



A Study of Voluntary Problem Sets on Student Interest, Motivation, and Performance

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Abstract

Various types of course assignments are often structured with different learning goals in mind. Homework assignments are designed to provide students with the necessary practice to hone skills, quizzes are designed to make sure students stay current with course topics, and exams are designed to allow students to demonstrate mastery of the material. Extra credit work, which the students can engage in voluntarily and which is usually used only to provide a small grade boost to offset the difficulty of a challenging course, may accomplish much more. This study seeks to investigate how voluntary, extra credit problem sets may be used to reach more elusive learning objectives such as to expose students to broad-scope topics, to encourage students to put more effort into the course, and most importantly to increase students' level of self-motivation to investigate class topics further, beyond what normal time commitments might allow.

Students were presented with a series of non-mandatory, free-response problems in the form of a thirty-day endurance challenge. The students had thirty days to solve thirty problems in addition to the normal workload of homework, quizzes, and exams they were asked to complete. Each daily problem opened to the students at 12:01 am and was due at 11:59 pm that evening. Students had only that twenty-four-hour period to complete each problem though each was designed to take only about twenty minutes to an hour to solve. To further encourage constructive competition between students and to bolster each student's sense of self-motivation, daily challenge leaderboards were posted. The leaderboards anonymously displayed each student's accumulated earnings in the challenge at the end of each day.

Student performance data was collected throughout the course and from their collegiate record to date and correlated to their participation and performance in the thirty-day challenge. Data taken included student individual course grades at the time the challenge started, individual course grades at the time the challenge ended, overall grade point average to date, and the total amount of points earned and number of problems completed during the thirty-day challenge.

After the challenge ended students were surveyed to gauge how valuable the students felt the challenge was to their overall course performance and whether they felt the voluntary problems and the leaderboard display of scores contributed to their sense of self-motivation.

Introduction

In an attempt to provide undergraduate engineering students with a deeper level of long-term learning, a popular hypothesis in engineering education is that variety is paramount (Felder & Brent, 2016). In attempting to achieve a variety of activities and types of activities in the college classroom, instructors find that the different exercises and assessments satisfy distinctive learning goals. Homework, for example, tends to provide students with repetitive practice, while exams are primarily used to assess mastery. One overarching goal of particular interest here are

those activities and assessments that affect a student's sense of self-motivation. A variety of in-class activities from hands-on demonstrations to eliciting class participation can be used to keep students motivated and to encourage them to investigate the topics covered in the course with a more personal drive. It is possible that the class activity of extra credit work, which the students can engage in voluntarily and which is usually used only to provide a small grade boost to offset the difficulty of a challenging course, may also accomplish the task of bolstering student motivation. This study seeks to investigate how voluntary, extra credit problem sets may be used to reach more elusive learning objectives such as to expose students to broad-scope topics, to encourage students to put more effort into the course, and most importantly to increase students' level of self-motivation to investigate class topics further, beyond what normal time commitments might allow (Felder & Brent, 2004). In addition, voluntary course assignments may allow for assessments that can reflect a student's work as a convincing demonstration of a higher-level of learning (Burrow, et.al, 2001). By mixing voluntary problems that are more complex with simpler ones, students who attempt those challenges may feel a stronger sense of accomplishment and reward.

Anecdotally, it is sometimes the experience of instructors that if a particular task is given as a requirement, (say the analysis of a 10-state process cycle in a thermodynamics course) that the assignment of that task is met with routine boredom. But assign the same task as an extra credit assignment and suddenly the task becomes an exciting challenge. Of course, this isn't the attitude of all students in a course, but it does beg the question of just how motivating can voluntary tasks be. In order to understand the relationship between student motivation and the structure of a particular classroom exercise, one must first understand student motivational theories.

There are many theories on motivation in the engineering education literature and it is suggested that they may all be categorized into the following four groups: (A) expectancy, (B) engagement, (C) expectancy plus value, and (D) motivation plus cognition (Brown, et.al 2015). "Expectancy" is essentially the idea that one's motivation to complete a task is directly tied to that individual's perceived ability in relation to that task. If one perceives their success rate on a task is high, they are motivated to complete that task. "Engagement" relates to reasons for motivation based on fundamental needs. An individual develops a need for competence, for autonomy, or a need to fit within a social group and those needs drive a desire or a motivation to fulfill that need. "Expectancy plus value" is a model that combines the expectancy of one's ability to complete a task with a further weighing of the subjective value one places on that task. Lastly, "motivation plus cognition" is a classification of motivational theories that inexorably tie learning in with motivation. One is not separate from the other.

Observing student motivation in practice provides the gap between motivational models and frameworks to concrete best-practices concepts for instructors. Findings suggest that a variety of instructor qualities contribute to engineering students engaging in need fulfillment or expecting task outcomes for success, such as inspirational ability, consistency, and classroom performance (Savage, et.al. 2011). The challenge is then in how best to stimulate student motivation by providing engaging classroom performances and couple that with assessments that encourage and provide opportunities for independent and self-satisfying learning. This study seeks to show that extra-credit assignments may possibly affect student motivation by stimulating a variety of student needs.

Methodology

Two undergraduate courses were used to test the effect of student performance on voluntary problems sets. The first course, which will be referred to as Course A, was a traditional lecture course in undergraduate dynamics during the fall 2016 semester with an enrollment of 125 students from various engineering disciplines such as civil engineering, industrial engineering, biological engineering, computer engineering, and electrical engineering. Course A was a two credit course designed specifically for students in disciplines other than mechanical engineering which is often taken as an optional technical elective in their curriculum. The course consisted of students from sophomore to senior level and was about 33% female and 67% male. The second course, which will be referred to as Course B, was a class in undergraduate thermodynamics and heat transfer with an enrollment of 127. Course B, like course A, was also of a traditional lecture-style format and was designed specifically for students in disciplines other than mechanical engineering. Course B was about 25% female and 75% male.

