

USING CAD TO HELP STUDENTS LEARN STATICS

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Abstract

Because statics involves careful visualization of physical processes, use of a CAD program can be a significant aid to learning. The author uses SmartSketch, a CAD program from Intergraph, in the statics course at Webb Institute. This article describes the CAD solutions of two statics problems: one involving a particle and the other a rigid body. The particle example involves a free body diagram and a vector polygon that shows the sum of forces equal to zero, while the rigid body example adds consideration of the sum of moments. In both cases, the solution process is straightforward and accurate.

SmartSketch

Several SmartSketch features are particularly useful in solving statics problems. Line types in SmartSketch enable the user to draw solid, dashed, and dotted lines with or without arrowheads, and the arrowhead(s) can be at either end of a line or at both ends. Dimensions are normally displayed as actual lengths, but in statics problems these lengths represent forces. Instead of displaying a dimension with a length unit, it is easy to display it with a force unit. Drawings in this article are all black on white because of publishing requirements. In the classroom, the author makes extensive use of color to clarify the drawings. SmartSketch drawings can be saved in native format or as DWG and GIF files.

For advanced problems, the author makes use of the *relationships* features in SmartSketch. These features allow the user to lock various characteristics of a drawing element. For instance a line may be fixed in place, two lines may be forced to remain parallel, perpendicular, or connected, and a line may be forced to

remain tangent to a circle. Advanced features of SmartSketch are explained in the following reference [2].

Other CAD programs may include some or all of these features. They can be used in ways that are similar to what is described here.

Example 1: Equilibrium of a Particle

The following problem is taken from Vector Mechanics [1]. The particle at point A is in equilibrium, and the tensions in cables AB and AC were to be found. Figure 1 shows the picture.

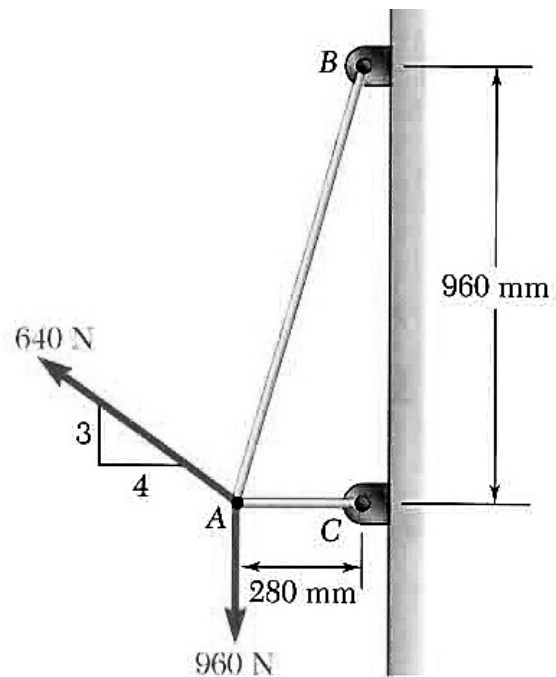


Figure 1: Particle Picture.

Step one was to create the free body diagram shown in Figure 2 from the picture.

