To Flip or Not to Flip, that is the Question

Abstract

Engineering is a field focused on problem solving, and hence engineering courses focus on students solving various problems related to course material. This type of course lends itself well to being taught in a 'flipped' format where a significant portion of class time is devoted to working homework problems, facilitating student/instructor interaction with an emphasis on the *students'* problem-solving methods and techniques. This paper examines a sophomore level statics course taught in two formats, a conventional lecture style and a partially flipped format. The 'partially-flipped' terminology is used because the course was formatted such that class time was divided between lectures on course topics and homework solving sessions (alternating between each). In comparing the two formats, the difference is essentially a trade between more in-depth lectures (and worked examples) and *individual* interaction between the instructor and students while the students solve problems. There is little doubt in the author's mind that this benefits some students greatly. However, the question that is hopefully addressed is, "Does this focus towards individual students benefit the class as a whole in some measureable manner?" To gain insights toward answering this question, the two courses are compared in several areas. The comparison between the formats is made using qualitative and quantitative data. Qualitative aspects of the comparison include course development and implementation as viewed by the instructor, student perceptions of the effectiveness of the format in learning the material (via student surveys, comments, and evaluations). While quantitative data are admittedly limited, an attempt is made to quantify student performance relative to the learning objectives in both course formats. This is accomplished by comparing student scores on common exam problems given during the course.

Introduction

A significant portion of an engineering career is focused on problem solving. As such, engineering courses often focus on problem solving. Additionally, in lower level courses, it is important to train the students in proper problem solving techniques, even to the level of format and organization. Many teaching methods have been and are used to emphasize these important aspects. In particular, the flipped-classroom is one method that one could see being very effective since the instructor and students have significant interaction while the students are working problems. Thus, not only can the instructor assist students in problem solving, but the instructor can help younger students develop appropriate problem solving techniques during this interaction.

The statics course at Southern Utah University presents an excellent opportunity to leverage a flipped class format. The statics course, ENGR-2010, is typically the first engineering course with problem solving and therefore students could benefit from significant interaction with the instructor while solving problems. The course is normally taught once a year, however during the 2015-2016 academic year it was taught both semesters by the same instructor. In the fall semester the course was taught in a more conventional lecture-style format. Based on instructor observations, other faculty observations and student comments, converting the course to a flipped format seemed appropriate. Unfortunately, due to the short amount of time between semesters there was not time to entirely convert the course format. However, there was an opportunity to begin to the process and teach the course in a partly-flipped format. The format was largely based on an existing course format used by another instructor for a statics class at another university.

The back-to-back semesters of the same course with the same instructor provided the opportunity to compare the two course formats. During the two semesters several of the same exam problems were used to be able to compare student performance as directly as possible (including exactly the same problem with different numbers, or only changed slightly such as moving a force on the structure). Additionally, the students were given a survey at the end of the course to attempt to understand the students' opinions as to whether or not they like the format and their perceptions of how their performance was affected by the course format.

Course Format

ENGR-2010 is the statics course for the engineering program. The course is normally taken in the first semester of the sophomore year. In the past, the course has been taught as a conventional lecture-style course with little in-class work. In the fall of 2015, students expressed interest in solving problems in-class and working homework during class time. Additionally, faculty that observed a lecture suggested exploring the flipped format. Due to the short amount of time between the fall and spring semesters, completely flipping the format was not practical. However, one of the faculty in the department was aware of a statics class taught at another university where a large portion of class time was devoted to students completing homework. Details on this class format can be found in reference [1].

In this example the class time was divided between lectures and homework roughly equally. A short lecture was provided for each topic on one day and the next class was devoted to solving homework related to the previous day's lecture. While it was not completely flipped, a significant portion of the flipped format is incorporated in that half the class is devoted to students completing homework problems.

Obviously, lecture time is now reduced, which presents potential issues. In a more conventional lecture-style course, there is plenty of time to cover material and detail and work several examples. Now with only half the time devoted to lecture, the challenge for the instructor is to cover material and complete examples in one class time sufficiently so students can complete homework based on that lecture. In some cases this is not an issue, but for more detailed topics this poses a significant challenge.

Following the example class[1], 'pre-lecture' assignments were created for students to complete prior to each lecture. The intent was for students to take the initiative to familiarize themselves with the material prior to the class lecture. The assignments included reading sections of the book and simple fundamental problems based on the reading. In the example class, these assignments were collected and graded at exams as part of a course notebook. In the current case, similar assignments were generated and available to the students but not graded.

As an example, in the fall semester, 9 pages of notes and 2 - 3 class days were spent on 3-D particle equilibrium, divided between theory and example problems worked on the board. In the spring semester, this material was covered as 1 topic. The students were expected to read the book material such that they could answer simple questions, such as defining and using unit vectors and drawing 3-D free-body diagrams. The lecture was reduced to 1 day (still 6 pages of notes but focused on worked examples) and another day was dedicated to students working homework problems in class (individually and in groups). The pre-lecture assignment and course notes can be found in Appendix A. A similar structure was put forth for all of the course topics.

Results

Student Performance

The partially-flipped course was evaluated in two ways. First, student performance on exam problems was compared to the previous semester. While entire exams were not exactly the same, each exam had similar questions or problems where numbers were changed but the problems were the same. The other method of evaluation was through student surveys. At the end of the course, students were given a survey asking their opinions about the format and questions about the course material.

For the assessment comparison, only engineering students in the courses were compared. The statics class was also required for engineering technology majors during the fall semester. However, the engineering technology curriculum is transitioning those students to another statics course. In the fall 2015 class 16 students were engineering majors and there were 20 engineering students in the spring class (18 of which responded to the voluntary survey).

Figure 1 shows average and low scores for several exam questions for the two classes. The labels for the questions (1 – 9) increase with time into the semester. Questions 1 and 2 are scores from the first exam, questions 3 – 5 are from the second and third exams while the last four questions (6 – 9) are from the final.

