Making Physics More Interesting And Relevant To High School Girls

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Purpose: To determine ways to make mechanics more interesting and relevant to high school girls.

Introduction: In general, high school girls seem to be less interested than boys in how and why things move. Boys tend to have a basic interest in cars, rockets, canons, etc. I taught a summer school course in honors physics at Xavier College Prep (an all-girls school) to a group of 20 high school girls entering their senior year. I wanted to use this opportunity to find out how I could make physics more interesting and relevant to their gender and age group.

The class covered mechanics using the modeling method. The students wrote sample questions near the end of selected units. The students rated the questions. We then conducted a discussion of their interests related to the unit. They were then asked to critique the various teaching methods used. I wanted to know which methods they thought helped them to best grasp difficult concepts. I have also included pre-test and post-test Force Concept Inventory (FCI) scores and percentage gains. Out of curiosity, I also included standardized college admissions test scores (where available). I particularly wanted to see how they compared to FCI pre-test scores.

Setting:
- Honors Physics, Xavier College Prep, Phoenix, AZ
- 5 week summer school course
- 5 hours per day
- 5 days per week

Class size: 20
Class make-up:
- all female students
- all going into senior year

Note: The students are predominantly white, middle to upper-middle class. Their range of abilities was typical of an average honors physics class. Some students excelled in math and others that struggled. All these students plan to attend college. Their reasons for taking physics in summer school varied - some just wanted to get it out of the way, while for others it was the only way to fit it into their schedule.

Facilities: The classroom has eight Pasco dynamics tracks, eight Windows-based computers, and IBM PSL probeware for mechanics.

Procedure: Near the end of selected units, every student developed one physics problem relating to her own interests and the unit being studied. These questions were typed up without corresponding names and passed back as a set of questions to the students. I purposefully did not edit the questions. The students rated each question on a scale from one to five, with one representing "least liked" and five representing "most liked." In order to obtain an adequate range of ratings, they could only assign a maximum of four of each rating number. They rated each question twice: (1) based on how well it pertained to the unit, and whether it could be solved with the given information; (2) based on how well they liked and were interested in the theme.

Near the end of selected units, the students wrote a critique on how we covered the unit. I instructed them to consider what helped them most to learn the difficult concepts. I also wanted to know what they believe did not work well for them. This was an anonymous assignment.

At the end of selected units, I facilitated a classroom discussion of their ideas and interests as they related to the particular unit. This was as a forum for discussing their critiques and questions, as well as any other comments they wanted to make.

The FCI was given on the first and last day of class. The results have been included in Appendix six. Out of interest, I have also included college admission test scores where available.

Data: I have included the data as separate appendices at the end of the report. Please note that I chose not to edit the questions. We discussed what was wrong with some of them after the students rated them. Many questions had drawings below them that are not included here. The numbers in parentheses to the right of each question are the rankings for 'question' and 'topic' based on the ratings given them by the girls. The rankings go from one to 19 or 20, depending on the number of questions, with one representing the most liked.

Appendix 1 - constant velocity questions
Appendix 2 - constant acceleration questions
Appendix 3 - statics questions
Appendix 4 - projectile motion questions
Appendix 5 - circular motion questions
Appendix 6 - FCI pre-test and post-test scores with % gains, along with college admissions test scores (where available)

Evaluation:
Analysis of the questions and their relative rankings gives some insight into the interests and knowledge of the high school girls.

- One of the first things I noticed was that some students did not have a good grasp of the concept studied. There are questions in the constant velocity section that involve accelerated motion. There are questions throughout that lack sufficient information. I ended up using all of the questions as one form of review for the tests. Each student had to try to solve every question. We then placed the solutions, or attempted solutions, on whiteboards and discussed the misconceptions associated with the questions. This turned out to be a very useful activity. I am going to incorporate it into the regular school year as a review technique.
- Some students had a difficult time following directions (surprise). For example, there is a question on universal gravitation within the projectile motion questions and another among the circular motion questions.
- A few questions appear to have been taken directly from a textbook.
- *The majority of questions were very creative. The recurring themes revolve around humor, current movies and TV shows, rock bands, and local school topics.* Evidently 'Snoopy' and 'Gilligan' are still current. The girls particularly liked questions directly related to their daily lives. Humorous questions involving their school included the weight of their book bags, academic courses, faculty and friends, parking problems, receiving detentions, being out of uniform, driving to school, pesky underclasswomen, and boys at Brophy, (the neighboring boys' school). The new Austin Powers was very a popular theme for questions.
- *There are very few sports-related questions.* This was surprising to me. I did not expect the typical football, baseball, or racecar questions, but our school has a very strong girls sports program. We dominate many sports in the state, and are known nationally for our golf and swimming teams, yet there was only one question related to these sports.
- The questions involving 'Wendy's' were popular. The girls relate to the frustrations of working typical low-wage jobs.
- In general, **they preferred humorous, well-organized questions that related to their everyday lives.**

The critiques written at the end of selected units were interesting. The following comments summarize both the critiques and the discussions. Both forums tended to cover the same areas.

