

2006-1764: CONNECTIONS PHYSICS REVIEW (CPR) PROGRAM

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Connections Physics Review (CPR) Program

Abstract – The Connections Physics Review Program (CPR) was created at Northeastern University to increase the confidence, grades, and retention of freshmen in the College of Engineering. Because of the traditional under representation of women in physics and engineering and the importance of physics introductory classes for first year engineering students, the CPR program has been developed to help students strengthen their physics and problem-solving skills.

Connections consists of a series of programs initially funded by the National Science Foundation (HRD #0217110) and now institutionalized by Northeastern's College of Engineering to strengthen the pathways for women and girls to pursue careers in engineering and science. The program targets the transition points from middle school to high school, high school to college, and college to career. Connections program components at the college level are extensive and include scholarships, social programs, a freshman residence LLC (Learning Living Community), outreach programs, academic support, e-mentoring, and career preparation. The Connections Physics Review program was established as one of the early initiatives and has evolved over a five year period to become one of the key academic components. Physics was chosen because of its place in the engineering curriculum (required first year course) and because the problem solving skills and knowledge were viewed as essential for future engineering success.

The Connections Physics Review program:

- ◆ conducts weekly sessions to review physics concepts introduced in lecture and to develop problem solving strategies.
- ◆ holds all sessions in the evening in the freshman residence hall (LLC).
- ◆ selects upper class women studying engineering (as role models) to lead the review sessions.
- ◆ heavily advertises the sessions (with free pizza) to entice women to all sessions.
- ◆ runs special mid-term and final reviews using faculty involved in teaching freshmen engineering courses.
- ◆ makes every effort to identify and assist struggling students with additional one on one tutoring.

CPR results have been very encouraging. Over 65% of the freshman engineering women participated in the program during the spring of 2005. These sessions were heavily advertised in the women's residence hall, but men were very welcome to join as well. Women who participated reported an increase in confidence as a result of the program. Average physics grades for women who participated in the spring semester of 2005 were 3.1 (out of 4.0) vs. 2.7 for women who did not. All of the women who withdrew or received a grade of D or lower did not attend any review sessions. Average freshman physics grades for spring 2005 were 2.587 for men (n=285) vs. 2.982 for women (n=58).

This paper discusses the CPR program strategies, implementation methods, results, and future plans.

Background

Despite consistent effort, interest among and representation in engineering for women is still much smaller than in society at large.^{1,2} Once women matriculate at the university, the need for retention among women is still an important factor in increasing the number of women in engineering and technical professions.³ Research has shown that women tend to drop out of engineering earlier and with higher GPA's than men, suggesting a lack of support and confidence. The crucial year appears to be the freshman year when the largest drop in engineering students is seen.⁴

Physics has particularly been a struggling point for women. Women are consistently underrepresented in the field, for example, currently representing only 22% of BS degrees in Physics.⁵ The major loss of women in physics appears to be between high school and college graduation.⁵ A solid background in physics is essential to future success in engineering coursework, while a shallow understanding can create future struggle in the undergraduate years. Focusing on improving support for these “gatekeeper courses” is an essential characteristic for successful retention.⁶ The study skills necessary for future engineering problem solving are often honed in the study of physics.

Engineers at Northeastern University take two introductory physics classes, the first being taught in the spring semester of their freshman year. Large physics lectures meet twice a week at Northeastern (usually between 50-100 students), a new and difficult experience for many freshman students. Women, in particular, feel isolated in large lecture classes, their minority status further accentuated, making them less likely to ask questions. Teachers often seem inaccessible and impersonal, struggling to cover a large amount of material, making physics unattractive and difficult for women.⁷ Large lectures can also result in only a low-level of learning as compared to more interactive group work.⁸ Students at Northeastern also participate in a smaller Interactive Learning Session (ILS) once a week, increasing the students' access to physics instructors and helping to alleviate some of the previously mentioned problems. However, adding more support for women engineers has been identified as a goal to increase their comfort and confidence in physics as well as improve their success and retention throughout their undergraduate career.

In order to address these problems and increase the confidence that women have in engineering, Northeastern's Women in Engineering (WIE) has implemented a “Connections” program. (*“Connections” is a series of programs initially funded by the National Science Foundation and now institutionalized by Northeastern's College of Engineering to strengthen the pathways for women and girls to pursue careers in engineering and science.*) The Connections Physics Review (CPR) program consists of weekly review sessions taught by undergraduate students with supplemental tutoring and test reviews. This program operates in parallel with many other social and academic programs to help women such as: a Connections Learning Living Community for freshman engineering women, a Connections computer lab designed solely for women in science and technology, an active SWE chapter, and other activities. This combination helps to combat the “chilly” environment many women engineering students have reported nationally.