Both course A and course B were taught in similar styles by the same instructor in a traditional, lecture-style format in which grades were determined by homework, quizzes, mid-semester exams, and a final exam. While the structure of the courses was fairly traditional, the transmission of course content was a hybrid of in-class and online delivery. Each lecture was filmed in a traditional 2- or 3-day a week schedule where students were encouraged, but not required to attend the live tapings. Those students who chose not to attend the live tapings could watch the recorded lecture videos online. The lecture videos and all course content, including homework assignments and quizzes, were published online through the Canvas learning management system. Homework assignments and quizzes published through Canvas required students to submit all solutions and answers online either by filling out online forms or by producing paper solutions and scanning them into pdf format for submission online. During-semester exams and the final exam were the only assessments that students were not able to complete online.

In addition to the course structure, several extra-credit assignments were offered to the students during the last month of the course in the form of a 30-day challenge. On each morning of the 30-day challenge period a new question would open to the students at 12:01 am. The challenge problem would remain online for the students to complete at their leisure during the day and were due at 11:59 pm that evening. Students were instructed to produce hand-written solutions, scan those solutions into pdf format, and submit them to Canvas before the midnight due date. Problems were designed to span a variety of difficulty levels from easy problems, intended to be solved in about 20 minutes, to complex problems that may take up to two hours to solve, with many difficulty levels in between. Student submissions were graded by teaching assistants in a relatively lenient fashion depending on the difficulty of the problem. Easy problems required fully correct values to be marked as correct while complex problems required only about 75% to 80% correctness to be awarded full marks. Each voluntary challenge problem that was marked correct earned the student a single point towards an exam.

The researcher was aware that some students were enrolled in both course A and course B during the semester studied and so the 30-days of each challenge were staggered by 15 days to minimize the time over which each course's challenge overlapped. At the end of each course's thirty-day challenge period, participants would be awarded a bonus based on how many challenge problems they completed successfully. A single bonus point was awarded for participants completing at

least 10 problems correctly, two bonus points for completing at least 20 problems correctly and five bonus points for completing all thirty problems. As was mentioned previously, each extra credit point (including the bonus points just mentioned) was added to students' exam pool. With a maximum of 35 bonus points attainable this amounted, considering the weighting of exams to the overall course grade, to a maximum of 5.25% for both classes.

The end of the challenge period roughly corresponded to the end of the semester at which point students were asked to complete a voluntary survey to gauge their level of participation in the challenge and whether or not they felt they had benefitted from it. In both courses, students were asked the same survey questions. Some of the questions surveyed the students about their voluntary participation in the challenge asking them (1) why they did or did not participate in the challenge and (2) how many problems they completed. Other questions in the survey asked the students to rate statements on a basic Likert scale with "Strongly Agree", "Somewhat Agree", "Neutral", "Somewhat Disagree", and "Strongly Disagree" being the available answers. The Likert scale questions were as follows:

1. The 30-day challenge problems motivated me to watch or attend class regularly
2. The 30-day challenge problems motivated me to investigate class topics further.
3. The 30-day challenge problems helped me to understand the application of course materials to engineering practice.

Several examples of the challenge problems are given in Appendix A for class A and Appendix B for class B.

Data Analysis

Participation in the voluntary problem challenge was gauged by inspecting several trends. First, the level of overall participation was tallied by calculating the total number of problems successfully completed by each student. Figure 1 (A) and (B) shows a histogram from course A and course B, respectively, of how many students completed various amounts of problems throughout the challenge. In light of general feedback, the 30-day challenge was viewed by the students as an endurance challenge. Predictably, the histograms showed a generally declining number of students completed higher numbers of total problems. The largest group of students completed five or less total problems, the second largest group completed between five and ten. From class A only a single student completed all thirty challenge problems correctly while four accomplished that feat in class B. The histogram for class A shows that all students completed at least three problems, while class B shows a significant portion of students that did not participate in the thirty-day challenge. This is due to the timing of the class A's thirty-day challenge whose last week conflicted with end-of-semester reading days. As per university policy, no assessments are allowed to be collected on those days and therefore each student in class A was automatically given credit during that period as long as they submitted a single online response. This is responsible for the peak seen for class A just after day 25. While it appears that Class A showed a 100% active participation rate from all 125 students, this is really only attributable to the automatic credit given on days 26 through 28. Removing those days from consideration there were 19 students in class A that did not turn in any extra credit solutions which amount to an

84.8% participation rate. Interestingly, class B also had 19 students that chose not to participate in the study (surely this is a coincidence), which amounts to an 85.0% participation rate.

Participation in the challenge was also detailed as a function of time. Figure 2 shows, for both courses, a timeline of how many problems were submitted for each day of the challenge. Participation grew and fell over time with the largest number of submissions coming towards the beginning of the challenge period for each class. Class A showed the highest participation on day-3 with a submission rate of about 60%, not including days 26, 27, and 28 because of the aforementioned reading days. Class B showed the highest participation on day-1 with a submission rate of about 72%. The days of lesser participation are also of note. The overall behavior of student participation was clearly affected by regular class assignment and exam schedules. A mid-semester exam was given in course A on day nine which is accompanied by a dip in submissions before and after. Course B had a mid-semester exam on day eleven which immediately follows the day of least submission on day ten.

The effect of participation in the challenge towards student performance is shown in Figures 3 (A) and (B) where attempts were made to find a correlation between final course grade and total number of successful problems completed. Little correlation was found between overall course performance and the performance on the challenge with a correlation coefficient of about 0.35 for course A and a correlation coefficient of about 0.28 for course B.

Perhaps more important than the affect participation in the challenge had on final course grade was the affect the challenge problems had on the student's perceived performance, perceived motivation, and the scope the course would have on their future endeavors.