- *The girls praised 'whiteboarding'.* Nineteen out of twenty girls mentioned that it was the most useful activity we did for learning the material. They repeatedly commented throughout the course on how helpful it was. I get the impression that none of their other teachers use that technique.
- *They liked the way I introduced a unit with a lab and let them figure out the relationship between the variables.* They specifically mentioned how they preferred that to the other approach where the lab is used more as a means of reinforcement. They also liked the fact that they could directly see the relevance of the labs to the material being studied. They particularly enjoyed labs that involved some form of competition.
- *'Graphs and Tracks' was popular.* I turn it into a competition. These students are very competitive.
- The students enjoyed using the computer probes to collect data. They also liked analyzing the data with the computer. They liked working with computer technology.
- They enjoyed working with dynamics carts and tracks. *They particularly liked labs involving hot wheel cars and tracks.* I practically had groups fighting over which color track and which hot wheel car to use. Girls have a reputation for being intimidated in the lab. I do not tend to see that in an all-girl setting.
- The majority of the class commented on how much *they liked hearing how the topic being studied related to real-life engineering problems and current areas of study in advanced physics.* They particularly commented on their interest in the relationship between physics and astronomy. They wanted to learn more about general relativity, particle accelerators, blackholes, dark matter, worm holes, etc. In fact, many of the girls were absolutely fascinated by these topics. I bias that due to my own interest in astronomy and cosmology.
- *They hated listening to me lecture.*
- Regarding videos, they thought that 'The Mechanical Universe' was relevant, but boring. I showed two short, OLD 'Conceptual Physics' videos by Hewitt - one on Newton's first law and the other on his third law. To my surprise they loved those videos. One student commented that they were the most interesting and relevant science-related videos she had ever seen.
- *They praised the overall climate of the classroom. I inject a lot of humor into the classroom. I try to create a relaxed environment where the students are comfortable with asking questions or making comments.*
- *They praised the worksheets* created in the Modeling workshops at Arizona State University and elsewhere.
- One student thought we did not use the textbook enough.
- *They grew tired of writing lab reports.*

The FCI results surprised me. This is a small sample size, but the results possibly indicate some significant findings.

- The pre-test scores are approximately 10% below the national high school average. I do not know if that is an anomaly, an indication of the type of person that chooses to take physics in summer school, or an indication of the strength of misconceptions held by high school girls.
- It is interesting to compare pre-test scores and percent gain to standardized test scores. There appears to be *no correlation between misconceptions coming into the physics class and math or verbal proficiency.* Students with fairly low SAT scores scored in the same range as students with very high SAT scores on the pre-test. One student has a perfect 36 ACT composite score. Very few students across the nation can test at that level. Yet her pre-test score is 20%. This is an indication of the strength of student misconceptions.

- *SAT and ACT scores do appear to indicate level of success in mastering physics concepts.* In general, lower standardized scores resulted in lower FCI gains, and higher standardized scores resulted in higher FCI gains. The student with the perfect ACT composite score scored a 93% on the post-test resulting in a normalized gain of 91%.
- The normalized gains are significantly below the average for [expert modelers'] courses using the modeling method, but are well above the average for traditional classes, and are right in-line with other reform methods. This was disappointing for me. Modeling works well in summer school. Absent are the restrictions of the typical 50-minute class period. Spending five and one-half hours per day with the same students is demanding. The student-centered approach of modeling is ideal for such a setting. Drawbacks to summer school are the long classes and the accelerated pace at which the students must absorb difficult concepts. They are also distracted by the simple fact that it is summer, although this also provides an advantage since students are not distracted by other classes or extra-curricular activities.

Conclusion:

High school girls are more interested in physics when they can directly connect it to everyday experiences. Humor is an important ingredient. The students prefer questions that are clear and well organized. Their favorite themes deal with their own school experience, movies, rock bands, and other areas of pop culture. They are not very interested in sports-related questions.

High school girls learn best in a hands-on environment. They particularly like to whiteboard lab results and problems. They overwhelmingly prefer the less 'structured' labs typical of modeling to "cookbook" labs. They prefer almost anything over listening to me lecture.

They are curious about their mechanical universe. They showed particular curiosity about modern physics and astronomy. That was a great way to pique their interest, although I had to remind them that they needed a firm foundation in the basics in order to properly tackle more advanced topics.

Although the sample size is very small, *there appears to be no correlation between misconceptions as measured by the Force Concept Inventory (FCI), when given as a pre-test, and standardized test scores.* Standardized test scores do correlate to the degree of success experienced by students in overcoming those misconceptions when taught physics using the modeling method.

Overall, the students loved the course. They were all surprised that physics could be so much fun. Most of them now wish they were taking it during the regular school year. They even chipped in and bought me a fathers' day card (loaded with positive comments) and two fathers' day presents - the updated version of Hawking's A Brief History of Time, and a framed photograph of all 20 students. It is a silver frame engraved with "Ptolemy, Copernicus, Galileo, Newton, Einstein, Hawking, Wyman." Not bad company for a high school teacher!

Appendix 1

Constant Velocity Questions

Directions: Rate the following questions from one (least liked) to five (most liked). In the column marked "Question Rating," rate how you liked the question as a whole. In the column marked "Topic Rating," rate how you liked the subject of the question. You may only give four 5's, four 4's, four 3's, four 2's, and four 1's in each category.