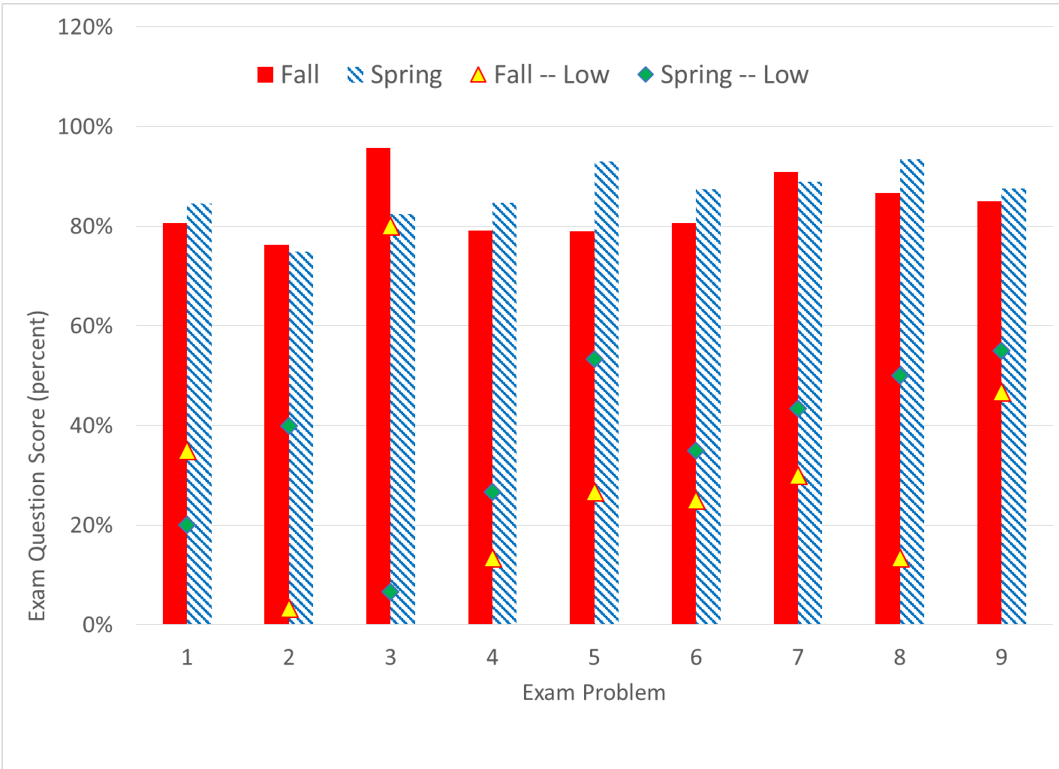

Figure 1: Comparison of exam problem scores.
Exam 1 (problems 1 - 2), Exam 2 (problems 3 - 5) and Final (problems 6 - 9), n = 16 (fall) and n = 20 (spring)

There does not appear to be any significant difference between the two classes if one examines the average scores (bars), and therefore does not support some studies where flipped classrooms have improved overall grades.[2] However, the lowest score on each question, denoted by the diamonds and triangles, shows a consistent trend for the second half of the semester (problem 4 and higher). The low score for the spring semester is on the order of 8% higher or more than the fall semester low score. This trend is perhaps explained by other research where higher performing students tend to not improve with the flipped format but lower performing students feel the course helped them improve their performance[3]. While this certainly is not conclusive it does seem to indicate that the lower performing students are helped by the flipped format as other research has shown. One might also draw the conclusion that the higher performing students are hurt by the format since the averages are similar but the low scores have improved. However, this is most likely not the case since the averages are relatively high and common errors for a near-perfect score are minor math errors, sign errors and the like and typically not concept related. Thus, it is unlikely that the higher performing students are comprehending less in the flipped format but suffering from careless mistakes.

This trend is not the same for the problems from the first exam. While there is no conclusive data to support a theory, this is potentially due to a switch in the pre-requisites for the course between the semesters. Physics was a required pre-requisite for statics for the fall statics class but this requirement was removed for the spring semester. Several students commented that they struggled with vectors in the first few weeks of the course because they had not covered them in other courses. However, these same students commented that they learned vectors so well in statics that it helped them in their physics course. This might explain the lower performance in the spring semester on the first exam.

Student Surveys

In addition to examining the assessments in the course the students were surveyed at the end of the semester. The survey asked the students whether they enjoyed the format of the class, whether or not they did the homework, and whether they felt the course format helped them learn the material. Figure 2 shows the student responses to the first question, whether or not they liked

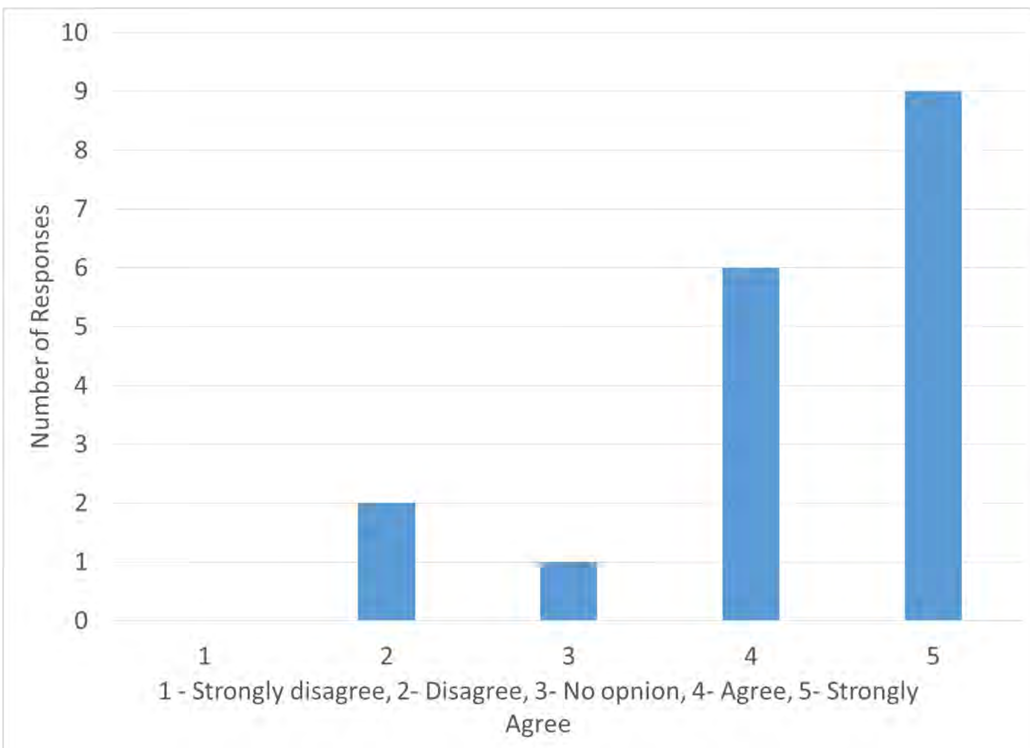

Figure 2: Survey responses to "Compared to other more conventional lecture-type courses, I enjoyed the format of the flipped class (alternating days of lecture and homework sessions)."

the format of the course. The majority of the students enjoyed the course format as others have found.[4] While survey data was not directly correlated with student grades, these survey results do not indicate a trend where mediocre students did not enjoy the flipped class.[5] Only 2 students indicated they did not enjoy the format. One of these students commented that the he felt intimidated when other students could complete the in-class problems more quickly. One might conclude that this student was one of the lower performing students in the class, but again, the survey data was not correlated with grades in this effort.