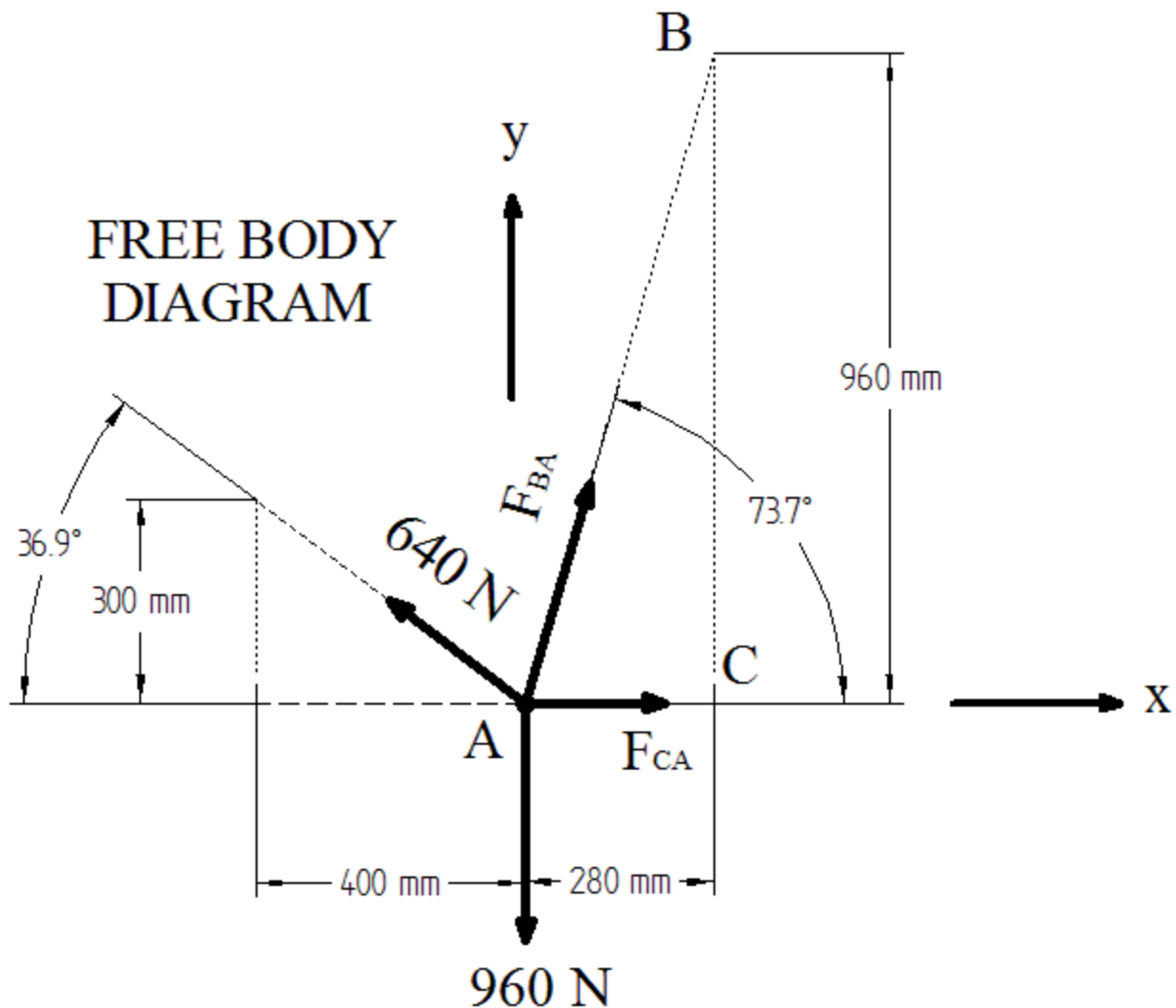


Figure 2: Particle Free Body Diagram.

Dashed construction lines with appropriate length dimensions were constructed first. Angular dimensions were measured using the dimensioning feature. Known and unknown forces were drawn. In this case the 640 N force and the 960 N force have known magnitudes and directions. The directions of F_{BA} and F_{CA} are known, because these forces are applied by cables, which can only be in tension. No attempt was made to scale the force vectors in Figure 2.

Step two was to construct the vector polygon based on the free body diagram. The vertical

960 N force was drawn first, based on an appropriate force scale. From the tip of the vertical force, the 640 N force was drawn at an angle of 53.1° to the vertical. These two vectors are shown as thick lines in the diagram below. For equilibrium the polygon must close, and the directions of F_{BA} and F_{CA} are known. Unknown force F_{BA} was drawn from the tip of 640 N force at an angle of 73.7° to the horizontal, and F_{CA} was drawn horizontally to the tail of the 960 N force. SmartSketch's "trim corner" feature was used to finalize the polygon by locating the intersection of the tip of F_{BA} with the tail of F_{CA} . The result is shown in Figure 3.