When asked if the challenge problems motivated students to regularly watch or attend lectures, about 47% of students in course A agreed with the statement while only 26% disagreed. About 50% of students in course B agreed with the statement and only 11% disagreed. Figure 4 shows these results.

When asked if the challenge problems motivated students to investigate class topics further, about 56% of students in course A agreed with the statement while only 27% disagreed. About 54% of students in course B agreed with the statement and only 13% disagreed. Figure 5 shows these results.

When asked if the challenge problems helped the students to understand the application of course topics to engineering practice, about 68% of students in course A agreed with the statement while only 13% disagreed. About 72% of students in course B agreed with the statement and only about 6% disagreed. Figure 6 shows these results.

Overall the completion rates between class A and class B are similar in average if not in trend. As was stated previously, class B began their 30-day challenge 15 days prior to class A, leaving class A to cope with perhaps more end-of-the semester issues and stress as they attempt to tackle challenge questions.

Also of interest is the apparent disparity between those who chose to answer several of the survey questions with "Strongly Agree". For class A, 12.5% of students and for class B, 24.1% of students, chose to answer the question that the challenge "motivated me to watch or attend class regularly" in this way. For class A, 24.0% of students and for class B, 16.5% of students, chose to answer the question that the challenge "motivated me to investigate class topics further"

as “Strongly Agree”. For the question that the challenge “helped me to understand the application of course topics” the results of “Strongly Agree” were 17.9% for class A and 41.8% for class B. This interesting trend can perhaps be explained from anecdotal evidence and feedback from students about the class. The general consensus was that class A’s challenge problems were more abstract and simple while still computationally challenging while class B’s challenge problems were more applicable to the real world in an obvious manner and quite difficult overall. The extra variety in real-world applications for class B would prompt more students to agree in its wide applicability. For class A, however, while the problems came from a variety of disciplines, the real-world nature of many of the problem were perhaps not marketed in convincing ways for the students to see that connection.

Conclusions

Overall student feedback on the thirty-day challenge was positive but strained. Most students wanted or felt they needed the extra credit and generally decided to participate in as much as their schedules would allow. Some students decided to purposely not engage in the extra credit challenge based solely on the fact that their calculated grade projections without it would be acceptable. And still others participated in the challenge simply because they were interested to see what other real-world applications of class topics existed.

The negative feedback that was received focused to two main factors: fatigue and complexity. A small percentage of students did not participate in the challenge as they felt the challenge problems were too difficult for the reward. Others felt that the rapid pace of the challenge was too much to keep up with. This contributed to patterns of behavior such as participation early in the challenge and less at the end, sporadic participation throughout the challenge, and also participation in every two- or every three-day cycles.

Ultimately, the majority of students felt that the challenge motivated them to participate in class and to study more. Perhaps the most quantifiable result, however, was the benefit the students gleaned from seeing more varied and more complex problems that were more indicative of what unique real-world engineering analysis challenges might hold.

Future Work

There were two aspects of the original formulation of this study that were not incorporated during the first semester the discussed activities were implemented. The first was the use of anonymous online leaderboards for students to track their performance in comparison to their peers. Students are given codes, in the form of simple digital image avatars, at the beginning of the challenge with which to identify their score on Canvas-published online leaderboards. Students do not know the corresponding avatars of their peers unless they volunteer to share them but can still track their performance on the challenge to everyone else in the class. This introduces an additional component of competition or an additional desire for completion that may influence the motivation associated with their course work.

The second, is the correlation of student performance and participation on the thirty-day challenge to their collegiate records to date. Investigating such a correlation may yield

information about whether voluntary exercises motivate or influence students when more traditional assessments provide less of a novel challenge.

These two considerations will be implemented during the present semester for inclusion and presentation during the summer.

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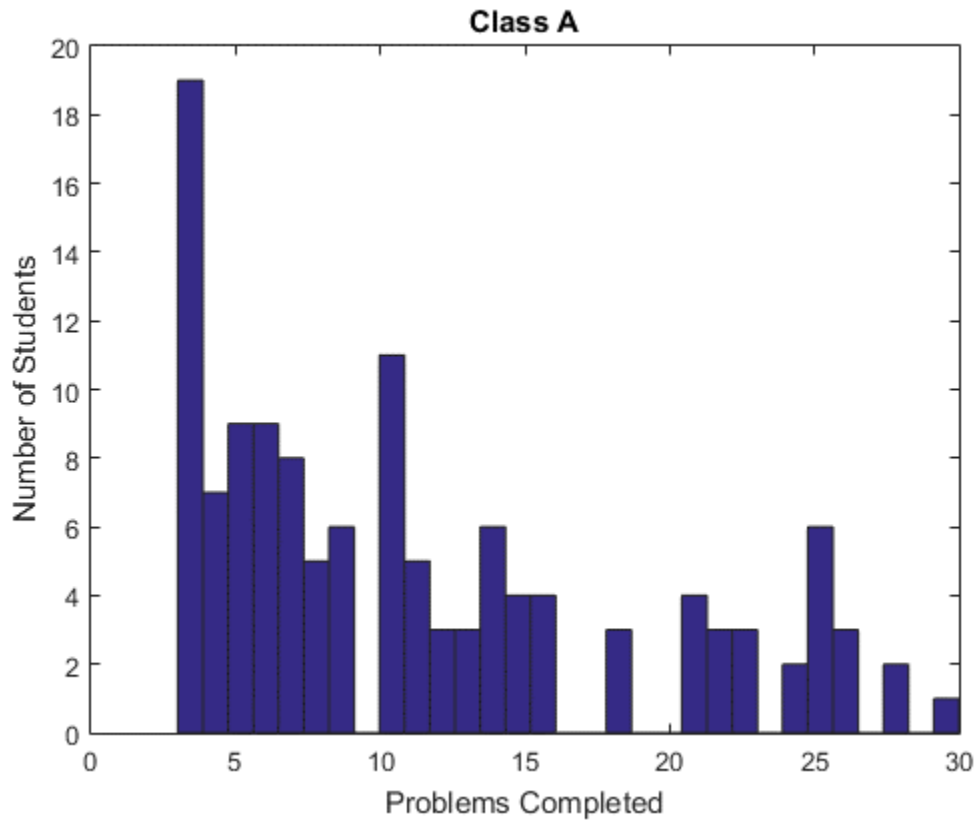


Figure 1(A): The histogram shows the level of participation of each student in the course. Every student completed at least three challenge problems, while only one completed all thirty problems successfully.

