Staff Survey on Educational Outcomes
TAM 2030, Dynamics, Spring 2013

Assembled by Andy Ruina

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1 Introduction

Each of the 12 undergraduate and graduate graders and TAs was given the following request at the end of the semester:

> For each of this course's 6 learning outcomes on the course Syllabet please
>
> i. Give the % of the students *you* would gauge as competent at the given item. You can give any caveats, error bounds, qualifications that you name.
>
> ii. Say, in words, how successful we were at this, with examples and anecdotes (e.g., based on problem sessions near the end of the semester, or HW near the end of the semester, or final exam problems).

The professor's assessments, are first.

2 Professor Andy Ruina's comments on educational outcomes

These assessments are based on questions in lecture, quiz responses in lecture, after-lecture questions, office hours, and the grading of about 10 students for each of the five problems on the final exam. **1)**

Can students draw free-body diagrams, distinguishing forces from inertial effects?

- **i.** 50% - 100%
- **ii.** If told to draw a free body diagram for a well-defined and familiar problem 100% will have it about right. On the other extreme, if told to do a problem where no explicit mention is made of free body diagrams, many students will still start right in with equations. When making the drawing many will not be clear about what is in the system and what is not. And many will not clearly indicate what is known about the forces in the free body diagram (e.g., magnitude?, direction?, neither?, both?).

2) Can students describe particle motion in 1-D, 2-D and 3-D employing Cartesian and path coordinates?

- **i.** 10% - 100%
- **ii.** For straightforward familiar problems using cartesian coordinates, most students seem to understand that $\vec{r}(t) = x(t)\hat{\imath} + y(t)\hat{\jmath}$ and that velocity and acceleration can be found by differentiation. On the other extreme, few students can use pat coordinates or the relative-acceleration formulas in unfamiliar situations.

3) Can students characterize 2-D motion, including vector angular velocities and accelerations?

- **i.** 20% - 90%
- **ii.** Most people know the words and symbols $\vec{\omega}$ and $\vec{\alpha}$. And most can calculate the relative velocity of two points on a rigid object using $\vec{v}_{B/A} = \vec{\omega} \times \vec{r}_{B/A}$. However, a substantial number of students are confused when using such concepts in complex situations, such as the kinematics of rolling.

4) Can students apply Newton/Euler laws to the motion of particles and rigid bodies?

i. 20% - 90%.

ii. Most students can write $\vec{F} = m\vec{a}$ and use it reasonably in simple familiar 2D particle motions. Most cannot use these equations functionally in complex new 2D problems involving both translation and rotation.

5) Can students use the principles of linear/angular impulse-momentum and work-energy to solve dynamics problems?

i. 20% - 80%

ii. If given a problem clearly lined up for conservation of some particular quantity, and that problem is similar to a homework problem, and just enough, and not too much information is given, most students can carry out the calculations for momentum, angular momentum, and energy. If all of these helpful aspects are lacking, many students will be poor at judging when to use differential equations and when to use conservation laws, and they are poor at judging which conservation law to use.

6) Can students recognize simple harmonic motion for 1-degree-of-freedom mechanical systems?

i. 10% - 90%

ii. Given the differential equation $m\ddot{x} + kx = 0$ most students can find a solution and the period of oscillation. But if the variables are changed in name, and it takes familiarity with a problem to know which symbols are constants and which are functions of time, they are not quick to recognize the equation or its solution.

3 Responses from TAs, graders and TA

The responses from TAs and graders on the following pages have been edited slightly for clarity (e.g., punctuation and grammar).

3.1 Matthew Kelly, Graduate TA, mpk72@cornell.edu

1) Can students draw free-body diagrams, distinguishing forces from inertial effects?

i. 85%

ii. The vast majority of students know how to draw a free body diagram. Most can do it correctly in challenging cases as well. I saw this while grading exams and in office hours.