	Question Rating	**Topic Rating**
1. During the 1999 Concert of the Year, performed by U2, you happen to be scanning the crowd and see a man holding a water bottle that he is about to throw at Bono. As you dive across the water bottle's path, your arms fly out in front of you, and you happen to notice that the little hand is on zero right as the bottle is leaving his hands. And, being such a smart XCP girl, you know that a BCP boy throws a slow 2.5 m/s (He's the baseball pitcher). Right as the water bottle smashes into Bono's guitar, you have a crowd surfer thrown on you, breaking your watch at 35 seconds. Determine the velocity of the water bottle.	(5)	(1)
2. A hot air balloon is going to travel around the world in 80 days. Calculate the average speed and average velocity of the first day of travel. The first 200 km is covered at 70 km/h for half the day, and the rest of the day is covered at 80 km/h.	(14)	(17)
3. Alice goes bowling at her local bowling alley, and during her game she sends the ball, which is travelling at constant speed, down the alley, which is 16.5 m long. The ball hits the pins at the end of the alley. Alice does not hear the ball hit the pins until 2.50 seconds after she released it from her hand. What is the speed of Alice's ball if the speed of sound is 340 m/s?	(13)	(12 - tied)
4. Running Roy is training for the upcoming Iron Man. Beginning at his house, he plans to run a 3 mile (4.83 km) circuitous route in one hour. Unfortunately, Roy did not plan his route very well. After going 1.5 miles, he comes to an end in the sidewalk. Puzzled, he stops, takes a drink of water and talks with the neighbors to discover the cause of this. When he begins running again, at a speed of 1 m/s, he notices fifteen minutes have elapsed. Qualitatively graph the **x** vs. **t** and **v** vs. **t** graphs. What is the average speed of his initial 1.5 miles? Average velocity?	(12)	(10 - tied)
5. If it takes Austin Powers 60 seconds to slide down a secret passageway (20 m) in order to make a groovy getaway, with an initial velocity of 3 m/s, what will his final velocity be?	(3)	(2)
6. It is a bright and shiny day, and you are on a hike with your friends. You see a beautiful waterfall pouring into a lake. All of your friends, including yourself, are in awe of the height and the steepness of the waterfall. You figure out that it takes about 20 seconds for the water to meet the lake (bottom) with the acceleration of 44.4 m/s2. Determine the velocity of the waterfall when it reaches the lake.	(4)	(12 - tied)

7. Bob Saget is rollerblading at a uniform velocity of 5 m/s. If Bob rollerblades to Denny's, 56 meters away, how long does it take Bob to reach his destination of happiness?	(6)	(4 - tied)
8. A spankin' new Z-3 is cruisin' down Fountain Hills Blvd at 43 m/s when, all of a sudden, a javelina darts across the street. The Z-3 slams on the brakes taking him 2.5 seconds to stop. What's his acceleration?	(15)	(10 - tied)
9. One morning while camping, the earth began to rumble, and a small herd of cattle raced through our campsite. After recovering from the shock, a tiny Pekinese dog ran by at a velocity of 4 m/s chasing the cows. The dog was allowed to chase the cattle for about 7 minutes before its owner caught up with it and picked it up. While resting for 3 minutes, the owner lectured the Pekinese on chasing things weighing more than 500 lbs. They then walked back the way they had come. It took the owner and her overconfident Pekinese 14 minutes to walk back to their campsite at a velocity of 2 m/s. Draw the **v** vs. **t** graph. Calculate the average velocity for the whole trip. Draw the motion map.	(1)	(6)
10. Xavier student X has to stay after school for 5 extra minutes because certain underclassmen seem to have trouble picking up their trash. Student X leaves the school at 2:35 P.M. and has a scheduled appointment at 2: 50 P.M. If the doctor's office is 12 miles from Xavier, at what average velocity (in miles per hour) must she travel in order to be on time?	(8)	(9)
11. A tour bus containing the band members of Matchbox 20 must reach Blockbuster Desert Sky, which is 113 miles away, in 1_ hours to perform a sound check. If the bus travels at a constant velocity, how fast must it go to get there on time?	(11)	(8)
12. At the end of a long school day, it takes 5 seconds of reaction time for a Xavier student to zip up her bag and jump from her seat after the bell rings. After these 5 seconds, she runs, screaming for joy, at constant velocity to her car parked 45 m away in "create-a-space" parking. The total time for this escape from school is 35 seconds, assuming the clock starts the moment the bell rings. Draw the **x** vs. **t** and **v** vs. **t** graphs. Find her average velocity after her reaction time. Draw a motion map. As soon as she reached her car, she realized she dropped her keys back at the Activity Center 20 m away and returned, skulking, at a speed of 0.5 m/s. What is her displacement after she reached her keys? How long did it take her to get her keys? Bonus: Is she now stuck in the parking lot for 30 minutes considering it's a Friday?	(7)	(3)
13. The Energizer bunny has a new Energizer battery to test its long-lasting power. San Francisco is where this furry pink bunny suggests the team shall travel. And so, the pink fur-ball is let loose to march himself across the 440 meter Golden Gate Bridge. He accelerates at 1.2 m/s2. The battery's energy will run out in 28 minutes from let go. Will the "drummer boy" make it across the bridge within this time?	(9)	(4 - tied)