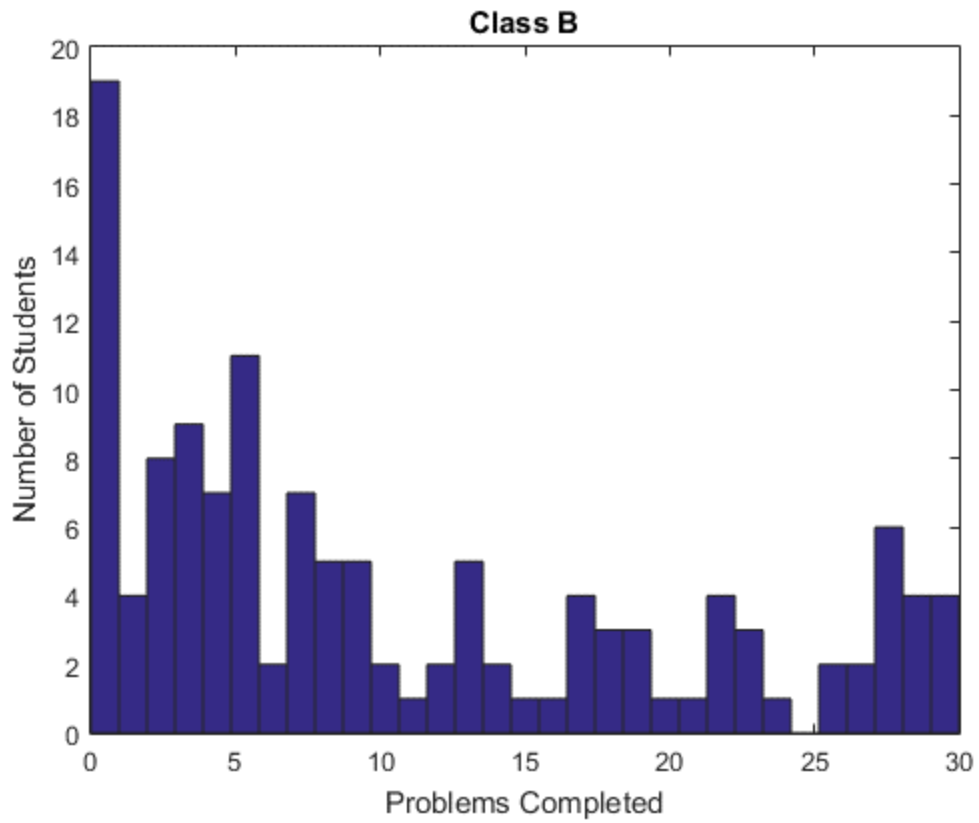


Figure 1(B): The histogram shows the level of participation of each student in the course. Nineteen students chose not to participate in the challenge and four students completed every challenge problem successfully.

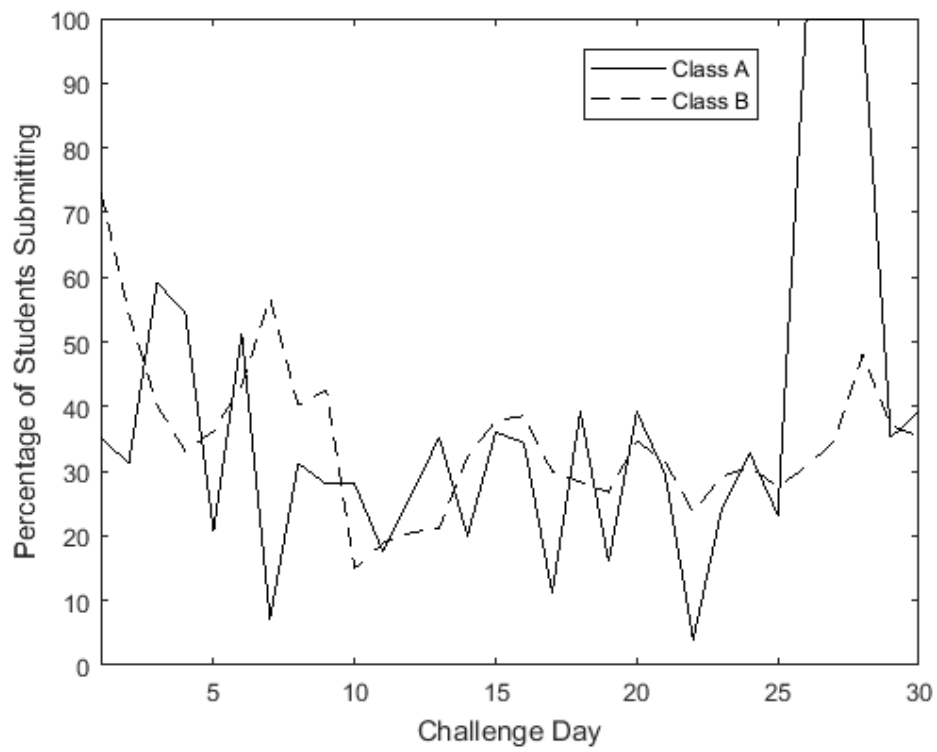


Figure 2: Out of 125 students for class A and 127 students for class B, this graph shows the percentage of correct student submissions on each day of the challenge