2) Can students describe particle motion in 1-D, 2-D and 3-D employing Cartesian and path coordinates?

i. 20%-50%

ii. All students can do 1-D motion. 90% can do 2-D cartesian coordinates, 70% can do 3-D cartesian coordinates. 20% can do 2-D and 3-D path coordinates. I worked with several students in office hours that were very confused about path coordinates. On the other hand, nearly everyone had a good idea of how to do polar coordinates in 2-D.

3) Can students characterize 2-D motion, including vector angular velocities and accelerations?

i. 90%

ii. Nearly all students are competent at this - it was emphasized in the course. I noticed that many of the weaker students were able to do 2-D motion using vectors in office hours.

4) Can students apply Newton/Euler laws to the motion of particles and rigid bodies?

i. 90%

ii. This was another aspect of the course that was stressed heavily, and students learned it. I saw this in office hours and while grading exams.

5) Can students use the principles of linear/angular impulse-momentum and work-energy to solve dynamics problems?

i. 30-60%

ii. Most students have a vague notion of these ideas, but many of them do not know when to apply them, or how to use them in tricky situations. The last problem on the final showed that the majority of students (80%) were not able to recognize that they needed to use conservation of angular momentum, and instead tried to conserve energy or use [sum of moments is equal to rate of change of angular momentum]. When working with students in office hours and in problem solving sessions I also noticed that they did not have a deep understanding of energy conservation.

6) Can students recognize simple harmonic motion for 1-degree-of-freedom mechanical systems?

i. 90%

ii. This topic was thoroughly covered, and most students know how to do it for simple systems. Most students would have trouble if the linearization was non-obvious.

3.2 Malika Grayson, Graduate TA, graysonmalika@gmail.com

1) Can students draw free-body diagrams, distinguishing forces from inertial effects?

- **i.** 75% of the students I encountered knew how to draw a correct free body diagram.
- **ii.** Continuous weekly problem sessions and homework helped in giving students the needed practice.

2) Can students describe particle motion in 1-D, 2-D and 3-D employing Cartesian and path coordinates?

- **i.** 100 % can describe motion in cartesian, coordinates and around 70 % can efficiently employ path coordinates.
- **ii.** In problem sessions students were progressively better able to convert to path coordinates or recognize the need for path coordinates.

3) Can students characterize 2-D motion, including vector angular velocities and accelerations?

- **i.** Over 75 % can not only understand how a given 2D system works, but can fully describe 2D motion mathematically
- **ii.** Students were able to adequately use the five term acceleration formula on homework and in problem sessions.

4) Can students apply Newton/Euler laws to the motion of particles and rigid bodies?

- **i.** More than 90 % can apply Newton Laws for a given system.
- **ii.** Towards the end of the semester, students were no longer guessing about what to use, but stating, step by step, what law should be used when and why.

5) Can students use the principles of linear/angular impulse-momentum and work-energy to solve dynamics problems?

- **i.** Over 90 % of students are more comfortable now with linear and angular momentum problems. About 70 % are comfortable with energy methods.
- **ii.** Homeworks, recitations, exams and problem sessions really helped in instilling the core factors for these methods.

6) Can students recognize simple harmonic motion for 1-degree-of-freedom mechanical systems?

- **i.** Over 90 % can readily recognize the simple harmonic motion of obvious systems such as a simple pendulum or a spring mass system. 65 % would be able to recognize more complicated system motions, such as for an inverted pendulum.
- **ii.** Again, homeworks, recitations and problem sessions as well as class examples most importantly provided the best practice and explanations for these topics. The only way to gauge if students really understood were by exams or problem sessions. Going through exams by students, I noticed an improvement, going through the semester.

3.3 Huichan Zhao, Graduate TA, hz282@cornell.edu

1) Can students draw free-body diagrams, distinguishing forces from inertial effects?

i. 95%

ii. Almost all students know that they should draw free-body diagram before solving a problem. A few of them sometimes didn't draw a "free" body diagram, leaving in other objects (like the slope) in. But these situations were not common at the end of this semester.