14. A boat travels toward Catalina Island from San Diego. The trip takes 6 hours; the speed of the boat is 30 mph. What is the displacement from San Diego to Catalina? From this, how far did the boat travel in 1 hour and 45 minutes?	(16)	(15)
15. Susie, when she spotted Dave Matthews at Desert Sky Pavilion, walked toward him in the positive direction. Her motion was recorded as follows: t (s) x (m) 0.0 0.0 2.0 6.0 4.0 12.0 6.0 18.0 8.0 24.0 10.0 30.0 a) Plot Susie's position vs. time. b) Plot Susie's velocity vs. time c) Find how far away Dave was from Susie when she first saw him (at time t = 0).	(2)	(7)
16. How many seconds does it take Tristan to drop 100 m from rest on the roof of his house? What velocity does he attain?	(20)	(19)
17. Kiki's Physics book is thrown from a building with an initial velocity of 25 m/s. If it takes 15 seconds to reach the ground, what is the final velocity? How tall is the building?	(19)	(16)
18. A Xavier girl is walking to school, which is 50 m south. After she reaches school, she sees Leonardo Di Caprio across the street 40 m west. If it takes her 5 seconds to get to Leo, what is her velocity?	(18)	(20)
19. A surfer approaches the beach at a constant velocity of 5 m/s. If he reaches the beach 10 seconds later, how far away was he?	(17)	(18)
20. a) Snoopy is chasing a cat through the house. If Snoopy's initial position is 0 m and if at 9 seconds it is measured that he has moved 100 m from his initial position, what is his velocity? b) If the cat starts 10 m ahead of Snoopy and it takes him 15 seconds to go 180 m, will Snoopy catch the cat?	(10)	(12 - tied)

Appendix 2

Acceleration Questions

Directions: Rate the following questions from one (least liked) to five (most liked). In the column marked "Question Rating," rate how you liked the question as a whole. In the column marked "Topic Rating," rate how you liked the subject of the question. You may only give four 5's, four 4's, four 3's, four 2's, and four 1's in each category.

	Question Rating	**Topic Rating**
1. Poor Jen wakes up late from cramming for the H. Physics test, misses her carpool, and gets stuck in traffic pulling into Xavier as the first bell rings. To avoid being late, Jen sprints 6.6 m/s at a uniform speed from Pierson to Ms. Rauscher's room, a distance of 100 m taking 57 seconds. She doesn't quite make it, but the dean offers an ultimatum. Figure out Jen's acceleration and show it to Mrs. Huttlemeyer who approves the work, or a detention.	(1)	(3)
2. Two bugs approach each other on the same flying plane. Each bug is going 20 km/h with respect to the ground. If they are initially 10 km apart, when will they smash into each other?	(16)	(13)
3. Johnny was driving his car when the light turned red. He decelerated from a speed of 20 m/s to rest, at the stoplight, a distance of 85 m. What was Johnny's acceleration?	(19)	(20)
4. Upon entering the water at the whistle, both swimmer A and B begin swimming at a speed of 2.5 m/s. Halfway across the 50 meter pool, swimmer A engulfs a rather large amount of chlorinated water. When she has regained her breath, she is 7 meters behind swimmer B. By how much will she have to increase her speed to tie with swimmer A? Sketch qualitative graphs for the **x** vs. **t**, **v** vs. **t**, and **a** vs. **t** graphs. a = x = v_0 = t = v =	(4)	(12)
5. The Concord can be accelerated from 2000 km/hr to 2500 km/hr in 2.3 seconds on a flight from New York to London. What is the acceleration? V = t = v_0 = a = ?	(8)	(19)
6. One day in homeroom, Rachel needed to borrow a highlighter from her friend, Erica, to highlight her notes that she needed to study. One major problem was that Erica sat on the other side of the room, and their homeroom teacher did not allow walking around. Erica decides to throw the highlighter to Rachel (without the teacher looking!). Erica throws the highlighter with a speed of 12.3 m/s. Since Erica throws so well, she accelerates the highlighter from behind her body to the point where it is to be released with a displacement of 1.7 m. Determine the acceleration of the (flying) highlighter.	(15)	(11)

7. One of the Backstreet Boys takes a whimsical, free-falling journey off a cliff. He begins his stopwatch the moment his feet leave the cliff, and when he pushes the stop button just before hitting the ground, it reads "12 s." What is his final velocity?	(2)	(2)
8. Mimi threw a vase of roses out of a 125 m building at her cheating boyfriend Mike at an initial velocity of 25 m/s. If the acceleration of the vase was 5 m/s2, and it took 5 seconds to reach Mike's head, what was the final velocity of the vase?	(7)	(6 - tied)
9. While standing in my garden, the llama that lives next door began running towards me and then proceeded to launch a llama luege at me. Tony (the llama) was traveling at a velocity of 10 m/s, and I am certain that when the slimy sputum hit my cheek it was going 15 m/s. If it took 6 seconds for the llama phlegm to leave Tony's lips and become plastered across my face, a) what was the acceleration of this flying saliva, and b) how far did it travel?	(6)	(4)
10. Xavier student X oversleeps her alarm clock by 20 minutes. This means that she arrives at school 10 minutes later than usual and must park in North Africa (a.k.a. the very very farthest end of Pierson Street) because there are <u>so many</u> driving sophomores attending Xavier. As she slams her car door shut, the first bell rings. By the time she locks the car and finds her backpack, student X has exactly 4 minutes to travel the 400 meters from her car to Mrs. Dupnik's homeroom. Assuming her initial velocity is 0 m/s, what must student X's rate of acceleration be so that she avoids her second tardy and Saturday morning detention?	(5)	(6 - tied)
11. A Xavierite is standing in the hall drinking a Coke. Suddenly, a nun comes around the corner and spots her. The girl starts running, accelerating at a rate of 1.3 m/s, until she reaches the triple doors, 80 meters away. How fast was she going when she finally escaped the nun?	(3)	(6 - tied)
12. Forty meters away from a bagel shop, Carolyn waits for her bus. All of the sudden, she inhales the delicious odor of newly baked Krispy Kreams and turns to see the sign of these fresh doughnuts in the bagel shop window. She immediately bolts toward the store increasing her speed 2 m/s every second. At what time does she reach the store. How fast is her nose going at the moment of ecstasy?	(10 - tied)	(9 - tied)
13. <u>Baywatch</u> stud David Hasselhauf sees a helpless woman stuck in the tides. He swims with an initial speed of 500 yd/min in 10 minutes. The beach babe uniformly increases his speed to 800 yd/min in 8 minutes until he finally reaches his victim. What was his acceleration during the time he increased his speed to the time he saved Pam Anderson's stunt devil? To be continued… v_0 = 500 yd/min v = 800 yd/min	(14)	(14 - tied)