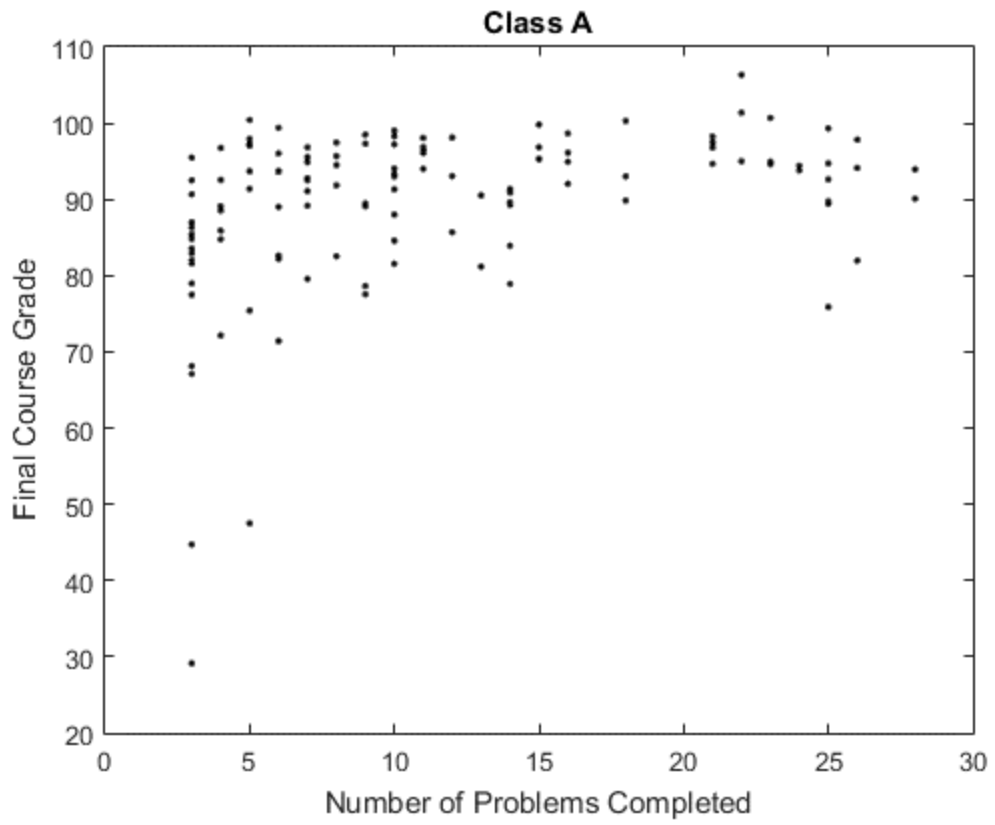


Figure 3(A): Scatter plot comparing student performance to participation in the challenge. A final course grade of 90 or above was awarded an A

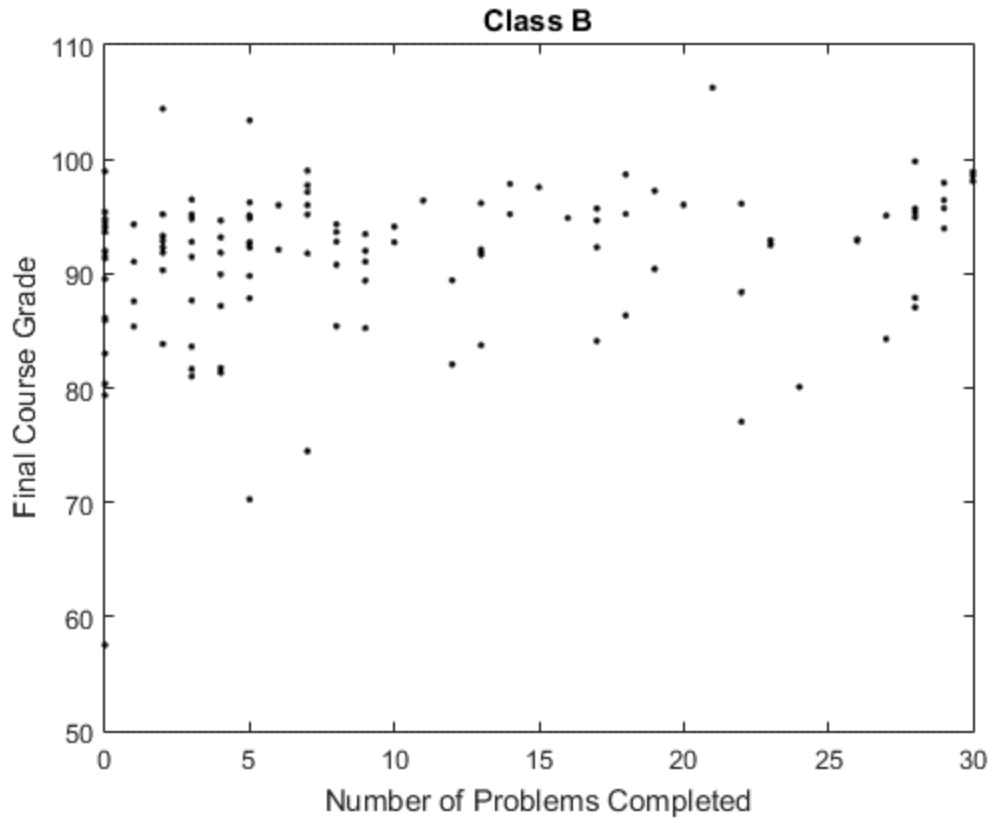


Figure 3(B): Scatter plot comparing student performance to participation in the challenge. A final course grade of 90 or above was awarded an A