The goals of this CPR program are to increase the confidence and academic aptitude of women in their freshman year. Physics was chosen because of its traditionally low appeal to women and because of its place in the freshman engineering curriculum. Desired results are a large participation by freshman women engineering students, a qualitative increase in confidence (both academically and in engineering in general), a quantitative increase in grades, and, over the long run, an increase in the retention rate for women in engineering at Northeastern University.

Freshman Physics Classes

Engineering students at Northeastern take their first physics class in the spring semester of their freshman year, covering the elements of Newtonian physics. This class involves a twice-weekly lecture held in a large lecture hall, a weekly small ILS session where students take quizzes and work on homework, two weekly homework assignments submitted online using the WebAssign program on Blackboard, and a weekly physics lab with lab reports. There are also two major exams: midterm and final.

Connections Physics Review (CPR) program

The CPR program to supplement the required physics course consists of three parts. First, there is a weekly review session taught by two undergraduate students. Second, there is individual one-on-one tutoring available for students, both those who request it as well as for students whose advisors recommend it. Finally, there are two reviews held before the midterm and final taught by an engineering faculty member involved in teaching the weekly freshman engineering physics ILS.

This program has been supported this past year through a Presidential Award for Excellence in Science, Engineering, and Mathematics Mentoring (PAESEM) to Professor Sara Wadia-Fascetti at Northeastern University. Thus, major recruitment for the program is for women students, though men are welcomed. Originally, very few men attended the sessions, but the word seemed to spread and, by the end of the semester, between 30 to 40% of attendees were male, especially at the final review sessions. Recruitment largely consisted of posters, both around the engineering school, as well as in the women's engineering dorm floor (Connections LLC). Emails were originally sent to all engineering women enrolled in physics to invite them to attend, with weekly emails being sent out thereafter. In addition, students deemed to be struggling in physics by their advisors were suggested to attend the sessions.

Weekly Review Sessions

Each week, a physics review session was taught by two undergraduate engineering women students. These students were selected based not only on their knowledge of physics, but also on their interest in promoting and supporting freshman engineering students. Having undergraduates teach the sessions helps to provide a positive role model, someone who has been "in their shoes" and could impart valuable knowledge on how to study for the exams, complete the homework, and succeed in their academic careers. Having two students lead the sessions has proven to be a key, allowing for consistency each week even with their hectic schedules. The student-teachers also attended the physics lectures each week, often sitting in on different

lecturers through the course of the semester. This had many benefits. First, the student-teachers had a more clear understanding of what is being presented in the class and the level of instruction. Secondly, they were also able to gauge gaps in learning – where the professor is unclear in one lecture or the material the professor skipped due to a lack of time. This allowed for the review session to be matched to the needs of the students. The student-teachers had a copy of the homework problems ahead of time and were able to prepare solution strategies for the review sessions. The student-teachers were compensated through the PAESEM grant.

The CPR sessions were held in the university's Living Learning Center, a classroom located in the freshman housing complex. This location was very close to the Connections dorm and greatly increased the number of students who attend each week. Because the location is so close, many students “tag along” with their friends, even if they had no original intention to attend. Pizza was also provided each week. Although almost all of the students have a meal plan through the school, this greatly increased the number of students attending.

Each review session ran between an hour and an hour and a half long depending on the complexity of the material covered during the week. The student-teachers presented a short review of basic principles from the week, as well as covered any tricky principles or gaps from various lectures and lecturers. Next, students present homework problems they are struggling with and the solutions are worked out together with a lot of interaction and questioning of the students. The key, however, was not to solve homework problems, but to help teach strategy and method to the students. The key concepts and principles used in each problem were summarized, as well as other situations where the concepts could be applied. Students were encouraged to ask questions about any principle with which they had doubts. In this environment, more women were willing to ask questions.

Weekly review sheets were prepared for the students (for an example, see Appendix A). These review sheets highlighted the key formulas, concepts, and strategies to solve the physics problems, especially in relation to concepts already covered in class. Although little more than a summary of lecture notes and the book, these notes especially seemed to improve the confidence of the students, drawing on a different learning style which seemed very beneficial.⁹ By presenting the material in a different way, students are provided more opportunities to develop their own learning style. The material seems less intimidating to mid-level students when succinctly summarized and also provides clues on appropriate study habits they should develop.

A final review sheet was developed just before the final exam. (This review sheet is included in Appendix B.) Through the teaching of the review sessions and especially through tutoring struggling students one-on-one, it was discovered that some students were overwhelmed with the number of equations and simply unable to discover the proper methods, strategies, and formulas to use, a common problem for beginning physics students.⁹ The sheet listed all of the common strategies, their accompanying equations, what variables they involved, and when to use them. For example, the section on kinematics is shown in figure 1.

