Different Teaching Styles and the Impacts on Test Design for Dynamics

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The pedagogical design of a classroom, including the class environment, assessment methods, and learning outcomes, impacts everything that students do and learn in that course. There are many different methods of teaching that have emerged and been explored in engineering classrooms in recent years such as flipped classrooms, repeated testing, courses with in-class hands-on activities, and also many courses that continue to be taught in a lecture-based environment. Undergraduate Dynamics is one of the standard engineering courses for many engineering majors where the content is well established and has not changed in decades; however, the implementation of different teaching styles has had an impact on the way the material is presented and covered in the class. Through discussion amongst three instructors at different universities with different teaching styles they discovered notable differences in how each instructor writes, solves, and evaluates their course problems in undergraduate Dynamics. The three teaching styles include (1) a flipped, recitation-based classroom that uses a mastery-based derivation approach to solving problems, (2) a lecture style class using the SMART Assessment approach, and (3) a lecture style class with 3 levels of student participation worked into the class to engage both reflective and active learners. The instructors chose several standard dynamics problems to analyze, where each instructor tailored the problem statement for their course and included how they would require the students to solve the problem and how they would evaluate the solution. These problems will be assigned for future exams in each instructor's class, graded in their own style, and then evaluated as a team to assess student learning outcomes. This work-in-progress paper will present the differences in the style of the problem statement, solution, and evaluation for some of these dynamics problems.

Introduction

Classroom design is unique to each instructor and each subject, but design differences can impact all aspects of the class including how students spend their time, their classroom environment, assessment style, and even how course content is presented and discussed. Students are adaptable and learn in many different styles that result in a variety of different outcomes, but often these different classroom designs are reported based on end-of-semester/year outcomes. However, the impact that pedagogy has on course content is more nuanced than only looking at end of semester outcomes. Pedagogical design affects how students learn a subject, the way they understand it, how they approach the problem whether systematically or intuitively, and their perspective on the hierarchy of concepts. Some of the different course designs used in the higher education classrooms range from large lecture classes to small, flipped classrooms which all promote different types of student experiences. Included in these types of classroom environments there could be differences in the types of active learning strategies used, assessment methods, instructional technology, and other classroom activities and interactions [1]. Each instructor has their past learning experiences, their content knowledge, their pedagogical knowledge, and it is all these factors that are combined to create their classroom experience [2]. There are many different classroom models used and each one has its own unique requirements, and the mode of content delivery is informed by these aspects [3].

The research on different course designs looks at many different outcomes, but most often the significant outcomes include affective variables like student satisfaction of the course. One example between a flipped and nonflipped course was done in an engineering design course to determine the differences in group satisfaction between the two courses [4]. Another comparison study had similar outcomes where they found the student satisfaction differed between a traditional class and a flipped class [5]. Another study in a business course found that teaching style affected student attitude towards the class [6]. A study took a different perspective and found that an instructors outlook on different teaching styles increased when project-based learning was used [7]. Many of these studies also compared end of semester grades to see if teaching style affected those, but there were no statistically significant results in student scores for courses with different teaching styles.

The field of engineering has seen a significant shift in implementation of innovative course designs in the last few decades. These changes are heavily supported by engineering education research and faculty connections made. Through these faculty connections, discussions about teaching the same courses and addressing similar classroom issues spur further innovation in classroom designs. The conversations are rarely about the course content but rather how that information is delivered and assessed, resulting in a variety of different methods that are being used to teach these content-stable courses. One example of this type of collaboration implemented different teaching styles in several Statics courses to determine how it affected students, but there was no significant difference found between the instructors [8].

Dynamics is one such engineering course that is a core mechanics course taken by aerospace, civil, mechanical, and other engineering majors where the content has been established for over a century, but there are many new pedagogical styles being adopted in dynamics courses. Some of these styles include introducing active learning activities and interactive online components [9]. There has also been work done to create a classroom environment based on student learning styles to improve the pass rate in a dynamics course [10]. Along with these examples, there are many other classroom styles that have been anecdotally shared amongst faculty at conferences and other gatherings.

Through these conference discussions, three instructors became interested in the different style Dynamics courses that they teach. This led to a collaborative effort to better understand the differences in each instructor's teaching style and how that affected student learning. It was discovered that there were significant distinctions amongst all three dynamics courses including the way course time is spent, how students are assessed, and even how students are presented with and required to solve the problems. To identify the differences and how it affects student learning outcomes including responses on test instruments like concept inventories, the three instructors identified dynamics problems that could be used in each course to compare how the problems would be written, solved, and evaluated. This paper is part one of a work-in-progress study that describes the three classroom designs and presents two sample problems that will be given to each instructor's class.

Classroom design – University A

University A is a large R1 public institution in the southeast that uses a flipped classroom mastery-based grading approach. The dynamics class is a two-credit course that meets for 50 minutes twice a week with an enrollment of 40-50 students. The course is designed on a module system where students are focused on a module topic for two or three weeks with an assessment given at the end of each module. Each module focuses on a new type of dynamics problem and includes: (1) particle dynamics, (2) particle energy methods, (3) rigid body rod-type problems, (4) rectangular rigid body dynamics, and (5) circular rigid body dynamics. The majority of class time is spent in a recitation format with no lecture done during class time. During class the students are actively working on the problems of the day with fellow students while the instructor walks around to answer any of their questions. The lecture has been moved to outside of class time through two short videos posted at the start of each module for a total of 10 videos posted for the entire semester. The videos include the main ideas for the new module topic and an example video that goes through a solution to an example problem. The recitation environment provides the students a supportive time to discover how to solve new problems and ask any questions they have on the topic. The students are asked to solve 4-6 problems for each module during the recitation and then assessed on a single problem at the end of the module that is similar in difficulty to the recitation problems. The types of problems solved in recitation are carefully chosen to show the different nuances between problems with similar physical attributes but different dynamic outcomes. During recitation students can have conversations about these nuances and it has been a valuable learning experience from the instructor perspective to have deeper conversations with each student to identify their individual struggles.