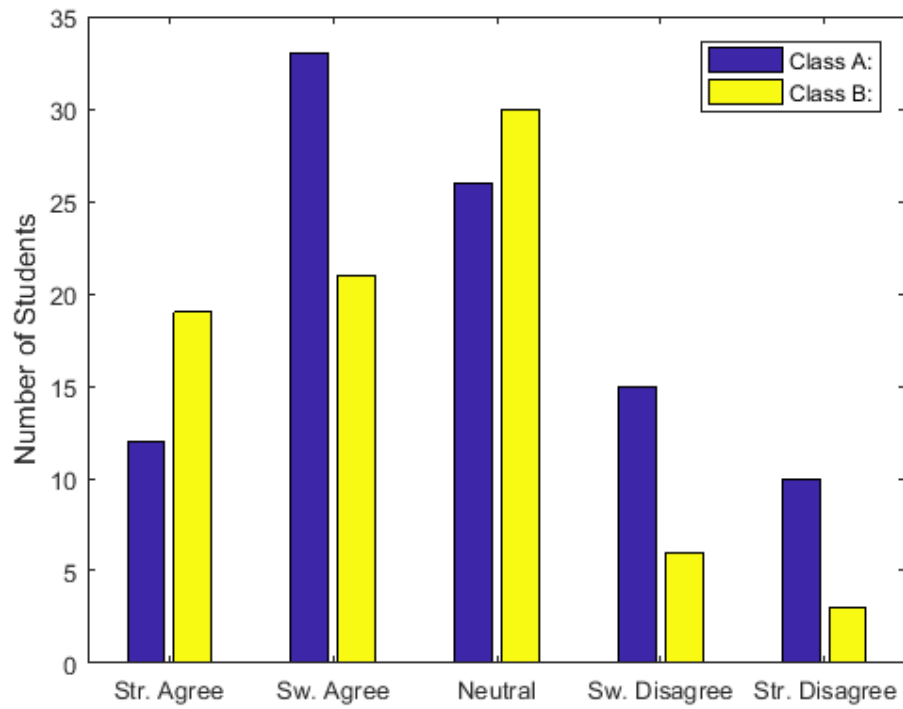


Figure 4: The thirty-day challenge problems motivated me to watch or attend class regularly.

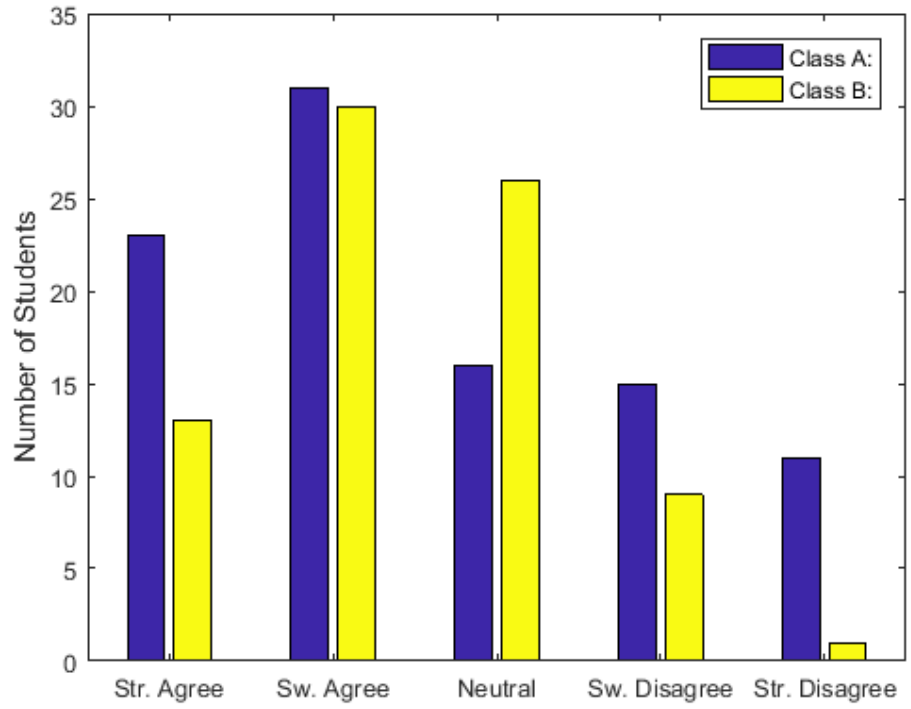


Figure 5: The thirty day challenge problems motivated me to investigate class topics further