14. A cyclist in the Tour de France is moving at a constant velocity of 25 m/s. Around the corner a steep hill is in front of him. As he encounters the hill, he speeds up by 5 m/s2. At the bottom of the hill, his velocity is 40 m/s. a) What is his acceleration at the bottom of the hill? b) How long did it take to reach the bottom?	(10 - tied)	(16)
15. A Xavier girl enters her house from the garage. If her initial velocity was 2 m/s, and she accelerates at a rate of 1 m/s2, calculate how long it takes the girl to be on the couch in front of the tube if the sofa is 50 m away. (Do not take the time required for sitting down and turning on the T.V. into account.)	(10 - tied)	(5)
16. A skateboarder skating at 6.2 m/s slows down at a uniform rate of 2 m/s2. How far will he have traveled when he finally reaches a velocity of 3.2 m/?	(20)	(18)
17. A phat Ford Mustang is cruising down Mills. It has an initial velocity of 50 m/s and travels 500 m in 10 seconds. At the light, its final velocity is 0.5 m/s. Find its acceleration in the 10 seconds traveled down Mills.	(17)	(14 - tied)
18. Four Xavier girls are driving at a speed of 30 m/s when they see the 'N Sync tour bus 500 m away. If it takes them 8 s to stop what is their acceleration?	(13)	(17)
19. Piano movers are hoisting a piano into an apartment 40 m up. Joe, the apprentice piano mover, messes up, and the piano is dropped. How long does Betty, who is standing underneath, have to move out of the way?	(18)	(9 - tied)
20. Gilligan and the Skipper are going on a three-hour tour with a group of tourists. If their boat accelerates from rest to 35.2 m/s over 50 m, what is their acceleration?	(9)	(1)

Appendix 3

Statics Questions

Directions: Rate the following questions from one (least liked) to five (most liked). In the column marked "Question Rating," rate how you liked the question as a whole. In the column marked "Topic Rating," rate how you liked the subject of the question. You may only give four 5's, four 4's, four 3's, four 2's, and four 1's in each category.

	Question Rating	**Topic Rating**
1. Bob decided to take an IQ test. When he was halfway through, the stress of failure overwhelmed him, and the questions about hidden boxes drove him crazy. He then imagined pushing the blocks off the test. If the three blocks are on a frictionless horizontal surface in contact with each other, determine the acceleration of the system and the net force of each block. If the three blocks added up to 10 kg, and F = 100 N, what do the boxes weigh?	(18)	(9)
2. A SENIOR is dragging away a junior's car that was inconsiderately parked in an "X" space. If the car weighs 500 kg and the senior is pulling with 200 N of force at a 30° angle, determine the normal force and the value of the frictional force. Extra Credit: Determine the time it takes Sarge to yell at the Senior for dragging the car.	(1)	(3)
3. You read in the newspaper that there is a fabulous shoe sale going on at the mall. After summer school, you speed on out to the mall to check the sale out. You decide to get these cute, flowery platforms for your date with Ricky Martin (hey, it could happen!). As you wait for the salesman to bring the platforms in your size, you see a sign for dresses on sale. Being the ultra-cool, super-smart Xavier girl, you want to calculate the tension in each cable holding up the sign. You figure that the angles are 65° and the sign has a mass of 25 kg. Draw a force diagram and determine the tension in each cable for the picture below.	(8)	(14)
4. While visiting a taping of <u>The Price is Right</u>, your name is called and you "come on down." You make a perfect bid on a pair of his and her motorcycles and go up on stage. You get to play Plinko for a chance to win $25,000. You go up to the board and drop the chip. If the chip has a mass of 3 kg, what is its weight?	(14)	(4 - tied)
5. Determine the weight of the ball if the system is in equilibrium. The cable at right exerts a 40 N force.	(17)	(19)
6. A girl pulls a 25 kg mutant, disobedient Chihuahua across the floor. She applies a 50 N force at an angle of 20°. a) What is the value of the normal force? b) What is the value of the frictional force opposing the motion?	(6)	(10 - tied)
7. A piano mover moves a piano up a 50° angled ramp. The mass of the piano is 300 kg. Find the normal force and frictional force.	(15)	(18)
8. Gilligan and the Skipper are searching for food on the desert isle that they are stranded on. Gilligan climbs a palm tree and picks three coconuts. One coconut has a mass of 500 g, the second has a mass of .3 kg, and the third has a mass of 375 g. What is the weight of each coconut? If Gilligan drops all three coconuts at the same time, which one will hit the Skipper, who is standing next the palm tree, first?	(9)	(7)