The instructor at University A uses a mastery-based grading system which requires students to document the core pieces to every Dynamics problem they solve. The mastery grading system is based on a list of mastery objectives that are unique to dynamics and created from the foundational steps needed to solve any problem in the course. The students are asked to solve all their course problems following the mastery objective list and are graded for each individual objective. For every assessment, each student receives a score for each objective item assessed in that problem. The scoring rubric is: a – complete and correct, b – minor calculation error, c – minor conceptual error, d - major conceptual error, and e – no evidence shown. The total number of assessment opportunities include five problems during the semester, one at the end of each module, and three additional problems on the final exam making a total of eight problems the students are tested on throughout the course. Over the eight assessment opportunities, each student’s demonstration of mastery for each objective is recorded and accumulated. Mastery of an objective is awarded to a student once they have shown that they can do an objective correctly four times. This means that they must do the objective correctly on four different problems throughout the semester. Once they have reached mastery in an objective, they cannot earn any more credit and must focus on the objectives that have not reached mastery yet. This approach encourages repeated demonstration of understanding for every concept through testing those concepts on different problems at different points in time, but it also allows students opportunity to have a bad test day and do poorly when they are first learning. Each students mastery begins at 0 and slowly increases throughout the semester. Their goal is to master all the objectives by the end of the semester, demonstrating proficiency in dynamics. The mastery-based grading system provides both the instructor and students with more detailed feedback of their understanding and has guided valuable conversations about student learning.

The creation of the mastery objectives for dynamics required a step back to identify and create a cohesive list of objectives that could be used to solve every problem in the course. This resulted in a mastery objective list that requires the students to derive the equations of motions from first principles for every problem. It is a derivation based approach where the solution requirements are much more detailed for each problem so fewer problems are solved overall in this course and it often takes students a full 50-minute class period to solve one dynamics problem. A list of the mastery objectives and a more detailed description of the course set up can be found in [11].

Classroom design – University B

University B is a large R1 public institution in the midwest that uses SMART pedagogy. SMART stands for Supported Mastery Assessment through Repeated Testing. This is a mastery-based approach that seeks to train students to solve problems systematically rather than relying on intuition. Students are trained to develop intuition after they have learned how to solve problems systematically. Most of the students are mechanical engineering majors who are required to take the course. The course is designed around 5 modules including: (1) Newtonian particle dynamics in cartesian coordinates, (2) Newtonian particle dynamics in normal-tangential and polar coordinates, (3) momentum and energy methods for particles, (4) Newtonian rigid body dynamics, (5) momentum and energy methods for rigid bodies.

The 7/9ths of the class is spent in lecture format with derivations and examples. The class uses think-pair-share and other active learning techniques. During active learning exercises, the instructor poses a problem and students work in groups. The instructor walks around to answer questions. The remaining 2/9 of the classroom time is spent taking exams. The professor is available outside of class for office hours and a class specific tutoring staff is available to students 5 nights a week.

Instruction focuses on developing and utilizing a clear process for solving problems. The instructor focuses on using the process for each example problem. Students are taught to focus on setting up problems more than struggling through the algebra to solve them. Exams are written with the intent of having problems that students don't recognize, but can be solved by the application of the process.

The instructor at University B uses a mastery-based grading system which requires students to get the correct answer with commensurate support. Support in Newtonian sections includes a Free Body Kinetic Diagram (FBKD), equilibrium equations, and kinematic/constraint equations. Exams are scored as:

a) Correct with correct support (100%)
b) Incorrect with support that contains a simple non-conceptual error (80%)
c) Incorrect due to a conceptual error or missing support (0%)

Students are given 6 problems on each exam broken down into 4 sections

1) Concept problems (2x) - Typically do not require computations.
2) Simple problems (2x) - Typically require 2-4 calculations.
3) Average problem (1x) - Textbook style problems.
4) Challenge problem (1x) - Hard textbook style problems.

Students who miss a problem on an exam are required to identify their errors and re-work the solution to ensure that they have identified all errors and have practiced the right approach. For each test, students have two attempts (version A and version B) that cover the same concepts but with different questions. The exam grade is a combination of the best section scores from the two. Thus, students have at least two attempts to demonstrate competency with the material.

A more detailed description of the teaching method and evidence of success can be found in [12, 13].

Classroom design – University C

University C is a M1 public institution in the midwest that uses a traditional lecture-based style of teaching with some active learning methodologies in the classroom. For each lesson, each student receives a paper handout with 3 problem statements and final answers. The lectures are done on a whiteboard and are divided into 3 sections. First, theory is developed while presenting and setting up the first example problem. This first problem is primarily led by the instructor, posing only minor probing questions to the students. Then students are allowed time to process and apply the theory to a second problem in small groups or on their own. Students are asked to develop diagrams and equations in their small groups. During this time, the faculty attends to any questions students may have while setting up the problem. After some time, the instructor collects the class and works through the second example as a class with direction from the instructor and input from students. Before the third example is presented, the students are again allowed time to set up their diagrams and equations. During presentation of this final problem, the faculty is simply drawing diagrams and writing equations on the board, solely with the input from the students. There is minimal input from the instructor other than to collect majority opinion on directions of vectors, signs and magnitudes of variables or other minor errors that may occur during problem set up. For each problem, the goal is only to arrive at a complete set of equations; no algebra is processed! The instructor has already illustrated to students how their calculators can solve a 3x3 system of equations or roots for a polynomial for them.

In terms of homework – two formats of homework are collected from the students. Generally, two problems per lesson are assigned to be completed online. This usually counts about 30% of their homework grade. One handwritten homework assignment is collected per lesson and graded on completeness, correctness and also on formatting and problem presentation as a method of illustrating expectations for how exam solutions should be presented. This accounts for the other 70% of their homework grade.

A summary of the course attributes for the three Dynamics classes is given in Table 1.

Table 1: Classroom design attributes for three different dynamics courses

Classroom attribute	University A	University B	University C
Number of students	40-50	80-100	15-35
Meeting time per week	Twice for 50 minutes	Twice for 50 minutes. Once for 110 minutes	Twice for 75 minutes
Class style	Flipped, recitation based	Lecture, active learning, testing	Lecture
Number of homework problems required	20	44	~30 online ~15 handwritten
Assessment style	Mastery based	Mastery Based	Rubric based ~40% Graphical Set Up (Coord. Sys, FBD), 30% Equations, 20% Solution 10% Tech. Communication/ Neatness
Number of tests	5 assessments + 1 final exam	10 assessments	3
Number of problems tested throughout semester	8	90	14
Solution process	Derivation from first principles	Systematic approach using a 'compass'. Formula sheet provided.	Systematic starting from coordinate system selection and moving to kinematics and kinetics.
Equation sheet for exams	Student hand-written single sided page	Created by Professor. 2 pages (8.5x11). Posted on the first day of class.	The Math and Dynamics portions of the FE eqn sheet is provided. Also required are FE approved calculators. These can solve 3x3 system of equations and 3rd & 2nd order Polynomials