Figure 3 shows the response data as to whether the students felt the course format helped them understand the material better. As can be expected, since most of the students enjoyed the course format, a similar number felt the course helped them understand the material. As can be seen from the data, not all students enjoyed the format. Some of these students provided additional comments which associated with their concerns. These comments indicated that some students did not enjoy working in groups or were intimidated when other students completed a problem before they did.

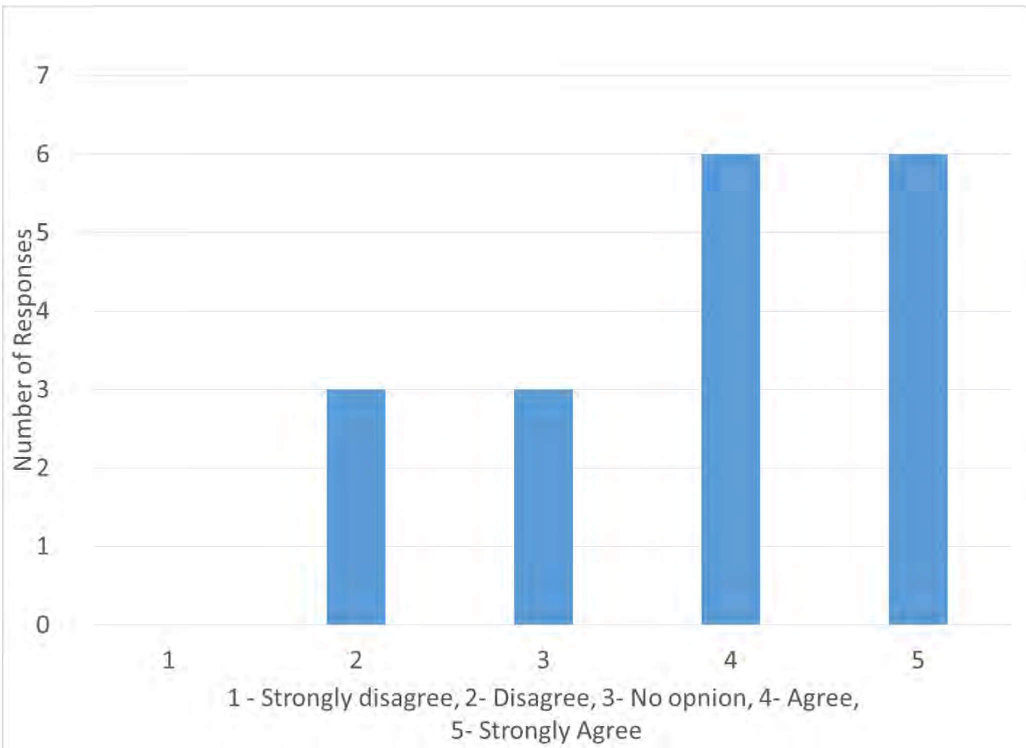

Figure 3: Response to: "I feel that the class format of having homework sessions during class time helped me better understand the material compared to a more traditional format." (n = 18)

Questions three and four pertained to the assignments in the course. Question 3 ask whether the students completed the 'pre-lecture' assignments. As can be seen from Figure 4 most of the students did not complete these assignments. Other studies have shown similar trends.[6] As one might expect, since the assignments were not graded most students did not complete the assignments. Conversely, nearly all of the students completed the homework on time (Figure 5)

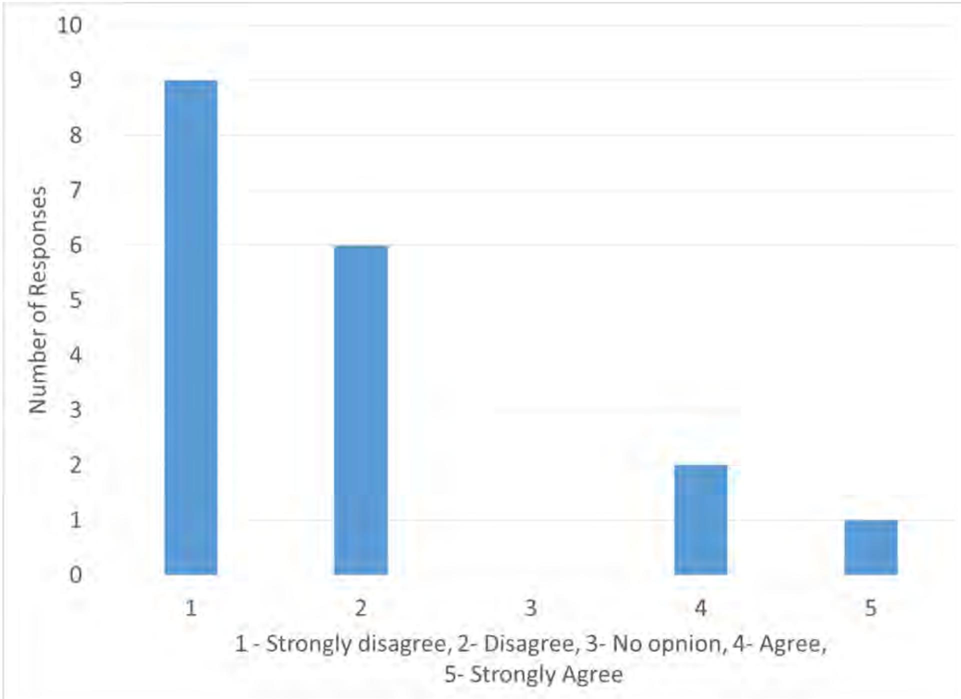

Figure 4: Responses to "I completed the ‘pre-lecture’ assignments most or all of the time.” (n = 18)