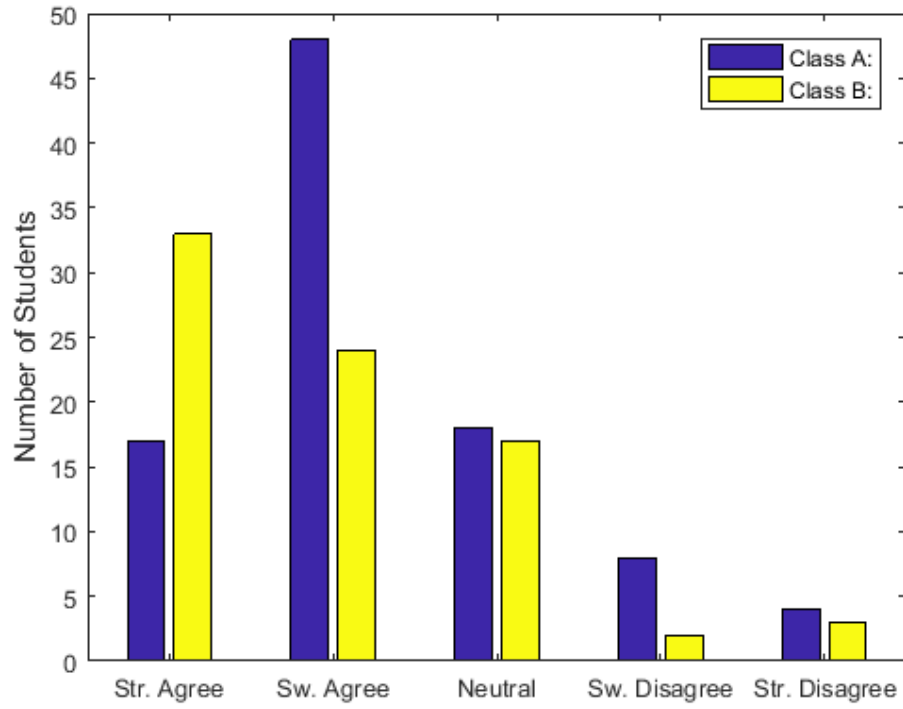


Figure 6: The 30-day challenge problems helped me to understand the application of course topics to engineering practice

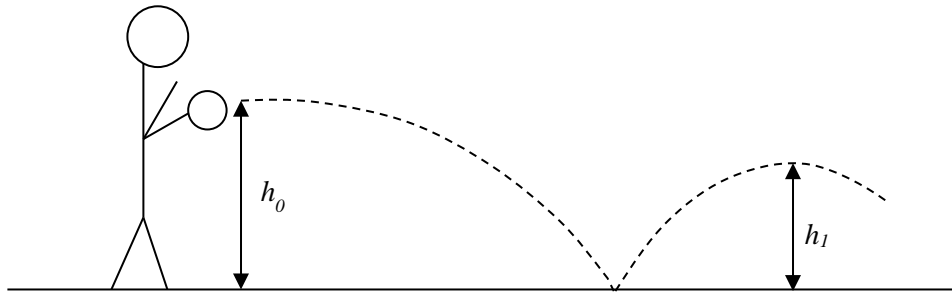
Appendix A: Three challenge problems from Class A

Thirty-Day Dynamics Challenge

Challenge Problem 2

Projectile Motion and Impact: Just for fun, a golfer throws a golf ball horizontally through the air and watches it bounce again and again down a long straight concrete path. The ball is thrown horizontally from a height of $h_0 = 1.5$ m with an initial speed of $V_0 = 28$ m/s. The coefficient of restitution between the golf ball and the concrete is $e = 0.92$.

- (A) Determine the maximum vertical height the golf ball will reach after its third bounce, h_3 .
- (B) Determine a formula for the maximum vertical height the golf ball will reach after its n th bounce, h_n , in terms of the variables, h_0 , g , e , and n .
- (C) The bouncing of a small sphere is modeled as dynamic particle motion. Particles are assumed to be point masses that take up no space, even though the diameter of a golf ball is about 42.7 mm in reality. Eventually, after enough bounces have occurred, the golf ball will cease bouncing and roll along the ground. If we suppose that rolling begins when the bounce height drops to half the sphere's true diameter, after how many bounces, m , will rolling begin?



$h_3 =$ _____

$h_n =$ _____

$m =$ _____

Thirty-Day Dynamics Challenge

Challenge Problem 11

Projectile Motion: A master Pokemon trainer stands poised to throw a pokeball at a wild Pikachu. The trainer's aim is practiced and accurate and, as such, always throws a pokeball with the same speed, $V_0 = 22$ m/s, and with the same angle above the horizontal, $\theta_0 = 15^\circ$. Catching a pokemon is then only a matter of precise timing! As Pikachu are intelligent and difficult to catch, they are prone to jumping at random moments to avoid capture. If the standoff begins at $t = 0$ s, and anticipating that the Pikachu will jump at $t_j = 3.0$ s, determine the interval of time, $t_1 < t < t_2$, over which the trainer must release the pokeball to guarantee capture.

The Pikachu is 0.5 m tall, jumps to a maximum height of 1.5 m, and capture is guaranteed if any part of the pokemon's body is touched by the pokeball. The pokeball is released at a height of 0.5 m above the ground and the Pikachu is 4.0 m away.



interval = _____ $< t <$ _____

Thirty-Day Dynamics Challenge

Challenge Problem 18

Air Resistance and Terminal Velocity: For an object in vertical free fall, starting from rest, and neglecting any retarding effects from air drag, the height and velocity of the object are simply found from the following constant acceleration kinematics equations:

$$z = h_0 - \frac{1}{2}gt^2 \quad V = -gt$$

If, however, we assume that air drag is present and proportional to the velocity, according to the expression, $D = -kmV$, then the height and velocity at any time, t , can be found by integrating the equations of motion to find:

$$z = h_0 - \frac{gt}{k} + \frac{g}{k^2}(1 - e^{-kt}) \quad V = -\frac{g}{k}(1 - e^{-kt})$$

Consider the penny drop scenario from the 102nd floor of the empire state building once again. The initial height of the penny is 381 m above street level and it is dropped from rest. We will assume the drag constant is $k = 0.01$ 1/s.

- (A) Determine the time it takes for the penny to hit the ground, z , and the velocity, V , it will have at that moment if there is no air drag.
- (B) Determine the time it takes for the penny to hit the ground, z , and the velocity, V , it will have at that moment if air drag is linearly proportional to velocity.
- (C) The velocity of an object will obviously increase as it falls. The drag force, however, will also increase with the velocity. Eventually, if the object falls long enough, the drag force will increase to the point where it equals the force of gravity. When this happens the resultant acceleration falls to zero and the velocity will remain constant from then on. This constant velocity is known as the *terminal velocity*, V_T . The terminal velocity can be determined from the velocity expression above by letting time approach infinity. Determine V_T for this scenario.