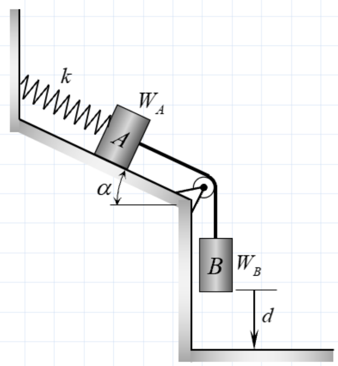
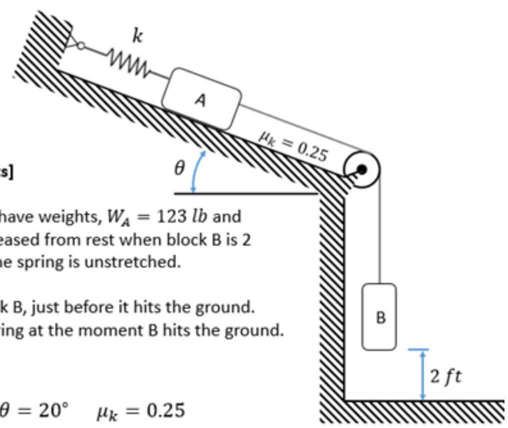
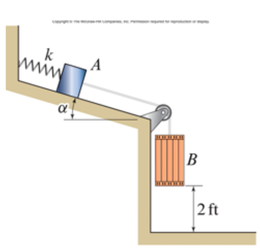
Chosen Problems

The three instructors created a set of problems that could be assessed in their courses. This assessment will happen during the Spring 2024-Fall 2024 semesters. Once the problems were chosen each instructor modified the problem statements to fit their course style. The problem statements for each instructor are given for two of the chosen problems followed by the instructor generated solution for the two problems. The included instructor generated solutions are more detailed than what the students would be expected to submit but includes the key components each instructor will look for when grading. The grading of the problems will be completed by the instructors of each course.

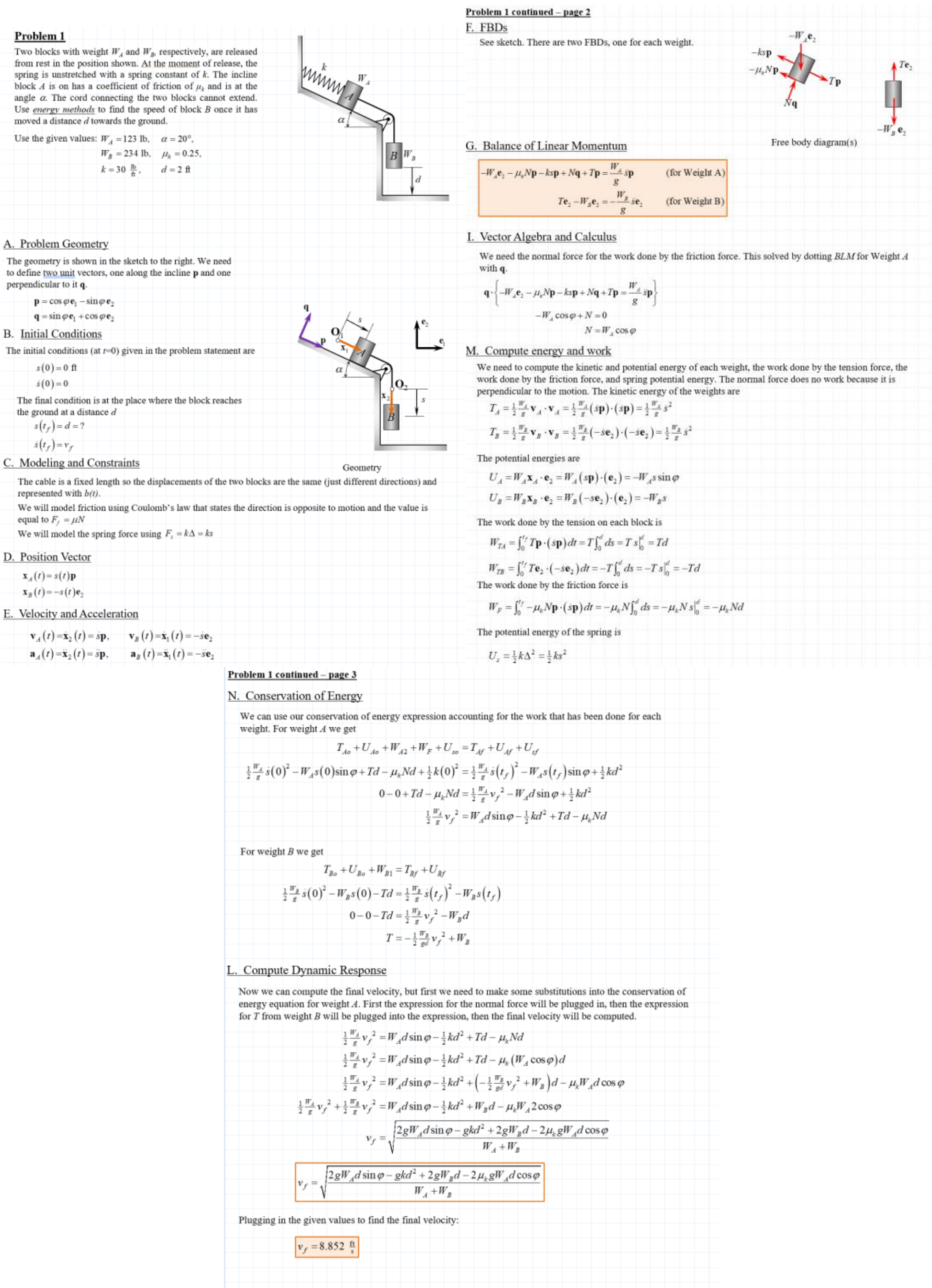
Sample Problem 1

The first sample problem is a particle dynamics problem that includes two masses connected by a cable with a spring. The students are asked to find the velocity of block B once it has moved a given distance. Table 2 includes the different problem statements for each university.