Kinematics Review Notes

- Equations: $v = v_0 + at$
 $x = x_0 + v_0t + \frac{1}{2} at^2$
 $v^2 = v_0^2 + 2a(x-x_0)$
 $a_r = v^2/r$ (for circular motion)
- Hints:
- can only use when a is constant
 - in 2D problems, we solve for both axis (x & y)
 - then, $a_x = 0$ & $a_y = -g = 9.8 \text{ m/s}^2$
 - if thrown at an angle, calculate v_{x0} & v_{y0}
- When to Use:
- 1 object
 - object thrown or dropped
 - in 2D, called “projectile motion”
 - Givens & unknowns include initial & final position and velocity
 - Only for constant acceleration
 - Use the radial acceleration for one object moving in a circle or arc

Figure 1

Based on qualitative comments from the students, this review sheet was very successful in helping students understand concepts and when to use them.

Tutoring

One-on-one tutoring was also made available for the freshman students with one of the student-teachers. This tutoring helped to supplement the rest of the physics instruction for those students who were still struggling. One of the most difficult parts of teaching the review sessions was identifying those students who could most benefit from one-on-one physics tutoring. Advisors and teachers of first year engineering students recommend struggling students to tutoring, especially after midterm grades were available. The student-teachers also tried to notice which students were struggling during the sessions; this is made much easier by having two students involved – one can teach, while the other can observe the students, their questions, and their responses.

Midterm and Final Reviews

Before both the midterm and final exams, a special longer review session (2 to 3 hours) was presented by a former freshman physics teacher who is a member of the engineering faculty. These reviews were advertised through posters as well as through the weekly sessions and were very well attended. Pizza was once again provided. Practice problems, especially in difficult areas, were solved by the professor. Although some students only attended these special review sessions, the confidence it helps to install in the students, especially as they prepare to take one of their first important midterms and finals, helped to achieve our goals.

Planning Meetings

Every few weeks, the student-teachers met with the Director of Women in Engineering (WIE). This time allowed for the student-teachers to discuss the sessions, tutoring, and plan for the

future. By meeting together often, the CPR program ran smoother and changed more dynamically in response to student's needs. Because the Director of WIE is in close contact with all of the freshman advisors, she would recommend additional students who were struggling and needed to attend the sessions as well as students who should take advantage of extra tutoring. Because the advisors have access to the academic standing of their students, this chain-of-command allows for a very efficient utilization of the CPR program. Based on these discussions, the student-teachers extended invitations individually to those students most in need.

This resulted in several very special success stories. For example, one student studying alone was struggling in physics. Her advisor admonished her to attend the physics review sessions, but she had not yet attended any. During the weekly planning meeting, the Director of WIE urged the student-teachers to send a personal invitation to her. After this invitation, she began attending every review session and began one-on-one tutoring sessions. At the time of intervention, this 1st year student had already taken the midterm and received a poor grade (18% where class average was in the high 60's). However, with this extra intervention, she was able to pull up her grade and eventually pass with a C- in the class. This one-on-one intervention was particularly successful for this student because it helped her look at the problems in a new way. She had been particularly confused about which formulas to use and had used kinematics to solve every problem on her midterm. With the emphasis in the review sessions on concepts and techniques and learning how to apply them, she was able to identify which equations to use on each problem. Thus, by addressing unique learning style needs and by intervening through the CPR program, women who previously would have been at risk for dropping out of engineering are continuing in their programs with higher GPA's, more confidence, and greater abilities in problem-solving.

Results

Attendance

One important indicator of outreach programs is the actual attendance of the program. No matter how well designed, the program must be attended to provide results. Often, small factors combine, bringing in a critical mass of attendance, at which point the program can succeed on its own merits.

This was definitely our experience in the CPR program. In prior years, the program received a small attendance, about 8-9 students each week. After analysis, a few small components of the program were changed to increase attendance. Originally, the program was held in an academic building on campus – this was changed to the Living Learning Center in the freshman housing area. Also, as mentioned, pizza and drinks were provided for each session. Although these factors seem small, attendance swelled with these additional changes. A third important factor to attendance success was employing two student-teachers. One of the teachers was always able to be there on-time, ready to begin the lesson.

Based on these factors, the program experienced great success this past year (spring 2005) with an average attendance of 21.4 students at all sessions. We had an average of 19.25 students at our Physics Review sessions with an average of 34.5 students at the midterm and final exam

reviews. The average student attended 4.2 sessions each. However, the average number of sessions for women was 5.5 compared to only an average of 2.7 for men.