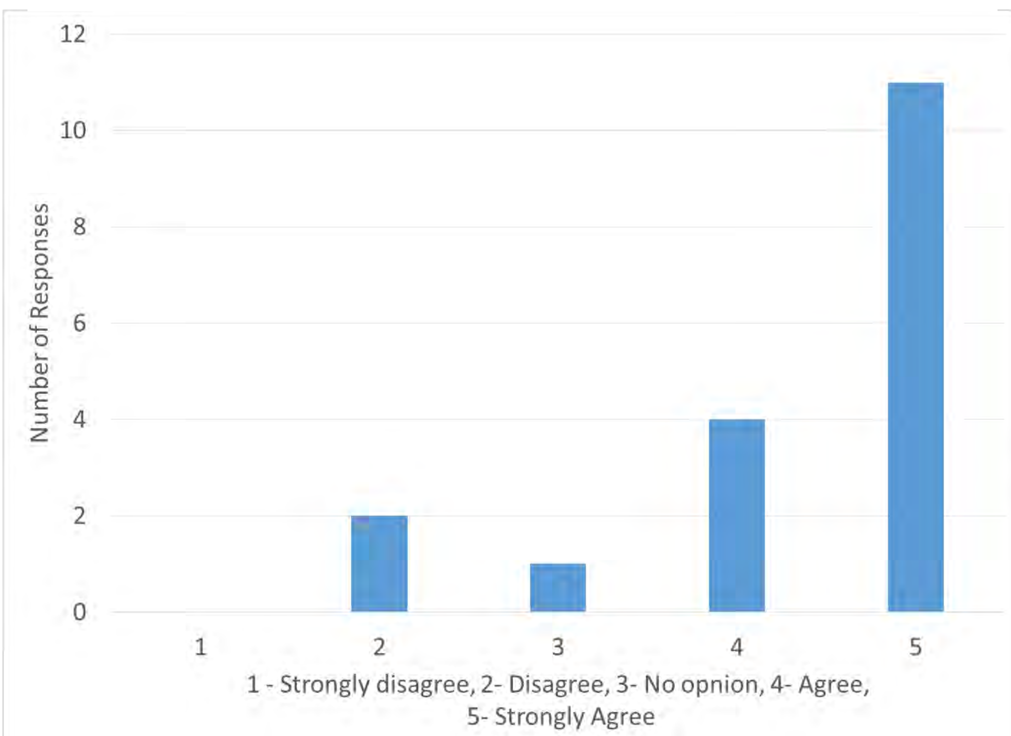

Figure 5: Responses to “I completed most or all of the homework on time.” (n = 18)

Since one of the primary changes in the class format was reduced lecture time, the students were asked whether or not they felt the reduced lecture time made the material more difficult to understand. Figure 6 shows the responses. Nearly 40% of the students felt that the shortened lectures made the material more difficult to understand. Comments relative to this question mostly indicated that some lectures appeared rushed and that more examples were desired.

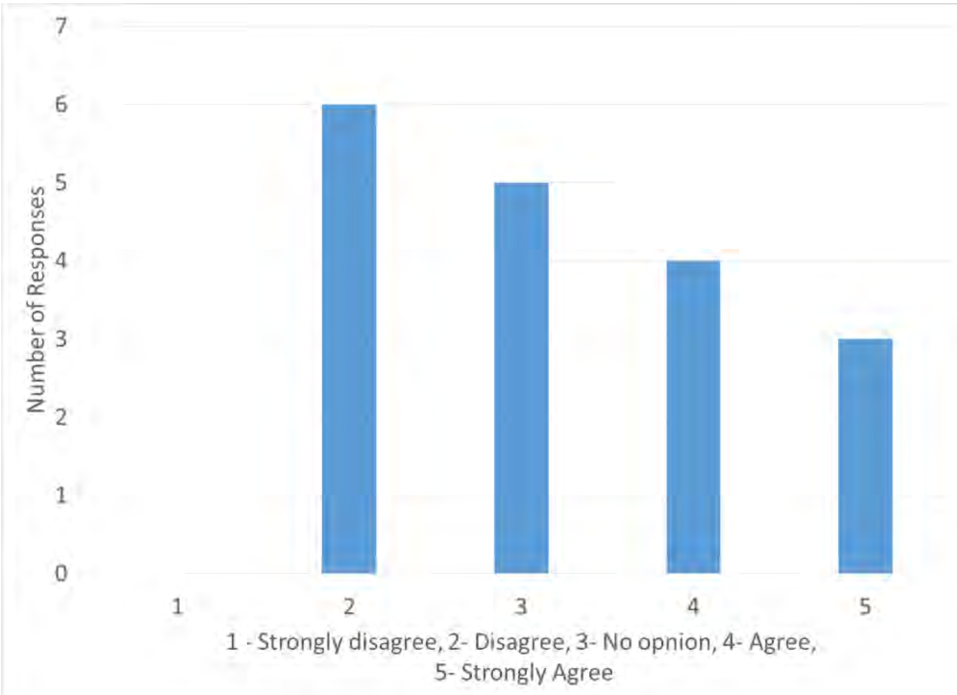

Figure 6: Responses to "The reduced time for lectures made the material more difficult to comprehend." (n = 18)

Given that several students felt they had difficulty understanding the material, one cannot help but wonder if there is any correlation between these responses and whether or not the students did the assignments. As was noted earlier, the majority of the students completed the homework, but most of the students did not complete the pre-lecture assignments. Figure 7 shows the student responses for both of these survey questions. Interestingly, the majority of the students that indicated the material was more difficult to understand given the short lectures also responded that they did not complete the pre-lecture assignments. This is indicated by a high response (5 or 5) for the solid blue column and a low response for the red patterned column (1 or 2). While the instructor readily admits that some of the lectures felt rushed when covering more complex material, it begs the question as to how much the students' difficulties could have been alleviated by completing the pre-lecture assignments.

