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A Specifications-Based Approach for the Design and Delivery of a Statics/Dynamics Course

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Introduction

Learning and teaching represent two complementary, but also separate aspects of the educational environment. A good, or great, teacher can assist a student in learning, but cannot necessarily instill the habits of good learning within a student. In contrast, good, or great, learners are capable of high levels of learning even in environments where teaching may be weak. As such, it seems that one of the primary responsibilities of a teacher ought to be the training of a student to become an effective learner. This training lies less in the classroom presence and behavior of the teacher and more on the learning environment created by the instructor [1-2]. A properly designed learning environment ought to minimize the influence of the teacher on learning while maximizing the learning habits of the student. One potential method for doing this is to create a ″specifications-based″ learning environment wherein the assessment of student performance is structured around requiring students to engage course materials in ways that are consistent with effective learning. This paper examines the application of a specifications-based environment to the design and delivery of a Statics/Dynamics course.

The specifications-based approach outlined in this paper is derived from two disparate fields. The first is that of Statistical Process Control as practiced in the manufacturing environment [3]. Statistical Process Control (SPC) operates on the premise that if the manufacturing processes are functioning within specification, then the final product will be within specification. The significant advantage of SPC is that it reduces or eliminates the need to perform quality inspections on the product. SPC has found applications in many fields, including healthcare [4] and education [5-9]. Most of the education related references focus on the larger topic of Total Quality Management (TQM) and its application to managing the educational institution rather than specific implementations of TQM or SPC to the classroom environment.

The motivation for applying the concepts of SPC to the classroom environment is the idea that if we can get students to engage in proven learning processes then less time and effort is required to inspect the results of the learning process. As W. Edwards Deming notes in his book, *Out of the Crisis*, ″you cannot inspect quality into a part.″ [10]. In both SPC and the educational environment, the quality of the product is determined by the process, not by the inspection.

The second foundation for the specifications-based course design is the process of ″specifications grading″ [11]. Specifications grading is a grading approach where work is graded on a go/no go basis. Grades are assigned based on the quantity of work successfully completed rather than relying on partial credit to assign grades to work that is not successfully completed. Specifications grading provides the means for controlling the process parameters. Each time the student completes work that is within the process parameters, credit is given and the student advances toward fulfilling the course performance requirements.

If we are going to help students engage in effective learning processes, then a natural place to start is with courses that are early in the student′s career. From an engineering perspective, this implies the ″gateway″ courses that students first encounter in their engineering studies. Of these, the courses in Engineering Mechanics (Statics, Dynamics) provide an essential foundation for several engineering disciplines which makes them logical candidates for the implementation of effective learning processes.

Before examining the use of specifications-based learning processes, we need to first define and establish those things that make learning effective. This is considered in the next section.

Identifying Effective Learning Processes

If you were counseling a freshman or sophomore student with advice on how to be more successful as a student, what advice would you offer to that student?

Common recommendations made to enhance student success include items such as: ″Attend class″, ″Take good notes″, ″Review your notes after class″, ″Spread out your studying instead of cramming for exams″, ″Read the text and prepare before you go to class″, ″Have designated time during the day where you study″, and other similar ideas. Most of us have given, or been given, such advice over the years. And while these are all sound advice, what are the odds of the student taking that advice to heart and acting upon it? Can we make students better learners simply by telling them how to be better learners? Or should we instead design our courses to engage students with effective learning strategies?

This section looks at some ideas for effective learning as we build into the actual implementation of these ideas. One thing to keep in mind is that the focus here is on developing the learning process. This is somewhat different from considering effective teaching practices. If we can design a course so that students are engaging in proper learning processes, we provide greater benefit to the student by not only teaching the current subject, but also equip the students to learn better when a teacher is not present.

A variety of anecdotal learning practices have been listed above. A number of these are formalized in the book, *Make it Stick: The Science of Successful Learning* [12]. A summary of effective learning practices from this resource suggests that students ought to be doing the following to learn better:

- Spacing out the practice of a task.
- Interleaving different tasks.
- Trying to apply information (solve a problem) before being taught the solution.
- Engaging a variety of forms of learning.
- Varying practice instead of bulk practice on one topic.
- Building on a foundation of prior knowledge.
- Putting learning into a larger context.
- Obtain and implement feedback.