2) Can students describe particle motion in 1-D, 2-D and 3-D employing Cartesian and path coordinates?

i. 85%

ii. Almost all students can use Cartesian coordinates to describe motions of a particle. But some students can't use path coordinates. In some situations where path coordinate are the better choice, they would still chose to use Cartesian coordinates.

3) Can students characterize 2-D motion, including vector angular velocities and accelerations?

i. 80%

ii. A students once ask me about the inertia of a mass point. I guess he doesn't know that only rigid objects have the concepts of angular velocity and acceleration.

4) Can students apply Newton/Euler laws to the motion of particles and rigid bodies?

i. 90%

ii. I think everyone knows how to use them, a few may use them incorrectly in detail.

5) Can students use the principles of linear/angular impulse-momentum and work-energy to solve dynamics problems?

i. 50%

ii. Half of the students can solve the square-tipping-over problem independently, which uses angular momentum conservation and energy conservation. [Andy's note: On the final exam most students had trouble with this problem, the last, perhaps time-rushed, problem.]

6) Can students recognize simple harmonic motion for 1-degree-of-freedom mechanical systems?

i. 70%

ii. Some student may not know what simple harmonic motion is.

3.4 Kevin Kircher, Graduate TA, kjk82@cornell.edu

1) Can students draw free-body diagrams, distinguishing forces from inertial effects?

i. 90%
ii. Based on exam grading.

2) Can students describe particle motion in 1-D, 2-D and 3-D employing Cartesian and path coordinates?

i. 70%
ii. I don't think most of the staff can employ path coordinates, let alone the students. 1-2D Cartesian and polar are good though, from recitation and exams.

3) Can students characterize 2-D motion, including vector angular velocities and accelerations?

i. 60%
ii. The knowledge is in their brains, but getting it on paper is a problem. Acceleration is consistently miscalculated on exams.

4) Can students apply Newton/Euler laws to the motion of particles and rigid bodies?

i. 80%
ii. AMB is the hammer they added to their toolbox this semester. Recitation and exams.

5) Can students use the principles of linear/angular impulse-momentum and work-energy to solve dynamics problems?

i. 70%
ii. n/a

6) Can students recognize simple harmonic motion for 1-degree-of-freedom mechanical systems?

i. 90%
ii. Exam grading says yes. Distinct improvement on this from prelim 3 to final.

3.5 Lorraine Weis, Graduate TA, lmw236@cornell.edu

1) Can students draw free-body diagrams, distinguishing forces from inertial effects?

i. 85%

ii. Most students can draw free-body diagrams successfully. However, for the arrow problem (Prelim 3, problem 3), some conflated their expectation for the behavior with the direction of the forces on the FBD.

2) Can students describe particle motion in 1-D, 2-D and 3-D employing Cartesian and path coordinates?

i. 90%

ii. Most students can describe particle motion in Cartesian coordinates, though some have trouble with path coordinates. For the rotating disk problems, most, appropriately, wanted to use polar coordinates instead.

3) Can students characterize 2-D motion, including vector angular velocities and accelerations?

i. 60%

ii. Some students had trouble using vector methods and instead tried to separate into components which allowed more algebra errors.

4) Can students apply Newton/Euler laws to the motion of particles and rigid bodies?

i. 85%

ii. Most students can apply Newton's laws to gain insight, for example with the pushing the bicycle problem.

5) Can students use the principles of linear/angular impulse-momentum and work-energy to solve dynamics problems?

i. 70%

ii. Most students use these principles to solve dynamics problems, and do so effectively.

6) Can students recognize simple harmonic motion for 1-degree-of-freedom mechanical systems?

i. 85%

ii. Most students are familiar with simple harmonic motion.

3.6 Ryan Gryszko, Undergraduate TA, reg98@cornell.edu

1) Can students draw free-body diagrams, distinguishing forces from inertial effects?