Table 2: Particle dynamics problem statements for Sample Problem 1

University	Problem Statement
A	**Problem 1** Two blocks with weight W_A and W_B, respectively, are released from rest in the position shown. At the moment of release, the spring is unstretched with a spring constant of k. The incline block A is on has a coefficient of friction of μ_k and is at the angle α. The cord connecting the two blocks cannot extend. Use *energy methods* to find the speed of block B once it has moved a distance d towards the ground. Use the given values: $W_A = 123$ lb, $\alpha = 20°$, $W_B = 234$ lb, $\mu_k = 0.25$, $k = 30\ \frac{\text{lb}}{\text{ft}}$, $d = 2$ ft 
B	**Average Problem [15 points]** **Problem 4:** Blocks A and B have weights, $W_A = 123\ lb$ and $W_B = 234\ lb$. They are released from rest when block B is 2 feet from the ground and the spring is unstretched. a) Find the velocity of Block B, just before it hits the ground. b) Find the force of the spring at the moment B hits the ground. Given values: $k = 30\frac{lb}{ft}$ $\theta = 20°$ $\mu_k = 0.25$ 
C	**Given:** Two blocks A and B weighing 123 and 234 lb, respectively, are released from rest as shown. At the moment of release the spring is un-stretched. In solving these problems, model A and B as particles, neglect air resistance, and assume that the cord is inextensible. Determine the maximum speed attained by block B and the distance from the floor where the maximum speed is achieved if α=20 deg, the contact between A and the incline is μk=0.25, and the spring constant is k=30 lb/ft.  **Find:** Determine the **1.** Force in the spring as Block B strikes the ground **2.** Speed of the Block B just before it strikes the ground

The problem statements ask for similar final results but are phrased differently. The difference in wording is a result of how students are asked to solve homework problems and exam questions in each course. The solution for the particle problem created for University A is provided in Figure 1.



Problem 1

Two blocks with weight W_A and W_B, respectively, are released from rest in the position shown. At the moment of release, the spring is unstretched with a spring constant of k. The incline block A is on has a coefficient of friction of μ_k and is at the angle α. The cord connecting the two blocks cannot extend. Use *energy methods* to find the speed of block B once it has moved a distance d towards the ground.

Use the given values: $W_A = 123$ lb, $\alpha = 20°$, $W_B = 234$ lb, $\mu_k = 0.25$, $k = 30\ \frac{\text{lb}}{\text{ft}}$, $d = 2$ ft

A. Problem Geometry

The geometry is shown in the sketch to the right. We need to define two unit vectors, one along the incline **p** and one perpendicular to it **q**.

$\mathbf{p} = \cos\varphi\,\mathbf{e}_1 - \sin\varphi\,\mathbf{e}_2$
$\mathbf{q} = \sin\varphi\,\mathbf{e}_1 + \cos\varphi\,\mathbf{e}_2$

B. Initial Conditions

The initial conditions (at t=0) given in the problem statement are

$s(0) = 0$ ft
$\dot{s}(0) = 0$

The final condition is at the place where the block reaches the ground at a distance d

$s(t_f) = d = ?$
$\dot{s}(t_f) = v_f$

Geometry

C. Modeling and Constraints

The cable is a fixed length so the displacements of the two blocks are the same (just different directions) and represented with $b(t)$.

We will model friction using Coulomb's law that states the direction is opposite to motion and the value is equal to $F_f = \mu N$

We will model the spring force using $F_s = k\Delta = ks$

D. Position Vector

$\mathbf{x}_A(t) = s(t)\mathbf{p}$
$\mathbf{x}_B(t) = -s(t)\mathbf{e}_2$

E. Velocity and Acceleration

$\mathbf{v}_A(t) = \dot{\mathbf{x}}_2(t) = \dot{s}\mathbf{p}$, $\quad \mathbf{v}_B(t) = \dot{\mathbf{x}}_1(t) = -\dot{s}\mathbf{e}_2$
$\mathbf{a}_A(t) = \ddot{\mathbf{x}}_2(t) = \ddot{s}\mathbf{p}$, $\quad \mathbf{a}_B(t) = \ddot{\mathbf{x}}_1(t) = -\ddot{s}\mathbf{e}_2$

Problem 1 continued – page 2

F. FBDs

See sketch. There are two FBDs, one for each weight.

Free body diagram(s)

G. Balance of Linear Momentum

$$-W_A\mathbf{e}_2 - \mu_k N\mathbf{p} - ks\mathbf{p} + N\mathbf{q} + T\mathbf{p} = \frac{W_A}{g}\ddot{s}\mathbf{p} \qquad \text{(for Weight A)}$$
$$T\mathbf{e}_2 - W_B\mathbf{e}_2 = -\frac{W_B}{g}\ddot{s}\mathbf{e}_2 \qquad \text{(for Weight B)}$$

I. Vector Algebra and Calculus

We need the normal force for the work done by the friction force. This solved by dotting *BLM* for Weight *A* with **q**.

$$\mathbf{q}\cdot\left\{-W_A\mathbf{e}_2 - \mu_k N\mathbf{p} - ks\mathbf{p} + N\mathbf{q} + T\mathbf{p} = \frac{W_A}{g}\ddot{s}\mathbf{p}\right\}$$
$$-W_A\cos\varphi + N = 0$$
$$N = W_A\cos\varphi$$

M. Compute energy and work

We need to compute the kinetic and potential energy of each weight, the work done by the tension force, the work done by the friction force, and spring potential energy. The normal force does no work because it is perpendicular to the motion. The kinetic energy of the weights are

$$T_A = \tfrac{1}{2}\tfrac{W_A}{g}\mathbf{v}_A\cdot\mathbf{v}_A = \tfrac{1}{2}\tfrac{W_A}{g}(\dot{s}\mathbf{p})\cdot(\dot{s}\mathbf{p}) = \tfrac{1}{2}\tfrac{W_A}{g}\dot{s}^2$$
$$T_B = \tfrac{1}{2}\tfrac{W_B}{g}\mathbf{v}_B\cdot\mathbf{v}_B = \tfrac{1}{2}\tfrac{W_B}{g}(-\dot{s}\mathbf{e}_2)\cdot(-\dot{s}\mathbf{e}_2) = \tfrac{1}{2}\tfrac{W_B}{g}\dot{s}^2$$

The potential energies are

$$U_A = W_A\mathbf{x}_A\cdot\mathbf{e}_2 = W_A(s\mathbf{p})\cdot(\mathbf{e}_2) = -W_A s\sin\varphi$$
$$U_B = W_B\mathbf{x}_B\cdot\mathbf{e}_2 = W_B(-s\mathbf{e}_2)\cdot(\mathbf{e}_2) = -W_B s$$

