A More Effective Sequence for Teaching Statics to Civil Engineering Students

by

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Introduction

Engineering Mechanics - Statics is a core course in most of the engineering disciplines, and is generally taught by a civil and/or a mechanical engineering faculty at the nations ABET accredited colleges and universities. The quality of the texts available in the market for teaching this course has drastically improved during the past ten to fifteen years. This is due to the fact of including real life problems as examples and homework problems in the text, as well as the utilization of colored drawings and pictures. Additionally, most of the texts also provide study examples through the electronic media in the form of CD ROM.

In spite of all the improvements that the authors have incorporated in the texts, the subject of Statics remains a difficult one for students. This assessment is based on the experiences of the author of this paper who has taught this course many times during the past more than thirty years. In particular, the students who are majoring in civil engineering have found this course quite difficult due to their not being quite familiar with the mathematical requirements that are necessary in handling the three dimensional parts of this course. The authors of the most generally available Statics texts, on the other hand, have maintained a sequence for the contents of the subject matter in their books that should be covered in Statics a course, as is given in the next section. Although logical from various aspects, this sequence does not appear to be very effective, especially for most of the civil engineering students as is explained later.

The Generally Prevalent Sequence in a 3-Hour Statics Course

The generally adopted sequence in a 3-hour Statics course given in *Vector Mechanics for Engineers* by Beer, Johnson, and Eisenberg is as follows:

- Introduction
- Statics of Particles
    - Forces in a Plane
    - Forces in Space
    - Rigid Bodies: Equivalent System of Forces
    - Equilibrium of Rigid Bodies
        - Equilibrium in Two Dimensions
        - Equilibrium in Three Dimensions
- Distributed Forces: Centroids and Centers of Gravity
    - Areas and Lines
    - Volumes

- Analysis of Structures
  - Trusses
  - Frames and Machines
- Forces in Beams and Cables
  - Beams
  - Cables
- Friction
- Distributed Forces: Moments of Inertia
  - Moments of Inertia of Areas
  - Moments of Inertia of Masses
- Method of Virtual Work

Similar topic sequences are also followed by almost all of the authors of other text books in Statics.

As can be noted above, the first four topics mentioned above, up to *Distributed Forces: Centroids and Center of Gravity,* include two-dimensional as well as three-dimensional concepts, the latter necessarily requiring the use of vector algebra to get simpler and logical, as well as, understandable solutions to problems. The rest of the topics shown above are primarily handled in the texts for two dimensional cases where the use of vectors is not needed, and their use makes understanding of problems and their solutions more complex. This is the case for the analysis of two dimensional trusses, and machines and frames; topics on friction, moment of inertia of areas, and mass moment of inertias of rods and thin plates. Some of the three dimensional topics of truss analysis and moments of inertia are rarely included in the first course in Statics. This is particularly true for courses taught to students in civil engineering discipline.

A Preferred and Tried Sequence of Teaching Statics to Civil Engineering Students

Throughout the years of teaching Statics to engineering students, this author noted the following disturbing fact from quite a large number of students, especially those who were having difficulty with the course. After having once been exposed to the concept of a force and/or a distance as a vector quantity in a three dimensional space, the students would tend to use these quantities as vectors utilizing vector notation and vector algebraic principles, even for problems involving only two dimensions. More often than not, this made the problem more awkward and difficult, and many students lost the physical meaning and understanding of the given problem, and got busy simply performing vector calculations.

In the view of this author, the real fun and enjoyment of teaching and learning Statics, and its principles, for undergraduate students comes not from manipulation of mathematical equations, but from a physical understanding of the equilibrium associated with real life situations normally encountered by all of us in our daily lives. These equilibrium principles can be emphasized to students with the help of many excellent two-dimensional examples and homework problems given in the current texts without making use of any vector calculations.

In an effort to remedy this situation and give students a solid grounding of equilibrium principles, including idealization of structures as well as application of correct boundary conditions for determinate problems, the author of this paper has successfully tried a new course sequence for the past few semesters. In this new sequence all concepts are initially covered for problems in two dimensions, thus, not requiring the use of any vector algebra. Thus, the chapter on statics of particles deals with forces only in a plane. Similarly, the chapter on equilibrium of rigid bodies limits itself to equilibrium in two dimensions only. Following similar philosophy, the chapters on distributed forces: centroids and center of gravity deal only with areas and lines, analysis of structures with 2-D trusses and frames and machines. Other subjects such as beams and cables, friction, moment of inertia and mass moment of inertia are also initially limited to two dimensions. Although many new concepts of statics have been taught to students in the above chapters, none involved the use of vector notation or vector algebra. It is only after the students have learnt all the above mentioned statics concepts and principles in two dimensions, and are quite comfortable with them, that they are asked to revisit the earlier chapters of statics of particles and equilibrium of rigid bodies, but now in three dimensions and using all the rigors of the vector notation and vector algebra. Students by this stage in the course are quite familiar with the basic principles of statics, and are easily able to deal with three-dimensional problems.

The author has also had the opportunity to have students evaluate the new sequence and report on its effectiveness. Almost all, over 90%, of the responding students have liked this sequence and have been very pleased with it. Some of the comments written by students at the end of the course during class evaluation are: '…leaving 3D for last subject is a great idea – it really helped me focus on fundamentals first before tackling 3D problems.' 'The teaching method of covering all the two-dimensional material first, then moving to 3-D was a good idea.' 'I enjoyed separating the course into 3D and 2D. I feel it gave us a chance to fully understand the 2D material before we were asked to move on to 3D.' 'I felt the way you taught the course was good. Putting the 3D at the end helped me to understand the material much better.'

Based on the above-cited students' comments and this author's experience, it may be time for all faculty who teach 'Statics' to civil engineering students to rethink the rationale of teaching Statics using the old and traditional sequence, and possibly adopt the new sequence of teaching 2-D Statics before 3-D Vector Statics. The objective of this paper is to present this author's experiences in teaching 'Statics' and to stimulate discussion among instructors on the merits (or demerits) of this new approach.