- **i.** 95%
- **ii.** The students are very competent with FBDs from previous classes. Sometimes I did notice that they might miss something especially if they break apart the system at hand.

2) Can students describe particle motion in 1-D, 2-D and 3-D employing Cartesian and path coordinates?

- **i.** 95% (Cartesian) 80% (Path)
- **ii.** The students are very competent with Cartesian coordinates from previous physics classes. Path coordinates are something new to them and although I sensed the students understood the material they were not entirely sure of the formulas or derivation of path coordinates; especially with problems employing path and polar coordinates.

3) Can students characterize 2-D motion, including vector angular velocities and accelerations?

- **i.** 85%
- **ii.** Students are very competent with 2D motion but once in a while I noticed problems with understanding the vector parts of this.

4) Can students apply Newton/Euler laws to the motion of particles and rigid bodies?

- **i.** 90%
- **ii.** The students in my opinion understand when to apply certain conditions and laws but once in a while forget that they can apply these laws. But they do certainly understand what they are and why you can use them.

5) Can students use the principles of linear/angular impulse-momentum and work-energy to solve dynamics problems?

- **i.** 75% (impluse-momentum) 85% (work-energy)
- **ii.** I felt a lot of the questions I received via Problem Solving Sessions and Office Hours were concerning impulse and momentum. It might have been that there was not much of a focus on that material or at least in not much depth. It could also be that rotation is something not focused on in previous courses and they must learn in this class how it affects momentum and energy.

6) Can students recognize simple harmonic motion for 1-degree-of-freedom mechanical systems?

- **i.** 100%
- **ii.** Yes, I do believe that this is something very recognizable to the students.

3.7 Alex Masetti, Undergraduate TA, awm62

1) Can students draw free-body diagrams, distinguishing forces from inertial effects?

- **i.** 90% of students drew free body diagrams correctly and were able to effectively use them to solve problems.
- **ii.** Nearly everyones' free body diagrams were effective and correct once drawn, although, even at the end of the semester, students were sometimes reluctant to start problems with free body diagrams, which made solving them difficult.

2) Can students describe particle motion in 1-D, 2-D and 3-D employing Cartesian and path coordinates?

- **i.** 95% of students were comfortable describing particle motion in different coordinate systems.
- **ii.** By the end of the semester, nearly everyone was comfortable using their knowledge of particle motion and coordinate systems to solve the more difficult problems which occurred at the end of the course.

3) Can students characterize 2-D motion, including vector angular velocities and accelerations?

- **i.** 90% of students could successfully characterize 2-D motion.
- **ii.** In the problem sessions at the end of the semester, most students were very comfortable using 2-D velocity and acceleration equations to solve problems. They had some difficulty solving problems with multiple rigid bodies and complicated linkages.

4) Can students apply Newton/Euler laws to the motion of particles and rigid bodies?

- **i.** 97% of students could apply Newton laws to the motion of particles and rigid bodies.
- **ii.** Very nearly everyone was very comfortable solving simple dynamics problems. Although some still had difficulty, by the end of the course, most students were capable of solving more complicated problems that required bridging kinematics and dynamics.

5) Can students use the principles of linear/angular impulse-momentum and work-energy to solve dynamics problems?

- **i.** 85% of students were good at solving impulse-momentum problems, and somewhat more were comfortable with using work-energy.
- **ii.** Although some students had difficulty with these problems, many developed intuition both for solving mechanics problems and for seeing when using energy could get useful information out of a difficult problem.

6) Can students recognize simple harmonic motion for 1-degree-of-freedom mechanical systems?

- **i.** 75% of students could recognize and solve SHM problems successfully.
- **ii.** Students sometimes found it hard to identify that a problem involved SHM, but, once they did, they were very capable of solving the problem and extracting useful information about the system's behavior.