The work done by the tension on each block is

$$W_{TA} = \int_0^{t_f} T\mathbf{p}\cdot(\dot{s}\mathbf{p})\,dt = T\int_0^d ds = T\,s\big|_0^d = Td$$
$$W_{TB} = \int_0^{t_f} T\mathbf{e}_2\cdot(-\dot{s}\mathbf{e}_2)\,dt = -T\int_0^d ds = -T\,s\big|_0^d = -Td$$

The work done by the friction force is

$$W_F = \int_0^{t_f} -\mu_k N\mathbf{p}\cdot(\dot{s}\mathbf{p})\,dt = -\mu_k N\int_0^d ds = -\mu_k N\,s\big|_0^d = -\mu_k Nd$$

The potential energy of the spring is

$$U_s = \tfrac{1}{2}k\Delta^2 = \tfrac{1}{2}ks^2$$

Problem 1 continued – page 3

N. Conservation of Energy

We can use our conservation of energy expression accounting for the work that has been done for each weight. For weight *A* we get

$$T_{Ao} + U_{Ao} + W_{A2} + W_F + U_{so} = T_{Af} + U_{Af} + U_{sf}$$
$$\tfrac{1}{2}\tfrac{W_A}{g}\dot{s}(0)^2 - W_A s(0)\sin\varphi + Td - \mu_k Nd + \tfrac{1}{2}k(0)^2 = \tfrac{1}{2}\tfrac{W_A}{g}\dot{s}(t_f)^2 - W_A s(t_f)\sin\varphi + \tfrac{1}{2}kd^2$$
$$0 - 0 + Td - \mu_k Nd = \tfrac{1}{2}\tfrac{W_A}{g}v_f^2 - W_A d\sin\varphi + \tfrac{1}{2}kd^2$$
$$\tfrac{1}{2}\tfrac{W_A}{g}v_f^2 = W_A d\sin\varphi - \tfrac{1}{2}kd^2 + Td - \mu_k Nd$$

For weight *B* we get

$$T_{Bo} + U_{Bo} + W_{B1} = T_{Bf} + U_{Bf}$$
$$\tfrac{1}{2}\tfrac{W_B}{g}\dot{s}(0)^2 - W_B s(0) - Td = \tfrac{1}{2}\tfrac{W_B}{g}\dot{s}(t_f)^2 - W_B s(t_f)$$
$$0 - 0 - Td = \tfrac{1}{2}\tfrac{W_B}{g}v_f^2 - W_B d$$
$$T = -\tfrac{1}{2}\tfrac{W_B}{gd}v_f^2 + W_B$$

L. Compute Dynamic Response

Now we can compute the final velocity, but first we need to make some substitutions into the conservation of energy equation for weight *A*. First the expression for the normal force will be plugged in, then the expression for *T* from weight *B* will be plugged into the expression, then the final velocity will be computed.

$$\tfrac{1}{2}\tfrac{W_A}{g}v_f^2 = W_A d\sin\varphi - \tfrac{1}{2}kd^2 + Td - \mu_k Nd$$
$$\tfrac{1}{2}\tfrac{W_A}{g}v_f^2 = W_A d\sin\varphi - \tfrac{1}{2}kd^2 + Td - \mu_k(W_A\cos\varphi)d$$
$$\tfrac{1}{2}\tfrac{W_A}{g}v_f^2 = W_A d\sin\varphi - \tfrac{1}{2}kd^2 + \left(-\tfrac{1}{2}\tfrac{W_B}{gd}v_f^2 + W_B\right)d - \mu_k W_A d\cos\varphi$$
$$\tfrac{1}{2}\tfrac{W_A}{g}v_f^2 + \tfrac{1}{2}\tfrac{W_B}{g}v_f^2 = W_A d\sin\varphi - \tfrac{1}{2}kd^2 + W_B d - \mu_k W_A 2\cos\varphi$$
$$v_f = \sqrt{\frac{2gW_A d\sin\varphi - gkd^2 + 2gW_B d - 2\mu_k g W_A d\cos\varphi}{W_A + W_B}}$$

$$v_f = \sqrt{\frac{2gW_A d\sin\varphi - gkd^2 + 2gW_B d - 2\mu_k g W_A d\cos\varphi}{W_A + W_B}}$$

Plugging in the given values to find the final velocity:

$v_f = 8.852\ \frac{\text{ft}}{\text{s}}$

Figure 1: Solution to particle problem for University A

The solution for the particle problem created for University B is provided in Figure 2.

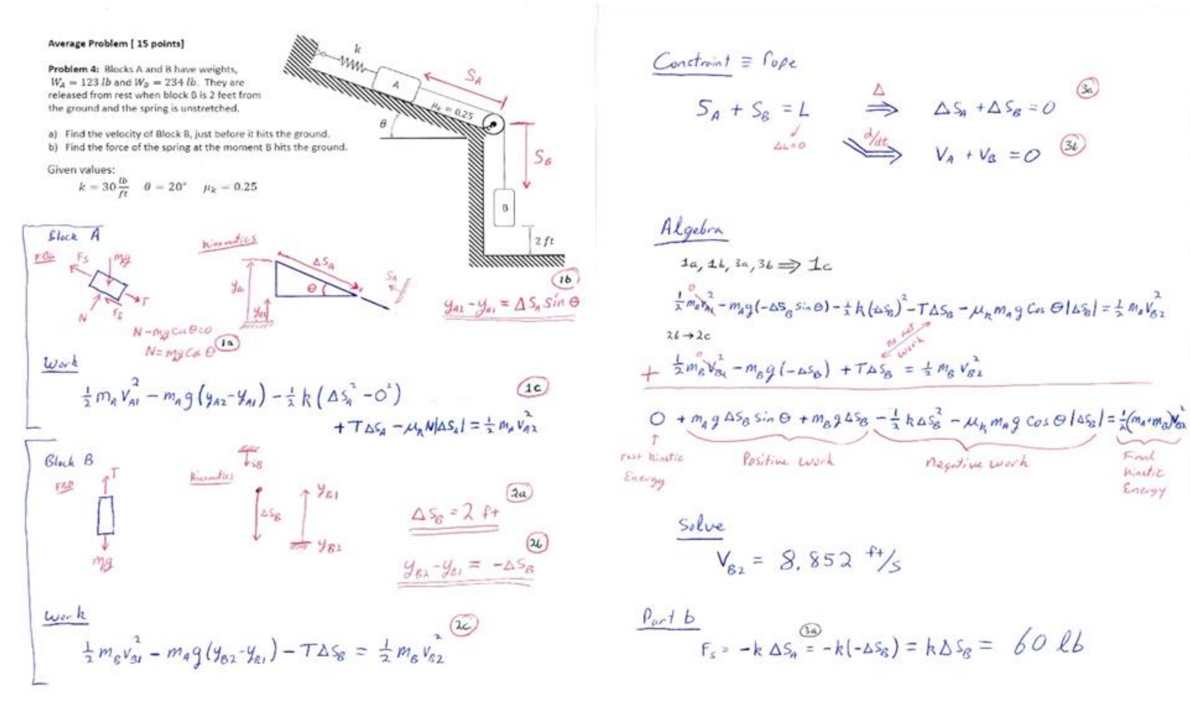


Figure 2: Solution to particle problem for University B

The solution for the particle problem created for University C is provided in Figures 3-1 and 3-2.