Many of the items in the above list are similar to the things we tell students to do. The question, however, lies not in ″what″ to do, but in how to provide an environment where students can engage with these learning practices. The specifications-based learning environment presented in this paper focuses not on the ways of being an effective teacher, but rather on the methods that can be used to create a learning environment that makes students effective learners.

If we accept the list above as a fair representation of good learning practice, the next step is to see if these items can be incorporated into the design of an engineering course. In this case, we are looking at the design of a Statics/Dynamics combined course that takes the students through the foundations of these topics in a one semester course.

Incorporating the Learning Processes into Course Design

As we examine the list of learning strategies given above, we need to consider how to engage students in a way that not only encourages these habits, but also, to some degree, requires the students to develop and use these habits. The premise is that if we can control the process within specified boundaries, the product will meet specifications. If we can dictate the process that students use to learn, we can better guarantee the fact that they have learned.

Statics/Dynamics is a reasonably straight-forward engineering course. Course topics are well established as is evidenced by the similarity found in textbooks for such a course. The challenge lies not in topics or resources, but rather how to arrange the course to engage student learning.

The course design presented in this paper builds upon the list of effective learning strategies by mandating that students engage the course in a manner consistent with proven learning strategies. Table 1 provides a list of the learning strategies from above. These are cross referenced with course processes that have been put in place to help students engage the particular learning strategy. The x′s in the table indicate the alignment between course processes and learning strategies.

Table 1: Relationship between course processes and learning strategies.

		Course processes						
		Doodling	Preclass problems	Notebooks	Homework	Review problems	Design problems	Computer analysis
Learning strategy	Spacing practice over time		x	x	x	x		
	Interleaving topics and tasks	x					x	
	Apply information before being taught	x	x					
	Variety in forms of learning	x		x	x		x	x
	Foundation of prior knowledge					x	x	x
	Learning in a larger context						x	x
	Obtain and implement feedback		x		x	x	x	

Table 1 includes seven different course processes designed to facilitate student learning. The subsections below discuss the rationale for these processes as well as the specifications that are used to evaluate successful completion of student submissions.

Doodling

Rationale: The process of ″doodling″ is used to require students to create a pictorial representation of current and past course information. Students are required to create a pictorial representation of each day′s topic before the student comes to class (doodles collected at the start of class). Students are also asked, at various points in the course, to create a ″review doodle″ that captures multiple concepts from the course in a single pictorial representation. The doodling practice thus provides a means to verify that students have applied course information before being taught, presents an opportunity for a different form of learning (translation of concepts into a pictorial language), and the interleaving of ideas in a summary doodle. More information on doodling can be found in references [13] and [14].

Specifications for Successful Submission: Doodles receive credit if they demonstrate a connection between course topics and a real application of the topic. Generic drawings or drawings that are copies of textbook problems do not receive credit.

<u>Preclass Problems</u>

Rationale: Students are required to solve one simple homework or conceptual problem prior to coming to class each day. This serves two purposes. The first is to provide a contact point with course material prior to being taught. The second is to start the process of spaced practice. A gap of one or more days typically exists between the time the students solve the preclass problem and then solve a homework problem.

Specifications for Successful Submission: Preclass problems are completed in the course Learning Management System (LMS). These are set up as ″Arithmetic″ problems where the student enters a numerical value as the solution to the problem. Students get three attempts (each attempt has the same problem but with different numbers) and are given credit for a correct answer. The multiple attempts encourage the students to locate and correct errors in real time, rather than relying on a grader to perform this task on a delayed basis.