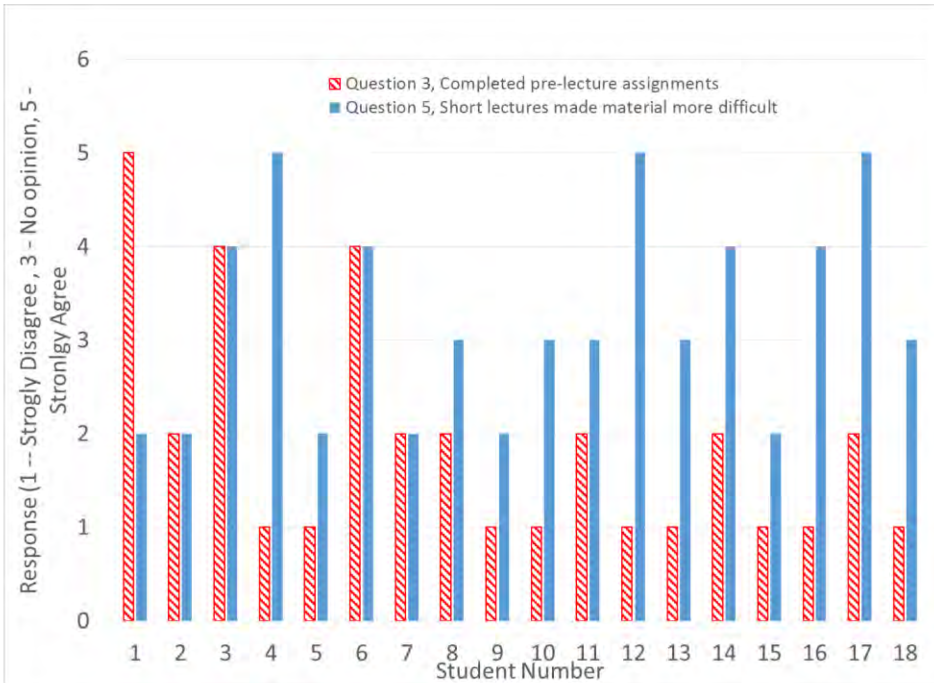

Figure 7: Comparison of responses to questions 3 and 5; completion of the pre-lecture assignments and perceived difficulty of the material.

Question 6 on the survey asked whether students would prefer a flipped-format class in the future. As can be seen in figure 8 that most of the students would prefer this type of class. While students seem to prefer this type of format, student perceptions as to whether this type of course improves their grade is less clear. Figure 9 shows the student responses to the last question in the survey (note that a negative response (1 or 2) indicates that the student feels a flipped class would improve his or her understanding of the material). While more students responded that they feel the flipped format would improve their understanding, it was not overwhelming (similar to question 6 in figure 9). While ten students felt that the format would improve their understanding, 7 did not feel that the format would help their understanding. Several of these responses came from students that performed well in the class and likely would perform well in any class format. However, it is interesting to note that students appear to enjoy and prefer the format but do not necessarily link it to their success in the class.

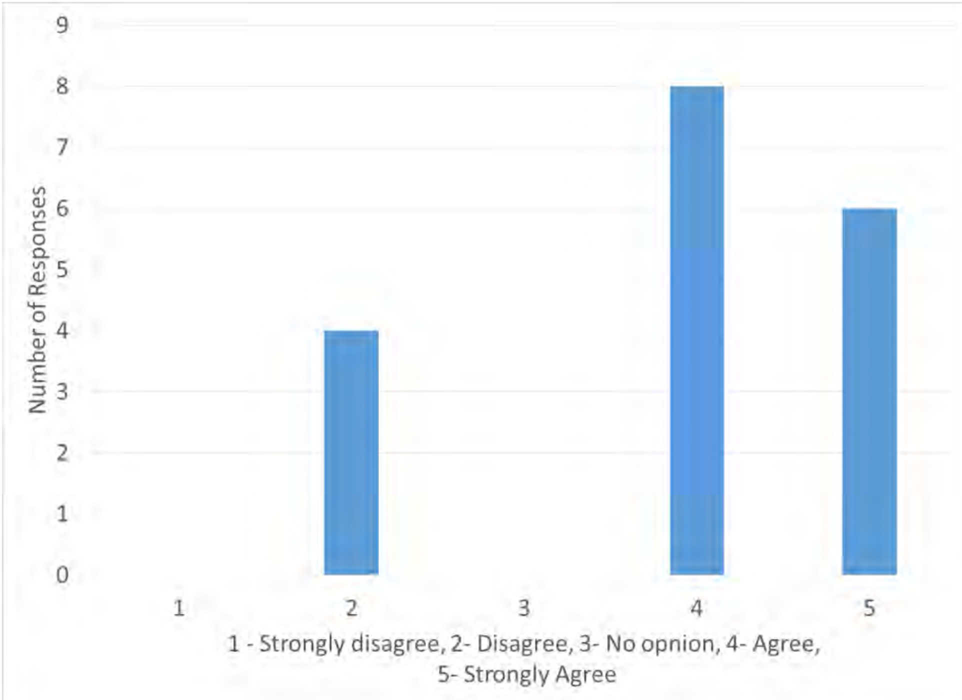

Figure 8: Response to question 6; "I would prefer this type of format over the more conventional format in similar classes I have to take in the future." (n = 18)

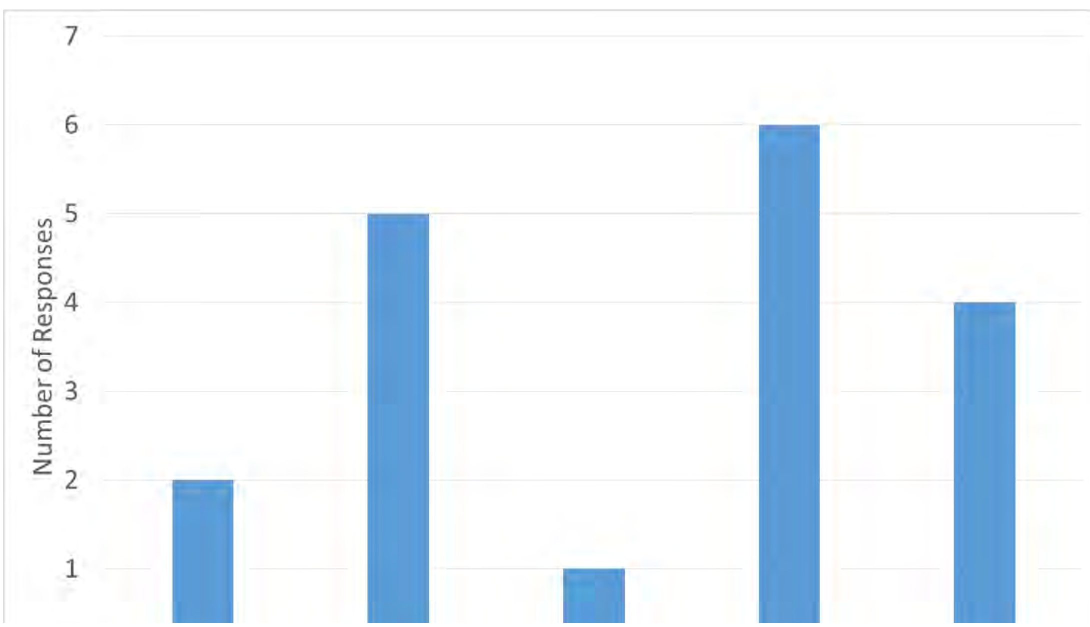

Figure 9: Student response to question 7; " I do not feel that the flipped class format helped me have an increased understanding of the material, I would have had a similar grade in a conventional lecture style class."
Note: a negative response (1 or 2) indicates that a flipped class will increase student understanding of the material.