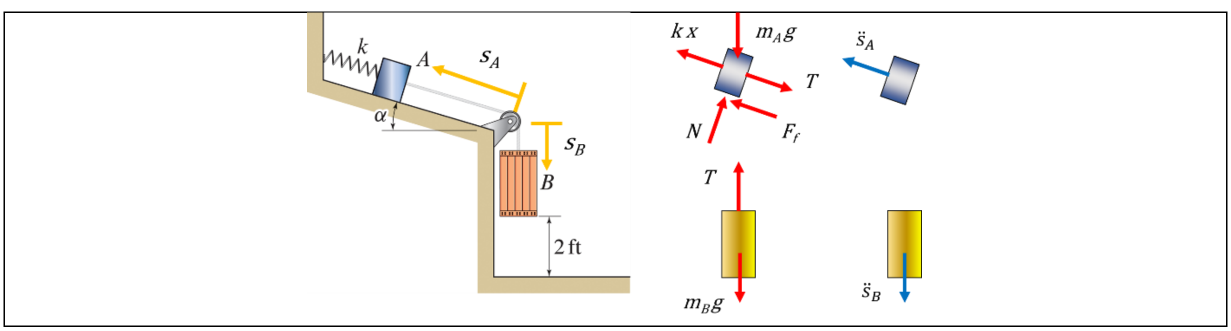


Figure 3-1: Diagrams for the solution to particle problem for University C

Solution:

1. Set up known Variables

```
In[ ]:= KnownsEx3Prb1 := {mA → 123/32.2, mB → 234/32.2, α → 20 π/180, vA1 → 0, vB1 → 0, g → 32.2, k → 30, x1 → 0, hA1 → 0, hB1 → 0, μk → 0.25, sB2 → 2}
```

2. Set up the Energy Equation

```
In[ ]:= eqn31Energy := 1/2 mA vA1^2 + 1/2 mB vB1^2 + mA g hA1 + mB g hB1 + 1/2 k (x1)^2 - Ff (sA2) == 1/2 mA vA2^2 + 1/2 mB vB2^2 - mA g sA2 Sin[α] - mB g (sB2) + 1/2 k (sA2)^2
        eqn31Fy := FN - mA g Cos[α] == 0
        eqn31Vel := vA2 - vB2 == 0
        eqn31ds := sA2 - sB2 == 0
        eqn31Fricn := Ff - μk FN == 0
        eqn31Fspring := Fsp - k sA2 == 0

In[ ]:= {eqn31Energy, eqn31Fy, eqn31Vel, eqn31ds, eqn31Fricn, eqn31Fspring} /. KnownsEx3Prb1 // MatrixForm

Out[ ]//MatrixForm=
( 0. - Ff sA2 == -468. - 42.0685 sA2 + 15 sA2^2 + 1.90994 vA2^2 + 3.63354 vB2^2 )
(                 -115.582 + FN == 0                                          )
(                  vA2 - vB2 == 0                                             )
(                  -2 + sA2 == 0                                              )
(                 Ff - 0.25 FN == 0                                           )
(                 Fsp - 30 sA2 == 0                                           )
```

3. Solve for unknowns

```
In[ ]:= Soln31 = Solve[{eqn31Energy, eqn31Fy, eqn31Vel, eqn31ds, eqn31Fricn, eqn31Fspring} /. KnownsEx3Prb1]

   ··· Solve: Solve was unable to solve the system with inexact coefficients. The answer was obtained by solving a corresponding exact system and numericizing the result.

Out[ ]= {{Ff → 28.8955, FN → 115.582, Fsp → 60., sA2 → 2., vA2 → -8.8517, vB2 → -8.8517},
         {Ff → 28.8955, FN → 115.582, Fsp → 60., sA2 → 2., vA2 → 8.8517, vB2 → 8.8517}}

In[ ]:= {{"Variable", "Value", "Units"},
           {"F_sp", Fsp, "lbf"}, {"vB2", vB2, "ft/s"}, {"F_f", Ff, "lbf"}, {"F_N", FN, "lbf"}} /. Soln31[[2]] // MatrixForm

Out[ ]//MatrixForm=
( Variable   Value    Units )
(   F_sp      60.      lbf  )
(   vB2      8.8517    ft/s )
(   F_f      28.8955   lbf  )
(   F_N      115.582   lbf  )
```

Figure 3-2: Calculations for the solution to particle problem for University C

First, a major difference between each solution is the medium used to create it. There is an electronically generated solution, a hand-written solution, and computationally solved solution. For the actual solution process for Problem 1 there is a noticeable difference in the length of each solution. University A is the longest with derivations required for each part of the solution using the vector expressions. University C computes the energy for the entire system while the other two solutions compute energy for each block individually and relates the two through the tension in the cable. Also, University B and C have a different definition for the origin points of each block. The origin points for those solutions are starting at the pulley while University A uses an arbitrary point that does not move noting that the length of the cable cannot change. This description results in different definitions for the positive direction of motion for block A, but the same result is reached for all three solutions.

Sample Problem 2

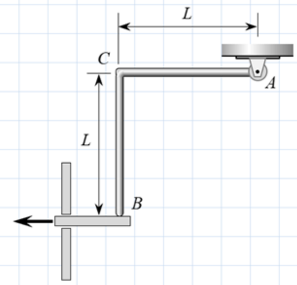
The second sample problem is a rigid body bent rod problem. The solution requires the students to find the initial angular acceleration and reaction force at the hinge along with other parameters unique to each instructor's style. The three problem statements are given in Table 3.