<u>Notebooks</u>

Rationale: Students are provided with a summary set of course notes. This set of notes includes approximately one page of notes for each lecture day, and a second page that contains example problems (problem statement only) and blank space to solve the problems. Student notebooks are checked once a week to ensure they have transcribed the sample problems that are worked in class onto their notebook pages. An essential part of this idea is that the blank space with the provided notebook pages is limited. As such, most students take course notes in a regular notebook and then transcribe the notes into the more confined printed notebook page later. This approach spaces their practice over time with a review of the daily notes, and also adds variety to the assessment of student engagement. A bonus is that the notebooks provide a well-organized compilation of course material.

Specifications for Successful Submission: Students must have completed solutions for all problems worked in class.

<u>Homework</u>

Rationale: Traditional homework problems are assigned on a daily basis and are due approximately 4-5 days after the class period. The homework problems continue the spacing of practice, building on the previous touchpoints of the preclass problems and the notebook problems. Two homework problems are assigned for each lecture period.

Specifications for Successful Submission: Homework problems are completed using the same specifications for successful completion as used for the preclass problems.

<u>*Review Problems*</u>

Rationale: Once the course enters its fifth week, one daily review problem is added to the daily homework requirements. This continues the spacing of learning by adding a fourth contact point (preclass, notebooks, homework, review) at a defined interval in the course. Review problems are spaced so that they occur at least two weeks after the topic was covered in class, and may extend back up to approximately five weeks.

In addition to daily review problems, the course also contains two review weeks, one at the end of the Statics portion of the course (in week 8) and one at the end of the Dynamics portion of the course (week 16). These weeks provide another spaced learning point so that by the time of the last review students have had five separate touchpoints spaced over approximately eight weeks for each course topic.

Specifications for Successful Submission: Review problems are completed using the same specifications for successful completion as used for the preclass problems.

<u>*Design Problems*</u>

Rationale: Open-ended design problems are used in the course to provide another form of engagement with course information and to present course content in a larger context. The ideal design problem asks students to integrate multiple course topics and apply them to create a unique solution. These problems require students to formulate their own values for a number of design variables with the results being driven by the choices they make. The design problems also provide a unique form of collaborative feedback for the students. Since each student chooses their own design parameters, each one is working a unique problem. This allows students to collaborate on the solution process, while also requiring each one to eventually apply that process to their own solution. The appendix of this paper contains a sample design problem statement. Students complete one design problem every 2-3 weeks.

Specifications for Successful Submission: Design problems have multiple parts. Each part must be fully correct for credit to be received for that part. Students are provided with a programmed spreadsheet that allows them to enter their unique design values and check their solutions as they are developed. Additional checks, such as free-body diagrams, are evaluated from the detailed solutions that students submit.

<u>*Computer Analysis*</u>

Rationale: Similar to the design problems, students are also given a set of computer problems where the goal is to use computer tools (MathCad in this case) to set up a problem and examine the effect of various parameters. These problems build on prior knowledge while providing a different context for learning. A sample computer analysis statement is also provided in the appendix. Approximately six computer projects are completed during the semester, alternating weeks with the design problems.

Specifications for Successful Submission: Students must submit a correct solution for each problem assigned. Computer problems often have their basis in either homework or design problems, allowing students to cross-check portions of their solutions for correctness.

Missing from the Process −Exams

One item that is obviously missing from the specifications-based approach to course design is the standard exam. The exam is analogous to an inspection point in a manufacturing line. In manufacturing, the inspection takes time. If the inspection fails, the assembly line might need to be shut down to find the flaw, or perhaps the flaw can be corrected with a ″quick fix″, but that does not mean the process is improved. Similarly, in the educational environment the exam disrupts the effective learning process by encouraging lumped learning and stopping the flow of learning to make an inspection. As such, the exam represents a process that is not consistent with the ideas of statistical process control, and is therefore not used in a specifications-based course. Most of the common rationale for using exams is captured by some combination of the other learning processes presented above.

The above subsections have outlined the assessment practices that are used in a Statics/Dynamics course to engage students in an effective learning process. The next section describes how the assignment specifications are tied to the overall grading system for the course.

