwhelming number of decontextualized example problems that engineering students solve during their undergraduate years. But an individual instructor is rarely in a position to make such a change. Instead, instructors are encouraged to take advantage of their well-established right to present content in their own way. With an effort to transform a few problems at a time, soon an instructor would find themselves in possession of a complete set of contextualized problems. Implementing these problems either one at a time or as a complete set would make important progress towards the goal of establishing engineering as an explicitly human-centered profession.

No meaningful objection can be raised that the examples given here are not grounded in the "core" technical content of the class. They simply do a better job than usual in demonstrating that engineering work is done squarely within a human and social context. No formal assessment of these examples was performed, due to the limited quantity of examples. However, I suspect that a strong coordinated effort to use contextualized example problems throughout the required courses in a discipline would reap benefits not only in student retention and performance, but also in the number of graduates who see engineering as a profession that serves humanity.

References

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