Table 3: Rigid body problem statements for Sample Problem 2

<table>
<tr><th>University</th><th>Problem Statement</th></tr>
<tr><td>A</td><td>

Problem 1

Two bars of length L have a uniform mass per unit length of ρ. The two bars are welded together at C to make the bent rod ACB. The hinge at A is frictionless. If the support at B is suddenly removed, determine (1) the equation of motion for the system, (2) the *initial* reaction that the pin A exerts on the rod ACB, and (3) the *initial* angular acceleration of the system.

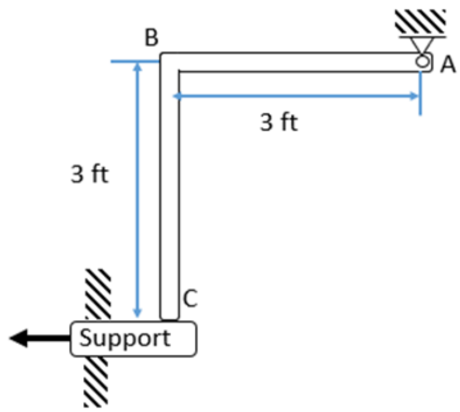


</td></tr>
<tr><td>B</td><td>

Average Problem [15 points]

Problem 4: The bar shown is a composite of of two equal mass bars of length $L = 3\ ft$ and weight $10\ lb$. If the support is suddenly removed, find

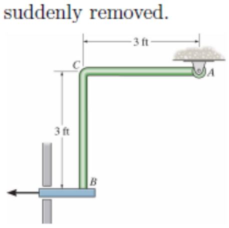
1) the angular acceleration of the beam at this instant.
2) the reactions at pin A.
3) [Bonus] When AB is vertical, the angular velocity of the beam is $\omega = 2\ rad/s$. What are the pin reactions at this moment.



A FBKD is required for this problem.

</td></tr>
<tr><td>C</td><td>

Given: **(RCH XXth Ed. P17.70)** Segments AC and BC each have a weight of 10 lbf. The support at B is suddenly removed.



Find: At the instant shown, determine the

1. location of the center of mass of the system,
2. angular acceleration of the system at this instant,
3. acceleration of the center of mass of the system, &
4. reaction that the pin A.

</td></tr>
</table>

The dynamic system is the same for the three problems, but each problem statement asks for slightly different final answers. The requested answers are based on the aspects each instructor emphasizes for a rigid body problem like this. University A includes asking for the equation of motion, while University B asks a bonus question, and the order of the requested answer for University C is done to help step students through the solution process. The instructor generated solutions for this sample problem are given in the figures below. The solution created for University A is provided in Figure 4.

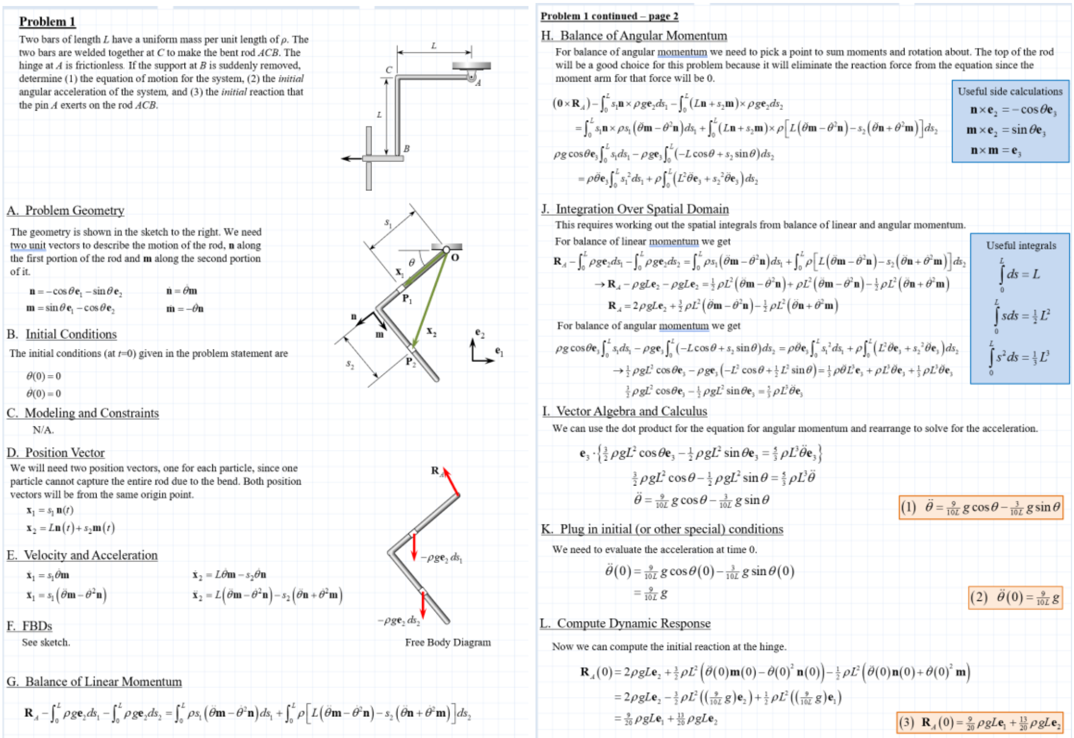


Figure 4: Solution to rigid body problem for University A

The solution created for University B is provided in Figure 5.

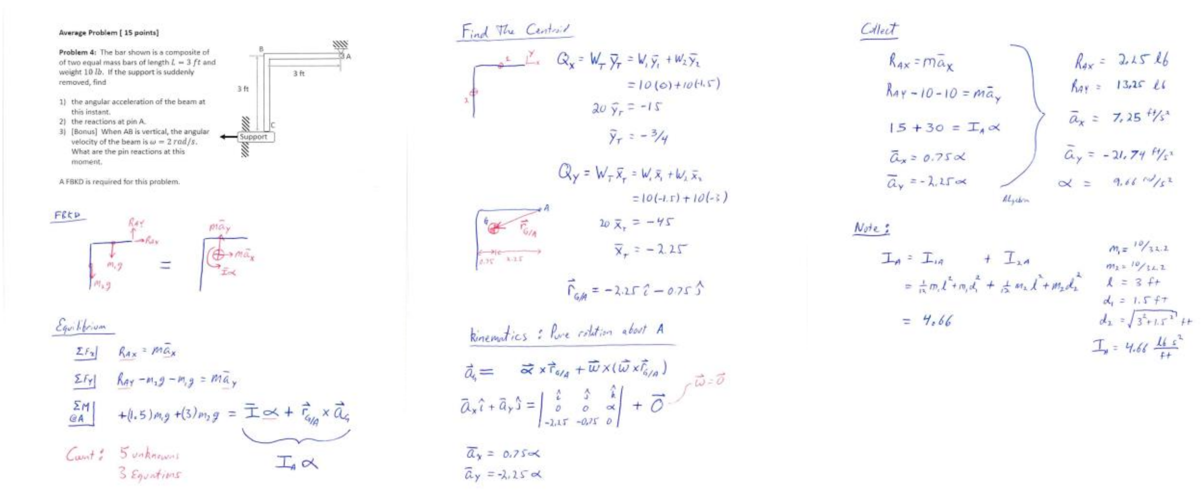


Figure 5: Solution to rigid body problem for University B

The solution created for University C is provided in Figure 6.