3.8 Lijia Wang, Undergraduate grader, lw344

1) Can students draw free-body diagrams, distinguishing forces from inertial effects?

i. 95%-100%

ii. As homework assignments progressed, free-body diagrams improved. They are not always drawn neatly, but in the end, almost all of them had the right forces and moments.

2) Can students describe particle motion in 1-D, 2-D and 3-D employing Cartesian and path coordinates?

i. 60%-80%

ii. Students were mostly able to do so in the homework assignments. However, since the solutions are available, some of them likely consulted the solutions. The exam scores indicate that quite a few students had trouble with the more complicated motions.

3) Can students characterize 2-D motion, including vector angular velocities and accelerations?

i. 70%-90%

ii. Students' homework assignments tend to be sloppy, without proper vector equations. But overall, toward the end of the semester, the quality improved. Though once again, some of them had trouble with the more complicated problems on the exams.

4) Can students apply Newton/Euler laws to the motion of particles and rigid bodies?

i. 80%-90%

ii. This is a very general question. Most students can apply Newton's Laws for simple motions. But the number of students that can adequately do this decreases with increasing complication of the motion.

5) Can students use the principles of linear/angular impulse-momentum and work-energy to solve dynamics problems?

i. 70%-90%

ii. Students improved with linear and angular momentum balance throughout the semester. Work-energy principles were not commonly used.

6) Can students recognize simple harmonic motion for 1-degree-of-freedom mechanical systems?

i. 80%-100%

ii. Based on the homework assignments, most students learned to adequately apply sinusoidal motion for one degree of freedom systems.

3.9 Matthew Pizzonia, Undergraduate grader, mhp56@cornell.edu

1) Can students draw free-body diagrams, distinguishing forces from inertial effects?

i. 95%

ii. As a grader, I believe almost all students were capable of doing this by the end of the course. Obviously, the accuracy with which they draw the diagrams depends on the complexity of the system, but for the most part, they did a good job. We stressed this on homeworks and exams, end by the end of the course, we almost never had to deduct point on homeworks for missing or incorrect FBDs.

2) Can students describe particle motion in 1-D, 2-D and 3-D employing Cartesian and path coordinates?

i. 85 %

ii. The % age of students that can do this depends on if we are talking about 1D, 2D, or 3D and whether its cartesian or path coordinates. Students definitely begin to struggle more as the number of dimensions increases, and based on homeworks, they have much less trouble with cartesian coordinates than with path coordinates. Still, by the end of the course, I'd say about 8 or 9 of every 10 students could successfully describe the motion of a particle. It tends to be the application or implication of that motion that gives them the most problems.

3) Can students characterize 2-D motion, including vector angular velocities and accelerations?

i. 85%

ii. This is about the same as the previous one. Considering how much emphasis is placed on deriving and solving the equations of motion of a system, they can do this successfully for the most part. If it is a system they haven't seen anything like, however, they probably will tend to struggle.

4) Can students apply Newton/Euler laws to the motion of particles and rigid bodies?

i. 75%

ii. Students can usually do this well, as the math required tends to be a bit less complex and rigid body motion + collisions tend to be a bit more intuitive. However, students seemed to do worse on these homeworks, so I would say that they were more capable of doing the math, but didn't all take the time to gain an intuitive understanding of the concepts before working out the problems.

5) Can students use the principles of linear/angular impulse-momentum and work-energy to solve dynamics problems?

i. 90%

ii. This is essentially key to this course. Conservation of energy, and understanding conservation or change in linear or angular momentum allows a student to solve most problems in this course. I believe that the students could again do this math quite well, but I believe their conceptual understanding was a bit lacking, making it difficult for them to approach problems they had no previous exposure to.

6) Can students recognize simple harmonic motion for 1-degree-of-freedom mechanical systems?

i. 85%

ii. I believe students understand and can recognize simple harmonic motion quite well. However, when it comes to applying this understanding to gain insight into the motion of a system, or to simplify a problem, they were hesitant to use this understanding. The reason for this is the same as for the previous few topics: *They are uncomfortable with problems they haven't seen before.*

3.10 Varun Natraj, Undergraduate TA , vrn3@cornell.edu

1) Can students draw free-body diagrams, distinguishing forces from inertial effects?

i. 100%

ii. All of the students I taught in problem sessions were able to draw clear and correct FBD's by the end of the semester.