Surveys

Midway through the course and after the course was completed (and students had received their grades), a survey was administered to gauge the effectiveness of the CPR program. The purpose of the first survey was to measure how effective each component of the program was, as well as to identify those students who had performed poorly on the midterm and would need extra support for the final. The purpose of the second survey was to measure the final effectiveness of the program, especially in terms of the confidence increase of the students and the program factors that contributed to its success.

Because of the small number of surveys returned (around 15 for both surveys), the results were not statistically significant. However, a few general comments can be ascertained from the final survey. Students who responded reported an increase in confidence due to the review sessions. When asked, "To what degree did the physics reviews increase your confidence? (1 not at all, 5 to a great degree)," they had an average increase of 3.1.

In terms of the helpfulness of various activities, the students rated the CPR components as helpful as can be seen in Figure 2.

| Survey item: | Rating: |
|-------------------------|----------------|
| Lectures | 2.6 |
| Textbook | 2.8 |
| Studying Alone | 2.8 |
| ILS | 3.0 |
| WebAssign | 3.1 |
| CPR Test Reviews | 3.7 |
| CPR Monday Night Review | 3.8 |
| CPR Review Sheets | 4.0 |
| Studying in a Group | 4.0 |

Student response on helpfulness of activities
(1 is not useful at all, 5 is very useful)
Figure 2

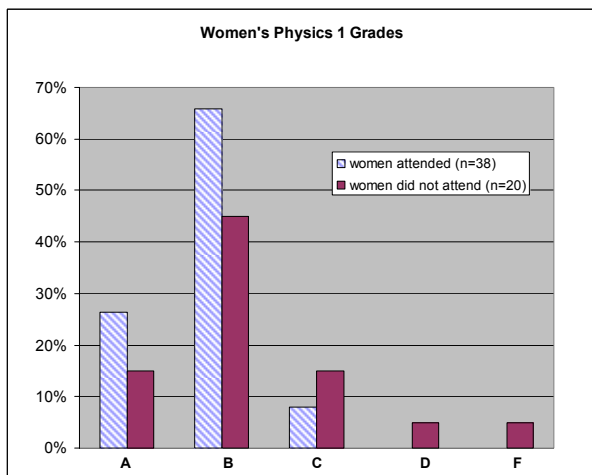
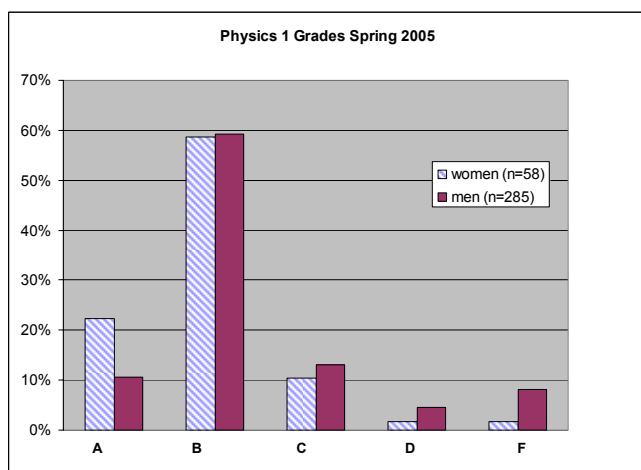
Statistics

After the physics course was completed and grades were assigned, all the results as well as other factors related to the students' success were compiled. A table of results from our physics grade analysis is located in Appendix C. A few comments based on these grades follow below.

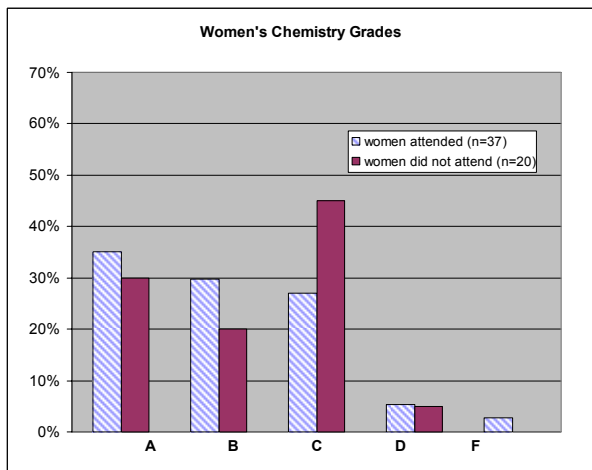
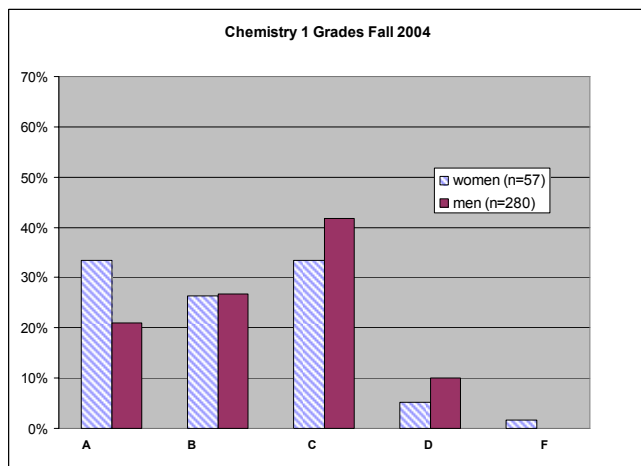
- Women had a higher grade in physics than men (2.982 versus a 2.587).
- Women received more A's than men (19% of women had an A versus 9% of men).
- Women received less F's than men (2% of women received an F vs. 8% of men).
- Overall, 65.5% of women attended at least 1 review session.
- The average number of sessions attended by women was 5.5.
- All of the women who withdrew or received D's and F's did not attend any review sessions.
- Those women who did not attend review sessions had lower grades in physics than women who did attend (an average grade of 2.707 versus 3.105).
- Of the women who attended a review session, 26.3% of those women received an A or A-.