SOLUTION

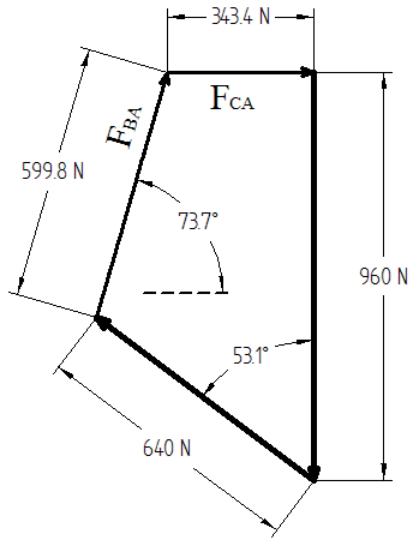


Figure 3: Particle Force Polygon.

The solution vectors for F_{BA} and F_{CA} are shown as thinner lines in Figure 3. The magnitudes of these forces were determined by the dimensioning feature. Thus

$$F_{BA} = 599.8 \text{ N} \quad \text{and} \quad F_{CA} = 343.4 \text{ N}.$$

Example 2: Equilibrium of a Rigid Body

This example is taken from the same source as Example 1. The picture is shown in Figure 4.

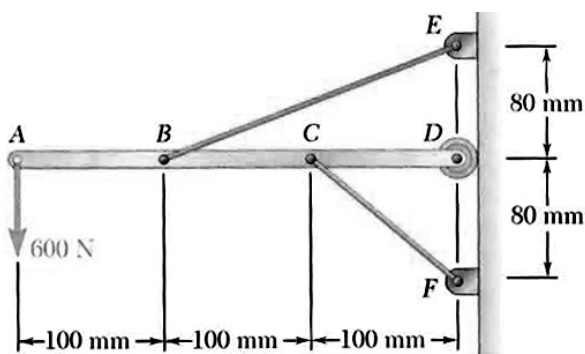
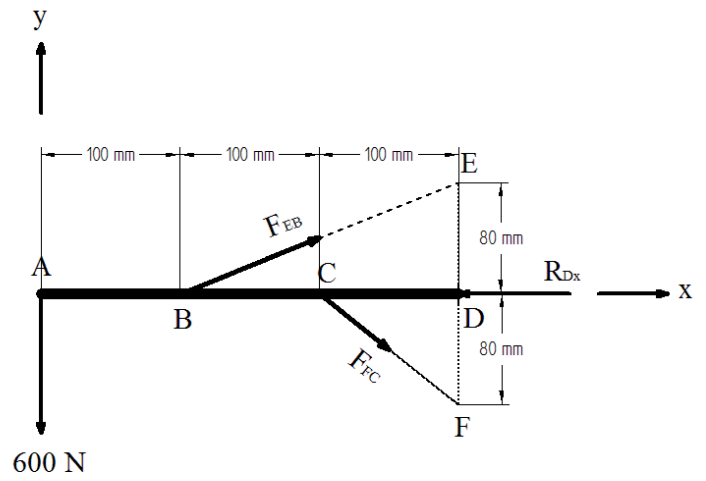


Figure 4: Rigid Body Picture.

Again the picture was transformed into a free body diagram, which is shown in Figure 5.

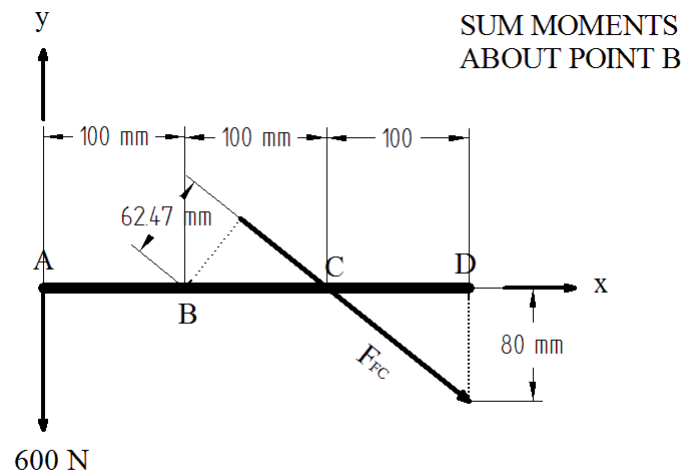
Because F_{FC} and F_{EB} are applied by cables, their directions are known.