Evaluating Students

The above description of course processes includes a description of the ″Specifications for Successful Submission″ for each type of assignment. The evaluation of students is formatted in a way that strives to connect the submission requirements with the course outcomes. This section briefly presents the course outcomes and how the above specifications are used to evaluate students and to assign grades.

The course has four major outcomes, as shown in Table 2. Table 2 also includes the assessments associated with each outcome along with the point values for each outcome and assessment category.

Students accumulate points in each of the outcome categories. These points are converted to a final grade by normalizing the grades in each category so that all outcomes are equally weighted in determining the final student grade. Table 3 provides the method for converting points earned in each category into ″Course Grade Points″, which are then converted into an overall course grade.

The use of the above grading approach has several positive aspects. The first is that it requires students to demonstrate an even performance across all course outcomes to achieve a high grade. Students cannot ″hoard″ extra points in one type of category to achieve a higher grade at the expense of a different outcome.

Table 2: Course Outcomes and Assessment Methods.

1. Students will engage the course in a professional manner. This includes proper preparation for class meetings, and keeping appropriate and accurate documentation of course topics. (100 points available)	
Assessments	Daily Doodles (26 pts)
	Preclass problems (37 pts)
	Notebook checks (37 pts)
2. Students will actively engage course topics to demonstrate their current and ongoing mastery of course information.	
a. Ability to engage current topics (88 pts available)	
Assessments	Daily Homework (88 pts)
b. Ability to sustain expertise on past topics (126 pts available)	
Assessments	Daily Review Problems (46 pts)
	Review Week Problems (80 pts)
3. Students will be able to apply computational tools to calculate and verify solutions to mechanics problems. (105 pts available)	
Assessments	Computational lab assignments (60 pts)
	Computational analysis of design problems (45 pts)
4. Students will demonstrate the ability to solve open-ended problems by specifying reasonable values for undefined variables, solving for dependent variables, and verifying the integrity of the solution. (100 pts available)	
Assessments	Design project assignments (100 pts)

Table 3: Course Grading Scheme

Objective	**Points Earned in Objective**								
1	90	80	70	60	50	40	30	20	10
2a	79	69	60	50	41	31	22	12	5
2b	114	100	87	76	63	51	40	27	15
3	95	85	75	60	50	40	30	20	10
4	90	80	70	60	50	40	30	20	10
Course Grade Points Awarded	**19**	**17**	**15**	**13**	**11**	**9**	**7**	**5**	**3**
Course Grades Based on Course Grade Points: 93+ = A; 91 = A-; 87-89 = B+; 83-85 = B; 81 = B-; 77-79 = C+; 73-75 = C; 71 = C-; 61-69 = D; <60 = F									

A second potential advantage of the above is that course grading is easily translated to the analysis of course outcomes. Each of the outcomes listed in Table 2 has a potential tie to ABET student outcomes. The natural grading processes in the course thus allow for direct translation to ABET outcomes, if so desired.

The above subsections have outlined the assessment practices that are used in a Statics/Dynamics course to engage and assess students in an effective learning process. The next section evaluates the results of this process approach to course design.

Effectiveness of Using the Specifications-Based Approach

One challenge of any method of teaching or course design is to prove that the approach works. In an exam-based environment, we tend to point toward exam scores as ″proof″, even though these scores may only be a measure of short-term memory and the ability to take exams. Demonstrating proof of learning is equally challenging for the specifications-based approach. One positive advantage of the specifications-based course design is that the course is built upon methods that have been shown to promote better learning. In theory, if the above processes are properly implemented, then the learning outcome should follow. This section examines the course results to see if that is indeed true.

One significant aspect of a well-designed specifications-based course is the workload. The experienced teacher of Statics or Dynamics probably has a feeling that the processes outlined above imply a relatively high workload. This is true. Grades are assigned largely based on the amount of work that is successfully completed with no partial credit for partial work. Workload is designed so that the student who completes an amount of work that would be considered ″average″ for the course (in an exam-based environment) would end up with a low B grade. The course operates on a specifications grading system [11]. Specifications grading is based on the idea that students who successfully complete more work will achieve a higher grade. Students know exactly what they have to do to achieve a particular grade and the student has the control over that achievement. This tends to make them willing to work a little harder, further improving the learning process.