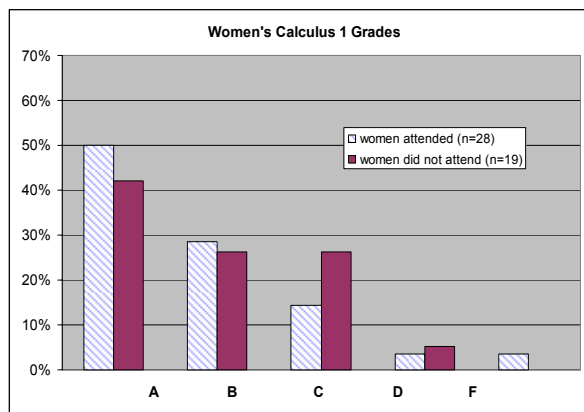
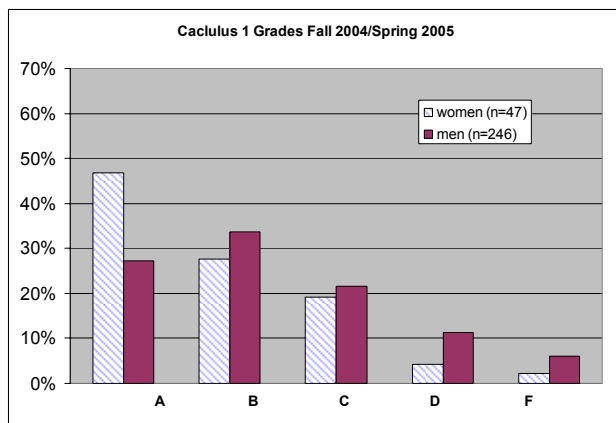
Men, on average, did not receive as large of a benefit from the review sessions as women. Only 11.9% of men attended at least 1 session. Most men did not attend review sessions until after the midterm and 9 men attended only the midterm or final review session. Overall, they also attended less sessions, at an average of 2.7 sessions each.

Results are shown in the following series of graphs. Women who attended CPR had fewer lower grades compared to women who didn't attend CPR and to men.



Grades for this same group in two other classes were compared: chemistry and calculus 1, both required freshman engineering classes the students had taken in the previous semester. Neither of these classes had review sessions and so were used for comparison purposes.





We found that chemistry grades do not share the same trend as the physics grades. There are once again D's and F's and a much larger percentage of C's in the group of women who attended physics review sessions. The number of A's in the two groups of women is virtually the same, whereas in physics there were many more A's in the women's review session group. The same trends are seen in calculus grades.

A multivariate linear regression was performed to confirm that the physics grades were statistically impacted by attending the review session, ruling out the effects of self-selection. The following variables were used:

- Attended – 1 if a student had attended at least one session, 0 otherwise
- rTotal – the total number of review sessions attended by the student
- Physics grade – the student's grade received in physics (spring semester 2005)
- Chemistry grade – student's grade received in chemistry (fall semester 2004)
- Math grade – student's grade received in their first semester calculus classes (fall semester 2004).
- Fall GPA – student's GPA in the fall 2005 at Northeastern (the semester before physics was taken).

Each of the grades was converted to a 4.0 scale, the same scale the GPA uses. Using the physics grade as the dependent variable in the regression, the chemistry grade, math grade, or Fall GPA was used as an independent variable as well as either Attended or rTotal. These various regressions were run for both men and women. Using a threshold of $\alpha = .025$, attending review sessions is statistically significant for women (both in terms of Attended and rTotal) with Chemistry, Math or Fall GPA. However, these were not statistically significant for men in any of these regressions.