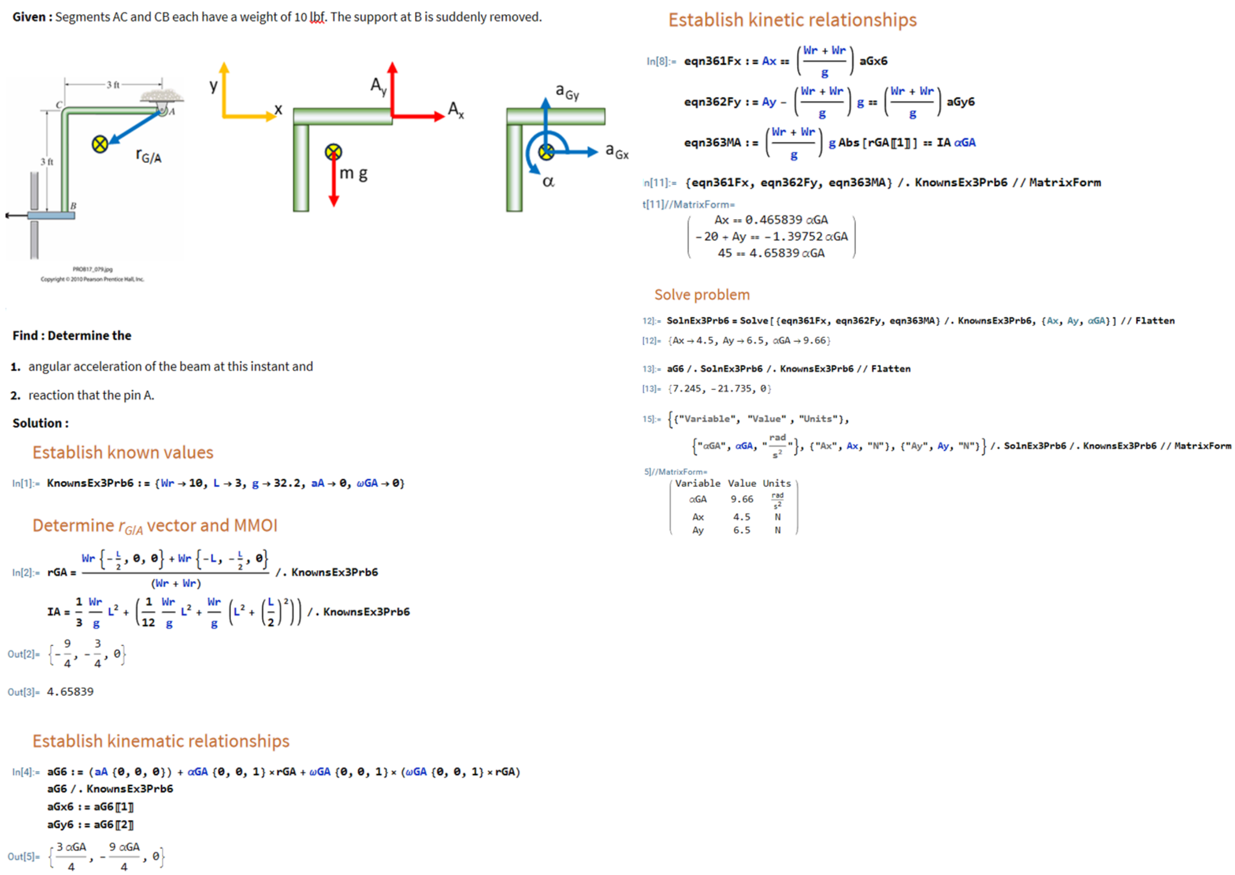


Figure 6: Solution to rigid body problem for University C

The differences in the problem solutions for this rigid body problem is the result of the different teaching styles each instructor uses and how the question is asked. The solution for University A requires an initial position vector for each piece of the rod using the geometry drawing followed by a free body diagram used to create the equation of motion for the problem. The weight is treated as a distributed force that is integrated for the equation of motion. University B requires a free body kinetic diagram (FBKD) followed by writing the general forms of the equilibrium equations to identify the unknowns. University C requires similar diagrams to University B but identifies the center of mass of the system on the FBD. The acceleration diagram is used to remind students which way positive accelerations are oriented when they start summing forces. Another difference is that both University B and C include finding the center of mass, which University C requires as an answer for this problem, but University A does not explicitly solve for this.

Major differences

The sample problems have noticeable differences in their problem statements and solution processes. The differences in the solutions, especially for Sample Problem 2, highlight the instructors different teaching styles. University A has created a derivation approach that goes through the same steps for each problem while including math calculations like integration to always result in finding the equation of motion of the system. University B has also created a systematic solution process for their students, where the process requires the students to start with an FBKD, then equilibrium equations, then identify knowns and unknowns, then use kinematics, and finally solve the problem. University C is not as explicit with their solution process but uses the problem statements to identify the steps the students should take to solve the problem. These all promote the development of a solution process unique to each course to solve dynamics problems. Each instructor's process is supported by their classroom environment and design.

Conclusion and Future Work

This work-in-progress paper describes three instructors with very different teaching and assessment styles for dynamics and provides two example problems that will be used as a test in each course over the next few semesters. The future work will include analyzing the student results from each course to evaluate and compare the differences. The outcomes that will be evaluated include correctness, solution process, conceptual understanding amongst other criteria. One of the research questions will be to identify how problem-solving skills that students learn for in class problems correlate to conceptual understanding on tests such as concept inventories. The results will be reported in part two of this study.

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