2) Can students describe particle motion in 1-D, 2-D and 3-D employing Cartesian and path coordinates?

i. 85%

ii. I think all students can use multiple coordinate systems, i just think that some still struggle to identify the best coordinate system.

3) Can students characterize 2-D motion, including vector angular velocities and accelerations?

i. 100%

ii. By the end of the semester it seemed like all students were comfortable with these concepts.

4) Can students apply Newton/Euler laws to the motion of particles and rigid bodies?

i. 100%

ii. This is a broad question, but I think that students have a solid basic understanding of the laws of motion.

5) Can students use the principles of linear/angular impulse-momentum and work-energy to solve dynamics problems?

i. 90-100%

ii. I believe that all students can utilize these concepts to solve dynamics problems. Some may still not be able to identify the quickest or easiest method though.

6) Can students recognize simple harmonic motion for 1-degree-of-freedom mechanical systems?

1. 85%

2. I think a lot of students can. But since there are varying levels of comfort with differential equations I have noticed some who don't identify SHM initially.

3.11 Michael Mehallow, Undergraduate grader, mjm468@cornell.edu

1) Can students draw free-body diagrams, distinguishing forces from inertial effects?

i. 95%

ii. Throughout the semester it was clear that students learned how to draw correct free-body diagrams, as evidenced by their homework assignments.

2) Can students describe particle motion in 1-D, 2-D and 3-D employing Cartesian and path coordinates?

i. 90%

ii. Students demonstrated their ability and improvement in describing particle motion in their homework assignments, and by correcting exam problems answered incorrectly.

3) Can students characterize 2-D motion, including vector angular velocities and accelerations?

i. 90%

ii. By the end of the semester almost all students were able to characterize 2-D motion, including angular velocity and acceleration.

4) Can students apply Newton/Euler laws to the motion of particles and rigid bodies?

i. 95%

ii. From homework assignments and exam corrections it could be seen that students were able to apply Newton and Euler Laws to both easy and advanced problems.

5) Can students use the principles of linear/angular impulse-momentum and work-energy to solve dynamics problems?

i. 90%

ii. The section of the course on impulse-momentum and work-energy successfully demonstrated how to use these concepts and was effective in teaching students how to apply these concepts to new dynamics problems.

6) Can students recognize simple harmonic motion for 1-degree-of-freedom mechanical systems?

i. 100%

ii. Essentially all students learned how to recognize simple harmonic motion by completing numerous problems involving oscillatory systems.

3.12 Katie Mcquade, Undergraduate Tutor, kam358@cornell.edu

I had 4 students I saw regularly. I only turned one student down who first asked for help in the middle of study week.

Feedback as far as what I saw:

Maybe it's my preference after intermediate dynamics and Lagrange equations, but I really love using energy to do problems. I constantly encouraged my students to use conservation of energy (either E_K+E_P= constant), or taking a time derivative of the total energy equation, $\dot{E}_K + \dot{E}_P = 0$). I didn't find that students were as willing to use, or just didn't think to use, energy as I would have liked them to be. Maybe more practice with energy would be helpful for them?

I don't think I saw too many problems with drawing proper FBDs, and everyone was good with understanding that you need one equation for each DOF. My students understood polar coordinates well. I ended up reinforcing a lot that deriving the acceleration vector from the position vector was a much better way to go than memorizing 5 term acceleration, if memorizing wasn't the student's strong suit.

In summary, for questions 1 - 4, my students did pretty well. With 5, the energy was a little lacking as I mentioned. For 6, they recognized simple harmonic motion well, but finding things such as natural frequency were sometimes a little difficult.