Instructor Notes

Having taught the course in both formats back-to-back semester, there are some observations worth mentioning. As the students indicated, some of the lectures did seem rushed. While anyone attempting to keep a schedule for a semester may find times when the lesson is rushed. However, this format tends to amplify the problem since each topic must be covered sufficiently for students to complete homework problems in the next session. Obviously, if the course were completely flipped this problem would be alleviated since the students could watch the lectures any time and as often as desired. Some of this can be worked as the course is taught more. Lectures can be refined but this will not completely solve the problem. This problem may also be reduced if the students complete the pre-lecture assignments. If the students come into class with a basic level of understanding, the lectures may flow more easily for them and questions during class may be reduced or focused on the finer points of the material rather than the main concepts (which typically require more explanation).

Another important aspect of the partially flipped class was the opportunity to see the students completing homework. Since this is the first real engineering analysis class the students take, effort is placed on formatting homework and problem solving methods in addition to concepts of statics. Watching students actually doing homework provides opportunities to correct bad homework habits earlier. Rather than simply grading turned-in homework and making notes, the student(s) can be stopped and shown the appropriate way to proceed. Based on observations, this seems to have more impact on the students as homework solutions were much improved over the previous semester regarding format and clear problem-solving technique.

Finally, one of the most valuable results of the partially-flipped format was the interaction with the students. The early homework classes essentially provided an ice-breaker where the instructor could interact with each of the students. Compared with the previous semester, as the class progressed many more students felt comfortable asking questions, coming to office hours and participating in class. This instructor feels this is in large part due to the fact that in the first couple of homework classes an intentional effort was made to interact with *each* student. This effort created a rapport which seemed effective in increasing communication.

Additionally, the previous homework was handed back during each homework class. This provided an opportunity to discuss the graded homework with the students (individually). Again, direct feedback individually can be given before the student has completed another homework, thus aiding in improving understanding, format, and problem solving techniques. This extra level of feedback seemed to have more impact than simply writing notes on the homework.

Lessons Learned

As mentioned, one of the most valuable lessons learned in this effort was that the homework sessions provided an avenue to develop a rapport with the students. This improved interaction between the students and instructor and had several positive effects. Most importantly, when students took advantage of the homework class they did not fall behind as questions did not have to wait until office hours or some other time outside class where the student could meet with the instructor. Additionally, the homework format and problem solving techniques were much improved over the previous semester. Specifically, seeing students do homework real-time and correcting issues as the students were initially working on the problem seemed to have more impact than through feedback while grading homework. Graded homework could also be examined in the homework classes, providing reinforcement to that type of feedback.

Lastly, while there are many improvements that could be made to the course, the most important change must be relative to the pre-lecture assignments in this case. It is clear that without tying these assignments to the student's grade they will not be taken seriously. Additionally, since most of the students that had difficulty understanding material in the shortened lectures also did not do the pre-lecture assignments, the data seem to indicate that student success could be improved further if the students completed these assignments. This issue will be addressed for the upcoming semester. There are several options, but the intent is to increase student completion of these assignments without creating an extra burden of grading on the instructor. One method being examined is using online textbook material. In this case, the students will have reading assignments in the online material and be quizzed on these assignments. The questions are concept questions or simple problems and can quickly be answered. The completion and success of the student can be automatically tracked and fed into online grading. Thus, the only burden on the instructor is minimal set-up in creating the reading assignments and coordinating the logistics to have the online material automatically fed into the grading system. Additionally, the software tracks the questions answered correctly and incorrectly, giving the instructor valuable data regarding areas where students have difficulty.

Conclusions

The ENGR 2010 class at Southern Utah University was partially-flipped between the fall and spring semesters of the 2015-2016 academic year. The resulting course appears to be a course format that most students enjoy and prefer. It is not clear that top performing students see any additional benefit compared to conventional course formats. However, it does seem that lower performing students do benefit from the format (both based on assessments in the course and student perceptions). Based on this experience it is critical that the instructor tie independent student learning to the student's grade (in this case pre-lecture assignments).

Acknowledgments

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Appendix A

Pre-lecture assignment for 3-D particle equilibrium

ENGR – 2010
Class Preparation

Lesson Topic (L-4): Forces in space, equilibrium of particles in space

Objectives:

1. Compute components of forces in 3-D space
2. Addition of concurrent forces in space
3. Solve problems involving equilibrium of a point in space

Reading Assignment: Beer, Johnston and Mazurek; Chapter 2.4, 2.5

Notes from reading:

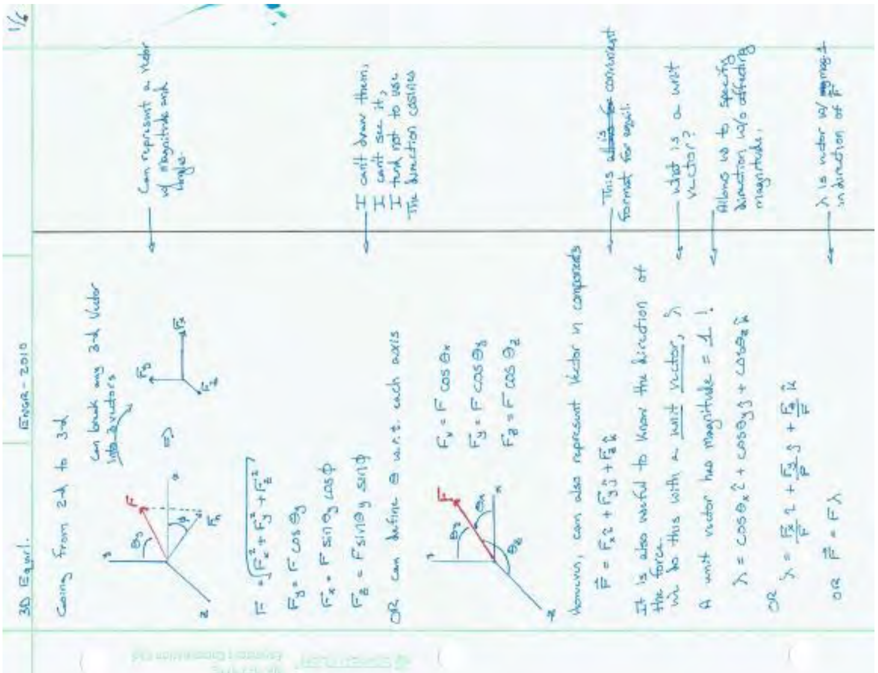
Define the rectangular components of a force w.r.t. the direction cosines