Table 4 provides a summary of student responses to the course workload and the overall learning experience in the course. Students were asked to rate the prompts in the table on a scale of 1-5 where 1 = low, 3 = neutral, 5 = high. Table 2 shows the average response score, as well the percent of students on either side of the neutral response. One particular challenge of the information in Table 2 is sorting out whether or not the student perception of better learning stems from the higher workload, or if it is from the processes used.

Table 4: Student perceptions of workload and overall learning.

Prompt	Mean	% low	% high
Workload in the course was (1=low, 3= avg, 5 = high)	4.3	0	83
My level of learning compared to similar courses was:	3.8	6	61
My overall satisfaction with this course was:	3.9	6	76

In an attempt to sort out the amount that each learning process contributed to overall learning, students were also asked about these processes. The results are presented in Table 5. These questions are rated on a scale of 1-5 where 1 = strongly disagree, 3 = neutral, 5 = strongly agree. The average response for each question is shown in the table along with the percent of students that lean toward both the ″agree″ and ″disagree″ sides of the statement. Several highlights related to Table 3 include the following:

1. Students strongly favored the notebooks as a means to review and organize course information. (This was somewhat of a surprise as the initial concern was that students would view this as a ″busywork″ exercise.)
2. Students strongly favor weeklong reviews over midterms from a learning perspective.
3. Students persist better in their homework when provided with immediate feedback and are given an opportunity to rework the problem before being graded.

4. Students were relatively neutral about their need to relearn information for review problems. Since these represent the 4th (daily review problems) and 5th (week long reviews) contact points with the course information, the possible implication is that the spreading of content contact points is having its desired impact.

The results in Table 5 provide some indication that the processes are working as intended.

Table 5: Student Evaluation of Learning Processes

Statement (scale is: 1=strongly disagree to 5 = strongly agree)	**Mean**	**% disagree**	**% agree**
The preclass problems made me feel better prepared for class.	3.6	17	61
The doodles made me feel better prepared for class.	3.2	33	50
The notebook helped me in my review of daily course information.	4.1	0	67
I tended to struggle with homework and review problems	3.5	33	56
The LMS-based homework format helped me better persist in my homework compared to submitting paper and pencil solutions.	4.1	6	67
I found that I had often forgotten information required to solve review problems and frequently needed to relearn information to solve these problems.	3	39	33
The use of midterms would help me learn better than the week-long reviews done in weeks 8 and 16.	1.6	94	0
The design problems required me to view course information differently compared to homework and review problems.	3.6	11	67

A final and somewhat more qualitative evaluation of the effect of the learning processes can be discerned from student comments related to various aspects of the course. Table 6 provides a summary of such feedback. The one thing that stands out most in these comments is the variation of responses when students are identifying which aspect of the course helped them learn the best. This demonstrates the benefit of including a variety of forms of learning within the design of a course. For each learning process listed in Table 6, the student comments also provide some alignment with the intent of the learning process as was established in Table 1.

One bonus process that shows up in Table 6 is that of collaboration. The course is run in an environment that encourages students to discuss their work and collaborate on finding solutions. This is a form of obtaining and implementing feedback. The assignments in the course have enough individuality in them that direct copying is difficult, but collaboration is likely. This seems to be a perfect balance as it promotes students teaching one another, which may be among the most effective of learning processes.