9. An extremely unhappy "bagger" boy has to do misplace for 1 hour. The cart full of groceries has a mass of 105 kg. The boy is exerting 650 N upon the cart to move it at 2 meters per second. a) Draw a force diagram. b) Determine the normal force. c) Determine the friction.	(4 - tied)	(8)
10. Willemina and Fergus are enjoying a romantic rickshaw ride when the operator decides to flee the mundane life of a rickshaw operator and frolic in the streets of Phoenix. Willemina, being a strong woman of the '90's, makes Fergus get down and pull the rickshaw. If the rickshaw is 80 kg and Willemina is 55 kg, and Fergus applies a force of 250 N at an angle of 10°, what is the normal force? What is the normal force if Fergus applies 250 N but Willemina decides to chase a jogger who bears a striking resemblance to one of the cuter members on 'N Sync?	(3)	(4 - tied)
11. In order to escape from Mr. (Oops, I mean Dr. He didn't go to six years of evil medical school to be called Mr.) Evil's underground lair, Austin Powers has to jump across a ravine filled with mutated sea bass. He backs up, runs, jumps, and…misses. However, this is not the end of our favorite British swinger. While falling down the side of the bank, he was able to grab on the floss that Agent Kensington had thrown to him and is now dangling above several hungry mutated sea bass. Austin decides to remain completely still so as not to anger the sea bass. If he has a mass of 85 kg, what is the tension on the floss.	(7)	(2)
12. While blading down a small hill with an incline of 30°, my friend and I spot the most beautiful, perfect, rippling man ever. My friend begins to drool and attempts to race after him, but I grab her shirt and am able to keep her stationary. How much force must I apply to keep her from embarrassing us both, if she weighs 135 lbs. (1 lb. = 4.45 N)? Assume that friction DOES exist on the hill. Remember to draw that force diagram!	(10)	(15)
13. Sizzlin' Sarah's Roadside Eatery recently opened just outside of Payson. She has noticed a drop in customers and hopes to attract more clientele. So, in addition to the large billboard two miles before her eatery, she wants to put up a huge sign (approximately 2500 grams) in the archway leading into her parking lot. Being so cheap, Sarah decided to hang the sign herself. However she made the cables different lengths, thereby having different tensions. Now, because Sarah was never one for calculations, and since she is really cheap, she has asked the local physics club to come and determine what her angles must equal in order for the sign to hang straight. The tension for cable A is 2000 N, while the tension for cable B is only 1972 N. a) Draw the force diagram for each cable. b) Find the angle for each cable.	(12)	(6)
14. In the system below is frictionless and the boat is in static equilibrium. What is the mass of Gilligan's boat if the Skipper pulls at 1000 N?	(13)	(13)
15. Dr. Evil wants to sabotage Austin Powers' sign by putting up his own, but he does not know the tension in the cables. Determine the tension in each cable.	(19)	(12)
16. To finish "cleaning" her room, Sally must slide just one more mound of books and papers into the bottom of her closet. The mound has a mass of 25 kg, and the magnitude of the frictional force is 100 N. What is the normal force acting on the pile? What force must Sally apply to the pile in order to move it at constant velocity?	(11)	(16)

17. Bob Saget, who weighs 300 kg, is standing near the edge of a high building. Bob Barker, who weighs 400 kg, takes advantage of the moment and pushes Bob Saget to his near death. Draw two force diagrams showing the force exerted on each Bob. Label the paired forces.	(2)	(1)
18. A 75 kg petty thief wants to escape from a 4^{th} story jail cell window. Unfortunately, a makeshift rope made of sheets tied together can support a mass of 50 kg. How might the thief use his "rope" to escape? Give quantitative answer.	(16)	(17)
19. The sign outside of Denny's is held by 2 cables. If the sign weighs 40 N, what is the tension in each cable?	(4 - tied)	(10 - tied)

Appendix 4

Projectile Motion Questions

Directions: Rate the following questions from one (least liked) to five (most liked). In the column marked "Question Rating," rate how you liked the question as a whole. In the column marked "Topic Rating," rate how you liked the subject of the question. You may only give four 5's, four 4's, four 3's, four 2's, and four 1's in each category.

	Question Rating	**Topic Rating**
1. A gerbil is thrown horizontally from a 3 meter high shelf. It hits the ground 1.5 meters away (from the base of the shelf unit). At what speed was it thrown?	(10 - tied)	(16)
2. Estimate the gravitational force between a 40 kg box and a 60 kg box.	(20)	(20)
3. Sally trips as she is running up to bowl and accidentally launches the ball backwards. The ball flies out of her hands at a 15° angle with a velocity of 10 m/s. Will the ball hit her best friend, who is standing 5 meters behind the lane?	(14)	(17)
4. Someone has placed a water slide at the top of a cliff overlooking a lake. The height of the cliff, including the water slide, is 17 m. If I land on Ms. R. who is 7 m from the base of the cliff, how long does it take me to squash Ms. R? (My v_{x0} is 5 m/s, and my v_{y0} is 0 m/s.)	(7)	(10)
5. In order for Austin Powers to defeat Dr. Evil in his latest scheme of taking over the world, he must launch Mini-me as a projectile with an initial velocity of 10 m/s at 45° above the horizontal in order to land directly on Frau Farbisina. (Frau Farbisina has the trigger in her hand for the bomb to blow up the world.) However if Austin misses the target, Mini-me will fly right into F.B.'s belly! Assume Dy = 0. Determine: a) hang time, b) maximum height, and c) range.	(4)	(2)
6. If you were to push Brittany Spears off a 100 meter cliff at a velocity of 5 m/s, how long would it take her to reach the rocky bottom, and what would be her horizontal displacement?	(9)	(11)
7. To prove her love for Walt Whitman and embracing nature, Ms. Rausher jumps out of a hot air balloon to be one with the birds as Dr. Laffy, Jefferson, and Emerson watch from Hannibal, Missouri. If the balloon was flying at a height of 650 meters and she lands 300 meters horizontally from the initial dropping point, how fast was the balloon going when Ms. Rauscher first jumped out?	(2)	(1)
8. My brother ran away to join the circus. Going to his first performance, lucky me, I got to light the cannon he was being shot out of at a 37° angle. After he went through the big top into the wild blue yonder, we calculated his speed to be 20 m/s. Calculate his maximum height, his time of travel, and when he hits the ground. (Yes, the ground, there was no net.)	(1)	(5)