FREE BODY DIAGRAM

Figure 5: Rigid Body FBD.

In this problem there are three equilibrium equations and three unknowns: the magnitudes of R_{Dx} , F_{EB} , and F_{FC} . Taking moments about B allowed the direct calculation of F_{FC} . The value of F_{FC} was determined from the construction shown in Figure 6.



$$F_{FC} = (600\text{N} \cdot 100\text{mm}) / (62.47\text{mm}) = 960.5\text{N}$$

Figure 6: Rigid Body Moments.

In Figure 6, forces that have no moment about B are omitted for clarity. The moment arm of F_{FC} was measured in the CAD drawing. This is

shown as a dotted line of length 62.47 mm. It was constructed to begin at point B and be perpendicular to F_{FC} . As in Example 1, the “trim corner” feature was used in this construction. With the value of the moment arm known, the magnitude of the force was calculated from the equation shown in the figure.

With the value of F_{FC} in hand, the values of R_{Dx} and F_{EB} were determined by constructing the force polygon in a process similar to Example 1. Figure 7 shows the force polygon.

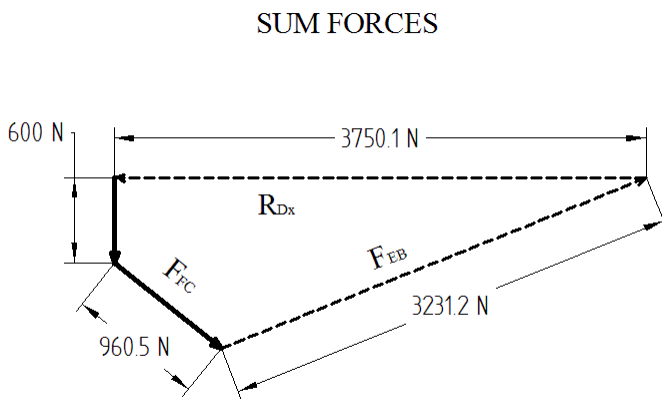


Figure 7: Rigid Body Force Polygon.

Unknown forces were measured using the dimensioning feature. The results are

$$R_{Dx} = 3750.1 \text{ N} \quad \text{and} \quad F_{EB} = 3231.2 \text{ N}.$$

Conclusions

In Example 1, the unknown forces acting on a particle were determined without recourse to any calculations. In Example 2, one simple calculation was needed, but no trigonometry was used. The use of CAD makes it possible to obtain very accurate answers in a process that emphasizes the visual nature of statics.

Using calculators or equation solving software, students perform calculations that confirm the graphical results.

Reference

1. Beer, Johnston, Mazurek, Cornwell. 2013. *Vector Mechanics for Engineers*. New York: McGraw-Hill.
2. Cheng, Ron K. C. 2005. *Using SmartSketch 5*. Clifton Park, NJ: Thomson Delmar Learning.

Biographical Information

Edwin G. Wiggins holds BS, MS, and Ph.D. degrees in chemical, nuclear, and mechanical engineering respectively from Purdue University. He is the Mandell and Lester Rosenblatt Professor of Marine Engineering at Webb Institute in Glen Cove, NY. Ed is a past chairman of the New York Metropolitan Section of the Society of Naval Architects and Marine Engineers (SNAME) and a past regional vice president of SNAME. A Centennial Medallion and a Distinguished Service Award recognize his service to SNAME. As a representative of SNAME, Ed Wiggins has served on the Engineering Accreditation Commission, the Technology Accreditation Commission, and the Board of Directors of the Accreditation Board for Engineering and Technology (ABET).