Table 6: Student comments to support various learning processes

Process associated with response	**Prompt:** Briefly comment on one or two aspects of the course that you found most engaging and helped you to learn best.
Review problems	*I found that the review problems helped me be able to rethink about the topics we covered in past classes. With those problems I could understand the information better.*
	The review problems instead of test was helpful with better reviewing problems instead of cramming information in for a test
Notebooks and doodles	*I really liked the notebooks. Having prewritten notes and examples for every concept was extremely helpful, especially since I typically struggle with organization. I also liked the doodles. They felt like easy points, but I started to notice that they were making me think differently about the material, in the sense that they brought the concepts from abstract to physical.*
Homework	*I liked that the homework was online because instead of handing it in and getting a grade and moving on we had the opportunity to correct our mistakes which is what actually makes you learn. In most other classes you hand it in and don't see it again or ever learn why it's wrong.*
Design problems	*The design problems seemed most engaging, causing you too use what you have learned to figure out how to get something in the real world to work.*
	I had to learn the most about concepts when it came to the design problems, I think they helped me learn the most.
Collaboration	*I think the openness to collaboration really helped me through this class. Although a lot of the problems had individualistic solutions it really helped to talk through the concepts of what was happening in the problems.*
	Overall, this course was really tough. However, one of the best "non-academic" skills I obtained from this class was collaboration. I firmly think that I would not have passed this course had I not worked with other students. We worked in groups for almost every assignment and especially labs. We never cheated by just copying answers, but we had to work together to crack the problem. One thing to consider is to make this course a group oriented course. Isn't that what most real-world engineering is anyways? I would strongly consider making at least the labs a group assignment. You always risk the chance of one or two members getting pulled along by other members in the group. But regardless we were forced into working together due to the difficulty of problems. I was happy with the bonds I have formed with my fellow classmates and look forward to working with them in the future.

Summary and Conclusions

This paper has looked at the use of a specifications-based approach for the design of a Statics/Dynamics course. The premise of the paper is that if we can design good learning processes into a course, then the student outcome will be good learning. The course design incorporates a variety of assessments in the course where each assessment is designed to promote one or more specific learning behaviors in the students. The initial results presented in this paper seem to indicate the students are executing the learning processes as intended.

As a final thought, a show on National Public Radio (NPR) recently addressed the idea of using ″clickers″ to train people in various tasks associated with locomotion [15]. The concept was similar to that presented in this paper with an emphasis on getting the person to execute the proper physical processes to perform a task. To set up the method, the show looked at the training of animals, such as training a pigeon to press a button in a box to get food. One button gives food, one button does nothing, and one button gives the bird a slight shock. Pretty soon the pigeon is only pressing the button that gives food. The transcript from the show poses this thought:

The challenge in teaching pigeons doesn't actually lie in teaching pigeons. The challenge lies in building a box in which the pigeons can learn. How to design learning so it becomes natural, commonplace, even predictable?

The show goes on to consider the role of the teacher:

Now, you might think that this makes teachers unimportant. You'd be completely wrong. The teacher is anything but a bystander. That's because it's the teacher who designs the world in which the student learns.

The goal of this paper has been to present the design of a better box in which students can learn. The work is ongoing.

References

[1] L. Spence, “The Case Against Teaching”, *Change*, vol. 33, no. 6, pp. 10-19, 2001.
[2] L. D. Fink, *Creating Significant Learning Experiences*, John Wiley & Sons, 2013.
[3] D. J. Wheeler, and D. S. Chambers. Understanding statistical process control. 1992 [E-book] Available online: https://qby88o6vgt08.storage.googleapis.com/EianqwYek8nKxCRaMq08.pdf.
[4] J.C. Benneyan, R. C. Lloyd, and P.E. Plsek, “Statistical process control as a tool for research and healthcare improvement,” *BMJ Quality & Safety* 2003; vol 12, pp. 458-464, 2003. Avaiable online: https://qualitysafety.bmj.com/content/qhc/12/6/458.full.pdf. [Accessed December 27, 2018].
[5] E. Sallis, *Total Quality Management in Education*, London: Kogan Page, 1993.
[6] M. S. Owlia (1996) “Quality in higher education-a survey,” *Total Quality Management*, vol. 7, no. 2, pp. 161-172, 1996.
[7] E. Mergen, D. Grant & S.M. Widrick, “Quality management applied to higher education,” *Total Quality Management*, vol 11, no. 3, pp. 345-352, 2000.