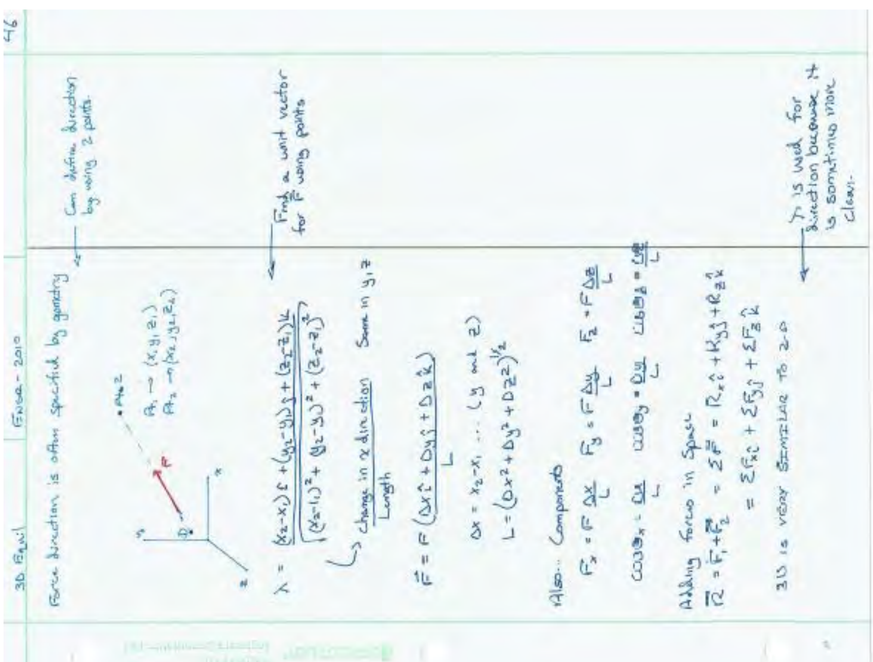
Define unit vector.

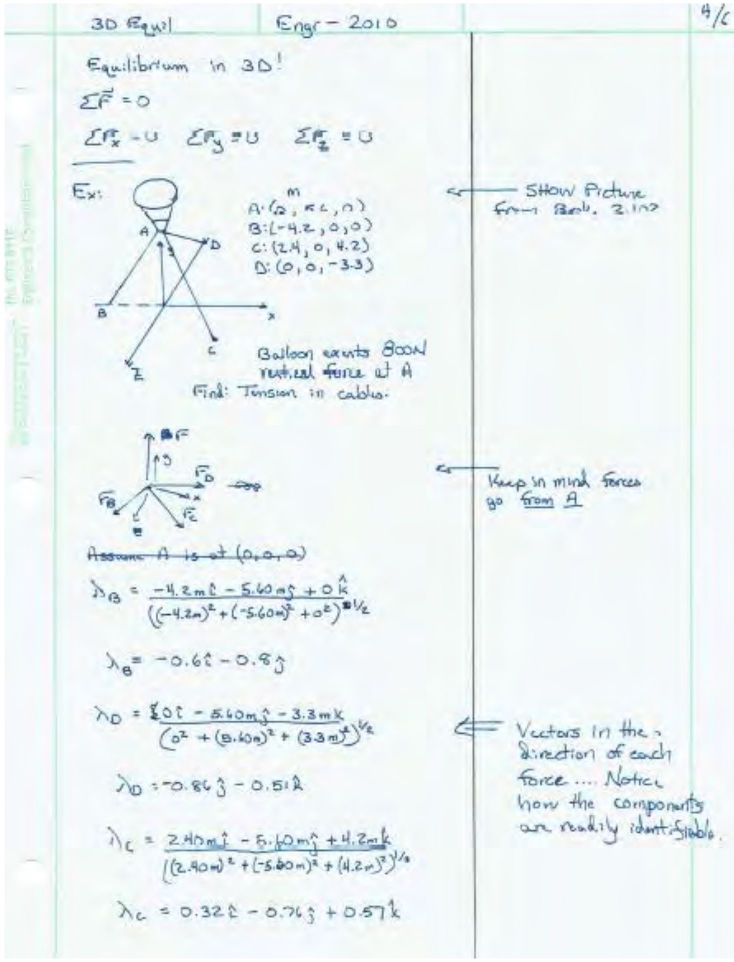
Write down the equations for the unit vector of a force in terms of the direction cosines, and in terms of the force components.

Draw a FBD for the point C for the loading shown.

Course Notes for 3-D particle equilibrium







3D Equil — Engr – 2010 — 4/6

Equilibrium in 3D!

$\Sigma \vec{F} = 0$

$\Sigma F_x = 0 \quad \Sigma F_y = 0 \quad \Sigma F_z = 0$

Ex:

m
A: (0, 5.6, 0)
B: (-4.2, 0, 0)
C: (2.4, 0, 4.2)
D: (0, 0, -3.3)

Balloon exerts 800N vertical force at A
Find: Tension in cables.