9. Jenny is busily making those delicious Big Bacon Classics at her favorite place to eat and work—Wendy's (PUKE!!!). Suddenly, a customer is unbelievably rude to Jenny, irritating her to no end (especially since most of her co-workers are incompetent, so she had to do all of their jobs—so she is exhausted). If she flings a patty of that peculiar square shaped meat at the unsuspecting "victim" at an initial velocity of 5 m/s, taking 3 seconds to splatter all over her face, how far away was the customer standing?	(5)	(3 - tied)
10. A softball player swings a bat, accelerating it from rest to 3.0 m/s in a time of 0.20 seconds. Approximate the bat as a 2.2 kg uniform rod of length 0.95 m, and compute the torque the player applies to one end of it.	(19)	(18)
11. Tony drops his cheating girlfriend off a plane with a height of 500 m. The girlfriend lands 400 m horizontally from the initial dropping point. How fast was the plane flying when she was thrown to her doom?	(16 - tied)	(14)
12. After being dismissed five minutes late from school because "the maid quit," you and your physics class bust a move to the top of the AC with a bucket of water balloons. If you throw the balloons with a velocity of 10 m/s at the Juniors (wannabe Seniors) who stole all the X spots, and it takes exactly 5 seconds for the first girl to get wet, how tall is the AC? Bonus: How long does it take for the maid to get her job back?	(3)	(6 - tied)
13. A hot air balloon going around the world within 30 days drops a message in a bottle from the height of 210 m. The bottle lands 25 m horizontally from the initial point. Determine the speed of the hot air balloon in the sky after the bottle was dropped.	(18)	(19)
14. Mini-me spots a cookie 2 m away. At what speed must he leap to reach the cookie before Number 2, who is travelling at 2 m/s 3 m away, does? Will Number 2 cry if he does not get the cookie? Will Mini-me bite Number 2?	(10 - tied)	(12)
15. In his efforts to stop Austin Powers, "the only man who could stop me now," Dr. Evil accidentally pushed Mini-me off a cliff of 55 meters at an initial speed of 10 m/s. Min-me lands 45 meters away, in a pool of ill-tempered mutated sea bass. What was the angle of Mini-me's flight? Will Dr. Evil be able to save Mini-me if he reaches him in 6 seconds, or will he "lose his head"? (Calculate time.)	(6)	(6 - tied)
16. A CD that makes the annoying bell noise every hour, on the hour, is launched across the field with an initial velocity of 25 m/s at an angle of 45° above the horizontal. ($D_y = 0$) Calculate the range of the CD.	(15)	(15)
17. Thelma and Louise are launched horizontally in their convertible Cadillac 30 m/s from a cliff 1000 m high. How far from the base of the cliff do they land before the car explodes? What is their final velocity?	(8)	(6 - tied)
18. A projectile, a Xavier Junior who parked in an "X" spot, was thrown off of a cliff with an initial velocity of 10 m/s. If the cliff was 50 m tall and 100 m away there was an anxious nun ready to hand out a detention for not having back straps, will the Junior get the detention?	(16 - tied)	(13)
19. Indiana Jones is trying to throw the Holy Grail across a pit full of snakes to his beautiful girlfriend of the week on the other side of the pit. If Indy throws the Holy Grail from 150 m above the pit at a velocity of 2.5 m/s, will it each the other side if the other side is 110 m high and 25 m away, or will he have to retrieve the Grail from a pit full of snakes?	(10 - tied)	(9)
20. The dynamic Bob Saget is launched horizontally from a cliff, which is 98 m high. If a circus midget catches him 100 m from the bottom of the cliff, at what velocity was Bob launched from the cannon?	(13)	(3 - tied)

Appendix 5

Circular Motion Questions

Directions: Rate the following questions from one (least liked) to five (most liked). In the column marked "Question Rating," rate how you liked the question as a whole. In the column marked "Topic Rating," rate how you liked the subject of the question. You may only give four 5's, four 4's, four 3's, four 2's, and four 1's in each category.