[8] G. Byrne, “Total Quality Management in Engineering Education—A Case Study from University College Dublin (National University of Ireland-Dublin),” *European Journal of Engineering Education*, vol 23 no. 4, pp. 435-442, 1998.
[9] B. Sayeda, C. Rajendran, and P.S. Lokachari. "An empirical study of total quality management in engineering educational institutions of India: perspective of management." *Benchmarking: an international journal*, vol. 17, no. 5, pp. 728-767, 2010.
[10] W. Deming, *Out of the Crisis*, MIT Center for Advanced Engineering Studies, Cambridge, MA, p.29, 1982.
[11] Nilson, L., *Specifications grading: Restoring rigor, motivating students, and saving faculty time*. Stylus Publishing, LLC, 2015.
[12] P. Brown, H.L. Roediger, M.A. McDaniel, *Make it Stick: The Science of Successful Learning*, Cambridge, MA: Harvard University Press, 2014.
[13] S. Brown, *The Doodle Revolution*, New York, NY: Penguin, 2014.
[14] J Mirth, *Using Doodles to Assist Learning in a Mechanical Engineering Course*, *Proceedings of 2019 ASEE Annual Conference*, Tampa, FL, 2019.
[15] S. Vedentam, “When Everything Clicks: The Power of Judgement-Free Learning”, Available online: https://www.npr.org/templates/transcript/transcript.php?storyId=616127481 [Accessed 12-18-2018]

Appendix – Sample design problem with computer simulation

Dynamics Design Problem – Kinetics and Energy

The engineering career did not pan out, so you decide to open your own bungee-jumping business. For those not familiar with bungee jumping, the basic premise of the operation is that you persuade people that it is a good idea to jump off a high platform with nothing more than a bungee cord attached to them. The bungee cord acts as a spring that “catches” the jumper at the bottom of the fall and allows them to safely experience the thrill of free falling without the need for planes and parachutes.

You set up shop at the Royal Gorge Suspension Bridge in Colorado (321m above the river – always good to have a river at the bottom just in case). Jumping regulations require your system to be set up so that the jumper experiences less than 3 g’s of acceleration during the jump. (Explaining the concept of “g’s”: One “g” is the acceleration of gravity. When you are standing (or sitting), you are experiencing “one g” of acceleration. If you were to accelerate upward at 9.81 m/s^2, you would experience “2 g’s” of acceleration. As such, “3 g’s” represents an upward acceleration of 19.62 m/s^2.) Assuming that a bungee cord behaves as an ideal spring, determine the specs for your bungee cord (original length, spring constant) for the following situations:

a) (10 pts) All of your jumpers have a mass of 70 kg
b) (5 pts) The mass of your jumpers may range between 60kg and 80kg.
c) (5 pts) The mass of your jumpers may range between 35kg and 135kg. Calculate a line-up of bungee cords that will accommodate this range of jumpers. The required weight range for each set of jumpers is specified on the cover page and in the spreadsheet used to check your design.

For all cases you will have to determine the experience that you want the jumper to have. Does your company operate on a "have a nice jump we are not going let you get anywhere near the bottom" safety philosophy, a "let's see if you can touch the water at the bottom" full thrills philosophy, or somewhere in between? Establish your philosophy and apply it to all of the above design scenarios that you choose to complete. NOTE: All students are expected to have different design philosophies!

Computer Simulations – For this project, the computer simulation tasks are:

a) (5 pts) Use MathCad to solve problem (a) above.
b) (5 pts) Use MathCad to create a plot that shows the g's experienced as a function of jumper weight for your chosen design for part (b) above. [Consider your plot results – be sure that they make sense!]
c) (5 pts) Use MathCad to create a design study plot with the following two curves. For both curves you will use your values from part (a) of the design project and solve for the value of the spring constant, k, as a function of the free length of your bungee cord. One curve will show the relationship between free length and spring constant of the bungee cord based on the energy equation. The other curve will show the relationship between free length and spring constant based on the kinetic equation (max g's). Plot both curves for values of free length from 50 to 110 meters. Experiment with different max g values and different mass values and include a 1-2 line comment in your MathCad file that describes what you discover.