These results suggest that women gain a greater benefit from the review sessions (judged by their final physics grade). This result is shown to be statistically significant, even when compared to grades in other courses as well as their GPA overall. One of the questions we looked at was: Why were the men's results not statistically significant? There are many possible reasons. First, fewer men attended the sessions than women (11.9% versus 65.5%) and less sessions overall (an average of 2.7 sessions versus 5.5 sessions). This lowered usage of the program resulted in less overall competence. Secondly, most men who did attend were specifically counseled to do so by

their academic counselor. Thus, the men who attended the sessions were already struggling in their classes to a much greater extent than the women who attended. (One of the future CPR goals is to improve the benefit to men who participate.)

Summary and Future Considerations

The Connections Physics Review program made major advances this past year (2005) towards its goals to increase the confidence as well as the grades of women in this “gateway” class. Attendance was high, with a majority of women attending the review sessions. Statistically, the women’s grades improved as they attended the review sessions seen through statistics on their final grades as well as regressions combined with scores in other classes and their GPA overall. Although men attended, their attendance was sparser and more heavily weighted toward struggling students.

In the process of analyzing the CPR program results, several areas for future improvement were identified. Attendance at CPR was high among women but in order to continue this trend (as well as improve participation among men), we hope to increase awareness of the value of participating in CPR. To address the turnover in student-teachers from year to year, we are finding it essential to pass information between the years. Review sheets partially achieve this task, but planning meetings between the student-teachers from year to year can help improve communication. Also, previously in review sessions, we had focused mainly on skills and strategies through solving homework problems. We would like to expand this to include a longer review of the principles learned that week as well as review problems similar to, but not identical to, the homework. The students would then have a stronger skills base on which to build as well as the experience of solving the problems twice – one set in the review sessions together and the actual homework set at home. This would increase students’ abilities, their practice time on physics, as well as their knowledge on appropriate ways to study in future engineering courses.

We would like to share the results of this program and discuss additional strategies to increase retention of all freshman engineering students (and women in particular) during the conference presentation.

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Appendix A: Sample CPR Weekly Review Sheet Forces, Including Friction & Tension

This week there was only one equation to remember. Memorize it. Use it!

$$F = m * a.$$

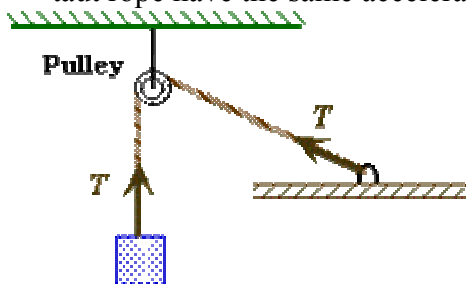
Remember, F is really the sum of forces or the net force.

Steps to solve all problems about forces:

- 1) Draw a **picture**. Label all forces.
- 2) Draw **free body diagram** for each object with appropriate forces.
- 3) Draw arrow for each object showing direction of **acceleration**. (If unknown, pick a probable direction – if the acceleration ends up negative, you just picked the wrong direction).
- 4) Pick appropriate **axes**, for example, if something is on a plane. (making the axes align with the acceleration is often the easiest choice).
- 5) If necessary, break forces into **components**.
- 6) Calculate the **net force** along each axis.
- 7) Write **2 equations** (per object) – 1 for each axis. (Use Net Force = $m * a$).
- 8) **Solve** for the unknowns.

Types of Forces we have discussed:

- 1) **Weight** – $F = mg$ (g on earth is 9.8 m/s^2). Remember this always points directly down. Every object with mass has this force.
- 2) **Normal** – F_n . This force always point perpendicular to the surface. Every object touching another object or surface (ex. Box on a table) has a normal force. This is the opposite & equal reaction mentioned in Newton's laws. This is found via calculations. It can not be negative.
- 3) **External Forces** – These are pushing or pulling forces specified in the problem.
- 4) **Tension** – Force from a rope. The same magnitude force acts along the rope (or at its ends). The direction of the tension is along the rope away from the object (see picture below). This must usually be found via calculations. (Note – objects connected with a taut rope have the same acceleration).



- 5) **Friction** – Force “rough” object exerts on the other to keep it from moving. Thus, this moves opposite direction of motion. There are two kinds of friction – static (to get motion started) and kinetic (once you are already moving). Friction is equal to μN where μ is a coefficient that depends on the materials (look in table). Objects touching other non-frictionless objects or surfaces have this.