← SHOW Picture From Book, 2.107

← Keep in mind forces go from A

~~Assume A is at (0,0,0)~~

$\lambda_B = \frac{-4.2m\hat{i} - 5.60m\hat{j} + 0\hat{k}}{((-4.2m)^2 + (-5.60m)^2 + 0^2)^{1/2}}$

$\lambda_B = -0.6\hat{i} - 0.8\hat{j}$

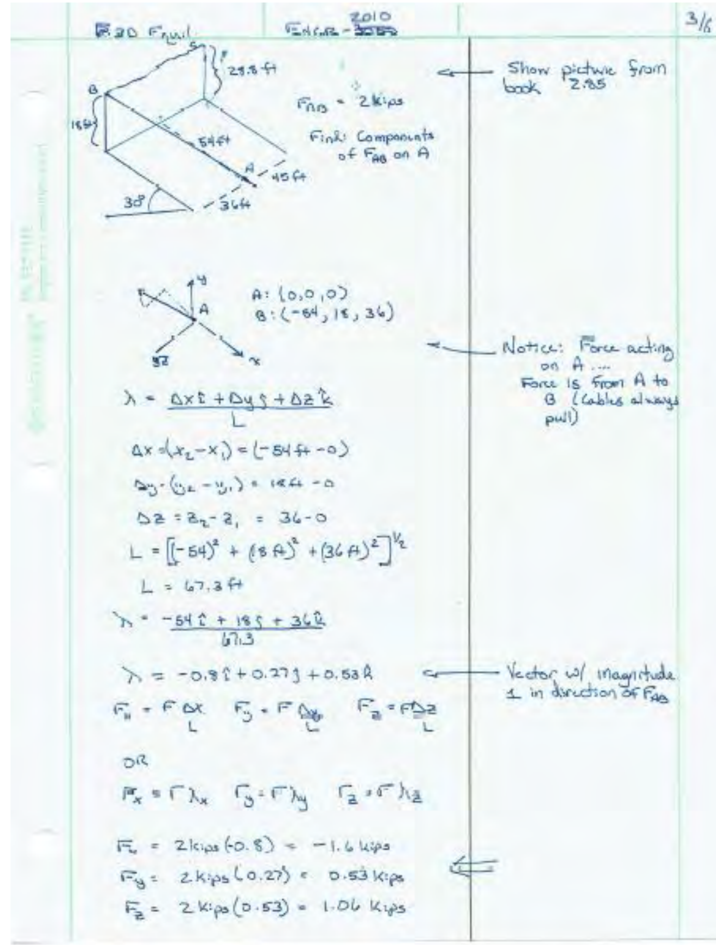
$\lambda_D = \frac{0\hat{i} - 5.60m\hat{j} - 3.3m\hat{k}}{(0^2 + (5.60m)^2 + (3.3m)^2)^{1/2}}$

$\lambda_D = -0.86\hat{j} - 0.51\hat{k}$

$\lambda_C = \frac{2.40m\hat{i} - 5.60m\hat{j} + 4.2m\hat{k}}{((2.40m)^2 + (-5.60m)^2 + (4.2m)^2)^{1/2}}$

$\lambda_C = 0.32\hat{i} - 0.76\hat{j} + 0.57\hat{k}$

⇐ Vectors in the direction of each force .... Notice how the components are readily identifiable.



3D Equil — Engr – 2010 — 3/6

27.8 ft, 18 ft, 54 ft, 45 ft, 36 ft, 30°

$F_{AB} = 2$ kips

Find: Components of F_{AB} on A

← Show picture from book 2.85

A: (0,0,0)
B: (-54, 18, 36)

← Notice: Force acting on A .... Force is from A to B (Cables always pull)

$\lambda = \frac{\Delta x\hat{i} + \Delta y\hat{j} + \Delta z\hat{k}}{L}$

$\Delta x = (x_2 - x_1) = (-54 ft - 0)$

$\Delta y = (y_2 - y_1) = 18 ft - 0$

$\Delta z = z_2 - z_1 = 36 - 0$

$L = [(-54)^2 + (18 ft)^2 + (36 ft)^2]^{1/2}$

$L = 67.3$ ft

$\lambda = \frac{-54\hat{i} + 18\hat{j} + 36\hat{k}}{67.3}$

$\lambda = -0.8\hat{i} + 0.27\hat{j} + 0.53\hat{k}$ ← Vector w/ magnitude 1 in direction of F_{AB}

$F_x = F\frac{\Delta x}{L} \quad F_y = F\frac{\Delta y}{L} \quad F_z = F\frac{\Delta z}{L}$

OR

$F_x = F\lambda_x \quad F_y = F\lambda_y \quad F_z = F\lambda_z$

$F_x = 2kips(-0.8) = -1.6$ kips

$F_y = 2kips(0.27) = 0.53$ kips ⇐

$F_z = 2kips(0.53) = 1.06$ kips

3D Equilibrium | Engr 2010 | 5/6

$\vec{F} = F\lambda$

$\vec{F}_B = F_B(-0.6i - 0.8j)$

$\vec{F}_C = F_C(0.32i - 0.76j + 0.57\hat{k})$

$\vec{F}_D = F_D(-0.86j - 0.51k)$

For Equilibrium....

$\Sigma F_x = 0 = -0.6F_B + 0.32F_C$ (1)

$\Sigma F_y = 0 = F - 0.8F_B - 0.76F_C - 0.86F_D$ (2) ← Don't forget $\vec{F}$!

$\Sigma F_z = 0 = 0.57F_C - 0.51F_D$ (3)

using (1) & (3)

$F_B = 0.53F_C \quad F_D = 1.12F_C$

(2) $F_C - 0.8(0.53F_C) - 0.76F_C - 0.86(1.12F_C) = 0$

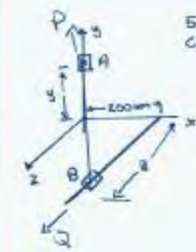
$F_C = \frac{F}{2.15} = \frac{800N}{2.15}$

$F_C = 372N$

$F_B = 197N$

$F_D = 417N$

3D Equil | Engr - 2010 | 6/6



525mm Long wire connects Collars on frictionless rods ← Show Picture 2.125

Find:
a) Tension in wire if $P = 341N\hat{j}$ and $y = 155mm$
b) Q required for Equil

a.) Assume equil @ A

$\lambda_W = \frac{200mm\hat{i} - y\,mm\hat{j} + z\hat{k}}{525mm}$

$\Sigma F_y = 0 = P + F_W\left(\frac{-y}{525}\right)$

→ Know P and y, can solve for F_W

b.)

$\Sigma F_z = 0 = Q - F_W\left(\frac{z}{525}\right)$ ← This is negative of λ_W we found in Part a.

Don't know z or Q....

$L^2 - 525^2 = (200mm)^2 + y^2 + z^2$ ← Know y = 165mm

Can find z, then Q