	Question Rating	**Topic Rating**
1. A cat with a mass of 4.54 g is swung in a horizontal circle, making 1 revolution per second. If the cat's tail is 0.305 meters in length, what is the cat's centripetal acceleration?	(12)	(13 - tied)
2. Calculate the velocity of a piece of trash moving in a stable circular orbit around the Earth at a height of 3700 km.	(20)	(19)
3. Joe is very, very bored, so he is spinning roundy-roundy to make himself dizzy. If his arm-span from fingertip to fingertip is 2.5 m (He is a very large guy.) and it takes him 0.5 seconds to go roundy-roundy once, what is his centripetal acceleration?	(14 - tied)	(7)
4. Attempting to flee from school as quickly as possible, I round a turn with a radius of 75 m at 45 mph. If the car I am in has a mass of 750 kg, what is the coefficient of friction between the tires and the road?	(9 - tied)	(11tied)
5. Calculate the velocity of a satellite moving in a stable circular orbit about the Earth at a height of 3600 km.	(16)	(17)
6. If you were to "spin the bottle" in a circle of radius 5 cm with a force of 30 N, how fast would it be spinning? How long before it comes to a stop, hopefully pointing to your dream guy?	(13)	(11 - tied)
7. A 200 gram ball at the end of a string is going roundy, roundy, roundy in a circle with a radius of 0.8 m. The ball makes exactly 3.00 revolutions in a second. What is its acceleration?	(2 - tied)	(10)
8. Some kids are playing tetherball with a sky ball on Friday the 13^{th}. The ball is attached to the end of a rotting cord and rotates in a circle of radius 1.5 m. If the cord will break when the tension exceeds 50 N, what is the maximum speed Fred the bully can hit it?	(14 - tied)	(13 - tied)
9. The infamous Wendy's customer is back for more. Jenny decides to show her once and for all who is the queen of Wendy's. She runs over to the customer (a quite large woman of 100,000 g), picks her up by her hair (Jenny is quite buff from those long hours of lifting sacks of French fries.), and begins to swing her around uniformly in a circle with radius of 0.900 m. The woman makes exactly 2 revolutions in a second. What is the centripetal acceleration?	(1)	(1)
10. A record player turntable of radius R, is turned by a circular rubber roller of radius R_2 in contact with it at their outer edges. What is the ratio of their angular velocities w_1/w_2?	(19)	(18)
11. Chichi the supernatural dog is riding a roller coaster. If the radius is 21 m and his velocity is 30 m/s, what is his centripetal acceleration?	(9 - tied)	(8)

12. While walking through the mall, you spot a sign that advertises a 50% off sale at J. Crew. If your center is exactly 50 m away from the store's center and it takes you 5 seconds to walk there, what is your velocity? (Hint: Account for the time it takes to maneuver your way through the slow shoppers—1.5 s.) Bonus: How long does it take you to realize that the catalog is <u>way</u> better than the store?	(6 - tied)	(5)
13. Estimate the gravitational force between two friends. One is 56 kg, and the other is 72 kg. They are standing 28 m apart.	(11)	(20)
14. At what speed (minimum) must a roller coaster be moving so the passengers won't fall out? (r = 12 m)	(18)	(16)
15. Up in his space station on the moon, Dr. Evil is getting ready to fire a missile and blow up the Earth. However, just as he is to push the button to launch the "laser," his rotating chair suddenly starts spinning uncontrollably. Now, all he wanted was a "rotating" chair that works. If Mini-me was in Dr. Evil's lap and once the chair started spinning, he was held out away from Dr. Evil's body, how long must Dr. Evil's arms be (the radius) if the chair is spinning at a speed of 5 m/s with a centripetal acceleration of 10 m/s2 and a period of 6 s.	(4)	(2)
16. A Xavier student had finally had it with the girls in front of her locker. In a desperate attempt to get them to clear out, the student began wildly swinging her backpack in horizontal circular motion. If the centripetal acceleration of the 5000 kg backpack (lots of books, you understand) was 0.5 m/s2, calculate the force acting on the backpack.	(2 - tied)	(3)
17. The toy race car speeds off across little Bobby's driveway. What minimum speed must the race car be traveling when making the turn without tipping on its side? Assume a radius of curvature of 0.75 m.	(17)	(15)
18. A dorky Brophy boy thinks he is so hot and tries to put the moves on you. Thus, you rotate your backpack above your head at constant velocity and let go. Your radius is 1 m, and the Brophy boy is 3 meters away. Calculate the velocity? How badly is the Brophy boy hurt?	(8)	(9)
19. A mouse named the Brain and his partner Pinky are trying to take over the world by setting a satellite into orbit around the Earth that will brainwash everyone into making him their leader. If the radius of the satellite's orbit is 7.5×10^3 km and if the satellite is being accelerated by a rocket at 3 m/s2, what is the velocity of the satellite?	(6 - tied)	(6)
20. The ever-present Bob Saget, tied to the end of a string, is cleverly rotated at a uniform rate in a vertical circle. If the radius is one meter and Bob is swung at a constant speed of 5.5 m/s, what is Bob's centripetal acceleration just before he is flung into a pit of raging circus monkeys? (Note: The circus monkeys do not affect the answer.)	(5)	(4)

Appendix 6

FCI Pre-Test and Post-Test Scores and Gains, along with college admissions test scores (where available)

Pre-Test (%)	Post-Test (%)	Normalized Percent Gain (%)	SAT Verbal/Math	ACT Composite Score
37	80	68	710/700	28
30	67	53	730/680	31
30	60	43		
27	50	32	490/480	
27	40	18	640/540	
27	57	41	650/600	
27	33	8	610/570	
27	87	82	800/750	34
23	80	74	730/660	30
23	50	35	450/490	
20	93	91	800/770	36
20	67	59	660/590	27
20	47	34	640/580	26
17	33	19	410/370	
13	70	66		
10	57	52	600/590	27
10	70	67	680/670	
10	37	30		
7	50	46	510/450	22
7	43	39	550/570	

Average Pre-Test score: 21%

Average Post-Test score: 59%

Average % gain: 48%