Appendix B: CPR Final Physics 1 Review Notes

Kinematics

Equations: $v = v_0 + at$
 $x = x_0 + v_0t + \frac{1}{2}at^2$
 $v^2 = v_0^2 + 2a(x - x_0)$
 $a_r = v^2/r$ (for circular motion)

- Hints:
- can only use when a is constant
 - in 2D problems, we solve for both axis (x & y)
 - then, $a_x = 0$ & $a_y = -g = 9.8 \text{ m/s}^2$
 - if thrown at an angle, calculate v_{x0} & v_{y0}

- When to Use:
- 1 object
 - object thrown or dropped
 - in 2D, called “projectile motion”
 - Givens & unknowns include initial & final position and velocity
 - Only for constant acceleration
 - Use the radial acceleration for one object moving in a circle or arc

Forces

Equations: $\sum F = ma$
 $W = mg$
 $F_{fr} = \mu F_N$

- Hints:
- Always draw a force diagram
 - One equation per axis (break forces into components first)
 - F_N is perpendicular to surface
 - F_{fr} points opposite direction of movement

- When to Use:
- Asks for a force
 - Asks for acceleration, esp. if more than 1 object.
 - Often involves planes, pulleys, tensions, & friction

Gravitation

Equations: $F = G(m_1m_2) / r^2$

- Hints:
- to find g , set $F = mg$ and solve for g
 - for satellites, set $F = mv^2/r$ (radial acceleration)
 - r is the distance from the center of one object to the other

- When to Use:
- to find g at a location
 - have BIG objects (i.e. planets) or things in space (i.e. satellites)

Work & Energy

Equations: $W = F_{\parallel}d = \int F \, dl = \Delta K$
 $K = \frac{1}{2}mv^2$
 $U_g = mgy$
 $U_{spring} = \frac{1}{2}kx^2$
 $U_G = -GmM_E/r$
 $\Delta K + \Delta U = W_{NC}$ (forces due to friction, air drag, etc.)
 $P = W/t$

- Hints: - Work & Energy have same units and are often set equal to each other
 - If you use these strategies with friction, remember W_{NC}
- When to Use: - Want to know v or x (can't use these to solve for a)
 - Object follows a path (down a ramp, on a roller coaster track, etc.)
 - You have a spring or a difference in height & a change in velocity
 - Have 2 separate times to compare

Linear Momentum

Equations: $p=mv$

$$p_{\text{initial}} = p_{\text{final}}$$

- Hints: - In elastic collisions, we also conserve kinetic energy, so we can use those formulas to solve as well.
 - Inelastic collisions rarely have enough to solve unless the objects stick together.
 - These equations can also be applied in 2D (momentum conserved in each dimension).

- When to Use: - Two objects collide
 - We know velocities or can calculate using kinematics
 - It says collision

Rotational Motion

Equations: $v = R\omega$

All kinematics equations with $v \sim \omega$, $\theta \sim x$, $\alpha \sim a$

$$\tau = RF_{\text{perpendicular}}$$

$$\sum \tau = I \alpha$$

$$I = \sum mr^2$$

$$I = I_{CM} + Mh^2$$

$$L = I\omega$$

$$L_{\text{initial}} = L_{\text{final}}$$

$$K_{\text{rot}} = \frac{1}{2} I\omega^2$$

$$K_{\text{tot}} = \frac{1}{2} mv^2 + \frac{1}{2} I\omega^2$$

- Hints: - 1 rev = 2π rad = 360°
 - In general, the concepts & strategies are same as before with new variables.
 - Often, in the problems, you will have to convert ω to be in terms of v and I to be in terms of m .

- When to Use: - When there's rotation
 - Things are spinning
 - You're asked for τ or I or L
 - It says the word "ANGULAR"
 - Now, choose the best method
 - o 1 object -> Kinematics
 - o Rotation -> Torque
 - o Changes in height/velocity -> Conservation of Energy
 - o Collisions -> Momentum
 - o People jumping on & off spinning things -> Momentum
 - o Pulleys, strings, etc. -> Torque

Static Equilibrium

Equations: $\sum \tau = 0$
 $\sum F = 0$ (one equation per axis)

When to Use: - No motion

Fracture & Stress

Equations: $\Delta L = 1/E * F/A * L_o$
Stress = F/A
Strain = $\Delta L / L_o$

When to Use: - stress, strain, change in length, safety factor, etc.