Appendix B: Three challenge problems from Class B

Thirty-Day Thermo Challenge

Challenge Problem 3

The van der Waals Equation of State: The study of ideal gases is a fundamental component of all introductory treatments of thermodynamics. However, just as no engine is perfectly reversible, no gas behavior is truly ideal. We have discussed previously how to use compressibility theory (the compressibility chart and the compressibility factor, Z) to determine whether or not a gas is “sufficiently close” to ideal behavior. This taught us that there is a range of conditions (pressures and temperatures) in which the ideal gas law, written below in terms of moles, is an accurate model of gas behavior.

$$PV = n\bar{R}T$$

But this is by no means the only gas model we have. In the 1870’s, J. D. van der Waals, introduced a slightly more complicated equation of state.

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = n\bar{R}T$$

The benefit was that even though the van der Waals equation of state was more complex and required knowledge of independent parameters, a and b , it served as a more accurate gas law for a much wider range of pressures and temperatures outside traditional “ideal” conditions.

Let’s compare the two equations to known tabulated data for water vapor, H_2O . For 1-kg of water vapor at $P = 100$ kPa and $T = 150$ °C. We’ll determine the volume three different ways:

- (A) Determine V using data given in table A-6 of the appendix on Canvas
- (B) Determine V using the ideal gas equation of state
- (C) Determine V using the van der Waals equation of state

Note: Remember that both equations above are in terms of moles, so make sure that you are using the correct value of the universal gas constant, \bar{R} , and that you properly convert from mass to moles as needed. Also, in order to use the van der Waals you will need to find values for the parameters a and b , which vary by gas, from somewhere.

Thirty-Day Thermo Challenge

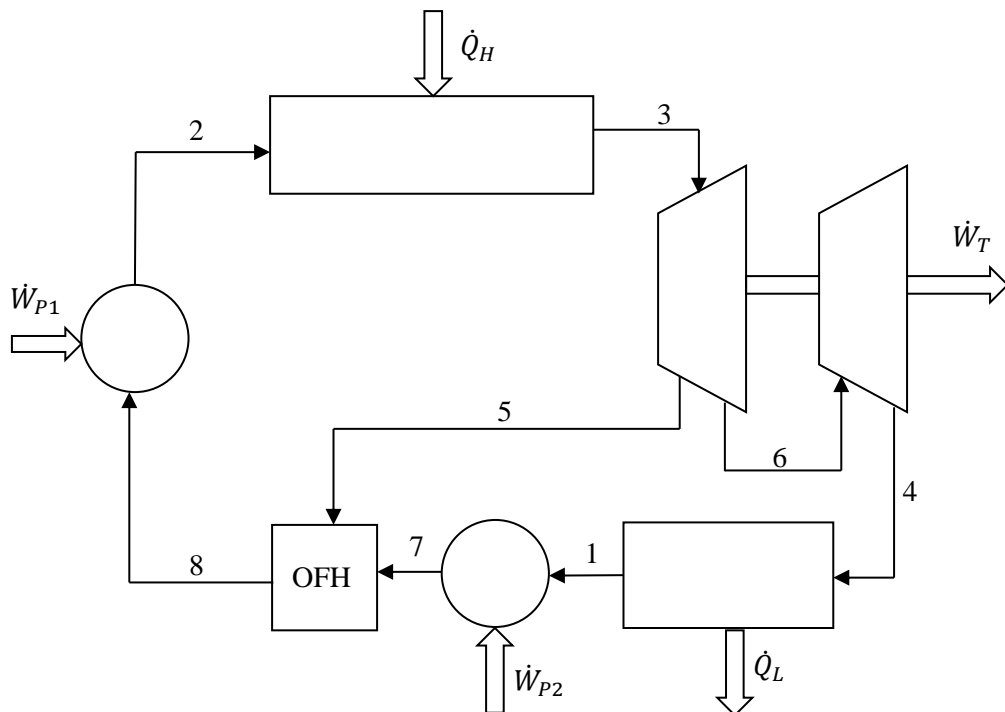
Challenge Problem 13

Ideal Rankine Cycle with Regeneration: After having investigated the Rankine cycle in detail, we can begin to augment the cycle with modifications beyond a theoretical model toward what might be practical in real life. In an effort to increase the thermal efficiency of the cycle, a small portion of hot steam is extracted from the turbine and sent to a mixing box to “preheat” the cold liquid before it enters the steam generator. The mixing box is often referred to as an *open feedwater heater* and the process that results is referred to as a *regeneration* process.

The Rankine cycle with regeneration operates with water as the working fluid and has the following conditions:

$$P_1 = 75 \text{ kPa}, x_1 = 0, P_2 = 2000 \text{ kPa}, T_3 = 700 \text{ }^\circ\text{C}, P_5 = P_6 = 1200 \text{ kPa}, x_8 = 0, \dot{m}_1 = 2.0 \text{ kg/s}, \dot{m}_5 = 0.5 \text{ kg/s}$$

Determine $h_1, h_2, h_3, h_4, h_5, h_6, h_7, h_8, \dot{W}_{P1}, \dot{W}_{P2}, \dot{Q}_L, \dot{Q}_H, \dot{W}_T$, and η_{th}



Thirty-Day Thermo Challenge

Challenge Problem 19

The Diesel Cycle: An idealized two-stroke Diesel cycle is shown in the P-V diagram below. It is identical to the Otto cycle except that the heat input process is modelled as constant pressure rather than constant volume. Assuming the fluid is air with a mean effective specific heat ratio, $k = 9/7$, and the following operating conditions,

$$P_1 = 100 \text{ kPa}, T_1 = 300 \text{ }^\circ\text{C}, m = 0.02 \text{ kg}, V_2 = 0.00190 \text{ m}^3, V_3 = 0.0062 \text{ m}^3$$

determine the unknown state variables: V_1 , P_2 , T_2 , P_3 , T_3 , P_4 , T_4 , and V_4 .