Waves & Oscillations

Equations: $f = 1/T$ $T = 1/f$
 $x = A \cos(\omega t + \phi)$
 $v = -\omega A \sin(\omega t + \phi)$
 $a = -\omega^2 A \cos(\omega t + \phi)$
 $\omega = 2\pi f$
 $\omega = \sqrt{k/m}$ for a spring
 $\omega = \sqrt{g/L}$ for a pendulum
 $F_{\text{damping}} = -bv$
 $x = A e^{-(bt/2m)} \cos(\omega' t + \phi)$
 $\omega' = \sqrt{(k/m) - (b/2m)^2}$
 $E_{\text{harmonic}} = \frac{1}{2} m v^2 + \frac{1}{2} k x^2$

When to Use: - When something has oscillations
- For pendulums
- When they say something undergoes “simple harmonic motion”
- When there is damped harmonic motion

Fluids

Equations: $p = m/V$
 $P = F/A$
 $P = pgh$
 $P_{\text{out}} = P_{\text{in}}$
 $P = P_o + pgh$
 $F_B = p_{\text{fluid}} g V_{\text{object}}$
 $A_1 v_1 = A_2 v_2$
 $P_1 + \frac{1}{2} \rho v_1^2 + p g y_1 = P_2 + \frac{1}{2} \rho v_2^2 + p g y_2$

Hints: - Change weights to $p_{\text{object}} g V$
- Draw a force diagram, esp. when dealing with buoyant force

When to Use: - Working with fluids & pressures
- Remember, fluids include liquids and sometimes gasses.

Appendix C: Physics Grade Analysis

All students

| Avg | n | stdev | A | A- | B | B- | B+ | C | C- | C+ | D | D- | D+ | F | U | I | NE | W | * |
|-------|-----|-------|-----|----|-----|-----|-----|----|----|----|----|----|----|----|----|----|----|----|----|
| | | | 36 | 7 | 91 | 72 | 40 | 24 | 10 | 9 | 14 | 0 | 0 | 24 | 0 | 2 | 0 | 11 | 3 |
| 2.653 | 343 | 1.01 | 10% | 2% | 27% | 21% | 12% | 7% | 3% | 3% | 4% | 0% | 0% | 7% | 0% | 1% | 0% | 3% | 1% |

Women

| Avg | n | stdev | A | A- | B | B- | B+ | C | C- | C+ | D | D- | D+ | F | U | I | NE | W | * |
|-------|----|-------|-----|----|-----|-----|-----|----|----|----|----|----|----|----|----|----|----|----|----|
| | | | 11 | 2 | 14 | 14 | 6 | 3 | 1 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0 |
| 2.982 | 58 | 0.78 | 19% | 3% | 24% | 24% | 10% | 5% | 2% | 3% | 2% | 0% | 0% | 2% | 0% | 0% | 0% | 5% | 0% |

Men

| Avg | n | stdev | A | A- | B | B- | B+ | C | C- | C+ | D | D- | D+ | F | U | I | NE | W | * |
|-------|-----|-------|----|----|-----|-----|-----|----|----|----|----|----|----|----|----|----|----|----|----|
| | | | 25 | 5 | 77 | 58 | 34 | 21 | 9 | 7 | 13 | 0 | 0 | 23 | 0 | 2 | 0 | 8 | 3 |
| 2.587 | 285 | 1.04 | 9% | 2% | 27% | 20% | 12% | 7% | 3% | 2% | 5% | 0% | 0% | 8% | 0% | 1% | 0% | 3% | 1% |

Women who did not attend any review sessions

| Avg | n | stdev | A | A- | B | B- | B+ | C | C- | C+ | D | D- | D+ | F | U | I | NE | W | * |
|-------|----|-------|-----|----|-----|-----|----|----|----|-----|----|----|----|----|----|----|----|-----|----|
| | | | 2 | 1 | 6 | 2 | 1 | 1 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0 |
| 2.707 | 20 | 1.01 | 10% | 5% | 30% | 10% | 5% | 5% | 0% | 10% | 5% | 0% | 0% | 5% | 0% | 0% | 0% | 15% | 0% |

Women who attended at least 1 review session

| Avg | n | stdev | A | A- | B | B- | B+ | C | C- | C+ | D | D- | D+ | F | U | I | NE | W | * |
|-------|----|-------|-----|----|-----|-----|-----|----|----|----|----|----|----|----|----|----|----|----|----|
| | | | 9 | 1 | 8 | 12 | 5 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.105 | 38 | 0.63 | 24% | 3% | 21% | 32% | 13% | 5% | 3% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

Men who attended at least 1 review session

| Avg | n | stdev | A | A- | B | B- | B+ | C | C- | C+ | D | D- | D+ | F | U | I | NE | W | * |
|-------|----|-------|----|----|-----|-----|-----|----|----|----|----|----|----|----|----|----|----|----|----|
| | | | 0 | 0 | 9 | 6 | 6 | 3 | 2 | 2 | 2 | 0 | 0 | 2 | 0 | 1 | 0 | 1 | 0 |
| 2.469 | 34 | 0.91 | 0% | 0% | 26% | 18% | 18% | 9% | 6% | 6% | 6% | 0% | 0% | 6% | 0% | 3% | 0% | 3% | 0% |